OCS Study
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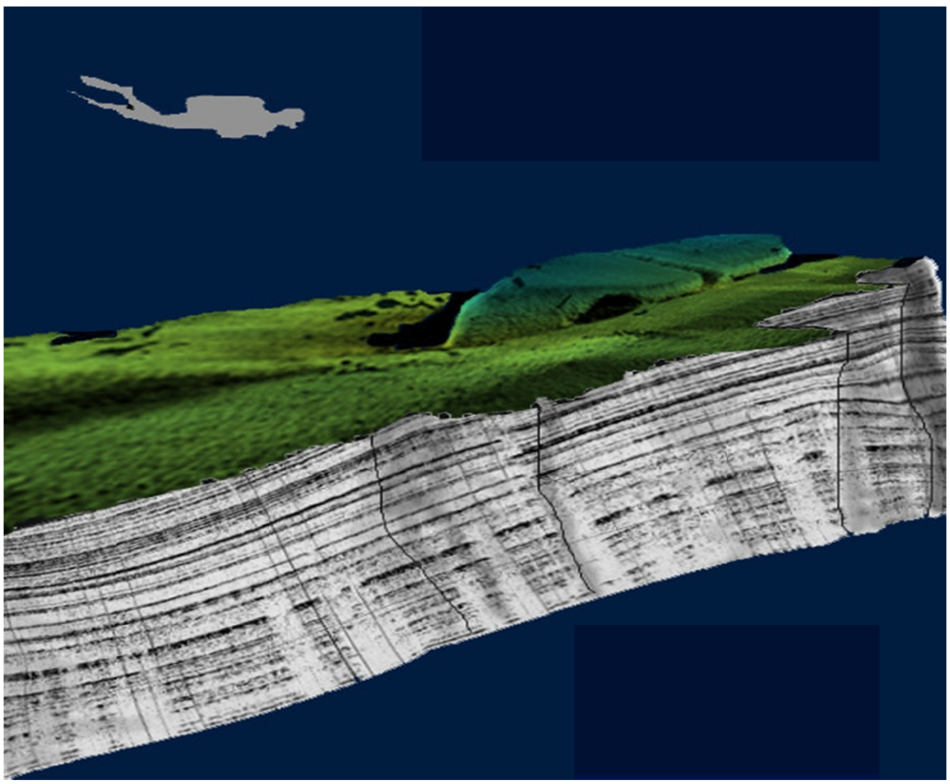
Archaeological Analysis of Submerged Sites on the Gulf of Mexico Outer Continental Shelf



U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region

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ABBREVIATIONS AND ACRONYMS

BLM	Dept. of the Interior, Bureau of Land Management
BML	Below mud line
BOEM	Dept. of the Interior, Bureau of Ocean Energy Management
BOEMRE	Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement
BSL	Below sea level
COTR	Contracting Officer's Technical Representative
DO	Dissolved oxygen
DSO	Dive Safety Officer
ft	feet
ft/sec	feet per second
GOM	Gulf of Mexico
INC	Incident of non-compliance
kHz	kilohertz
LAR	Linear accumulation rate
LOA	Length overall
m	meter
m/sec	meters per second
mg/L	Milligrams per liter
M/V	Motor vessel
MMS	Dept. of the Interior, Minerals Management Service
MVUS	Merchant Vessels of the U.S.
ms	millisecond
NIMA	National Imaging and Mapping Agency
NOAA AWOIS	National Oceanic and Atmospheric Administration Automated Wreck and Obstruction Information System
NOAA NHC	National Oceanic and Atmospheric Administration National Hurricane Center
NRHP	National Register of Historic Places
nT	nanotesla
NTL	Notice to Lessee
OCS	Outer Continental Shelf
P&A	Plugged and abandoned [well]
ppT	Parts per thousand
SS	Steamship
µm	micron
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
UWF	University of West Florida

1. INTRODUCTION

1.1 BACKGROUND

Tesla Offshore, LLC, was awarded a contract in 2009 by the former Minerals Management Service (MMS) (then from May 2010 until October 201, the Bureau of Ocean Energy Management, Regulation and Enforcement, now the Bureau of Ocean Energy Management [BOEM]) to investigate six shipwreck sites on the Outer Continental Shelf (OCS), Gulf of Mexico (GOM). The sites were to be investigated through geophysical survey and a combination of diver observation and sediment core acquisition. The purpose of the study was to verify that the targets were shipwrecks, and, if possible, to provide identifications and assessments of potential eligibility for listing on the National Register of Historic Places (NRHP). A second aim of the study was to provide an assessment of site formation processes that impact the individual wreck sites. The six sites ranged in water depths from 11 to 36.5 m (36 to 120 ft) below sea-level (BSL) and were located across the north-central and northwestern GOM, from Morgan City, Louisiana to Galveston, Texas.

The contract was awarded on September 27, 2009. Geophysical data was obtained at the six contracted study sites between March and August 2010. Diving operations were performed in August 2010. Before the fieldwork began, a contract modification was approved that would allow investigation of additional sites in case diving was restricted due to the *Deepwater Horizon* oil spill that had occurred in April 2010. Though the oil spill did not adversely impact activities at any of the study sites, additional sites were added to the scope of work in the field with input and approval from the Contracting Officer's Technical Representative, Dr. Christopher Horrell. A total of 11 sites were investigated during dive operations (Table 1.1). Following field work, it was decided that the study would benefit from geophysical data acquisition at two of the sites that had been added in the field. A second contract amendment was requested and approved to acquire additional geophysical data at the two supplemental sites and for including these wrecks in the overall analysis and modeling.

Table 1.1

Study Sites

Lease Protraction	State	BOEM Site Number	Classification	Tentative ID
South Pelto	LA	380	Wooden vessel	Unknown wooden vessel
Ship Shoal	LA	433	Vessel	*R.W. Gallagher*
Ship Shoal	LA	386	Vessel	*Heredia*
South Marsh Island	LA	373	Vessel	*Cities Service Toledo*
High Island	TX	15488	Vessel	Unknown
Galveston	TX	15366	Vessel	Unknown
South Timbalier	LA	389	Vessel	*J.A. Bisso*
Galveston	TX	236	Vessel	USS *Hatteras* (confirmed)
East Cameron	LA	15326	Barge	Unknown
East Cameron	LA	322	Vessel	Unknown
West Cameron	LA	Pending	Unknown	Unknown

Sediment core data was collected at eight of the 11 sites investigated during diving operations. As a time- and cost-saving measure, core data was not analyzed for sites where no shipwreck was identified. Sediment cores were not collected on Site 386, because unsafe conditions restricted diving operations (Chapter 3.3.3). Radioisotope analysis was performed on sediment samples for six of the study sites. The purpose of this analysis was to provide dates for sediment disturbances and estimates of sediment deposition rates at the sites. Oceanographic modeling was performed to provide baseline information on regional processes that affect sediment and water current movement in and around the study sites. Due to the complexity involved in the modeling, cost, the number of sites, and the large area of interest, three datums were selected across the study area and used as the basis for the modeling. These models were then extrapolated to address all of the primary study sites.

Figure 1.1 illustrates the geographic range of the wreck sites and their approximate water depths.

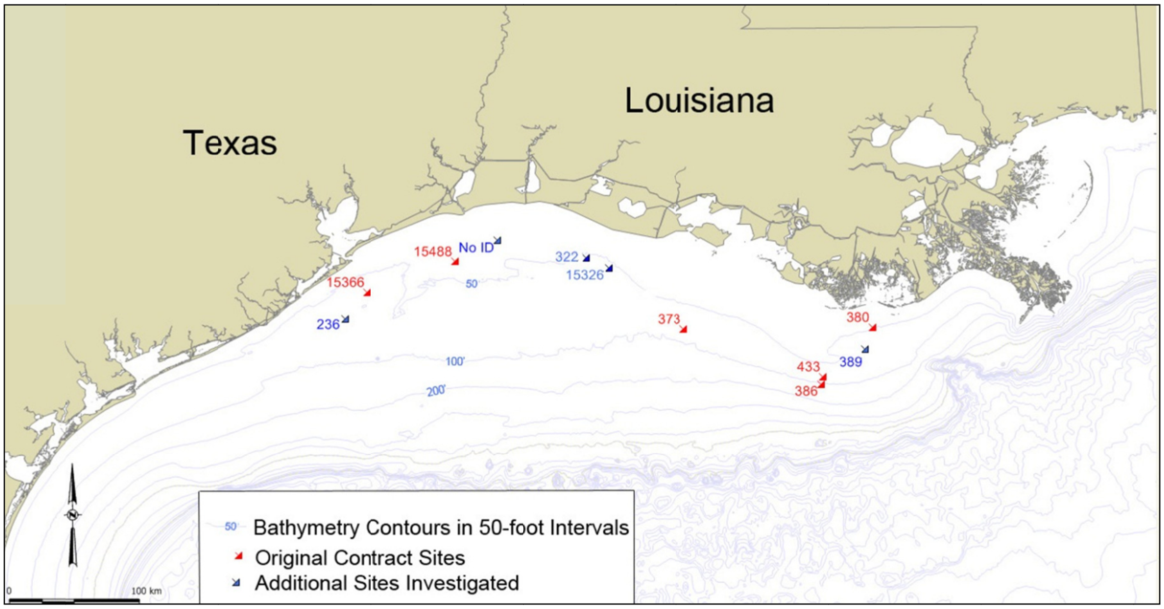


Figure 1.1. Site distribution map.

The current study collected comprehensive data sets for eight unidentified shipwrecks or targets on the GOM OCS to determine their potential historical significance and formulate a thorough understanding of site formation processes impacting each site. Three additional sites were investigated through diver observations only, to determine their identities and potential historical significance. The site matrix at a shipwreck site includes the physical condition and orientation of the shipwreck and any disarticulated components, as well as the environmental variables for each site, including but not limited to sediment type, water quality, seafloor stratigraphy, wave heights, wave periods, and current conditions.

The following chapters detail the interdisciplinary approach designed by the Key Scientific project team members: Principal Investigator Amanda Evans, Co-Principal Investigator and Program Manager Matt Keith, Diving Field Director and Archaeologist Gregory Cook, Principal Geomorphologist Dr. Patrick Hesp, and Oceanographer and Geomorphologist Dr. Graziela Miot da Silva Hesp. This report is written by the above contract principals with extensive contributions from Archaeologist Erin Voisin and Geologist Dr. Mead Allison, and contributions from Eric Swanson. This report was assembled by Amanda Evans, Matt Keith, and Erin Voisin with assistance from Stuart Bledsoe. Amanda Evans, Matt Keith, and Erin Voisin contributed to all phases of the report. Gregory Cook and Eric Swanson prepared diving methodology text as well as a write-up of the results of the diving investigations. Gregory Cook also provided research and text on the study wrecks and their historic analogs. Patrick Hesp and Amanda Evans synthesized the oceanographic data and results of sediment cores in Chapter 5. Graziela Miot da Silva Hesp assisted with relevant literature reviews. Patrick Hesp assisted with analysis of the geophysical data pertaining to scour on the sites and oceanographic analysis. Mead Allison prepared text related to the methodology and results based on the radioisotope analysis with assistance from Amanda Evans.

1.2 CURRENT MANAGEMENT STRATEGIES FOR OCS SHIPWRECKS

The GOM has played an integral role in the nation's cultural and historical heritage. Evidence of the nation's maritime and economic history is represented by shipwreck sites covering approximately 500 years of exploration and exploitation across the region. Historically significant shipwreck sites documented throughout the GOM range from 16th-century ships of discovery to World War II-era U-boats.

Archaeological sites can provide invaluable information that is missing from the historical record. Explicitly, the archaeological record consists of static evidence that can be scientifically examined to reveal information omitted from or misrepresented in the historical record. The archaeological record is unique in this regard; information that can be garnered from archaeological sites can contribute to a better understanding of the past. Shipwreck sites are tangible connections with history and, due to the often sudden or violent causes of their sinking, many have the added gravitas of being the final resting places of passengers and crews. For these reasons, federal laws such as the National Historic Preservation Act (1966), Executive Order 11593, and the Sunken Military Craft Act (2005) were enacted to provide for the identification and protection of archaeological resources.

BOEM, U.S. Department of the Interior, is tasked with regulating activities associated with mineral extraction on the OCS in the U.S. In accordance with Section 106 of the National Historic Preservation Act, the BOEM GOM OCS Region has issued multiple Notices to Lessees (NTLs) and other supporting documentation that provide rules and guidelines for investigating and protecting submerged archaeological sites on the OCS. Presently, NTL 2005-G07 designates survey requirements in leases that are considered archaeologically significant. Because all lease and pipeline surveys in the GOM already require geophysical hazard surveys (NTL 2008-G05), the hazard and archaeological surveys can often be performed in tandem.

In brief, the archaeological NTL requires a geophysical survey using single beam bathymetry, side scan sonar, magnetometer, and sub-bottom profiler in water depths under 200 m (656 ft). In water depths over 200 m (656 ft), magnetometer and sub-bottom profiler are no longer required. The requirement for archaeological surveys was based on a predictive model that indicated either the occurrence and preservation of prehistoric sites, or the presence of historic shipwrecks. A maximum survey line spacing interval of 50 m (164 ft) is required in blocks that have been designated high probability for shipwreck occurrence in water depths under 200 m (656 ft). Leases that are considered high probability for prehistoric occurrence, or that are in water depths exceeding 200 m (656 ft), require a maximum line spacing interval of 300 m (984 ft). The high probability model for requiring surveys in specific blocks was used from the first archaeological mitigation in 1973 until April 2011. However, the high probability model did not account for all shipwrecks, especially those occurring in deeper water. A mitigative document was prompted by documented cases of archaeological site damage and/or vandalism in blocks that were not originally identified as high probability areas for archaeological site occurrence; the document was issued in April 2011. The potential need for implementation of archaeological surveys or inspections is now considered in the National Environmental Policy Act (NEPA) analysis for permitted activities, regardless of their location, in the GOM. At the time of writing, survey parameters remain unchanged, but the mitigation applies to all seafloor-disturbing, federally-permitted activities related to mineral extraction for which an Environmental Assessment (EA) is prepared. In the GOM, this concerns primarily well drilling, platform installation, pipeline installation, alternative energy projects, and less commonly, sediment or resource extraction.

The sites presented in this report are located within a relatively low energy, micro-tidal environment of the GOM system (Curray 1960; Morton et al. 2004:21). Wave conditions, current movement, sediments, and other environmental variables affect shipwreck sites continuously, and these conditions can become exaggerated during extreme storm events. Currently, BOEM is responsible for managing cultural resources on the OCS, and specifically for balancing activities of the offshore oil and gas industry with the protection of cultural and natural resources. Avoidances are assigned to archaeological sites to protect them from anthropogenic (human-induced) impacts and also to prevent the archaeological resource from posing a hazard to offshore development (Evans et al. 2009). A recent BOEM-funded study produced data useful for determining appropriate avoidances for deep-water shipwreck sites (Church et al. 2007); however, the biological and environmental processes documented at these sites are not applicable to shallower sites located on the continental shelf. A 2006 study discussed the relevance of avoidance criteria on shallow sites (Enright et al. 2006); a 2011 study assessed the impacts of recent hurricanes on shipwreck sites (Gearhart et al. 2011). Beyond these recent studies, there is limited data for modeling more accurate avoidance zones based on site formation and environmental processes for archaeological sites on the continental shelf.

The data in this study is used to assess the long-term stability of the investigated shipwrecks on the OCS; it may assist BOEM as part of their mission to help better manage submerged cultural resources and guide regulations. An important aspect of this management strategy is to assess the effectiveness of prescribed avoidance zones to ensure that oil and gas development does not adversely impact shipwrecks.

As discussed by Enright et al. (2006:141), "The goal of avoidance should be protection of shipwrecks and their associated debris fields from any kind of adverse effect by federally permitted activities on the OCS." Most commonly, BOEM designates avoidance zones of 305 m (1,000 ft) to protect shipwrecks on the OCS; larger avoidance zones ranging from 457 to 609 m (1,500 to 2,000 ft) have been used for sites in deeper water and for sites that have established historic significance. Smaller avoidance zones, typically ranging from 61 to 152 m (200 to 500 ft) are often prescribed to unidentified sonar targets and magnetic anomalies. The study sites discussed in this report have been assigned avoidance zones of 305 m (1,000 ft) by BOEM, with the exception of *Hatteras*, which has been assigned an avoidance zone of 609 m (2,000 ft).

Avoidance zones are initially recommended by the archaeologist who is contracted to interpret the data and conduct the archaeological assessment, and are then evaluated and possibly revised by BOEM archaeologists as part of the plan or pipeline review process. Since BOEM maintains records of previous surveys, BOEM archaeologists often have additional data available that can be used to supplement a given survey. The coordinates of all targets to be avoided and their avoidance criteria are then provided to the operator as part of the BOEM approval notification. The supplied avoidance information is typically a single coordinate based on the centerpoint of a target or anomaly and a radius.

Following the completion of a permitted activity, operators are required to submit measured plats that show the location of all bottom disturbances associated with seafloor installations and pipeline installation. For pipelines, this includes the location of all anchors used during construction and the placements of associated anchor chain. These plats are analyzed during the post-installation review process to ensure that avoidance stipulations were met during the permitted activity. If anchors or chains impact an avoidance zone, BOEM may issue an Incident of Non-Compliance (INC) and require the operator to inspect the target or conduct other mitigative measures.

1.3 REPORT CONVENTIONS

This report is structured to integrate the results of the geophysical survey, diver investigations, environmental sampling, and oceanographic modeling in such a way that the reader can focus solely on an individual site of interest, or read about the regional findings based on cross-site comparisons and modeling. Following this introduction, Chapter 2 discusses the research methodology and details the equipment, parameters, and specifications that were used for the study. Chapter 3 discusses each study site individually, presenting detailed results of analyses at each location. The original six study sites are discussed first, followed by the two contract modification sites, which are followed by the three sites that were investigated only during diving operations. Chapter 4 discusses the historical significance of the wreck sites as they pertain to regional chronologies and assesses their potential eligibility for placement on the NRHP. Chapter 5 discusses the natural and cultural site formation processes impacting the study sites, and focuses on a regional discussion and comparison of the individual data sets presented in Chapter 3. The final section, Chapter 6, summarizes the results and recommends avenues for future research.

This contract was awarded by the Minerals Management Service, U.S. Department of the Interior (MMS). After the contract was awarded, the name of the agency was changed to the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE). Effective in October 2011, a reorganization created the Bureau of Ocean Energy Management (BOEM). Before the 1982 passage of the Federal Oil and Gas Royalty Management Act, which placed offshore regulatory responsibility with the MMS, offshore resources in the GOM had been managed by the U.S. Department of the Interior's Bureau of Land Management (BLM). Throughout this report, the bureau is referred to as BOEM, except when referring to a specific past action or regulation performed under the auspices of one of the previous agencies.

Citations follow the format outlined by the Bureau of Ocean Energy Management. The locations of most of the study sites were obtained through geophysical surveys. Because geohazard and archaeological assessments performed in compliance with BOEM regulations are typically conducted using the same methodology, in most cases these assessments are combined into a single report. Most of these reports are prepared by an archaeologist and a geologist or geophysicist. When referencing these reports, the authors' names are given with the archaeologist listed first because the archaeological portion of the report was typically the most relevant component for this study and in some cases was the only portion available for review.

Lease numbers and OCS designations have been redacted from the titles of these reports for confidentiality purposes.

BOEM requires that surveys in the GOM use U.S. measurement units (feet and inches). Because of the prevalence of oil and gas industry-related research in the GOM, virtually all references, maps, and data were initially obtained and/or reported in feet. Also, most of the study sites are U.S. built and/or registered vessels that used U.S. measurement units. Formatting guidelines for BOEM studies require International or metric units as the primary convention. All measurements in this report, therefore, are given in metric with U.S. units (feet and inches) given in parentheses. In most cases, the original unit was feet; metric conversions were calculated specifically for this report.

2. RESEARCH DESIGN AND METHODOLOGY

2.1 Background and Archival Research

The majority of the sites investigated for this study were identified by geophysical surveys performed on behalf of oil and gas industry operators in compliance with BOEM regulations. Initial background research into the study sites started with the shipwreck database maintained by BOEM. This database was initially prepared under contract by Garrison et al. (1989) and was updated by Pearson et al. (2003); it contains a comprehensive listing of shipwrecks in the region, drawn from sources such as the U.S. Coast Guard, National Imaging and Mapping Agency (NIMA), National Oceanic and Atmospheric Administration Automated Wreck and Obstruction Information System (NOAA AWOIS), and Louisiana and Texas state site files. BOEM also maintains records of previous surveys that were conducted under their jurisdiction. Where possible, copies of pre-existing surveys that encompassed study sites were provided for inclusion in this study by COTRs Mr. Dave Ball and Dr. Christopher Horrell. In some cases, a full report of findings was available, including samples of geophysical data, tabulation of sonar targets and magnetic anomalies, and survey maps. In other cases, the complete report was not available, and only a single image of a wreck site or minimal text was available. Complete details of the discovery and subsequent investigation of each wreck site are given in Chapter 3, the Site Results section of this report.

Three of the originally contracted shipwreck sites had been tentatively identified before this study; therefore, historical research at these locations focused on confirming or refuting the preliminary identifications. The remaining three study sites had been unidentified before this study. Research at every study site included an assessment of reported wrecks within, minimally, 32 km (20 miles) of each site. Additional information on reported wrecks within the search radii for each site was obtained from publicly available sources, such as the Merchant Vessels of the U.S. (MVUS), and the USCG Port Information Exchange System. Published dimensions were not always directly comparable with overall measurements of wrecks observed in the field or ascertained from geophysical data. Lengths published in MVUS, for example, do not always represent length overall. MVUS publishes the length on tonnage deck for registered vessels, which is defined as the length along the tonnage deck from the fore part of the outer planking at the bow to the after part of the sternpost of screw steamers, or to the after part of the rudderpost on other vessels. For vessels with three or more decks, the tonnage deck is the second deck from the keel. The upper deck is considered the tonnage deck for all vessels with fewer than three decks (MVUS 1942:5). In the case of MVUS lengths used in the research of potentially identified shipwrecks, they were considered minimum lengths for an intact hull. Published dimensions and other criteria were used to eliminate reported losses as possible candidates for the wreck sites. Texas and Louisiana State Site File forms and the NOAA Automated Wrecks and Obstruction Information System (AWOIS) also provided additional information on wreck parameters and locations.

Primary archival research was conducted in May 2011 at the National Archives in Washington D.C. and College Park, Maryland. Other archives and museums that were consulted include: The Daughters of The Republic of Texas Library at the Alamo; The Baltimore Museum of Industry; the Mariner's Museum; the Hagley Museum & Library; the Oregon Historical Society; U.S. Coast Guard, Historian's Office; National Archives at New York City; MIT Museum, Hart Nautical and General Collections; National Museum of American History, Smithsonian Institution; National Museums Northern Ireland; San Francisco Maritime National Historical Park; the Becker Collection at Boston College; and the Regional Military Museum in Houma, Louisiana. Secondary sources pertaining to World War II vessels, convoys, and U-boat campaigns in the GOM were also consulted when attempting to refute or confirm the identities of tentatively identified study sites.

2.2 GEOPHYSICAL DATA

A geophysical survey was conducted over each site in order to obtain site level information about each wreck, including the size, shape, and orientation of each wreck and any associated targets. Geophysical sensors also recorded information pertaining to each wreck site's environment, including bathymetric contours, seafloor gradient, scour zones and depth, and subseafloor stratigraphy. Survey methodology included the use of both passive and active sensors deployed in a towed array at each site. The use of geophysics in archaeology, specifically in underwater archaeology, is a widely accepted practice because of the ability to accurately record large areas of the seafloor in greater detail than can be identified through visual survey alone.

BOEM has previously funded studies to refine methodologies for the acquisition and interpretation of magnetometer data as it relates to submerged cultural resources (Garrison et al. 1989; Pearson et al. 2003). Magnetometers are passive sensors that record the Earth's ambient magnetic field, created by the interaction of the Earth's "metallic nickel-iron core" and "viscous lower mantle" (Herz and Garrison 1998:165). The resulting magnetic field varies in intensity from approximately 35,000 to 70,000 nanoteslas (nT), depending on distance between the north and south poles (Herz and Garrison 1998:165). Local aberrations in the Earth's magnetic field (anomalies) can result from the presence of a ferromagnetic object, or objects and sediments whose magnetization has been altered by human activity (Herz and Garrison 1998:167-169; Mussett and Khan 2000:162). It is important to note that all objects have the potential to become magnetized; therefore, recorded anomalies do not always represent human-made materials, let alone archaeological materials. Sediments, rocks, heated surfaces, and other naturally occurring features may become magnetized and produce anomalies sufficient to be recorded by magnetometers. Magnetic anomalies as interpreted for offshore survey reports were defined by Garrison et al. (1989) as a deviation in the ambient magnetic field measuring 5 nT (gammas) or more, and recorded across three or more consecutive data samples. Enright et al. (2006) restated this definition using the same intensity criteria, but using a distance measurement of 6 m (19.7 ft) or more rather than using a predefined duration of time.

As discussed in Camidge et al. 2010, Enright et al. 2006, and Garrison et al. 1989, there are inherent limitations to contouring magnetic data. Magnetometer data for this study was acquired in order to identify any disarticulated components or artifacts within the overall site; however, virtually all of the study sites have significant quantities of metal. The process of contouring magnetic data can make it difficult or impossible to identify smaller anomalies that are obscured by much larger, adjacent anomalies within the site. The result is that the smaller anomalies that may be caused by distinct targets away from the main body of a wreck are unidentifiable on the contour map. Also, contoured data is interpolated across survey lines, suggesting greater data density than is actually recorded (Camidge et al. 2010). For these reasons, magnetometer data interpretation for this study also included an analysis of individual anomaly characteristics and plotting of each individual anomaly.

The remaining geophysical sensors used for this project are active acoustic sensors, including side scan sonar, single beam echosounder, multibeam echosounder, and sub-bottom profiler. Additional data was acquired at selected study sites using a 3-D scanning sonar system. Acoustic sensors are ubiquitous in underwater survey because of the superior ability of sound waves to propagate through water. Sound waves will travel at varying frequencies through the water column to depths of up to 10,000 km (Wille 2005). Generally, acoustic sensors operate by emitting a specific frequency signal and recording both the amount of time it takes the signal to return to the receiver and the strength of the returned signal (Wille 2005; Blondel 2009).

Acoustic data collection depends on the actual speed of sound in two-way time travel through the water column; data can be acquired using the average speed of sound in salt water, 1,500 meters/second (m/sec) (~5,000 ft/sec) or adjusted for the actual speed of sound recorded by velocity casts, or sound velocity profiles, conducted at each study site and specific to that data set (Wille 2005:27). The measured speed of sound can be applied directly to the data during acquisition or as a correction during data post-processing. Acoustic data, or imagery based on sound is produced when an object has a different acoustic impedance than its surroundings; acoustic impedance, also known as backscatter, is defined as “the product of the density and the speed of sound” (Wille 2005:29). A change in either density or speed of sound will produce an acoustic echo. Sound images of marine environments do not have a genuine color and generally are black and white, with a dynamic gray scale, although for ease of interpretation they can be changed to a false color scale (Wille 2005:30). Figures based on acoustic data in this report use both gray scale and false color scales.

The side scan sonar, single beam echosounder, multibeam echosounder, and 3-D sonar are all acoustic devices designed to image or provide bathymetric data of the seafloor. The side scan sonar provides backscatter imagery to either side of the sensor; this highlights changes in object density, resulting in a picture that illustrates textural changes in the seafloor, or acoustic imagery of seabed objects such as a shipwreck. Lower sonar frequencies can travel further resulting in a wider coverage area, which allows surveys to be conducted much more rapidly using a wider survey grid; however, this is offset by decreased imaging resolution. Higher frequencies can provide much-improved imaging, but the area of seafloor that can be covered in a single pass is reduced. The single beam echosounder is used primarily to provide water depth values directly beneath the sensor. The disadvantage is that values are present only directly beneath the area traversed by the survey vessel, so data must be interpolated between survey lines. Wider survey line spacing intervals, coupled with complex seafloor conditions, will result in a less than accurate bathymetric map. Multibeam echosounders solve this problem by using multiple pings in a swath pattern similar to that of the side scan sonar. The result is that with proper survey design, more than 100% seabed coverage can be obtained, which results in very accurate bathymetric maps. Many multibeam echosounders also provide backscatter capabilities that can image density changes similar to those of the side scan sonar. The 3-D sonar used for this study operates in a way similar to a multibeam echosounder, except that it produces a focused array producing real-time imagery with an advertised data density 100 times greater than traditional multibeams (CODAOctopus 2011). The Echoscope allows researchers to view data from multiple angles, thus allowing water column noise to be filtered out in real-time.

Sub-bottom profiling, or the acquisition of subseafloor echosounder data, is used to record the internal structure of subsurface sediments, which can be used to characterize an extended area or compare against core stratification to identify localized anomalies (Wille 2005:52-56). Sub-bottom profiling is a balance between high resolution of near-seafloor stratigraphy, achieved by using higher frequencies, and penetration into deeper sediment structures, which is done using lower frequency signals (Wille 2005:53).

2.3 Data Acquisition

The study contract initially required geophysical data acquisition at six study sites. After diving operations in August 2010, the contract was amended to include data acquisition at two additional sites, which had been added to the diving operations in the field.

All geophysical data acquisition was performed aboard the motor vessel (M/V) *Nikola* from March 5, 2010 to June 7, 2011 (Figure 2.1).

Figure 2.1. Geophysical survey vessel M/V *Nikola*.

Acquisition was typically timed to correspond with periods when *Nikola* was operating in the vicinity of one of the study sites. The contract called for only side scan sonar and magnetometer acquisition at each site. In addition to these sensors, a single beam echosounder, a multibeam echosounder, and a sub-bottom profiler were employed on all sites. Velocity probes were deployed at each site (typically at the commencement and termination of the survey) to measure the true speed of sound for calibration and processing of acoustic sensors. During data acquisition at three of the study sites, Tesla also deployed a CODA Echoscope© 3-D sonar mounted to *Nikola*'s hull.

The geophysical systems used on all sites included a Marine Magnetics SeaSpy© total field magnetometer, an Edgetech 2400-FS© 120 & 410 kHz dual frequency side scan sonar, an Odom EchoTrac Mk III© 24 & 200 kHz dual frequency single beam echosounder, an Edgetech SB-216© 2-16 kHz chirp sub-bottom profiler, and a R2 Sonic 2024© 200–400 kHz multibeam echosounder. A CODA Echoscope© 3D sonar was used during acquisition at three of the original contract sites. The sensor configuration for *Nikola* is shown in Appendix A. The single and multibeam echosounders and the Echoscope were pole-mounted to the hull of *Nikola*. All other sensors were towed behind the vessel. The hull-mounted sensors were positioned by the Veripos© augmented DGPS network and interfaced into a QINSy© hydrographic package by QPS©. The towed sensors were positioned using differential-enabled GPS receivers provided by the WAAS and USCG reference station networks interfaced to an EZ-Nav navigation package by Geonav Marine Systems©.

All towed sensors are positioned relative to the vessel's antennae. The sub-bottom profiler was towed at a constant distance behind the survey vessel. Cable changes were made for the sonar and magnetometer, as needed, to ensure that sensors were operated at the optimum height above the seabed. On occasion, sensors were towed beyond recommended specifications in order to avoid shipwrecks with significant relief above the seafloor. Sensor setbacks at each site are tabulated in Sensor Line Logs which have been provided to BOEM along with copies of the original data. To compensate for real-time cable changes, digital magnetometer and sonar data were set-back corrected by feeding cable counter data directly into the navigation system. An algorithm within the navigation software uses the height of the tow-fish above the seafloor subtracted from the water depth (to calculate the depth of the tow-fish), the cable counter value, and a cable catenary calculation to provide true-setback for each sensor in real-time. Specifications for all geophysical sensors and equipment are included in Appendix A.

The geodetic datum for the survey was NAD 27, State Plane Coordinate System (Louisiana South or Texas South Central), Lambert Projection, in feet. Survey grids at each site were designed to parallel the orientation of each wreck, when known, based on available data. In most cases, two separate survey grids were employed and centered on the reported site coordinates. Both grids were typically oriented parallel and perpendicular to the orientation of the wreck site. The first survey grid covered a radius of 300 m (~1,000 ft) past the reported wreck coordinates. Survey lines were spaced at 100 m (328 ft) line spacing intervals. The side scan sonar was operated at 120 kHz and set at 100 m (328 ft) range to confirm the shipwreck position. The lower frequency spectrum allows the tow-fish to be flown higher in the water column, thereby reducing the risk of impacting the wreck site. The wider swath setting also provided maximum coverage of the seafloor while reducing time and costs. The second grid covered a 150-m (~500-ft) radius around the wreck site and used a 30-m (98.4-ft) line spacing interval with the sonar operating at 410 kHz and set at a 50-m (164-ft) range. The higher frequency spectrum provided increased resolution of the wreck and seafloor surrounding the wreck site while providing a tighter grid for magnetometer, multibeam, and sub-bottom profiler acquisition. The dual survey grid methodology also allowed for the comparison of magnetic contours using two different line spacing intervals over similar grids.

Survey lines were numbered using separate numbering conventions according to line spacing interval and direction. For example, on Site 433, 100-m spaced lines that parallel the wreck are numbered consecutively, beginning with number 1, while the 100-m survey lines that are perpendicular to the wreck are consecutively numbered beginning with number 101. The 30-m spaced lines parallel to the wreck start with number 201 and the 30-m perpendicular lines start with number 301. Re-runs were deemed necessary in the field if sensor quality was compromised, the vessel was forced off-line, or sensors were out of specification. Each survey line re-run is appended with a letter designation.

The grids described above were used on all sites except the shallowest site (Site No. 380), where the shallow water depths precluded the ability to achieve adequate sonar coverage using the 100-m line spacing interval. All lines at Site 380 were run at 30-m line spacing, covering the full 300-m radius. Sites Nos. 389 and 236 were added as part of a contract amendment and employed 30-m and supplemental 15-m survey lines directly over the shipwreck site, but fewer 100-m survey lines. Navigation post-plot maps for each of the eight geophysical survey grids are included in Appendix B.

2.4 Data Processing

Echoscope acquisition and preliminary data processing was performed by Pete Henstridge using CODA UIS©, QPS QINSy©, and QPS Qloud© software. Multibeam bathymetry acquisition and preliminary processing was performed by James Collier and Kyle Edmonds using QPS QINSy© and Qloud© software. Additional processing and preparation of final figures was performed by Matt Keith. All bathymetry maps and seafloor renderings were prepared using the multibeam bathymetry data. Depths are shown in meters on all maps included in this report. Bathymetric datum was the NGVD 29 vertical datum for mean sea-level with water depths adjusted for the measured velocity of sound in seawater during acquisition. All measurements were recorded in standard units and converted to metric for the final report.

Sonar and sub-bottom profiler data interpretation was conducted using the latest CODA GeoSurvey Software. CODA Survey Engine Seismic+ software was also used for sub-bottom profiler interpretation.

Magnetometer data was acquired in an ASCII format and interpreted using Tesla Offshore's proprietary MagPick software. All magnetometer interpretation and tabulation was performed by Amanda Evans. All magnetic anomalies are tabulated in Appendix C, which details the anomaly characteristics and survey parameters in relation to the navigation post-plot for each site. Matt Keith prepared the magnetometer contours using proprietary Tesla software developed by Bill

Loggin. This software filters the data set by removing all data points that do not exceed specifications for gamma count increase over a specified distance. The remaining values are saved as a negative or positive value relative to the ambient background field. The result is the ambient background is removed and only anomalous readings remain, negating the need for a base station. This data was then contoured using Surfer© software. Excellent correlation was noted between individually mapped anomalies and contoured data.

All maps and figures for this report based on the geophysical data were prepared by Matt Keith, with assistance from Tesla drafting staff.

2.5 Diving Parameters

The diver investigation phase of the project involved Principal Investigator Amanda Evans (Tesla Offshore), Co-Principal Investigator Matt Keith (Tesla Offshore), Diving Field Director and Archaeologist Gregory Cook (UWF Archaeology Institute), Dive Safety Officer (DSO) Fritz Sharar (UWF Marine Services Department), Archaeologist Norine Carroll (UWF Archaeology Institute), and archaeological divers from the University of West Florida (UWF), including Aleks Adams, Daniel Haddock, Mercedes Harrold, Sarah Linden, Andy Marr, Bill Neal, Jake Shidner, Eric Swanson, and Wes Perrine. COTR Dr. Christopher Horrell and Marine Archaeologist Melanie Damour accompanied the field crew as observers for BOEMRE, and also participated in diving operations.

It was recognized, from the initial planning stages that the field crew would benefit from preparatory dives conducted as a team and in water depths and conditions similar to those expected in the open GOM. Field equipment was tested before deployment and, where necessary, modifications were made to ensure optimum data quality during field operations. A dive in water depths equal to the deepest study site was conducted, involving field crew members, that simulated archaeological tasks that would be conducted during contracted field operations. Also, before field work began, all project divers went through supervised underwater entanglement exercises organized by UWF's DSO Fritz Sharar. This was deemed necessary because many shipwrecks in the GOM are fouled by fishing line and netting which create entanglement hazards for divers in low to zero visibility conditions. The DSO had absolute authority to call dives for any reason in order to ensure the safety of all crew members.

Figure 2.2. Project dive team and crew of M/V *Spree*. First row from left to right: Amanda Evans, Fritz Sharar, Bill Neal. Second row: Mercedes Harrold, Norine Carroll, Chris Horrell. Third row: Wes Perrine, Melanie Damour, Sarah Linden, Greg Cook, Melanie Wasson, Ross Tague. Fourth row: Matt Keith, Jake Shidner, Andy Marr, Danny Haddock, Eric Swanson, Butch Boggess. Last row: Capt. Frank Wasson, Aleks Adams, Colm O'Reilly, and Capt. John Camp.

Fieldwork began on August 11, 2010, leaving port from Morgan City, Louisiana, and proceeded for 16 days until arrival at Galveston, Texas, on August 26, 2010. Dive operations were conducted onboard the M/V *Spree*, a 30.5-m (100-ft), former crew boat converted to a live-aboard diving vessel. The archaeological dive crew was tasked with investigating six primary targets, with five secondary targets added in the field. The overall goal for diver investigations involved acquiring enough data to help determine whether any site is eligible for nomination to the NRHP, and collecting data used in modeling site formation processes in order to provide long-term management recommendations. Divers recorded measurements, photographs, and video, when possible, of sites to provide detailed documentation that supplemented overall site data generated from the geophysical data. Divers also collected water samples at each wreck site, and sediment cores. All 11 primary and secondary sites were investigated over the course of 246 logged dives, with total bottom time exceeding 120 hours.

Before fieldwork began, a general briefing on the various sites chosen for investigation and proposed diving methodology was made at Tesla Offshore LLC's office in Baton Rouge. In addition, each field day began with an in-depth overview by Matt Keith on the history and the remote sensing data relating to sites to be investigated on that day, followed by site-specific safety briefings by DSO Fritz Sharar. As part of the safety briefing, risk assessments were outlined for each site, incorporating remote sensing data, bathymetry data, as well as personal observations of the sea-state and presence of any currents, weather, etc. When appropriate, additional safety and control measures were taken to ensure diver safety and efficiency of data collection. After the site-specific safety briefing, archaeological priorities and the general dive plan were outlined by Greg Cook.

BOEM provided their Kongsberg Mesotech MS 1000 sector scanning sonar and tripod for use during diving operations. The Mesotech was deployed from the stern of the M/V *Spree* and used to identify and orient dive teams on the site before they entered the water and to plan vessel moves and anchoring.

On Site 236, the Mesotech was deployed during dive operations allowing top side personnel to monitor divers in real-time. Supplemental sonar imagery was recorded with the Mesotech during the diving operations and represents unprocessed static imagery; it is therefore discussed throughout this report along with the diving operations as opposed to the geophysics.

Figure 2.3. Viewing the Mesotech data. From left to right: Greg Cook, Melanie Damour, Matt Keith, Chris Horrell.

Captain Frank Wasson navigated to the provided coordinates for each dive site, and then used the vessel's echosounder to position the boat slightly off of the dive site. Spot buoys were then thrown to mark the location for the first dive team. Fritz Sharar and Greg Cook conducted the first dive at each site in order to locate the target, establish a descent line at an appropriate location on the site, and evaluate the site for safety concerns and archaeological investigation priorities. After this initial dive, any modifications to the safety plan were communicated to the dive crew, and teams of archaeological divers were tasked with specific objectives to be carried out in particular diagnostic areas of the site. This generated a continuous feedback loop, with divers communicating their findings after completing their dive to those suited up and prepared to continue the investigation based on what had been completed or observed during previous dives. This resulted in an efficient dive rotation that often involved multiple dive teams working on different sections of the site, and clear communication between teams as to the status of the overall goals for the archaeological recording. After completing operations on each site, archaeologists transcribed their notes, cataloged video and still photographs, and made preparations for further investigations as the M/V *Spree* transited to the next site for investigation.

Site maps based on diving and geophysical data were prepared by Greg Cook. Aleks Adams assisted with the preparation of the Site 389 site plan. C. Lee McKenzie prepared the final maps in Microsoft® Publisher which were entered into AutoCAD software and finalized by Tesla personnel. Measurements of diagnostic features taken in the field were recorded in standard U.S. units (feet and inches), and converted to metric for the final report.

2.6 Coring and Environmental Analyses

In addition to the historical significance and archaeological aspects of this study, environmental factors were analyzed to determine site formation processes impacting the wreck sites. The majority of analyses used in long-term environmental monitoring require repeated site visits for long-term data collection; however, due to time and budget constraints, this was not an option for the present study. Core acquisition was required as part of the contracted scope of work, and the research design and sampling strategy was constructed to maximize the amount of information that could be produced from a single visit to the site, effectively collecting a snapshot of site conditions and applying the data in more detailed long-term scenarios. Cores were collected by divers, rather than from the vessel, for two reasons: first, to avoid incidental damage to the site caused by remote coring, and, second, to allow divers to position the core barrel so that sediments were collected as close to the hull as possible. Water samples were added to the research design as a cost effective way to provide additional information, and were sampled at the actual wreck site depths. Core lithology and environmental samples are illustrated in Appendix G; water sampling results are tabulated in Appendix F. Analyses of sediments captured stratigraphically within the cores were used to measure conditions at the time of sampling and applied to estimates of long-term processes, while water sample test results were compared with known values and ranges across the GOM.

Figure 2.4. Bill Neal and Amanda Evans remove a core sleeve from the 36” corer.

Coring devices are generally designed for either sand or silt and clay. Because there is no universal bottom sediment sampler, the coring device chosen for this study was based on the most likely types of sediment to be encountered. The sites investigated are located offshore Texas and Louisiana, and the most likely sediments to be analyzed are principally quartz sands and muds. The latter are modern, suspended and transported during river high flow stages, storms and hurricanes, and preferentially deposited during calm conditions. Sand layers are predominantly relict and deposited near the coastline by transgressive events (Curray 1960), or can be attributed to and/or reworked by storms or hurricanes. Based on regional environmental studies, silts and clay were anticipated with varying amounts of sand.

A Wildco 2” diameter, 36” length coring device was selected for use in this study. The core length was chosen because it was manageable by divers in the open GOM and it provides a sufficient profile of sediments for use in planned grain size and radioisotopic analyses. The analyses could be conducted, however, only if the cores captured the uppermost sediments. Diver-collected cores have been shown to retain greater integrity than those sampled with a gravity corer (Mudroch and Azcue 1995:54). It was not possible, however, to exclude all types of disturbance in the sediment stratigraphy. Sources of disturbance include, “the pressure wave in advance of the sampler; tilting or skewed penetration of the sampler; and washout or other loss during retrieval to the sampling platform” (Mudroch and Azcue 1995:56).

Matt Keith and Amanda Evans were responsible for collecting the sediment cores. Due to the physical requirements of handling the coring unit and sampling tubes, and the low to zero visibility conditions on site, cores were usually acquired with a three-person dive team. Following acquisition, each core sleeve was capped at depth before surfacing. Water samples were collected by Amanda Evans during coring dives using sterile 8 oz. water sampling bottles. Core sleeves were sealed, labeled, and cataloged on the boat immediately after acquisition, and stored upright on the vessel to avoid unnecessary mixing of strata within the core sleeve.

Sediment cores were opened immediately after the conclusion of field operations by Amanda Evans and Matt Keith in Baton Rouge, Louisiana. Cores were split, catalogued and logged; core logs were prepared using LogPlot 7 software. Sediment samples were immediately obtained and shipped to Dr. Mead Allison at the University of Texas for radioisotope analysis (Section 2.8). The remaining cores were measured for sediment shear strength (where possible) and samples were taken for grain size analysis. Grain size samples were collected from units identified during core logging in order to refine the final core log. Samples were collected and placed into labeled Whirl-Pak bags and weighed. Grain size measurements were conducted by Cory Sills, under the direction of Dr. Patrick Hesp, using a laser particle counter at the Louisiana Universities Marine Consortium (LUMCON). Results were exported into a Microsoft® Excel® spreadsheet; grain size S-curves were created, and plotted. Amanda Evans calculated median and graphic mean grain sizes for each sample following methods published by Folk (1980). Median is the most commonly used definition due to its simplicity; median represents the grain size diameter found at 50% on the cumulative S-curve (Folk 1980:41). Graphic mean is a more accurate representation of grain size within a given sample and is calculated by averaging the diameters of grains at three places along the cumulative S-curve; $(\Phi16 + \Phi50 + \Phi84)/3$ (Folk 1980:41). A Pocket Penetrometer and mini-torvane were used for down-core shear strength measurements.

According to Lee (1985:215), both the Torvane and Pocket Penetrometer are quick and efficient tools, which, depending upon the operator, can produce data that is good for creating a "rough comparative index of strength." Shear strength measurements were obtained where possible, or when sediment cohesion and water content resulted in reliable measurements. Down core sediment content in open ocean samples increases as the water content decreases; according to Mudroch and Azcue (1995:66), "in fine-grained material, the water content is about 80% at the 10 cm sediment depth, 70% at the 20 cm sediment depth, and about 50–60% at the 30–40 cm sediment depth. Below 50 cm, the sediment usually becomes more compacted and there is little change in water content."

Water samples were tested by Amanda Evans for pH, salinity, and dissolved oxygen content. An Amprobe WT-30 salinity pen-style meter was used for salinity measurements and calibrated using a 30g/L NaCl solution. Remaining instruments included an Extech Instruments ExStik DO600 dissolved oxygen meter and ExStik EC500 pH/Conductivity/TDS/salinity meter. Water sampling measurement accuracy for dissolved oxygen, salinity, and pH were +/- 2% of the Full Scale. The EC500 did not have the range necessary to measure the higher salinity levels found in the open GOM, and therefore could be used only for pH readings; conductivity and TDS are related to salinity readings and therefore were not recorded from the EC500 meter. Measurements for pH were made after completion of a one-step calibration using 7.0 pH solution. Handling of collected water samples followed USGS standards for water quality testing (USGS 2010). While it is acknowledged that long-term monitoring with repeat visits to a site throughout the year are necessary to understand site chemistry and seasonal fluctuations, it was felt that this information could provide valuable baseline data and a useful comparison between site specific measurements and published data sets for the GOM.

2.7 OCEANOGRAPHIC ANALYSES

Long-term site formation processes are an integral component of shipwreck site research and management. Oceanographic processes contribute to observable changes to the vessel from its pre-wrecking event appearance to the documented wreck site investigated on the seafloor. Numerous post-depositional site formation investigations address the roles of seafloor scour, bioturbation, chemical processes, and mechanical processes, such as currents, waves, and storm surge (Robinson 1981; Gifford 1982; MacLeod 1989; Henderson 1990; Lenihan 1990; Quinn et al.1997; Cullimore and Johnston 2003; McNinch et al. 2006, Quinn 2006, Quinn et al. 2007). One of the principal mechanisms for preserving both wooden and metal-hulled shipwrecks identified from these studies is the degree of sediment cover that protects the site from chemical, physical, and biological degradation. Oceanographic research for this study focused on the potential for sediment transport and mobility at the site, including accretion and scour, as it relates to site exposure. Grain sizes and shear strengths measured from core samples can provide information concerning the sediments impacted by modeled oceanographic patterns (Keith and Evans 2009; Rego et al. 2011).

Due to the prevalence of oil and gas industry exploration, the GOM's near surface geology has been extensively studied (e.g., Bernard 1970; Curray 1960; McClelland 1979). Sediment distribution on the continental shelf of the GOM indicates that the sediments between the Mississippi Delta and the Mexican border can be divided into two basic units: (1) transgressive nearshore sands and (2) shelf muds (Curray 1960; Balsam & Beeson 2003). Major portions of the Texas and Louisiana shelf are covered with clay and varying amounts of sand, silt, and organics (Allison et al. 2000; Gordon et al. 2001; Balsam & Beeson 2003; Ellwood et al. 2006).

Sediment deposition, erosion, and scouring are most accurately measured by long-term monitoring using such devices as current meters or profilers, sediment traps, and erosion pins. Because of the contract's relatively short duration and the inability to make repeated site visits, site-specific data was compared with established data sets to determine maximum potentials for scour and ranges of active sediment deposition. Maximum potentials are defined as those resulting from extreme storm events, including recent hurricanes, such as Katrina, Rita, and Ike. Estimates of sediment transport under combined wave-current conditions are used to infer the impact of hydrodynamic processes on the shipwrecks, particularly with regard to site exposure. Sediment transport occurs in three different ways: by rolling, saltation, and suspension, any of which can occur after individual grains are moved by fluid drag (Dyer 1986). As the flow intensity increases, individual grains moving along the bottom take off due to impact with stationary grains. In this case, the mode of sediment transport changes from rolling and sliding to jumping (saltation) along the bottom (U.S. Army 2002). When the vertical components of the turbulent velocity are approximately equal to the setting velocity of the grain, these jumps are higher and the grain can return to the bed and saltate again or be taken into suspension (Dyer 1986).

Computer modeling of sediment transport was conducted by Deltares, under contract to Dr. Patrick Hesp, for three datum points in the GOM (Rego et al. 2011). Because of the complexity of the computer modeling, creating models for each shipwreck study site was cost-prohibitive. Instead, three separate datum points were selected, representing water depths of 15.5, 26.0, and 31.0 m (50.8, 85.3, and 101.7 ft) below sea level (BSL). The first datum corresponds with Site 373 and used water depths and grain sizes acquired as part of this study. The second two datums correspond with sites analyzed as part of a separately-funded study, which included grain size sampling and analysis. Datums 2 and 3 were specifically chosen since they correlate closely with water depths and grain sizes for many of the sites included in the current shipwreck study (Figure 2.7). Sediment types at the selected datums also represented typical grain sizes found at the study shipwreck sites. The modeling incorporated H*WIND data for recent hurricanes and simulated hydrodynamics and waves using proprietary Delft3D-FLOW and Delft3D-WAVE models in the GOM basin using a rectangular model of 10km resolution around the datum points. Smaller, curvilinear models of 50 m (164 ft) maximum resolution were also created with Delft3D-FLOW and Delft3D-WAVE to simulate localized conditions. Curves for each site were created representing model results for both loose and consolidated sediment types. Hurricane surface wind speed data was prepared by NOAA and is available as real-time analyses of tropical cyclone surface wind observations (H*WIND). Delft3D-FLOW is a three-dimensional hydrodynamic model that simulates horizontal and vertical water movement on the continental shelf. Delft3D-WAVE is designed to simulate the transformation and propagation of "random, short-crested, wind-generated waves in coastal waters" (Rego et al. 2011).

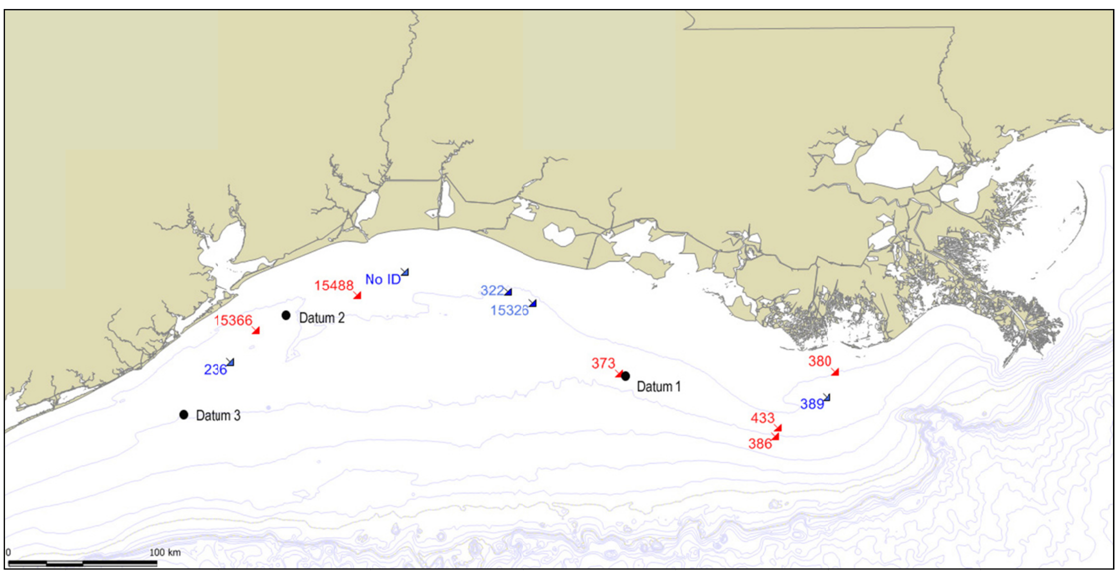


Figure 2.5. Distribution of study sites and location of the datums used in oceanographic modeling.

Results of the computer modeling produced estimates of potential sediment transport for given water depths and sediment types in the GOM during extreme storm events. Maximum potentials for sediment transport calculated for the datum point most appropriate to a given shipwreck site's water depth and location were compared with site specific sediment accretion estimates provided by radiosiotopic analysis (Section 2.8) and were also compared with published studies of GOM oceanography and sediment transport. Geophysical data, specifically multibeam bathymetry, side scan sonar, and sub-bottom profiler were then used to attempt to quantify or qualify sediment mobility at each of the shipwreck sites given the rates of accretion and potential for sediment transport. Computer modeling also resulted in wave height, period, and directional data for recent hurricanes in the GOM, and also scour patterns, which are summarized and correlated with the shipwreck study sites in Chapter 5.

2.8 RADIOISOTOPE ANALYSIS

A primary objective of the coring was to determine site formation processes; this information would result in recommendations related to long-term site management. Sediment accumulation rates and scour are typically monitored as part of long-term projects, requiring multiple site visits and measurements over an extended period (Masselink and Hughes 2003). It was determined that reaching the goals of the study would be aided by the inclusion of radioisotope analysis as a proxy indicator of sedimentation and possible scour (Allison and Lee 2004; Allison et al. 2005; Neill and Allison 2005). Radioisotope tracers, particularly Lead-210 (^{210}Pb) and Cesium-137 (^{137}Cs), may provide an indication of recent processes, due to their short half-life duration. A variety of particle-reactive radioisotopes have been applied to the study of seabed mixing and accumulation in coastal environments. For this study, the use of multiple tracers (^{210}Pb and ^{137}Cs) allowed for examination of seabed processes on several time scales, given that the characteristic time scale of each tracer is about 4 to 5 half-lives. ^{210}Pb ($t_{1/2}$ = 22.3 yr) is a naturally occurring daughter product of the Uranium-238 (^{238}U) decay series.

Radiochemical samples were collected from cores acquired at six of the shipwreck sites: 389, 433, 373, 15488, 15366, and 236. All samples were prepared on August 29, 2010, immediately after the completion of diving operations. Sampling methodology included preparation of continuous 1 cm sediment slices to a depth of 5 cm down the core. For sites 433, 373, and 236, additional near-surface samples were prepared, consisting of continuous 2 cm slices between 5 and 11 cm downcore. For all cores, near-surface samples were followed by 2 cm slices collected every 10 cm downcore from the last near-surface sample. Samples were weighed individually, and packed in sterile Whirl-Pak bags, labeled with the site number, date of acquisition, water depth, distance from shore, and sample depth.

Samples were shipped immediately to the University of Texas Institute for Geophysics and analyzed for downcore activities of the particle-reactive radiotracers ^{210}Pb (naturally occurring, 22.3-year half-life) and ^{137}Cs (atmospheric thermonuclear testing in 1954–72, 30-year half-life). These tracers have been widely used in marine sediments to calculate sediment accumulation rates extending back ~100 years as tracers in sediment dynamics. During analysis, it became apparent that, in the present application to marine archaeological research, it would be possible to address two questions. The first was to determine post-disturbance sediment accumulation rates or erosion signatures that would contribute to an understanding of the likelihood and rates of shipwreck burial or scour, both of which are related to site preservation. The second was whether the sediments in the immediate vicinity of the wreck site preserve a disturbance "time marker" in the steady state sediment deposition record that can provide an independent estimate of the date of the wrecking event, which would be particularly useful for unidentified wrecks. The second question became apparent during lab analysis, during which it was observed to have merit. Data collection and sampling strategies conducted before the lab work, however, were not designed specifically for this task. Results presented in the following chapters suggest that this method may have merit in future applications.

Sediment samples from the cores arrived wet at the University of Texas Institute for Geophysics laboratory. Activities of the particle-reactive radiotracers ^{210}Pb and ^{137}Cs were measured for sediment intervals that were initially freeze-dried and finely ground. Wet and dry weights of each sample were recorded and used to calculate sediment porosity. Radiochemical samples were packed in either 50 mm diameter Petri dishes (planar geometry) or 60 mm long test tubes (well geometry), sealed to prevent Radon-222 (^{222}Rn) loss, and allowed to ingrow to secular equilibrium for ^{210}Pb for at least three weeks. Samples were then counted for 1–2 days using both coaxial planar and well-type, low-energy germanium (LEGE) γ-spectrometers; detector type was dependent on sample size (all samples from a single core were counted by one detector type). ^{137}Cs activities were determined using the 661.6 keV photopeak. Total ^{210}Pb activity was determined from the 46 keV photopeak and supported ^{210}Pb activities were determined by using averaged activities of the Radium-226 (^{226}Ra) daughters ^{214}Pb (295 and 352 keV) and Bismuth-214 (^{214}Bi) (609 keV). Detector efficiencies for this geometry were calculated using a natural sediment standard (IAEA-300 Baltic Sea sediment) and detector backgrounds at each energy of interest were determined using sample container blanks (Cutshall et al. 1983). A best-fit linear regression of the natural log of excess ^{210}Pb ($^{210}Pbxs$) with depth below any surface mixed layer of homogenous activity was used to determine the sediment accumulation for the past ~100 years (Nittrouer and Sternberg 1981). ^{137}Cs ($T½$ = 30 years) is the product of fallout from atmospheric testing of thermonuclear weapons that began in 1954. Two time markers for ^{137}Cs with depth can be used: the depth of maximum ^{137}Cs penetration (1954), and the depth of maximum ^{137}Cs fallout in the northern hemisphere, which, according to Chmura and Kosters (1994), occurred in 1963. ^{137}Cs rates can be calculated by dividing the depth of the 1954 or 1963 peak occurrence in the core by the number of years passed; errors are derived by extrapolating across the core interval represented by that particular year. Final accumulation rates were depth-corrected to a standard core porosity (75%) to expand or contract interval depths (to allow for inter-comparison of sites in linear terms) and can be converted from linear accumulation rates (LAR; consolidation-corrected cm/y) to mass accumulation rates (MAR; $g/cm^2/y$) (Allison et al. 2007). Radioisotope sample locations are shown on individual core logs in Appendix G and sampling results are tabulated in Appendix F.

2.9 Standardization

The above-mentioned methodologies are to be considered the standard procedures followed at all sites. Protocols and conventions are detailed in this chapter to avoid redundancy in the following report sections. Chapter 3 details the individual results for each study site. Alterations to the above stated methodologies were required at some sites or for specific analyses; those alterations are described in detail in the relevant section.

3. SITE RESULTS

The original contract stipulated investigation of six shipwreck sites located in federal lease areas offshore Louisiana and Texas, between South Pelto to the east, and Galveston to the west (Sites 380, 433, 386, 373, 15488, and 15366). A geophysical survey was conducted over each survey site before diving operations, to allow divers to use the most recent geophysical data at each site to target areas for further investigation. Due to the *Deepwater Horizon* incident, which occurred less than four months before dive operations, the project team planned alternate sites for the diving phase of the project in case oil or other on-site conditions prevented safe diving on any of the contracted sites. Alternate sites included numbers 389, 15326, 322, and a target in the West Cameron lease area (site number pending). The site of the USS *Hatteras* (Site 236) was also included as an alternate to allow documentation of site conditions, and add to existing site data based on sporadic monitoring visits. None of the contracted sites had to be skipped due to impacts from *Deepwater Horizon*, but additional time was available to investigate the prepared alternates. Following conclusion of dive operations, and in consultation with the COTR, the contract was amended to include geophysical survey over two of the alternate sites (Sites 389 and 236). All sites investigated are detailed in the following sections.

Table 3.1

Sites Investigated

BOEM Site Number	Hull Type	Tentative ID	Propulsion	Function
380	Wooden vessel	Unknown wooden vessel	Unknown	Unknown
433	Vessel	*R.W. Gallagher*	Oil-screw	Tanker
386	Vessel	*Heredia*	Oil-screw	Passenger & freighter
373	Vessel	*Cities Service Toledo*	Oil-screw	Tanker
15488	Vessel	Unknown	Unknown	Unknown
15366	Vessel	Unknown	Unknown	Unknown
389	Vessel	*J.A. Bisso*	Oil-screw	Tow vessel
236	Vessel	USS *Hatteras* (confirmed)	Steam-screw	Military
15326	Barge	Unknown	Unknown	Unknown
322	Vessel	Unknown	Unknown	Unknown
Pending	Unknown	Unknown	n/a	Unknown

3.1 SITE NO. 380, SOUTH PELTO AREA, REPORTED WOODEN WRECK

3.1.1 Site Background

Site number 380 is located in the South Pelto Area south of the Cat Island Pass Shipping Channel, between Isles Dernieres and Timbalier Island, which serves as the entrance into Terrebonne Bay. The only known account of this wreck comes from the NOAA AWOIS database (Record 9003), where it is identified as both “Unknown Wooden wreck” and “Dangerous Wreck.” The AWOIS entry, dated August 2, 1994, reports that the wreck was investigated by divers who observed wooden vessel remains consisting of “ribs, keel and rudder post.” The wreck was reportedly located on a sandy bottom and oriented NE by SW. The vessel location is defined as highly reliable. The wreck reportedly measured approximately 35.59 m (120 ft) long by 5.49 m (18 ft) wide and was described as a wooden vessel. No imagery or site plans were available. The wreck condition listed in the BOEM database was identified as 2 (partially intact, 25–50%) and exposure was listed as 2 (hull partially buried by sediment, less than 50%). Seafloor sediments were reported as sand and the water depth was reported as 7 m (23 ft). NOAA archaeological personnel Dave Alberg and Joe Hoyt were consulted for additional information pertaining to this record, but no additional information was identified.

BOEM records indicate that no known geophysical surveys had been conducted over the area of the reported wreck. In 1978, a 10” pipeline was installed that crosses within 62.5 m (205 ft) of the putative wreck site. In 1974, the Bureau of Land Management issued the first NTL requiring archaeological surveys for oil and gas development (NTL 74-10). This NTL was followed by NTL 75-03, which required archaeological surveys before drilling operations, the installation of any structure, or the installation of pipelines. Based on the chronology of NTLs, it can be concluded that a geophysical survey should have been conducted for the 10” pipeline, in compliance with NTL 75-03. The BOEM archaeology division had no records of any such survey; therefore, it was not possible to determine if a survey had taken place or if the wreck was identified before the pipeline was installed. The 10” pipeline is listed as active, and ongoing maintenance associated with the pipeline could potentially disturb the seafloor in the vicinity of the site. No other infrastructure is located within 1,525 m (5,000 ft) of the site.

3.1.2 Geophysical

Geophysical data acquisition was conducted at Site 380 on June 1 and 2, 2010, aboard the M/V *Nikola*. The survey grid was centered on the reported wreck position and extended out in a 300-m (1,000 ft) radius surrounding the wreck site, and consisted of 22 east-west survey lines (numbered 1–22) and 22 north/south survey lines (numbered 101–121) spaced 30 m apart (see Navigation Post-Plot Map, Appendix B; Figure B-1). Sonar data was acquired at 410 kHz, using a 50-m (164-ft) range (see Chapter 2 and Appendix A for complete sensor specifications and survey vessel configuration).

Bathymetry data indicates that water depths range from 10 to 12.4 m (33 to 41 ft) within the survey grid. Water depth at the reported shipwreck site is 11.1 m (36 ft). No significant scour zones or other macro-bathymetric irregularities were observed (Figure 3.1.1).

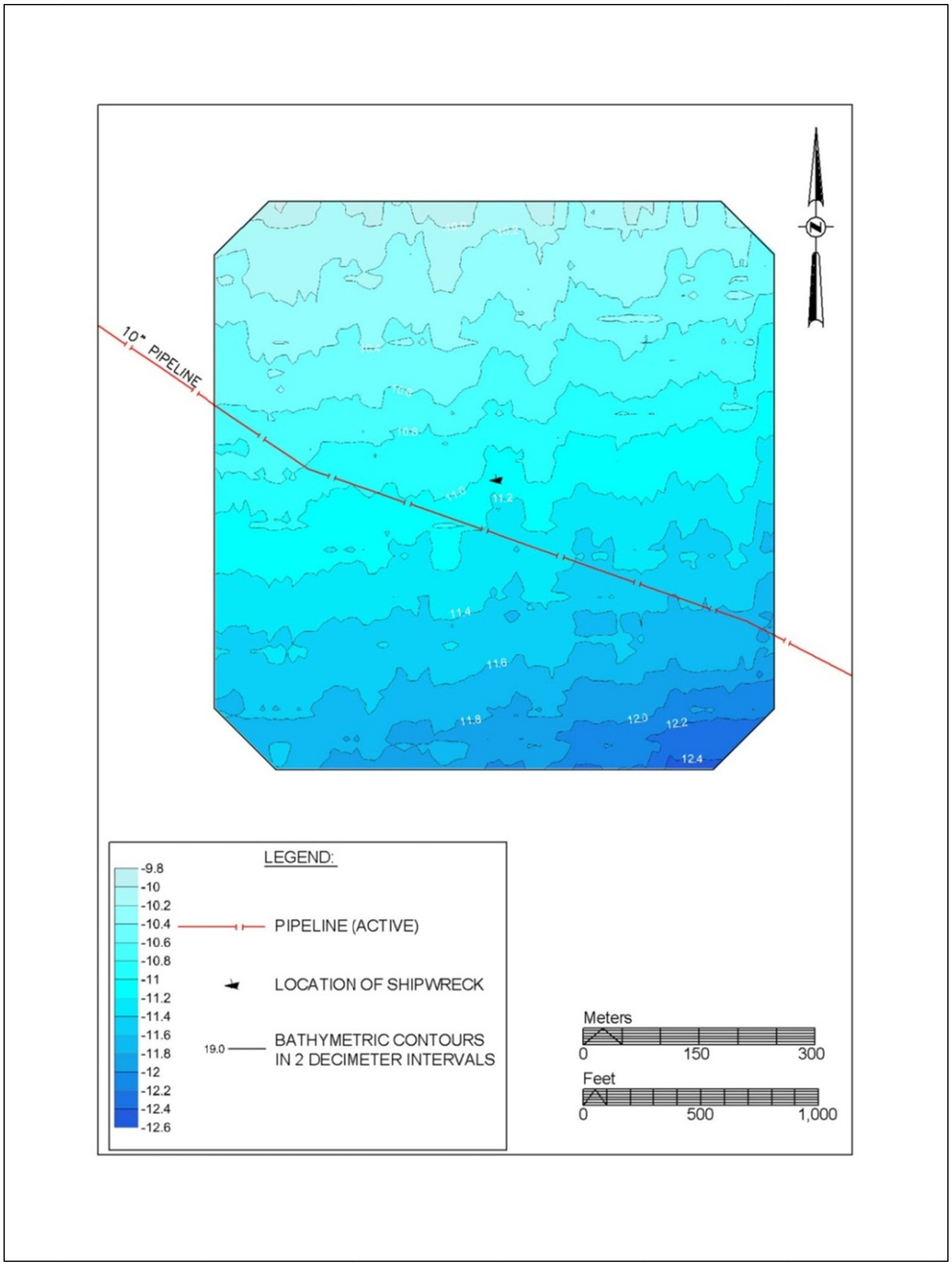


Figure 3.1.1. Bathymetry map surrounding site 380 in 2-decimeter intervals.

Sonar data highlighted a medium reflective seafloor, indicative of course-grained sandy sediments with some clay and or silt content (Figure 3.1.2). Although some minor divots and irregularities were evident, no trawl scars or other seafloor disturbances were observed; this indicates that either sediments lack sufficient cohesion to retain the imprint of drag scars or a combination of sediment transport/accretion rates and scour act to neutralize microbathymetric features.

Sub-bottom profiler data penetration in the southern portion of Site 380 ranged from 6 to 7.6 m (20 to 25 ft) before the data was attenuated completely by a strong, somewhat irregular gas front. The seafloor in the south consists of a strong reflector followed by a thin zone of parallel strata. This, in turn, overlies a zone of mostly acoustically transparent sediments, followed by parallel bedded laminated strata. Sub-bottom attenuation increases as the survey grid progresses to the north, likely due to the increased presence of surficial sand deposits associated with the flanks of Ship Shoal, which is located west of the site. In the extreme northern portion of the survey grid, sub-bottom penetration was reduced to the upper 1.2 m (4 ft) of surficial strata (Figure 3.1.3). Diffractions were occasionally resolved over the 10" pipeline. No other irregularities or disturbances that could be attributed to a shipwreck site were evident on the sub-bottom profiler data.

Magnetometer data produced numerous large dipolar anomalies that verified the published coordinates for the 10" pipeline. A total of 34 additional anomalies were observed that cannot be attributed directly to the pipeline. These individual anomalies are detailed in the Magnetic Anomaly Table for Site 380 (Appendix C). A cluster of five magnetic anomalies was identified at the reported shipwreck position, including anomaly nos. 16, 19, 20, 40, and 44. Anomaly no. 16 is a 37 nT dipolar anomaly with a 72-m (237-ft) duration, no. 19 is a 9 nT negative monopole with an 18.5-m (61-ft) duration, no. 20 is a 252 nT dipole with a 42-m (137-ft) duration, no. 40 is a 89 nT complex anomaly with a 47-m (154-ft) duration, and no. 44 is a 6 nT dipole with a 17-m (57-ft) duration. These anomalies are tabulated in Appendix C and can be correlated with their positions on the survey post-plot map for Site 380 (Appendix B; Figure B-1). The magnetic contour map clearly shows these anomalies extending beyond the pipeline and over the reported wreck site (Figure 3.1.4). Although interference from the nearby pipeline reduces the ability to provide a comprehensive prediction of the amount of ferromagnetic mass present at the reported shipwreck site, the size and distribution of these anomalies indicates that a significant quantity of buried ferromagnetic material is present at this location.

Although the combined geophysical data did not provide any indication of a clearly resolved intact shipwreck within the survey grid, magnetometer data at the location of the reported shipwreck site indicated that diver investigation was warranted.

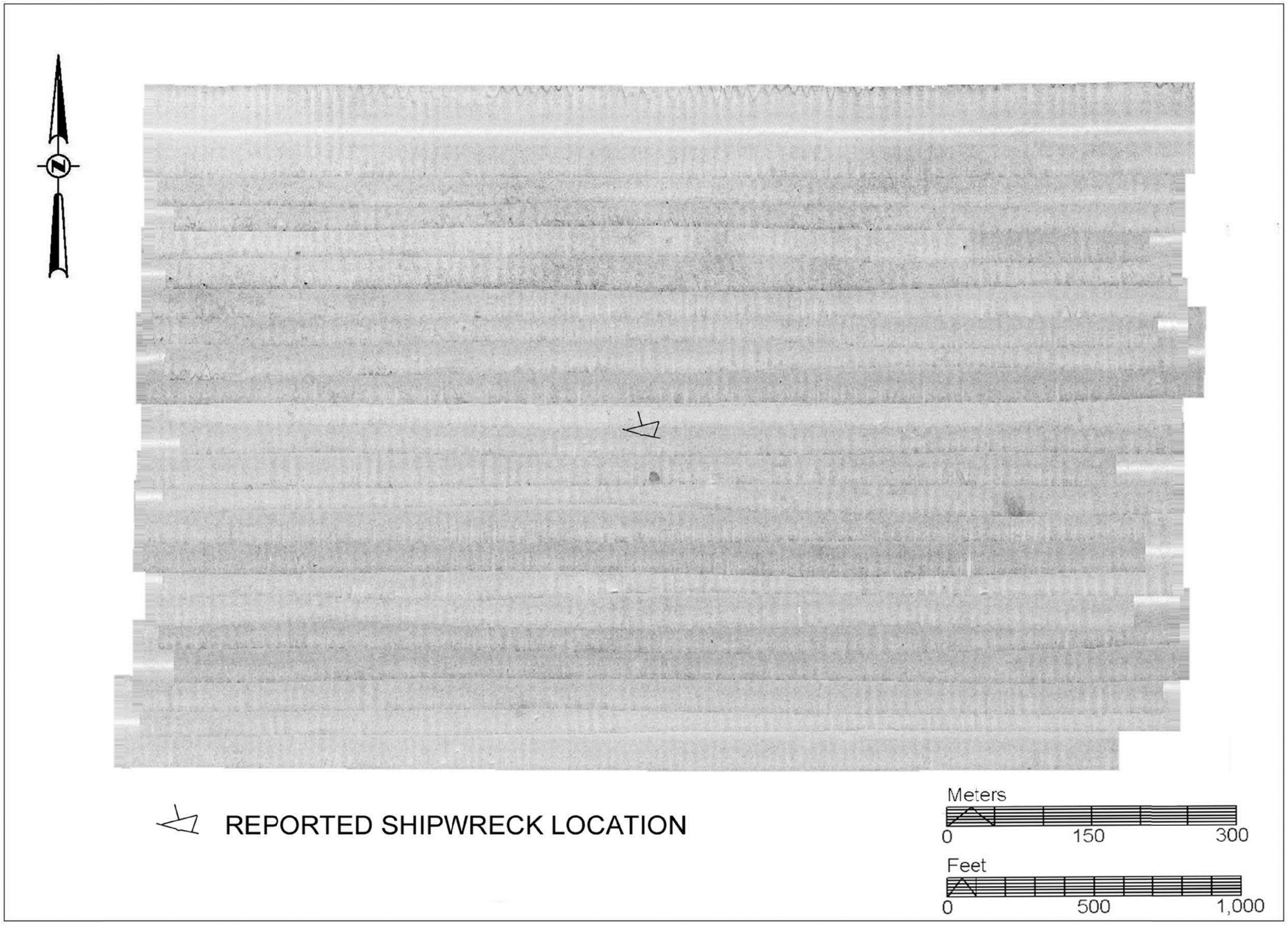


Figure 3.1.2. 410 kHz sonar mosaic of seafloor surrounding Site 380.

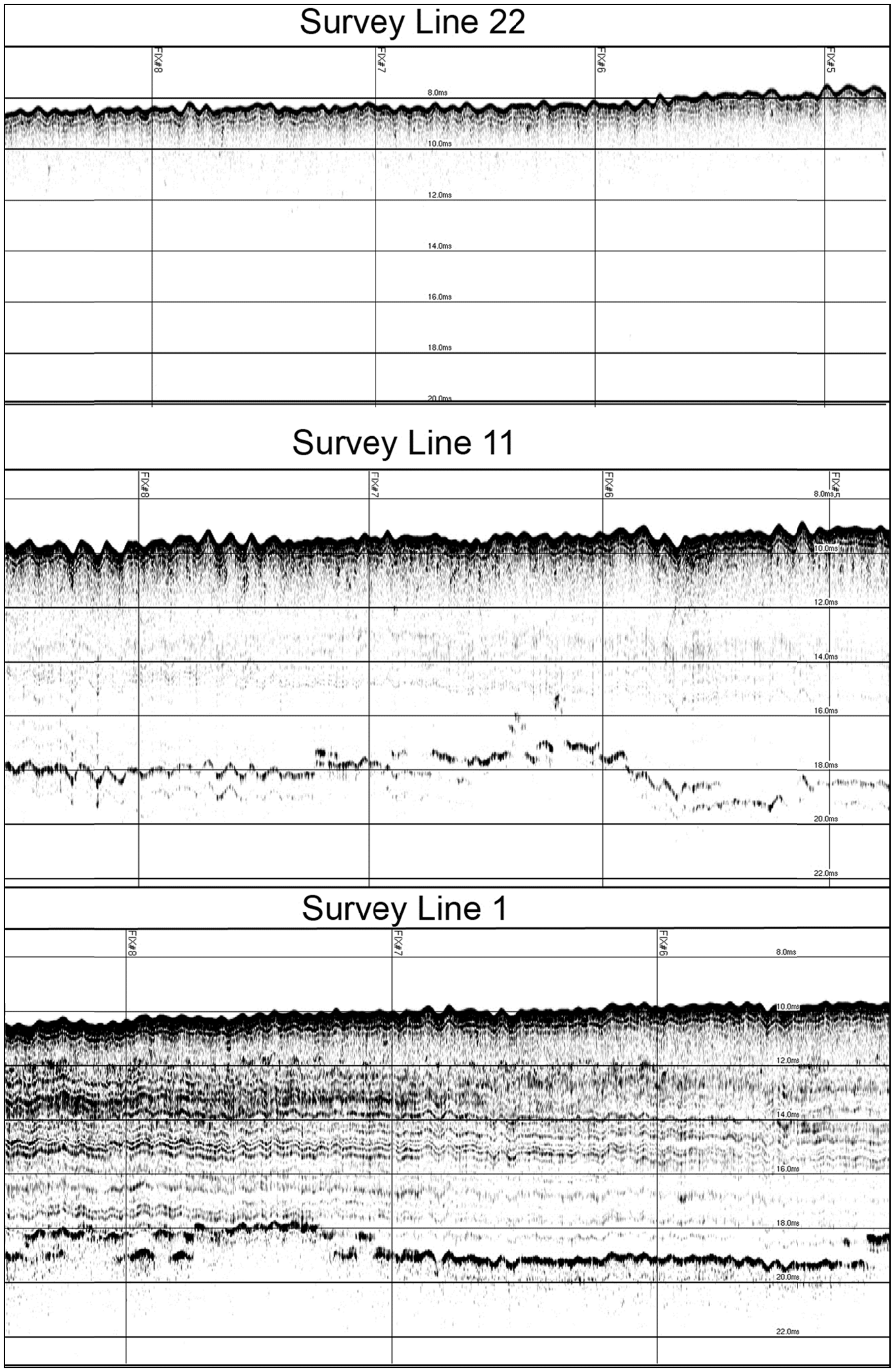


Figure 3.1.3. Sub-bottom profiles of survey lines 1, 11, and 22, Site 380. Heading for all three lines was 270 degrees (right to left). Data penetration decreases from north (Line 22) to south (Line 1). Vertical scale lines in 150-m increments. Horizontal scale lines in 2 millisecond intervals.

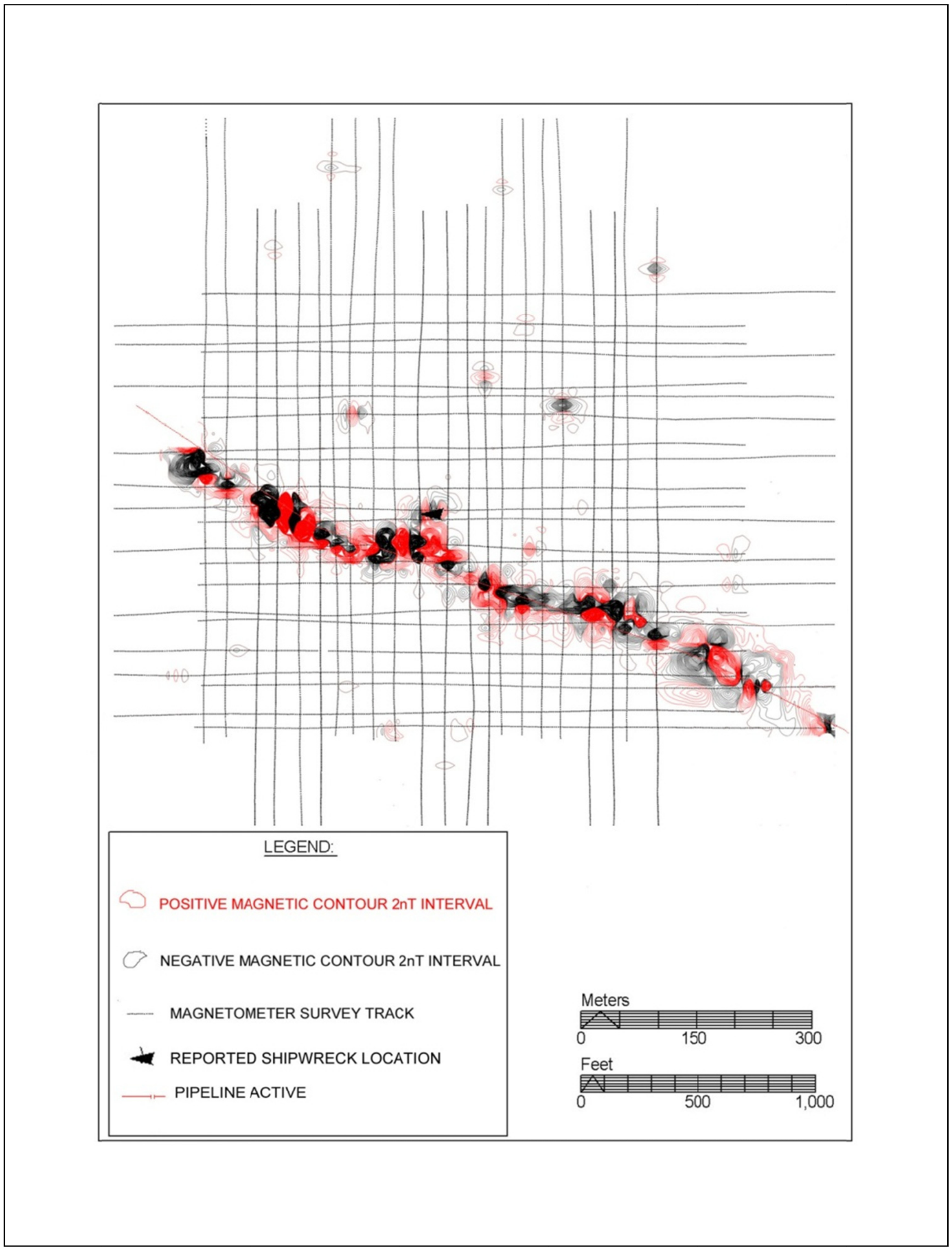


Figure 3.1.4. Magnetic contours in 2 nT intervals at Site 380.

3.1.3 Diving

During the diving field cruise, Site 380 was the first site visited due to its proximity to the point of embarkation in Morgan City, Louisiana. Diving operations at this site took place on August 13, 2010, from the M/V *Spree*.

- Average recorded water depth on bottom: 10.67 m (35 ft).
- Total bottom time on site: 18.37 hours. Average dive time: 39.26 minutes.
- Visibility: 1.5–1.8 m (5–6 ft).

A buoy was dropped at the spot of the reported coordinates for the wreck and diving operations commenced from this point. Using a handheld metal detector, dive teams conducted extensive circle searches. The most significant object encountered was an iron band protruding from the sediment for a distance of approximately 5 m (16 ft), and measuring 3.2 cm (1.25 in) in width, and 1.25 cm (0.5 in) in thickness (Figure 3.1.5). Archaeologists hand-fanned around the band, but found no distinctive features (i.e., rivets, fasteners, etc.) or other associations.

Figure 3.1.5. Photographs of metal band. 10 cm scale bar in 2 cm intervals.

A baseline was established along the band to facilitate additional circle searches at either end using the hand-held metal detector. These searches were extended in each direction beyond the band. The metal detector searches produced a few weak targets which, after investigation, proved to be random modern wire nails, beer cans, copper tubing, fragments of fiber-optic cable, small metal/shell concretions, and a fragment of a modern wooden board measuring 10.2 cm (4 inches) by 2.5 cm (1 inch). There was no indication of any intact wooden structure; instead, the site appeared to be a debris field of random, discarded material. One of the small concretions was recovered after its location was noted. The concretion was carefully opened on the dive vessel. Objects within the concretion included a plastic housing and a modern wire nail (Figure 3.1.6).

Figure 3.1.6. Photograph of concretion (at top), copper tubing (at bottom), and objects recovered from inside concretion (middle). 10 cm scale bar in 2cm intervals.

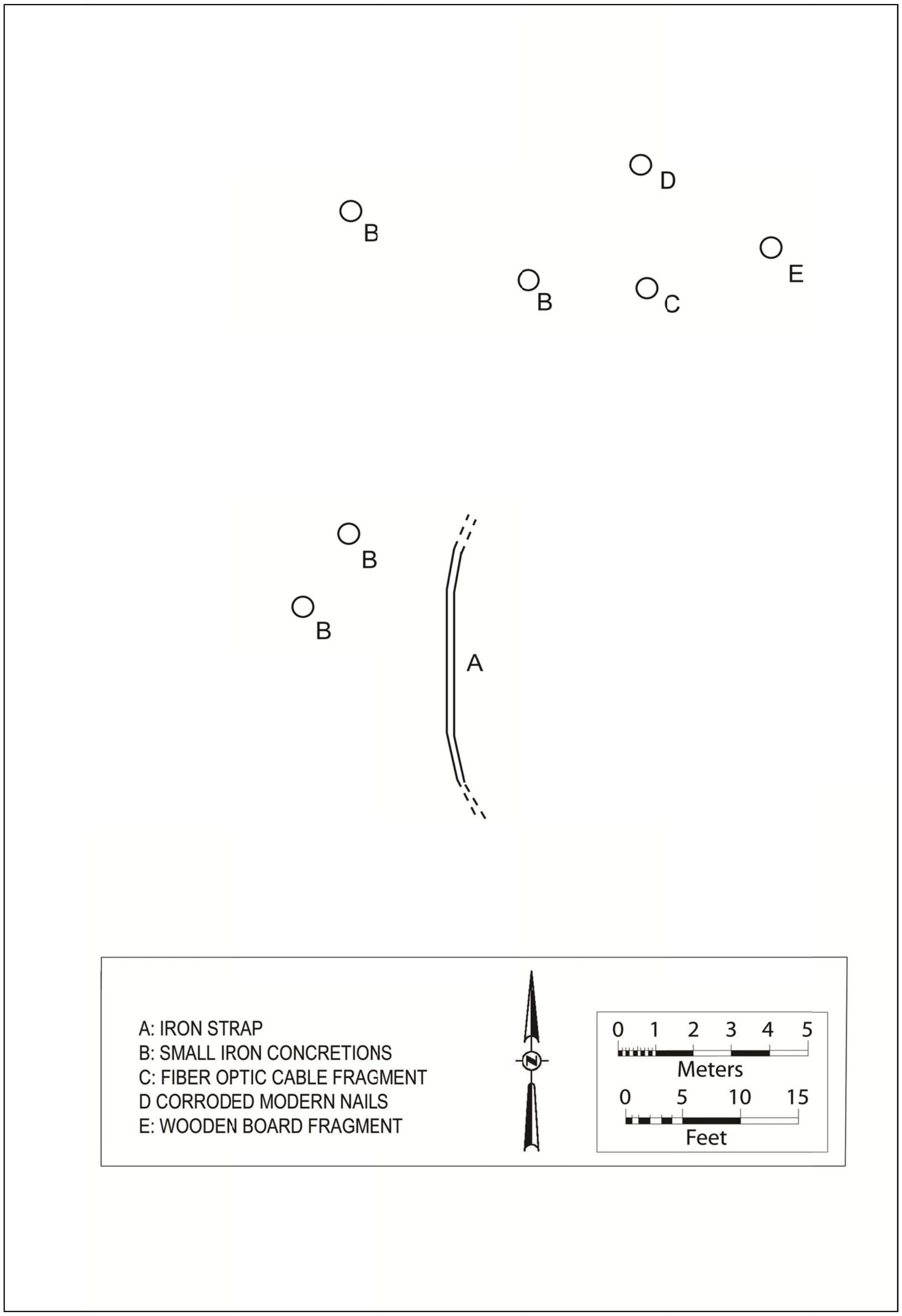


Figure 3.1.7. Site plan map showing relative distribution of objects identified at Site 380.

No evidence of an intact shipwreck was identified in the vicinity of Site 380. The objects identified on site did not appear to be historically significant, or associated with a shipwreck. The relative distribution of these objects is shown in Figure 3.1.7.

3.1.4 Site Environment

Sediment cores were not collected at this site due to the absence of any archaeological materials. Therefore, no information is available for sediment stratigraphy, grain size, radioisotopes, or shear strength at Site 380. It was decided in the field that the resources required to analyze cores from this site would be better used on additional cores from subsequent sites.

3.1.4.1 Water Sampling

One 8-ounce water sample was collected from Site 380 on August 13, 2010 at a depth of 11.2 m (37 ft) below sea level (BSL). Water temperature at the time and depth of acquisition was 86° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.2). Salinity was measured in parts per thousand (ppT). Dissolved oxygen (DO) is reported in milligrams per liter (mg/L).

Table 3.2

Water Sample Results for Site 380

Type	**Average**
Salinity (ppT)	31.60
pH	7.24
Dissolved oxygen (mg/L)	6.75

3.2 SITE NO. 433, SHIP SHOAL AREA, PROBABLE *R.W. GALLAGHER*

3.2.1 Site Background

Site number 433 is located in the Ship Shoal Federal Lease Area south of Isles Dernieres, Terrebonne Parish, Louisiana. The first known contemporary visit to the site was by Avery Munson and Gary Hebert, who located the wreck based on coordinates supplied by local fishermen and shrimpers. They conducted a diver investigation of the site on August 2, 1984. The MMS appears to have first been notified of the site's location as the result of a geophysical lease survey conducted in 1989 by John E. Chance and Associates. The resulting interpretation and report were performed by Marine Archaeologist Dr. Robert J. Floyd and Geophysicist Robert Callahan (Floyd and Callahan 1989). The slant range corrected sonar image in the report does not clearly resolve the wreck (Figure 3.2.1). The wreck is identified in the report as the Steam Ship (SS) *Heredia*.

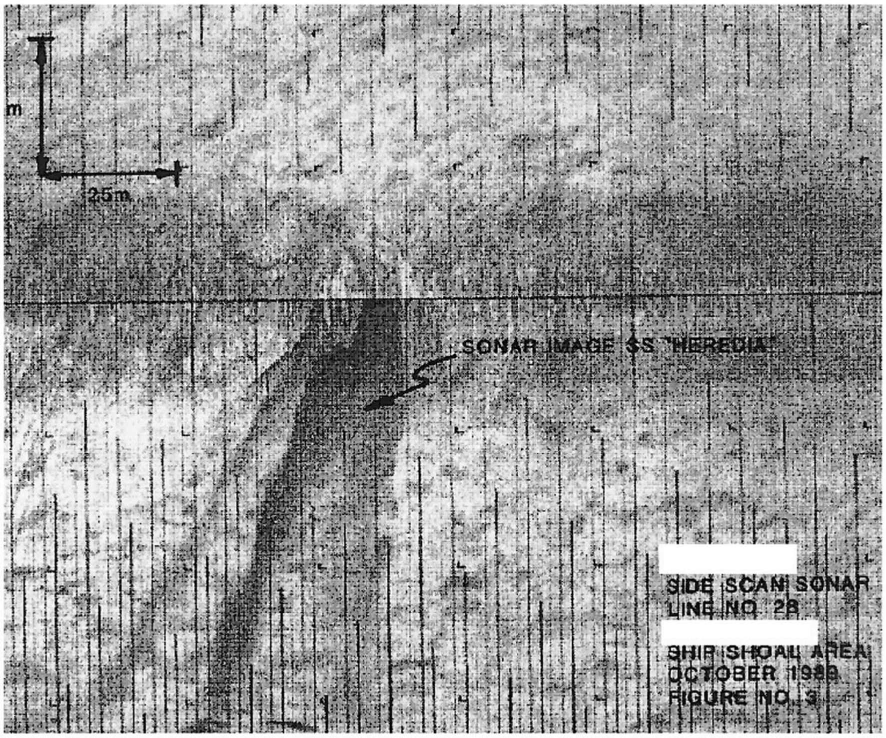


Figure 3.2.1. Sonar image of Site 433 (Floyd and Callahan 1989).

In 1992, an oil slick over the site was investigated by commercial divers contracted by the U.S. Coast Guard (Treadway 1992; Christ 2005:93). Christ reports that a sample of oil was recovered and divers attempted to patch the leak (Christ 2005:93). An article on the leak published in the New Orleans *Times Picayune* (Treadway 1992) identifies the wreck of *Heredia* as the source of the oil (see Section 3.3). Although coordinates are not provided in the article, it is believed that the wreck in question is actually Site 433; this is because of the amount of oil leaking (*R.W. Gallagher* was a tanker and *Heredia* was a freighter) and the reported 80-ft water depth which corresponds with the depth at Site 433.

The wreck was subsequently verified through a geophysical lease survey performed in 1996 by Cochrane Technologies, Inc. The resulting interpretation and report were performed by contract Archaeologist Allen Saltus, Jr., and contract Geophysicist S. Dean El Darragi (Saltus and El Darragi 1996; Figure 3.2.2). The Cochrane report reads, "The sonar image suggests that the structure is about 450 ft long and some sixty to seventy-five ft wide. Deck rail and other deck features appear to be present." The report indicates that the presence and position of the wreck were also verified by the magnetometer, echosounder, and sub-bottom profiler. The final assessment prepared in 1996 suggested that the feature was likely either *R. W. Gallagher* or *Heredia*. Both vessels were reported to have gone down in the same general area, and both were victims of German submarines in 1942. Sonar imagery of the wreck in the Cochrane report was poor, but a sub-bottom profiler image over the wreck site indicated that the shipwreck projected at least 7 m (23 ft) above the seafloor.

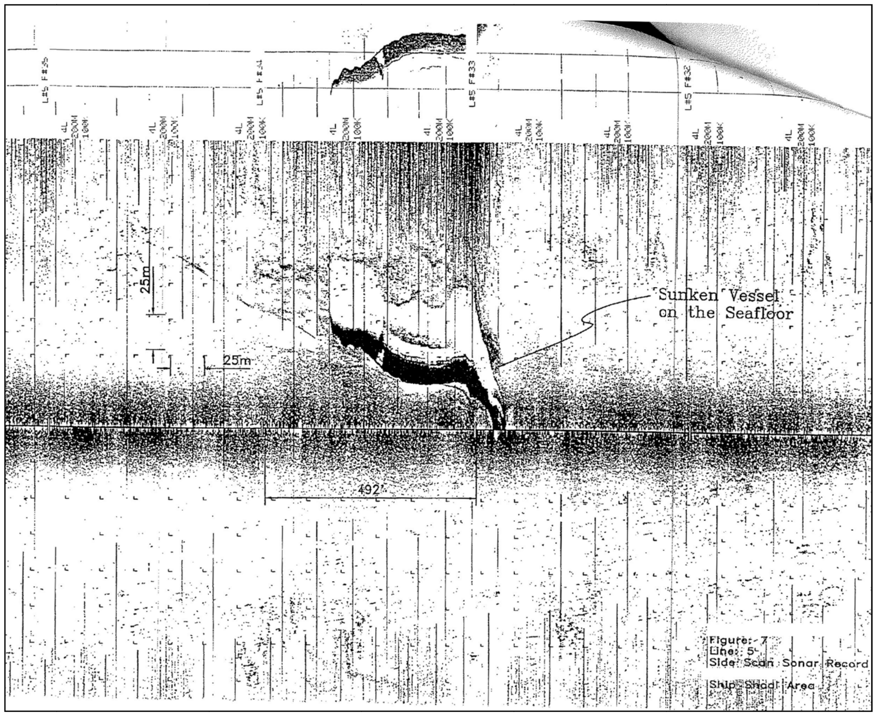


Figure 3.2.2. Sonar image of Site 433 (Saltus and El Darragi 1996).

The NOAA AWOIS database reports an unknown wreck with coordinates in the vicinity of the BOEM position for Site 433. The record indicates that the wreck was reported to MMS and a single side scan sonar image was available. The database record indicates that U.S. Coast Guard divers intended to investigate the wreck, but no subsequent entry was available and any results of the diving are unknown. According to the BOEM database, the vessel at Site 433 was at one point identified as *Heredia*, possibly based on the 1989 geophysical survey or the 1992 Coast Guard inspections. Avery Munson subsequently notified MMS that his earlier investigations indicated that the vessel was, in fact, *R.W. Gallagher* (BOEM Database 2011).

No known infrastructure is located within 300 m (1,000 ft) of the site. A plugged and abandoned (P&A) well is located 655 m (2,150 ft) SE of the site and two pipelines, a 16” abandoned line and a 30” active line, are located 1,535 m (5,035 ft) to the SW.

3.2.2 Geophysical

Geophysical data for Site 433 was acquired on July 17, 2010 and June 3, 2011 aboard the M/V *Nikola*. Thirty- and 100-m grids were centered over the reported wreck site and oriented parallel and perpendicular to the published orientation of the wreck site (see Navigation Post-Plot Map Appendix B; Figure B-1). Side scan sonar, sub-bottom profiler, magnetometer, multibeam, and single beam bathymetry data were acquired at the site (see Chapter 2 and Appendix A for a full description of geophysical sensor suite and navigation parameters).

All high-frequency survey lines were finished at Site 433 on July 17, 2010, but rough sea states precluded finishing the acquisition of low frequency sonar lines. The sonar needs to be towed much higher off of the bottom for lower frequency data acquisition, making it more susceptible to rough seas. To maximize vessel time, the vessel moved to Site 386 to run high-frequency sonar lines until sea state allowed for acquisition of higher quality, low frequency data at Site 433. During operations and before finishing the low frequency survey lines at both sites, *Nikola* was diverted at the request of MMS and BP to perform seismic operations at the Macondo well in support of relief well operations; because of this, data acquisition on site was not finished. A return trip was made to both sites in June 2011, and the low frequency (100 kHz) survey lines were finished. During interpretation of the 2010 geophysical data it was noted that the actual orientation of the vessel differed from published information; therefore, the survey grid was reoriented for use during the June 2011 survey work to provide better image quality over the wreck site.

Ambient water depths are 26–27 m (85–88.5 ft) throughout the survey grid (Figure 3.2.3). The multibeam data illustrates that the wreck is upside down, with a large break towards the south (Figure 3.2.4). The vessel is oriented with the bow facing 204 degrees SSW and the stern facing 23 degrees NNE. An additional hole in the hull appears to be located on the NE portion of the wreck (towards the starboard stern). Significant, broad scour zones are evident around the shipwreck extending to the west and SW. Deeper, more concentrated scour zones are evident on the west side of the wreck near the break in the hull and toward the stern reaching as deep as 29.6 m (97 ft). Multibeam data appears to provide an indication of some stern assemblage (such as running gear and/or propeller) as well as the lower portion of a transom stern, the upper portion of which is buried in the seafloor (Figure 3.2.4).

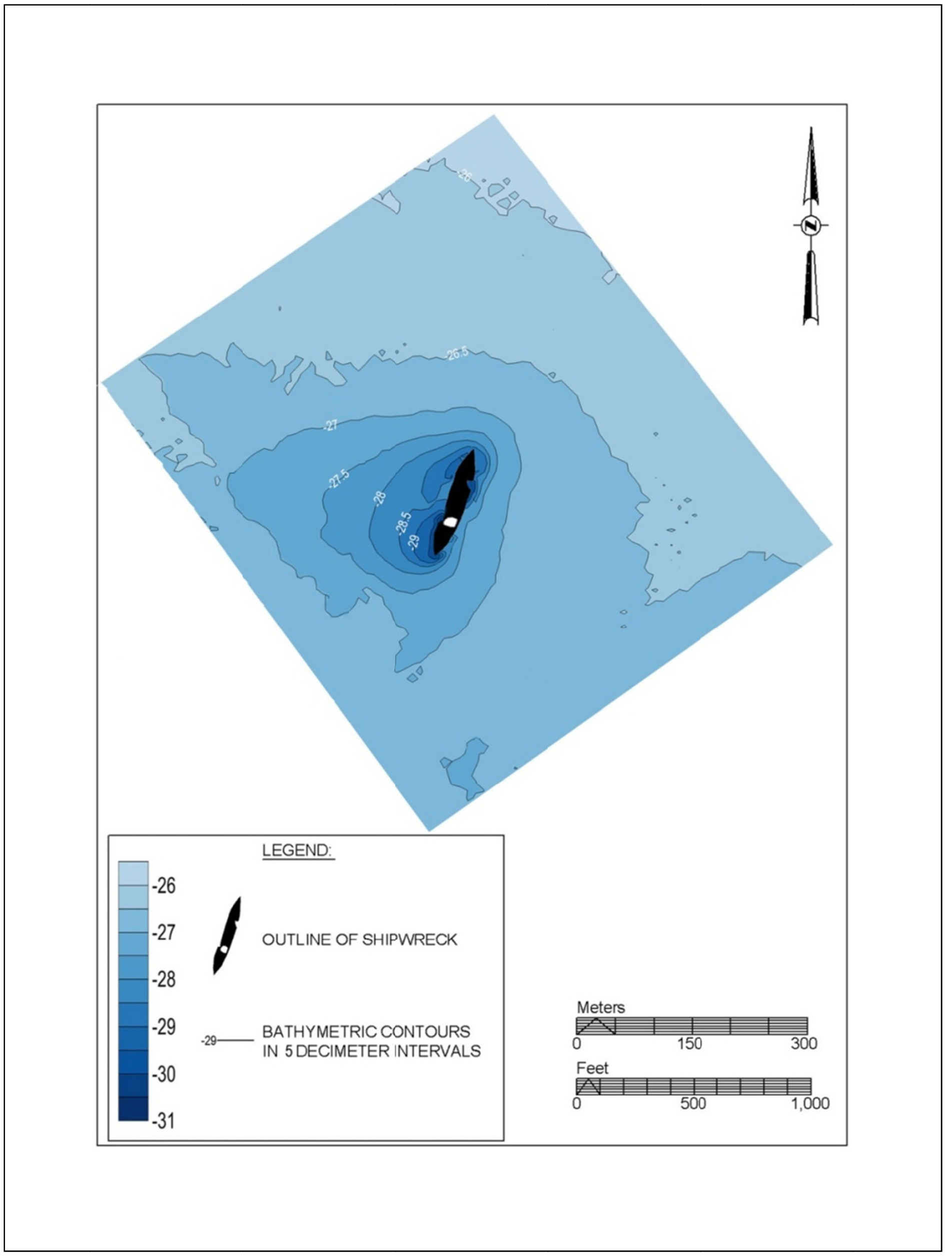


Figure 3.2.3. Bathymetry surrounding Site 433 in 5-decimeter intervals.

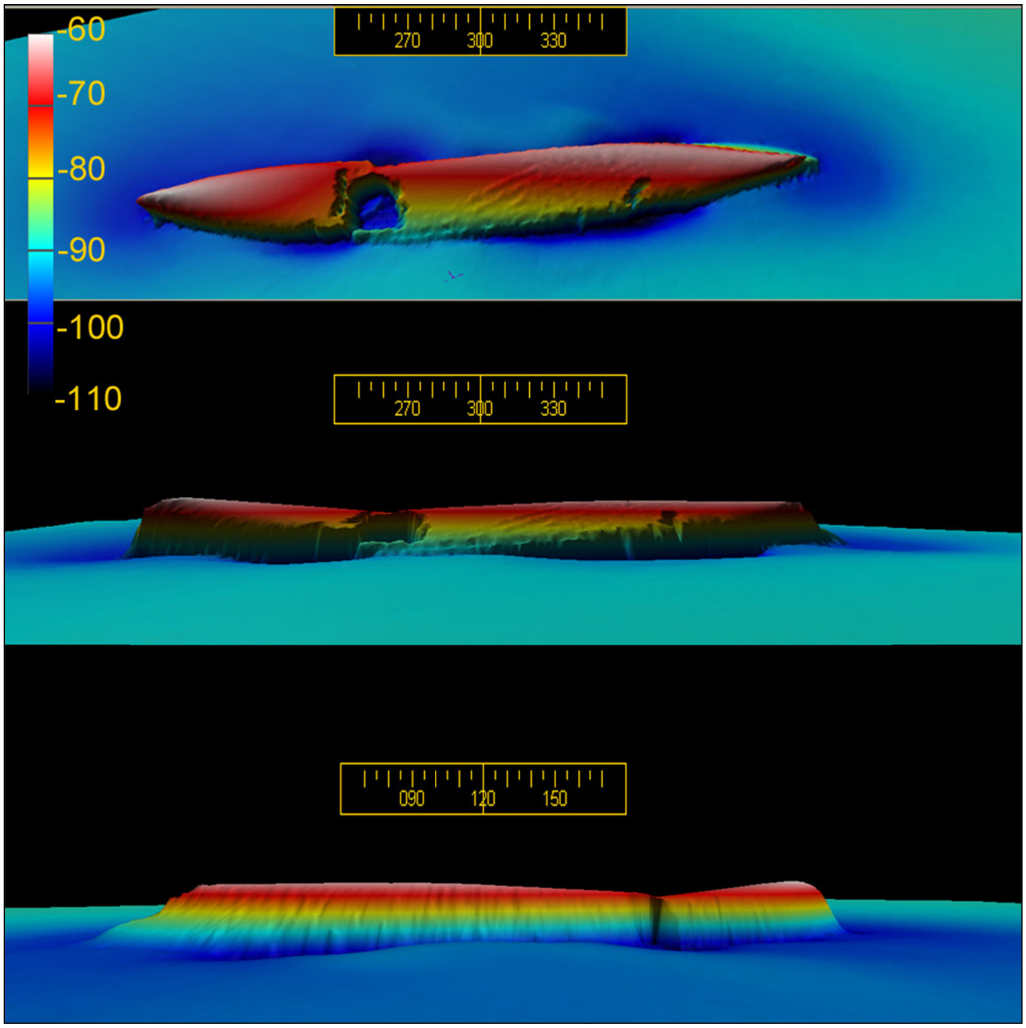


Figure 3.2.4. 3-D multibeam renderings of Site 433.

The 100 kHz sonar data clearly imaged the wreck site in its entirety, but did not have sufficient resolution to identify specific components of the vessel or changes in seafloor texture. The 410 kHz survey grid clearly outlined the wreck, provided details around the break in the hull, and increased resolution at the stern of the vessel. No significant variation in sediment grain size was evident on the high frequency sonar. As noted previously, the wreck is inverted on the seafloor, with the bow oriented towards the SSW. The vessel's rudder and propeller can be clearly seen on the high frequency sonar imagery (Figure 3.2.5). Two sonar targets were identified away from the wreck site. The first is a small, irregular feature approximately 91 m (300 ft) SSW of the wreck, situated along the same axis as the wreck itself. The second was a length of cable or pipe located NNE of the wreck and associated with a significant cluster of magnetic anomalies. An anchor drag scar, measuring 53 m (173 ft) in length and approximately 2.4 m (8 ft) wide, was observed 284 m (930 ft) SW of the wreck. Figure 3.2.6 shows a sonar mosaic created using only the 100 kHz survey lines that parallel the wreck site; an inset shows the wreck at 410 kHz from Survey Line 402.

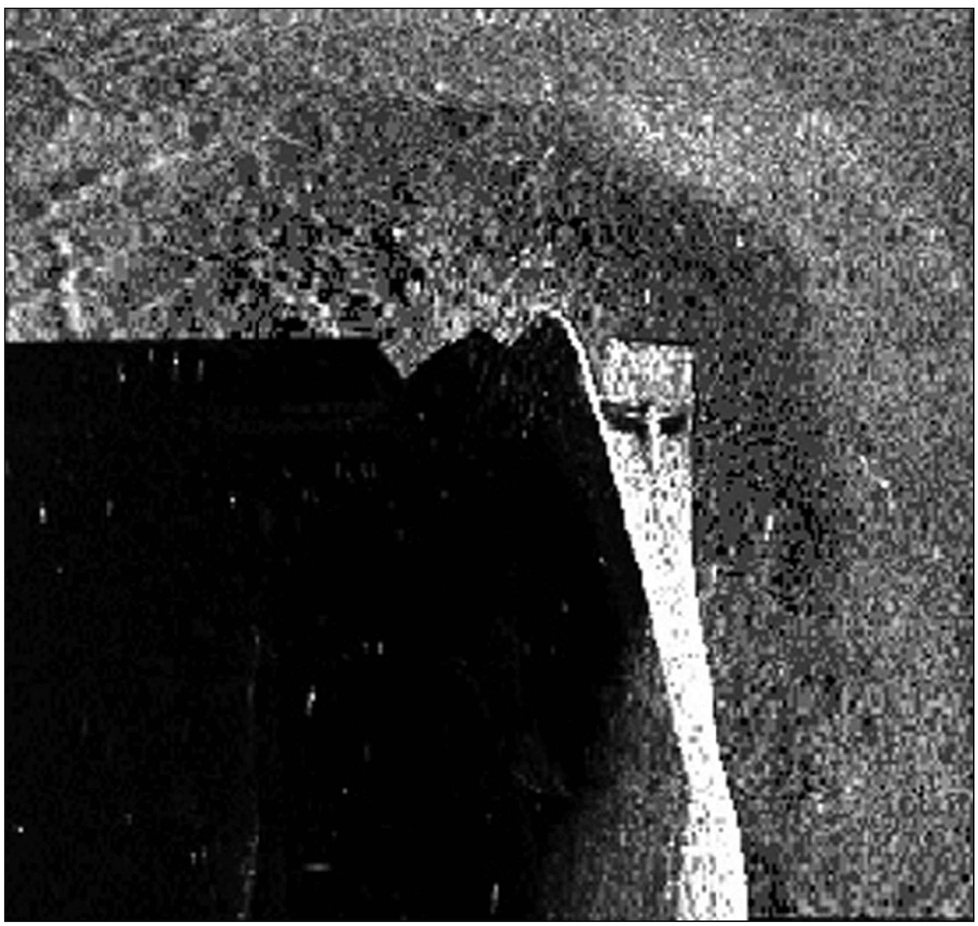


Figure 3.2.5. 410 kHz sonar image of vessel's stern from survey Line 402.

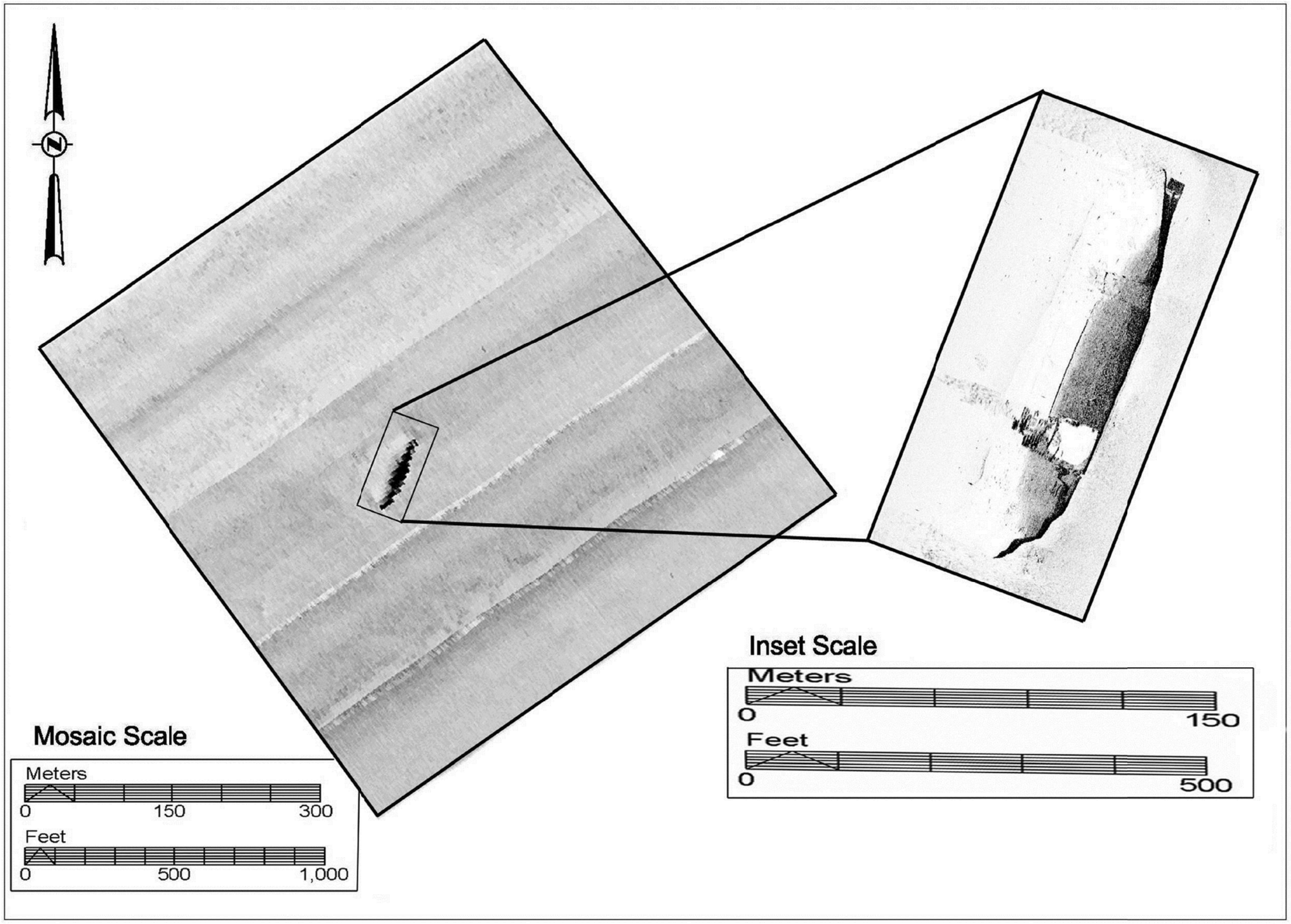


Figure 3.2.6. 100 kHz side scan sonar mosaic of Site 433. Inset is 410 kHz data.

Acoustic imaging indicates that the shipwreck measures 140 m (458 ft) by an estimated 22 m (72 ft). The large break in the vessel's hull measures approximately 12 m (40 ft) by 10 m (33 ft). The wreck sits approximately 7.3 m (24 ft) above the seabed. Acoustic multibeam data recorded the curvature of the inverted hull and some internal structure (Figure 3.2.7).

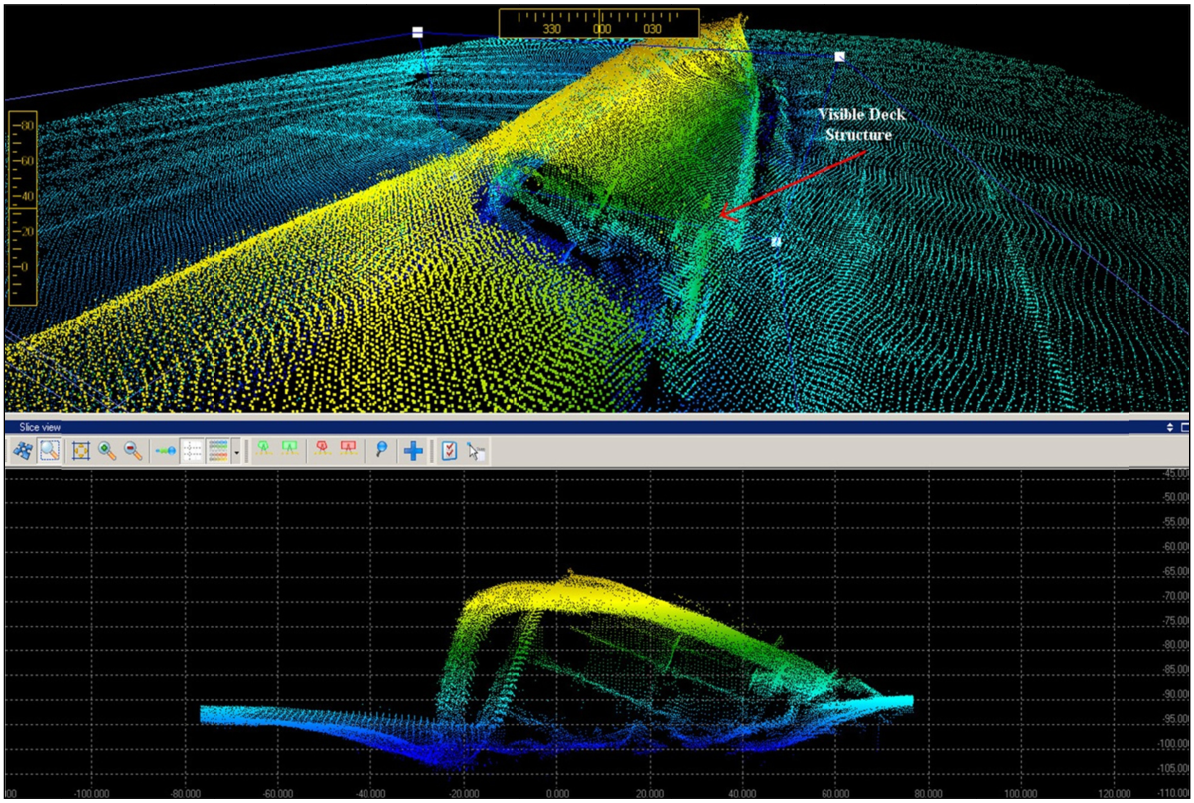


Figure 3.2.7. Multibeam imagery of wreck at Site 433 showing internal structure.

Sub-bottom profiler data penetrated 14–18 m (45–60 ft) throughout the survey grid. The stratigraphic profile consists of alternating bands of parallel strata, occasionally interrupted by acoustically transparent zones of fine silts or sands. The scour zones surrounding the wreck site are the only significant irregularity in the sub-bottom data set. Sediments appear truncated within the scour zones and no apparent infill of relict scour has taken place. Figure 3.2.8 shows two stratigraphic profiles; Survey Line 307 runs close to the wreck site, just to the NE where the deepest, sharpest, scour zones are evident. Survey Line 302 is SW of the wreck, but slightly further where the scour is broader and shallower.

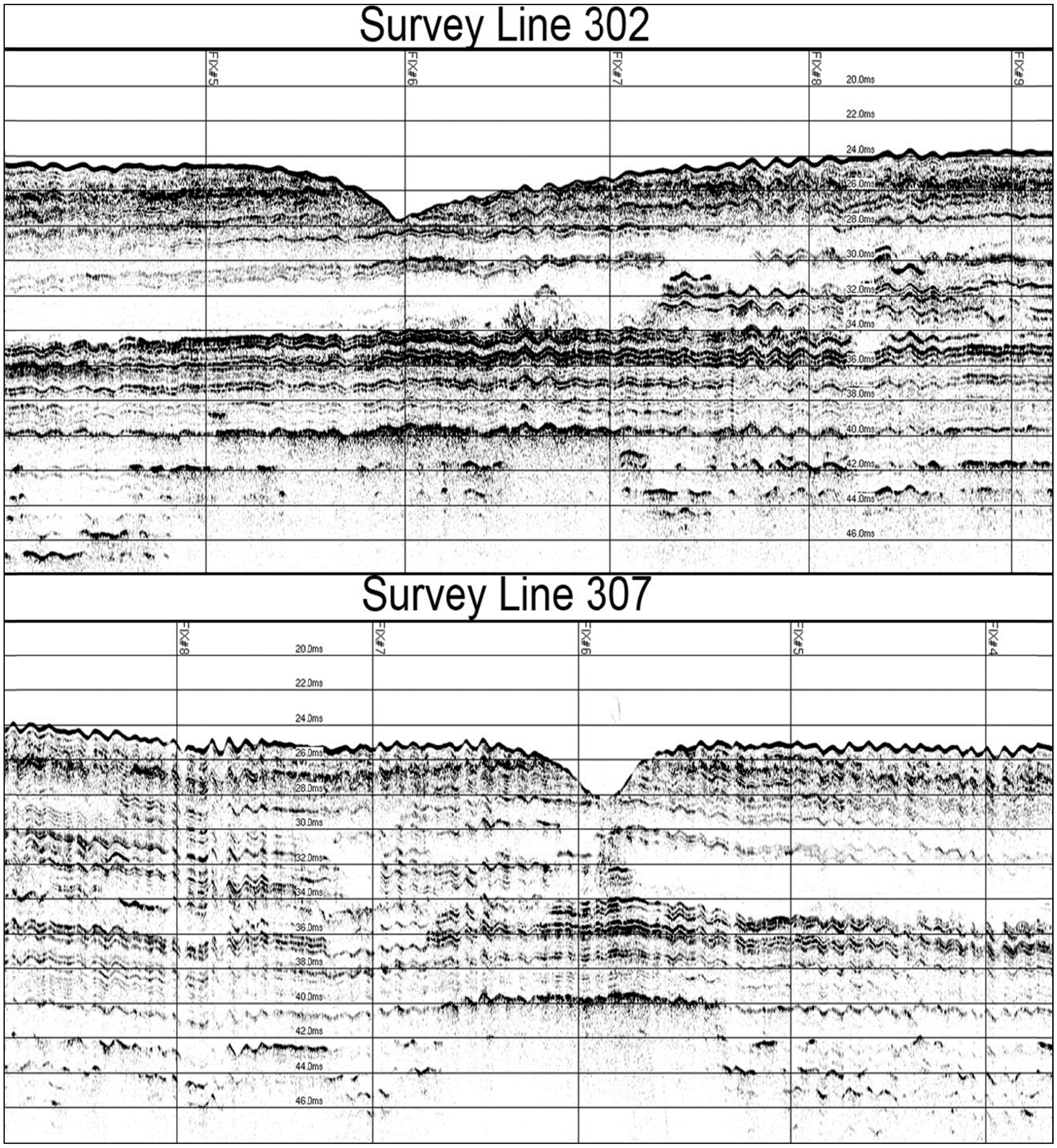


Figure 3.2.8. Sub-bottom profiles of survey lines 302 and 307, Site 433. Line 302 is located SE of the wreck, with a heading of 310 degrees. Line 307 is located NW of the wreck with a heading of 130 degrees. Vertical scale lines in 150 m increments. Horizontal scale lines in 2-ms intervals.

Magnetometer data produced massive anomalies over the hull of the large metal-hulled shipwreck. A total of 19 magnetic anomalies were identified that could not be directly attributed to the hull of the shipwreck. All individual magnetic anomalies have been tabulated and are included in Appendix C. A contour map was also prepared that highlights changes to the ambient field using contours shown in a 4 nT interval (Figure 3.2.9). Anomaly nos. 3, 9, 14, 15, 16, and 37 were located in relative proximity to the wreck and may represent small quantities of debris related to the wrecking event. It should be noted that these anomalies are not discernible within the contour maps due to the massive signature produced by the wreck. They were instead identified by analyzing the individual trace plot for each survey line. Two significant anomaly clusters were identified further from the wreck site, both of which lie approximately 240 m (787 ft) from the site, one to the east and the other to the NE. The eastern cluster is the smaller of the two and is comprised of Anomaly nos. 8 and 10. Anomaly no. 8 is a 10 nT positive monopole with a 19.5-m (64-ft) duration and Anomaly no. 10 is a 51 nT negative monopole with a 34-m (111-ft) duration. No seafloor features or debris were evident on the correlating geophysical data that correspond with this anomaly cluster; therefore, it is unknown if the anomalies are related to the shipwreck or are intrusive. The larger anomaly cluster is located to the NE and includes Anomaly no. 2, a 315 nT negative monopole with a 62.5-m (205-ft) duration, no. 6, a 28 nT dipole with a 45-m (148-ft) duration, no. 11, a 153 nT dipole with a 46.6-m (153-ft) duration, no. 12, a 157 nT negative monopole with a 67-m (220-ft) duration, and no. 13 a 10 nT positive monopole with a 30-m (99-ft) duration. This cluster is associated with a length of cable or pipe measuring 12 m (40 ft) in length and spanning 15 cm (0.5 ft) above the seafloor.

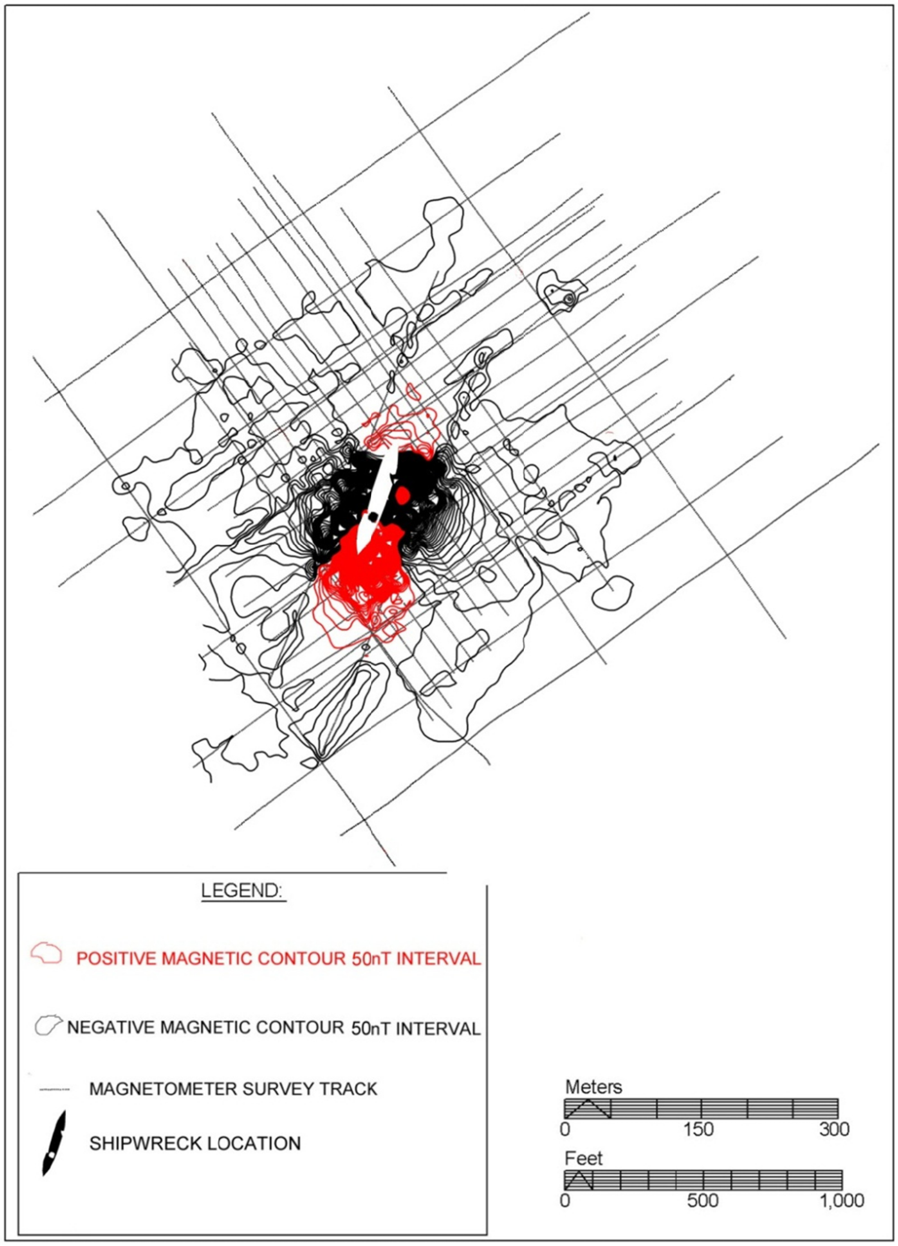


Figure 3.2.9. Magnetic contours in 50-nT intervals at Site 433.

3.2.3 Diving

Diving operations at Site 433 took place on August 15, 2010 from the M/V *Spree*.

- Maximum recorded water depth during dives: 29.5 m (97 ft).
- Total bottom time on site: 10.32 hours. Average dive time: 25.79 minutes.
- Visibility: 3–9 m (10–30 ft) on wreck, 1.5 m (5 ft) near area of hull damage, zero on seabed.

Dive teams were limited in their bottom time due to the vessel's sheer size and depth. Each dive team was assigned a specific task while on the vessel, measuring and photographing key diagnostic features that would aid in the identification and assessment of the vessel. Diving operations managed to examine the entirety of the wreck, but focused primarily on diagnostic aspects, including the rudder, the propeller, hull plating, and the bilge keel (Figure 3.2.10).

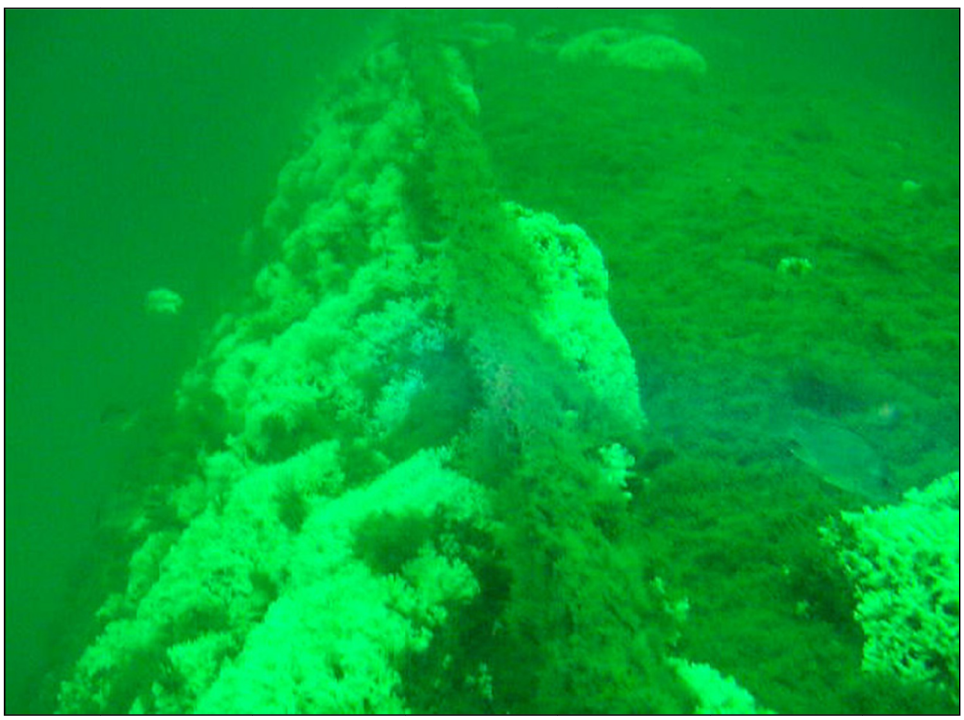


Figure 3.2.10. Image still highlighting bilge keel aft of midships. (Courtesy of Captain John Camp).

Near midships, the I-beam shaped bilge keel measures 36 cm (14 in) in height and increases to 45 cm (18 in) at the base of the keel. Divers also attempted to inspect breaches in the hull that were observed on the remote sensing data, believed to be caused either by the torpedo strikes or post-depositional deterioration. Only one of the breaches was accessible to divers; it appeared to be the result of extensive torpedo damage approximately 46 m (150 ft) from the bow of the vessel. Because of the relatively featureless hull, this area also served as a secure point to establish the descent line for the site. The damage at this point is extensive, and suggests that the torpedo blast nearly broke the ship into two pieces, as only a small portion of the bilge keel and surrounding hull plating connects the bow to the remainder of the vessel.

On the starboard side, the hull breach measures nearly 4.3 m (15 ft) at the largest observable point, while the port side breach measured 8.4 m (28 ft) at the turn of the bilge, and actually grew larger as the hull extended downward into the sediment. Divers noted that they could see clearly through, from the port side to the starboard side of the hull, at this breach. The hull plates appear to bend inward on the port side, and outward on the starboard side, lending credence that this damage was, in fact, caused by a powerful explosion, and not merely due to post depositional deterioration. The ship's rudder and propeller were mapped in detail. The rudder extends from the keel of the vessel down into the seafloor and measures 3 m long by 3 m deep (9.84 by 9.84 ft). The propeller contained a four-blade configuration with individual blades measuring 2.5 m long and 1.34 m wide (8.2 by 4.4 ft) (Figure 3.2.11)

Figure 3.2.11. Propeller blades. (Photograph courtesy of Colm O'Reilly.)

Divers noted small droplets of oil rising from the wreck, and an oil sheen was visible by the topside crew on the research vessel (Figures 3.2.12).

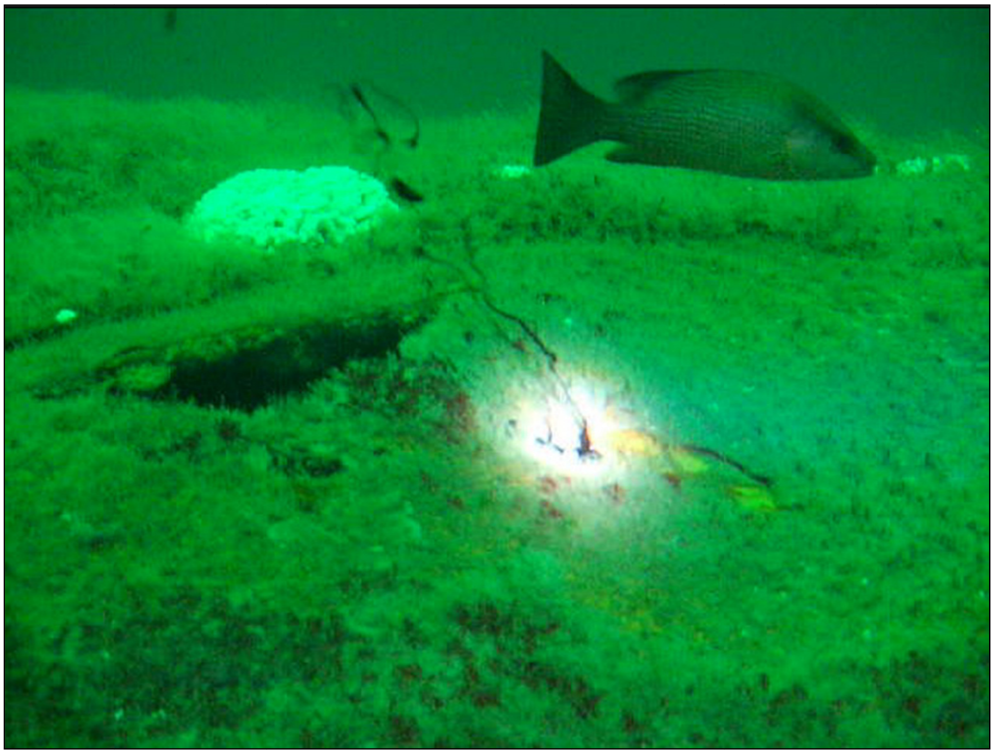


Figure 3.2.12. Image still showing oil seeping from the wreck site. (Video courtesy of Captain John Camp.)

Sector scanning sonar data over the wreck site was obtained after diving operations. Although the size of the vessel precluded imagery of much of the wreck, excellent imagery of the stern assemblage was obtained (Figure 3.2.13).

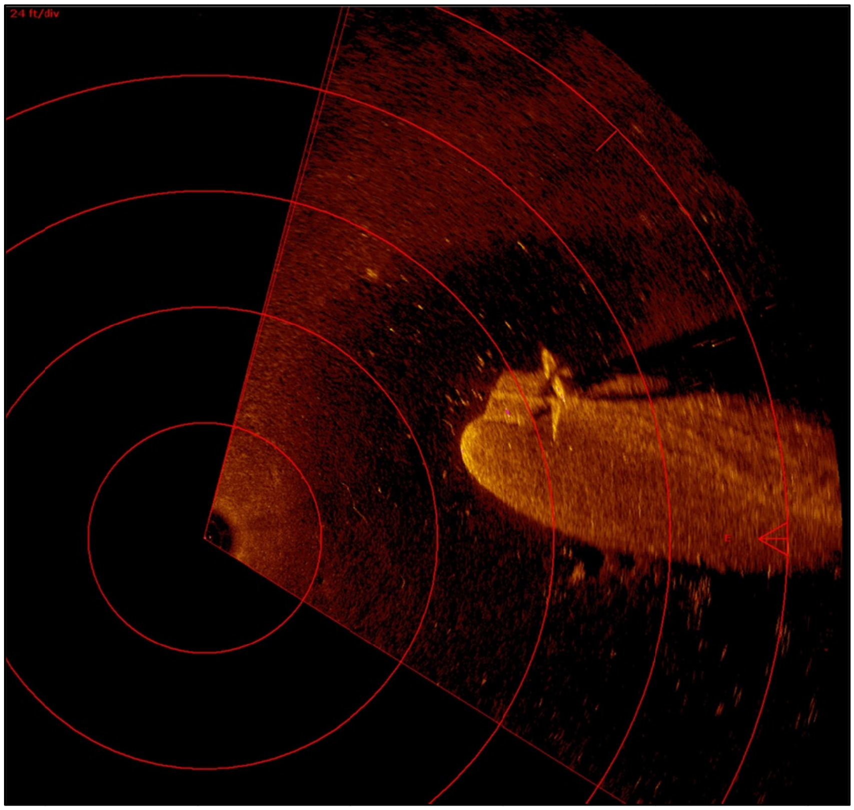


Figure 3.2.13. Sector scan highlighting the stern of the vessel.

3.2.4 Site Environment

3.2.4.1 Water Sampling

Two 8-ounce water samples were collected from Site 433 on August 15, 2010 at depths of 29.5 m (97 ft; sample 1) and 27.4 m (90 ft; sample 2) BSL. Water temperature at the time and depths of acquisition was 77° F.

Repeat measurements were taken for pH, salinity, and dissolved oxygen content for each sample and averaged (Table 3.3). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.3

Water Sample Results for Site 433

Type	Sample	Average
Salinity (ppT)	1	32.70
Salinity (ppT)	2	32.10
pH	1	7.767
pH	2	7.837
DO (mg/L)	1	6.79
DO (mg/L)	2	6.98

3.2.4.2 Core Lithology and Grain Size

Two cores were collected from Site 433 on August 15, 2010. The first was collected from the west side of the vessel at approximately midships at a depth of 29.5 m (97 ft). Visibility at the seafloor was zero. During sampling, the core barrel encountered significant resistance; divers noted the presence of metal in the immediate area. It is very probable that the first attempt at core collection was conducted on sediments overlying a piece of hull debris; however, blackwater conditions and limited bottom time made this difficult to confirm. Due to the lack of visibility, even with primary and secondary lights, divers were unable to read their gauges. Once core refusal was noted and no immediate area was identified for re-sampling, the coring attempt was aborted. Core no. 1 resulted in a maximum of 22 cm of sediment. A second core was collected from the east side of the vessel at midships from a depth of 27 m (90 ft). This coring attempt was successful and resulted in a 75 cm stratigraphic sample. Core no. 2 was used for all subsequent sampling, while Core no. 1 was only used to correlate near surface lithology.

From each of the three units observed within Core no. 2, samples were gathered and measured for grain size. Median and graphic mean calculations demonstrate that sediments from Site 433 are cohesive-clay dominant. The measured sediments became increasingly fine downcore, transitioning from coarse silt at the seafloor to either fine silt (graphic mean) or very fine silt (median).

Shear strength measurements were taken using both a pocket penetrometer and a mini-torvane. The pocket penetrometer was used with an adapter specifically for use in sediments with low shear strengths; however, the penetrometer measurements were deemed inaccurate due to their proximity to areas disturbed through radioisotope sampling downcore. The 2” diameter core sleeve did not capture sufficient mass to allow for accurate shear strength measurements at the same depths as grain size and radioisotope samples, which were taken from corresponding depths on opposite halves of the core to allow for direct comparisons. Mini-torvane measurements were offset 2.5 cm from previous radioisotope samples and taken at 5 cm intervals down each half of the split core; they were deemed more accurate. The averaged measurements are provided in Table 3.4.

Salinity, pH, and DO measurements were also obtained from pore water trapped in Sediment Core no. 2, and pH measurements were taken of sediments within the core. The pore water analysis resulted in higher salinity and lower pH and DO values than measured from samples collected in the water column. Average pore water salinity was 36 ppT; average pore water pH was 7.5; average DO was 6.097 mg/L. Downcore measurements of pH values in Core no. 2 sediments were higher than any of the measurements obtained from water samples; the average sediment pH was 7.9.

Table 3.4

Averaged Shear Strength Measurements from Core No. 2, Site 433

Depth (cm)	ksf
5	0.032
10	0.032
15	0.128
20	0.192
25	0.218
30	0.230
35	0.256
40	0.282
45	0.256
50	0.256
55	0.243
60	0.281
65	0.289
70	0.256
75	0.218

3.2.4.3 Radioisotope Analysis

Radioisotope analysis of sediments sampled from Core no. 2 reveals a post-disturbance linear accumulation rate (LAR) of 0.17 cm/yr (Figure 3.2.14). Based on the sampling interval, it appears that a disturbance had occurred 78 to 98 years before the 2010 core collection. Pre-disturbance sediments show a trend of downcore decay in the two points shown in Figure 3.2.15, but this is insufficient data to ascribe an LAR for pre-disturbance accretion.

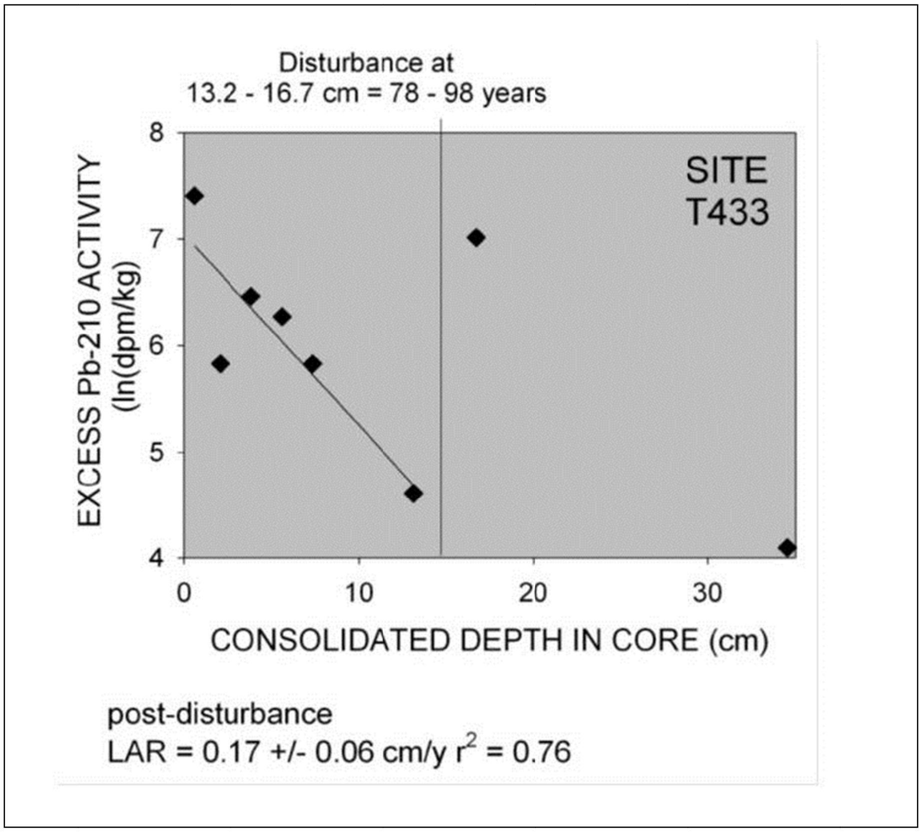


Figure 3.2.14. Downcore ^{210}Pbxs activity and linear sediment accumulation rate (LAR) calculations for Site T433.

3.2.4.4 Oceanographic Analysis

The potential impact of hurricanes on seafloor scour is suggested by oceanographic modeling conducted at three datum sites in the GOM as a proxy for seafloor conditions at the current shipwreck site (Rego et al. 2011). Datum 1 simulated hurricane impacts at a site in 26 m of water with cohesive-clay dominated sediments, similar to the conditions found at Site 433. Datum 1 is located east of the eye of the two modeled hurricanes, Ike and Rita, but still within the extents of hurricane force winds associated with both storms. Site 433 lies just east of the maximum extent of hurricane force winds associated with both storms and just west of the maximum extent of hurricane force winds associated with Hurricanes Gustav and Katrina (Appendix F; Maps F-1 & F-2). Site 433 is therefore expected to have experienced lower potential scour rates than modeled at Datum 1 during Ike and Rita. Although grain sizes were measured for Site 433, bulk density and plasticity were not. The degree of sediment consolidation and potential for mud fluidization are therefore unknown and scour estimates are based solely on flow conditions (Rego et al. 2011). Scour estimates were generated for both loose and consolidated bed scenarios for each of the modeled hurricanes. In all cases, maximum hurricane-induced scour was followed by re-deposition of sediments, resulting in smaller net scour estimates. Storm-related scour modeled at Datum 1 resulted in maximum scour of between 1.5 m (loose) and 3 cm (consolidated); net scour ranged from 21 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011).

3.3 SITE NO. 386, SHIP SHOAL AREA, PROBABLE *HEREDIA*

3.3.1 Site Background

Site 386 is located in the Ship Shoal Federal Lease Area south of Isles Dernieres, Terrebonne Parish, Louisiana. C.J. Christ reports diving on the site in the early 1970s (2011, pers. comm.) and Avery Munson and Gary Hebert investigated the site through diving on August 5, 1982 (Munson 2011, pers. comm.). Both Christ and Munson appear to have independently identified the wreck based on the condition of the site and examination of several diagnostic artifacts. The wreck was subsequently located through a geophysical survey conducted in 2004 by the Louisiana State University Coastal Fisheries Institute in partnership with the Louisiana Department of Wildlife and Fisheries (Figure 3.3.1). The shipwreck was reported to MMS, who, in turn, consulted wreck coordinates provided by Munson and determined that the unidentified vessel was likely the steam freighter *Heredia*. The LSU report reads:

> We located one uncharted wreck within the SSARPA. The object is approximately 100m in length and 25m in breadth . . . . The location of this wreck was not indicated on the RNCs or on the updated Electronic Navigation Charts (ENCs). Conversations with MMS archaeologists indicated that this wreck may be the US “Heredia”, a steam freighter that was sunk on 19 May 1942 by a German U-boat. MMS did not previously have a side scan image or accurate location on this vessel. Other sources have indicated that this may not be the Heredia (Wilson et. al. 2004:18-19).

Based on coordinates and descriptions reported to the U.S. Navy (Henderson 1942; Powers 1942a), it appears that both *Heredia* and *R.W. Gallagher* sank within close proximity to one another. Conflicting coordinates for *Heredia* and *R.W. Gallagher* have been published by various sources (Rohwer 1983; Wiggins 1995). These irregularities, coupled with incidental sonar imagery, likely led to the one-time misidentification of Site 433 as *Heredia* (see Section 3.2). The results of the geophysical and diver investigations at Site 386 were compared with available records in an attempt to either refute or confirm that Site 386 is in fact the wreck of *Heredia*.

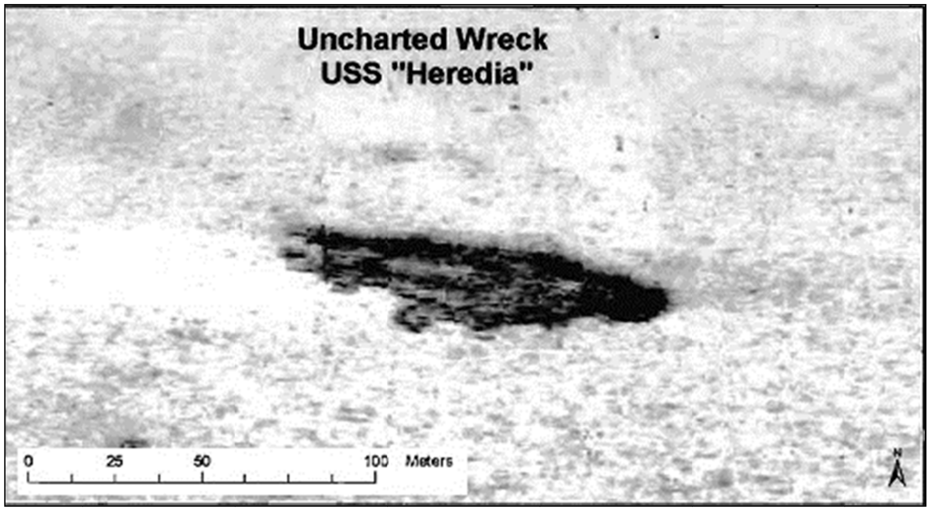


Figure 3.3.1. Sonar image of Site 386 (Wilson et al. 2004:30).

No known infrastructure is located within 300 m (1,000 ft) of Site 386. Pipelines are located to the north, ESE, and south of the site: 838 m (2,750 ft), 1,250 m (4,100 ft), and 1,473 m (4,830 ft) respectively. A large platform complex is located approximately 2,455 m (8,050 ft) to the NE. The site is also located within the Ship Shoal reef planning area maintained by the Louisiana Department of Wildlife and Fisheries (LDWF 2011).

3.3.2 Geophysical

Geophysical data was acquired at Site 386 on July 18, 2010 and June 3 and 4, 2011 aboard the M/V *Nikola*. Thirty- and 100-m survey grids were centered on the wreck coordinates and oriented parallel and perpendicular to the published orientation of the wreck site (see Navigation Post-Plot Map Appendix B; Figure B-3). Side scan sonar, sub-bottom profiler, magnetometer, multibeam, and single beam bathymetry data were acquired at the site (see Chapter 2 and Appendix A for a full description of geophysical sensor suite and navigation parameters).

The geophysical survey at Site 386 was run in tandem with the acquisition at Site 433 due to their proximity. Once all high frequency survey lines were finished on Site 433, survey operations moved to Site 386 (before finishing the low frequency survey grid). During operations and before finishing the low frequency survey lines at both sites, at the request of MMS and BP, *Nikola* was diverted to perform seismic operations at the Macondo well in support of relief well operations. Due to the diversion of *Nikola*, data acquisition on site was suspended. A return trip was made to both sites in June 2011 at which point the 100 kHz lines were finished.

Water depths are 32.8 to 36 m (107.5 to 118 ft) throughout the survey grid (Figure 3.3.2). The multibeam data illustrates that the wreck is right side up, listing to starboard (Figures 3.3.2 and 3.3.3). Broad scouring was evident surrounding the shipwreck, extending more prominently to the north. Deeper, more concentrated scour zones are evident along the north side (port) and stern of the wreck and most significantly at the port bow where water depths may reach over 37 m (121 ft) (Figures 3.3.2 and 3.3.3).

Sonar data corresponds with multibeam data, indicating that the wreck site is oriented with the bow facing 95 degrees ESE. The 100 kHz survey grid clearly imaged the wreck site in its entirety, but did not have sufficient resolution to detail specific components of the vessel or changes in seafloor texture. The 410 kHz survey grid clearly outlined the wreck, providing details of the numerous components that sit atop the hull and on the surrounding seafloor. Ancillary wreck components are scattered across the seafloor close to the wreck, with smaller amorphous quantities of debris identified as far as 91 m (300 ft) south and 46 m (150 ft) east of the wreck. It is unknown if these targets are associated with the wreck site. No significant variation in sediment grain size was evident on the high frequency sonar. A sonar mosaic was created using only the survey lines that parallel the wreck site. An inset image shows a composite of various high frequency sonar lines providing uninterrupted imagery of the entire wreck (Figure 3.3.4).

The main component of the wreck site measures 112 m (367 ft) by 19 m (62 ft). A debris field is scattered at the stern of the vessel; when this field is included in the overall length measurements, the wreck measures 119 m (390 ft). Ancillary components of the wreck site were resolved both within the hull and on the surrounding seafloor. The most significant such component is a large box-like structure located on the starboard side of the vessel, aft of midships. This object measures approximately 4.3 m (14 ft) by 7.6 m (25 ft). The geophysical data indicates that although much of the vessel's hull appears relatively intact, the superstructure appears to be heavily disturbed and disarticulated.

Sub-bottom profiler data penetrated 7.6–9 m (25–30 ft) throughout the survey grid. The sub-bottom data is similar to Site 433, which is not surprising considering the proximity of the two sites. The stratigraphic profile consists of alternating bands of parallel strata, occasionally interrupted by acoustically transparent zones of fine silts or sands. Scour zones surrounding Site 386 are less significant than those surrounding Site 433. Sediments appear truncated within the scour zones and no apparent infill of relict scour has taken place. Figure 3.3.5 shows a stratigraphic profile close to the wreck site (Survey Line 509) where the deepest, sharpest scour zone is evident.

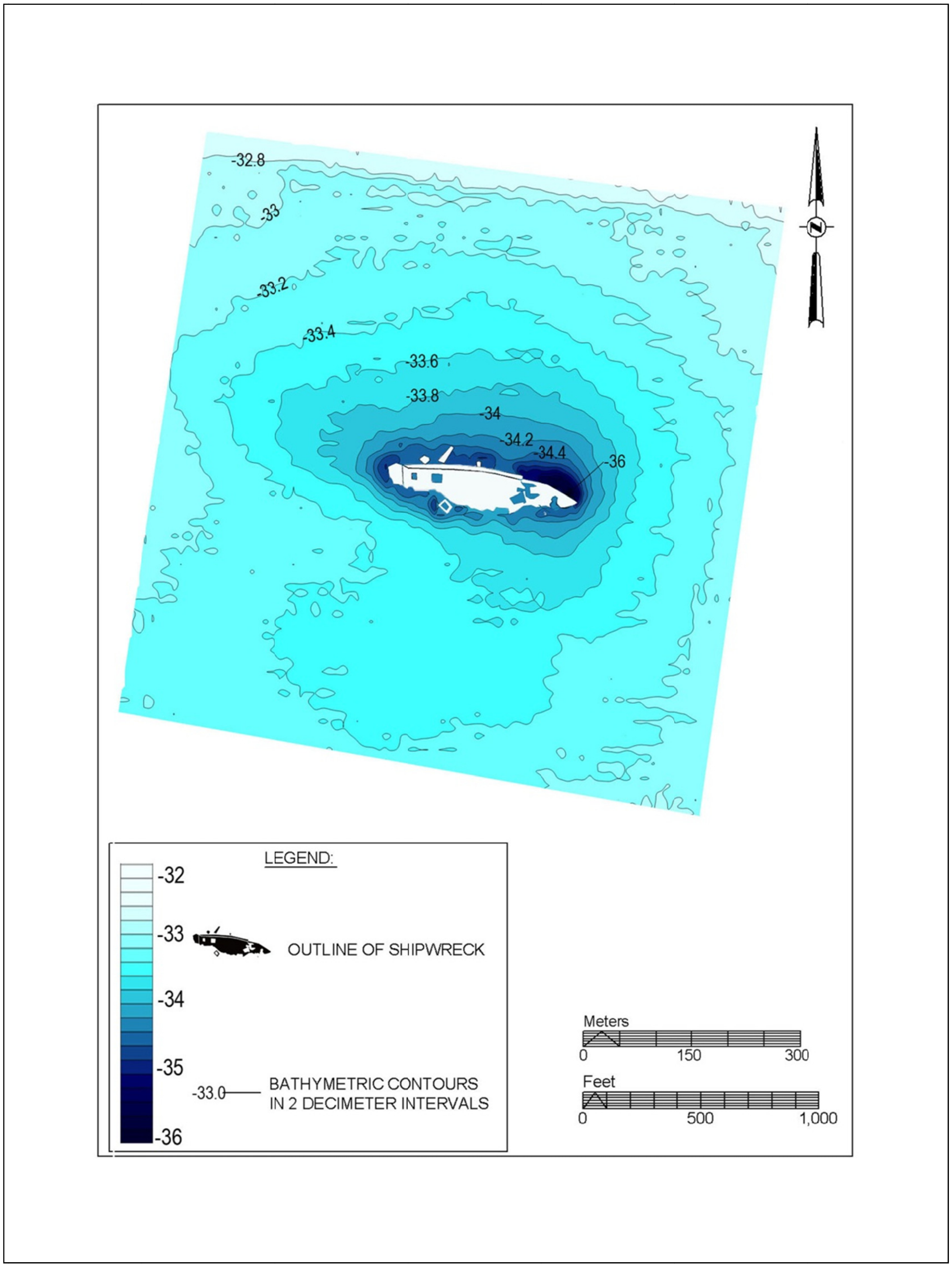


Figure 3.3.2. Bathymetry surrounding Site 386 in 2-decimeter intervals.

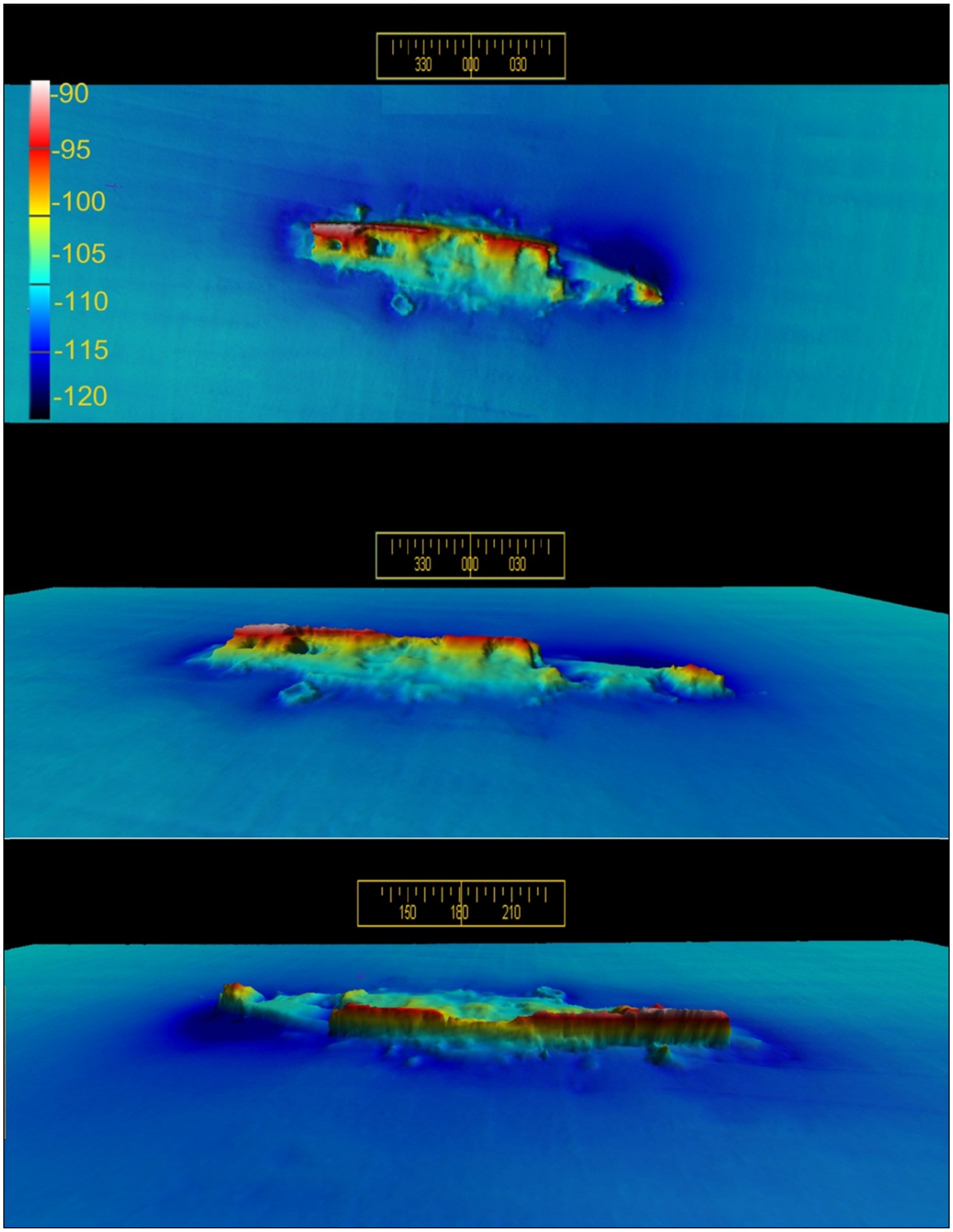


Figure 3.3.3. 3-D multibeam renderings of Site 386.

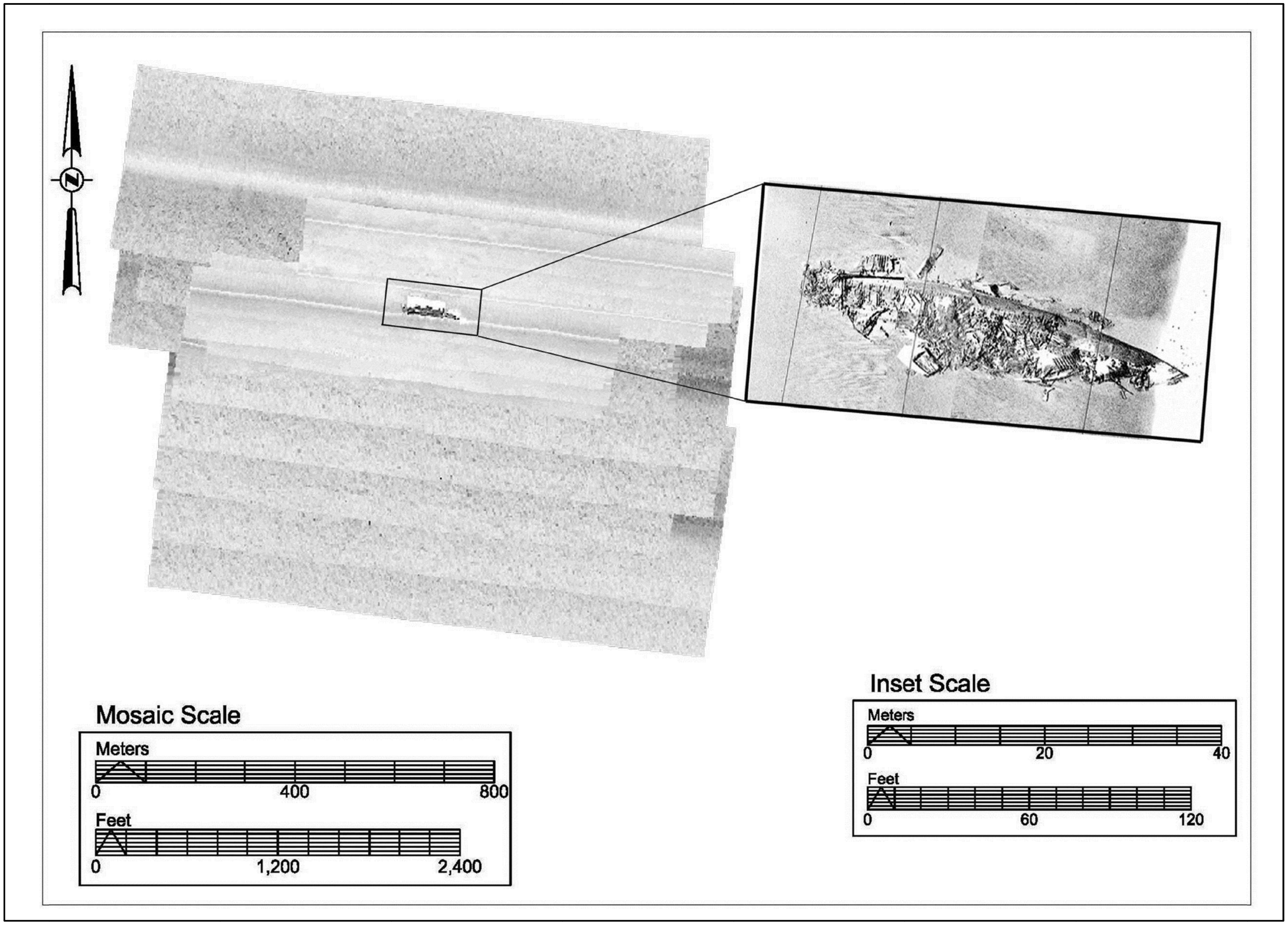


Figure 3.3.4. 120 and 410 kHz side scan sonar mosaic of Site 386. Inset is a composite of 410kHz. Data is from multiple survey lines.

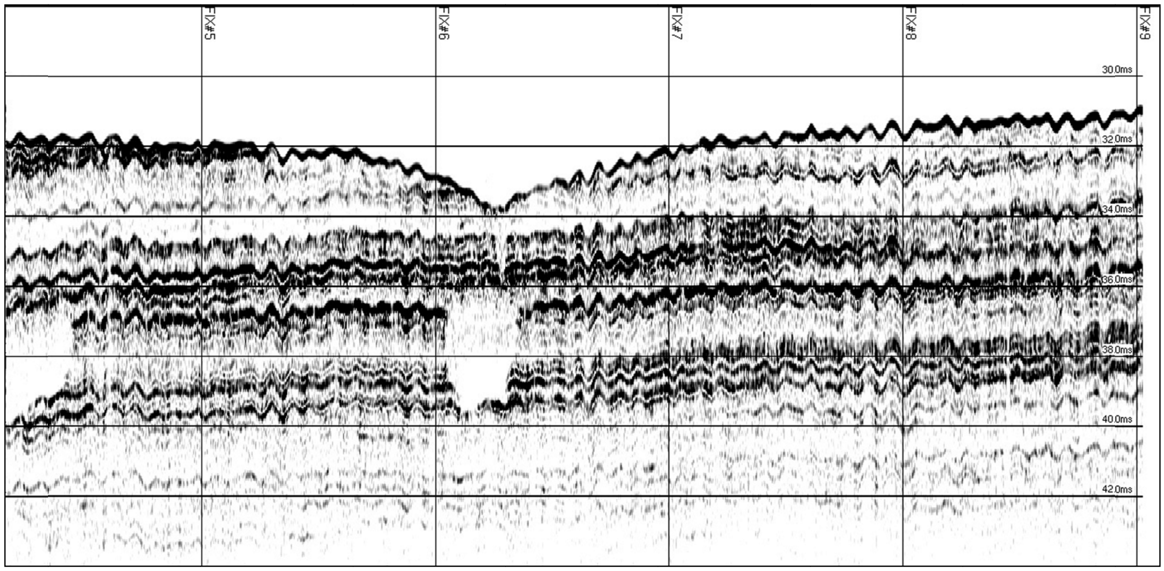


Figure 3.3.5. Sub-bottom profile of survey line 509, Site 386. Line 509 is located east of the wreck, with a heading of 10 degrees. Vertical scale lines in 150-m increments. Horizontal scale lines in 2-ms intervals.

Magnetometer data produced very high intensity, long duration anomalies stretched east/west along the axis of the reported shipwreck site. A total of 55 magnetic anomalies was recorded which could not be directly attributed to the main hull of the wreck. These individual anomalies are detailed in the Magnetic Anomaly Table for Site 386 (Appendix C). Magnetic Anomaly nos. 4, 12, 13, 14, 17, 18, 20, and 52 were identified in close proximity to the wreck site. These anomalies appear to be related to smaller quantities of debris that can be seen on the sonar and multibeam data scattered on the seabed surrounding the wreck site. It should be noted that these anomalies are not discernible within the contour maps and were identified by analyzing the individual trace plot for each survey line (Figure 3.3.6).

Small clusters of anomalies were also identified further from the wreck. The most significant of these clusters is located 265 m (870 ft) NW of the wreck site. This cluster includes Anomaly nos. 9, 10, and 50. Anomaly no. 9 is a 62 nT, 44-m (145-ft) negative monopole; no. 10 is a 9 nT, 23.4-m (77-ft) negative monopole; and no. 50 is a 9 nT, 44-m (145-ft) negative monopole. The area surrounding this anomaly cluster was beyond the extent of the 30-m survey grid; therefore, the seafloor was only imaged by low frequency sonar data. No seafloor features or debris were evident that correspond with this anomaly cluster; therefore, it is unknown if the anomalies are related to the shipwreck or are intrusive.

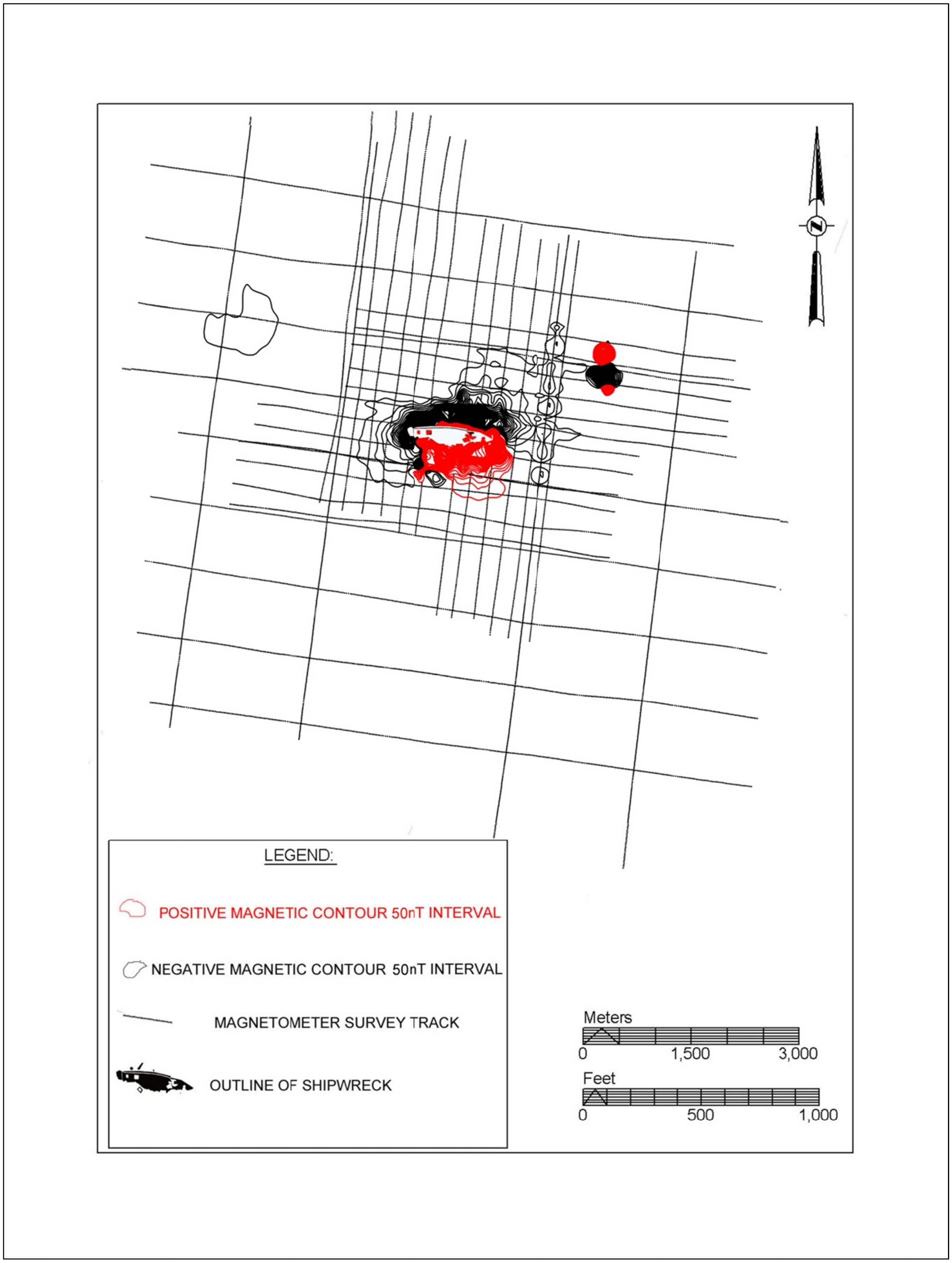


Figure 3.3.6. Magnetic contours in 50-nT intervals at Site 386.

3.3.3 Diving

Diving operations on Site 386 took place on August 16, 2010 from the M/V *Spree*. The sector scanning sonar was deployed before diving began and, although it could not image the site in its entirety, it provided details of various site components (Figure 3.3.7).

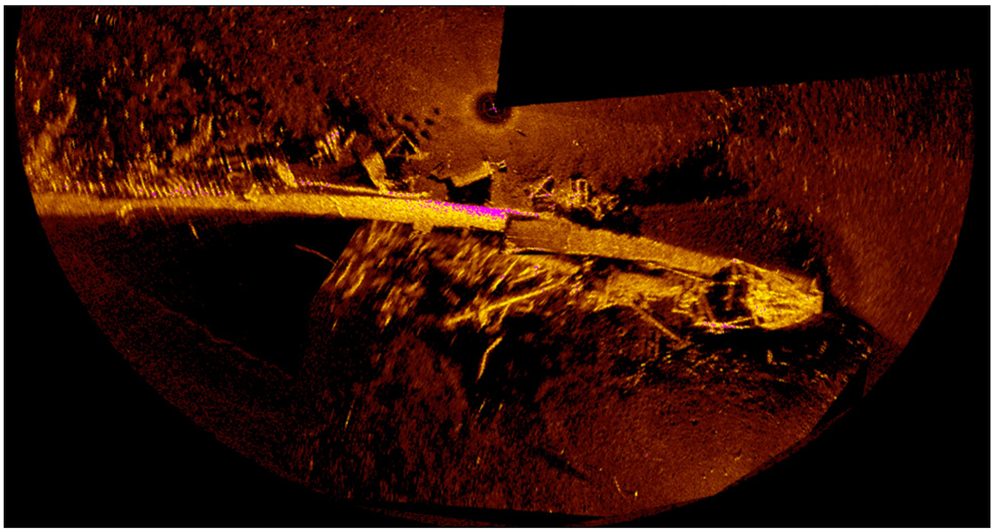


Figure 3.3.7. Sector scanning sonar composite image oriented north up.

- Maximum recorded water depth during diving: 25 m (80 ft).
- Total bottom time: 3 hours. Average dive time: 22.5 minutes.
- Visibility: 30 m (100 ft) in water depths less than 25 m (80 ft) BSL. 0 to 0.5 m (0 to 1.5 ft) in water depths greater than 25 m (80 ft) BSL.

The wreck site location was verified from the Mesotech scans and verified by the initial dive team. The wreck site was obscured by a thick layer of suspended sediment (floc) that began at approximately 25 m (80 ft) BSL. Visibility below the floc layer decreased quickly, creating a black water diving environment. Due to the risk of an entanglement/impalement hazard in zero visibility, as well as uncertainty about the maximum water depth within some of the scour zones surrounding the wreck site, the DSO decided to limit operations to circle searches to identify any visible remains extending above the flocculence. Possible steel frames were identified by the first dive team extending above the flocculence. Detailed investigation of these components was not possible since they extended into the flocculent layer, where visibility was zero, and diving conditions were deemed unsafe by the DSO. Despite conducting large 60-m (200-ft) circle searches at approximately 25 m (80 ft) of water depth, no other portions of hull structure were accessible to divers. Divers noted that throughout the duration of the search, small droplets of oil could be seen rising to the surface, verifying that they were over a wreck-site.

Immediately after the second dive team returned to the surface, weather conditions deteriorated and *Spree* returned to the dock at Morgan City, Louisiana. While the team waited out the storm, *Spree* was refueled and additional equipment and supplies were obtained from Tesla Offshore's office and local hardware stores. Due to the conditions encountered on site, the DSO decided that further dive operations were unsafe, and that no further investigation would be conducted on Site 386; dive operations proceeded to the next site.

3.3.4 Site Environment

3.3.4.1 Water Sampling

One 8-ounce water sample was collected from Site 386 on August 16, 2010 at a depth of 21.3 m (70 ft) BSL; divers did not descend below a maximum depth of 25 m (80 ft) at this site since visibility and probable entanglements created an unsafe diving environment. The water sample was collected by the first dive team and is assumed to be representative of conditions impacting the wreck site at deeper depths. Water temperature at the time of acquisition was 83° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.5). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.5

Water Sample Results for Site 386

Type	Average
Salinity (ppT)	33.60
pH	7.563
Dissolved oxygen (mg/L)	6.78

3.3.4.2 Core Lithology and Grain Size

Due to the poor visibility and dangerous conditions observed in the field, the DSO restricted divers to a maximum depth of 25 m (80 ft); therefore, no sediment cores were obtained from the seafloor at approximately 32.8–36 m (107.5–118 ft).

3.3.4.3 Oceanographic Analysis

The potential impact of hurricanes on seafloor scour is suggested by oceanographic modeling conducted at datum sites in the GOM as a proxy for seafloor conditions at the current site (Rego et al. 2011). Datum 1 is located east of the eye of the two modeled hurricanes, Ike and Rita, but still within the extents of their associated hurricane force winds. Site 386 lies just east of the maximum extent of hurricane force winds associated with both storms and just west of the maximum extent of hurricane force winds associated with Hurricanes Gustav and Katrina (Appendix F; Maps F-1 & F-2). Site 386 is therefore expected to have experienced lower potential scour rates than modeled at Datum 1 during Ike and Rita.

Since core data was not obtained at this site, comparisons are made between potential scour zones and observed sub-bottom profiler data. Storm-related scour modeled at Datum 1 resulted in maximum scour between 1.5 m (loose) and 3 cm (consolidated); net scour ranged from 21 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011). Datum 3 models represent scour estimates for a site located in 31 m of water, similar to the current site; sediments are likely coarser at Datum 3 than would be expected from samples at Site 386. Using the loose bed scenario, maximum scour ranged from 1.3 m (Ike) to 60 cm (Rita); consolidated bed scenarios resulted in net scour of 30 cm (Ike), but a net sediment accretion of 5 cm from Hurricane Rita (Rego et al. 2011). The sub-bottom profiles recorded closest to the hull at Site 386 depict scour zones that lack any evidence of sediment infill or re-deposition.

3.4 Site No. 373, South Marsh Island Area, Probable *Cities Service Toledo*

3.4.1 Site Background

Site 373 is located in the South Marsh Island Federal Lease Area, south of Marsh Island, Vermilion Parish, Louisiana. The site was reported to MMS as the result of a geophysical lease survey performed by John E. Chance and Associates, Inc., on October 19 and 20, 1992 (Figure 3.4.1). The October 1992 report was written by Marine Archaeologist Laura Landry and Senior Geophysicist Jeffrey Thomas. The hazard section of the report reads:

> Sonar data revealed a significant contact that is interpreted to be a sunken ship. This ship appears to be lying hull up, measures approximately 65 x 420 feet, and protrudes up from the seafloor about 28 feet. The ship also appears to have broken into two major pieces. There are two linear contacts extending out from the ship approximately 80 feet to the north and 225 feet to the south. These linear features could represent either seafloor dragmarks or lengths of cable or chain. Other scattered pieces of debris are also observed in the vicinity of the shipwreck. The 40 gamma, 1,500-foot duration magnetic anomaly detected on line 10, 1,130 gamma, 2,000-foot duration anomaly on line 11, and the 30 gamma, 1,300-foot anomaly on line 22 are directly related to the sunken vessel. The 1,000+, 650-foot anomaly detected on line 11 is probably associated with a piece of scattered ferrous debris associated with the shipwreck. A number of other targets which remain unidentified are scattered about the wreck which do not correlate with magnetic anomalies (Landry and Thomas 1992: 20).

In the hazard and archaeological sections of the report, the dimensions of the wreck site differ. The hazard section reports that the wreck is 128 m (420 ft) by 20 m (65 ft); the archaeological section reports that the wreck is 137 m (450 ft) by 20 m (65 ft). The report does not postulate a possible identity for the wreck, but it does point out that German U-boats operated in this area during World War II and this wreck could represent one of the victims.

The BOEM database identifies this wreck as the tanker *Cities Service Toledo*. It is unclear from the database when the vessel at Site 373 was first identified as *Cities Service Toledo*, but it is possible that this first identification was made by avocational divers. C.J. Christ was part of a group that dived on the site on June 19, 1971 (Christ 2006; 2011, pers. comm.). They found the site based on coordinates supplied to their boat captain by a local fisherman. While on the site, they noted that the vessel was upside down and had a single screw. Christ notes that they could see the rudder, but the propeller was missing (2006).

A 10" abandoned pipeline runs WNW of the wreck site. The pipeline was installed in 1972 and lies approximately 438 m (1,435 ft) WNW of the wreck at its closest point. A grouping of abandoned wells and removed platforms are located north of the site, the closest of which lies approximately 680 m (2,230 ft) to the north.

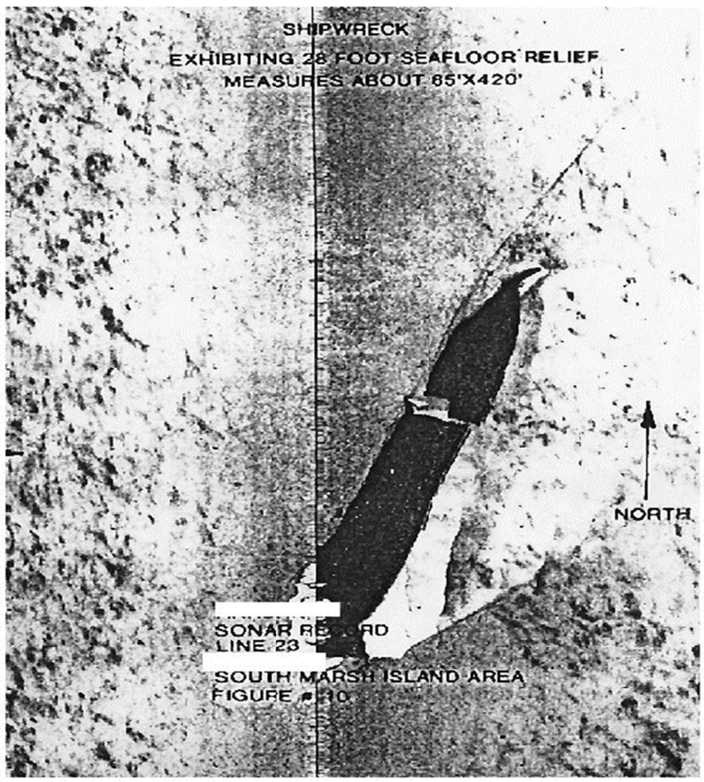


Figure 3.4.1. Side scan sonar image of Site 373 (Landry and Thomas 1992).

3.4.2 Geophysical

Geophysical data acquisition was conducted at this site on March 5 and 6, 2010 and additional data was obtained on May 30 and 31, 2010 aboard the M/V *Nikola*. The survey grid extended out in a 300-m (1,000-ft) radius surrounding the wreck site. Two separate survey grids were run over the site, both containing survey lines paralleling the wreck site. A total of 12 survey lines were run using 100 kHz sonar data and spaced 100 and 200 m apart for reconnaissance and to maximize sonar coverage. A total of 23 survey lines were run using 410 kHz sonar data and spaced 30 m apart for increased sonar resolution, multibeam coverage, sub-bottom profiling, and magnetic contouring (see Navigation Post-Plot Map Appendix B; Figure B-4). Side scan sonar, sub-bottom profiler, magnetometer, multibeam, and single beam bathymetry data were acquired at the site during both the March and May field operations. A CODA 3-D Echoscope was also used during the March operations (see Chapter 2 Methodology and Appendix A for a full description of geophysical sensor suite and navigation parameters).

The seafloor throughout the survey area is a fairly constant 27 m (88.5 ft), with undulations ranging from 26.8 to 27.2 m (88 to 89 ft) (Figure 3.4.2). The multibeam data illustrates that the wreck is hull up with a major break just south of midships. The wreck sits approximately 6.7 m (22 ft) above the surrounding seafloor. The vessel appears to be listing slightly to the eastern side (Figure 3.4.3). Scouring was evident surrounding the shipwreck and extended primarily to the western side with deeper, more concentrated zones to the north, south, and at the break in the hull south of midships. Water depths within these scour zones reach a maximum of 28 m (92 ft).

Sonar data corresponds with multibeam data, indicating that the wreck site is oriented along a roughly north-south axis with the north end oriented at 17 degrees and the south end oriented at 197 degrees. The 100 kHz survey grid clearly imaged the wreck site in its entirety, but did not have sufficient resolution to detail specific components of the vessel or changes in seafloor texture. The 410 kHz survey grid clearly outlined the wreck and provided details of some seafloor mottling surrounding the wreck as well as an increase in reflectivity extending SE of the hull. This reflectivity change may be the result of an increase in sediment grain size, or may be related to very small quantities of debris associated with deterioration of the wreck site. A possible ancillary component of the wreck site was resolved just north of the hull; this may represent a small length of cable or line. Figure 3.4.4 shows a sonar mosaic created using the low frequency sonar lines that run perpendicular to the wreck site and the high frequency lines that parallel the wreck site. An inset shows a composite of two high frequency sonar lines, providing uninterrupted imagery of the entire wreck.

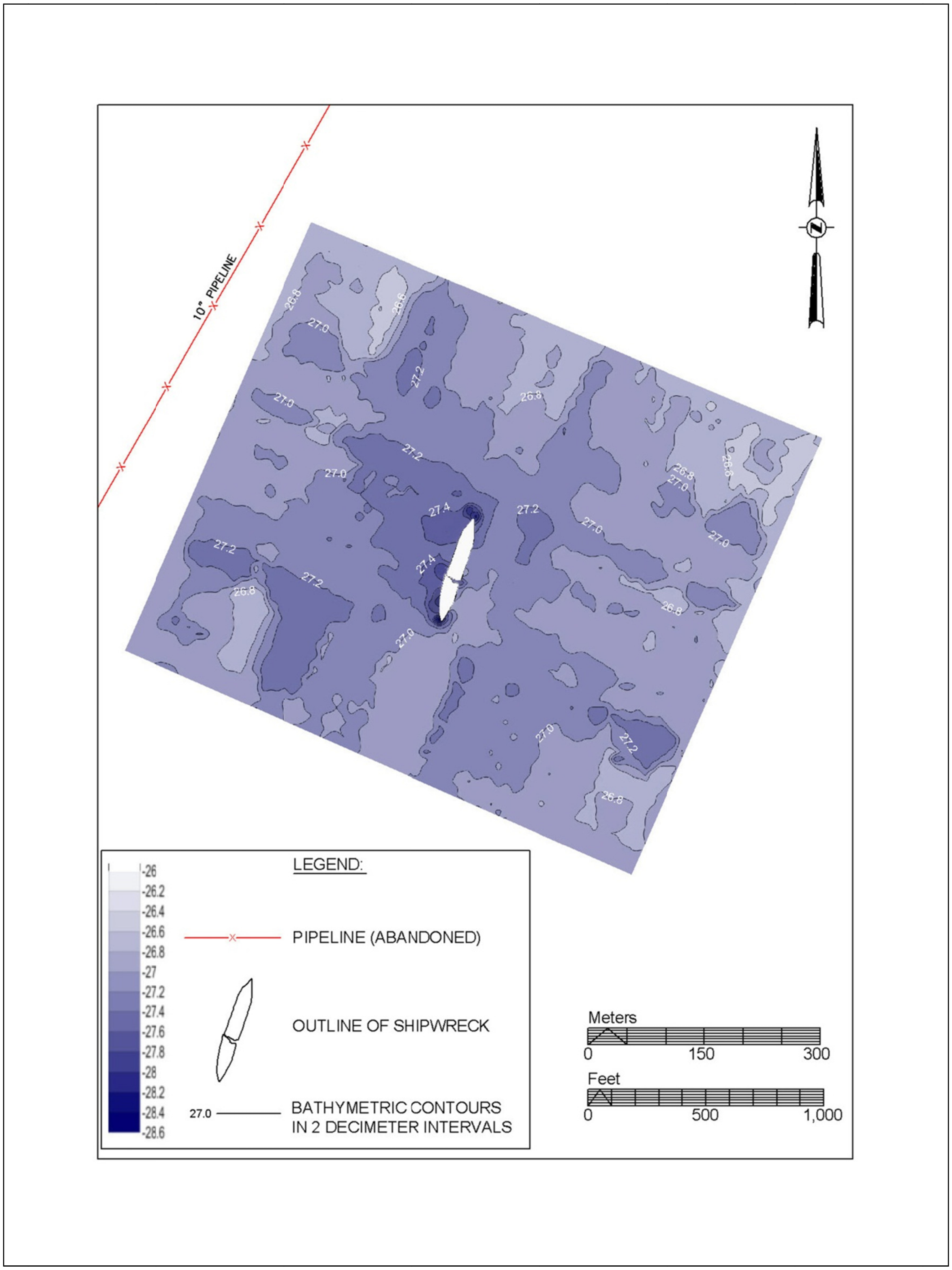


Figure 3.4.2. Bathymetry surrounding Site 373, in 2-decimeter intervals.

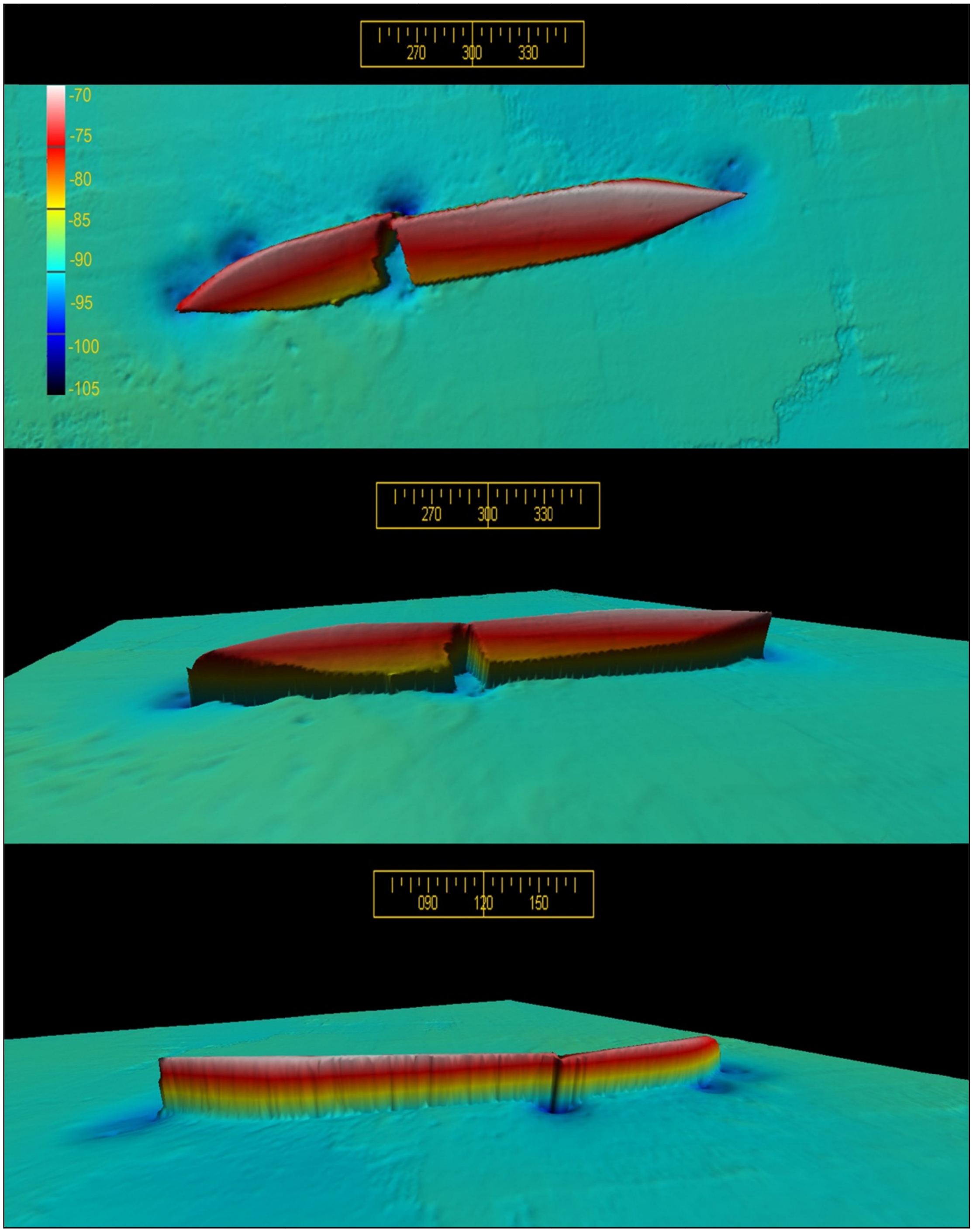


Figure 3.4.3. 3-D multibeam renderings of Site 373.

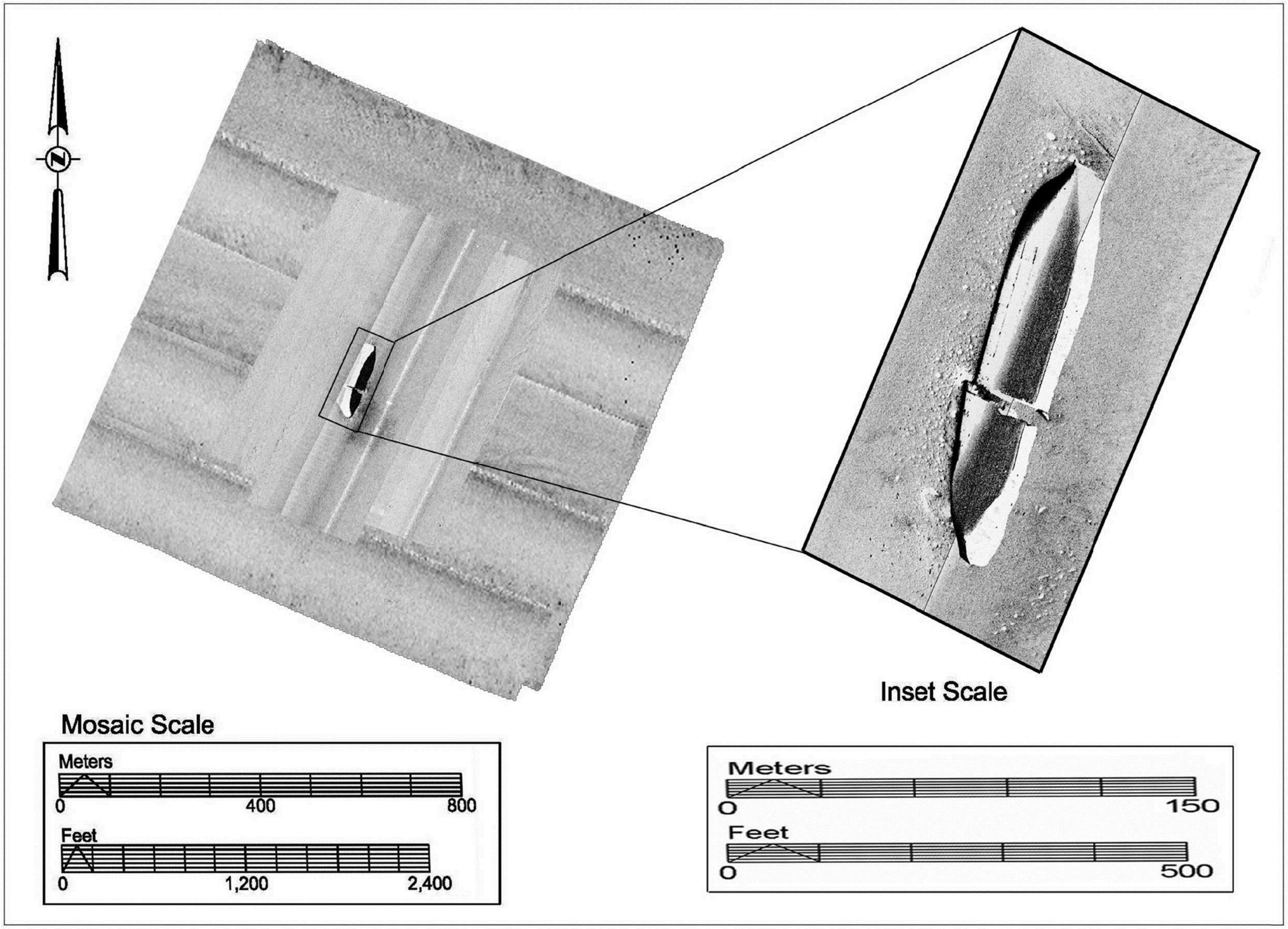


Figure 3.4.4. 120 and 410 kHz side scan sonar mosaic of Site 373. Insert is a composite of two 410 kHz lines of data.

In addition to the multibeam and side scan sonar data, the CODA 3-D Echoscope was employed at this site during the March operations. The resulting real-time imagery provided detail of a second hole in the hull of the vessel that lies along the SE side of the wreck; this is believed to be the result of a torpedo impact (Figure 3.4.5).

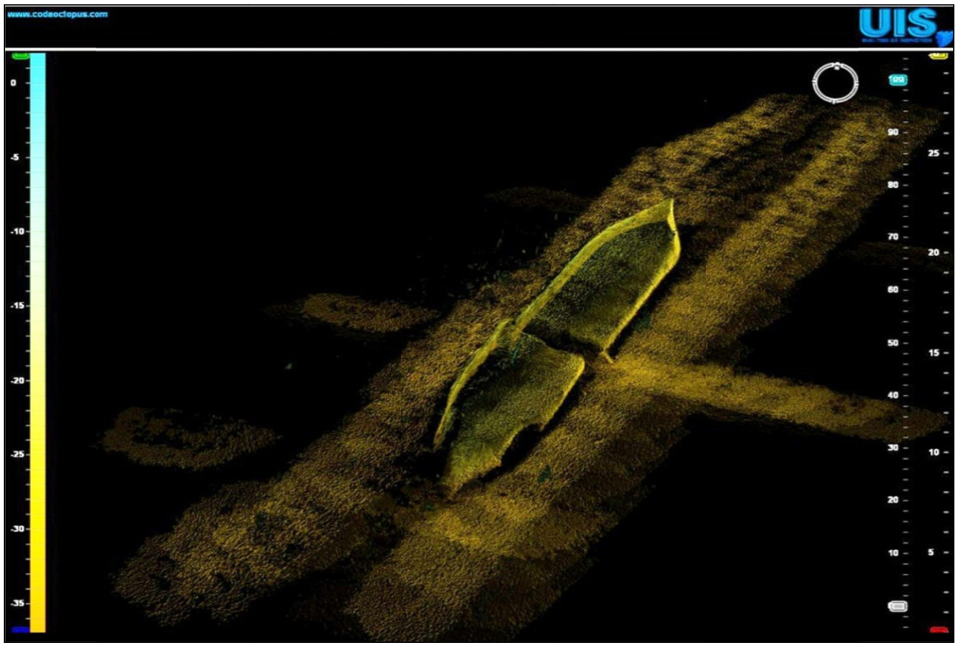


Figure 3.4.5. Echoscope still of Site 373, from CODA UIS software.

The combined sonar, multibeam, and echoscope data supports the original interpretation that the wreck is nearly split in half. The wreck site measures 141 m (463 ft) by 19.8 m (65 ft) and sits 6.7 m (22 ft) above the seafloor. The breach in the hull measures approximately 18.2 m (60 ft) by 6 m (20 ft). It is not clear from the geophysical data which end is the bow and which is the stern. No evidence of running gear or rudder was observed.

Sub-bottom profiler data penetrated 10.7 m (35 ft) throughout the survey grid. The stratigraphic profile consists of a moderate to strongly reflective seafloor, followed by an acoustically amorphous zone approximately 1.5 m (5 ft) thick. This is followed by approximately 6.1 m (20 ft) of well-laminated, parallel-bedded strata. The base of this zone is an unconformity that overlies acoustically amorphous, foreset deltaic deposits. Significant, broad scour zones are evident to the western and southern portions of the wreck. Unlike Sites 433 and 386, the scour zones are not very prominent; instead, they have been in-filled to depths of 1.5 m (5 ft). The following figure shows a stratigraphic profile close to the wreck site (Survey Line 205) demonstrating minor seafloor depression with in-filled scour approximately 1.5 m (5 ft) thick (Figure 3.4.6).

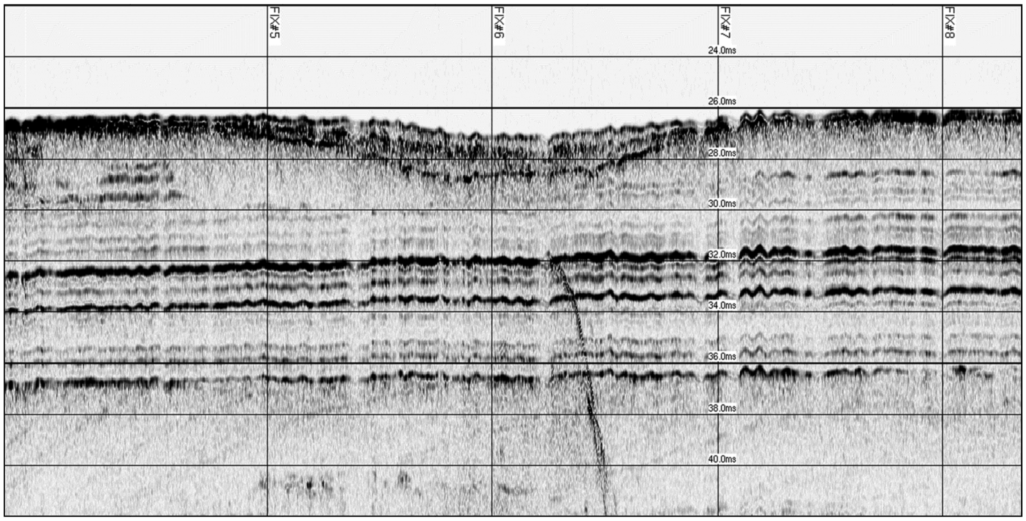


Figure 3.4.6. Sub-bottom profile of line 205, Site 373. Line 205 is located west of the wreck site with a heading of 10 degrees. Vertical scale lines in 150-m increments. Horizontal scale lines in 2-ms Intervals.

Magnetometer data produced a number of very high intensity, long duration anomalies directly over and adjacent to the hull of the shipwreck. A total of 20 magnetic anomalies were recorded which could not be directly attributed to the main hull of the wreck. Anomalies no. 2, 6, 8, 11, 16, 17, 18, and 20 were identified in close proximity to the wreck site. These anomalies appear to be related to smaller quantities of debris that may be buried in the surficial sediments surrounding the wreck site. It should be noted that these anomalies are not discernible within the contour maps and were identified by analyzing the individual trace plot for each survey line. Due to the massive signature of the metal hull, it is not possible to identify all smaller quantities of debris directly adjacent to the wreck site (Figure 3.4.7).

Contoured magnetometer data identified the abandoned 10" pipeline at the western extent of the survey grid within the run-out of survey line 103. Some small clusters of anomalies were also identified further from the wreck site. The most significant of these clusters is located 370 m (1,215 ft) NW of the wreck site. This cluster includes Anomalies no. 13, 14, and 15. Anomaly no. 13 is a 404 nT, 46-m (153-ft) positive monopole, no. 14 is a 69 nT, 22-m (72-ft) positive monopole, and no. 15 is a 15 nT, 15.5-m (51-ft) dipole. Anomaly no. 13 has characteristics consistent with a pipeline crossing; however, the source of the anomaly lies 128 m (420 ft) east of the reported pipeline. Since the pipeline was just beyond the extent of the survey grid, there was not enough evidence to determine if the pipeline is displaced or if the anomaly represents a separate ferromagnetic source. Because of this cluster's proximity to the pipeline as-built position, it is likely that it is related to pipeline construction or maintenance. The area surrounding this anomaly cluster was beyond the extents of the 30-m survey grid; therefore, the seafloor was imaged by only low frequency sonar data. No seafloor features or debris were evident that correspond to this anomaly cluster.

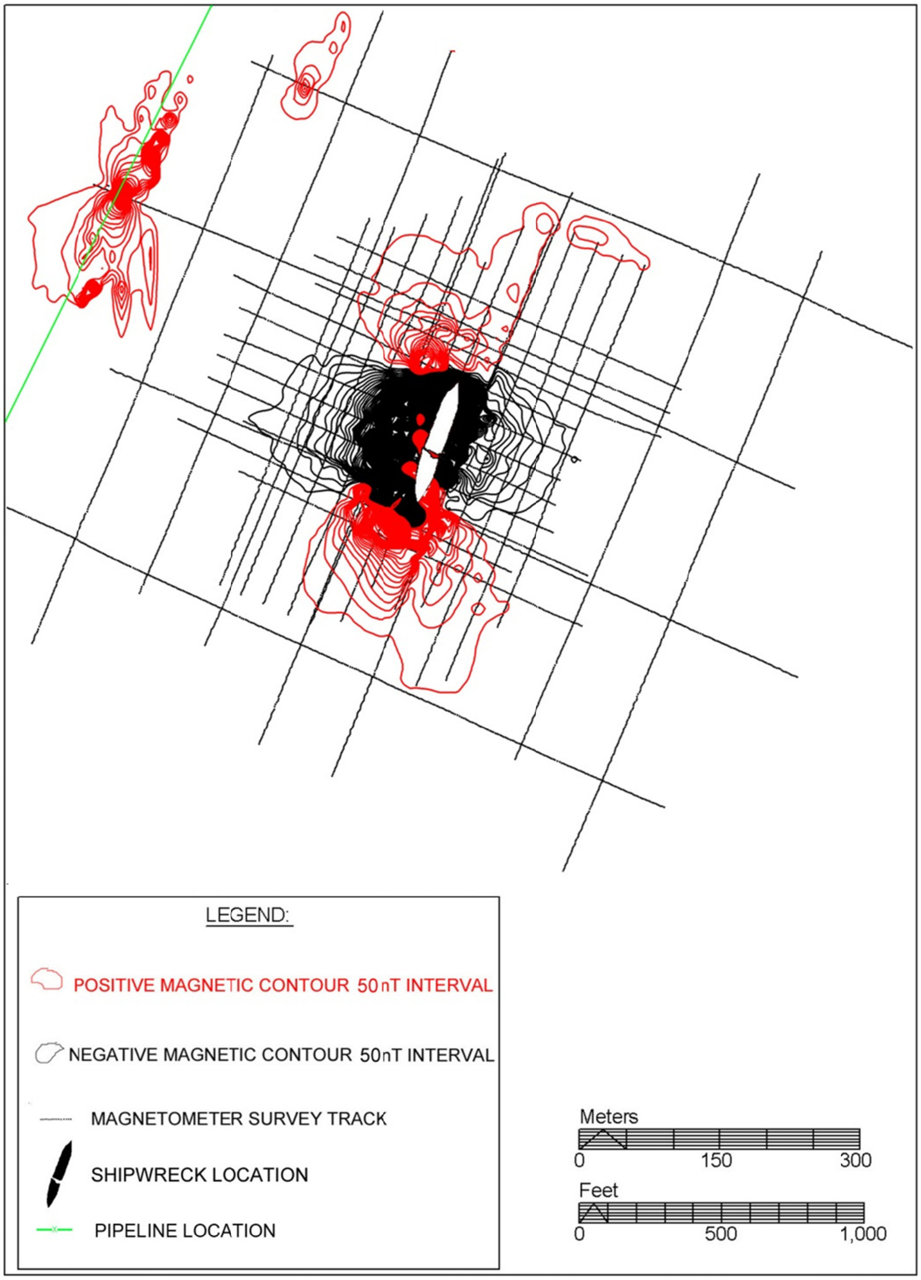


Figure 3.4.7. Magnetic contours in 50-nT intervals at Site 373.

3.4.3 Diving

Diving operations on Site 373 took place on August 18 and 19, 2010 from the M/V *Spree*.

- Maximum recorded water depth on bottom: 26 m (85 ft).
- Total bottom time: 6.63 hours. Average dive time: 23.41 minutes.
- Visibility: 1.8–6 m (6–20 ft) on wreck, 0–0.9 m (0–3 ft) on seafloor.

Like Site 433, the wreck at Site 373 is upside down on the seafloor, reducing the number of accessible diagnostic features. Before diving operations, dive teams reviewed plans of the tanker *J.A. Bostwick* (the former name of *Cities Service Toledo*) that had been obtained from the Hagley Museum (Appendix E; Figures E-27-29). These plans contained extensive design and construction details, including the vessel's propeller and rudder assembly. Based on these drawings, the project team decided to concentrate initial diving operations on the stern of the vessel in an attempt to obtain potentially diagnostic data that could be compared to the plans.

The first dive team established a descent line at the southern end of the shipwreck. Geophysical data was unable to distinguish the bow from the stern at Site 373, and it was quickly determined that the southern end was in fact the bow of the vessel. The descent line was subsequently moved to the stern of the vessel, where it was secured to the propeller shaft (Figure 3.4.8). Teams that investigated features on this vessel developed drawings, measurements, and photographs for the propeller shaft and hull plating. It immediately became apparent during diving operations that salvage had likely occurred on the vessel after sinking, as the rudder, sternpost, and propeller had been removed. Attempts to clean and record hull plating details met with marginal success because of the heavy marine growth on the hull and the limited time divers had on the site. Other activities on this site included looking for the remains of any draft marks on the stern, and searches off of the stern to verify that the rudder/propeller were not disarticulated and subsequently obscured by near-seafloor sediments. Despite conducting these searches at 24 m (80 ft) water depth and investigating a deep scour off of the stern at 27 m (90 ft), no indication of the missing stern features were found.

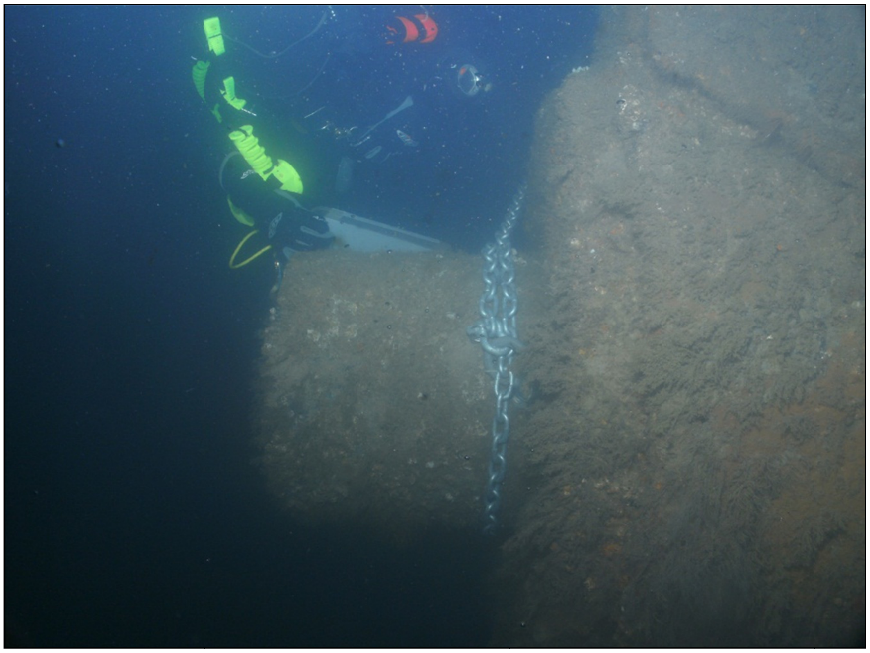


Figure 3.4.8. Photograph of propeller shaft with descent line attached.

The Mesotech was deployed the evening of August 18, 2010. Although multiple drops were made, due to the size, shape, and height of the vessel, no useful imagery was obtained.

3.4.4 Site Environment

3.4.4.1 Water Sampling

One 8-ounce water sample was collected from Site 373 on August 19, 2010 at a depth of 24.7 m (81 ft) BSL. Water temperature at the time of acquisition was 83° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.6). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.6

Water Sample Results for Site 373

Type	Average
Salinity (ppT)	30.80
pH	8.013
Dissolved oxygen (mg/L)	7.45

3.4.4.2 Core Lithology and Grain Size

A single core was collected from Site 373 on August 19, 2010. Divers positioned the core approximately 15 m (49 ft) south of the northernmost end of the wreck and 25 m (82 ft) to the east; water depth at the core site was approximately 27 m (89 ft), similar to the ambient seafloor. Water depth at the coring location was recorded using the divers' wrist mounted dive computers. The core resulted in a 58 cm stratigraphic sample.

Samples were subsequently collected from each of two units observed within the core lithology and measured for grain size. Median and graphic mean calculations both demonstrate that sediments from Site 373 are cohesive-clay dominant, and consist of medium silt (graphic mean). Based on median grain size, the near seafloor sediments are fine silt and increase in size to medium silt downcore. Shear strength measurements were not obtained for this site because radioisotope sampling did not leave sufficient material to measure with either the penetrometer or the mini-torvane in the 2" diameter core sleeve.

3.4.4.3 Radioisotope Analysis

Sediments from Site 373 do not show any evidence of a downcore decay trend in Pb activity that can be used to arrive at a linear accumulation rate (LAR). Although there are several sharp changes in activity downcore (lines at 3 and 42 cm on Fig. 3.4.11), no age can be ascribed to them. No sharp downcore differences in porosity or grain size were observed downcore; hence, the overall absence of downcore decay in Pb activity cannot be linked to changing coarse fraction percentage.

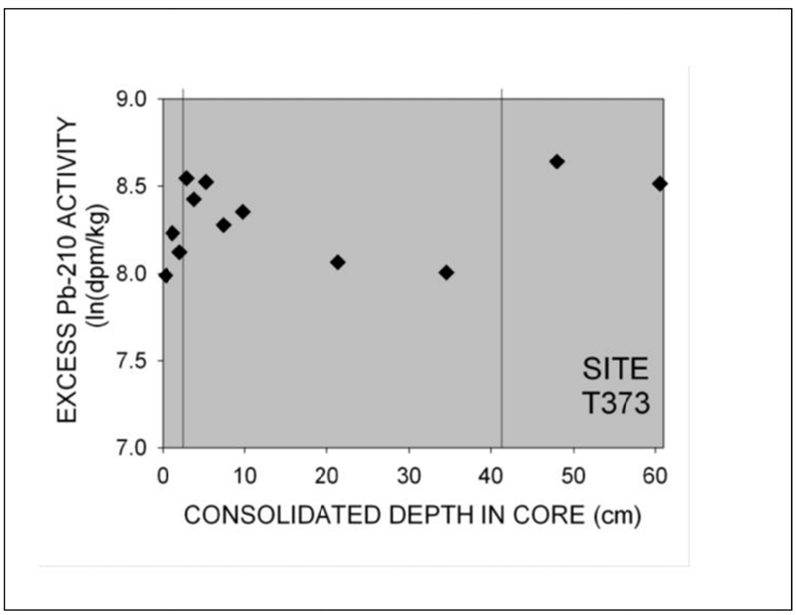


Figure 3.4.9. Downcore ^{210}Pbxs activity for Site T373.

3.4.4.4 Oceanographic Analysis

Oceanographic modeling of flow conditions was conducted using recorded wave and current patterns during Hurricanes Ike and Rita as applied to measured grain sizes for seafloor sediments at Site 373 (Datum 1; Rego et al. 2011). Site 373 is located east of the eye, but within the swath of hurricane force winds associated with both storms modeled in this exercise (Appendix F; Maps F-1 & F-2) Datum 1 was based on coordinates very close to Site 373 with the same water depths and sediment types. Scour estimates were generated for both loose and consolidated bed scenarios for each of the modeled hurricanes. In all cases, maximum hurricane-induced scour was followed by re-deposition of sediments, resulting in smaller net scour estimates. Storm-related scour modeled at Site 373 resulted in maximum estimates of between 1.5 m (loose) and 3 cm (consolidated); net scour ranged from 21 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011).

3.5 Site No. 15488, High Island Area, Unknown Modern Wreck

3.5.1 Site Background

Site number 15488 is located in the High Island Federal Lease Area, south of Jefferson County, Texas. The site is approximately 13 km (8 miles) SE of a modern shipping fairway that connects Sabine, Port Arthur, and Galveston.

The site was originally identified during a geophysical survey performed by Thales Geosolutions, Inc., in December 2001. The geophysical data analysis and resulting report were prepared in 2002 by Marine Archaeologist, Robert J. Floyd and Marine Geologist, John L. Rietman. The archaeological report states:

> Available references on shipwrecks in the general vicinity… include the *Doris* (1915), *Shamrock* (1939), *Frances H.* (1909), the *Lydia* (1909), and the *Emma Harvey* (1916). The magnetometer and side scan sonar records… were examined for wrecks, and the wreck located 700 feet southeast of the… 6-inch pipeline appears to be a modern work boat approximately 75 feet long and 20 feet wide. The magnetic readings (#4 and #16) indicate a vessel slightly under 100-ton class. The coordinate for the sonar image should be used as the center of avoidance rather than the magnetic readings in this specific case. (Floyd and Rietman 2002:19)

This wreck was not entered into the MMS shipwreck database; it was again "discovered" during a geophysical survey performed by Tesla Offshore in May of 2008. The geophysical data analysis and resulting report were prepared by Marine Archaeologist Amanda Evans, and Geoscience Manager Matt Keith (Evans and Keith 2008). The hull of the vessel measured 21 m (69 ft) in length with a beam of approximately 7 m (22 ft). The wreck was determined to rest upside down with the bow facing NE. The sonar data indicated that debris was present on the port side, including a linear projection extending out and away from the hull (Figure 3.5.1). The 2008 report also concluded that the vessel was likely a modern workboat, "It is unlikely based on the initial survey data that the vessel is a historic resource, however it should be avoided by a distance of approximately 300 m (1,000 ft) until a definitive assessment can be made of the vessel's potential historical significance" (Evans and Keith 2008).

A 6" abandoned pipeline lies 190 m (625 ft) NW of the site and a 4" abandoned pipeline lies 660 m (2,165 ft) NE. A few P&A wells are located in the area, the closest of which lies 1,400 m (4,590 ft) to the SSE.

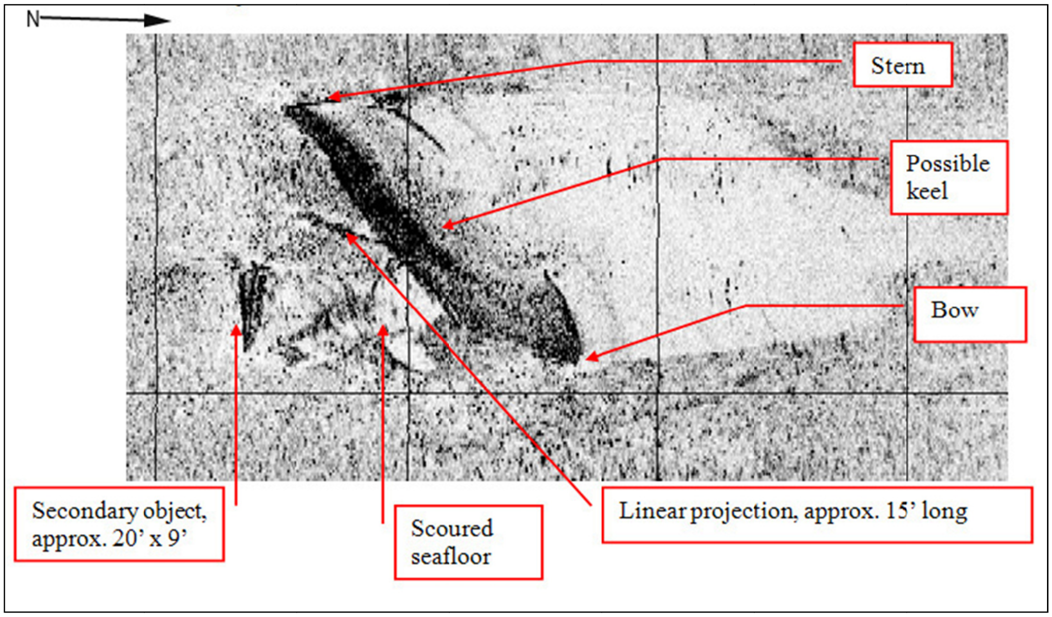


Figure 3.5.1. 410 kHz side scan sonar image of Site 15488 (Evans and Keith 2008).

3.5.2 Geophysical

Geophysical data acquisition was conducted at Site 15488 on March 17, 2010 and on August 16 and 17, 2010 aboard the M/V *Nikola*. Side scan sonar, sub-bottom profiler, magnetometer, multibeam, and single beam bathymetry data were acquired at the site during both the March and August field operations. A CODA 3-D Echoscope was also used during the March operations (see Chapter 2 Methodology and Appendix A for a full description of geophysical sensor suite and navigation parameters).

Due to rough seas, data quality was severely compromised during initial survey operations. A return trip was made to the site and all sensors (with the exception of the echoscope) were re-run. The survey grid extended out in a 300-m (1,000-ft) radius surrounding the wreck site, centered on the vessel's position. Two separate survey grids were run over the site, both containing survey lines parallel and perpendicular to the wreck site. A total of 12 survey lines were run using 100 kHz sonar data and spaced 100 and 200 m apart for reconnaissance and to maximize sonar coverage. A total of 23 survey lines were run directly over the wreck site using 410 kHz sonar frequency and spaced 30-m apart for increased sonar resolution, multibeam coverage, sub-bottom profiling, and magnetic contouring (see Navigation Post-Plot Map Appendix B; Figure B-5).

Water depths throughout the survey area range from 13.4 to 13.8 m (44 to 45 ft) (Figure 3.5.2). The multibeam data illustrates that the wreck is upside down and the bow is oriented 65 degrees NE. The wreck sits approximately 2.1 m (7 ft) above the surrounding seafloor and appears to be listing to the NW side (starboard). Scour appears to be limited to the area immediately surrounding the wreck site with maximum depth reaching 14 m (46 ft).

Sonar data corresponds with multibeam data, indicating that the wreck site is oriented with the bow facing NE. The 100 kHz survey grid clearly imaged the wreck site in its entirety, but did not have sufficient resolution to detail specific components of the vessel or changes in seafloor texture. The 410 kHz survey grid clearly outlined the wreck and provided details of some seafloor mottling surrounding the site. Debris associated with the wreck site was identified off of the SE side, just fore of midships. Seafloor scars caused by trawling activities are also evident on the sonar data.

Figure 3.5.3 shows a sonar mosaic created using the low frequency and high frequency sonar lines that were run parallel to the wreck site. An inset shows the wreck as imaged from survey line 307. Sonar data did not produce high quality imagery over the wreck site, likely due to the difficulty in imaging the wreck with acoustics because of the angular hull and the angle at which the wreck site has settled into the seafloor.

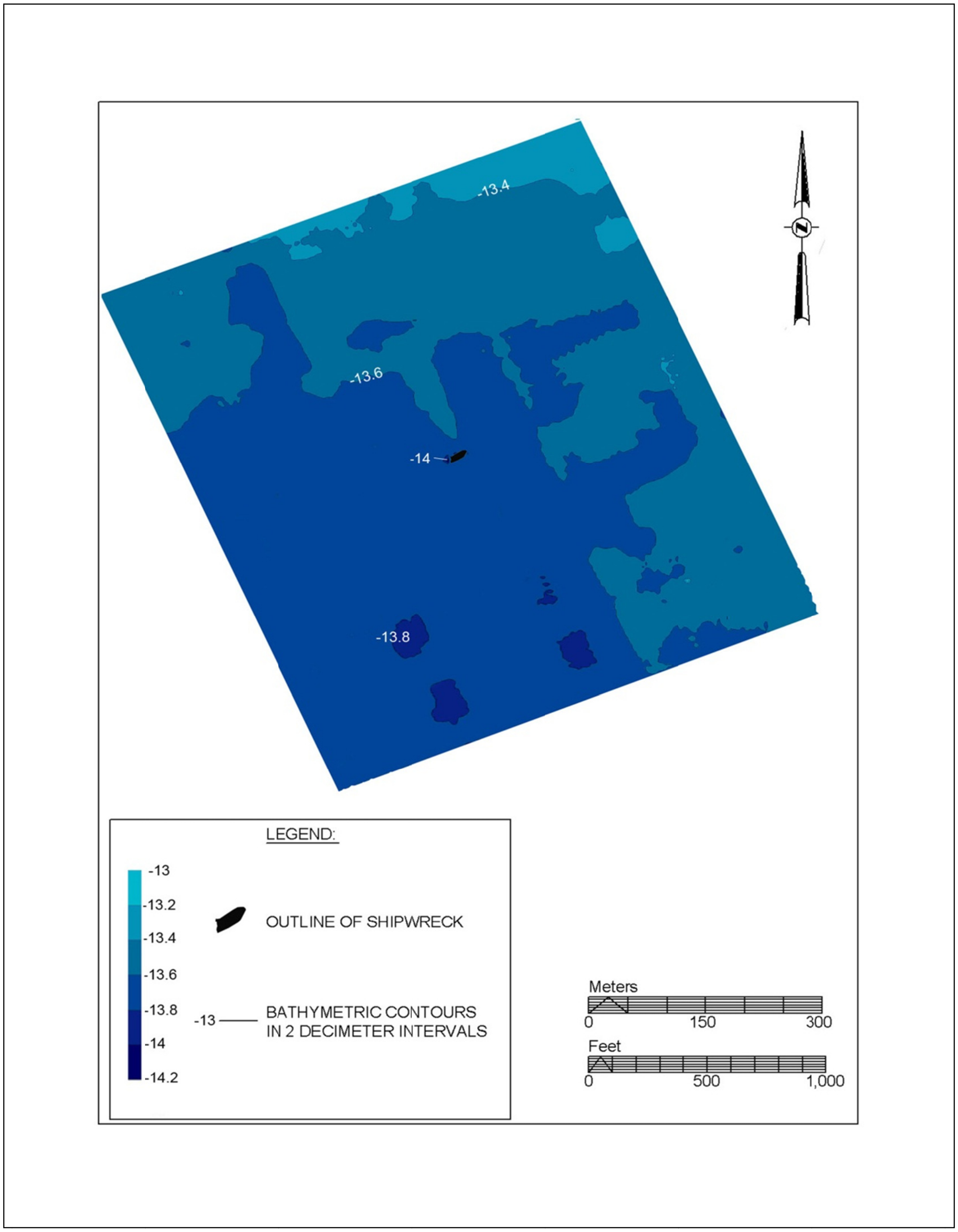


Figure 3.5.2. Bathymetry surrounding Site 15488, in 2-decimeter intervals.

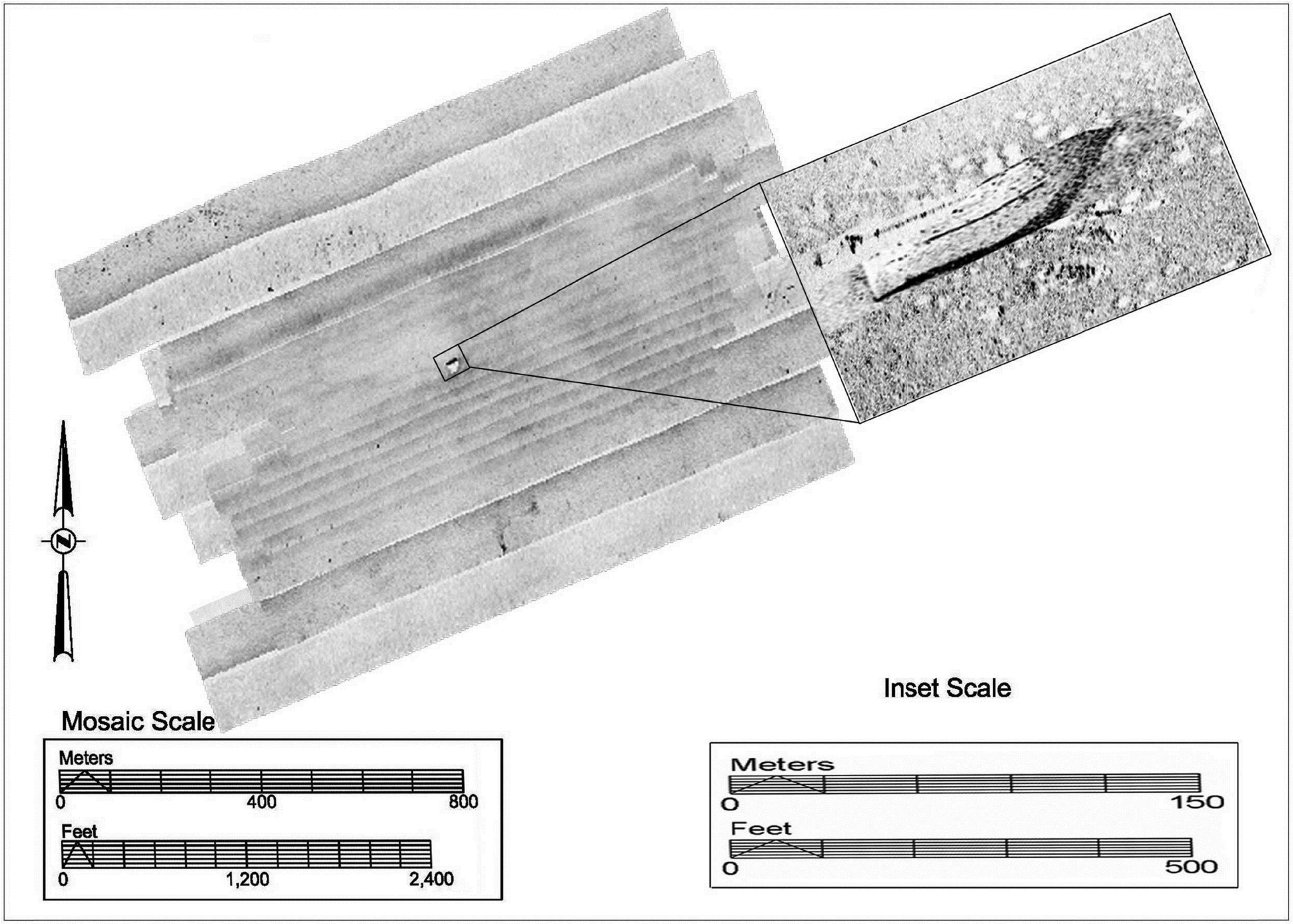


Figure 3.5.3. 120 and 410 kHz side scan sonar mosaic of Site 15488. Inset at 410 kHz.

In addition to the multibeam and side scan sonar data, the CODA 3-D Echoscope was employed at this site during March operations. The resulting imagery provided excellent detail of the listing hull and running gear (Figure 3.5.4). The data indicate that the starboard side of the wreck is buried in the seafloor sediments and the port chine is the highest point on the wreck site.

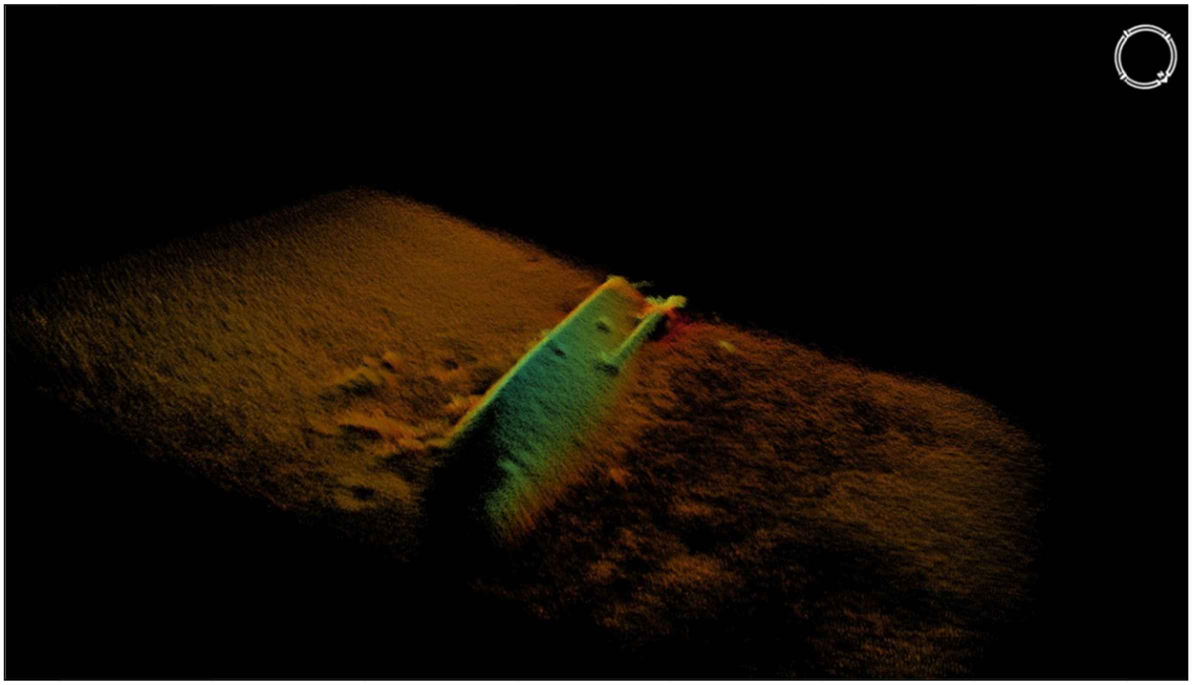


Figure 3.5.4. Echoscope still image of Site 15488, from CODA UIS software.

The combined sonar, multibeam, and echoscope data support the original interpretation that the wreck is upside down with intact running gear, and a field of debris located off of the port side. The wreck site measures approximately 21 m (70 ft) by 6 m (20 ft).

Sub-bottom profiler data is unstratified, indicative of sediments with a high concentration of course-grained, sandy deposits. The seafloor is typically strongly reflective, although a thin layer of weakly reflective surficial deposits is occasionally present (Figure 3.5.5). Poorly resolved paleo-channels are evident throughout the area with margins extending to within a few feet of the seafloor. Sediments within the channel deposits exhibit sag into the underlying strata. The shipwreck lies directly over an observed paleo-channel. Scour zones surrounding the wreck site are restricted to the area immediately adjacent to the hull. In-filled scour is evident extending further from the wreck. The following figure shows a stratigraphic profile (Survey Line 305) immediately SW of the wreck site where the typical scour sequence is evident.

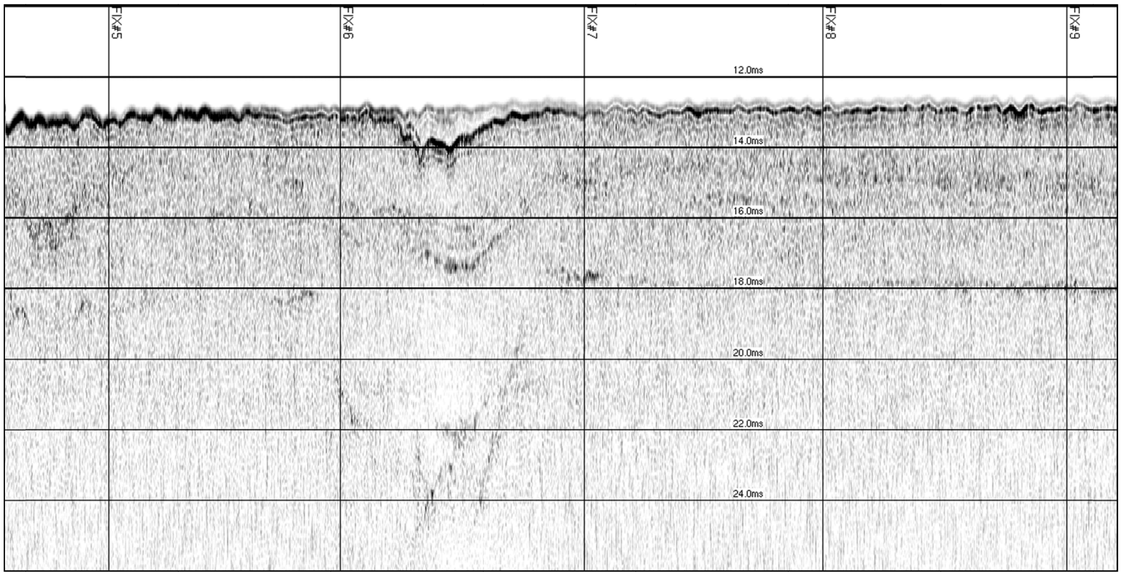


Figure 3.5.5. Sub-bottom profile of line 305, Site 15488. Line 305 is located SW of the wreck site, with a heading of 330 degrees. Vertical scale lines in 150-m increments. Horizontal scale lines in 2-ms intervals.

Magnetometer data very clearly highlighted the wreck site and the 6” pipeline that runs NNW of the wreck (Figure 3.5.6). The wreck at Site 15488 produced fewer and generally smaller magnetic anomalies than had the larger shipwrecks discussed previously. A few scattered anomalies not attributed to the main body of the wreck were identified further from the site, but most were small and none was identified on multiple survey lines.

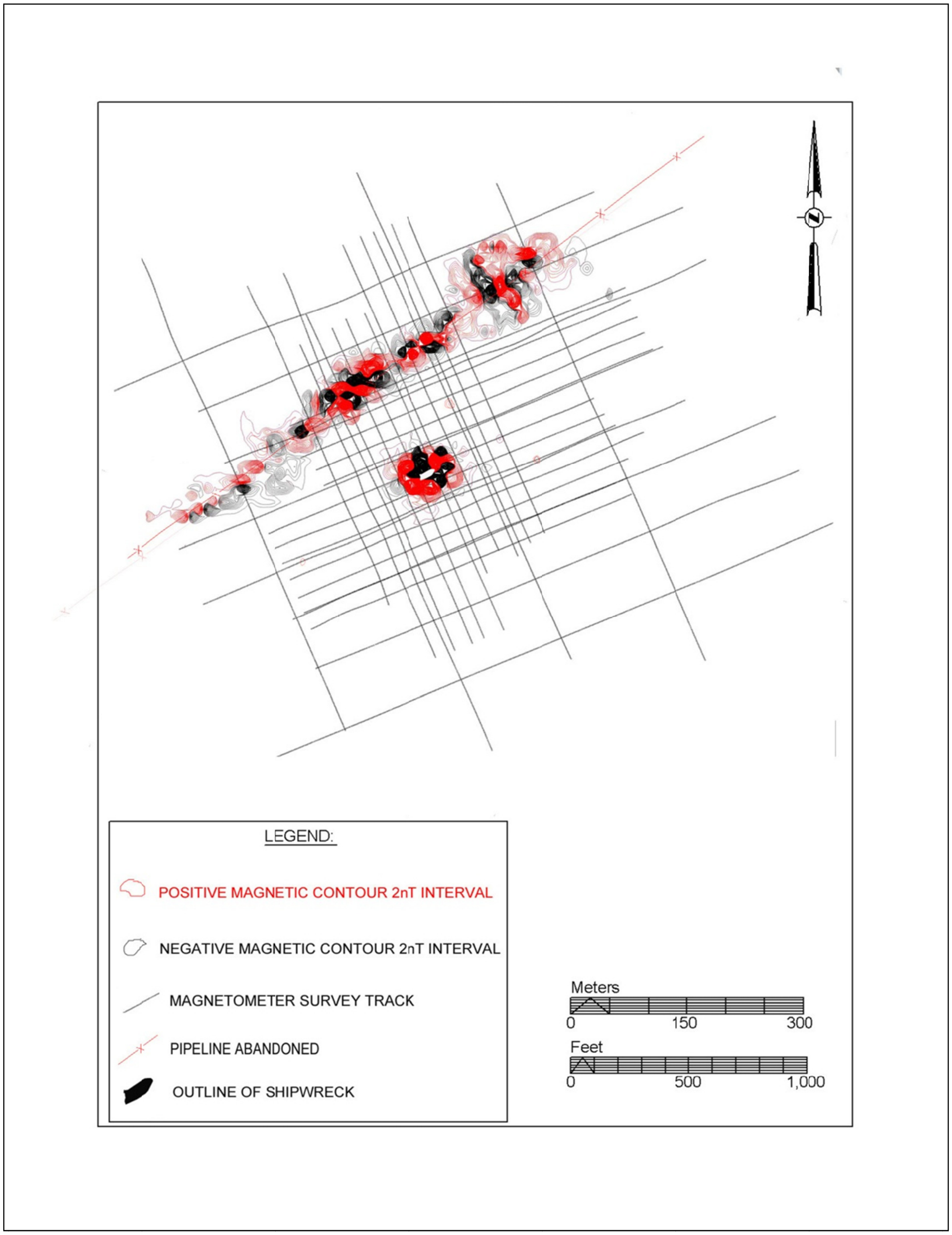


Figure 3.5.6. Magnetic contours at Site 15488, at 2-nT intervals.

3.5.3 Diving

Site 15488 was investigated on August 21, 2010 from the M/V *Spree*.

- Water depth: 14 m (46 ft).
- Total dive time: 7.77 hours. Average dive time: 25.89 minutes.
- Visibility: 0–0.3 m (0–1 ft).

The sector scanning sonar produced imagery that correlated with the previous side scan, multibeam, and echoscope images indicating that the vessel was upside down with intact running gear (Figure 3.5.7).

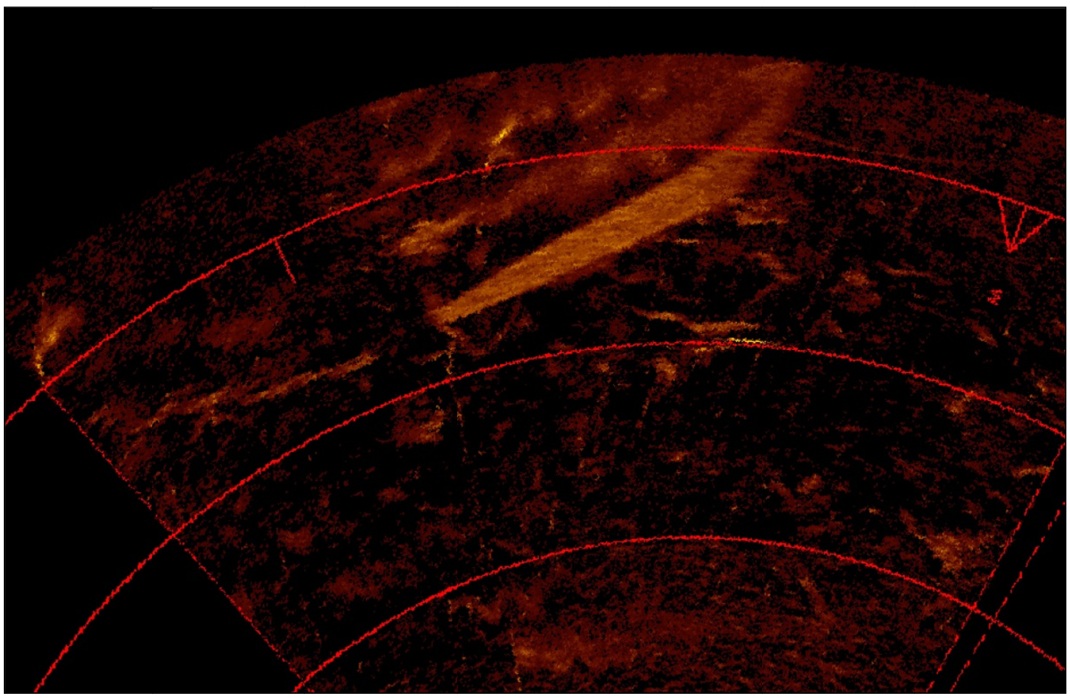


Figure 3.5.7. Sector scanning sonar image of Site 15488.

Dive teams encountered an upside-down, metal-hulled vessel with relatively few diagnostic features, and an associated debris field of net-covered iron objects (presumably parts of the vessel). The ship was powered with a single, 4-bladed propeller; the blades measured 60 cm (24 in) in length, with a maximum width of 40 cm (16 in). A single central metal rudder was observed intact, with horizontal vanes near its bottom and top. The vessel has a transom stern, and no letters or other markings could be seen or felt by divers. Raised sections or "vanes" were noted near the bow and stern. Close examination of the hull indicated that blue bottom anti-fouling paint was preserved under a thin layer of growth. A through-hull speedometer transducer was noted on the hull bottom as well. Poor visibility precluded photography and reduced the effectiveness of mapping.

3.5.4 Site Environment

3.5.4.1 Water Sampling

Two 8-ounce water samples were collected from Site 15488 on August 21, 2010 at a depth of 14 m (46 ft) BSL. Water temperature at the time of acquisition was 88° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.7). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.7

Water Sample Results for Site 15488

Type	Sample	Average
Salinity (ppT)	1	31.5
Salinity (ppT)	2	31.80
pH	1	8.02
pH	2	7.837
DO (mg/L)	1	6.915
DO (mg/L)	2	6.87

3.5.4.2 Core Lithology and Grain Size

Two cores were attempted at Site 15488 on August 21, 2010. The first core was attempted south of the wreck, but divers experienced core refusal at a depth of approximately 10 cm (4 in). Sediments were observed to be sandy and exhibited a lack of cohesion resulting in the core falling out of the core barrel before it could be capped. A second attempt was made at the wreck site, to the east of midships less than 1 m south of the hull; water depth at the successful core site was approximately 14 m (46 ft), similar to the ambient seafloor. The core resulted in a 67 cm stratigraphic sample.

Samples were collected from each of four units observed within the core lithology and measured for grain size. Median and graphic mean calculations demonstrate different patterns downcore. Median grain size indicates fining downcore, from medium silt in the upper two samples to medium/fine silt, and fine silt. Graphic mean calculations indicate a more complex grain size pattern with alternating layers of coarse and medium silt downcore. Shear strength measurements were not obtained for this site due to disturbance caused by sampling for radioisotopes, which did not leave sufficient material for the penetrometer or the mini-torvane to produce accurate measurements in the 2” diameter core sleeve.

3.5.4.3 Radioisotope Analysis

Radioisotope analysis at Site 15488 indicates a post-disturbance linear accumulation rate (LAR) of 0.06 cm/yr. Based on the sampling interval, a disturbance occurred 45 to 63 years prior to the 2010 core collection. No sharp downcore differences in porosity or grain size are observed in the pre-disturbance zone; hence, the overall absence of downcore decay in Pb activity cannot be ascribed to changing coarse fraction percentage. The most likely scenario is that the seafloor event disturbed (mixed) *in situ* sediments.

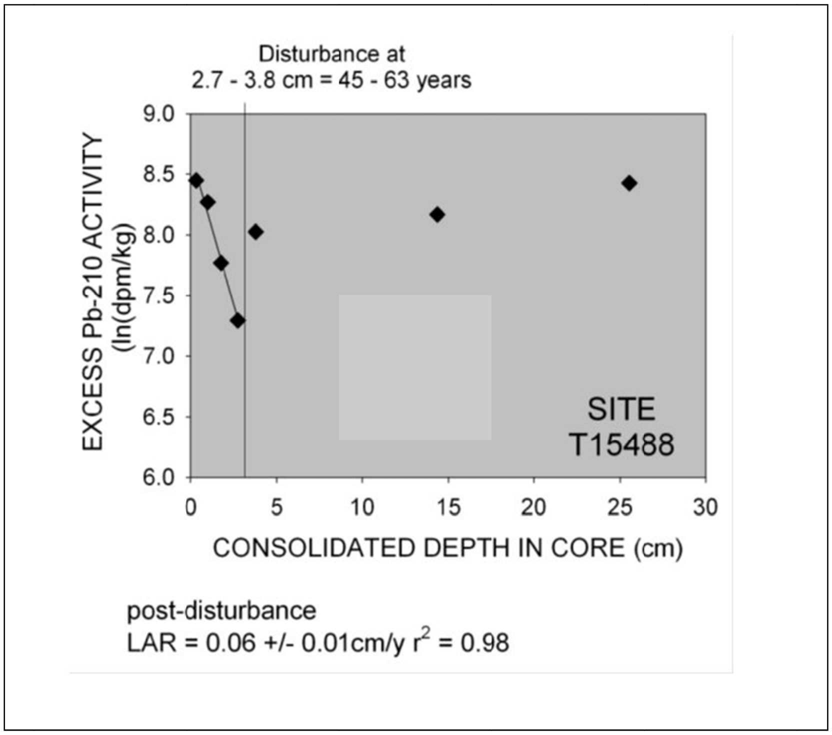


Figure 3.5.8. Downcore ^{210}Pbxs activity and linear sediment accumulation rate (LAR) calculations for Site T15488.

3.5.4.4 Oceanographic Analysis

The potential impact of hurricanes on seafloor scour is suggested by oceanographic modeling conducted at three datum sites in the GOM as a proxy for seafloor conditions at the current shipwreck site (Rego et al. 2011). Datum 2 simulated hurricane impacts at a site in 15.5 m of water, similar to the conditions found at Site 15488. Datum 2 and Site 15488 are located between the eyes of Hurricanes Rita and Ike; Site 15488 and Datum 2 were east of the eye of Hurricane Ike, which passed this area as a category 2 storm, and west of Rita, which passed as a category 3 hurricane (NOAA NHC; Appendix F; Maps F-1 & F-2). Sediment samples from Datum 2 were analyzed as part of a separate study and indicate that the surficial seafloor consists of coarse, medium, and very fine silt, with small amounts of very fine sand. Although grain sizes were measured for Site 15488, bulk density and plasticity were not. The degree of sediment consolidation and potential for mud fluidization are therefore unknown and scour estimates are based solely on flow conditions (Rego et al. 2011). Scour estimates were generated for both loose and consolidated bed scenarios for each of the modeled hurricanes. In all cases, maximum hurricane-induced scour was followed by re-deposition of sediments, resulting in smaller net scour estimates. Ike-related scour modeled at Datum 2 resulted in maximum scour of between 1.0 m (loose) and 0.2 cm (consolidated); net scour ranged from 30 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011). Less scour was calculated during Rita, with a maximum of 84 cm (loose) and a net scour of 10 cm (loose); under the consolidated bed scenario there was little to no net scour resulting from Rita. Results may vary slightly at Site 15488, but should be comparable.

3.6 Site No. 15366, Galveston Area, Unknown Modern Wreck

3.6.1 Site Background

Site 15366 is centered on the east Texas inner continental shelf SSE of the mouth of Galveston Bay. The wreck is located in an Anchorage area associated with the safety fairway out of Galveston Bay. A reported "Dumping ground, discontinued" is located SE of the site (Mississippi River to Galveston, C.&G.S. Coastal Chart #12116A. 1971; Saltus and El Darragi 2005).

The site was identified by a geophysical lease survey performed by Cochrane Technologies, Inc., in March, April, and May of 2004. The survey used a 50-m by 900-m survey grid with the primary survey lines oriented north-south. The geophysical data analysis and resulting report were prepared by Marine Archaeologist, Allen R. Saltus, Jr. and Marine Geophysicist, S. Dean El Darragi (Saltus and El Darragi 2005). The report reads, "A shipwreck was captured on the sonar image . . . . The sonar feature, Side Scan Contact No. 3, was also covered by two additional survey lines, Lines 105 and 106, and provided additional data and verification of the target location. The vessel measures 66 ft long and 13 ft wide. This sonar feature is associated with a magnetic anomaly." In addition to the shipwreck, the Cochrane report identified Side Scan Contact No. 1, approximately 389 m (1,275 ft) SW of the wreck. Sonar target No. 1 measured 4.88 by 0.6 m (16 x 2 ft) and was associated with four magnetic anomalies, the largest of which was an 8,327 nT dipole with a duration of 63 m (207 ft).

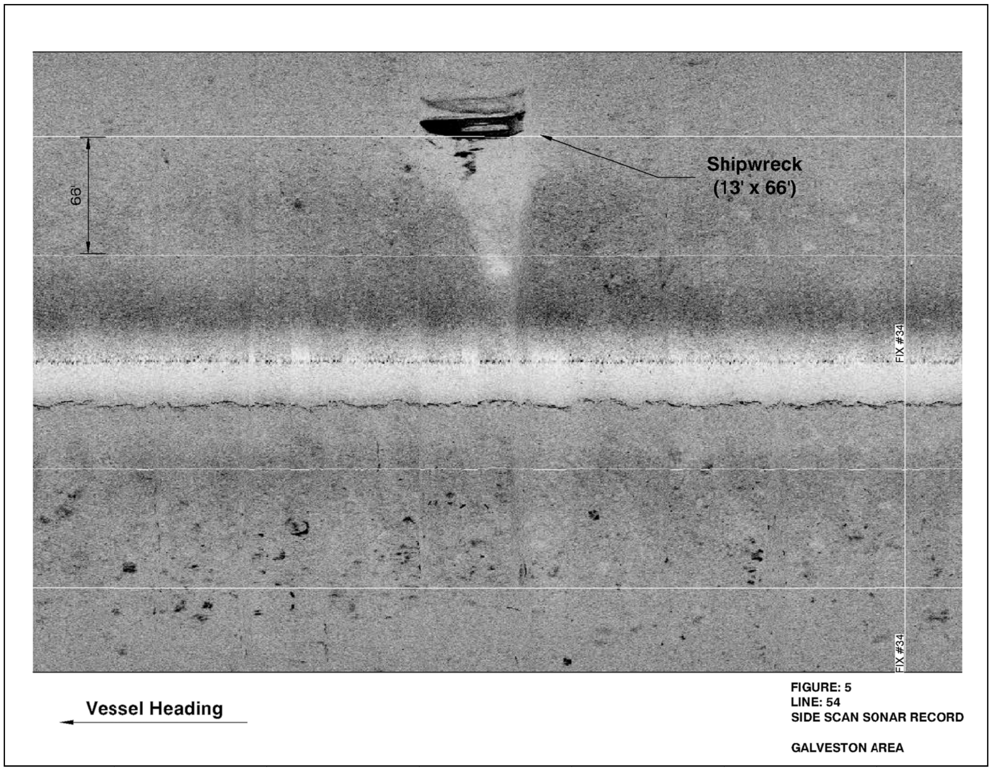


Figure 3.6.1. Cochrane sonar image of Site 15366.

An earlier study had been conducted over this area in 1985 by John E. Chance and Associates (Floyd and Savarino 1985). The report prepared by Marine Archaeologist Robert J. Floyd, and Geophysicist Mark Savarino, indicates that no sonar targets, debris, or shipwrecks were identified on the sonar data. The fact that the wreck was not observed in the 1985 survey may indicate that the shipwreck is modern and would provide a *terminus post quem* of 1985 and a *terminus ante quem* of 2004. It is also possible that the shipwreck pre-dates 1985 and was simply not identified during the Chance geophysical survey. There is limited discussion of the sonar data in the Chance report. Appendix B of the report indicates that the sonar "scale" was 100 m. It is assumed that this refers to the range setting of the sonar. No sonar data sample was included and no other indication of the sonar range setting is mentioned in the report.

Based on the Chance navigation post-plots, it was determined that the survey line spacing interval was 150 m. If the range had been set at 100 m, this would have provided 100% seafloor coverage, but limited redundant coverage and no coverage beneath the nadir of the sonar tow-fish. Given these parameters, it is not difficult to imagine that a small shipwreck may have been missed beneath the nadir of the tow-fish, or not identified on the sonar due to noise or attenuation of the sonar signal. Coordinates for the wreck supplied by Cochrane were used to plot the location of the wreck, which is in close proximity to a Chance survey line. Since the wreck appears to be oriented north-south, which is the same orientation as the Chance survey lines, this further supports the possibility that the wreck could have been missed beneath the nadir of the sonar.

The Chance survey did not identify any magnetic anomalies on the survey line that crosses almost directly over the shipwreck. A small magnetic anomaly was identified on the adjacent survey line; however, the characteristics of the anomaly and the fact that the survey line lies nearly 150 m (492 ft) east of the wreck, suggest that it is unlikely that these are related.

Although in 2004 Cochrane identified four anomalies associated with the shipwreck, none was identified more than 120 m (~400 ft) from the wreck site. Figure 3.6.2 shows the Chance and Cochrane survey lines in relation to the shipwreck and associated magnetic anomalies.

The 1985 Chance survey identified a magnetic anomaly in close association with the two anomalies (247 and 248) identified from the Cochrane survey but no evidence of Side Scan Contact No. 1 was apparently identified on their sonar data.

The Chance survey used a Geometrics 801/03 proton procession marine magnetometer. The type of magnetometer used during the Cochrane survey is unknown (the full survey report was not made available for review). The lack of significant magnetic anomalies on Chance's closest survey line cannot be attributed to differences in sensor technology; however, it is possible that the magnetometer was malfunctioning, incorrectly recorded, or incorrectly interpreted. Although the fact that the shipwreck had not been identified in 1985 by either sonar or magnetometer data supports a deposition date post-1985, there is still a remote possibility that the wreck was simply not identified due to faulty data acquisition. There is also a slight possibility that the wrecking event pre-dates 1985, but post-depositional processes introduced the wreck to its present location sometime after 1985.

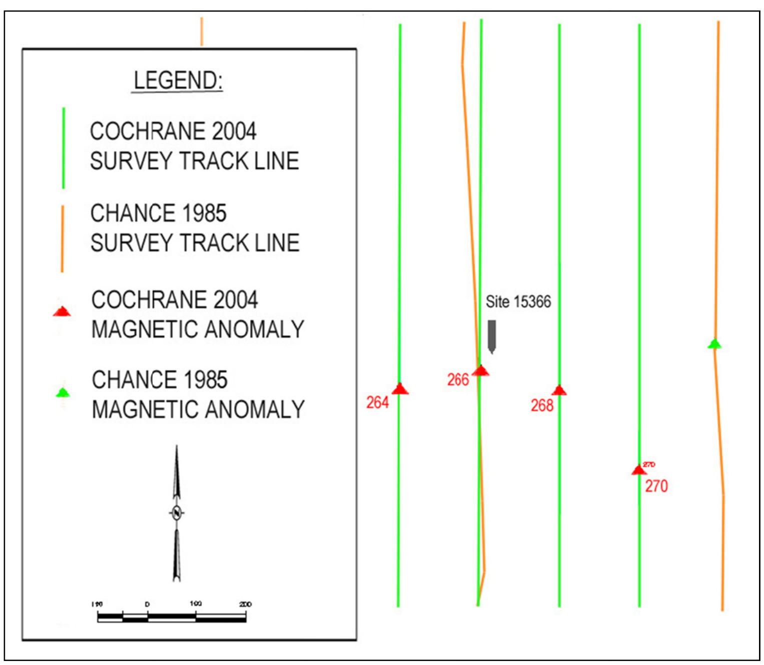


Figure 3.6.2. Map showing Chance and Cochrane survey lines and magnetic anomalies in relation to reported shipwreck coordinates.

A minimal amount of infrastructure reportedly exists in the vicinity of Site 15366. An 8” active pipeline is reportedly located approximately 780 m (2,560 ft) west of the shipwreck and a P&A Well is located approximately 670 m (2,200 ft) to the SW.

3.6.2 Geophysical

Geophysical data acquisition was conducted at Site 15366 on March 20, 2010 and on August 17, 18, and 19, 2010, aboard the M/V *Nikola*. A CODA 3-D Echoscope was used during the March operations, but weather conditions negated the ability to acquire suitable data with the remaining sensors at this time. Side scan sonar, sub-bottom profiler, magnetometer, multibeam, and single beam bathymetry were acquired at the site during the August field operations (see Chapter 2 Methodology and Appendix A for a full description of geophysical sensor suite and navigation parameters).

The survey grid extended out in a 300-m (1,000-ft) radius centered on the wreck site. Two separate survey grids were run over the site, both containing survey lines paralleling the wreck site. A total of 12 survey lines was run using 100 kHz sonar data and spaced 100 and 200 m apart for reconnaissance and to maximize sonar coverage. A total of 23 survey lines was run directly over the wreck site using 410 kHz sonar frequency and spaced 30 m apart for increased sonar resolution, multibeam coverage, sub-bottom profiling, and magnetic contouring (see Navigation Post-Plot Map Appendix B; Figure B-6). An additional two survey lines were run over the reported location of Cochrane’s Sonar Contact No. 1.

The seafloor throughout the survey area is a constant 18 m (59 ft). The only identifiable bathymetric irregularities can be directly attributed to the wreck site (Figure 3.6.3). A scour zone surrounds the wreck site, with a significant expression extending SW of the site. Water depths within the deepest portion of scour, just SW of the wreck, reach a maximum of 18.8 m (62 ft). The multibeam illustrates that the wreck is upside down with the bow facing almost directly south. The wreck sits approximately 1.8–3.4 m (6–11 ft) above the surrounding seafloor.

Sonar data indicates that the wreck is oriented along a 180-degree axis, with the bow directly to the south. The 100-kHz survey grid clearly imaged the wreck site in its entirety, but did not have sufficient resolution to detail specific components of the vessel or changes in seafloor texture. The 410-kHz survey grid clearly outlined the wreck and provided details of some seafloor mottling and possible scour zones surrounding the wreck. Debris associated with the wreck site is identified off of the eastern side, just fore of midships. Trawl scars were also observed on the seafloor within the survey grid. Figure 3.6.4 shows a sonar mosaic that was created using the low frequency and high frequency sonar lines that run parallel to the wreck site. An inset shows a composite image of the wreck. Sonar data did not produce high quality imagery over the wreck site, likely due to the relatively small size of the site and the difficulty in acoustic imaging of the wreck due to the angle of the vessel’s hull. Lines 201 and 202 were run in an attempt to investigate a reported sonar target and associated magnetic anomalies located SW of the shipwreck but did not result in an identified source of the target or anomalies.

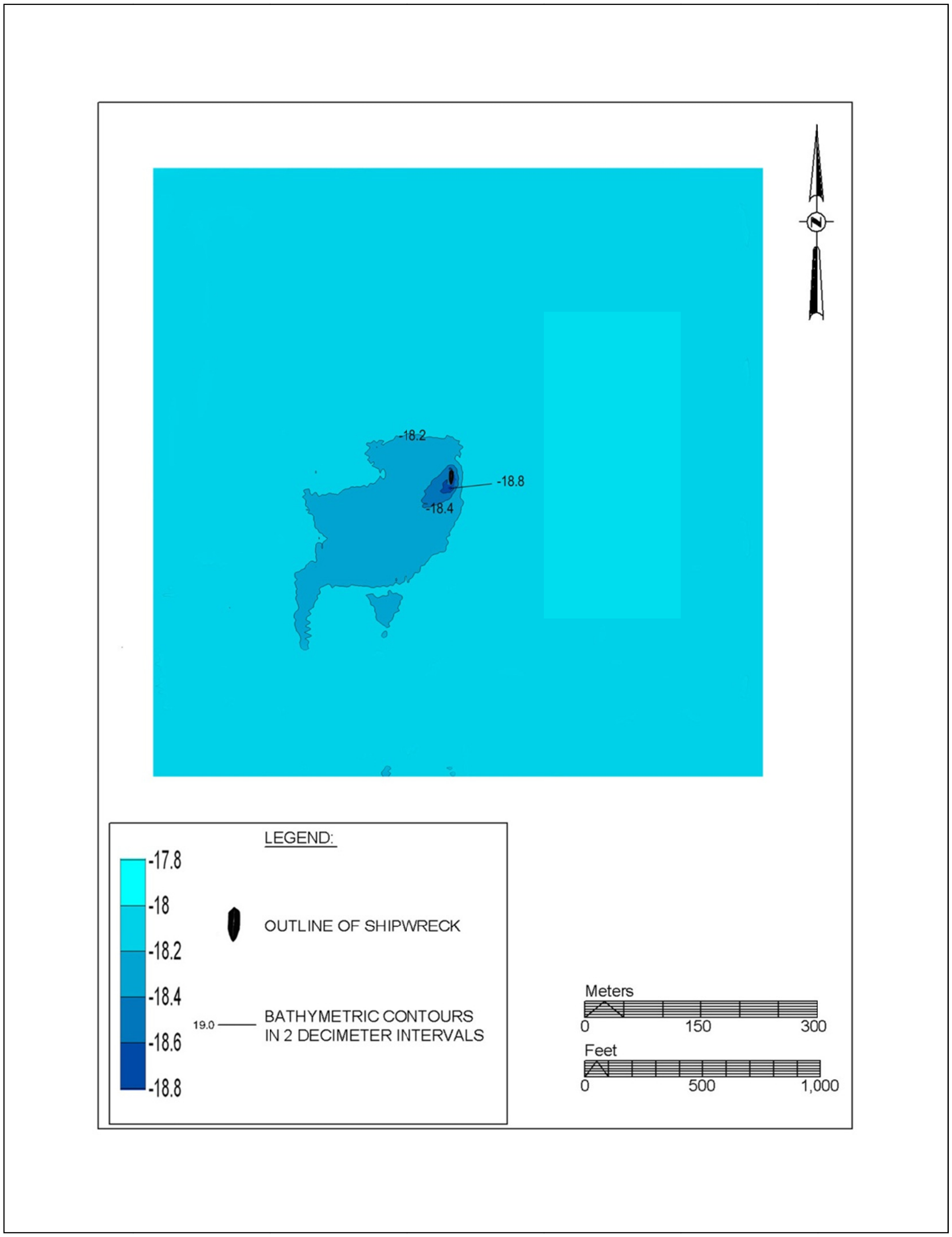


Figure 3.6.3. Bathymetry surrounding site 15366, in 2-decimeter intervals.

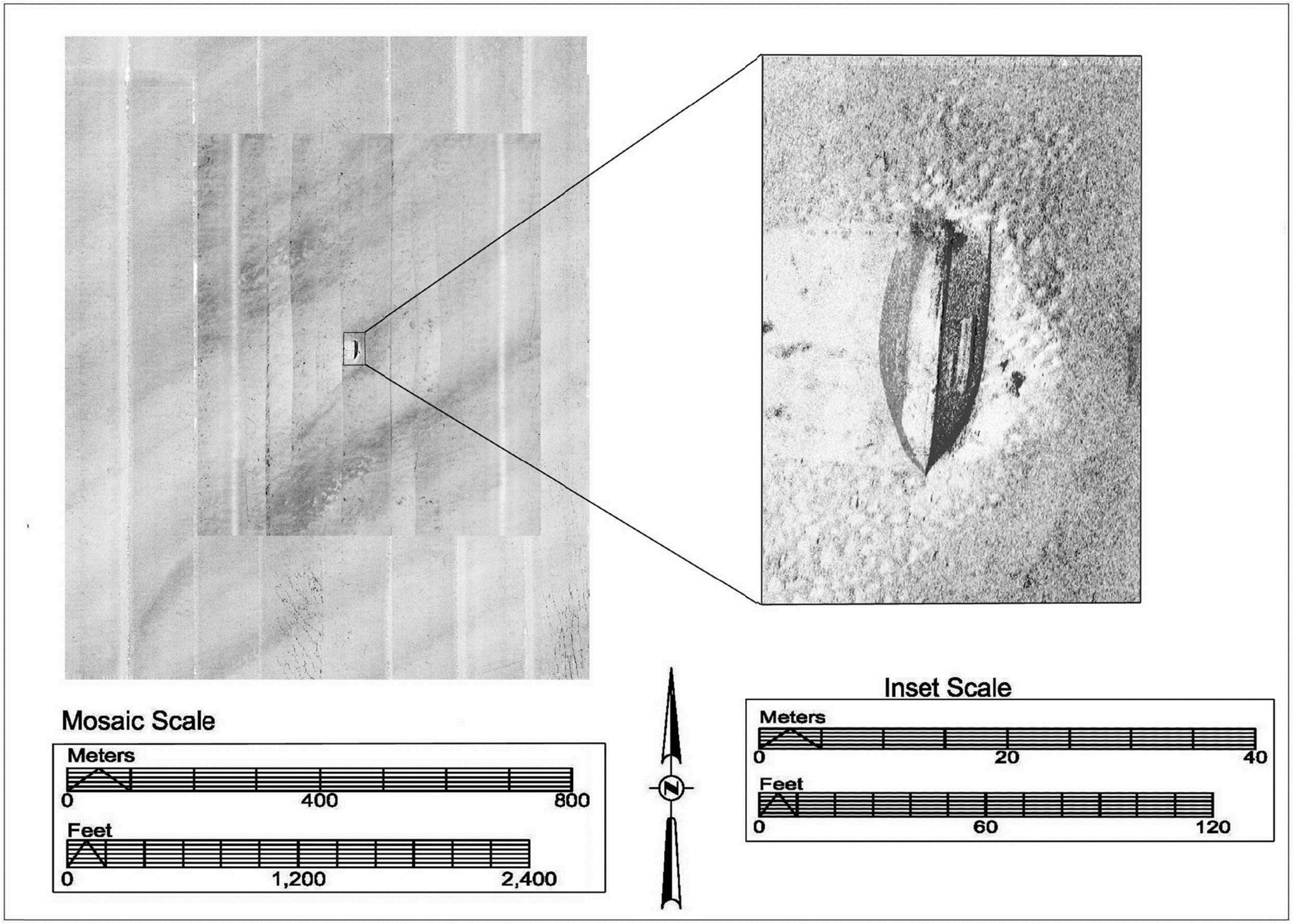


Figure 3.6.4. 120 and 410 kHz side scan sonar mosaic of Site 15366. Inset shows a composite image of the wreck site produced from 410 kHz data.

In addition to the multibeam and side scan sonar data, the CODA 3-D Echoscope was employed at this site during the March operations. The resulting imagery correlated with the other acoustic sensors and provided additional imagery of the vessel's running gear (Figure 3.6.5).

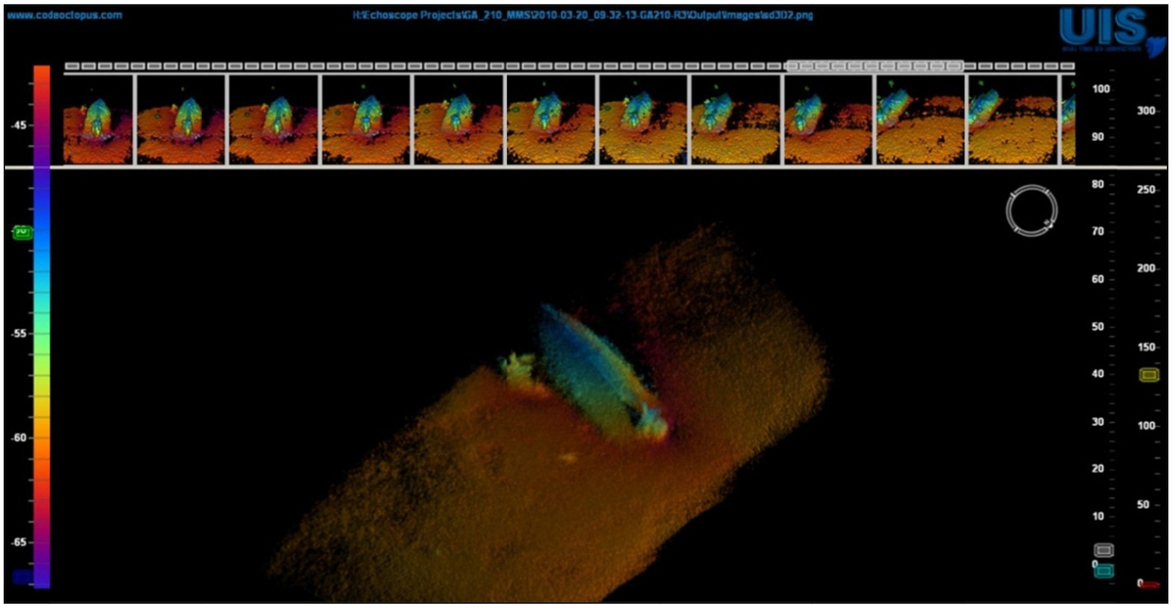


Figure 3.6.5. Echoscope still image of Site 15366, from CODA UIS software.

The combined sonar, multibeam, and echoscope data demonstrate that the shipwreck is upside down on the seafloor. The wreck site measures approximately 23.5 m (77 ft) to what appears to be the stern of the vessel, and 24.7 m (81 ft) to the end of the propeller. Measured width is approximately 7 m (23 ft). The stern of the wreck appears to be partially buried, although an unusually large running gear assemblage appears to be present.

Sub-bottom profiler data penetrated to an average depth of 14.4 m (47 ft) before data was attenuated by an irregular gas front. Surficial sediments are approximately 3 m (10 ft) thick and are moderately to highly reflective, and represent generally acoustically amorphous deposits with some internal stratification. This unit is followed by a zone of poorly resolved, unstratified deposits approximately 3.7 m (12 ft) thick. This zone in turn overlies approximately 7.6 m (25 ft) of poorly resolved, weakly to moderately reflective, parallel layered strata. Scour zones surrounding the wreck site were broad and shallow and do not extend very far from the vessel. Some minor infill may be present within the closest zones. The following figure shows a stratigraphic profile (Survey Line 305) close to the wreck site where the typical scour sequence is evident (Figure 3.6.6).

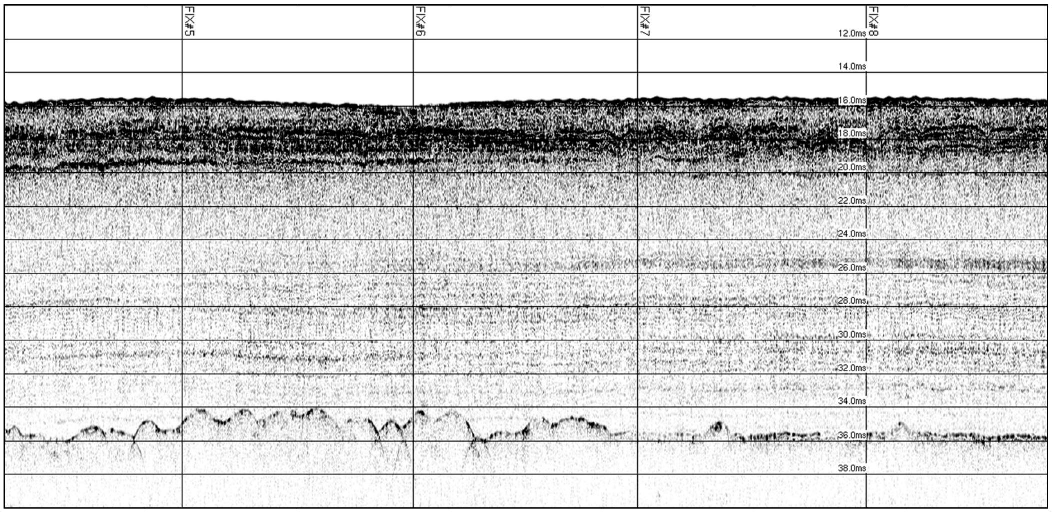


Figure 3.6.6. Sub-bottom profile of survey Line 305, Site 15366. Line 305 is located west of the wreck site, with a heading of 360 degrees. Vertical scale lines in 150-m increments. Horizontal scale lines in 2-ms intervals.

Magnetometer data very clearly highlighted the wreck site (Figure 3.6.7). The largest magnetic anomalies attributed to the wreck measured between 2,687 and 28,115 nT with durations between 145.4 m and 196 m (477–642 ft). Only six anomalies were recorded that did not directly correlate to the wreck. Most of these anomalies were relatively small and isolated. Lines 201 and 202 were run in an attempt to investigate a reported sonar target and associated magnetic anomalies located SW of the shipwreck. No magnetic anomalies were identified on either of these lines; however, Anomaly no. 4 was identified at the beginning of Line 101 approximately 30 m (98 ft) north of Line 202. Anomaly no. 4 from the 2010 data falls in between Anomaly nos. 247 and 248, which were identified from the 2004 Cochrane survey, and is an estimated 30 m (98 ft) NW of an anomaly identified from the 1985 Chance survey. Anomaly no. 4 from the 2010 data was a 243 nT negative monopole with a duration of 48 m (158 ft). This was the most significant anomaly identified in the survey grid not directly attributed to the shipwreck. As discussed in the previous sonar text, no targets were identified in association with this anomaly, and Sonar Target No. 1 from the Cochrane survey was not re-located.

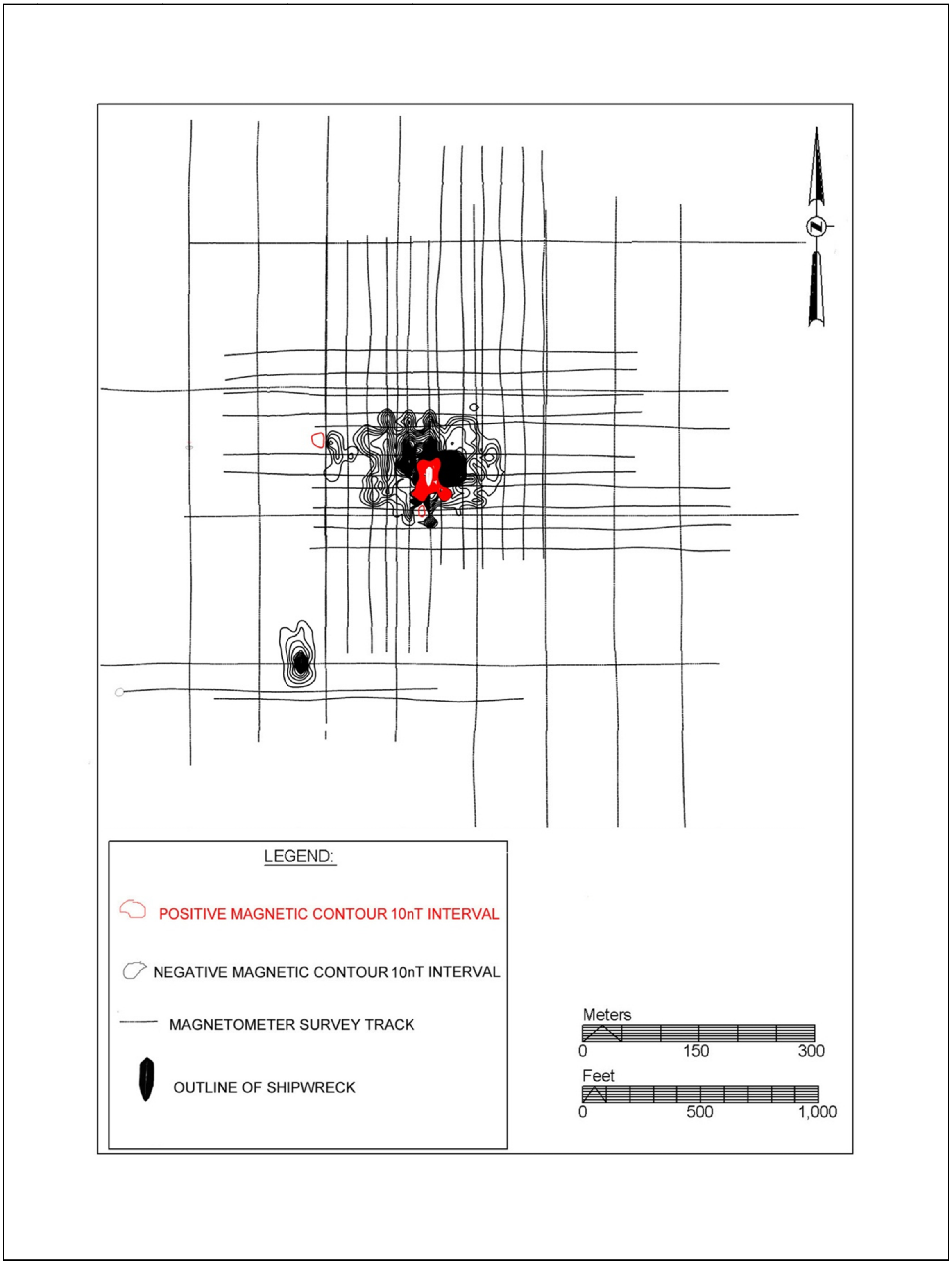


Figure 3.6.7. Magnetic contours in 10-nT intervals at Site 15366.

3.6.3 Diving

Diving operations on Site 15366 took place on August 22 and 23, 2010, from the M/V *Spree*.

- Average recorded water depth on site: 18.25 m (60 ft).
- Total bottom time: 6 hours. Average dive time: 22.5 minutes.
- Visibility: 0–0.3 m (0–1 ft).

The Mesotech Sector Scanning Sonar was deployed before diving operations to verify the wreck location and provide supplemental imagery. The sector scans detailed the mottled seafloor and the stern of the vessel (3.6.8). The rudder is evident, protruding from the stern of the vessel, as is what appears to be a shrouded propeller.

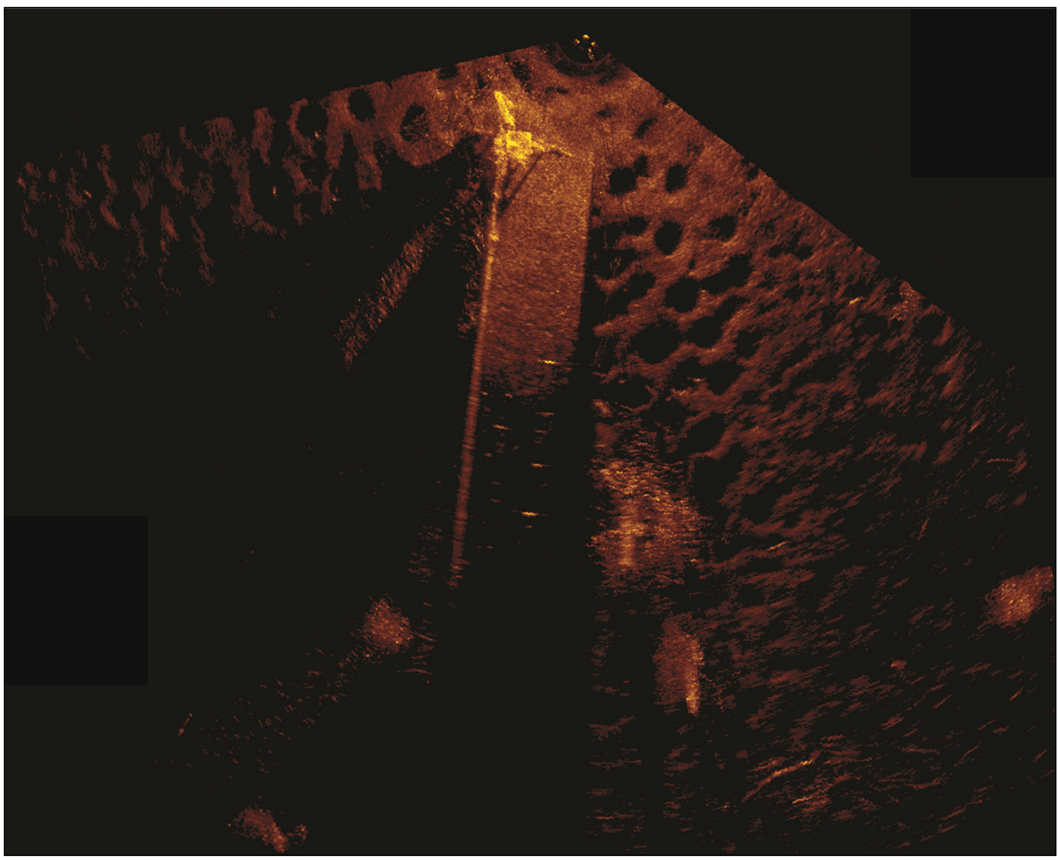


Figure 3.6.8. Mesotech scan highlighting the stern at Site 15366. Oriented north up.

This site was verified by divers as a metal-hulled wreck lying upside down on the seafloor oriented with its bow facing south. The single four-bladed propeller is shrouded within a nozzle. Immediately aft of the nozzle and propeller assembly divers noted a single metal rudder. A keel runs most of the length of the hull and extends across the nozzle to the rudder. The keel measures 47 cm tall, 16 cm wide at its base and 3 cm wide along its length, and is shaped similar to an "I-beam." Longitudinal protrusions, likely for engine cooling, run along the length of the hull

(Figure 3.6.9). The vessel exhibits black bottom paint preserved under a layer of marine growth, and divers discovered distinctive marks of two diagonal white stripes on the port bow.

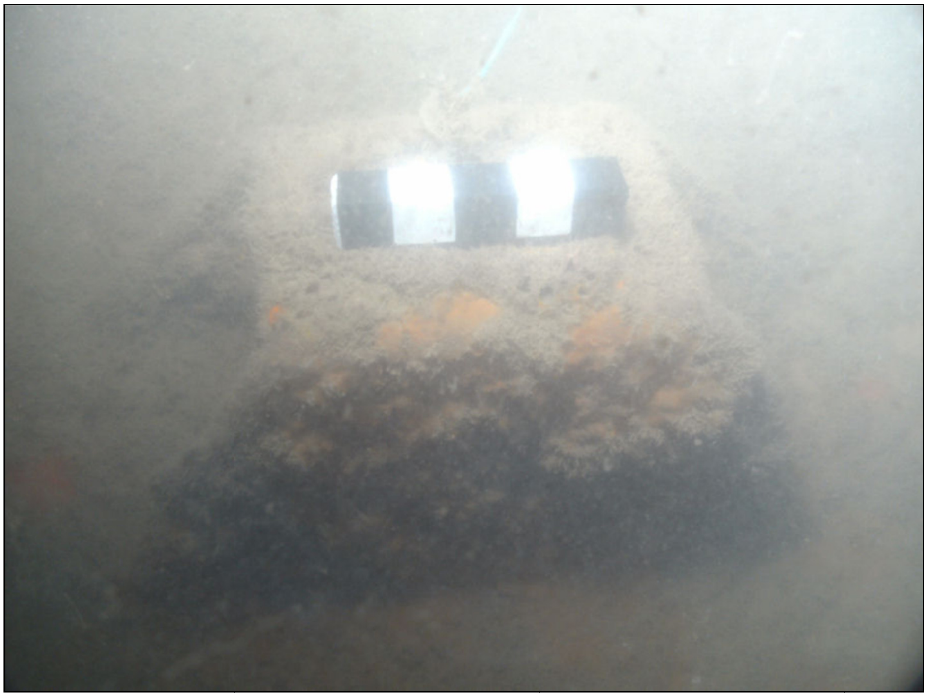


Figure 3.6.9. Longitudinal protrusion on hull of site 15366. 10 cm scale in 2 cm intervals.

3.6.4 Site Environment

3.6.4.1 Water Sampling

Two 8-ounce water samples were collected from Site 15366 on August 23, 2010, at a depth of 18 m (59 ft) BSL. Water temperature at the time of acquisition was 88° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.8). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.8

Water Sample Results for Site 15366

Type	Sample	Average
Salinity (ppT)	1	33.2
Salinity (ppT)	2	33.1
pH	1	8.097
pH	2	8.16
DO (mg/L)	1	7.455
DO (mg/L)	2	7.48

3.6.4.2 Core Lithology and Grain Size

Two cores were attempted at Site 15366. On August 22, 2010, the first core was attempted approximately 8 m (25 ft) from the wreck site, directly below the descent line; however, divers encountered well-consolidated sediments that offered significant resistance to coring. Less than 5 cm (2 in) were captured in the core barrel. A second core was attempted on August 23, 2010 approximately 1.8 m (5 ft 9 in) off of the wreck site. Core no. 2 resulted in a 52 cm stratigraphic sample of sediments at the wreck site.

Samples were collected from each of five units observed within the core lithology from Core no. 2 and measured for grain size. Median and graphic mean calculations demonstrate gradual fining downcore from samples 1 through 3; sample 4 is a coarser fraction and represents a possible disturbance event or storm deposit layer. Shear strength measurements were not obtained for this site, due to disturbance from sampling for radioisotopes, which did not leave sufficient material for the penetrometer or the mini-torvane to measure in the 2” diameter core sleeve.

3.6.4.3 Radioisotope Analysis

Site 15366 shows a post-disturbance linear accumulation rate (LAR) of 0.15 cm/yr, overlying a disturbance event noted downcore between 3.5 and 12.7 cm. Based on the sampling interval, it was determined that the disturbance, which could have resulted from an extreme storm event or ground disturbing activity such as the wrecking event, occurred 23–85 years before the 2010 core collection. Pre-disturbance sediments show variable activity downcore. If the low activity outlier at 38 cm depth (Fig. 3.6.6) is the result of a coarse-grained interval it could be classified as ignored decay, and the remaining points would indicate a very high LAR (>1 cm/y). This would suggest a significant decrease in accumulation post-dating the disturbance event.

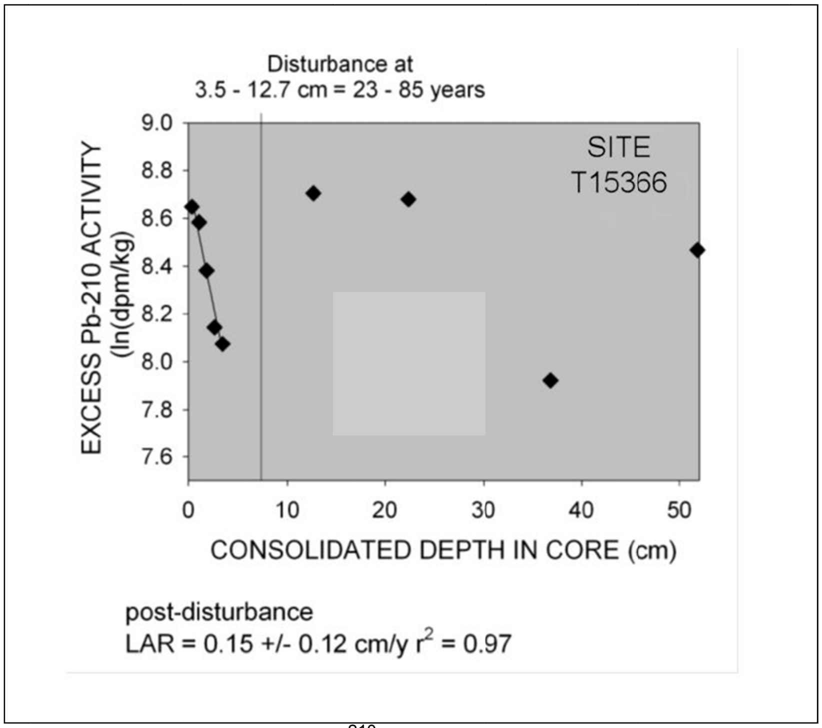


Figure 3.6.10. Downcore ^{210}Pbxs activity and linear sediment accumulation rate (LAR) calculations for Site T15366.

3.6.4.4 Oceanographic Analysis

The potential impact of hurricanes on seafloor scour is suggested by oceanographic modeling conducted at three datum sites in the GOM as a proxy for seafloor conditions at the current shipwreck site (Rego et al. 2011). Datum 2 simulated hurricane impacts at a site in 15.5 m of water with cohesive-clay dominated sediments, similar to the conditions found at Site 15366. Datum 2 is located between the eyes of Hurricanes Rita and Ike, both of which passed as category 2 storms; datum 2 was closer to the eye of Hurricane Ike. Site 15366 was located almost directly under the eye of Hurricane Ike, which was a Category 2 hurricane when it passed over the site (NHC NOAA).

Based on a separate study, grain sizes at Datum 2 include coarse, medium, and very fine silt, and small amounts of very fine sand. Although grain sizes were measured for Site 15366, bulk density and plasticity were not. The degree of sediment consolidation and potential for mud fluidization are therefore unknown and scour estimates are based solely on flow conditions (Rego et al. 2011). Scour estimates were generated for both loose and consolidated bed scenarios for each of the modeled hurricanes. In all cases, maximum hurricane-induced scour was followed by re-deposition of sediments, resulting in smaller net scour estimates. Ike-related scour modeled at Datum 2 resulted in maximum scour of between 1.0 m (loose) and 0.2 cm (consolidated); net scour ranged from 30 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011). Less scour was calculated for Rita, with a maximum of 84 cm (loose) and a net scour of 10 cm (loose); under the consolidated bed scenario, there was little to no net scour resulting from Rita. Results likely vary at Site 15366, but should be comparable.

3.7 SITE NO. 389, SOUTH TIMBALIER AREA, PROBABLE *J.A. BISSO*

3.7.1. Site Background

Site number 389 is located in the South Timbalier Federal Lease Area south of Timbalier Island, in Terrebonne Parish, Louisiana. This wreck was not one of the six original contract sites, but it was added to the contract as an amendment during diving operations in August 2010.

Site 389 was originally discovered during a pipeline pre-lay survey performed by Oceaneering International, Inc., for Transcontinental Gas Pipe Line Company in 1991 (Marmaduke 1991; Figure 3.7.1). Only the archaeological section of the report was available for review and no maps or tables of sonar or magnetic anomalies were enclosed. The archaeological assessment was prepared by William Marmaduke of Northland Research, Inc. Latitude-longitude coordinates were provided for the shipwreck in the text of the archaeological assessment. The reported coordinates plot approximately 1,585 ft west of Site 389 as identified in this study. According to the text of the report, all coordinates were acquired in State Plane, Louisiana South. It is possible that the coordinate was converted improperly or mistyped when converting to latitude/longitude which could account for the discrepancy along the x axis only.

Marmaduke describes the target as:

> . . . side-scan sonar depicts an elongated, lozenge-shaped object on the sea floor . . . , measuring 29 meters (95 ft) long and 7.6 meters (25 ft) wide." . . . "The wreck appears to consist of a hull and central superstructure, the whole wreck possible [sic] canted to one side. Its side-scan image suggests that it is largely intact on the sea floor, and the magnetometer recorded only single anomalies on the lines that passed close enough to the wreck for detection. The sizes and durations of these anomalies suggest steel construction. A dark, amorphous, smaller image is visible on the side-scan records just beyond the far end of the main image, partially obscured by the acoustic shadow cast by the superstructure. This may represent a piece of attached hull. (Marmaduke 1991:8–9)

According to historical records, the closest wreck to the area was reportedly the towing vessel *J.E. Bisso*[1]. Marmaduke (1991) stated, "The overall length and width of the object imaged on side-scan sonar is appropriate for this type of vessel, although there is no precise data on the *J.E. Bisso* itself available for examination at this time." Based on correspondence exchanged between Marmaduke and MMS Archaeologist Rik Anuskiewicz, it appears that there was, at one time, some speculation that the wreck might be *U-166*, a German U-boat lost in 1942. The BOEM shipwreck database reads, in part, "The German sub, *U-166* once thought to have sunk in the vicinity in WWII and Northland report suggests object may be sub. In April, 2001 remains of U-166 [were] located in Mississippi Canyon Area, so this object can not [sic] be that sub." The

1 It appears that "*J.A. Bisso*" was misspelled as "*J.E. Bisso"* in the NIMA database and, at one time, in the MMS database. MVUS records clearly use "*J.A. Bisso"* for the wreck that reportedly sank nearby.

Northland report clearly states, however, that the vessel is too short to be *U-166* and attributed the identification of *J.E. Bisso* to the wreck, stating, "Except for the Wreck of the *J.E. Bisso*, the data does not suggest the presence of a shipwreck." and "Northland recommends that Transco avoid the position of the [sic] *J.E. Bisso* by at least 300 meters (984 ft) in all its construction activities."

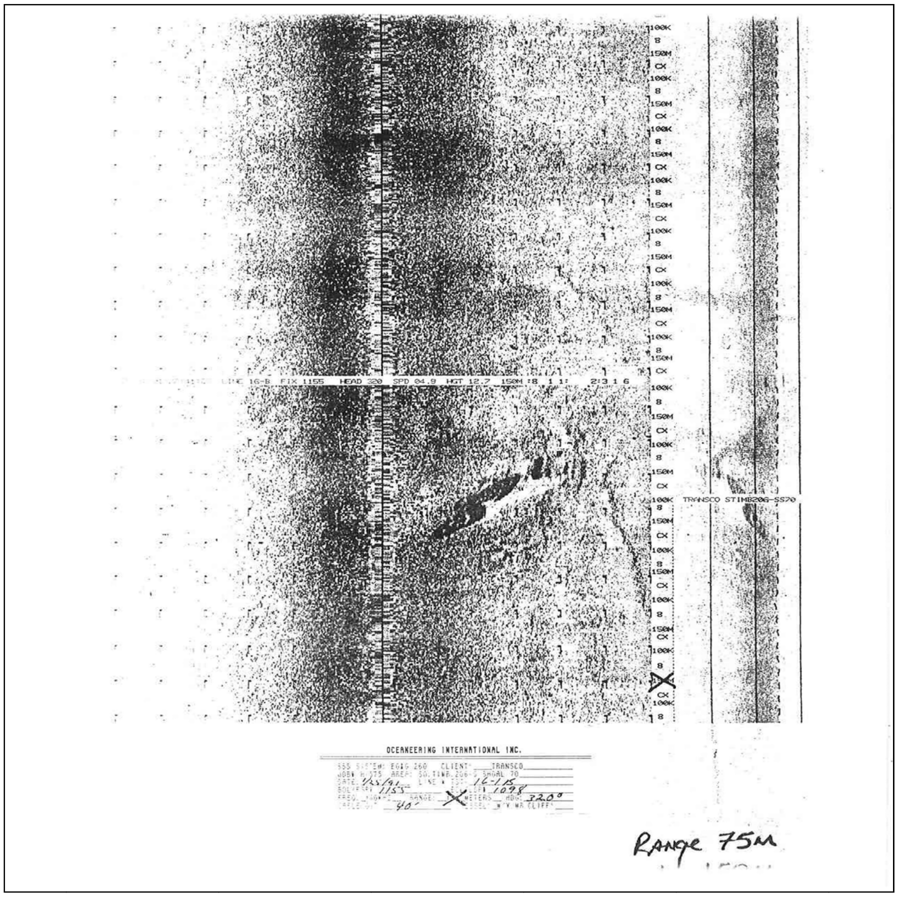


Figure 3.7.1. 100 kHz side scan sonar image set at 75-m range. Direction 320° NNW (Marmaduke 1991).

Before the 1991 survey, in 1981 Racal-Decca Survey, Inc., conducted a survey over the entire lease on behalf of CNG Producing Company. The resulting report was prepared by Marine Survey Archaeologist Jack Hudson of Cultural Resource Services, Inc. and Geophysicist Thomas Neurauter then of Racal-Decca Survey, Inc. (Hudson and Neurauter 1981). No shipwreck was identified, but an unidentified sonar target and two associated magnetic anomalies were identified that correspond with the verified position of Site 389. The two magnetic anomalies were 200 and 365 nT, respectively. No information on anomaly duration, signature, or tow-fish height was provided. Neither the original data nor an image of the target was available for review. The archaeological analysis section written by Hudson states, "A distinct but unidentified target appears . . . in association with the large magnetic anomalies at the same location." The conclusions section of the report implies that the target and associated magnetic anomalies may be caused by an unknown oil and gas well. It also states, "However, it would be advisable to avoid the immediate vicinities of these locations unless or until they can be shown to be other than cultural resource features." It appears certain that this target and the associated magnetic anomalies represented the same shipwreck as Site 389 but poor data quality precluded the ability to correctly identify it.

In August 2001, as part of an MMS-funded study, Pearson et al. (2003:5.18-5.19) attempted to investigate Site 389. They surveyed a 518 m by 300 m (1,700 by 1,000 ft) grid centered 27 m (90 ft) from the coordinates provided in the 1991 survey report. As discussed above, the coordinates from the 1991 report plot approximately 483 m (1,585 ft) from the present location of Site 389; therefore, the survey grid used by Pearson et al. was not centered over the wreck site, and was unable to relocate the target.

In 2005, Tesla Offshore, LLC, conducted a geophysical survey for Millennium Offshore Group, Inc., and identified a shipwreck at the current location for Site 389 (Floyd and Clemmons 2005a and 2005b). The resulting reports (one site specific report (2005b) and one pipeline assessment (2005a)) prepared by Marine Archaeologist Robert J. Floyd and Marine Geologist Rick Clemmons indicated that the wreck measured 25.9 m (85 ft) by 9.1 m (30 ft) and protruded 3.1 m (10 ft) above the seafloor. The wreck was recommended for avoidance by 152.4 m (500 ft). The Tesla sonar imagery identified an ancillary object off the port side of the vessel (Figure 3.7.2).

An MMS-funded contract performed by PBS&J in 2007 acquired sonar imagery over Site 389 as one of three ancillary sites added to their contract while fieldwork was in progress. The PBS&J report indicates that the site was suspected to be the wreck of *J.A. Bisso* based on the MMS (now BOEM) database. PBS&J acquired sonar imagery of the wreck but did not dive on the site (Figure 3.7.3). The report focused only on the potential impacts of Hurricane Katrina to the wreck site, based on a comparison of the 2005 Tesla sonar imagery and the 2007 PBS&J imagery (Gearhart et al. 2011:129-130). No dimensions for the wreck are given in the PBS&J report, and no evidence of the ancillary object identified from the 2005 data was identified on the 2007 sonar imagery.

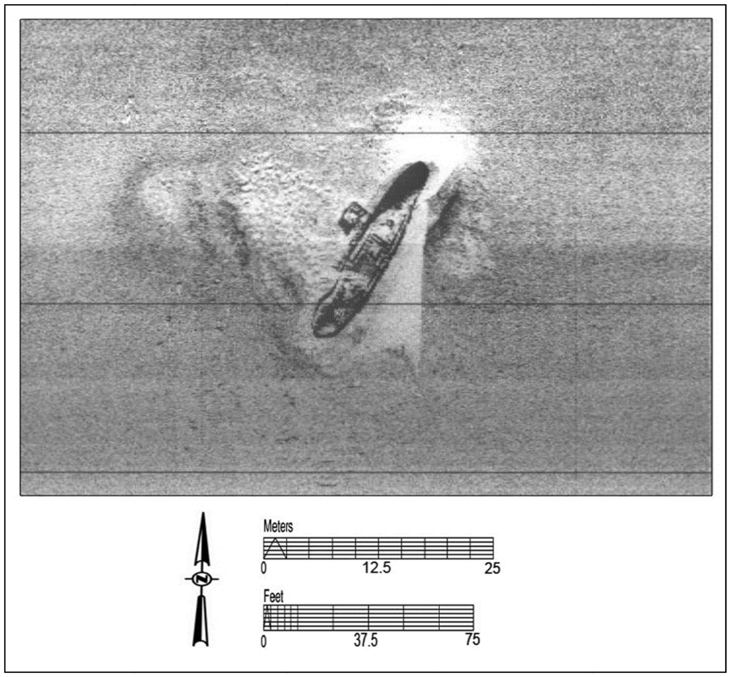


Figure 3.7.2. 410 kHz side scan sonar image set at 75-m range (Floyd and Clemmons 2005).

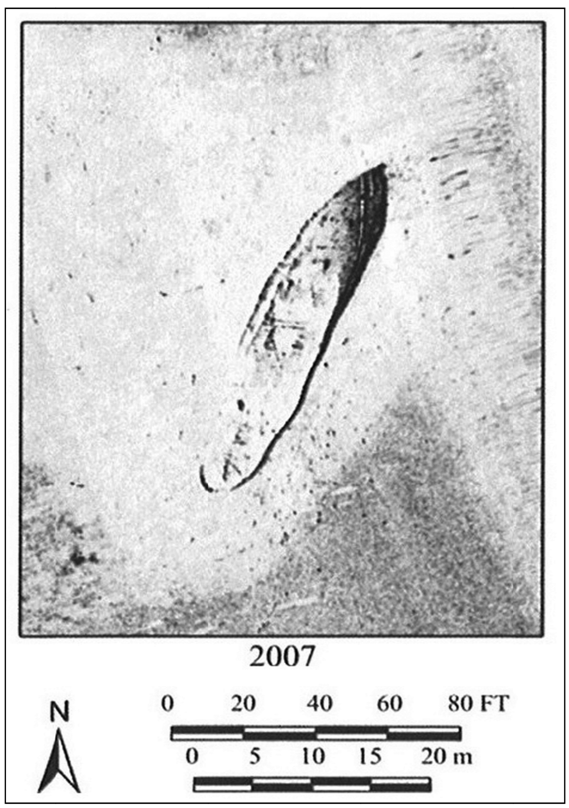


Figure 3.7.3. 500 kHz side scan sonar image set at 75-m range (Gearhart et al. 2011).

The closest oil and gas infrastructure to the shipwreck is a 6" abandoned pipeline located approximately 866 m (2,840 ft) north of the wreck. The No. 6 caisson and an associated 4" abandoned pipeline are located approximately 975 m (3,200 ft) to the NNE.

3.7.2 Diving

Site 389 was added to the scope of work for this study during diving operations performed in August of 2010. The M/V *Spree* arrived on site the evening of August 13, 2010 and the Mesotech was deployed to verify the site location and orientation (Figure 3.7.4).

Diving operations commenced the morning of August 14, 2010.

- Average recorded water depth on bottom: 18.3 m (60 ft).
- Total bottom time on site: 17.82 hours. Average dive time: 33.41 minutes.
- Visibility: 3–6 m (10–20 ft) on wreck, 0.3–1 m (1–3 ft) towards port stern, 0–0.5 m (0–1.5 ft) on seabed.

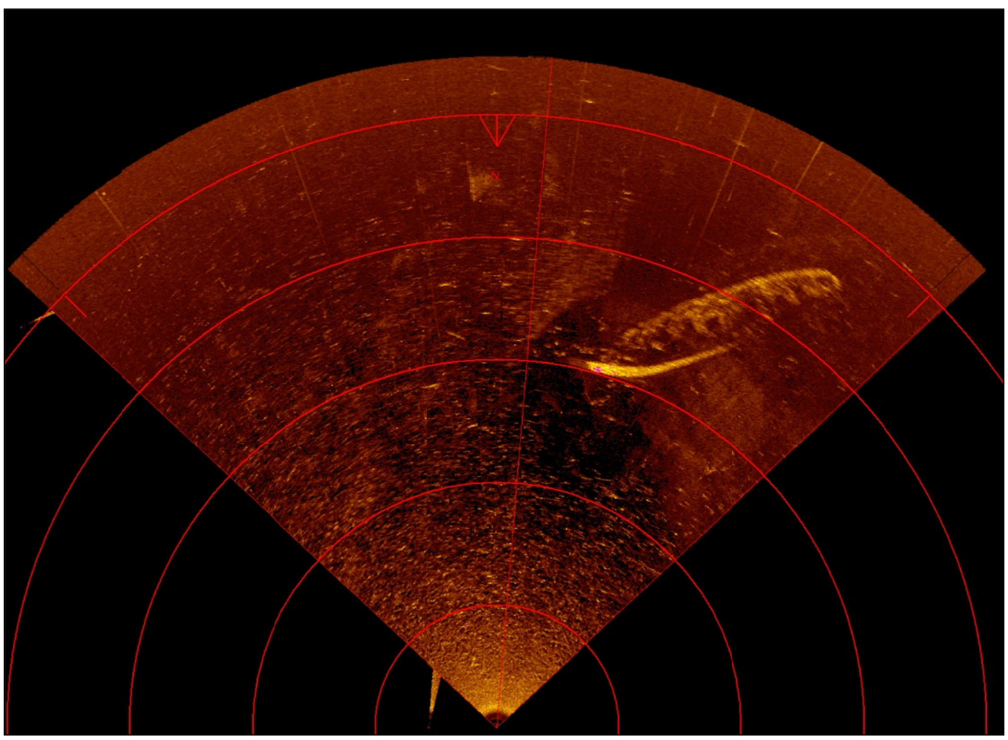


Figure 3.7.4. Sector scanning sonar image of Site 389.

Information gathered during diving operations indicated that the hull structure is well preserved, and many aspects of its hull are still in fairly good condition. Portions of the superstructure have deteriorated or collapsed, revealing interior structures and features, such as port holes and unidentified tanks in the stern of the vessel (Figure 3.7.5). A baseline was established running from bow to stern, and divers focused on gathering data in the form of measured drawings, video, and still images. Other significant diagnostic features that were recorded on this vessel included a double-headed, longitudinally-oriented bitt on the bow, two upright capstans (one on the bow and one offset to the port stern), the lower preserved remains of superstructure that allowed a reconstruction of cabin space, and a deck-mounted stern quadrant related to the vessel's steering system. Approximately 8 m (25 ft) of the aft port side of the vessel is buried under seafloor sediments. Archaeologists conducted extensive circle searches off of the port and starboard sides of the vessel, in an effort to identify additional superstructure identified from the 2005 geophysical data, but encountered no additional debris or structure.

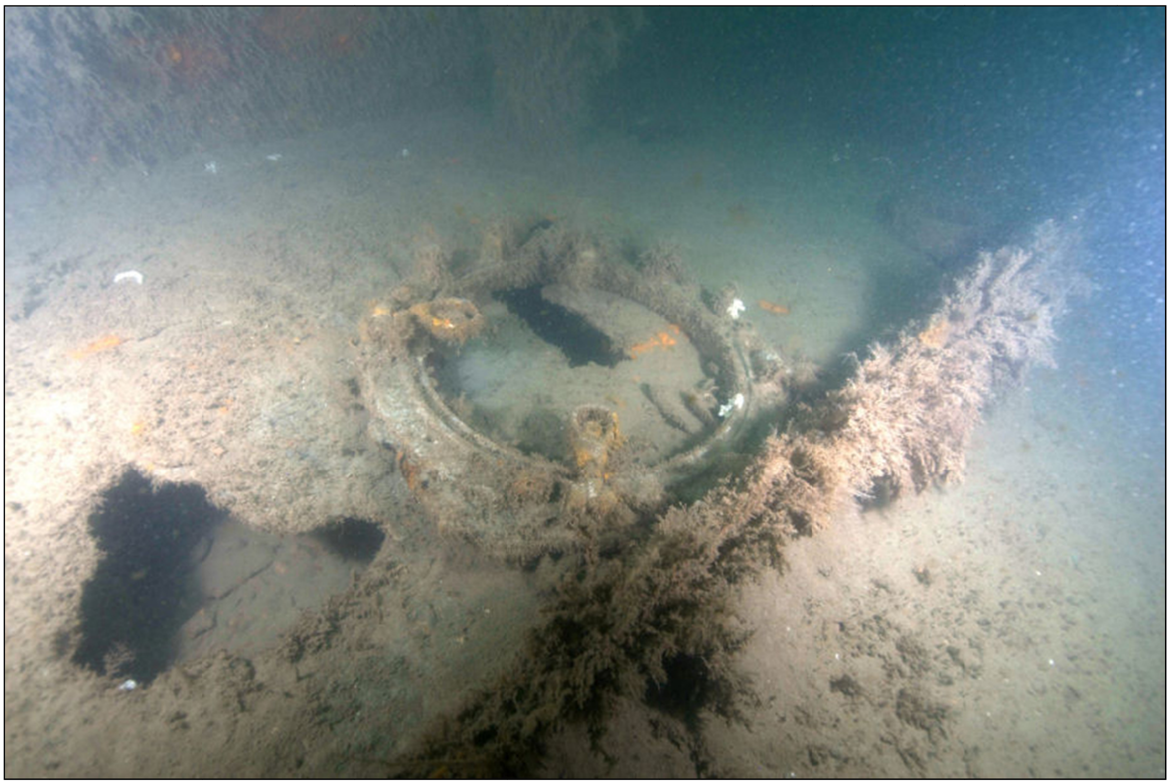


Figure 3.7.5. Porthole resting on deck. (Photograph Courtesy of Colm O'Reilly.)

3.7.3 Geophysical

Geophysical data was acquired at Site 389 on February 13 and 14, 2011, aboard the M/V *Nikola*. The 30 x 100 m grid was oriented parallel and perpendicular to the wreck site (see Navigation Post-Plot Map Appendix B; Figure B-7). Side scan sonar, sub-bottom profiler, magnetometer, multibeam and single beam bathymetry were acquired at the site (see Chapter 2 and Appendix A for complete sensor specifications, survey vessel configuration, and navigation parameters).

Water depths are 18.4–21 m throughout the survey grid (Figure 3.7.6). Significant scour zones are evident around the shipwreck extending to the NW. The multibeam clearly illustrates that the wreck is listing towards the port side (Figure 3.7.7). A significant portion of the bow is exposed due to a large scour zone, highlighting an apparent raked bow that would sit higher in the water column than the stern of the vessel. The starboard stern is flush with the seafloor.

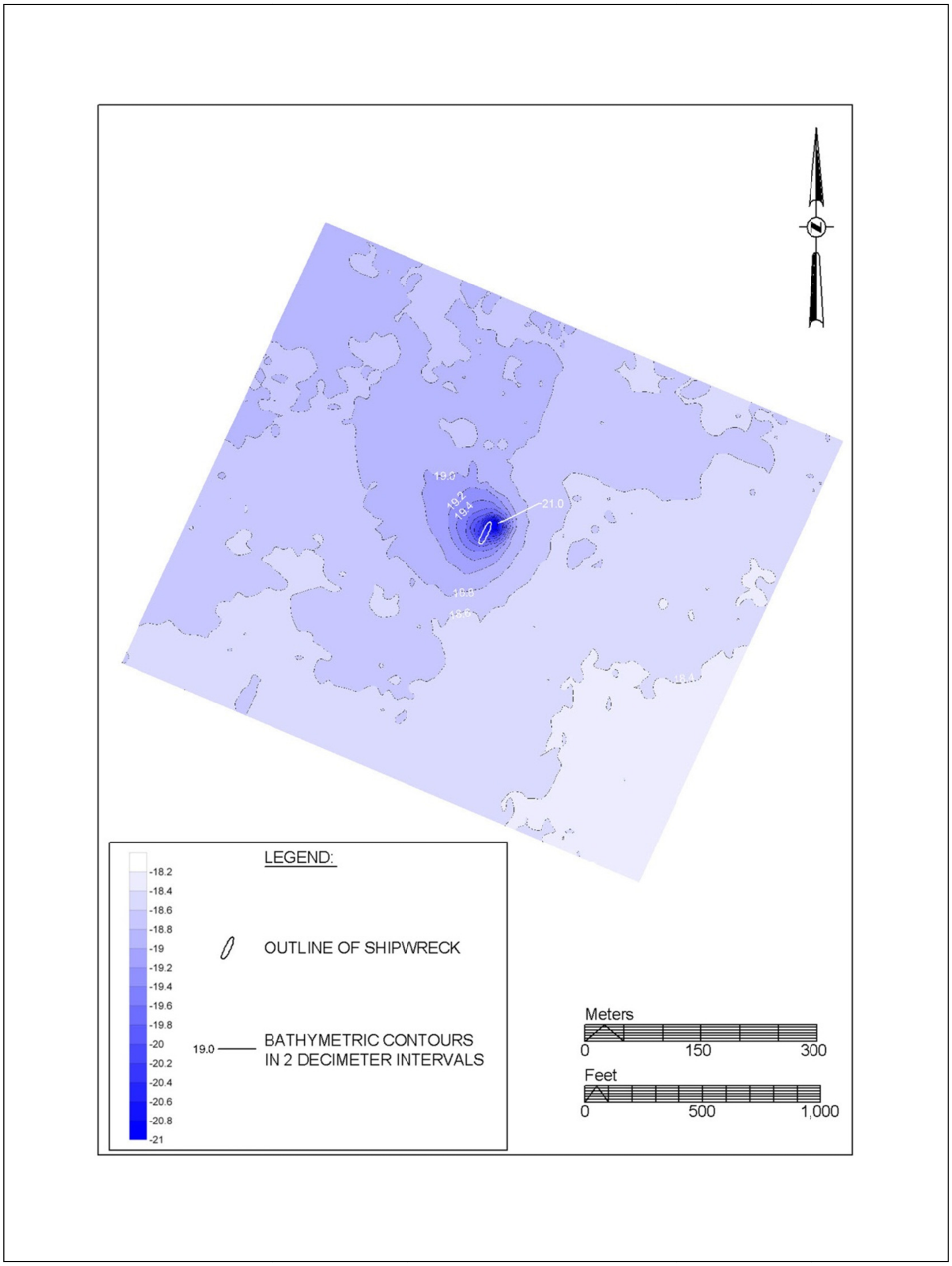


Figure 3.7.6. Bathymetry surrounding Site 389 in 2-decimeter intervals.

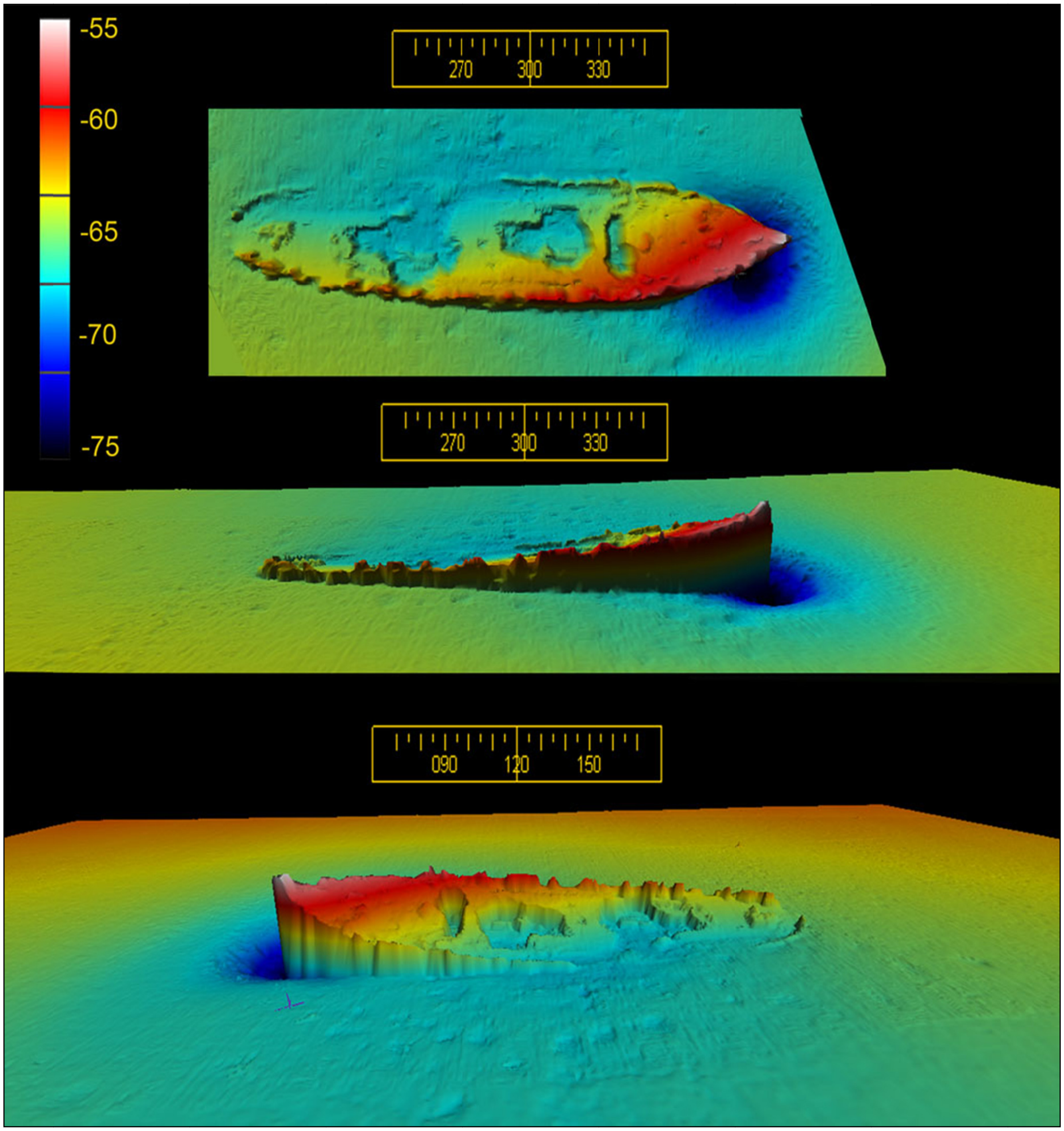


Figure 3.7.7. 3-D multibeam renderings of Site 389.

Sonar indicates that the wreck site is oriented with the bow facing 30 degrees NNE. The 100-kHz survey grid clearly imaged the wreck, but did not have sufficient resolution to define changes in seafloor texture attributed to scour. The 410-kHz survey grid clearly outlined the wreck as well as variation in sediment grain size. As noted previously, the wreck site is right side up, but listing significantly towards the port. The effect is that the sonar data obtained on the eastern side of the wreck casts a significant acoustic shadow obscuring all deck components. Figure 3.7.8 shows a sonar mosaic created utilizing only the survey lines that parallel the wreck site. It includes the 410-kHz sonar data overlaying the 100 kHz data. An inset shows the wreck from Survey Line 204. No evidence of the ancillary objects identified on the 2000 or 2005 sonar data sets was observed.

The combined geophysical data indicates that the vessel measures 32 m (105 ft) by 7 m (23 ft). The wreck lists to port, with the starboard side projecting farther into the water column. The highest point of the wreck sits an estimated 3 m (10 ft) above the ambient seabed at the bow, approximately 1.5 m (5 ft) at midships, and is flush with the seabed at the stern.

Sub-bottom profiler data indicates a consistent stratigraphic profile throughout the survey area. A strongly reflective seafloor is followed by approximately 1.8 m (6 ft) of parallel to sub-parallel layered, but somewhat discontinuous moderately reflective beds. A fairly strong reflector that parallels the seabed is evident and followed by another sporadic reflector beneath this horizon before acoustic attenuation sets in. Another strongly reflective horizon is evident at approximately 7.6 m (25 ft) BSL. The scour zones surrounding the wreck site are the only significant irregularity in the sub-bottom data set; however, no apparent infill of relict scour was observed. Instead, the subseafloor reflectors appear to be truncated by the scour depressions. Figure 3.7.9 shows a stratigraphic profile (Survey Line 305) close to the wreck site where the typical scour sequence is evident as well as a typical profile further away from the wreck (Survey Line 209) where no scour was observed.

Magnetometer data produced a number of very high intensity, long duration anomalies directly over and adjacent to the hull of the shipwreck (Figure 3.7.10; Appendix C). A total of 15 magnetic anomalies were recorded which could not be directly attributed to the main hull of the wreck. Fairly significant anomaly clusters were identified NNE and SSW of the wreck. The northern cluster consisted of Anomalies no. 16, 19, and 20. All of these anomalies had fairly short durations; Anomaly no. 20, a 55 nT, 20-m (66-ft) negative monopole, had the greatest intensity. The southern cluster was comprised of Anomalies no. 14, 17, 22, and 28. The largest of these in intensity was no. 14, a 22 nT, 27-m (89-ft) positive monopole. These anomaly clusters may be related to smaller quantities of debris associated with the wrecking event that may be buried in the surficial sediments surrounding the hull of the vessel.

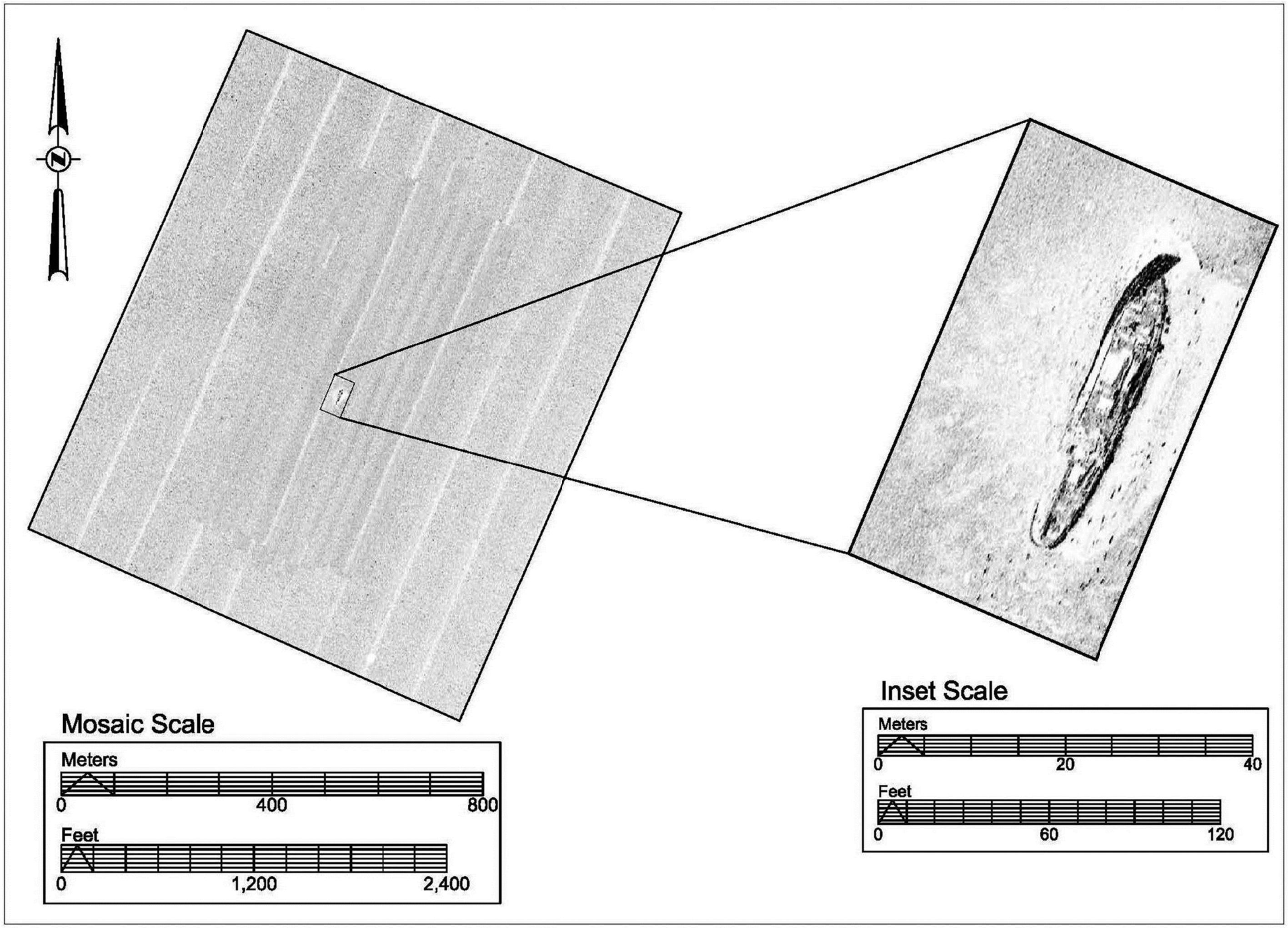


Figure 3.7.8. 120 and 410 kHz side scan sonar mosaic of Site 389. Inset at 410 kHz.

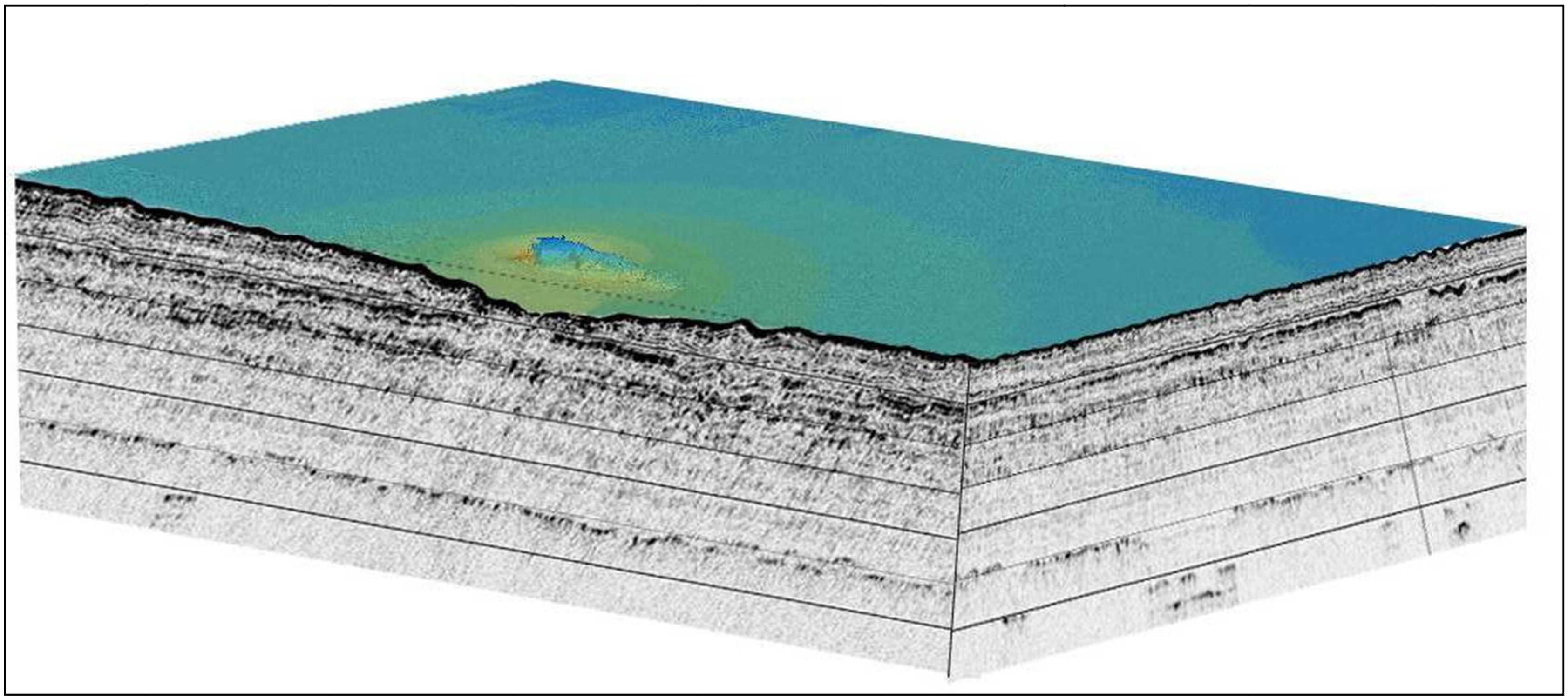


Figure 3.7.9. Shallow stratigraphy cube at intersection of sub-bottom profiler Lines 305 and 209. Vertical scale lines in 2-ms intervals. Seafloor rendering based on multibeam bathymetry data.

Figure 3.7.10. Magnetic contours in 5-nT intervals at Site 389.

3.7.4 Site Environment

3.7.4.1 Water Sampling

One 8-ounce water sample was collected from Site 389 on August 14, 2010 at a depth of 20 m (66 ft) BSL. Water temperature at the time of acquisition was 86° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.9). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.9

Water Sample Results for Site 389

Type	Average
Salinity (ppT)	31.4
pH	7.496
Dissolved oxygen (mg/L)	7.017

3.7.4.2 Core Lithology and Grain Size

Two cores were collected from Site 389 on August 14, 2010. The first was collected from the north side of the vessel, approximately 8 m (25 ft) from the bow of the vessel at a depth of 20 m (66 ft). Visibility at this location was extremely limited and diminished as coring activities disturbed near-surface sediments. Core no. 1 resulted in a maximum of 60 cm of sediment. A second core was collected from the SE side of the vessel just off of the starboard stern at a depth of 20 m (66 ft). Core no. 2 resulted in a 47 cm stratigraphic sample.

Core no. 2 was positioned closer to the hull than Core no. 1 and was therefore chosen for grain size and radioisotope sampling. Core no. 1 was used primarily for correlation of near-seafloor stratigraphy and shear strength measurements. Samples were collected from each of the three units observed within Core no. 2 and measured for grain size. Median and graphic mean calculations demonstrate that sediments from Site 389 become increasingly fine from sample 1 to sample 2, transitioning from fine sand to fine silt. Sample three, however, represents a coarser fraction of very fine sand, possibly representing a storm deposit or other intrusion.

Subsequent salinity, pH, and DO measurements were measured for pore water trapped in the sediment core, resulting in higher salinity and lower pH and DO values. Average pore water salinity was 34.267 ppT; average pore water pH was 7.31; average DO was 5.1 mg/L. Sediment pH values were obtained for sediments closest to the wreck site, captured within Core no. 2. The pH values were measured downcore and were generally higher than all water sample measurements, ranging from 8.12 to 7.73 between the seafloor and 60 cm below surface.

3.7.4.3 Radioisotope Analysis

Sediment samples from Site 389 demonstrate a post-disturbance linear accumulation rate (LAR) of 0.08 cm/yr. Based on the sampling interval, a disturbance layer was identified within the sediment column at a depth of 4.0 to 14.2 cm. The disturbance was most likely caused by either the wrecking event or an extreme storm event, and occurred 50–178 years before the 2010 core collection. Pre-disturbance sediments show no downcore decay; porosity, and grain size data suggest this is likely the product of observed changes in coarse sediment frequency.

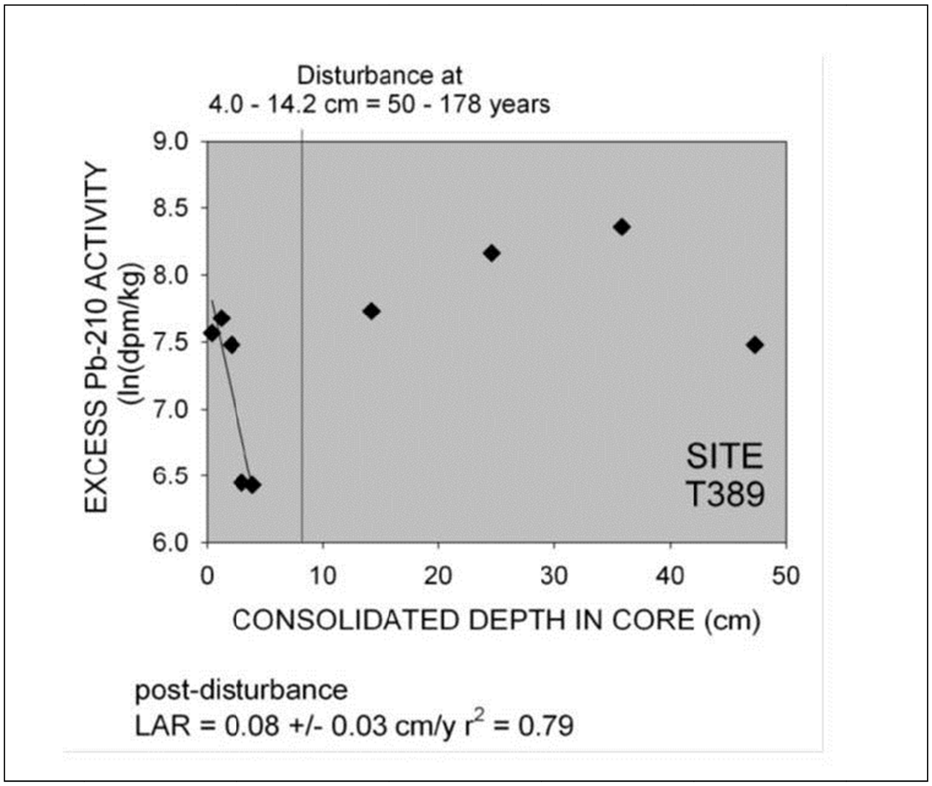


Figure 3.7.11. Downcore ^{210}Pbxs activity and linear sediment accumulation rate (LAR) calculations for Site T389.

3.7.4.4 Oceanographic Analysis

The potential impact of hurricanes on seafloor scour is suggested by oceanographic modeling conducted at separate datum sites in the GOM that serve as a proxy for seafloor conditions at the current shipwreck site (Rego et al. 2011). Datum 1 simulated hurricane impacts at a site in 26 m of water with cohesive-clay dominated sediments, while Datum 2 simulated hurricane impacts at a site in 15.5 m of water with a seafloor consisting of coarse, medium, and very fine silt, and small amounts of very fine sand. Both datums are used in this comparison due to water depth at Site 389, which is between the two depths represented by the datum sites, and the variability of sediment grain sizes between the datums and Site 389. Storm-related scour modeled at Datum 1 resulted in maximum scour of between 1.5 m (loose) and 3 cm (consolidated); net scour ranged from 21 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011). Hurricane Ike-related scour modeled at Datum 2 resulted in maximum scour of between 1.0 m (loose) and 0.2 cm (consolidated); net scour ranged from 30 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011). Less scour was calculated to have occurred during Hurricane Rita, with a maximum of 84 cm (loose) and a net scour of 10 cm (loose); under the consolidated bed scenario there was little to no net scour resulting from Rita. Modeled estimates from the datums indicate possible storm scour ranging from a maximum 1.5 m to 84 cm (loose) and 3 cm to 0.2 cm (consolidated); net scour estimates range from 21 to 10 cm (loose) and 3 cm to none (consolidated).

3.8 Site No. 236, Galveston Area, USS *Hatteras*

3.8.1 Site Background

Site No. 236 was added to the scope of work during August 2010 dive operations and an amendment was subsequently added to the contract to include geophysical data acquisition over the site. This site is the known location of the USS *Hatteras*, a Union Civil War gun-boat that is listed on the NRHP and is a Texas State Archaeological Landmark (Texas Site 41GV68). Although the site's identity is known, it was felt that the acquisition of geophysical data and including the site in the scope of work would provide beneficial data for continued monitoring of the site. This was also the first known archaeological investigation of the site since Hurricane Ike heavily impacted the Galveston region in September of 2008.

As Arnold and Hudson (1981:13) stated, the site is shown on nautical charts and has been known to the Texas diving community for some time. The site was "re-discovered" in the 1970s through investigations performed by an amateur treasure hunting group (Cloutier 1976; Arnold and Hudson 1981; and Arnold and Anuszkiewicz 1995). This group organized as Hatteras Inc., and filed an admiralty arrest in U.S. District Court, Galveston Division. The arrest was eventually challenged by the U.S. government, which won the lawsuit on February 25, 1981 on the grounds that the vessel remained U.S. Navy property (U. S. District Court, Southern District of Texas, Galveston Division 1984). During the case, at least eight artifacts that had been recovered from the site were placed in the custody of the U.S. Marshal.

Following the court case, the Bureau of Land Management (later the Minerals Management Service), with support from the Texas Historical Commission and the Institute for Nautical Archaeology at Texas A&M University, took an active role in monitoring and mapping the site (Arnold and Hudson 1981; Arnold and Anuszkiewicz 1995; Irion 2000). Their investigations resulted in the preparation of site maps and documentation of the site matrix, and provided a record of the condition of the exposed portions of the site at various points in time.

Recent known archaeological investigations at the *Hatteras* wreck site have occurred as parts of MMS-funded studies conducted by PBS&J in 2004 and 2007 (Enright et al. 2006; Gearhart et al. 2011). PBS&J acquired sonar and magnetometer data over the site and performed a brief diver investigation in 2004 (Enright et al. 2006). A single sonar image was published that provides an indication of the degree of exposure at the wreck site. Subsequent sonar data was obtained as part of a hurricane-impact study in 2007, but because no evidence of disturbance was observed on the sonar data, no diving was done to verify site conditions (Gearhart et al. 2011:133)

The remains of *Hatteras* are located within a modern shipping fairway that runs parallel to shore from Port Aransas on the Texas coast toward Sabine along the Louisiana-Texas border. The closest infrastructure to the site is a P&A Well located 2,210 m (7,250 ft) ENE of the site.

3.8.2 Diving

Hatteras was the final site investigated during diving operations, which took place on August 24 and 25, 2010 from the M/V *Spree*. The purpose of investigating this site was to report on the current condition of the wreck, and record any changes in or newly-revealed features at its location since the passage of Hurricane Ike in 2008.

- Average water depth at seafloor: 17.5 m (58 ft).
- Total bottom time: 26.07 hours. Average dive time: 30 minutes.
- Visibility: 2.4–3 m (8–10 ft) at slack tide when bottom currents were minimal, 0.3–0.9 m (1–3 ft) when tides were coming in or out.

Two full days of diving were performed on the wreck. Divers recorded diagnostic features of the vessel, such as the paddle-wheel hubs, the paddle-wheel shaft, the stern assemblage, machinery that may be related to the vessel's cylinder or steam chest, iron frames in the vessel's stern, the sternpost, and also a previously-noted but unnamed iron structure that was identified as the vessel's walking beam. A makeshift erosion pin was also placed on site adjacent to the starboard paddlewheel (Section 5.3.8.3).

Previously, *Hatteras* had been investigated by archaeologists (Arnold and Hudson 1981; Arnold and Anuskiewicz 1995; Enright et al. 2006; Gearhart et al. 2011; Don Keith pers. comm. 2011), but comparisons to site plans generated from previous visits indicated that the wreck had been more exposed during the 2010 fieldwork than had been previously documented. Project archaeologists in 2010 conducted in-depth recording and underwater photography of features in order to create an expanded site plan. Features and details noted during dive operations are listed below.

Paddlewheel Components: The most evident portion of the extant vessel is the paddlewheel shaft, which lies in a north-south orientation and terminates at either end with the paddlewheel hubs (Figures 3.8.1, 3.8.2, and 3.8.3). The shaft is 30 cm (12 in) in diameter, but increases to 50 cm (19.5 in) near the paddlewheel hubs. The entire shaft, extending from the southern hub to its northern counterpart, measures 13.3 m (43.5 ft). The paddlewheel hubs are composed of an inner and outer hub, which form a 1-m (3.25-ft) space for the paddle arms and buckets; both hubs are 1.9 m (6.25 ft) in diameter. The northern paddlewheel hub includes partial remains of paddlewheel spokes and at least one partial bucket. The spoke measures approximately 4 m (13 ft) in length, and the broken bucket fragment is 0.5 m (1.6 ft) wide.

Figure 3.8.1. Divers Andy Marr and Jake Shidner mapping the starboard paddlewheel. (Photograph courtesy of Colm O'Reilly.)

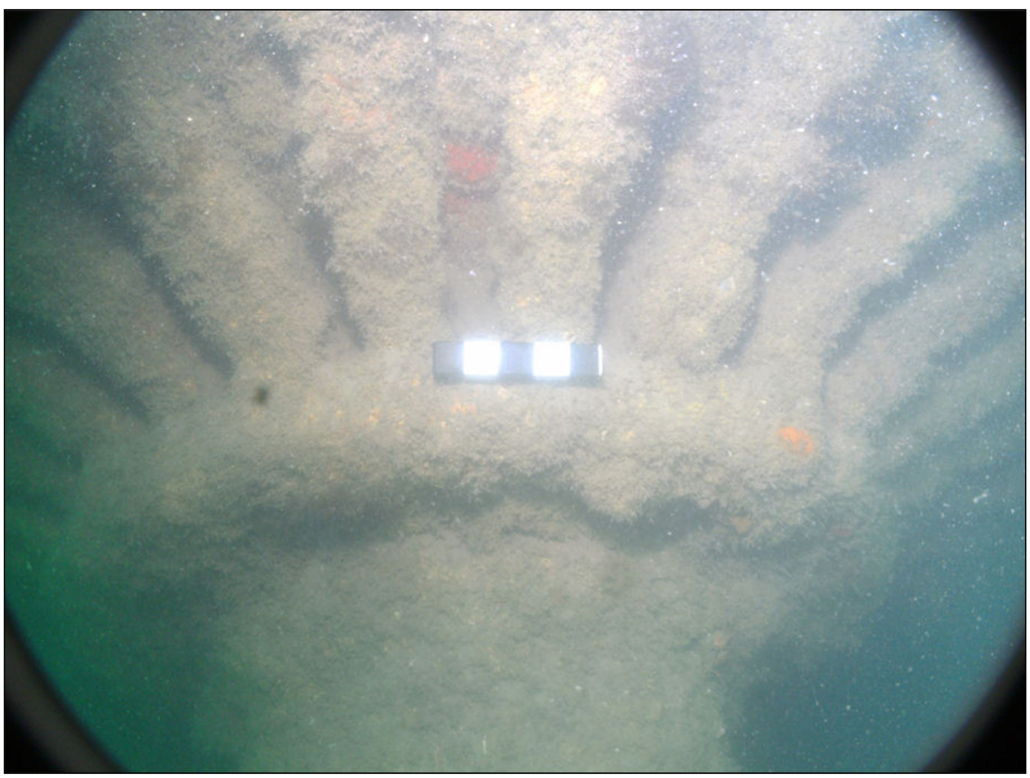


Figure 3.8.2. The starboard paddlewheel and shaft. Scale is 10 cm with 2-cm increments.

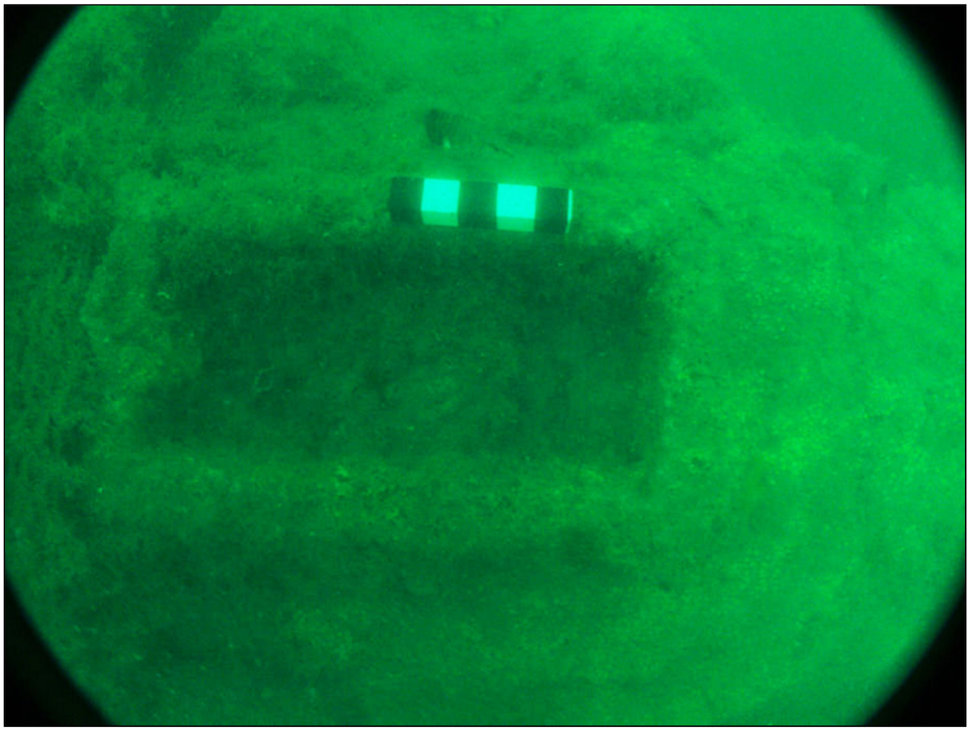


Figure 3.8.3. Rectangular housing on paddlewheel shaft adjacent to the starboard paddlewheel.

Propulsion Components: Near the southern paddlewheel, features that have been described as a cylinder, valve assembly, and/or steam chest lay exposed and were recorded by divers. The largest object, tentatively identified as the engine's cylinder, is 5.4 m (17.75 ft) long and 1.6 m (5 ft) wide. The smaller component, made up of two 2-m (6.5-ft) long pieces of what may have been the steam chest, are located immediately to the south of the cylinder, and average 0.6 m (2 ft) in diameter. Adjacent to these components, what is tentatively identified as the piston rod lay partially exposed over a distance of 4.8 m (15.75 ft).

Walking Beam: Masses of what are presumed to be engine components heavily obscured by shrimp net, cables, and line are situated toward the middle of the site, adjacent to either side of the paddlewheel shaft. Closer inspection of the western component verified that it represents the partially exposed walking beam, which transferred power from the engine to the paddlewheel through the crank shaft and connecting rod. In fact, the connecting rod is still attached to the walking beam on its eastern extent. Divers noted nearly 3.65 m (12 ft) of the upper portion of the walking beam, and could feel the vertical strut at the center of the beam despite it being obscured by net material before it descended below the seafloor. The width of the walking beam and connecting rod were estimated at approximately 20 cm (8 in).

Stern Frames: The sector scanning sonar data indicated that a feature lay to the west of the paddlewheel shaft. Archaeologists conducted searches in this direction, and discovered approximately 25 partially exposed iron cant frames, and the upper portions of the stern post and possible rudder post. Though they appear corroded or primitively fashioned, frames average 6 cm (2.5 in) in width, and the potential stern post measures 10 cm (4 in) square. The space between frames varies from 10 cm (4 in) to 30 cm (12 in).

3.8.3 Geophysical

Geophysical data was acquired at the *Hatteras* site (Site 236) on February 13 and 14, 2011 aboard the M/V *Nikola*. Survey coverage was centered on the paddlewheel assemblage, and extended out in a 300-m (1,000-ft) radius surrounding the wreck site. Two separate survey grids were run over the site, both containing survey lines paralleling the wreck site. A total of 12 survey lines were run using 100 kHz sonar frequency and spaced 100 and 200 m apart for reconnaissance and to maximize sonar coverage. A total of 24 survey lines were run directly over the wreck site using 410 kHz sonar frequency and spaced 15 and 30 m apart for increased sonar resolution, multibeam coverage, sub-bottom profiling, and magnetic contouring (see Navigation Post-Plot Map Appendix B; Figure B-8). Side scan sonar, sub-bottom profiler, magnetometer, multibeam, and single beam bathymetry were acquired at the site (see Chapter 2 and Appendix A for a full description of geophysical sensor suite, vessel configuration, and navigation parameters).

Water depths are 16.6–17.8 m (54.5–58 ft) throughout the survey grid (Figure 3.8.4). The seafloor is irregular surrounding the wreck site, with water depths decreasing to the south approaching a sand ridge that extends east/west throughout the survey grid. Ambient water depth is 17.8 m (58 ft) at the wreck site, with a zone of apparent wreck-induced scour that surrounds the wreck components and reaches a maximum depth of 18 m (59 ft). Multibeam data indicated that structural components projecting into the water column include the paddlewheel assemblage, the cylindrical objects east of the paddlewheel, the stern assemblage, and two instances of unidentified objects located towards the bow of the ship.

Side scan sonar indicates that the seafloor composition is highly variable. Throughout the northern and southern portion of the survey grid, the seafloor is lightly to moderately reflective, indicative of fine grained silts and clays. A highly reflective ridge extends just south of the wreck site that is comprised of course-grained sands. The 410 kHz sonar data clearly resolved sand ripples throughout this zone. The sonar resolved all of the exposed components and indicates that the wreck primarily lies in a zone of finer grained sediment along the northern flank of the courser grained sand ridge. It is unknown if this zone formed naturally or was formed due to the intrusion of the wreck site. Figure 3.8.5 shows a sonar mosaic created by using all of the 410 kHz sonar lines overlain with the 100 kHz sonar lines perpendicular to the wreck. An inset shows the wreck site as seen from Survey Line 204.

The geophysical data indicates that the distance between the stern of the vessel and the paddlewheel assemblage at midships is 33 m (108 ft). The distance between the two paddlewheels is 17 m (54 ft). In addition to the primary components mapped during diving operations, three additional targets were identified in the vicinity of the exposed portion of the site and may be associated with the wreck. The first of these lies 11.5 m (38 ft) NNW of the stern of the vessel. The second two targets are in close proximity to each other (7.3 m or 24 ft apart) and lie approximately 30 m (100 ft) SE of the cylinder and interpreted steam chest components.

Sub-bottom profiler data indicates a fairly consistent stratigraphic profile throughout the survey area. A strongly to moderately reflective seafloor is followed by approximately 3 m (10 ft) of mostly amorphous moderately reflective strata. Further penetration is all but eliminated by an irregular unconformity. The poor penetration and lack of stratification is caused by the high sand content within the surficial sediments. Irregular areas of more highly reflective amorphous strata are occasionally evident within the upper 30–90 cm (1–3 ft). This zone is much more prominent and appears to extend as deep as 4.5 m (15 ft) BML in certain areas directly surrounding the wreck site (Figure 3.8.6).

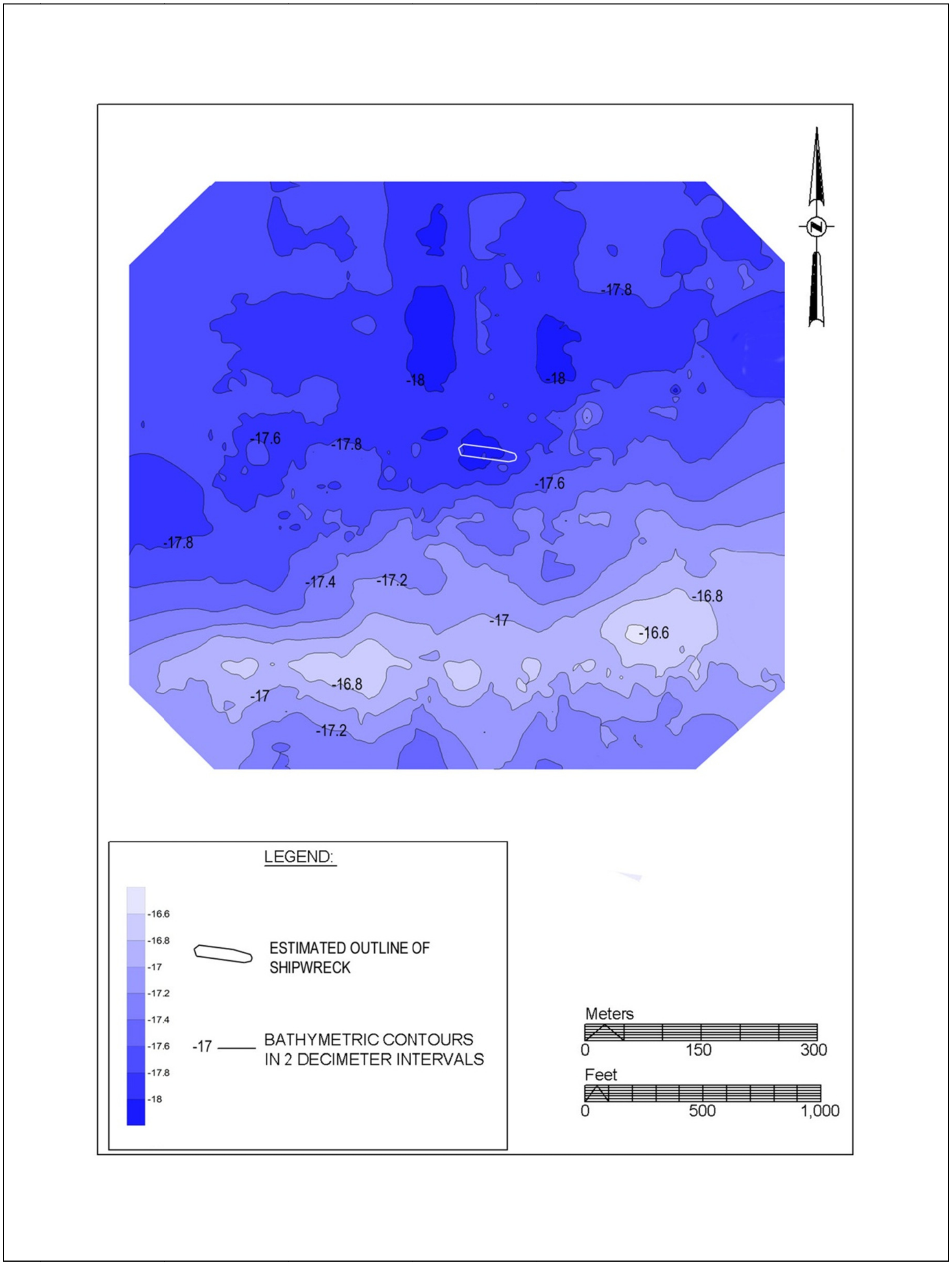


Figure 3.8.4. Bathymetry surrounding site 236 in 2-decimeter intervals.

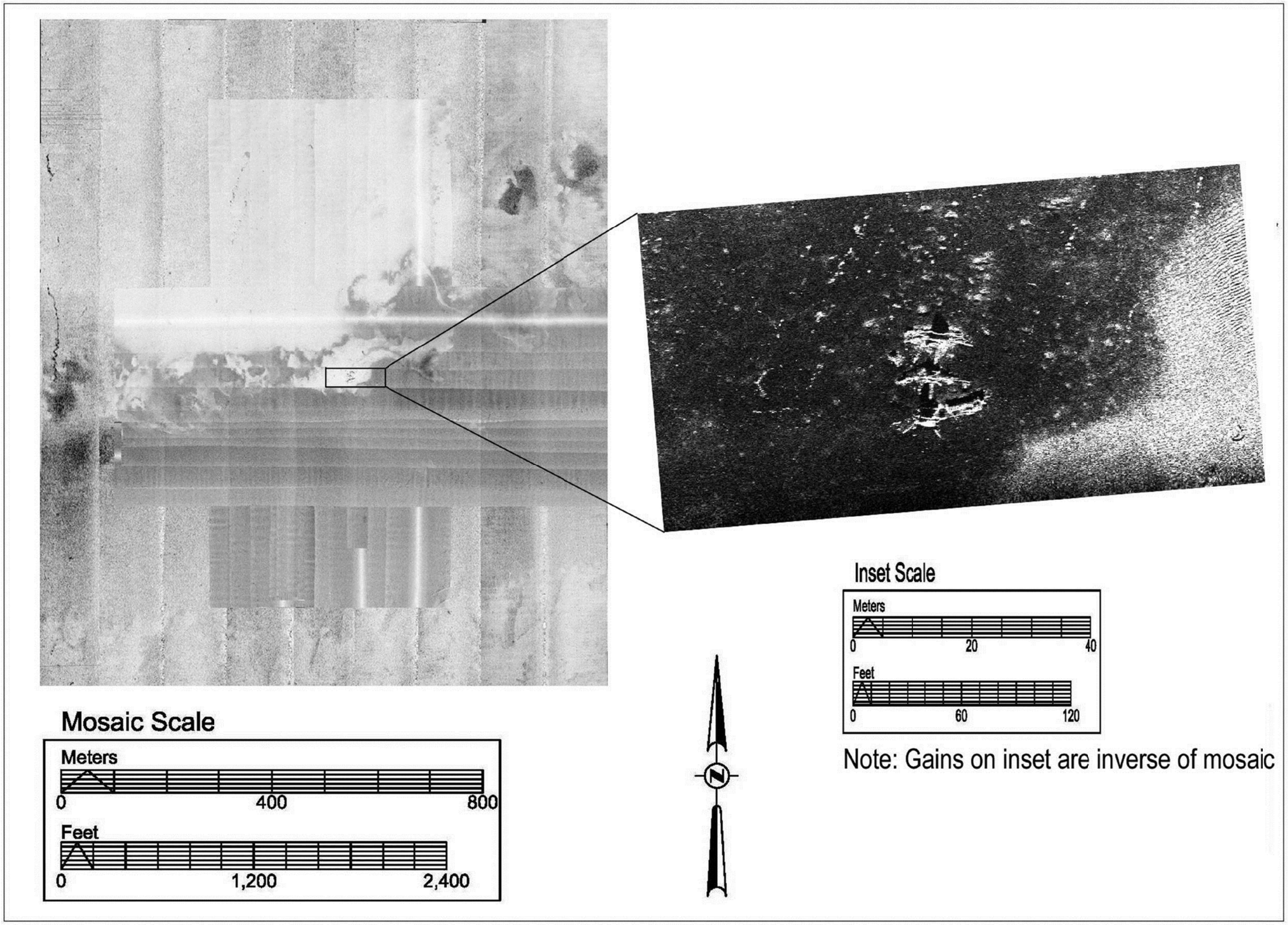


Figure 3.8.5. 120 and 410 kHz side scan sonar mosaic of Site 236. Inset at 410 kHz.

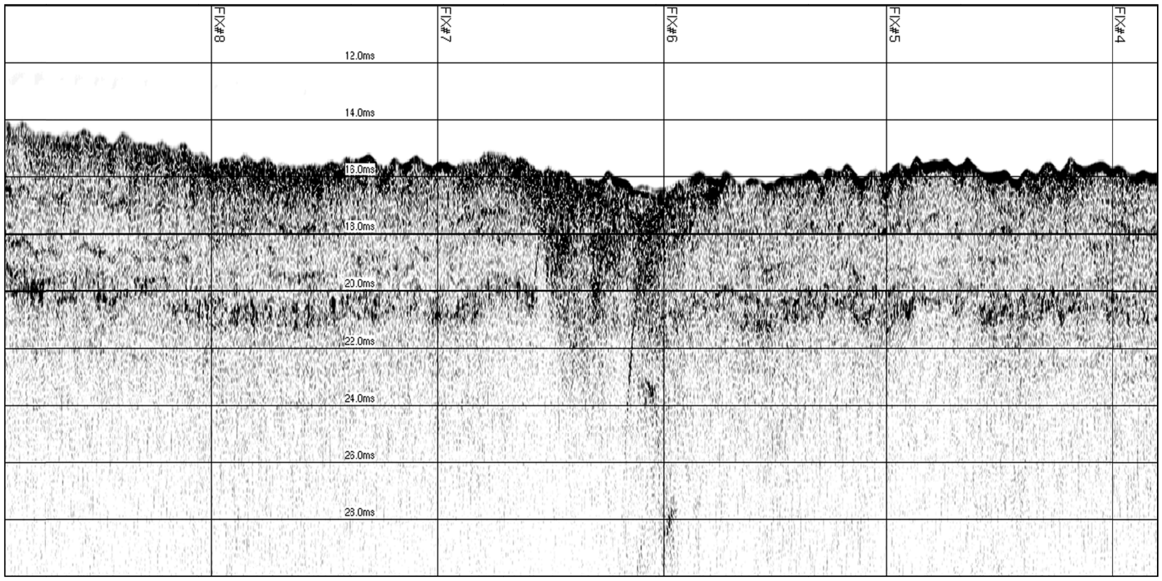


Figure 3.8.6. Sub-bottom profile of survey Line 307, Site 236. Line 307 is located north of the wreck, with a heading of 92 degrees. Vertical scale lines in 150-m increments. Horizontal scale lines in 2-ms Intervals.

Magnetometer data very clearly highlighted the wreck site (Figure 3.8.7). Because it was known that a significant portion of this shipwreck was buried, the central survey grid line spacing interval was reduced from 30 m (91 ft) to 15 m (49 ft) to enhance magnetometer contouring. The largest and most significant concentration of anomalies was identified directly over the paddlewheel assemblage.

Anomalies in this area include nos. 8, 26, 27, 29, 39, 41, 42, and 43. These anomalies are primarily very large intensity, larger duration complex, or dipolar anomalies produced from running directly over a large concentration of ferromagnetic debris. As expected, larger duration, but smaller intensity anomalies, such as nos. 13, 36, 38, 39, 46, and 47, are seen along the same north-south axis, but further from the wreck site. A dense concentration of anomalies was identified towards the stern of the vessel. Some of these, such as Anomalies no. 17, 20, and 23, are low intensity, high duration, monopolar anomalies identified on north-south survey lines that are produced from the central mass of the wreck site further to the east. Within this area, though, anomalies, such as nos. 24, 25, and 46, are dipolar or complex anomalies with higher intensities, indicating that some smaller, but still significant, quantities of ferromagnetic debris are present beneath the seafloor west of the vessel's stern.

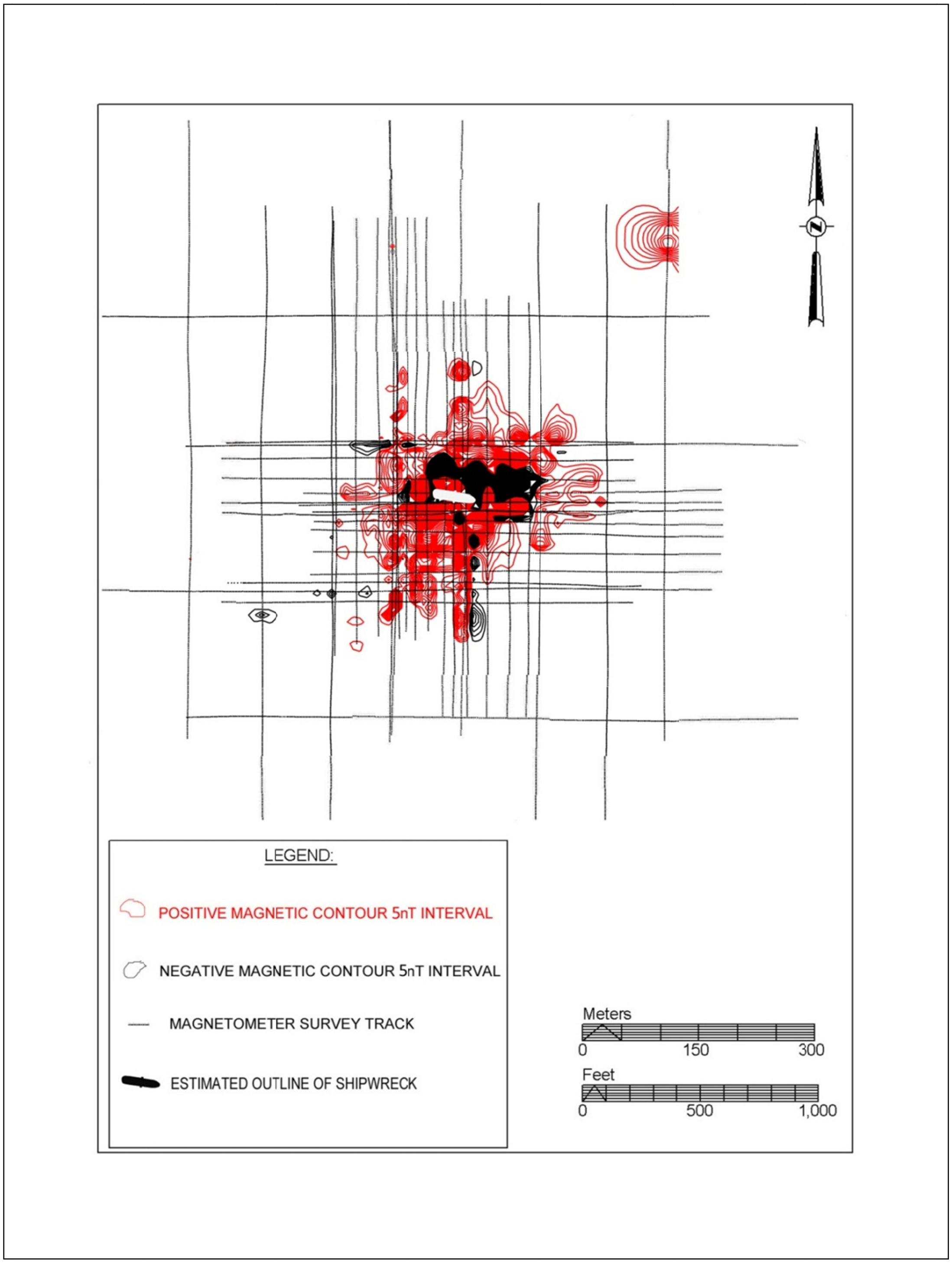


Figure 3.8.7. Magnetic contours in 5-nT intervals over location of the USS *Hatteras*.

Anomalies no. 10, 31, and 32 are located along north-south survey lines east of the wreck site. All three are monopolar anomalies with large durations and are likely produced by the main component of the wreck to the west; however, the relatively high intensities of Anomaly nos. 31 and 32 may indicate that some significant concentration of debris may be located closer to the bow of the vessel. A larger cluster of anomalies is located SW of the wreck, but all are small intensity, low duration anomalies. This cluster indicates that some smaller quantities of scattered debris are present in this area; these may be related to the vessel's loss following battle. Additional small anomalies were identified scattered further from the site, but it is unknown if these are related to the shipwreck or are intrusive. Because the site is within a shipping fairway, debris associated with passing marine traffic is common.

3.8.4 Site Environment

3.8.4.1 Water Sampling

One 8-ounce water sample was collected from Site 236 on August 24, 2010 at a depth of 18 m (60 ft) BSL. Water temperature at the time of acquisition was 84° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.10). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.10

Water Sample Results for Site 236

Type	Average
Salinity (ppT)	34.40
pH	8.033
Dissolved oxygen (mg/L)	7.467

3.8.4.2 Core Lithology and Grain Size

Two cores were collected from Site 236. Sediments across the site were extremely variable. The first core was collected on August 24, 2010, approximately 1 m (3 ft) north of the port-side paddlewheel, at a depth of 18 m (60 ft). Visibility at this location was limited and diminished as coring activities disturbed near-surface sediments. Core no. 1 resulted in a maximum sample of 65 cm of sediment. A second core was collected from the south side of the vessel just off of the starboard paddlewheel at a depth of 18 m (59 ft) on August 25, 2010. Divers noted increased resistance to core barrel penetration through sediments in this area, suggesting greater sediment cohesion. Core no. 2 resulted in an 82 cm stratigraphic sample. Sediments at the western end of the wreck, near the identified sternpost and rudder, contained high concentrations of course-grained sands. Because the Wildco Hand-corer was not designed for sampling in unconsolidated sands, two modified core sleeves were used to collect approximately 10 cm plugs of near-surface sediment.

A total of ten samples was collected from the nine lithologic units observed within Core no. 2 and measured for grain size. Grain size measurements were also made on two samples taken from the second sand plug obtained near the stern area. Median and graphic mean calculations demonstrate that sediments from the paddlewheel area on Site 236 represent varying intervals of silts and sands, likely representing storm deposits. Samples measured from the stern area represent fining downcore, from sand to silt, without the varying intervals noted in Core no. 2 samples. Core no. 1 was primarily used to correlate near surface lithology, but due to the frequency of coarse-grained sand intervals in both cores, shear strength measurements were not obtained, as neither the penetrometer nor mini-torvane are suitable for measuring cohesionless sediments, such as sand. Core no. 2 was measured for pH in downcore sediments.

Subsequent salinity, pH, and DO measurements were conducted on pore water trapped in Sediment Core no. 2 and sand plug no. 2. Pore water samples from both the core and the sand plug resulted in higher salinity and lower pH and DO values. Average pore water salinity from Core no. 2 was 34.567 ppT; average pore water pH was 6.877; average DO was 1.237 mg/L. Average pore water samples from sand plug no. 2 resulted in salinity of 35.567 ppT; pH was 7.28; DO was 3.4 mg/L. Sediments in Core no. 2 were measured downcore for pH; measured values were similar to water samples measurements, ranging from 7.36 to 8.11 from the seafloor to a depth of 80 cm below surface.

3.8.4.3 Radioisotope Analysis

Sediments at Site 236 display excellent pre- and post-disturbance ^{210}Pb trends with depth. Disturbance produced a sharp hiatus in excess activity at a depth somewhere between 8.6 and 11.1 cm in the seabed. Using the post-disturbance linear accumulation rate (LAR) of 0.14 cm/yr allows this disturbance to be dated in the range of 61 to 79 years before the 2010 core collection. While there are only three pre-disturbance excess points (r2=0.86), sufficient evidence exists to assign an LAR before the disturbance of 0.33 cm/yr. This indicates that sediment LAR at Site 236 has decreased by almost 2 mm/yr since the disturbance event.

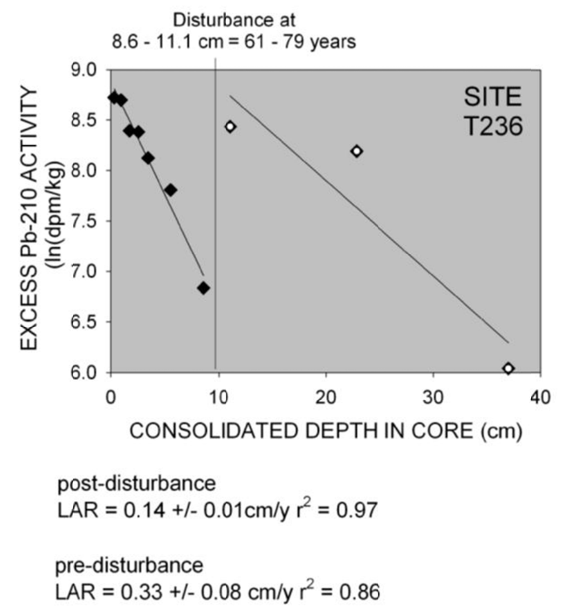


Figure 3.8.8. Downcore ^{210}Pbxs activity and linear sediment accumulation rate (LAR) calculations for Site T236.

3.8.4.4 Oceanographic Analysis

In the absence of long-term sediment scour monitoring, the modeling of punctuated, extreme scour events, such as hurricanes, can provide an estimate of sediment transport and redeposition. Oceanographic modeling was conducted at three datum sites in the GOM, all of which are used as a proxy for seafloor conditions at Site 236 (Rego et al. 2011). Datum 1 simulated hurricane impacts at a site in 26 m (85 ft) of water with cohesive-clay dominated sediments, while Datum 2 simulated hurricane impacts at a site in 15.5 m (51 ft) of water with a seafloor consisting of coarse, medium, and very fine silt, and small amounts of very fine sand. Datums 1 and 2 represent water depths less than and greater than depths measured at Site 236. Datum 3 models represent scour estimates for a site at a depth of 31 m (102 ft), much deeper than Site 236, but datum 3 sediments are coarser than either of the other datums and more accurately represent sediments at the stern area of Site 236.

Storm-related scour modeled at Datum 1 resulted in maximum scour of between 1.5 m (loose) and 3 cm (consolidated); net scour ranged from 21 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011). Hurricane Ike-related scour modeled at Datum 2 resulted in maximum scour of between 1.0 m (loose) and 0.2 cm (consolidated); net scour ranged from 30 cm (loose) to 0.03 cm (consolidated) (Rego et al. 2011). Less scour was calculated during Hurricane Rita, with a maximum of 84 cm (loose) and a net scour of 10 cm (loose); under the consolidated bed scenario there was little to no net scour resulting from Rita. Using the loose bed scenario, maximum scour at Datum 3 ranged from 1.3 m (Ike) to 60 cm (Rita); consolidated bed scenarios resulted in net scour of 30 cm (Ike) but a net sediment accretion of 5 cm from Hurricane Rita (Rego et al. 2011). Modeled estimates from the datums indicate possible storm scour ranging from a maximum 1.5 m to 60 cm (loose) and 3 cm to 0.2 cm (consolidated); net scour estimates range from 30 cm to a net accretion of 5 cm (loose), and 3 cm to none (consolidated).

3.9 Site No. 15326, East Cameron Area, Unknown Barge

3.9.1 Site Background

Site number 15326 was not one of the six original study sites. It was added to the contract during diving operations in August of 2010, and was investigated only by divers, with no contract-specific geophysical acquisition. The wreck site located in East Cameron Area was originally identified during a 2004 Tesla Offshore, LLC, geophysical survey (Floyd and Clemmons 2004) and relocated in a 2005 survey by the same company (Evans and Floyd 2005). Side scan sonar records highlighted massive wreckage of a large barge that appears to be broken in two (Figures 3.9.1 and 3.9.2). Large magnetic anomalies verified that the wreckage is primarily metal. “The wreckage protrudes 5 feet above the seafloor in places, but much of the hull has settled into the surficial sands. The target components cover 200 to 225 feet of horizontal distance with 30 feet of width (Evans and Floyd 2005).” The wreck was recommended for avoidance by 304.8 m (1,000 ft) until the wreckage could be further investigated to determine the actual age and nature of the vessel.

Sonar imagery from both the 2004 and 2005 data shows numerous trawl scars from shrimping. Data recorded in both the 2004 and 2005 surveys depict trawl scars on the seafloor, some of which intersect the wreck (Figure 3.9.1 and 3.9.3).

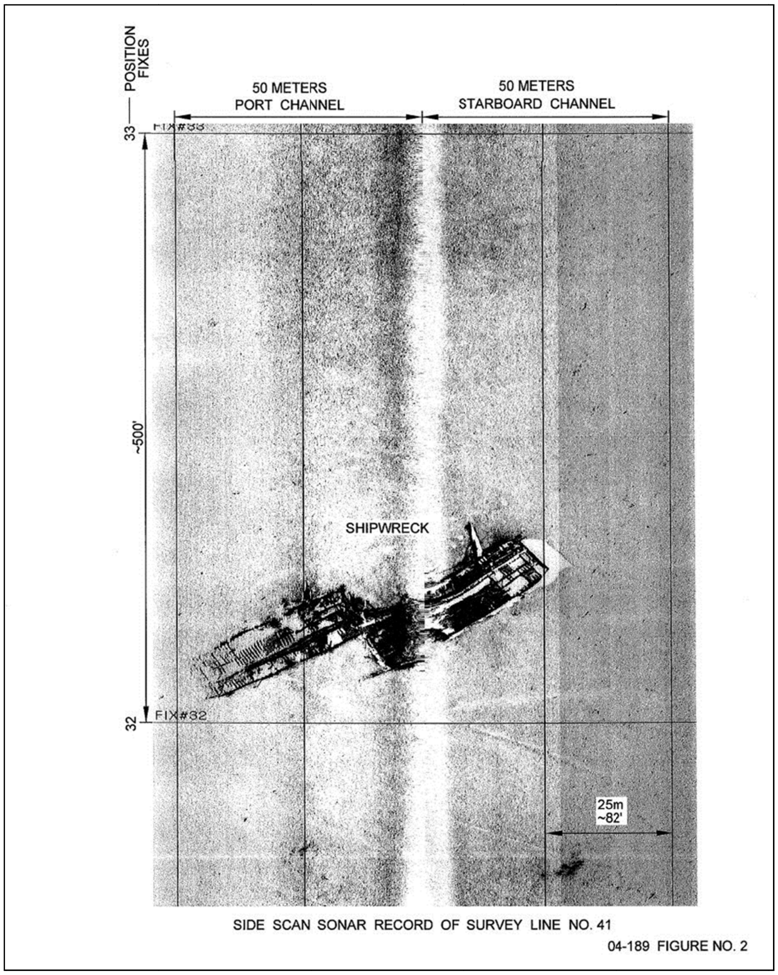


Figure 3.9.1. 500 kHz side scan sonar image of Site 15326. Image north up (Floyd and Clemmons 2004).

A 4” pipeline was installed based on the 2005 survey data, which re-verified the wreck, and has since been abandoned. This pipeline route was designed to avoid the wreck by 313 m (1,025 ft). Other than the now-abandoned pipeline, the closest infrastructure includes a well located approximately 580 m (1,900 ft) ESE and a platform located approximately 655 m (2,150 ft) WNW.

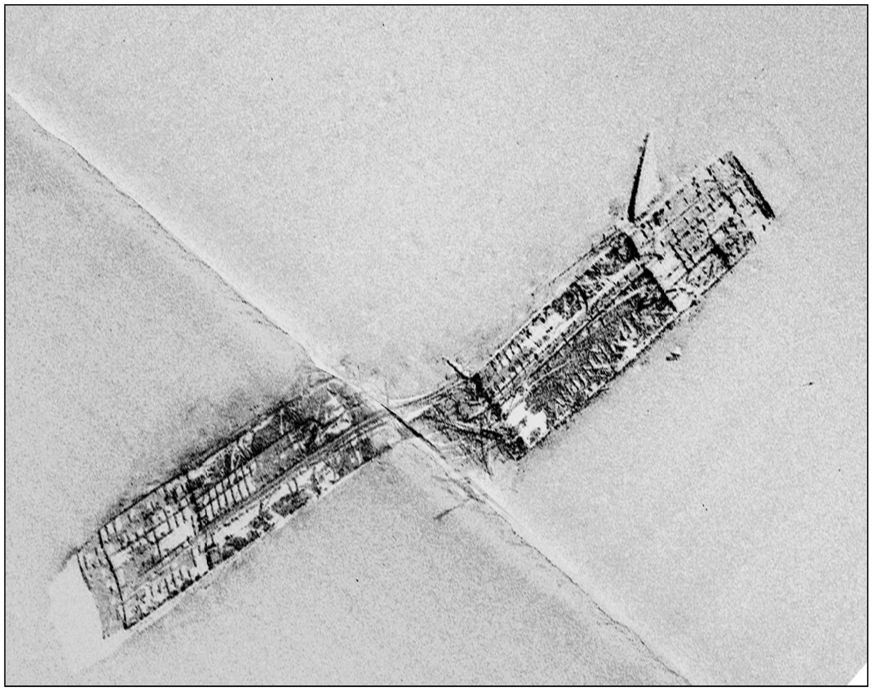


Figure 3.9.2. 500 kHz side scan sonar image of Site 15326 from Survey Line 301. Image north up (Image courtesy of Tesla Offshore, LLC.)

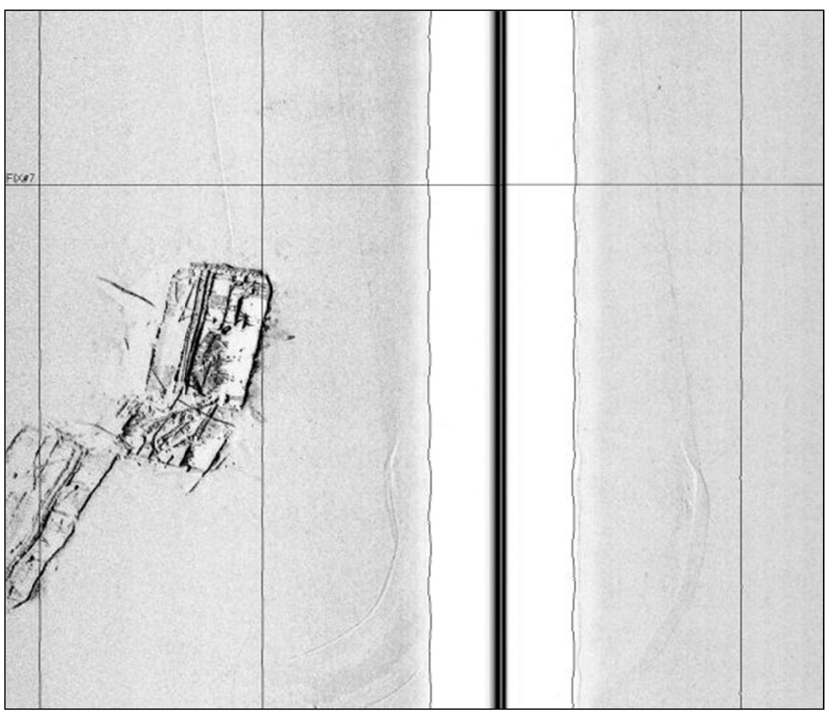


Figure 3.9.3. Side scan sonar image of Site 15326, highlighting trawl scars. (Image courtesy of Tesla Offshore, LLC.)

3.9.2 Diving

Diving operations on Site 15326 took place on August 20, 2010, from the M/V *Spree*.

- Average recorded water depth on site: 16.75 m (55 ft).
- Total bottom time: 7.12 hours. Average dive time: 26.69 minutes.
- Visibility: 0–0.3 m (0–1 ft).

Operations at the site commenced with the deployment of the Mesotech Sector Scanning Sonar. Mesotech imagery identified the outline of the wreck, but did not successfully image it in its entirety or provide additional detail beyond what was available from the pre-existing side scan data (Figure 3.9.4).

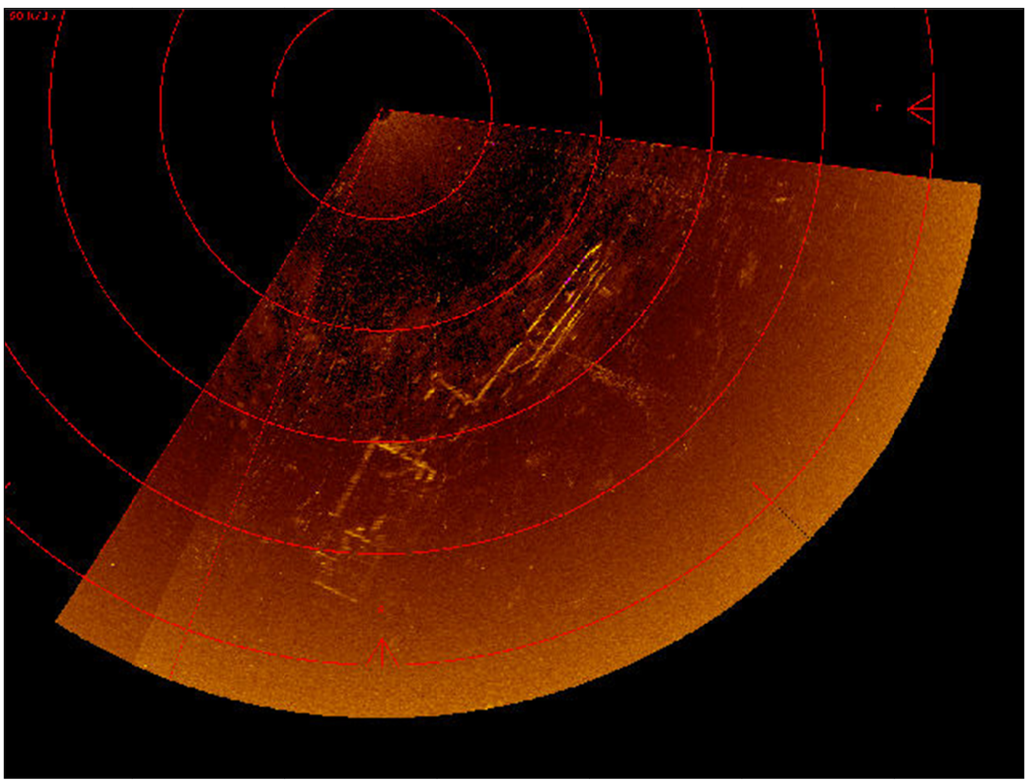


Figure 3.9.4. Sector scan of Site 15326 oriented north up.

During diving operations, visibility was extremely poor and the site had little relief above the surrounding sediments. Archaeologists established a baseline extending from the southern portion of the wreck 13 m (43 ft) to the NE for initial exploration of the site, since guidelines were required to navigate in the zero-visibility environment. There is little vertical relief, and divers noted a square shape to the ends, indicative of an industrial barge-type design. An extensive quantity of shrimp net and probable fishing line covers the wreckage, creating an entanglement hazard and obscuring most of the potentially diagnostic features. Due to poor visibility, most observations were based on touch. While investigating the wreck's perimeter, divers reported feeling a windlass or winch type device near the southern extent of the site. Disarticulated hull and decking were identified as far as 4 m beyond the outer-hull. Observed frames were evenly spaced and constructed of steel or iron.

3.9.3 Site Environment

This site was investigated during diving operations only. The contract modification did not include additional analysis of the site through geophysics, modeling, and sampling; therefore, only analyses that could be conducted at little or no additional cost were performed.

3.9.3.1 Water Sampling

One 8-ounce water sample was collected from Site 15326 on August 20, 2010 at a depth of 17.4 m (57 ft) BSL. Water temperature at the time of acquisition was 86° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.11). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.11

Water Sample Results for Site 15326

Type	Average
Salinity (ppT)	32.1
pH	7.323
Dissolved oxygen (mg/L)	6.69

Subsequent salinity, pH, and DO measurements of pore water trapped in Sediment Core no. 2 resulted in higher salinity and lower pH and DO values. Average pore water salinity was 33.867 ppT; average pore water pH was 6.997; average DO was 2.01 mg/L.

3.9.3.2 Core Lithology and Grain Size

Two cores were collected from Site 15326 on August 20, 2010. The first was collected within 2 m (6 ft 6 in.) of the western end of the wreck, on the south side, resulting in a maximum of 89 cm of sediment at a depth of 17.4 m (57 ft). A second core was collected from the south side of the vessel at midships, near the observed break in the hull at a depth of 17 m (56 ft) and resulted in a 92 cm stratigraphic sample.

Grain size measurements and radioisotope analysis were not conducted for samples from these cores, but lithology was noted, and approximate grain size classifications were made based on the observed sediments. Based on published data, the seafloor in this area is expected to be clayey sand (MMS 1983); however, qualitative assessment indicates near-surface sediments are sandy silt and fine downcore to clayey silt, with occasional intrusive sand lenses. Downcore measurements of pH values were taken from both cores, and indicated higher pH levels in sediments immediately surrounding the wreck than in the water column; average pH values from

Sediment Core no. 1 measured 8.034 to a depth of 85 cm below surface and average values from Sediment Core no. 2 measured 8.163 to a depth of 80 cm below surface.

3.10 Site No. 322, East Cameron Area, Unknown Modern Wreck

3.10.1 Site Background

Site number 322 was not one of the six original study sites. It was added to the contract during diving operations in August 2010, and was investigated only by divers, with no contract specific geophysical data acquisition.

Site number 322 is located in the East Cameron federal lease area and was identified originally by a geophysical survey conducted by John E. Chance and Associates in 1991 (Floyd and Thomas 1991). The survey report indicates that the wreck measured 6 m (20 ft) by 20 m (65 ft) and exhibited 1.2 m (4 ft) of relief.

While conducting subsequent operations in the area in 2005, Tesla Offshore, LLC, ran six survey lines over the wreck site to provide additional imagery of the wreck (Floyd 2005; Figure 3.10.1). The wreck is oriented with the bow facing the NW. Based on the 2005 data set, the wreck measured approximately 17.3 m (57 ft) in length, 3–3.9 m (10–13 ft) in width, and rises off the seafloor approximately 0.6 m (2 ft) at the bow. The stern has subsided into the sediments. Only the "pilothouse" portion sits 0.6–0.9 m (2–3 ft) above the deck.

Figure 3.10.1. 410 kHz side scan sonar image of Site 322 from survey Line 305. Oriented north up (Floyd 2005).

Existing infrastructure closest to Site 322 includes a 16” pipeline located approximately 924 m (3,030 ft) to the NNE and a P&A well located approximately 1,268 m (4,160 ft) to the NNW.

3.10.2 Diving

Diving operations on Site 322 took place on August 20, 2010, from the M/V *Spree*.

- Average recorded water depth on bottom: 16.75 m (55 ft).
- Total bottom time: 3.93 hours. Average dive time: 23.6 minutes.
- Visibility: 0–0.3 m (0–1 ft).

The Mesotech Sector Scanning Sonar was deployed upon arrival to the site. The data indicated that the vessel remained upright, and, although the data quality was limited, the pilot house and surrounding deck structure were clearly identified (Figure 3.10.2).

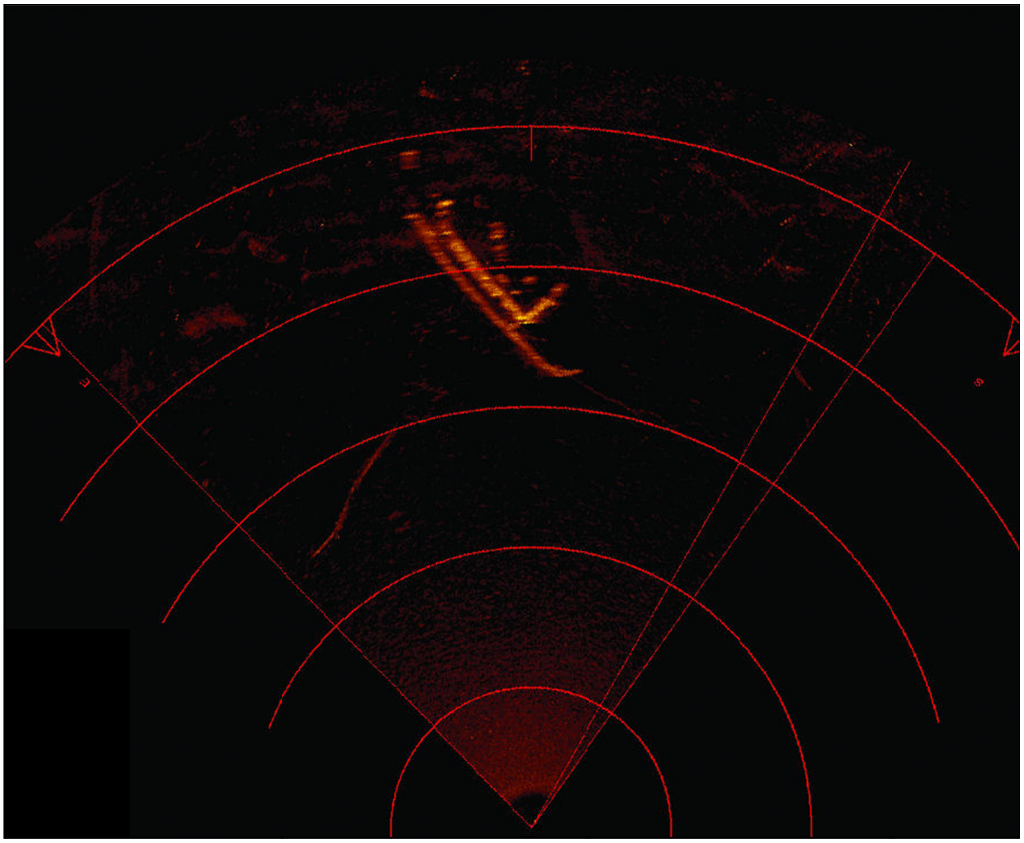


Figure 3.10.2. Mesotech scan of Site 322 oriented north up.

Divers determined that this site represents a relatively small, metal-hulled working vessel sitting upright on the seafloor. Approximately 6 m (20 ft) of the superstructure/pilot house was visible, including port holes with intact glass, and a winch and bitt on the deck. One dive team noted what appeared to be rubber gasket material around the port holes, as well as port and starboard running lights on the pilot house. The site is covered extensively in shrimp net and fishing line, creating significant entanglement hazards on site. A portion of what appears to be a boom extending off of one side suggests that the vessel is a fishing or shrimp boat.

3.10.3 Site Environment

This site was investigated only during diving operations. The contract modification did not include additional analysis of the site through geophysics, modeling, and sampling; therefore, only analyses that could be conducted at little or no additional cost were performed.

3.10.3.1 Water Sampling

One 8-ounce water sample was collected from Site 322 on August 20, 2010 at a depth of 17 m (56 ft) BSL. Water temperature at the time of acquisition was 88° F. Repeat measurements were taken for pH, salinity, and dissolved oxygen content and averaged (Table 3.12). Salinity was measured in parts per thousand. Dissolved oxygen (DO) is reported in mg/L.

Table 3.12

Water Sample Results for Site 322

Type	Average
Salinity (ppT)	31.9
pH	7.23
Dissolved oxygen (mg/L)	6.735

3.10.3.2 Core Lithology

Two cores were collected from Site 322 on August 20, 2010, both of which were within 5 m (16 ft) of the hull. The first core resulted in a maximum of 81 cm of sediment at a depth of 17 m (56 ft) and the second core resulted in a 91 cm stratigraphic sample from a depth of 17.4 m (57 ft).

Grain size measurements and radioisotope analysis were not conducted for samples from these cores, but lithology was noted, and approximate grain size classifications were made based on the observed sediments. Based on published data, the seafloor in this area is expected to be clayey sand (MMS 1983); however, qualitative assessment indicates near-surface sediments are sandy silt and fine downcore to clayey silt, with occasional intrusive sand lenses.

Salinity, pH, and DO measurements were taken of pore water trapped in Sediment Core no. 1, which resulted in higher salinity and pH values but lower DO values. Average pore water salinity was 34.167 ppT, average pore water pH was 7.507, and average DO was 5.77 mg/L. Downcore sediment measurements of pH values were taken for both cores and indicated higher pH levels in sediments immediately surrounding the wreck than in the water column. The average pH values from Sediment Core no. 1 measured 8.072 to a depth of 80 cm below surface and average values from Sediment Core no. 2 measured 8.046 to a depth of 80 cm below surface.

3.11 SITE NO. PENDING, WEST CAMERON AREA, MODERN DEBRIS

3.11.1 Site Background

This site was added to the contract during diving operations in August 2010 and was investigated through dive operations. The site had not been added to the BOEM database at the time of the field work and, to date, no site number has been attributed to this object.

The study site located in West Cameron Area was previously identified by a geophysical survey performed in 2007 by Tesla Offshore, LLC. The resulting report was prepared by Marine Archaeologist, Amanda Evans; Marine Geophysicist, Erika Geresi; and Marine Geophysicist, J. Wyn Prior (Evans et al. 2007). Target no. 7 was identified as a potentially significant object that warranted avoidance (Figures 3.11.1 and 3.11.2). According to the report, the target:

…appears to be a significant compound target consisting of several discrete parts which are observed from different angles on four survey lines. The target covers an area of approximately 44’ x 47’ with a maximum recorded relief of 5’. The largest single feature within the target measures approximately 17’ x 6’ as recorded from survey line 102. Target no. 7 is associated with a cluster of unidentified magnetic anomalies including #120, 124, 127, 128, and 136, and should be avoided by a distance of 1,000’. Sonar target no. 7 may represent a disarticulated shipwreck or ballast pile. (Evans et al 2007 Appendix F:3)

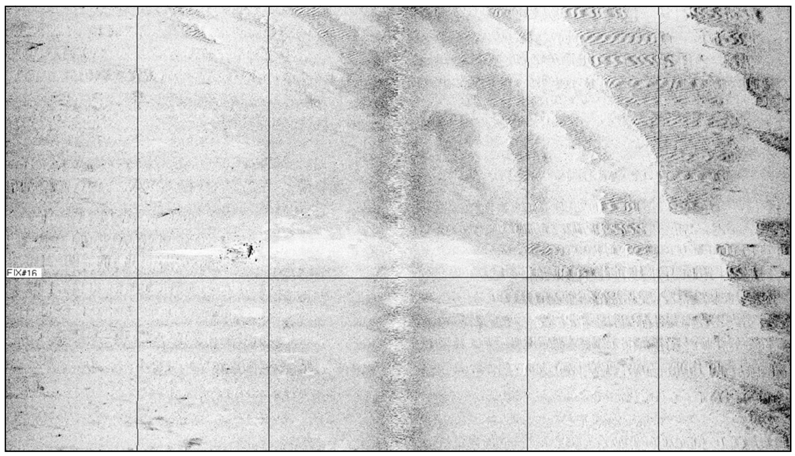


Figure 3.11.1. 410 kHz side scan sonar image of target No. 7 from survey Line 88. Oriented west up (Evans et al. 2007).

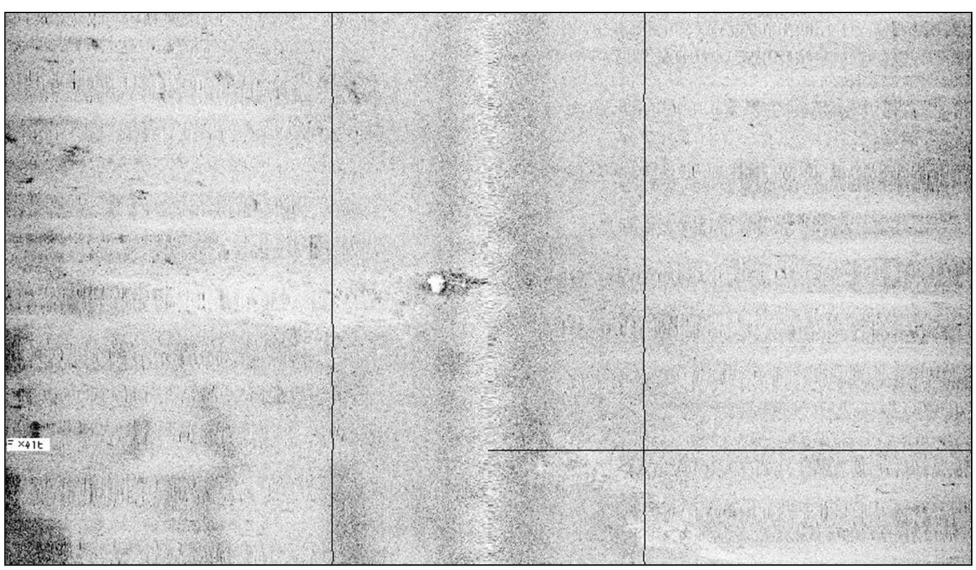


Figure 3.11.2. 410 kHz side scan sonar image of sonar target No. 7 from survey Line 89. Oriented west up (Evans et al. 2007).

Additional geophysical data acquisition was not part of the current contract; however, Tesla Offshore was contracted by an operator to conduct a subsequent survey over this area following 2010 field study operations. The field-investigated target was "boxed–in," providing supplemental high resolution sonar data over the site. The new sonar imagery indicated that only a rectangular target was evident, measuring 5.5 m (18 ft) by 1.8 m (6 ft) and sitting 1.2 m (4 ft) above the seafloor (Evans and Bronikowski 2010). The 2010 survey report referred to the field-investigated feature as Sonar Target No. 9. Although it is possible that the site has been altered by hurricane or anthropogenic processes, a re-examination of the 2005 data suggests that areas of dense seafloor texture, immediately apparent on the higher resolution 2010 data, may have given the incorrect impression of a multi-component site.

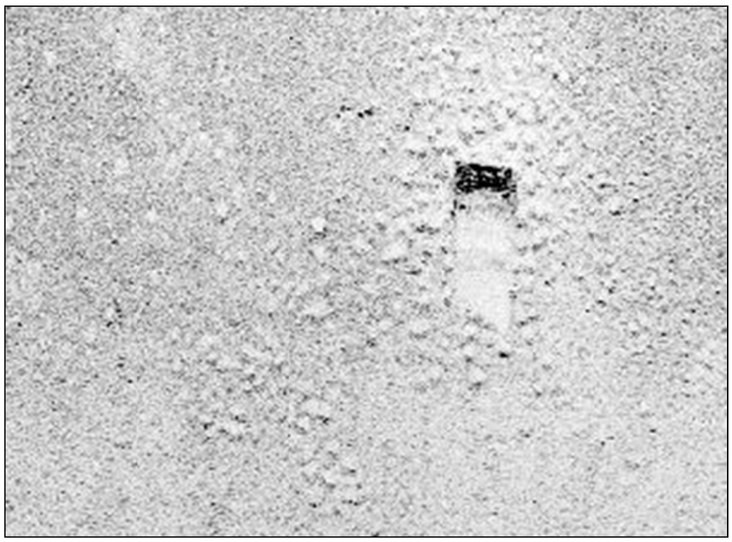


Figure 3.11.3. 410 kHz sonar image of sonar target No. 9 from survey Line 20. Oriented north up (Evans and Bronikowski 2010).

As of 2011, the area surrounding the site is a designated sand resource extraction zone based on unpublished, revised boundaries dictated by the BOEM[2]. According to NTL 2009-G04, no bottom-disturbing activity that will last longer than 180 days (such as the installation of a platform or pipeline) can take place within a designated sediment resource area. This regulation precludes both the practical extraction of oil and gas as well as the installation of pipelines.

The primary threat to archaeological resources in this area will not be new oil and gas development, but sand extraction. The closest existing infrastructure to the target is a 6" pipeline installed in April of 2011 located a minimum of approximately 1,890 m (6,200 ft) to the NE. A pipeline assembly is located approximately 2,995 m (9,822 ft) to the west and a platform with associated pipelines is located 4,595 m (15,072 ft) to the east.

2 The published Sabine East OCS Sediment Resource Area lies just west of the site (NTL 2009-G04). Based on correspondence with BOEM, this zone has been extended to encompass the site.

3.11.2 Diving

Diving operations at this site took place on August 22, 2010 from the M/V *Spree*.

- Average recorded water depth: 9.75 m (32 ft).
- Total bottom time: 10.68 total dive hours. Average dive time: 30.52 minutes.
- Visibility: 0–0.5 m (0– ~1.5 ft).

The sector scanning sonar was deployed upon arrival on site. Sector scanning sonar set at a 45-m range (150-ft) imaged a relatively featureless seafloor with a single unidentified object toward the outer extent of the data. This object appeared to be rectangular in shape with protrusions extending past each end in opposite directions.

Divers located the site through circle searches in near-zero visibility. They encountered a heavily concreted structure, projecting approximately 1.2 m (4 ft) above the seafloor. After securing a descent line and buoy to the target, dive teams began exploring the site. Teams conducted probing and metal detector surveys around the object, while other archaeological divers recorded the structure. The primary target is a rectangular-shaped feature, measuring 3.6 m (11.5 ft) in length and 88 cm (2.9 ft) in width. The object sits 1.2 m (4 ft) above the seabed at the highest point. Internal levers and a possible concreted winch drum are integrated into the object. Metal sheeting extends along the object into the seafloor. Divers observed one area where the metal sheeting curves back up out of the seafloor; minimal hand fanning indicated that the curved object was attached to the main feature but buried under several cm of sandy sediment. Including the sheeting and the main rectangular component, the object is 4.1 m (13.5 ft) in width (Figure 3.11.4).

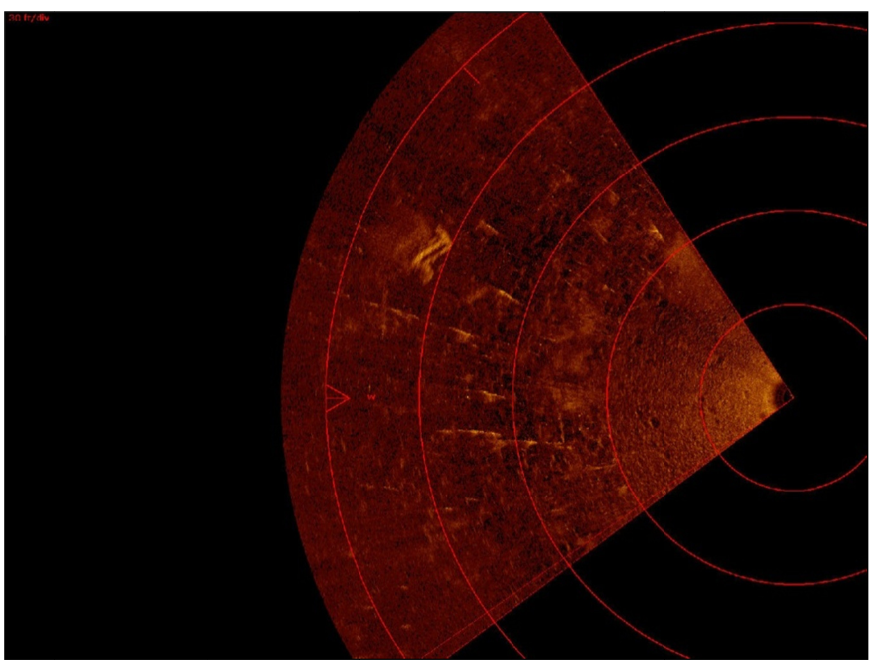


Figure 3.11.4. Sector scan highlighting unidentified object.

Magnetic readings extend several meters in every direction from the central structure, and divers recorded “hits” in an area extending 2 m (6.5 ft) to the north, 3 m (9.8 ft) to the south, 7 m (22 ft) to the east, and 2.5 m (7.5 ft) to the west. Based on the diver observations, it was determined that the object was heavy machinery associated with industry activities, likely oil and gas or fishing.

3.11.3 Site Environment

Because of the absence of any archaeological materials, neither sediment cores nor water samples were collected at this site. It was decided in the field that the resources required to analyze samples from this site would be better used on the remaining study sites. Therefore, no information is available for sediment stratigraphy, grain size, radioisotope, or shear strength in this area.

4. HISTORICAL SIGNIFICANCE

4.1 Regional Expectations for the GOM

The Gulf Coast region has experienced steady maritime traffic for the last four hundred years. Documented shipwrecks along the Texas and Louisiana coasts include a diverse array of vessel types, ranging from sailing vessels, to steamships, to modern crew boats. In a study funded by MMS (now BOEM) for the purpose of researching site expectations throughout the GOM region, Garrison et al. (1989) divided shipwrecks of the northern GOM into five distinct cultural and chronological periods: New Spain Period, 1500 to 1699; Colonial Period, 1700 to 1803; American Period, 1803 to 1865; Victorian Period, 1866 to 1899; and the 20th century, 1900 to present. The periods of exploration and early settlement were characterized by the Spanish, French, and English ventures, each of which contributed to the composition of the Gulf Coast region. Settlers in the GOM region depended on ships and boats for transportation of people and supplies, and wrecks of numerous nationalities are located in this region. As maritime transportation and travel escalated and evolved, so did the network of routes used by these vessels.

Beginning in the 16th century, the GOM was heavily traveled as part of the primary trade routes between Europe and the Spanish Main. Ships exploited a steady pattern of wind and water currents to travel across the Atlantic Ocean. Seasonal winds known as trade winds created a reliable sailing route for ships traveling from the west coast of Africa into the Caribbean Sea, the Antilles and, ultimately, the GOM. Blowing westward across the Atlantic for 300 days of the year, trade winds maintained a near-constant speed, and rarely exceeded 14 knots, creating ideal sailing conditions (Greenwood 1991:13). Trade winds influenced early sailing routes, and mariners capitalized on both surface winds and a reliable series of ocean current regimes. The North and South Equatorial currents merge in the Atlantic to flow westward into the southern Caribbean, fluctuating between speeds of five and eight knots. Hurricanes typically follow this same pattern. Once on the leeward side of the Lesser Antilles, vessels are sheltered from trade winds and make use of a system of predictable water currents. These currents flow clockwise, following first the South and then Central American coastlines until passing through the Yucatan Channel (Greenwood 1991:13). At the Yucatan Channel, the powerful Gulf Stream flows from west to east along the Gulf Coast, carrying ships towards the Florida Straits and back out into the open Atlantic, where strong eastward winds called westerlies aid ships sailing out of the GOM to Europe (Greenwood 1991:13). Caribbean hurricanes generally form in the Atlantic Ocean, near the Cape Verde Islands off the West African coast, exhibiting an average diameter of 600 km to 800 km (372 to 497 miles), and move at a relatively low rate of speed (Bolay 1997:65).

During the age of sail, the persistence of favorable wind and current regimes facilitated the establishment and growth of coastal ports along the northern GOM. Steady increases in ship traffic resulted in an increasing frequency of shipwrecks throughout the region. Known sites representative of each time period have been identified throughout the GOM, from the sixteenth to the twentieth centuries.

The oldest wrecks found in the GOM region are located off Padre Island, Texas. In 1554, four Spanish vessels set sail from San Juan de Ulua, Mexico for Havana, Cuba, and ultimately Europe. These vessels had no intention of nearing the Texas coast, but three of the four ships were blown off course or attempted to outrun a storm and consequently ran aground on the shoals near Padre Island, Texas (Francaviglia 1998:44). Remains of the three wrecked vessels, *Santa Maria de Yciar*, *San Estéban*, and *Espíritu Santo*, were uncovered by Hurricane Carla in 1961; these are three of the earliest wrecks to be located and excavated in the New World (Arnold and Weddle 1978). A second set of 16th-century wrecks is located on the eastern side of the GOM. The Emanuel Point wrecks are artifacts of Don Tristan de Luna's failed attempt to colonize Florida in 1559 (Smith at al. 1998; Smith et al. 1999; Cook 2009).

Following these early Spanish wrecks are examples from each subsequent century, as exploration expanded and shipping became more established in the GOM. The 17th century is represented by a French colonial wreck, the 1686 site of *La Belle* in Matagorda Bay, Texas. The ship was part of the fleet under the command of French explorer Rene Robert Cavelier Sieur de la Salle during his attempt to relocate the mouth of the Mississippi River, and also demonstrates French encroachment into the predominately Spanish region (Bruseth and Turner 2005; Francaviglia 1998). Eighteenth-century wrecks in the GOM include *El Nuevo Constante*, one of two Spanish vessels lost in a hurricane in 1766 off the coast of Louisiana while traveling from Mexico to Spain (Pearson and Hoffman 1995).

The Mardi Gras shipwreck dates to approximately 1815 and holds the distinction of being one of the first scientifically excavated deepwater wrecks (Ford et al. 2008). Commercial shipping was aided in the 19th century with the development and increasing availability of steam-powered vessels. The mid to late 19th century ushered in an era of rapid port development and expansion across the GOM. New York venture capitalist Charles Morgan expanded his New York–New Orleans shipping empire by linking small ports of the Texas Gulf Coast with New Orleans, creating a "triangular" trade route (Francaviglia 1998:128). Sidewheel steamships were well suited to the conditions found along the Gulf Coast, and steamship commerce was successful in large part because of their unique construction. By 1838, regular steamship service operated between Texas and New Orleans.

Despite the growing popularity of steamships, sailing sloops and schooners comprised the bulk of all vessels operating in and out of the GOM in the mid-19th century. Vessels carried a diversity of cargo, as illustrated by the manifest of the ship *Maria*, sailing from New Orleans to Matagorda, which included "corn, flour, sperm candles, tobacco, starch, hardwood, sewing items, spices, medicines, cowbells, molasses, hardware, fancy goods, crockery, shoes, hats, and dry goods (Francaviglia 1998:141-142)." Maritime commerce continued to increase along the Gulf Coast with the inclusion of transoceanic ships, Atlantic freighters, and river steamships (McAlister 1993:63). Additionally, improvements were made in maritime infrastructure to support the increasing numbers of vessels operating across the coast. In addition to shipping, the shipbuilding industry prospered along the Gulf Coast.

Continuing into the 20th century, shipping vessels continued to diversify. Wooden vessels began to be replaced by larger metal-hulled ships, especially tankers and refrigerated cargo vessels. Commercial sailing ships and steam-screw engines were largely replaced by oil- and diesel-screw ships. Today, vessels commonly used in the GOM include shrimp boats, commercial fishing vessels, tow vessels, and specialized industrial boats, such as pipelay barges, dive boats, crew boats, and drilling rigs. Modern shipwrecks also include recreational vessels, such as sail boats, catamarans, charter fishing boats, and other small craft.

The GOM has also been an active theater of war. During the mid-19th century, the GOM region proved strategically important during the Civil War as Union blockades attempted to shut down Confederate commerce and prevent the transportation of goods and troop supplies. In the 20th century, World War II brought German U-boats into the GOM. Over approximately 18 months between 1942 and 1943, U-boats disrupted trade and commerce, attacking a total of 116 vessels from Texas to the eastern Florida coast, and as far south as Cuba and Honduras (Wiggins 1995:114-115). The hulls of vessels attacked during the U-boat campaign litter the seafloor, along with one German U-boat.

Shipwrecks included in this study span three general time periods: the Civil War-era, World War II, and the era of modern Gulf Coast industry and commerce. Each of these periods has specific vessel types and is related to unique events important in U.S. history.

4.1.1 Civil War Era

During the American Civil War, Union and Confederate forces fought for control over the various ports of the GOM. Specifically, the ports of New Orleans and Galveston were coveted for their economic and regional importance. After forming as a state, Texas sided with the South in the Civil War. As part of the Confederate States of America, the port of Galveston was blockaded early in the war by Union Naval vessels. Galveston was the largest city in Texas at the outbreak of the Civil War, with a population of over 7,500; the Union blockade slowed commercial traffic and slowly squeezed the economy of the entire state (Francaviglia 1998:194). Evidence of the multiyear Union blockade and the Battle for Galveston is found near present-day Galveston, in the form of Confederate Blockade runners (such as *Denbigh* (41GV143) and *Will of the Wisp* [41GV90]) and Union gunships (such as *Westfield* [41GV151]).

The city of Galveston was surrendered to Union forces on October 4, 1862, but was soon retaken by the Confederates. On New Year's Day, 1863, General Magruder's Confederate forces successfully reclaimed Galveston after defeating the Union gunships *Westfield* and *Harriet Lane* (Underwood 2003:84-91). Union naval forces were sent to protect the city against attack, including the vessel *Brooklyn*, commanded by Commodore H.H Bell, and six other gunships. As discussed in Chapter 3, shortly after it arrived off of Texas, the USS *Hatteras* engaged the Confederate raider CSS *Alabama* and was sunk offshore of Galveston Island. The sinking of *Hatteras* was important in reducing the Union's ability to re-take Galveston and all but eliminated their plan to push further into the interior of Texas (U.S. Naval War Records 1895; 2003 [1921]; Snyder 1938).

4.1.2 World War II

In early 1941, the U.S. was not an active participant in World War II, but it was peripherally involved through the Lend-Lease Act, supplying oil and gasoline to Great Britain (Morison

1970:37). Increased supply to overseas markets resulted in oil and gasoline shortages in the U.S., and necessitated domestic increase in production capacity (Wiggins 1995:13). This increase in production required an increase in shipping to transport oil and gas products to inland and overseas markets. In the early 1940s, approximately twenty percent of all tankers in the U.S. were put into service supplying oil and gas to Great Britain, and the remaining domestic tankers were altered to increase their capacities in an attempt to meet the growing demand for fuel (Wiggins 1995:14). Tankers were of paramount importance to the war effort. Plans to build an interstate oil pipeline from Texas to Philadelphia and New York, and a smaller pipeline from Louisiana to North Carolina, were canceled with the formation of the Supply Priorities and Allocations Board (Wiggins 1995:14). According to Rear Admiral Emory Land, too much steel would need to be diverted from naval uses to build the pipelines: “I’d rather build tankers than pipelines. If that’s not satisfactory, I’d rather build barges. I don’t know where they can get 750,000 tons of steel, but if it’s coming from the navy or our ships, I’m against it” (Wiggins 1995:14). The cancellation of the proposed pipelines meant that the majority of the U.S. oil and gas supply was transported by ships.

The U.S. officially entered World War II when Congress declared war on Japan on December 8, 1941, following the attack on Pearl Harbor (Morison 1970:114). Germany, in turn, declared war on the U.S. on December 11, and quickly began operations against U.S. interests (Morison 1970:114). The first German U-boat attack in U.S. waters took place on January 14, 1942, when *U-123* sank *Norness*, a Panamanian tanker, 97 km (60 miles) from Long Island in the Atlantic Ocean (Rohwer 1983:74; Wiggins 1995:16). During the next two years, the Gulf Front was patrolled by U-boats whose mission was to disrupt transportation of wartime fuel and supplies to Allied forces. The first known German submarine in the GOM was *U-507*, which attacked and sank *Norlindo*, on April 30, 1942 (Wiggins 1995:22-24). *U-507* was almost immediately joined in patrolling the GOM by *U-506*.

A total of 70 ships were attacked in the GOM by 24 U-boats that patrolled its waters during 1942 and 1943 (Rohwer 1983; Wiggins 1995). Of the 70 recorded attacks, 56 resulted in the sinking of the ship and the remaining 14 sustained damage, but were not sunk (Wiggins 1995). During this tense time in the GOM, Merchant Mariners and the Naval Armed Guard were the frontline defenders of Allied vessels. Coastal defense was further bolstered by a mandatory dim-out order issued to combat the rising U-boat threat. The dim-out began in Galveston on June 1, 1942, and on June 2 was expanded to include most of the Texas and Louisiana coastlines (Wiggins 1995:88). The purpose of dimming coastal lights was to prevent artificial light from silhouetting ships, which made them visible to U-boats and therefore vulnerable to attack. The dim-out along the Gulf coast was lifted in November of 1943 after the threat was observed to wane as a result of the effectiveness of armed convoy travel and other antisubmarine tactics (Wiggins 1995); as also, the construction of the “Big Inch” pipeline from Texas to New Jersey reduced the need for oil transport by tanker (Irion 2000:145).

4.1.3 Industry and Commerce

Vessel types typical of the past two centuries range from vernacular craft to international ships with functions that include fishing, commercial transport, military use, and, more recently, oil and gas-related vessels and personal pleasure craft. The ports of the GOM served as a backdrop to commerce and trade bolstered by various burgeoning industries. Settlers found the wealth of cypress and oak forests of Louisiana beneficial as both building materials and trading exports. Rafts were used to transport lumber and moss to market and major exports of sugar, cotton, and tobacco were shipped to the wider markets of Europe. According to Terrell (1990), despite the abundance of local fauna, early fur trading in the area focused on exports traveling down river from Canada. In Louisiana, the fur industry and fishing commerce did not fully develop until the 19th century (Terrell 1990). River and coastal commerce thrived before the advent of inland railway systems and interstate roadways of the 20th century (Terrell 1990).

Oil and gas exploration and development are crucial in the economy, cultural, and social fabric of the Louisiana and Texas Gulf Coast. The evolution of this industry came about as industry pioneers moved from drilling on land to drilling in marshes and shallow water environments in the late-19th and early-20th centuries, and then eventually moved out into the open waters of the GOM. The first oil well drilled in Louisiana on land was in 1901. The first offshore fixed platform wells and the first wells drilled out of the sight of land was offshore of Louisiana in the Ship Shoal area in 1947 (BOEMRE 2011; NOIA 2011). By the 1930s and 1940s, mobile drilling units moved across the Louisiana and Texas coasts and, before long, coastal exploration expanded further seaward (Austin et al. 2008).

Oil and gas production began to grow throughout the Gulf Coast, evolving from a specialized industry to become the backbone of the regional economy. World War II activities in the GOM restricted the growth of the offshore industry, but the end of the war signaled the start of an industrial boom. The increase in offshore technological development was aided by the availability of surplus war materials. Items originally intended for the war effort found other applications in this growing industry as they were auctioned off following the end of the war (William Bisso 2011, pers. comm.). Today, the oil and gas industry in the GOM consists of a massive landscape of infrastructure, including abandoned and extant wells connected to the onshore processing centers through a complex network of pipelines and cables. The industry has developed into a steadfast economic and cultural force in the region bringing with it fleets of task-specific vessels. Today, oil and gas exploration is one of the largest industries in offshore areas throughout the world, from the North Sea to West Africa to Brazil. The formative stage of this massive global industry can be traced to the earliest innovators offshore of Louisiana and Texas.

The modern maritime landscape includes not only oil and gas associated vessels, but numerous and varied ship types that exhibit new innovations in equipment, propulsion, and even composition. Historically, fishing has been an important economic driver for the Gulf Coast. The various types of fishing vessels active in the central GOM include trawlers, oyster dredges, menhaden purse seiners (commonly referred to as pogy boats), and pelagic or demersal fishing vessels (Sainsbury 1986). In 1937, commercial trawlers were introduced to Louisiana to begin harvesting newly-discovered shrimp populations in the GOM. The first trawlers were South Atlantic-style vessels used off the coast of Florida. These vessels were quickly adapted by Louisiana and Mississippi fishermen who called the vessels “floridiane trawlers” because of their Florida origins (Center for Traditional Louisiana Boat Building 2007). Early shrimp trawlers were constructed of wood with deep, soft-chined hulls (Brassieur 2004). Trawlers used in the GOM were distinct from other trawlers used in and around the U.S. because of their forwardcabins or wheelhouses. Early-style trawlers, such as the South Atlantic and Floridiane, are still built and used by Louisiana shrimpers in the offshore GOM region. Although ancillary components, such as engines, navigation equipment, buoys and other fishing gear, may have changed, the overall shape of the vessel has remained static.

According to Sundstrom's (1957) classification system, large trawlers in the GOM region could be constructed of either steel or wood. Steel was not generally used in ship construction until the Bessemer process was developed in 1856. The use of steel became more common in the 1880s, but did not become commonplace until the 20th century. The earliest shrimp trawlers in coastal Louisiana were made from wood, and some continue to be made this way today. Wooden-hulled vessels can date to virtually any time period, but construction techniques and the condition of the wood can provide a good indication of temporal association. A few boat builders in coastal Louisiana continue to build wooden-hulled trawlers for use in the GOM, but metal-hulled trawlers are much more prevalent (Brassieur 1989).

4.2 ARCHAEOLOGICAL AND HISTORICAL ANALYSIS OF STUDY SITES

4.2.1 Site No. 380, South Pelto Area, Reported Wooden Wreck

In a study prepared for MMS, Pearson et al. (2003) developed a probability model for historic shipwreck occurrence throughout the GOM, designating certain areas within federal jurisdiction as having a higher probability than others based on variables such as location to historic shipping routes and reported hangs, obstructions, and vessel losses in the area. Based on that probability model, site no. 380 is located within an area deemed to have a high probability for shipwreck occurrence. Coastal Environments, Inc., (1977) published the location of major historic shipping routes used from the 16th through 20th centuries. These maps show that Site 380 was landward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977; Plate 6), and in close proximity to coastal sailing routes used during the 18th and 19th centuries (CEI 1977; Plates 7 and 8). Site 380 is completely unidentified, but, based on its location in relation to these historic shipping routes, it is possible that the vessel could be associated with coastal sailing routes from the 18th and 19th centuries. The site is not located within any major shipping routes used during the first half of the 20th century, but would have been along the most common route for vessels traveling inland into areas surrounding Houma, Louisiana (CEI 1977; Plate 9).

A comprehensive list of 55 wrecks within 48 km (30 miles) of Site 380 was compiled to ascertain the identity of the reported wooden wreck. Of these reported wrecks, lengths and/or gross tonnage were available for 49 of them. Known shipwrecks in the general vicinity appear to be primarily modern vessels probably related to either the oil and gas or fishing industries; some of these wrecks may be historically significant. Shipwrecks reported within 48 km (30 miles) of the study site with similar published dimensions or features to those reported by NOAA are detailed in Table 4.1.

Table 4.1

Reported Shipwrecks in the Vicinity of Site 380 with Similar Dimensions

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
Carl Tide	184	106.2'	22.2'	December 18, 1965	Tow service
Sargent		112’		1985	Motor vessel
Jake (3)	88	86’	24’	1985	Motor vessel
Miss Four Hundred	65	61.6’	18.4’	January 5, 1969	Wooden fishing vessel
L & L	38	47.8’	18.1’	January 26, 1969	Wooden fishing vessel

Measurements are taken from Merchant Vessels of the U.S. (MVUS).

Of these vessels, *Miss Four Hundred* and *L&L* are reported to be wooden ships, although they are both much smaller than the dimensions recorded for the study vessel listed in the NOAA AWOIS record. The vessels *Sargent* and *Carl Tide* are the only wrecks with available dimensions that fit within the general reported dimensions of the unidentified wooden wreck. The composition of these two vessels is unknown. *Sargent* has the closest dimensions to the 36.5 m (120 ft) by 5.5 m (18 ft) reported in the NOAA database. This vessel sank in 1985; the date of construction is unknown. The NOAA record for Site 380 is fairly limited and does not give any indication about the condition or age of the reported wooden shipwreck. Although wooden construction is often indicative of a historic shipwreck, wooden-hulled vessels are still built today (Section 4.1.3).

For the majority of human maritime history, wood was the most common building material for ocean-going vessels. Wooden shipbuilding declined in the late-19th century when old growth timber supplies became scarce and iron and, later, steel production were industrialized. Wooden shipbuilding came back into fashion for a short time during World War II due to steel shortages (Christensen and Angerer 1977). Today, although composite materials are the most common for hull construction, some shipyards still build wooden-hulled vessels for recreational, commercial, and even military applications (Christensen and Angerer 1977; Brassieur 1989).

No evidence of a sunken wooden ship was evident within the area inspected by divers. The objects identified on site were not indicative of a historic shipwreck. It appears that either the coordinates for the wreck site supplied in the NOAA database were incorrect, or the wreck is no longer present at this location. If the published coordinates are incorrect, it is likely that they are off by more than 300 m (~1,000 ft). The geophysical data indicates that although scattered magnetic anomalies were identified within the survey grid, the majority of these were small or restricted to a single survey line. No sonar targets were apparent on the seafloor and no buried objects were identified on the sub-bottom profiler data. Multibeam data was also unable to identify any seafloor targets or structures. The only magnetic anomaly cluster was centered in the area investigated by divers. It is also possible that in the intervening time since 1994, when the NOAA AWOIS record was entered, the shipwreck designated as Site 380 was salvaged, possibly as a direct result of the diver investigation mentioned in the reference. The scattered objects, specifically the metal strap, appear to be the source of the magnetic anomalies at the site. These objects may have been intrusive and unrelated to a shipwreck, but it is possible that they are associated with a previously salvaged wreck site or salvage operations. If these objects were associated with the wreck, there is not enough material to determine the nature or construction of the vessel. If the wreck was salvaged, it most likely consisted of an intact hull. In this environment, because of wood-boring organisms and high energy dynamics, a wooden-hulled wreck would not maintain structural integrity for long. If an intact wooden wreck was salvaged at this location, it was likely a recent wreck that had not had time to experience significant deterioration.

4.2.2 Site No. 433, Ship Shoal Area, Probable *R.W. Gallagher*

Based on the probability model developed by Pearson et al. in 2003, the study site is located within an area considered to have a high probability for shipwreck occurrence. According to CEI (1977), Site 433 was seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), and in close proximity to coastal sailing routes used during the 18th and 19th centuries (CEI 1977: Plates 7 and 8). The site is not located directly within any major shipping routes used during the first half of the 20th century, but it is adjacent to routes running from Cameron, Louisiana, and Port Arthur, Texas, between the Straits of Florida (CEI 1977: Plate 9). Based solely on the wreck's location, the vessel is most likely associated with activities from the 18th century onward.

Based on the acquired geophysical datasets and diver investigations conducted in 2010, the study site is interpreted as a steel-hulled tanker or freighter with massive breaches in the hull; these are interpreted as torpedo holes. A total of 15 vessels of similar type and dimension were reportedly sunk by torpedo attack off the Louisiana coast during World War II. A comprehensive list of 55 vessels lost within a radius of 56 km (35 mi) was compiled and analyzed as potential candidates for the wreck at Site 433. Of these reported wrecks, details such as length and gross tonnage were available for 45 vessels. The size of the Site 433 wreck and the apparent torpedo holes indicated that the vessel was most likely the victim of a German U-boat attack. Of these, the vessels detailed in Table 4.2 have been selected as possible candidates for Site 433, based on their reported location at the time of sinking and their overall dimensions. The vessels *Sheherazade* and *R.M. Parker. Jr*. are located in the general vicinity of Site 433, but have been identified through a previous study and nominated for inclusion on the NRHP (Enright et. al. 2006).

Table 4.2

Reported U-boat Casualties in the Vicinity of Site 433

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
Ontario [1]	3009	292.2’	42.2’	May 7, 1942	Freighter
Gulfoil [2]	5188	383’	51’	May 16, 1942	Tanker
Heredia [2]	4732	378.8’	49.8’	May 19, 1942	Freighter
Hamlet [3]	6578	408.5’ (LOA)[7]	55.2’	May 27, 1942	Tanker
Cities Service Toledo [2]	8192	465.2’	60’	June 12, 1942	Tanker
Cities Service Toledo [5]		480’ (LOA)			
Rawleigh Warner [1]	3663	322’	46’	June 23, 1942	Tanker
Bayard [4]	2160	315.2’ (LOA)	44.3’	July 6, 1942	Passenger
R.W. Gallagher [2]	7989	445.4’	64.2’	July 13, 1942	Tanker
R.W. Gallagher [5, 6]		463’ (LOA)			

Sources: (1) BOEM Database, (2) MVUS (length on tonnage deck), (3) Kjærvik and Tandberg 1985, (4) Redaksjonen 2011, (5) Bethlehem Shipbuilding 1938, (6) Standard Oil 1946 (7) Length Overall (LOA).

The measured dimensions from the geophysics indicate that Site 433 measures approximately 140 m (458 ft) by 22 m (72 ft). Because the vessel is upside down and the top half is buried in the seafloor, it was not possible to obtain the overall length of the vessel from stem to stern. A transom stern appears to extend into the mudline, indicating that the overall length of the vessel at topsides may be slightly longer than the exposed portion. It is also possible that the large break in the hull could impact the accuracy of length overall measurements. Because much of the vessel appears to be listing to starboard and the upper portion of the hull is buried in the mudline, it is not possible to obtain accurate breadth measurements.

As discussed in Chapter 2, published measurements often vary because of differing reference points. The overall variability among these numbers can be as small as 3 percent and as large as 13 percent. This is based on a comparison of measurements from large World War II-era tanker and freighter class vessels for which length and breadth measurements were available using both length overall measurements and length on tonnage deck. Based on the measurements included in Table 4.2, *Cities Service Toledo* and *R.W. Gallagher* appear to be the only vessels in the same length class as Site 433. Both vessels also have similar breadths. Based on the results of the geophysics, it is apparent that Site 433 is not *Heredia* as was once postulated (Section 3.2.1), due in part to the 24-m (79-ft) difference in length and 3-m (10-ft) difference in breadth between Site 433 and the known dimensions of *Heredia*.

The published length overall measurement for *Cities Service Toledo* is 146 m (480 ft). Based on the geophysics, Site 433 is 6.7 m shorter (22 ft) and 3.7 m (12 ft) narrower than *Cities Service Toledo*. Site 433 measures 13.7 m (45 ft) longer and 2.4 m (8 ft) narrower than the MVUS dimensions for *R.W. Gallagher*, but there is only a 1.5-m (5-ft) difference in the published overall length. No other known wrecks are reported in this portion of the GOM with similar dimensions as the wreck at Site 433.

Overall dimensions taken from Tesla's geophysical data and observations made during the 2010 diver investigation were found to be consistent with known details of the *R.W. Gallagher*. The published length overall of *R.W. Gallagher*, 141 m (463 ft), is slightly longer than the 140 m (458 ft) measured from the geophysical data. Considering that a small portion of the transom stern appears to be buried in the mudline, these measurements appear to correlate very closely.

R.W. Gallagher was investigated in the 1980s by Avery Munson, and his observations of the wreck site were similar to those made during the 2010 dive investigation (Avery Munson 2011, pers. comm.). At the time of his investigations, Munson determined that Site 433 was the remains of *R.W. Gallagher* (BOEM Database 2011). During his years of researching World War II-era wrecks in the GOM, Munson obtained a copy of the plans for a class of vessels that included *R.W. Gallagher* from Bethlehem Shipbuilding before the company was sold in 2003. A copy of the plans was provided to the study by Mr. Munson and is included in Appendix E (Figure E-1). The plans are specifically for Esso hull no. 4306, but were duplicated and used for hulls no. 4307 (*R.W. Gallagher*), no. 4308, no. 4309, and no. 4349 (Bethlehem Shipbuilding 1938). After the sale of Bethlehem, company records were accessioned to the Hagley Museum and Library, including a table containing hull measurements and launching dates. A measured drawing of *R.W. Gallagher* was obtained from the William A. Baker Nautical Collection housed at the MIT Museum (Appendix E; Figure E-2).

R.W. Gallagher was a steel-hulled, steam-screw tanker built in 1938 by Bethlehem Shipbuilding Corporation of Sparrow's Point, Maryland, for Standard Oil Company of New Jersey (Department of Commerce (MVUS) 1942) as part of Standard Oil's "Esso" fleet (Figure 4.1). The vessel was built to operate as a crude oil tanker within Standard Oil's fleet and was one of five sister ships (Standard Oil 1946). *Esso Baton Rouge* (hull no. 4306), *R.W. Gallagher* (hull no. 4307), *Esso Baltimore* (hull no. 4308), and *Esso Charleston* (hull no. 4309) were all built from the same plan in 1938. *Esso Nashville* (hull no. 4349) followed in 1940. In an official number request that Bethlehem Shipbuilding submitted for the vessel on July 29, 1938, the vessel is described as having a plain head, elliptical stern, one deck, and two masts. Ship construction commenced on January 11, 1937, and the launch date was recorded as January 22, 1938. The 7,989 gross ton vessel reportedly measured 135.8 m (445.4 ft) in length on tonnage deck, 19.6 m (64.2 ft) in breadth, with 10.7 m (35.2 ft) depth of hold (Bureau of Marine Inspection and Navigation [BMIN] 1937; MVUS 1942). An overall length measurement of approximately 141 m (463 ft 1-1/4 in) was reported in a document detailing the Esso fleet published by Standard Oil in 1946 and was corroborated by the table acquired from the Hagley Museum and Library (Standard Oil 1946; Hagley Museum and Library Bethlehem Steel Collection). The vessel was likely named for Ralph W. Gallagher, Vice President and member of the Executive Committee of Standard Oil in 1937 (Larson et al. 1971).

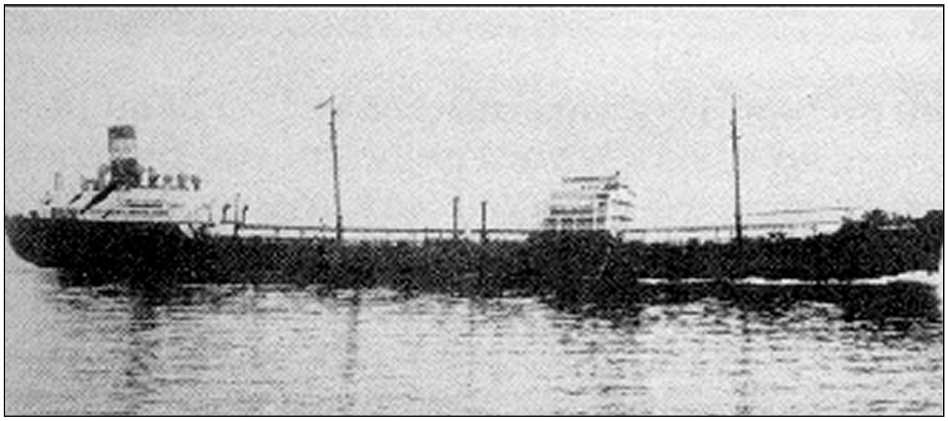


Figure 4.1. Photograph of *R.W. Gallagher* ca. 1938 (Standard Oil 1946:357).

On April 20, 1942, *R.W. Gallagher* was time chartered to the U. S. War Shipping Administration under contract no. WSA-2122-R (U. S. Maritime Commission [USMC] 1942b; Appendix E; Figures E-4-6). For the next two weeks, the vessel underwent arming and defense alterations at the Newport News Shipbuilding & D. D. Corporation in Norfolk, Virginia (Office of the Chief of Naval Operations [OCNO] 1942b; 1942f). When the vessel was released on May 4, 1942, it had been restructured to include accommodations for 16 armed guardsmen and one officer. The vessel had also been outfitted with degaussing equipment, a defense system used to alter the magnetic signature of a vessel as protection against magnetic mines planted by enemy forces (Bureau of Ordnance [BO] 1942) and repainted gray. The gray color scheme was standard for vessels operating under the authority of the U.S. Navy (Ole Varmer 2011, pers. comm.). Armament installed during the 1942 refit included: one 5-inch .51-caliber MK 7 Model 2 gun located C/L Aft; one 3-inch .23-caliber MK 14 gun located C/L Forward; two .50-caliber Browning machine guns located aft on both the port and starboard sides; and two .30-caliber machine guns located on the bridge deck, one each to the port and starboard (OCNO 1942b; 1942f).

Two months later, on July 13, 1942, under the command of Captain Aage Petersen, *R.W. Gallagher* was traveling from Baytown, Texas, to the Key West Anchorage in Point Everglades, Florida, carrying almost 81,000 barrels of bunker fuel oil, when she was struck by two torpedoes fired from *U-67* under the command of Kapitänleutnant Günther Müller-Stockheim (Henderson 1942; Rohwer 1983:109; Browning 1996:184). Both torpedoes reportedly struck *R.W. Gallagher's* starboard side, at the no. 3 cargo tank forward of amidships and the pumproom forward of the engine room (Henderson 1942). As the crew launched the undamaged lifeboats, the vessel reportedly listed to starboard and continued to burn before sinking. Survivor statements indicate that the degaussing equipment exploded upon torpedo impact (Henderson 1942). At the time of attack, seven lookouts were on duty. Survivors reported seeing the attacking U-boat surface as the vessel sank (Henderson 1942; Browning 1996:184). The survivors identified the submarine as *U-28* from the identification number painted on its conning tower (Henderson 1942). This conflicts with the U-boat records collected by Rohwer (1983) which indicates the vessel was attacked by *U-67*. According to the Standard Oil publication (1946), *R. W. Gallagher* was reportedly the sixteenth vessel in the Esso fleet lost as a casualty of war.

Of the 52 men aboard the vessel at the time of the attack, nine crewmen and one naval guard were lost in the sinking (USCG 1942-1944a). A total of 12 U.S. Naval Armed Guardsmen were on board the vessel during its final run (USCG 1942-1944a). The injured were reportedly taken to the Marine Hospital in New Orleans; one crew member reportedly died in the Marine Hospital in Baton Rouge (Henderson 1942; USCG 1942-1944a).

As stated above, the account of the sinking indicates that the vessel was struck by two torpedoes on the starboard side, at the no. 3 cargo tank and the pump room forward of the engine room. A site map based on the combined geophysical data and diving operations indicates that there are two large holes in the hull, both located on the starboard side of the wreck (Figure 4.2). The larger of the two is forward of amidships and the smaller is aft of amidships. Line drawings and site plans of *R.W. Gallagher* illustrate the location of these compartments (Appendix E; Figures E-1-2) and verify that the breaches in the hull of Site 433 match closely with these locations on the wreck. The vessel reportedly listed to starboard during sinking, which corresponds with the observed condition of the wreck on the seafloor.

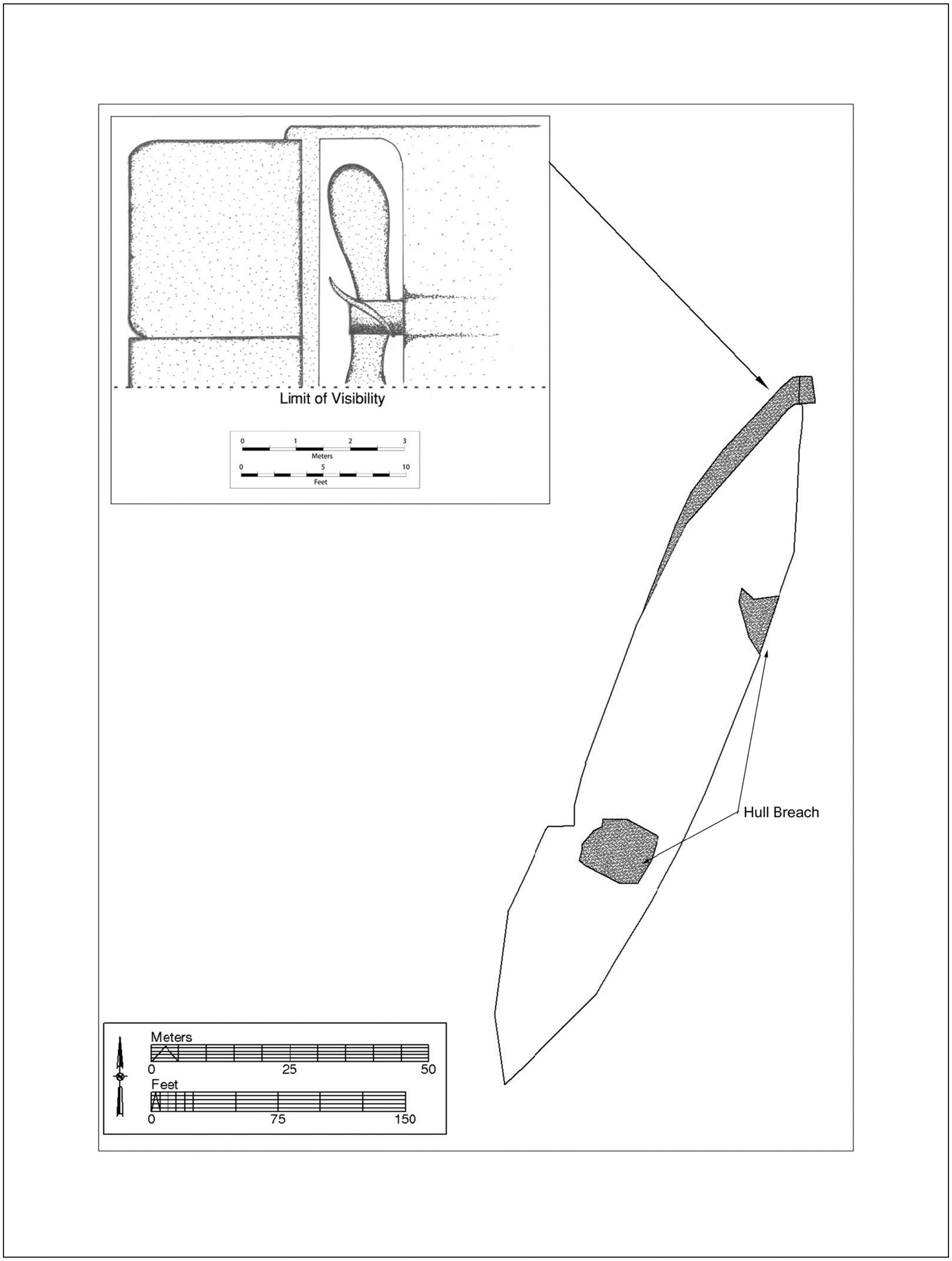


Figure 4.2. Site plan of Site 433, based on diver investigation and remote sensing data.

Two generally available primary sources contain location information for World War II casualties in the GOM. The first is the Navy's Summary of Statements by Survivors, prepared based on interviews conducted shortly after the sinking. The second source is the coordinates recorded by the German U-boat captains. Rohwer published locations from U-boat records in the German archives that describe the approximate coordinates for attacks based on the German map convention used in the GOM (Appendix D; Map D-3). Unfortunately, the published version of this map is small and does not provide a great deal of detail; however, it is still useful for estimating the approximate position of World War II torpedo victims. Rohwer also included coordinates that he reports as having come from "Allied Sources," but he does not elaborate on the source of that information (Appendix D; Map D-1). In some cases, Rohwer's "Allied Source" coordinates correspond with the Summary Statements locations, in some cases they correspond with the coordinates published in the MVUS publication, and in other cases they do not correlate with any source identified through this research.

There is a degree of variability in the reported positions of sinking for *R.W. Gallagher* (Appendix D; Map D-2). In the Navy's Summary of Statements by Survivors (Henderson 1942), the reported position for *R.W. Gallagher* when attacked falls almost directly between the location of Sites 433 and 386, falling approximately 3.5 km (2.2 miles) SSW of Site 433. The MVUS lists this same set of coordinates for *R.W. Gallagher* (1945).

Information archived by the Navy includes a document (Serial no. 19284) dated January 18, 1944, from Lieutenant Paul W. Kraemer (Kraemer 1944). This document, titled "R.W. Gallagher (Tk), Wreck no. 628, Determination of depth of water above the wreck of" reports that the shipwreck site was identified in 27.4 m (90 ft) of water. Significant oil slicks were present for several hundred yards north of the buoy that had been placed to signify the wreck's location. Divers investigated the wreck in order to attach marker buoys. They determined that the wreck was "turned over on her beam ends and well buried in the soft bottom." Soundings were then performed to verify that at least 15.2 m (50 ft) of clearance were available for navigation over the wreck. It was determined that a minimum of 18 m (59 ft) of clearance was present. Coordinates in this document are similar to those provided in the Summary Statement of Survivors account and put the wreck 1,341 m (4,400 ft) NE of the position published by Henderson and MVUS.

Based on the U-boat accounts published in Rohwer (1983), the position for *R.W. Gallagher* seems to plot in the general vicinity of Site 433. Rohwer (1983), however, provides a second set of coordinates for the wreck, which places the site in approximately 4.5 m (15 ft) of water near Ship Shoal. Rohwer does not cite the source for the second set of coordinates, instead simply referencing "Allied Sources." Map D-2 in Appendix D shows both the Rohwer and Henderson/MVUS positions for *R.W. Gallagher* in relation to Site 433. It should be noted that Rohwer (1983) states that all latitude-longitude coordinates are given in degrees minutes. This correlates with the convention used in U.S. government documents at the time, including the Summary of Statements by Survivors and MVUS publications. The coordinates given by Rohwer for *R.W. Gallagher* do not match any other coordinate identified through this research. Interestingly, if Rohwer's coordinates for the wreck are plotted as latitude-longitude decimal degrees instead of degrees minutes, they plot in close proximity to Site 433.

A more detailed account of *R.W. Gallagher*'s sinking is given by Captain Aage Petersen, and published in *Ships of the Esso Fleet in World War II* (Standard Oil 1946). This account indicates that the vessel was following a standard coastal route on course for the Ship Shoal Buoy (which was supposed to flash white). The buoy was not seen (the Captain later postulates that the U-boat may have extinguished its light), so the vessel continued on course toward the green Ship Shoal Wreck Buoy. As *R.W. Gallagher* approached the green Ship Shoal Wreck Buoy, the ship was attacked. Ship Shoal refers to both a drowned sand shoal that runs parallel to the Louisiana Coast in approximately 6.7 m (22 ft) of water and also to the federal oil and gas lease protraction that encompasses this portion of the GOM. Water depths over the shoal itself range from 3 to 4.8 m (10–16 ft). Numerous accounts of U-boat attacks are referenced in relation to the Ship Shoal Buoy (Henderson 1942; Powers 1942a; and Smith 1942). It is unknown if this buoy would have been located directly over the shoal itself, or further offshore closer to the locations provided by Henderson (1942), Kraemer (1944), and MVUS (1945). According to the U.S. Coast Pilot (U.S. Department of Commerce 1936), there were two navigation beacons in the vicinity of Ship Shoal at this approximate time. The first is Ship Shoal Lighthouse, which was located directly over the shoal in approximately 4.3 m (14 ft) of water. The lighthouse was reportedly visible from a distance of 19 km (12 miles). The second was Ship Shoal Lighted Whistle Buoy 2, located 29 km (18 miles) from the Ship Shoal Light at a bearing of 177 degrees (U.S. Department of Commerce 1936). The Lighted Whistle Buoy 2 would have been in close proximity to Site 433 and the coordinates for *R.W. Gallagher* published in Henderson and MVUS. If one assumes that Capt. Petersen was referring to the lighthouse and the Lighted Whistle Buoy, then his account correlates closely with Navy and MVUS coordinates for the wreck as well as the location of Site 433.

Site 433 lies upside down on the seabed; therefore, diagnostic elements are somewhat limited. *R.W. Gallagher* is known to have been an oil tanker built in 1938, with a single screw propeller. A single screw propeller was identified on Site 433. In addition to the measurements and observations at the vessel's stern, what has been identified as a bilge keel was recorded from diver observations. By the early- to mid-20th century, bilge keels were extremely popular for reducing rolling in vessels while at sea. Manning writes, in his 1942 *Manual for Ship Construction*, that bilge keels had been proven in this capacity, and "they are therefore fitted on practically all ships at the turn of the bilge, extending from 50 to 75 percent of the length of the hull…" (1942:75). The ubiquity of the bilge keel and the single screw do not provide enough evidence to conclusively identify the site alone. Figure 4.3 details the sterns of Sites 433 and 373 as recorded during diver investigation, and compares these details with the ship's plans acquired for the *R.W. Gallagher* hull type and *J.A. Bostwick* (*Cities Service Toledo*). The diver observations support the identification of Site 433 as *R.W. Gallagher*, based on the straight transition from keel to propeller well and the observed shape of the rudder. What was left at Site 373 indicates that the propeller well was curved, corresponding with the detailed plans acquired for *J.A. Bostwick*. Both vessels underwent refits after their initial construction, but there is no evidence that the rudder and propeller assemblies and stern hull shapes were altered and so can be used as identifying details.

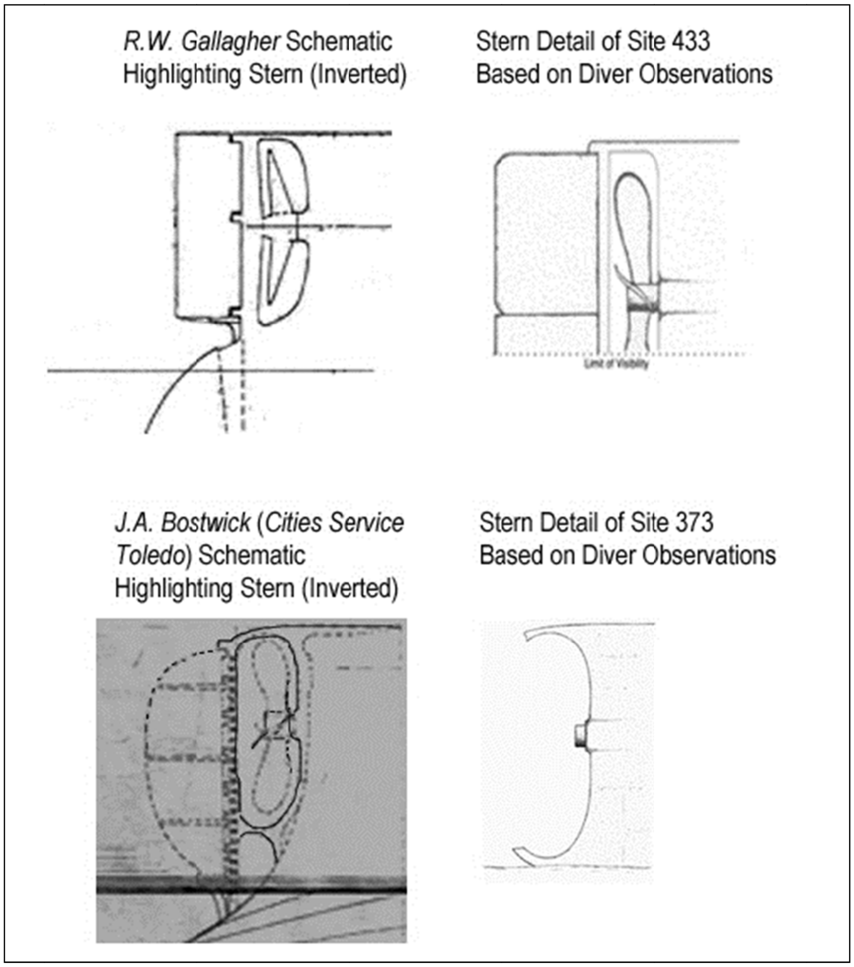


Figure 4.3. Stern assemblage of Sites 433 and 373, based on diver observation, compared with stern assemblage of *R.W. Gallagher* hull type and *Cities Service Toledo Plan.*

The account of sinking, the reported coordinates of attack, the correlation of the stern assemblage with the ship's plans, and the overall dimensions all support the identity of Site 433 as *R.W. Gallagher*.

4.2.3 Site No. 386, Ship Shoal Area, Probable *Heredia*

Based on the probability model developed by Pearson et al. in 2003, the study site is located within an area considered to have a high probability for shipwreck occurrence. According to CEI (1977), Site 386 was seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), and in close proximity to coastal sailing routes used during the 18th and 19th centuries (CEI 1977: Plates 7 and 8). The site is not located directly within any major shipping routes used during the first half of the 20th century, but is adjacent to routes running from Cameron, Louisiana and Port Arthur, Texas to the Straits of Florida (CEI

1977: Plate 9). Based solely on the wreck's location, the vessel is most likely associated with activities from the 18th century onward.

Site 386 has been tentatively identified as the SS *Heredia*. The reported location of *R.W. Gallagher* lies approximately 6.18 km (3.84 miles) to the north; no other reported shipwrecks are located in the immediate area. Based on the acquired geophysical data and diver investigations conducted in 2010, the study site is interpreted as an upright steel-hulled ship with severe site disarticulation. A comprehensive list of 55 reported wrecks within 56 km (35 miles) of Site 386 was compiled and analyzed as a starting point for identifying the wreck. Of these reported wrecks, details, such as length and gross tonnage, were available for 45. The number of similarly-sized vessels that are reported to have sunk in this part of the GOM is limited and virtually all were victims of German U-boat attacks during World War-II; a total of fifteen comparable vessels were identified (Appendix D, Map D-1). The following table details World War II-era casualties of German U-boats that have been selected as possible candidates for Site 386, based on their reported location of sinking and their overall dimensions. The vessels *Sheherazade* and *R.M. Parker. Jr*. are located in the general vicinity, but have been identified through a previous study and nominated for inclusion on the NRHP, and have therefore been excluded as possible candidates for Site 386 (Enright et. al. 2006).

Table 4.3

Reported U-boat Casualties in the Vicinity of Site 386

Vessel Name	**Gross Tonnage**	**Length**	**Breadth**	**Date of Sinking**	**Vessel Type**
Ontario [1]	3009	292.2'	42.2'	May 7, 1942	Freighter
Gulfoil [2]	5188	383'	51'	May 16, 1942	Tanker
Heredia [2]	4732	378.8'	49.8'	May 19, 1942	Freighter
Hamlet [3]	6578	408.5' (LOA)	55.2'	May 27, 1942	Tanker
Cities Service Toledo 2	8192	465.2'	60'	June 12, 1942	Tanker
Cities Service Toledo [5]		480' (LOA)			
Rawleigh Warner [1]	3663	322'	46'	June 23, 1942	Tanker
Bayard [4]	2160	315.2' (LOA)	44.3'	July 6, 1942	Passenger
R. W. Gallagher [2]	7989	445.4'	64.2'	July 13, 1942	Tanker
R. W. Gallagher [5,6]		463' (LOA)			

Sources: (1) BOEM Database, (2) MVUS (length on tonnage deck), (3) Kjærvik 2011, (4) Redaksjonen 2011, (5) Bethlehem Steel Collection courtesy of Hagley Museum & Library, (6) Standard Oil 1946.

The combined geophysical data over Site 386 indicates that the wreck measures between 112 m (367 ft) and 119 m (390 ft) in length, with an estimated breadth of 19 m (62 ft). Based on the combined sonar and multibeam bathymetry data, it appears that a portion of the vessel's stern has broken off and lies virtually flush with the seabed. This debris scatter is irregular and makes it difficult to obtain a precise measurement. It appears that the 119 m measurement is a more accurate assessment of the vessel's original overall length. Because the vessel is listing to starboard and appears to have been heavily damaged, there is no way to obtain a precise measurement of the vessel's breadth.

Table 4.3 indicates that vessels in the same class as Site 386 are limited to *GulfOil*, *Hamlet*, and *Heredia*. Measurements for *GulfOil* and *Heredia* are length on tonnage deck, so it is likely that both ships are an estimated 3-14 % longer than the published dimensions; published length for *Hamlet* is length overall and should correlate directly with observed overall measurements from geophysical data.

Based on Rohwer's (1983) coordinates (Appendix D; Map D-1), *Hamlet* was sunk in the Eugene Island federal lease protraction in approximately 42.6 m (140 ft) of water. *Gulf Oil* was lost in the Mississippi Canyon lease protraction in over 300 m (1,000 ft) of water (Rohwer 1983). A wreck was located at a depth of approximately 610 m (2,000 ft) and identified as *GulfOil* during the *Lophelia* deepwater studies commissioned by MMS (later BOEMRE, now BOEM) (BOEMRE 2010). *Hamlet* has been tentatively identified by a geophysical lease survey 40 km (25 mi) ESE of Rohwer's published coordinates (BOEM database 2011). The BOEM database indicates that, based on sonar data, the length of the wreck was 152 m (500 ft). This length is inconsistent with information obtained for *Hamlet*, which indicates that the vessel was 124.5 m (408.5 ft) in length overall (Kjærvik and Tandberg 1985).

Before investigation in 2010, Site 386 was tentatively identified as the freighter *Heredia*, based on Avery Munson's communications with MMS (BOEM database 2011). Although the vessel could not be comprehensively investigated by divers during the course of this study, the reported location of sinking, overall measurements, vessel shape, and visible diagnostic components observed on geophysical data were found to be consistent with those of *Heredia*.

Heredia was built in 1908 by Workman, Clark & Co., in Belfast, Ireland, for the UK Tropical Steamship Company, a subsidiary of United Fruit (Goldberg 1993:332). The 4,943 gross ton passenger liner reportedly measured 115.5 m (378.8 ft) in length, 15.2 m (49.8 ft) in breadth, with a 9 m (30 ft) depth of hold (MVUS 1942; Figure 4.4). She was built as part of the "Great White Fleet" of passenger liners (Appendix E; Figures E-16-17). The triple deck, steel-hulled, steam screw-propelled vessel was fitted with a triple expansion engine and a refrigerated cargo compartment. During a run in 1909, *Heredia* ran aground off the coast of Nicaragua and could not be extricated from its position for about a month and a half (Goldberg 1993:333). Following the incident, the passenger liner was sent to Newport News, Virginia, for repairs (Goldberg 1993:333). She was officially registered in the U.S. in April of 1915, servicing shipping and passenger routes to and from New Orleans, Louisiana, with her home port listed as New York, New York (BMIN 1914). In 1921, *Heredia* underwent a major overhaul in the Brooklyn yard of Robins Repair Company and her adjusted gross tonnage was reported as 4,734. The boilers were converted from steam to oil burners and passenger spaces were rearranged throughout the superstructure (OCNO 1942a; 1942d; Goldberg 1993:335).

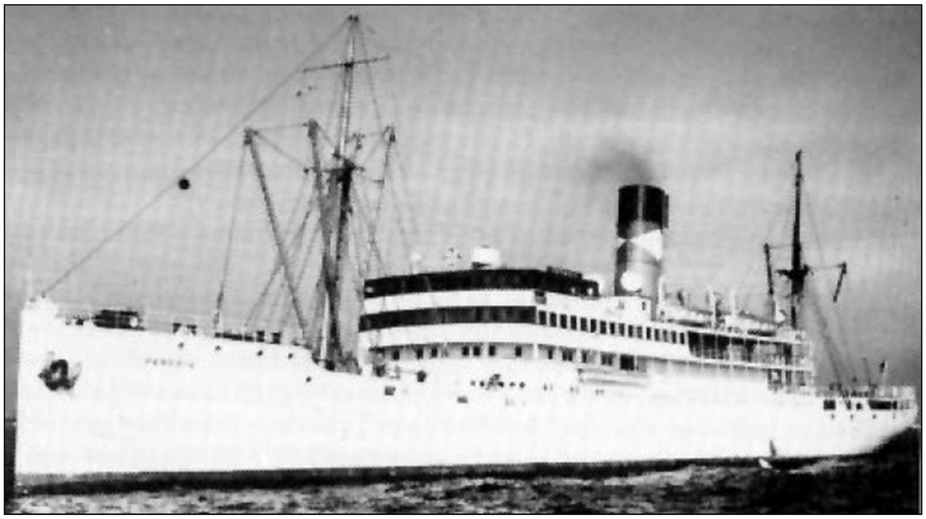


Figure 4.4. SS *Heredia,* date unknown (Goldberg 1993:334).

In December 1932 *Heredia* was chartered by the States Steamship Company. It was renamed *General Pershing*; its sister ships *Cartago* and *Parismina* were renamed *General Lee* and *General Sherman,* respectively (BMIN 1932; Goldberg 1993:336). States Steamship was a trans-Pacific passenger liner company with service out of Portland, Oregon, to various ports throughout Japan, China, and the Philippines. On return trips the vessel made port in San Francisco, California (Timetable 1932 Bjorn Larsson private collection; Appendix E; Figure E-17). The official insignia of the States Steamship Company was the swastika, a bent version of a Greek cross universally known as a sign of good luck before the Nazi party adopted a version of the symbol. After World War II, the company attempted to keep the symbol but met with so much animosity that they eventually adopted the seahorse as their new insignia (Goldberg 1993). In December 1937, *General Pershing* returned to the service of United Fruit Company and its name was officially changed back to *Heredia* (BMIN 1937).

During the onset of World War II, non-military vessels were targeted for attack in order to disrupt Allied trade and transportation. During this time, many non-military vessels added defensive weapons and were accompanied by armed guards to protect the ship, and, more important, to protect the passengers and supplies. On March 26, 1942, *Heredia* was fitted with armament and passenger compartments were restructured for armed guard accommodations (OCNO 1942a; 1942d). The vessel was fitted with a 3-inch .23-caliber MK XIV gun on the poop deck, and two .30-caliber machine guns installed one each at the starboard deck house and the port deck house (OCNO 1942a; 1942d). Goldberg (1993) reports that *Heredia* was the only United Fruit vessel of her class not chartered by the War Shipping Administration. On April 19, 1942, the War Shipping Administration sent a request for the scheduled charter of *Heredia* upon return to an American port (USMC 1942c); however, *Heredia* would not have the chance to fulfill this obligation.

On May 19, 1942, under the command of Captain Erwin F. Colburn, *Heredia* was on a return trip to New Orleans, Louisiana, from Puerto Barrios, Guatemala, when the vessel was struck by three torpedoes fired from *U-506*, under the command of Kapitänleutnant Erich Würdemann (Powers 1942a; Goldberg 1993:337; Rohwer 1983:97; Browning 1996:111). The vessel was carrying a cargo of 1,400 tons of fruit, 412 tons of coffee, 38 tons of cocoa, 6 tons of pharmaceuticals, 3 tons of miscellaneous cargo and eight passengers (USMC 1942d; USCG 1942-1946). Reports following the attack indicate that the vessel was fired upon by at least two submarines. The dual U-boat attack reports, however conflict with other sources. According to Rohwer (1983), only *U-506* claimed responsibility for the attack. Research conducted at the German archives by C. J. Christ and supplemented by interviews with German U-boat personnel did not find any evidence that two submarines fired upon the same vessel in the GOM theatre (Christ 2011 pers. comm.).

What is not in dispute is that the first and second torpedoes struck portside and the third struck amidships on the starboard side of the vessel (Powers 1942a). The reports of torpedo strikes on both sides of the vessel may be responsible for the accounts of multiple U-boats. Conversations with C. J. Christ of the Regional Military Museum in Houma, Louisiana indicated that another explanation could account for the conflicting locations of torpedo strikes. When a vessel was hit on one side while under way, the vessel would have listed to one side while the engines were turned "hard over," subsequently turning the vessel about. This may account for the location of additional torpedo strikes on the opposite side of the original strike (Christ 2011 pers. comm.). At the time of sinking, *Heredia* was fitted with a three-gun complement and six lookouts were on duty (Powers 1942a). Survivor statements reported that the vessel burned as she sank and was completely submerged in approximately three minutes (USCG 1942-1946). Würdemann's account of the sinking reported that *Heredia* sank quickly but unevenly, with the stern hitting bottom first (Wiggins 1995). According to remarks attributed to Würdemann, after the stern end sank "the forecastle up to the bridge for the moment is still sticking up out of the water but going down too … several brightly illuminated lifeboats and rafts were lowered" (Wiggins 1995:46).

Of the reported 48 crewmen and six naval armed guards, 30 crewmen were lost in the attack, including 28 regular crew and two crew members who had joined the ship during the voyage, five of the Navy gun crew, and one passenger (Powers 1942a; USCG 1942-1946). Most surviving passengers and crew were rescued by passing trawling vessels, including *Papa Joe*, *Conquest*, and *J. Edwin Treakle*, and were transported to Morgan City, Louisiana (Powers 1942a; USCG 1942-1946). Three survivors were rescued by seaplane and taken to New Orleans (Powers 1942a; USCG 1942-1946).

There is a significant degree of variability in the reported positions of sinking for *Heredia*. In the Navy's Summary of Statements by Survivors (Powers 1942a), no coordinates for the wreck are given. Instead, survivors reported that the vessel was attacked 3 km (2 miles) SE of the Ship Shoal Buoy. This is assumed to be the same buoy that *R.W. Gallagher* reportedly passed just before her attack. However, no records could be identified which provide a location for any buoy with this name in 1942. *Heredia* reportedly went down quickly and forcefully, driving the stern into the seafloor while the bow was still afloat. Under these circumstances the vessel should have sunk in place and would not have floundered or floated far from the reported location of attack.

Coordinates published by Rohwer (1983) place *Heredia* in relatively shallow water near Ship Shoal (in close proximity to his coordinates for *R.W. Gallagher*). These coordinates place the vessel 42 km (26 miles) NNW of Site 386 (Appendix D; Map D-2). The vessel that attacked

Heredia, *U-506*, had a draft of 4.7 m (15.5 ft) (Möler and Brack 2004:98), meaning it could not submerge in water depths much less than 6 m (20 ft). Water depths over Ship Shoal currently range from 3 to 4.8 m (10 to 16 ft) and ambient water depths around the shoal are approximately 6.7 m (22 ft), making it unlikely that a U-boat would have attacked *Heredia* in such shallow waters, or that a liner of *Heredia's* size would have sailed so close to a charted shoal. However, as discussed in Section 4.2.2, if Rohwer's coordinates are assumed to be latitude-longitude decimal degrees, they plot in close proximity to the reported location for Site 386.

The coordinates reported in the MVUS (1945) place the wreck of *Heredia* in 915 m (3,000 ft) of water, directly south of Sites 386 and 433 (Appendix D; Map D-2). No direct source is attributed for the MVUS coordinates, and it appears probable that they are incorrect, because these water depths do not correlate with the account of the sinking which stated that the vessel's stern hit the seafloor (Wiggins 1995:46). Complicating the issue, the position published in Rohwer based on German U-boat map convention places *Heredia* in relatively deep water, and in close proximity to the MVUS plotted position (Appendix D; Map D-3).

Despite the discrepancies in published coordinates, the combined data sets, including survivor statements, vessel dimensions, information provided by Avery Munson and C.J. Christ, and geophysical data, especially the imagery obtained from the side scan sonar and multibeam bathymetry data, Site 386 appears to be the remains of *Heredia*. Figure 4.5 shows a site plan prepared from the combined multibeam and sonar data compared with a historic photograph of *Heredia* (when it was operating as *General Pershing*).

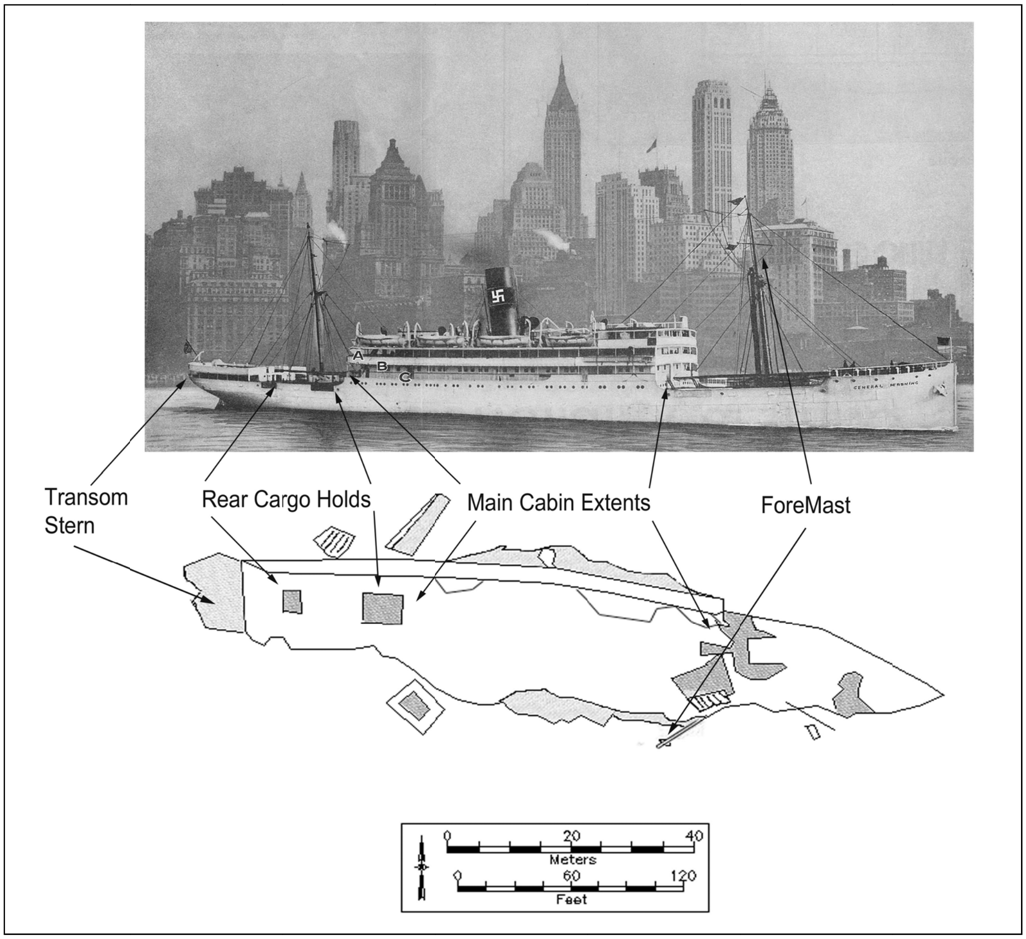


Figure 4.5. Photograph ca. 1933 of *General Pershing* compared to the annotated site map of Site 386 (State Steamship Lines 1934).

Hamlet and *Heredia* have similar published dimensions and wrecked in relative proximity to one another (using the most credible published coordinates). *Hamlet* is reportedly 124.5 m (408.5 ft) in length (likely length overall) and *Heredia* is 115.5 m (378.8 ft) (length on tonnage deck). Site 386 is estimated at 119 m (390 ft) in length, based on the geophysical data. This length corresponds more closely with *Heredia*, which, after factoring in the 3-14% increase in length between length on tonnage deck and length overall, would fall closely within the 119-m (390-ft) range. In addition, the geophysical data from Site 386 indicates that the stern of the vessel was severely damaged and appears to have broken off from the rest of the vessel. This correlates with the account of the sinking of *Heredia* which indicates that the vessel impacted the seafloor stern first. This interpretation of events is also supported by imagery of *Heredia* which highlights a sharply sloped transom stern, as seen in Figure 4.5. *Hamlet* was a tanker with a much more gradual slope to the stern, which would have been less likely to result in the level of collapse seen on Site 386 (Figure 4.6). Naval documents provided by Avery Munson indicate that *Heredia* was scheduled for demolition because it was deemed a menace to navigation. According to the memo, dated 9 February 1944, "demolition operations were planned" at several wreck sites, including *Heredia*, "but sweeping over their buoyed or charted positions disclosed that they had either disappeared or that there was an acceptable depth of water over them" (U.S.

Navy Department, Bureau of Ships 1944). The survey work was conducted by the Navy Training School (Salvage), but no specific information on the survey location is provided, other than "buoyed or charted location." As a result of operations in 1944, at least 11 named wrecks were either removed or demolished as menaces to navigation, and it is possible that *Heredia* was subsequently located and demolished, or was demolished as an unidentified menace to navigation, which would account for the wreck's appearance and extremely disarticulated nature. If this did occur, no records were uncovered as part of this research. Conversations with Christ (2011, pers. comm.) and Munson (2011, pers. comm.) indicate that during diving investigations of the site in the 1970s and 1980s, they identified diagnostic elements on the wreck which were consistent with *Heredia*.

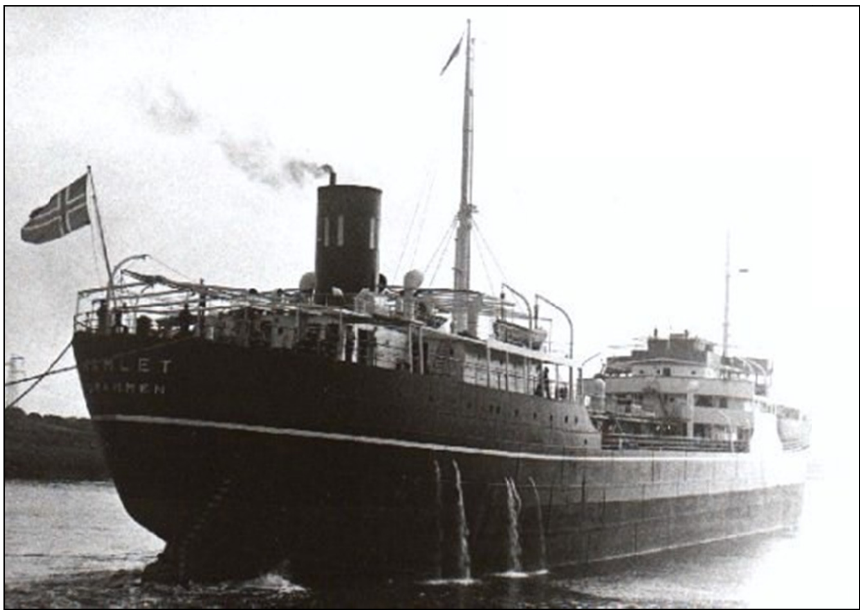


Figure 4.6. Photograph of *Hamlet*, date unknown (Helgason 2011).

4.2.4 Site No. 373, South Marsh Island Area, Probable *Cities Service Toledo*

Based on the probability model developed by Pearson et al. in 2003, the study site is located within an area considered to have a high probability for shipwreck occurrence. According to CEI (1977:Plates 6-9), Site 373 was seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), and in close proximity to coastal sailing routes used during the 18th and 19th centuries (CEI 1977: Plates 7 and 8). The site lies within the major shipping routes used during the first half of the 20th century running from Cameron, Louisiana and Port Arthur, Texas to the Straits of Florida (CEI 1977: Plate 9). Based solely on the wreck's location, the vessel is most likely associated with activities from the 18th century onward.

A comprehensive list of 63 wrecks within 56 km (35 miles) of Site 373 was compiled and reviewed. Of these reported wrecks, 59 had recorded details, such as length and gross tonnage. Based on the acquired geophysical datasets and diver investigations conducted in 2010, the study site is interpreted as a steel-hulled tanker or freighter with apparent torpedo holes. A total of 15 vessels of similar type and dimension were reportedly sunk by torpedo attack off the Louisiana coast during World War II. Of these, the vessels detailed in table 4.4 have been selected as possible candidates for site number 373. The vessels *Sheherazade* and *R.M. Parker. Jr*. are located in the general vicinity, but were identified through a previous study and may be eligible for nomination to the NRHP (Enright et. al. 2006). They are excluded as possible candidates for the vessel at Site 373.

Table 4.4

Reported U-Boat Casualties in the Vicinity of Site 373

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
Ontario [1]	3009	292.2’	42.2’	May 7, 1942	Freighter
Gulfoil [2]	5188	383’	51’	May 16, 1942	Tanker
Heredia [2]	4732	378.8’	49.8’	May 19, 1942	Freighter
Hamlet [3]	6578	408.5’ (LOA)	55.2’	May 27, 1942	Tanker
Cities Service Toledo [2]	8192	465.2’	60’	June 12, 1942	Tanker
Cities Service Toledo [5]		480’ (LOA)			
Rawleigh Warner [1]	3663	322’	46’	June 23, 1942	Tanker
Bayard [4]	2160	315.2’ (LOA)	44.3’	July 6, 1942	Passenger
R.W. Gallagher [2]	7989	445.4’	64.2’	July 13, 1942	Tanker
R.W. Gallagher [5,6]		463’ (LOA)			

Sources: (1) BOEM Database, (2) MVUS (length on tonnage deck), (3) Kjærvik 2011, (4) Redaksjonen 2011, (5) Bethlehem Steel Collection courtesy of Hagley Museum & Library, (6) Standard Oil 1946.

Based on the geophysical data, Site 373 measures 141 m (463 ft) by 19.8 m (65 ft). In Table 4.4., vessels identified with similar dimensions are limited to *Cities Service Toledo* and *R.W. Gallagher*.

Before investigation, this vessel had been tentatively identified as *Cities Service Toledo*. Component measurements taken during the 2010 diver investigation were consistent with ship plans (Appendix E; Figures E-27-29) acquired from the Hagley Museum’s Bethlehem Steel archival collection (Bethlehem Shipbuilding 1938); however, this was not sufficient to absolutely identify the wreck as *Cities Service Toledo*. The published overall length of *R.W. Gallagher* is 141 m (463 ft), which matches precisely with the measured length of Site 373, but this measurement may be misleading. The uppermost portion of the transom stern is partially buried at the site of the inverted hull, reducing the overall measurement available from the data. If this is indeed the case, *R.W. Gallagher* is too short to be the wreck at Site 373 and the measurements acquired from geophysical data are more consistent with the 146 m (480 ft) measurement of *Cities Service Toledo*. In addition to the measurements, the account of the sinking and corresponding locations of the torpedo holes supports the identity of this wreck as the tanker *Cities Service Toledo*.

Cities Service Toledo was built in 1918 by Bethlehem Shipbuilding Company in Wilmington, Delaware, for Standard Oil Company of New Jersey (MVUS 1918-1942; Figure 4.7). A request for official number was filed by Bethlehem Shipbuilding Corporation, Harlan Plant on July 9, 1918 (BMIN 1918). The request lists the original name of the vessel as *J. A. Bostwick*, and describes the vessel as a 7,929 gross ton, steam screw-propelled tanker equipped with three decks, one mast, quadruple expansion engine, a plain head, and round stern (BMIN 1918). The listed measurements were given as 141.8 m (465.2 ft) in length, 18 m (60 ft) in breadth, with 8 m (26.4 ft) depth of hold (BMIN 1918). The vessel was likely named *J. A. Bostwick* after the industrialist and one-time Standard Oil executive. In 1927, *J. A. Bostwick* was listed in *Merchant Vessels of the U.S.* as an oil-powered steamship (MVUS 1927). This was the first time the vessel was designated in the annual MVUS listing as using fuel oil, and suggests that the vessel was converted to oil no later than 1927. On March 19, 1929 the vessel name was changed to *Cities Service Toledo* following a change of registered owner from Standard Oil to the Cities Service Company (BMIN 1929).

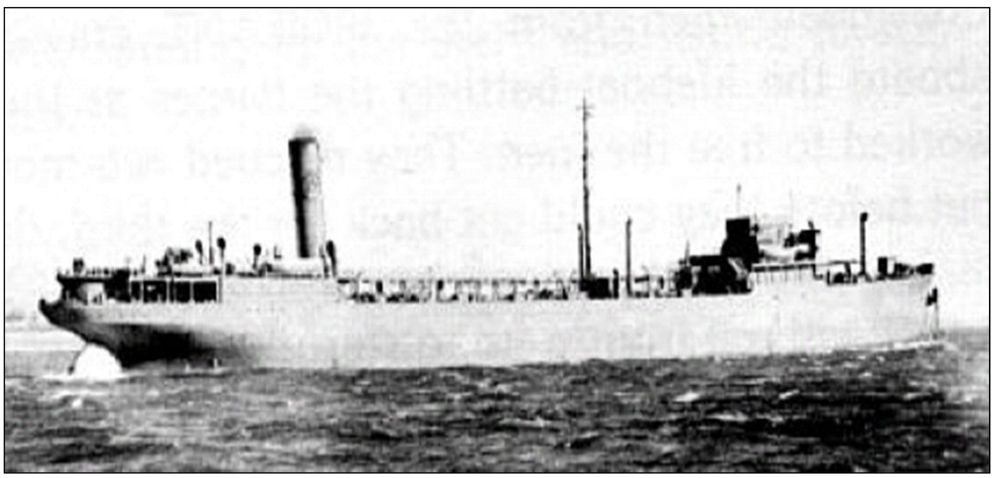


Figure 4.7. *Cities Service Toledo*, date unknown (Moore 1983:54).

On April 20, 1942 *Cities Service Toledo* was time chartered to the War Shipping Administration under contract no. WSA-1611-R (USMC 1942a). Between April 27 and May 20 of that year, the vessel underwent arming and defensive restructuring at the Bethlehem Key Highway Yard in Baltimore, Maryland (OCNO 1942c; 1942g). When the vessel was released, it held accommodations for 12 armed guardsmen and one officer. The vessel was also fitted with armed installations: one 5-inch .51-caliber MK 8 gun located one platform aft, two .50-caliber Browning MK 2 machine guns located on pillboxes aft, and two .30-caliber Colt MK 3 machine guns located on pillboxes on the bridge. The new tonnage post-restructuring was reported as 8,192 (OCNO 1942c; 1942g).

On June 12, 1942, the vessel was traveling from Harbor Island, Texas, to Portland, Maine, under the command of Captain K. Toivola, who was operating under orders from the U. S. government. During this run, the vessel was attacked by *U-158* under the command of Kapitänleutnant Erich Rostin (USCG 1942-1944b; Powers 1942b; Rohwer 1983:103). The tanker was transporting a cargo of 80,237 barrels of Light Refugio Crude oil, or approximately

10,626 tons (USMC 1942e). Four torpedoes were fired into the starboard side, hitting the nos. six, seven, four, and five tanks respectively (Powers 1942b). On the fourth strike the vessel caught fire, and sank two hours after the attack (Powers 1942b). At the time of the attack there were six lookouts on duty (Powers 1942b; Browning 1996:140).

Of the ship's 37 crew and nine U.S. Naval Armed Guardsmen, there were reportedly 31 survivors (USCG 1942-1944b). The survivors include 17 men who escaped in a lifeboat and 14 others who jumped into the water and were rescued by the passing tankers *Belinda*, *Gulf King*, and *San Antonio* (USCG 1942-1944b; Powers 1942b). The merchant crew survivors were taken to Burwood, Louisiana, and then transported to New Orleans; the Navy crew members were taken to the Naval Section Base in Algiers, Louisiana. The bodies of six crew and three guardsmen were recovered and taken to Morgan City, Louisiana. Five crewmen and one Naval guard were reported as missing (USCG 1942-1944b; Times Picayune 1942).

There is some degree of variability in the reported positions of sinking for *Cities Service Toledo*. In the Navy's Summary of Statements by Survivors (Powers 1942b), the position of the attack, when plotted, falls approximately 18 km (11 miles) NNE of Site 373 in 17 m (55 ft) of water. This same position is published in Rohwer (1983), who may have used the Summary Statements as the source of his information. Although imprecise, the German map convention position for the wreck seems to also correlate with this general portion of South Marsh Island, offshore of Louisiana (Appendix D; Map D-3).

The MVUS publication has a different set of coordinates, placing the sinking 74 km (46 miles) WNW of Site 373 in the East Cameron Federal lease protraction (Appendix D; Map D-2). It is unknown where the MVUS coordinates were obtained.

Despite this degree of variability, of the eight unaccounted-for World War II causalities reported in this part of the GOM, only *Cities Service Toledo* is reported to have been lost in the general vicinity of Site 373 (Appendix D; Map D-1).

Additional evidence supplements the relative correlation of the overall dimensions and the reported position of sinking in suggesting that Site 373 is, in fact, the wreck of *Cities Service Toledo*. The account of the sinking appears to correspond with the condition of the wreck site. As discussed above, four torpedoes were fired on the starboard side and hit the nos. 6, 7, 4, and 5 tanks, respectively (Powers 1942b). The largest break in the hull is predominately on the starboard side of the vessel, just fore of midships. In addition, a large hole was also observed near the starboard bow of the ship. Although the location of each tank is not specified on the ship's plans (Appendix E; Figures E-27-29), it can be assumed from other contemporary ship plans that the tanks were numbered consecutively from bow to stern. Following this convention, the no. 4 tank corresponds with the foreward hole while the nos. 5, 6, and 7 tanks correspond with the much larger break in the hull, just fore of midships. Based on the plans for *J.A. Bostwick*, the vessel was designed so that midships corresponded with the inferred no. 6 tank, with nos. 7 and 8 located aft of midships and all other tanks located fore of midships. The majority of the aft section of the vessel consisted of the engine room, the boiler room, and the fuel oil tanks (Appendix E; Figures E-27-29).

Since the wreck was inverted, many potentially diagnostic elements were obscured during both geophysical and diver survey. The vessel's hull was comprised of overlapping plates, suggesting that the ship was built with the "raised and sunken" system of plate attachment, rather than flush or clinker plate arrangements. Contemporary ship construction sources state that this was the most common means of steel hull construction during this period (Manning 1942:19-20).

Although *J.A. Bostwick*'s plans show extensive detail of the vessel's stern, as discussed in Chapter 3, the propeller and rudder were missing from the wreck site. It is unknown when this occurred, but it should be noted that diver investigations in 1971 reported that the rudder was present, but that the propeller had been removed (Christ 2006). Due to the sheer size of these components, removal would have required a sizable boat and equipment for salvage. Although records were not discovered, it is possible that the propeller was removed by the U.S. Navy after the sinking, because of war-time shortages of brass, but again this is only conjecture. It is unknown when or why the rudder was removed. It does not appear that it was broken; instead, the clean nature of the remaining components indicates that the rudder was cut from its fittings. Divers investigating the wreck for this study noted that there was a single propeller shaft, whose dimensions matched precisely with the dimensions shown on the plans for *J.A. Bostwick*. Also, divers observed that the shape of the propeller well and the stern hull correlate with the design depicted on the blueprints of *J.A. Bostwick* (Figure 4.8; Appendix E; Figure E-29). As illustrated in Figure 4.3, stern details of Sites 433 and 373, based on diver observations, show remarkable similarities with the ship's plans acquired for *J.A. Bostwick* and the *R.W. Gallagher* hull type. Both vessels are known to have undergone refits, and it is possible that some design elements are likely to have changed, but it is unlikely that major integral features, such as the rudder assembly and hull shape, would be modified significantly from the original construction plans. Therefore, it is believed that the stern features recorded from diver observations can be used to identify the wreck with a degree of certainty. The diver observations support the identification of Site 373 as *Cities Service Toledo* based on the curved propeller well. The combined lines of inquiry all support the identification of Site 373 as the tanker *Cities Service Toledo*.

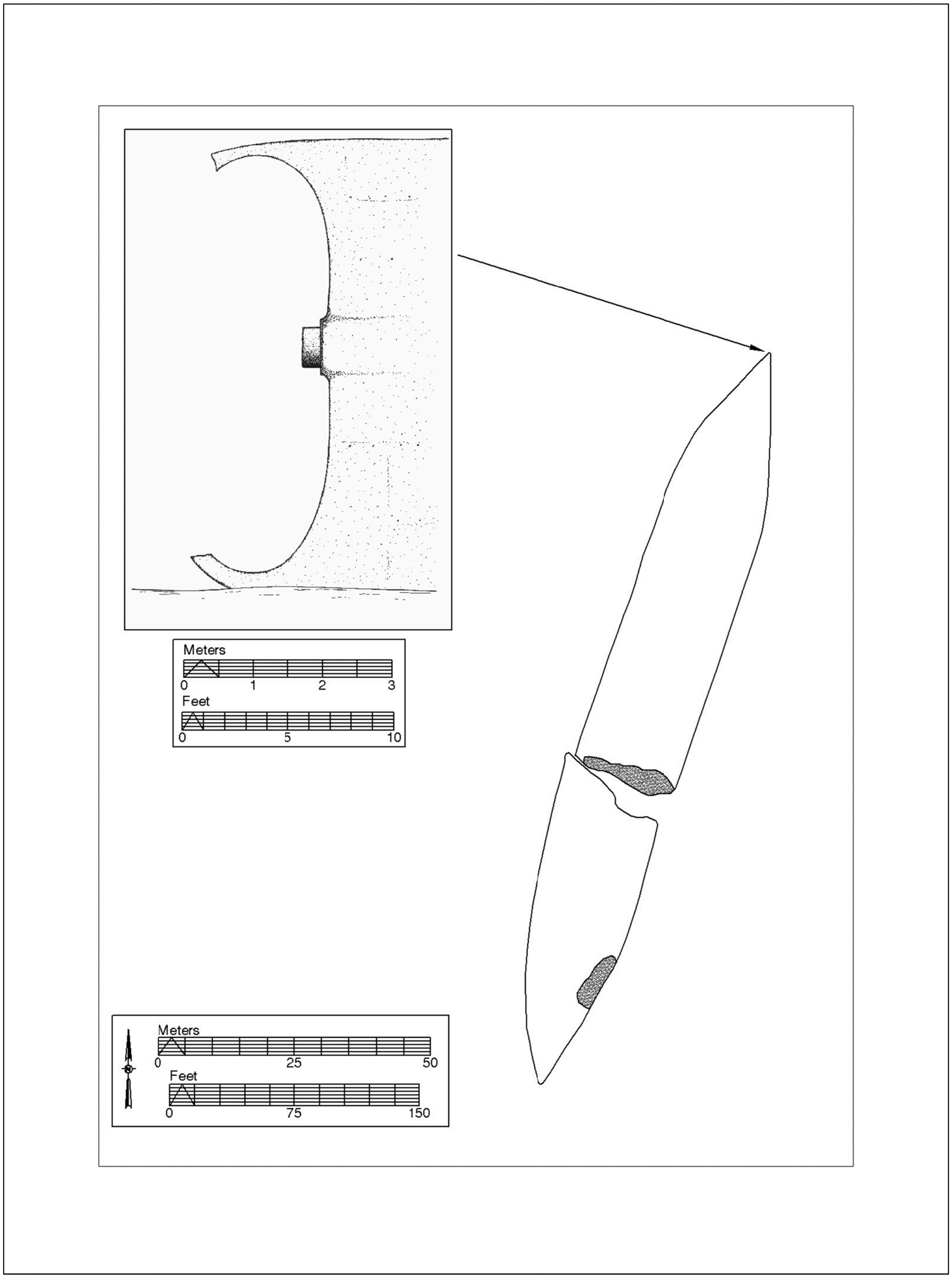


Figure 4.8. Site plan of Site 373, based on diver investigation and remote sensing data.

4.2.5 Site No. 15488, High Island Area, Unknown Modern Wreck

Based on the probability model developed in 2003 by Pearson et al., the study site is located within an area considered to have a high probability for shipwreck occurrence. According to CEI (1977:Plates 6-9), Site 15488 was seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), seaward of coastal sailing routes used during the 18th century (CEI 1977: Plate 7), and between routes used during the 19th century (CEI 1977: Plate 8). Site 15488 is located between major shipping routes used during the first half of the 20th century running from Port Arthur and Galveston, Texas to the Straits of Florida (CEI 1977: Plate 9). Based solely on the wreck's location, the vessel is most likely associated with activities from the 19th century onward.

Study site number 15488 had no tentative identification prior to this study. A comprehensive list of 48 wrecks reportedly lost within 48 km (30 miles) of Site 15488 was compiled, and of those included on the list details such as length and gross tonnage were found for 34. Reported wrecks in the vicinity of Site 15488 and with similar hull type or dimensions have been detailed in Table 4.5 and are the most likely candidates for wreck identification.

Table 4.5

Reported Shipwrecks in the Vicinity of Site 15488 with Similar Dimensions

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
Victory		68'		1990	Fishing vessel
Laurentine III	77	72.1'	22.2'	September 30, 1999	Fishing vessel
Gulf Lee		68'		1984	
Susan & Gretta	63	60.2'	17.8'	August 12, 1956	Fishing vessel
San Antonio (7)	73/ 96	67.3'/ 78.6'	19'/ 25.9'	1976	Towing/Misc.
Miss Behave		65'			

All measurements from Merchant Vessels of the U.S. The 1977 record of loss for San Antonio could not be located. Seven vessels named San Antonio were located the year before loss, and dimension ranges for these are shown.

Geophysical data indicates that Site 15488 measures 21 m (70 ft) by 6 m (20 ft). Each of the wrecks shown in Table 4.5 could be the identity of Site 15488; *Victory*, *Laurentine III*, *Gulf Lee*, and *San Antonio* are the most likely candidates. All of the vessels in the table sank before 2001 (when the wreck was initially discovered) and all have similar dimensions. Based on the diver inspections, it appears likely that this vessel is a small workboat similar to any of the above vessels. Based on the dimensions, *Laurentine III*, a steel-hulled fishing vessel built in 1978 in Bayou La Batre, Alabama is the most likely candidate, but this vessel was reportedly identified by a 2003 geophysical survey in another area (BOEM database 2011). It was not possible to acquire additional geophysical data or dive on the wreck previously identified as *Laurentine III*; therefore, no comparisons can be made between the data sets.

During dive operations at Site 15488 in 2010, the running gear appeared to be a fairly common type used in many small working boats. Raised sections or "vanes" were noted near the bow and stern, which may have been added to increase stability and/or efficiency while under way. Alternatively they could have been components of the engine's coolant system (Dix 2011, pers. comm.). The through-hull transducer is a fairly common addition to both modern working and pleasure boats. Due to poor visibility on the site and lack of diagnostic components, a detailed site plan was not generated for this wreck.

Of the known wrecks with similar dimensions reported in the area, *Susan and Gretta*, built in 1944 and one of the vessels named *San Antonio*, built in 1940, meet National Register eligibility requirements based on their age alone. Since these vessels are all modern working boats and many are owned by small companies or private individuals, there is usually limited information available regarding specifications or plans. Based on the dimensions, material of construction, propeller, apparent through-hull transducer, anti-fouling paint, and hull vanes, this vessel appears to represent a modern working vessel that would not be eligible for the National Register. No evidence could be found to indicate specialized design elements that would distinguish this vessel from other work vessels, nor does it represent the best example of its type.

4.2.6 Site No. 15366, Galveston Area, Unknown Modern Wreck

Based on the probability model developed by Pearson et al. in 2003 the study site is located within an area considered to have a high probability for shipwreck occurrence. According to CEI (1977:Plates 6-9), Site 15366 is located just seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), and in close proximity to coastal sailing routes used during the 18th and 19th centuries (CIE 1977: Plates 7 and 8). The site lies within major shipping routes used during the first half of the 20th century running to and from Galveston, Texas (CEI 1977: Plate 9). Based solely on the wreck's location, the vessel is likely associated with activities from the 18th century onward, with an emphasis on the 20th century.

Study site number 15366 had no tentative identification prior to this study. Reported wrecks within the vicinity of Site 15366 of similar type and dimension have been researched. A comprehensive list of vessels reported within a 48-km (30-mile) radius of the study site was prepared. Of the 58 vessels reported within the search radius, 54 had detailed information including length or gross tonnage available. Table 4.6 details the strongest candidates for wreck identification, based on proximity to the site and overall dimensions.

Table 4.6.

Reported Shipwrecks in the Vicinity of Site 15366 with Similar Dimensions

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
William Hayes	69	76.4'	21.2'	July 16, 1957	Fishing vessel
Barbara D.	96	70'	26'	December 27, 1983	Tugboat
Bonita	44	72.5	19.6'	July 21, 1909	Schooner

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
Keturah	77	83.4’	21.3’	June 20, 1957	Fishing vessel
High Liner		73’		September 15, 1998	Fishing vessel

Measurements from Merchants Vessels of the U.S.

The geophysical data at Site 15366 indicates that the vessel measures approximately 24.3 m (80 ft) by 7 m (23 ft). *Bonita* is a schooner that wrecked in 1909; based on the diver observations of the wreck, it can be excluded from consideration. The remaining five vessels are working vessels and are more likely candidates. *Keturah* and *William Hayes* have the most similar dimensions to the wreck at Site 15366, based on the information summarized in Table 4.6. Based on age alone, both vessels are eligible for nomination to the National Register; however, these dates do not correlate with the potential *terminus post quem* of 1986 established in Chapter 3 and based on pre-existing survey data surrounding the wreck site. Of the vessels identified in Table 4.6, only *High Liner* wrecked later than 1986, and has a similar length measurement as the wreck at Site 15366.

The primary diagnostic component of Site 15366, as identified by divers, was the shrouded propeller (Figure 4.9). The shrouded nozzle could have been used on any of the vessels identified in Table 4.6, with the exception of *Bonita*. There are various designs of nozzles, such as the “Kort Nozzle,” but, in general, these are shrouded, ducted propeller assemblies typically designed for increasing thrust at low speeds, and commonly used on workboats, such as tugs and shrimping trawlers (Kort 1938). These devices became common in the early-20th century, and versions remain in use today. The hull protrusions and black and white anti-fouling paint could help to identify the wreck; however, like Site 15488, archival research is widely unavailable for working vessels, such as fishing boats and tugboats in the GOM. Based on the dimensions, construction material, shrouded propeller, anti-fouling paint, and hull protrusions, this vessel appears to represent a modern working vessel that would not be considered eligible for the National Register. No evidence could be found to indicate specialized design elements that would distinguish this vessel from other work vessels, nor does it represent the best example of its type. Site 15366 is therefore not interpreted as historically significant.

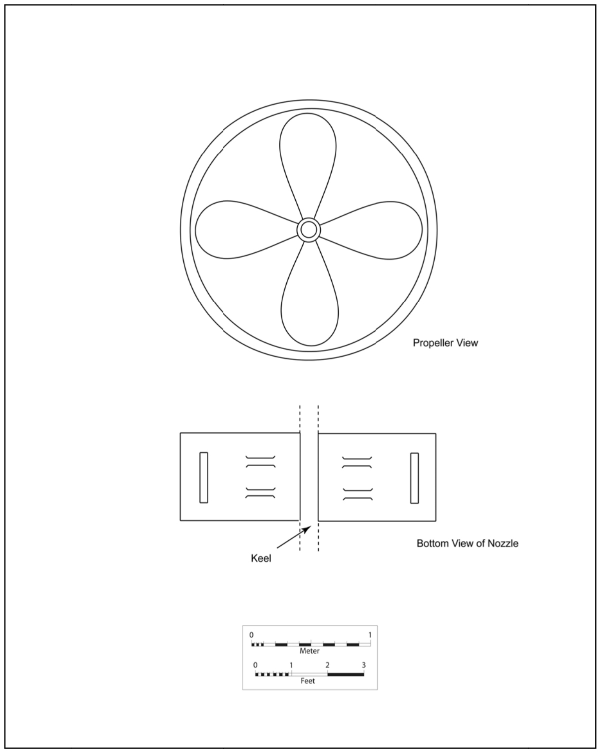


Figure 4.9. Detail of shrouded propeller.

4.2.7 Site No. 389, South Timbalier Area, Probable *J.A. Bisso*

Based on the probability model developed in 2003 by Pearson et al., the study site is located within an area considered to have a high probability for shipwreck occurrence. According to CEI (1977), Site 389 is located directly within the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), and in close proximity to coastal sailing routes used during the 18th and 19th centuries (CEI 1977: Plates 7 and 8). The site is not located within any major shipping routes used during the first half of the 20th century, but would have been directly along the path for any vessels traveling inland into areas surrounding Houma, Louisiana (CEI 1977: Plate 9). Based solely on the wreck's location, there is a high probability that this wreck represents a historic resource, as it is located in an area of consistent vessel traffic since the 16th century.

Before the start of this study, Site 389 had been tentatively identified as the vessel *J.A. Bisso* (Section 3.7.1), but there are several reported shipwrecks located within the immediate vicinity of the site. Reported wrecks of similar type and dimension within the vicinity of the study site were identified; Table 4.7 details the strongest candidates for the wreck at Site 389. A more comprehensive list of 144 wrecks within a 58-km (36-mile) search radius of Site 389 was compiled. Of the identified losses, details such as length or gross tonnage were available for 80.

Table 4.7

Reported Shipwrecks in the Vicinity of Site 389 with Similar Dimensions

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
J.A. Bisso	224	102.3’	23.7’	December 7, 1957	Towing vessel
Carl Tide	184	106.2’	22.2’	December 18, 1965	Tow service
Lance		110’		1993	
Sargent		112’		1985	Motor vessel
Joseph H. Davis	135	105,2’	19.6’	March 2, 1959	Fishing vessel
Jan H.	185	114.8’	32.1’	1965	Sailboat/ Freight
Atlas (16)	7 to 183	29.4’–117’	9’–29.5’	1974	

Measurements from Merchant Vessels of the U.S. The 1974 record of loss for Atlas could not be located. Sixteen vessels named Atlas were located the year before loss, and the range of dimensions for all 16 vessels is shown in the table.

Based on the geophysical data, Site 389 measures 32 m (105 ft) by 7 m (23 ft). A number of vessels that reportedly sank in the area were identified with similar measurements, including *J.A. Bisso*, *Carl Tide*, and *Joseph H. Davis*. The vessel sits upright on the seabed; measurements of the vessel’s length overall, based on the geophysical data, appear to be fairly accurate. All of the available measurements for the vessels in Table 4.7 come from MVUS, and may not fully represent overall length from stem to stern (Section 2.1). Based on the combined geophysical data and the diver investigations, Site 389 was identified as a probable towing vessel or ocean-going tug. *J.A. Bisso* and *Carl Tide* are the only towing vessels identified in Table 4.7 as possible candidates for the wreck at Site 389. Based on the reported coordinates of sinking, *J.A. Bisso* was reportedly lost 4 km (2.5 miles) WNW of Site 389, while *Carl Tide* was reportedly lost 16 km (10 miles) to the NNW. The proximity to the reported sinking location, coupled with measurements of the wreck site, and photographs of *J.A. Bisso* supplied by William “Cappy” Bisso, support the identification of Site 389 as the towing vessel *J.A. Bisso*.

Originally named *Alaska*, *J.A. Bisso* was a 224 gross ton, steam screw-propelled tugboat built in 1906 in Sorel, Quebec, by G. A. Pontbriand for Sincennes-McNaughton (Figure 4.10; Mills 2002; Library and Archives Canada 2009). Vessel dimensions are listed as approximately 31 m (102 ft) in length, 7 m (24 ft) in breadth with 4 m (14 ft) depth of hold (MVUS 1919). The Canadian Vessel Index (Library and Archives Canada 2009) states that *Alaska*’s registry was closed in 1918, and notes that it was sold to Americans. In 1919, *J.A. Bisso* is first recorded under American registry with the owner listed as the New Orleans Coal and Bisso Towboat Co. (MVUS 1919). In 1948, *Bisso*’s registration was amended to refer to an oil screw-propelled tug (MVUS 1948). During an interview with William Bisso, it was indicated that *J.A. Bisso* was one of the first of the Bisso fleet to be converted after the conclusion of World War II (William Bisso 2011 pers. comm.).

Figure 4.10. Photograph of *Alaska*, date unknown. (Courtesy of William “Cappy” Bisso.)

J.A. Bisso foundered on November 7, 1957, while traveling from Sabine, Texas, to New Orleans, Louisiana (MVUS 1959). The story told in the Bisso yards by one of the survivors was that the vessel was towing a derrick barge when it encountered rough weather. Reportedly, one of the deck hatches had been left open, but before the problem was discovered the vessel had already taken on too much water and began to go under. Those aboard were able to transfer to the derrick barge and cut the towing lines, ensuring that no casualties resulted from the accident. The crew waited for rescue aboard the derrick (William Bisso 2011 pers. comm.). The account of the vessel’s sinking suggests that fairly accurate coordinates would have been available for determining the location of the lost vessel, because it was lost during a multi-vessel construction operation that would have had state of the art positioning for the time.

Before the investigation and diving operations conducted in 2010, Site 389 had been tentatively identified as *J. A. Bisso*. This analysis appears to have been based exclusively on dimensions and imagery obtained from geophysics and the proximity to the reported location of sinking. The diving phase of this project, coupled with the more detailed geophysics produced for this study, demonstrates that elements of Site 389 were found to be consistent with details acquired from images of *J. A. Bisso*. A site plan was prepared using offset measurements taken during diving operations and supplemented with still photos, video, and geophysical data acquired as part of this study (Figure 4.11). This data allowed for a detailed comparison between the wreck and the last known photograph of *J. A. Bisso*, which was reportedly taken during the derrick barge move just before the vessel was lost (Figure 4.12). Despite apparent damage to the site, a number of potentially diagnostic features were recorded aboard the wreck that supports the identity of the vessel as a tug, and, more specifically, as *J.A. Bisso*.

Caldwell (1946) discusses the design of screw tugs at a time when coal powered steam vessels were still being built, but oil had become recognized as a much more efficient and cost effective fuel alternative. He argues that a converted oil powered engine was an estimated 2.5 times more efficient than coal, while a similar vessel that used a diesel internal combustion engine was 4.5 times more efficient than coal (Caldwell 1946:3-4). Although focusing primarily on the development of British tugs, Caldwell's observations appear to be valid for tugs built in North America, as well. This fuel efficiency led companies, such as Bisso Towing, to undertake the expense of converting an entire fleet of vessels to diesel power.

Caldwell (1946) grouped early 20th century tugs into four types: Type 1) Ocean-going; Type 2) Coastwise and Estuary; Type 3) Estuary and Harbor; and Type 4) River and Dock. Based on the length alone, Site 389 could fall into Types 1, 2, or 3. When comparing length to breadth ratios, Site 389 and the published dimensions of *J.A. Bisso* fit neatly between Caldwell's ideal dimensions for an Ocean-going tug and a Coastwise/Estuary tug. Ocean-going vessels have an ideal length to breadth ratio of 4.75:1 while Coastwise/Estuary tugs typically have a length to breadth ratio of 4.25:1 (Caldwell 1946:29). Based on the geophysical data, Site 389 has a length to breadth ratio of 4.56:1. The published dimensions for *J.A. Bisso* indicate that it had a minimal length to breadth ratio of 4.32:1.

Features identified on Site 389 during diving operations that are consistent with period tugs include the stern quadrant, stern and bow capstans, bits, Samson post, and the overall shape of the vessel. Caldwell (1946:29) argues that the breadth of a tug at midships should taper in immediately for the tug to perform various close quarters tasks safely and efficiently.

The deck-mounted stern quadrant seems to be a typical feature of many tugs of this period. Caldwell (1946:44) argues that it was not advisable to have the steering gear on the deck of an ocean-going tug due to the inability to access it during rough seas. His corresponding diagrams of ocean-going tugs confirm the lack of a deck-mounted quadrant, while his diagrams of Type 2 and 3 tugs both show quadrants on the stern deck similar to both Site 389 and *J.A. Bisso*. The location and dimensions of the quadrant identified during diving corresponds closely with photographs of *J.A. Bisso* (Figure 4.12).

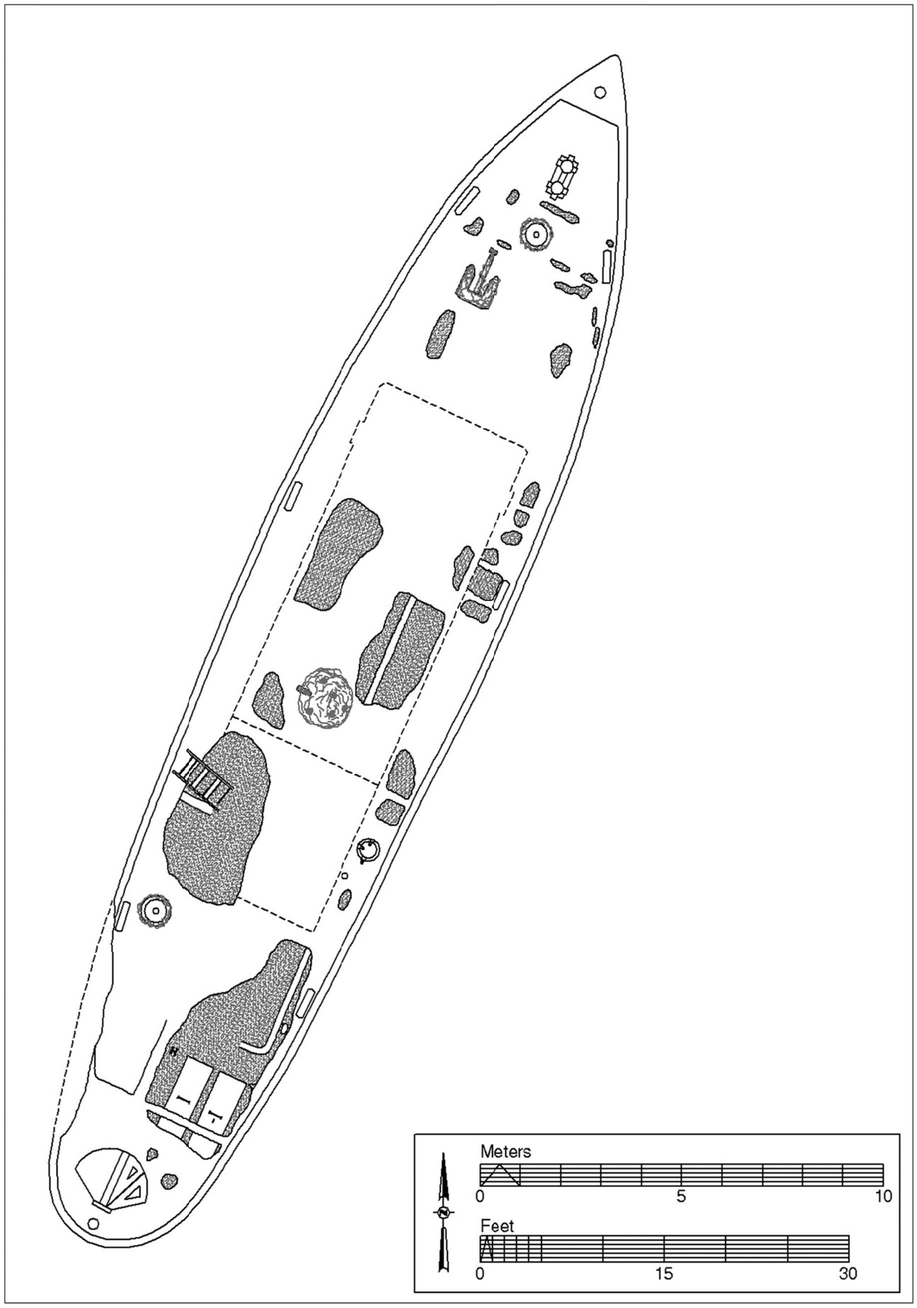


Figure 4.11. Site plan of Site 389.

The wreck's stern capstan included holes near the top for manually operating the machinery with a capstan bar, and it appears similar to "warping capstans" that could be hand-, steam- or electrically-driven. These were common in the early- to mid-20th century for warping a vessel to a pier, wharf, or for attaching to a vessel in the case of tug boats (Manning 1942:73). The bow upright may be a Samson post. The Samson post was fitted on the center line of the tug's foredeck just abaft of the stem. It was typically a steel tube 9–12 inches in diameter, standing 24 inches above the top bulwark (Caldwell 1946:46).

During diving operations, unknown tanks were observed through holes in the vessel's deck near the stern. William "Cappy" Bisso indicated that when the Bisso fleet's vessels were refitted, they often left the original steam engine and boiler in place because it was more cost-effective and less labor-intensive than removing them. The tanks had the added advantage of providing additional ballast and weight (William Bisso 2011 pers. comm.). As Caldwell (1946:3) points out, ". . . the most valuable characteristic that any tug can possess is weight." This is because a tug must handle vessels much larger than itself while also maneuvering in winds and seas that can cause the tug to lose traction despite the power of its engines. The added weight or displacement gives the tug additional traction that enables it to more effectively handle its tow load. If these tanks do, in fact, represent the vessel's original engine and boiler, this could provide valuable information about the original steam engine, the early replacement internal combustion engine, or even the transition between the two.

Due to the breaches in the hull, a number of additional components were observed that remain unidentified because of limited time on site, biofouling and corrosion that obscured site components, and limited visibility. Subsequent visits to the site could provide additional useful information about the vessel and add to the existing site plan.

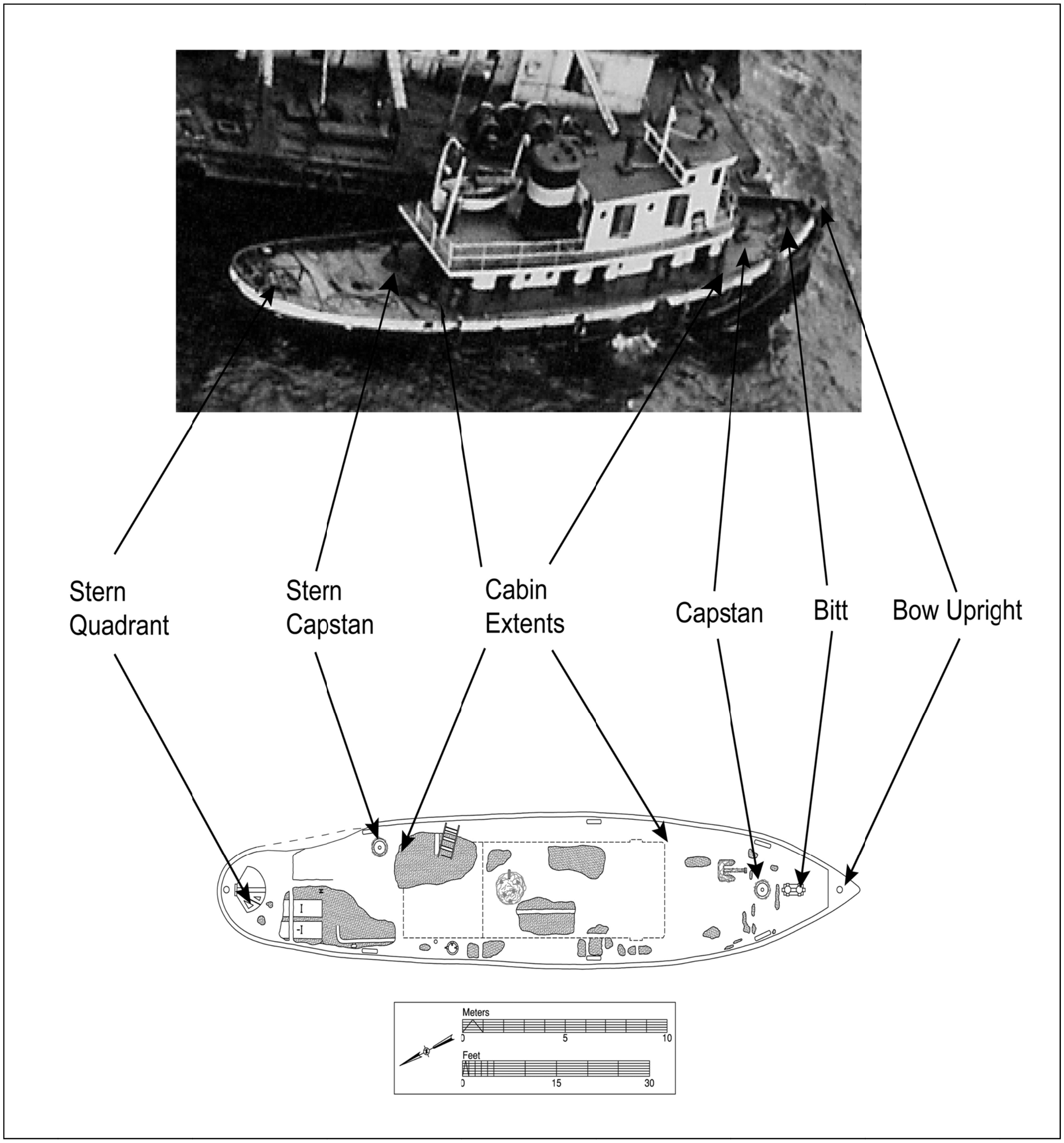


Figure 4.12. Comparison between last known photograph of *J.A. Bisso* and the site plan.

4.2.8 Site No. 236, Galveston Area, USS *Hatteras*

Site 236 was previously identified as the USS *Hatteras* in U.S. Court and is listed on the NRHP.

Originally named *St. Mary's*, this merchant vessel was built in 1861 for Charles Morgan by the Harlan & Hollingsworth Company of Wilmington, Delaware. On September 25, 1861, *St. Mary's* was acquired by U.S. Navy Admiral S. F. Du Pont for $110,000 (U. S. Naval War Records 2003 [1921]). At the time of construction, the dimensions were given as 64 m (210 ft) in length, 10.3 m (34 ft) beam, and 5.5 m depth (18 ft) with a tonnage of approximately 1,126. *St. Mary's* was classified as an iron-hulled, side-wheel steamer, with the rigging classified as that of a "3-masted schooner." The machinery was listed as one engine, including a "condensing, beam" with a cylinder diameter of 127 cm (50 in). The engine stroke was listed as 335 cm (132 in) and was outfitted with a sickel's cut-off. The boilers were described as having the flues below and the tubes above (U. S. Naval War Records 1895). In October 1861, *St. Mary's* was officially commissioned by the Navy and renamed the USS *Hatteras* (Silverstone 2001). The vessel's original battery included four 32-pound cannons weighing 2,700 pounds each, but was amended on November 21, 1861, by the inclusion of one 20-pound rifle. (U.S. Naval War Records 1895).

Hatteras began naval service in November 1861 under the command of Commander George F. Emmons and was dispatched to Key West, Florida to join the South Atlantic Blockading squadron. *Hatteras* was subsequently assigned to the blockade of Apalachicola, Florida and shortly after transferred to Cedar Key, Florida for blockade duty. It was at Cedar Key that *Hatteras* helped stop a fleet of nine blockade runners. After a successful tour in Florida, *Hatteras* was transferred to Berwick Bay, Louisiana to join the Gulf Blockading squadron. During this tour, the crew captured ships off of Pass Christian, Mississippi and Vermilion, Louisiana, including the steamers *Governor A. Mouton* and *Indian No. 2*, the schooners *Magnolia* and *Sarah*, the sloops *Poody* (which was subsequently renamed *Hatteras Jr.*) and *Elizabeth*, and the brig *Josephine* (U. S. Naval War Records 2003 [1921]). In November 1862, the command of *Hatteras* was transferred to Commander Homer C. Blake (Arnold and Anuskiewicz 1995:84). On January 3, 1863, Rear Admiral David Farragut ordered the steam sloop of war *Brooklyn*, under the command of Commodore H.H. Bell and six gunboats from the Mobile, Alabama blockading squadron to retake control of Galveston from the Confederates (Underwood 2003:92). *Hatteras*, under Commander Blake, was part of this squadron.

On January 11, 1863, fleet commander Commodore Bell ordered *Hatteras* to investigate an unknown bark-rigged vessel (Underwood 2003:92). At around 3 p.m., *Hatteras* was ordered to pursue the "strange sail" (U.S. Naval War Records 1895:18). After some four hours of pursuit, *Hatteras* was within distance to ask the identity of the vessel. After being told that the unidentified vessel was of British flag, Blake ordered a small boat launched with six crewmen. These crewmen were to board the strange vessel and confirm its identity. After the boat had been launched, the "British" vessel revealed its true identity as the notorious Confederate vessel *Alabama*. *Alabama* began an assault upon *Hatteras* (Figure 4.13). With the Union ship ablaze and rapidly sinking, Blake signaled the enemy in surrender, hoping to save the lives of his crew. *Alabama* accepted, and began transferring crew and officers from *Hatteras* to *Alabama*. Those aboard the small boarding boat escaped capture and were able to return to Galveston. As a result of the attack, two members of the *Hatteras* crew were reported killed and another five were wounded (U.S. Naval War Records 1895).

Figure 4.13. “Destruction of the Gunboat Hatteras by a Rebel Cruiser off Galveston, Texas” (Schell 1863, Courtesy of the Becker Collection, Boston College 2011).

In Blake’s correspondence to Secretary of the Navy Gideon Welles, dated January 27, 1863, he described the treatment of *Hatteras’* crew as prisoners of war. The officers were given the liberty of the ship while the crewmen were put into chains. Blake also described *Alabama*’s arrival at Port Royal, Jamaica, where the Union crew was released to the American Vice-Consul, without clothing and in poor condition.

Ship plans were researched in order to learn more about the extant structure at Site 236, but no plans for Charles Morgan’s *St. Mary’s* (hull number 75) were located. Complicating matters is the fact that several other vessels named *St. Mary’s* were built by Harlan and Hollingsworth and both pre-date and post-date the eventual *Hatteras* (Harlan and Hollingsworth 1886). Plans for a 450-ton steamer named *St. Mary’s* were discovered in the Harlan and Hollingsworth archival collection at the Mariner’s Museum in Newport News, Virginia but these appear to be related to an earlier vessel. The vessel *St. Mary’s*, hull number 41, was built in 1856 for Claghorn and Cunningham (Appendix E-39) (Harlan and Hollingsworth Company 1886). Based on measurements acquired from a Harlan and Hollingsworth publication (1886), the steam engine components of the cylinder diameter and length of stroke for both steamboats *St. Mary’s,* hull numbers 41 and 75, were compared to the identified plans. The dimensions matched exactly with hull number 41 whose published measurements are given as 76.2 cm by 2.4 m (30 in by 8 ft). The Harlan and Hollingsworth (1886) table of vessels further documents that in 1862, following the sale of hull number 75 to the U.S. government, Charles Morgan had another side-wheel steamship commissioned and also named this vessel *St. Mary's*. This vessel, hull number 80, bears the exact measurements given for *Hatteras*; the only difference is the new steamer was approximately 50 tons lighter. Both hull numbers 75 and 80 are listed as 64 m (210 ft) in length, 10.4 m (34 ft) in breadth, with 5.5 m (18 ft) of draft, and engine measurements are listed for both as 127 cm by 3.4 m (50 in by 11 ft). A notation in the remarks column indicates that hull number 75 was "afterward called *Hatteras* by U. S. Govt." (Harlan and Hollingsworth 1886).

Diver observations at Site 236 indicate that the stern cant frames are iron and the stern post and rudder stock appear to be made of wood. No outer-hull components were evident, therefore it was not possible to determine if the vessel was of composite construction, with iron frames and wood planking, or iron-plated. *St. Mary's* was built in the Wilmington, Delaware yard of Harlan and Hollingsworth in 1861. The Delaware valley saw the birth and development of iron shipbuilding in the U.S., with the first documented iron steam vessel *Codorus*, built in 1826 (Morrison 1945:1-2). Wilmington was one of the U.S.'s pioneering iron shipbuilding centers, and the industry benefitted from access to the nation's greatest number of iron rolling mills in eastern Pennsylvania. Samuel Harlan and Elijah Hollingsworth established their repair shop in 1836 primarily for the locomotive industry, but quickly diversified to include iron shipbuilding. By the start of the Civil War, Wilmington shipyards produced more iron vessels than any other city in the U.S., and the Harlan and Hollingsworth shipyard was the most prolific iron shipbuilding firm in the country (Thiesen 2006:80-86). It is no accident, then, that *Hatteras'* origins lay in this regional shipbuilding center.

Thiesen (2006) argues that early iron ships evolved from wooden shipbuilding and were built in the tradition of wooden-hulled vessels, often with the same design parameters and techniques. Although the exposed portions of *Hatteras* were limited, this appears to correspond with the construction of the exposed cant frames, which were irregular and pointed and appear to have been forged individually rather than mass-produced.

All of the information gathered during the 26 total dive hours on Site 236 was plotted to create a master site plan (Figure 4.14). Only mechanical and hull components were identified during diving operations, no individual artifacts were observed by any of the divers, but it should be noted that no excavation was conducted.

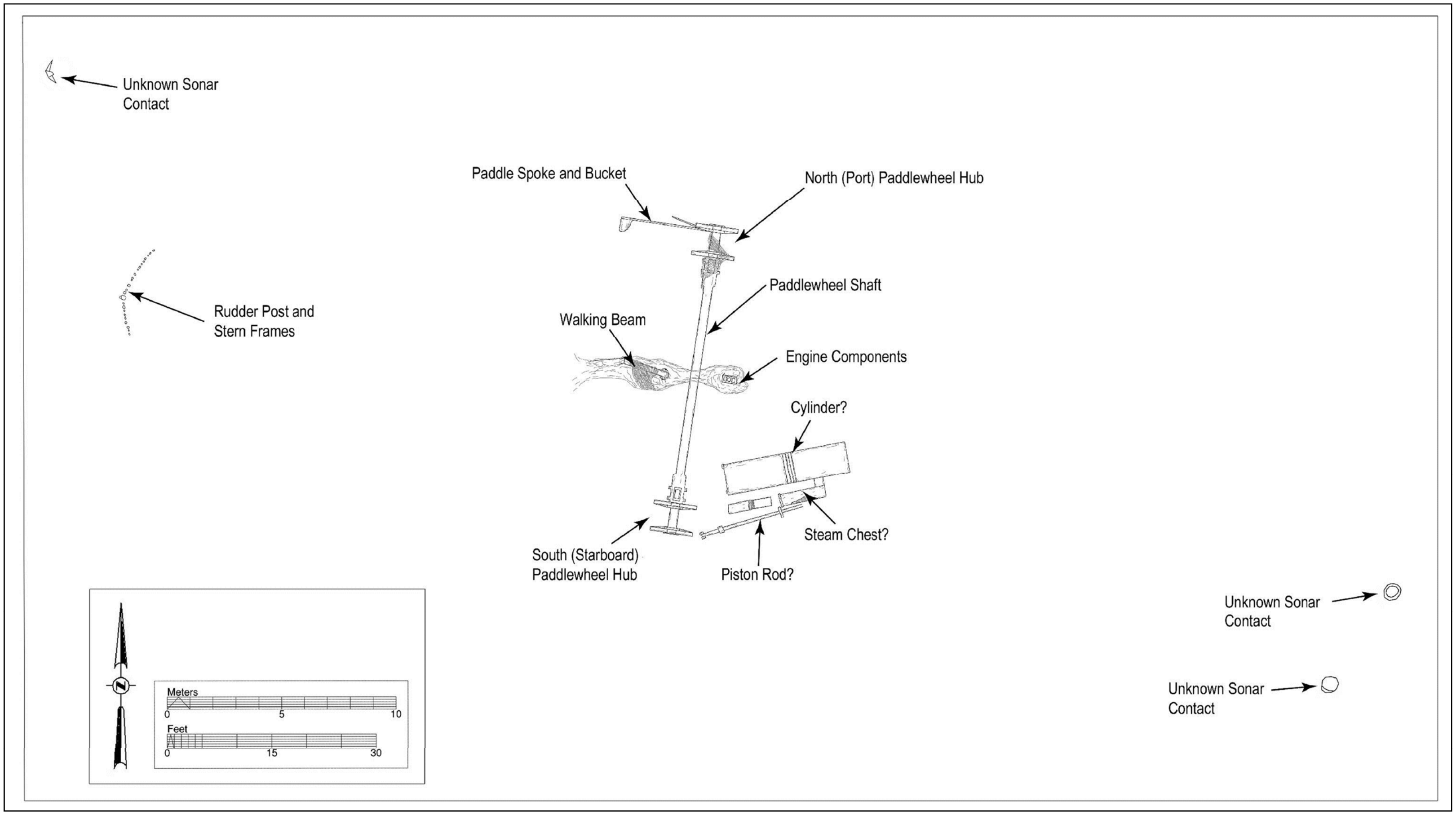


Figure 4.14 .Site plan of exposed portions of the USS Hatteras.

Artifacts have been previously recovered from the *Hatteras* shipwreck site. In the 1970s, treasure hunters recovered eight artifacts from the site (Appendix E; Figure E-40), which included:

(a) Builder's plate marked "Harlan and Hollingsworth and Co., Iron Ship and Steam Engine Builders no. 327, Wilmington Delaware, 1861";
(b) Two small bronze oil cups with covers;
(c) One brass steam valve;
(d) Two large bronze priming cups, one with attached pipe stem;
(e) One oiling pipe stem; and
(d) One iron ball with eye, weighing approximately 45 pounds. (U.S. District Court, Southern District of Texas, Galveston Division 1984:2).

These artifacts were confiscated and are now in the care of the Corpus Christi Museum of Science and History. The brass builder's plate was the central diagnostic element that was used to confirm the identity of the ship as the steamship *Hatteras*. It is unknown what the number "327", refers to on the builder's plate. All records indicate that *Hatteras* was designated by Harlan and Hollingsworth as hull no. 75. The "327" may refer to the engine number or some other internal designation. Although Harlan and Hollingsworth built steam engines, it is not possible to indicate conclusively if they manufactured *Hatteras'* engine. One of the more interesting recovered artifacts is the 45-pound ball (Appendix E; Figures E-40-42). Research and consultation with archaeologists and ordnance experts familiar with Civil War artifacts have not provided a conclusive identity for the ball. The object can be discounted as ordnance due to the flat bottom, size of the handle, and the fact that neither *Hatteras* nor *Alabama* had guns of this size aboard. Speculation has included use as part of a shackle for weighing down prisoners, a sounding device, tension weight, gaming equipment (similar to weights used in Highland game throwing events), and even an early form of a correcting sphere for a binnacle. Because no records have been identified containing contextual or provenience information for this artifact, it has been extremely difficult to identify its function or purpose. This demonstrates the need to document sites thoroughly before recovering artifacts, which is a requirement for proper archaeological excavation.

4.2.9 Site No. 15326, East Cameron Area, Unknown Barge

Based on the probability model developed in 2003 by Pearson et al., the study site is located within an area that is not considered to have a high probability for shipwreck occurrence. According to CEI (1977), Site 15326 was seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), and just seaward of coastal sailing routes used during the 18th and 19th centuries (CEI 1977: Plates 7 and 8). The site is located within shipping routes used during the first half of the 20th century running between Cameron, Louisiana and the Straits of Florida (CEI 1977: Plate 9). Based solely on the wreck's location, it is most likely associated with modern activities, rather than the historic shipping lanes.

There are no reported shipwrecks located in the immediate vicinity of site number 15326 and prior to this investigation no tentative identification was assigned to the site. The available geophysical dataset exhibits wreckage that protrudes 0.9 to 1.5 m (3 to 5 ft) above the seafloor in places, but much of the hull has settled into the surficial sediments. The hull components are approximately 67 m (220 ft) in length and measure 12.5 m (41 ft) in width. The vessel is interpreted as iron or steel, based on observed magnetic signatures. Reported wrecks in the vicinity of Site 15326 have been researched and a comprehensive list of 29 wrecks within a 32-km (20-mile) radius was assembled. Of the reported losses, 22 contained detailed information, such as length or tonnage, and only two of these wrecks exceeded 30 m (100 ft) in length (Table 4.8). The remaining wrecks are too small to be the vessel at Site 15326.

Table 4.8

Reported Shipwrecks in the Vicinity of Site 15326 with Similar Dimensions

Vessel Name	Gross Tonnage	Length	Breadth	Date of Sinking	Vessel Type
Shoal Harbor	193	120.5’	20.5’	1955	Fishing vessel
Lafourche	198	130.6’	34.1’	1971	Oil exploration

Measurements taken from Merchant Vessels of the U.S.

No means of propulsion were identified on the wreck site during diving operations in 2010, and geophysical data was limited to a previous survey of the area (Section 3.9.1); no new geophysical data was acquired over this site. It is possible that the barge was lost during a towing operation and, because it is not a self-propelled vessel, its loss was not recorded in any available databases.

This site appears to be a steel or iron barge that is split into two pieces. Barges are commonly used to transport goods or equipment in the GOM region, and have also been used in offshore construction. Due to limited visibility and netting which obscured much of the site, not enough information is available to make a determination on age or identity. During diving, no diagnostic elements were identified that would establish historical significance for this site. The large, rectangular barge is not interpreted as historically significant based on this limited data set.

4.2.10 Site No. 322, East Cameron Area, Unknown Modern Wreck

Based on the probability model developed in 2003 by Pearson et al., the study site is located in an area that is considered to have a low probability for shipwreck occurrence. According to CEI (1977), Site 322 is located seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), and just seaward of coastal sailing routes used during the 18th and 19th centuries (CEI 1977: Plates 7 and 8). The site is located within shipping routes used during the first half of the 20th century running between Cameron, Louisiana and the Straits of Florida (CEI 1977: Plate 9). Based solely on the wreck’s location, it is most likely associated with modern activities, rather than the historic shipping lanes.

There are no reported shipwrecks located in the immediate vicinity of Site 322 and, before this investigation, no tentative identification had been assigned to this site. The available geophysical datasets depict an upright hull measuring between approximately 17.3 m (57 ft) and

20 m (65 ft) in length and between approximately 3 m (10 ft) and 6 m (20 ft) in width. The results of the 2010 diver investigation suggest that the vessel may be a 20th-century fishing vessel. A comprehensive list of 70 wrecks and obstructions within a 48-km (30-mile) radius of Site 322 was assembled. Of these vessels, details such as length and tonnage were available for 45 vessels. Candidate vessels closest in type and dimensions to Site 322 are shown in Table 4.9.

Table 4.9

Reported Shipwrecks in the Vicinity of Site 322 with Similar Dimensions

Vessel Name	Gross Tonnage	Length	Breadth	Date Built	Date of Sinking	Vessel Type
Vona Mabry	63	58.7’	18.6’	1950	1956	Fishing vessel
Martha Gene	14	56’		1939	June 10, 1959	
E. M. Hartrick	34	55.7’	15.1’	1916	1950	Oil screw wood tug
Ramos Pride	49	54.2’	18.1’	1944	1960	Fishing vessel
Sarah Marie		54’			1985	Fishing vessel
Coastal Rambler	95	66’	20’	1965	February 26, 1986	Fishing vessel
Voncille	38	51.2’	17.3’	1943	1953	Fishing vessel
Miss Patsy	13/127	46.6’/ 68.8’	15.3’/ 22.1’	1949/ 1974		Fishing vessel
Lucky Moon		70’			October 29, 1999	Fishing vessel

Measurements from *Merchant Vessels of the U.S.*

Diver observations indicate that this vessel represents a relatively modern steel-hulled working vessel, most likely a fishing trawler. *E.M Hartrick* was a wooden tug, and is therefore excluded as a candidate for Site 322. Seven separate fishing vessels with similar dimensions as the vessel at Site 322 are reported in the general area; this makes them possible candidates for the identity of the wreck (Table 4.9). Very little diagnostic information is available for Site 322, and without additional data about the candidate vessels, it is not possible to discern one wreck as the most probable identity of Site 322. Many of the fishing vessels reported lost in the search radius meet the 50-year age requirement for National Register eligibility, based on the date they were built. Age, however, is not the only requirement, and as demonstrated by the number of reported fishing vessel losses in the area, many of which sank in the 1950s, these are unlikely to demonstrate a unique representation of type.

4.2.11 Site No. Pending, West Cameron Area, Modern Debris

Based on the probability model developed in 2003 by Pearson et al., the study site is located within an area that is considered to have a low probability for shipwreck occurrence. According to CEI (1977), this site is located seaward of the most frequent routes of coastal exploration used during the 16th and 17th centuries (CEI 1977: Plate 6), seaward of coastal sailing routes used during the 18th century (CEI 1977: Plate 7), and between sailing routes used during the 19th century (CEI 1977: Plate 8). The site is located within shipping routes used during the first half of the 20th century running to and from Port Arthur, Texas (CEI 1977: Plate 9). Based solely on the wreck's location it is most likely associated with activities in the 19th century or later.

There are no reported shipwrecks located in the immediate vicinity of this site and no tentative identification was assigned before the start of this study. Reported wrecks and obstructions within the vicinity of this study site have been researched and a comprehensive list of 138 wrecks and obstructions within a search radius of 48 km (30 miles) was compiled. Of the identified losses, 64 have records that contain details such as length that can be compared with the feature at this site. None of the reported objects or shipwrecks found in available databases provides a suitable identification or clear association with this target.

The combined diver investigations and geophysical datasets indicate that a single rectangular object representative of heavy machinery, likely associated with commercial activity (such as oil and gas or fishing), sits on the seafloor (Figure 4.15). Metal detectors used on site identified buried components extending a significant distance beyond the exposed portion of the site. No documentary records were found which can be correlated to this target. The site may be the result of an accident loss or intentional dump. It is possible for objects, such as winches, to fall off of a ship or barge as a result of a storm or an accident during heavy lift operations. Other possibilities for the presence of this feature include the intentional discarding of modern debris, either for disposal purposes or for use as an unofficial, private fishing habitat.

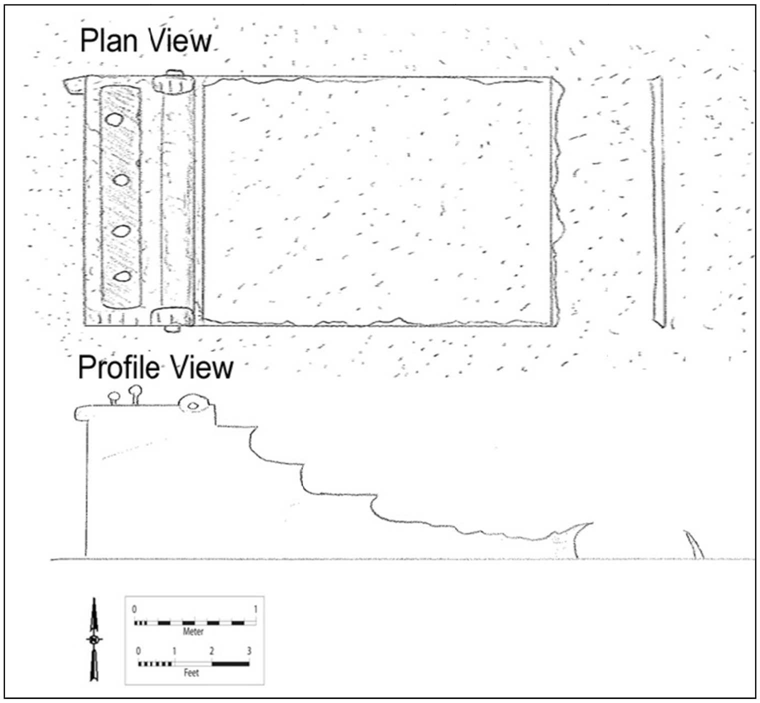


Figure 4.15. Plan and profile of exposed portion of site.

4.3 NRHP Eligibility

Requirements for determining National Register eligibility are published in National Register Bulletin, V.20, and in 36 CFR 60.4. To meet National Register eligibility criteria, an archaeological site (fifty years or older) must adhere to at least one of the following criteria:

A. Be associated with events that have made a significant contribution to the broad patterns of our history;
B. Be associated with the lives of persons significant in our past;
C. Embody distinctive characteristics of a type, period, or method of construction, or represent the work of a master, or possess high artistic value, or represent a significant and distinguishable entity whose components may lack individual distinction;
D. Have yielded, or be likely to yield, information important in prehistory or history.

In addition to eligibility criteria A–D listed above, a historic vessel must retain integrity of location, design, setting, materials, workmanship, feeling, and association. Determining the significance of an historic vessel depends on establishing whether the vessel is: 1) the sole, best, or a good representative of a specific vessel type; 2) associated with a significant designer or builder; or 3) involved in important maritime trade, naval, recreational, government, or commercial activities (36CFR60.4). Five distinct categories of vessels may be eligible for listing on the National Register, including shipwrecks, which are defined as "a submerged or buried vessel that has foundered, stranded, or wrecked. This includes vessels that exist as intact or scattered components on or in the sea bed, lake bed, river bed, mud flats, beaches, or other shorelines …" (NPS 1992:3).

The significance of an historic vessel can be determined only through a systematic investigation of the vessel's qualities, associations, and characteristics.

The archaeological assessments of the study sites were designed to address the following types of information:

1. Identification of the specific type of vessel and documentation based on a physical inspection of the vessel and a documentation of its history.
2. Identification of the historic context(s) associated with the vessel based on a documentation of its history.
3. Determination that the characteristics of the vessel make it either the best or a good representative of its type.
4. Evaluation of the significance of the vessel based on the National Register criteria.
5. Evaluation of the vessel's integrity and a listing of features that the vessel should retain to continue to possess integrity.
6. Evaluation of a vessel's special characteristics that might qualify it for National Register listing even though it might be less than 50 years old or some aspect of its present condition generally would not qualify it for listing.

4.3.1 Civil War

The USS *Hatteras* was the only site investigated as part of this study that dates to the Civil War-era, and is already listed on the NRHP. *Hatteras* is the only U.S. warship sunk at sea in the GOM (Irion 2000:141). It has been referred to as one of the most important underwater archaeological sites in the U.S. (Arnold and Anuskiewicz 1995:86; Irion 2000:143). After its loss, no contemporaneous salvage attempts were made on *Hatteras* (U. S. District Court, Southern District of Texas, Galveston Division 1984). Assuming that the artifacts that treasure hunters recovered from the site in the 1970s, and referenced in the ensuing court case, are the only items salvaged from the site, the remaining assemblage should be relatively intact, including the crew's belongings and personal effects and military and vessel equipment. This could provide an invaluable trove of information on shipboard life during the Civil War. In addition to the context of the war, the ship itself represents an early iron-hulled vessel that was constructed during a time when shipbuilders were experimenting with the transition from wooden shipbuilding techniques to a separate methodology for metal-hulled vessels. Although some details of the wreck's engine components and dimensions are known, no known plans or diagrams of the vessel are available. The ship itself therefore also represents a significant historic resource.

4.3.2 World War II

Based on the combined results of this study, Site 433 is believed to be the remains of *R.W. Gallagher*; Site 373 is believed to be the remains of *Cities Service Toledo*; and Site 386 is believed to be the remains of *Heredia*. All three vessels were casualties of German attacks in the GOM during an eighteen-month period between 1942 and 1943 that saw intensive U-boat patrols in U.S. waters. *Heredia* was sunk on May 19, 1942; *Cities Service Toledo* was sunk on June 12, 1942; and *R.W. Gallagher* was sunk on July 13, 1942. *Heredia* was the only one of the three that was not chartered by the U.S. War Shipping Administration and remained in private hands at the time of the attack. All of the vessels, though, show modifications and additions meant to counter the U-boat menace. All three vessels were armed with multiple guns and accompanied by a complement of naval armed guards.

Based on Criterion A, the affiliation with events important to U.S. history, all three vessels may potentially be eligible to the NRHP because of their roles in supplying the U.S. economy during the war, their efforts to evade the German U-boat attacks, and the tragic events of their sinking, during one of the few incursions in modern history by foreign powers into U.S. waters at a time of war.

Heredia was originally built in 1908 as a steam powered liner, and the vessel's boilers were converted from steam to oil in 1921. *Heredia* was also one of the earliest vessels outfitted with refrigerated cargo holds for transportation of produce (Goldberg 1993). *Cities Service Toledo* (originally named *J.A. Bostwick*) was built in 1918 as a steam powered tanker. Sometime before 1927, the vessel was fitted for use with fuel oil. Both vessels are representative of a major technological shift from steam power to oil. In both cases, the boilers appear to have been retained, and re-fitted as opposed to installing new diesel engines. These vessels are both representative of steam powered vessels forced to convert to a much more efficient fuel source to stay profitable and competitive in an expanding industry. Because of this, these two vessels are potentially eligible under Criterion C, because they are representative of a distinctive, but short-lived technological shift that played a crucial role in the nation's industrial history.

All three vessels are potentially eligible under criterion D, having yielded, or being likely to yield, information important in prehistory or history. National Register Nomination forms for all three sites have been prepared for submittal to the National Park Service.

4.3.3 Modern Industry

The towing vessel *J.A. Bisso* operated in the oil fields of the GOM from 1919 until 1957, when it sank during towing operations. Built in 1906, *J.A. Bisso* was a turn-of-the-century tug with the potential to provide valuable information about early commercial activity in the GOM. The vessel was converted from steam but retained its original boilers and so is a rare remaining example of early steam-powered tugs. As of 1980, Ted Miles and Norman Brouwer had compiled a partial list of extant historic steam tugs and towboats throughout the U.S. and Canada. They were able to find only four steam tugboats still active and a total of 14 that had been converted to diesel (Lang and Spectre 1980). Most of the steam tugboats located were found conserved within nautical museum collections throughout both countries (Lang and Spectre 1980). A general review published by William Burt (2000) of tugboats registered in the U.S. indicated that approximately four percent were less than five years old and the majority were older than 20 years. The publication also noted that an active steam tugboat is rare; the remaining examples are either conserved and on display in museum collections or in such disrepair that they are unseaworthy (Burt 2000). During an interview with a descendant of the owner of *J. A. Bisso* and current president of Bisso Marine, it was reported that no steam or converted diesel tugboats are active within their fleet; all were scrapped for parts (William Bisso 2011 pers. comm.).

J.A. Bisso is potentially eligible for inclusion on the National Register under criteria C and D because of the rarity of the type and the information it can provide on technology and industry at this early point in the nation's offshore development.

In addition to *J.A. Bisso*, Site 15326 (modern barge) and the modern debris located in the West Cameron area (no site number assigned) both appear to be related to commercial activity, possibly oil and gas development. Although the exact purpose of the debris identified at the West Cameron site remains unidentified, it appears to represent out-of-context, disarticulated remains. These appear to represent an industrial winch and hydraulics and are not likely to represent any unique or historic technological achievement. This target is not believed to represent a historically significant resource and does not warrant further investigation.

Because of the degree of site burial, limited visibility, and a large quantity of netting obscuring the site, the assessment of Site 15326 was fairly limited. Portions of the site that were observed appear to be consistent with modern construction and equipment and did not appear to represent a unique technological achievement or exemplary representation of vessel type. Based on the limited results of the diving survey, this site is believed to be related to modern construction and is not interpreted as historically significant,. Although these sites may have had economically important roles in the region, they do not appear to represent unique examples of type nor do they meet any other criteria for historical significance necessary for inclusion on the National Register.

Sites 15488, 15366, and 322 may all be associated with fishing or trawling. The identities of these three vessels remain unknown, and they are unassociated with known events or persons of historical significance. None of these vessels appears to exhibit any unique characteristics that would qualify them for inclusion on the National Register. These types of vessels are ubiquitous in the GOM, and are not a unique or exceptional representation of type.

4.4 SUMMARY

Of the 11 total sites investigated through this contract, four are potentially eligible for National Register nomination: *R.W. Gallagher*, *Heredia*, *Cities Service Toledo*, and *J.A. Bisso*. The three World War II-era vessels are considered historically significant because they are more than 50 years old and meet the requirements of criteria A and D. Their association with German U-boat attacks in the GOM during World War II puts these vessels firmly in the context of events that had important roles in the broad patterns of both U.S. and world history. The sites themselves could contain additional information that would expand our knowledge of history and that makes them eligible under criterion D. Information that could be gained through more detailed study includes a better understanding of the environmental impacts of sunken tankers and submerged hydrocarbon cargos, civilian and military responses to submarine attack (as evidenced by the reported degaussing equipment and armament), and information about life aboard these ships that has not been published in official records. Finally, *Heredia* (Site 386) and *Cities Service Toledo* (Site 373) meet Criteria C because each represents the transition from steam powered vessels to fuel-oil propulsion.

The tugboat *J.A. Bisso* is also older than 50 years, and meets the requirements of criteria C and D. Originally built as a steam-powered tug, *J.A. Bisso* retains its boilers and other original equipment after its conversion to oil propulsion. *J.A. Bisso* is representative of the beginnings of the offshore oil and gas industry, which is an entrenched economic and cultural way of life in Louisiana and Texas.

5. SITE FORMATION PROCESSES

It has been well established that shipwreck sites are subject to numerous processes that produce measurable changes that impact the ship, the artifacts, and their context over time (Muckelroy 1978; Stewart 1999; Quinn 2006). For most shipwreck sites, the wrecking event itself is the single most catastrophic event that occurs to the site, and it is followed by a number of inter-related processes that cumulatively impact the shape and condition of the site. These site formation processes can be caused by environmental and anthropogenic factors and can impact both the interpretation of the site and decisions about its long-term management.

The following sections introduce pertinent research and data examining the role of environmental site formation processes across the study area (Section 5.1) and anthropogenic activities that have impacted or could impact wreck sites (Section 5.2). These environmental and anthropogenic processes are identified at each of the contract study sites (Section 5.3) and observed patterns and comparisons are made across sites (Section 5.4).

5.1 Environmental Site Formation Processes

5.1.1 Introduction

Environmental processes that impact submerged shipwrecks are the cumulative results of the interaction of geologic, biologic, chemical, and oceanographic variables. As part of the marine environment of the GOM, shipwrecks are subjected to warm water organisms, bioturbation, seasonally variable water chemistry, varying wave directions and current velocities, sedimentary movement, and occasional but extreme storm events.

Bioturbation is one of the leading causes of the deterioration of wooden shipwrecks and organic components (Muckelroy 1978:53; Wachsmann 2011:206-207). One of the most well-known wood-damaging organisms is the *Teredo navalis* (also known as shipworm), a small salt-water bivalve that causes structural damage to ship timbers by burrowing into planks and other exposed surfaces. Other wood-damaging organisms that are prevalent throughout the GOM include Gould’s shipworms (*Bankia gouldii*), wood piddocks (*Martesia cuneiformis*), striated wood piddocks (*M. striata*), and gribbles (*Limnoria tripunctata*), all of which bore or burrow into submerged wood (Kaplan 1988:258, 261). In warm salt water these organisms accelerate decay, deteriorating the condition of organic components that are not protected by burial beneath seafloor sediments.

With the exception of *Hatteras* (Site 236), the vessels included in this study are metal-hulled ships that sit largely exposed on the seafloor and project into the water column. For these sites, corrosion and mechanical processes are the primary mechanisms of deterioration. Mechanical processes include the physical impact of waves, currents, and storms on the integrity of the hull and any disarticulated components. The rates and extents of corrosion depend on a number of complex factors; the most significant of these is water chemistry, which can be measured through variables such as salinity, pH, and dissolved oxygen (DO). When buried in sediment, metal-hulled shipwrecks are protected against the long-term effects of corrosion through DO and salinity; however, pH levels in the sediment may still be conducive to anaerobic corrosion-causing, sulphate-reducing microbes.

Sediment accretion and scour are directly related to site burial or exposure and can be measured in a number of ways. For long-term studies at a given site, erosion pins and sediment traps can be placed around the site, allowing researchers to collect repeat measurements over time and assess rates and patterns of change. Repeat visits were not possible for this study; therefore, variables related to accretion and scour were measured from unique samples and existing data was modeled to indicate possible rates of change at each site. Grain size, sediment transport potential as a function of flow regimes, and, where possible, shear strength measurements were used to provide information on the potential for sediment scour. Sediment cores acquired on each site were sampled for analysis of ^{210}Pb and ^{137}Cs isotopes in order to provide estimates of sediment accretion rates. This data also provided insight into the impacts of storms on the seabed at the study sites.

5.1.2 Sediment Movement and Hydrodynamics

Physical, biological, and chemical factors all contribute to the deterioration of shipwreck sites, but sediment overburden is the most significant means of site preservation (Ward et al. 1999). This is particularly true in warm saline environments, such as the GOM. Shipwreck exposure and/or burial can occur in several ways. Objects on the seafloor may subside below surficial sediments, become buried by the accretion of sediment on top of the existing feature, become exposed through scour and erosion of existing sediments, or any combination of these processes. Sedimentation rates are most accurately determined through long-term monitoring and repeat site visits; however, estimates of recent sedimentation can be determined by examining nearby current and sediment data, and can also be assessed through analysis of radioisotope tracers, as discussed in Section 5.1.2.3 (Allison and Lee 2004; Allison et al. 2005; Neill and Allison 2005). Hurricanes may also be used in oceanographic modeling because in water depths equivalent to the study area, they represent extreme conditions that may result in a punctuated change in seafloor equilibrium. Seafloor properties, such as sediment cohesion and shear strength, may also impact subsidence potential, and can be analyzed through analysis of core data (Conlin 2005b; Keith and Evans 2009).

Waves and currents impact the physical remains of an archaeological site and the sediments that act as a protective barrier to buried materials. The mechanical actions of currents and waves, particularly in shallow sites, can severely damage submerged structures, including thick iron plating. On the USS *Arizona*, hull plates have been observed to flex significantly during wind-induced tidal surge (Lenihan 1990:97). Although these impacts are acknowledged, the measurement of such forces was beyond the scope of this study. A separate study performed for BOEMRE (previously MMS, now BOEM) focused on the impacts of hurricane forces on the hulls of submerged shipwreck sites (Gearhart et al. 2011).

Scour and erosion can impact shipwreck sites in several ways. McNinch et al. (2006) demonstrated that erosion and scour caused by waves and seasonal tides contribute to artifact burial, thereby promoting preservation below the seafloor. Alternatively, erosion or scour can remove protective sediment layers and reintroduce historic shipwreck components to deterioration from organisms and the environment. As demonstrated by Quinn (2006), this can occur when shipwreck sites are subjected to various current flow regimes, or the shipwreck site itself can induce scour by altering the natural flow regime and impact vortex development in a given area.

The GOM is typically categorized as a micro-tidal, low energy environment (Curray 1960:231-234); this may lead to the incorrect assumption that bottom sediments, and ultimately shipwrecks, in this area are not impacted by oceanographic processes. Physical processes, such as semi-permanent currents, tidal currents (normal and hurricane), and waves (normal and hurricane), impact the initial distribution of sediments from their sources and can also rework and modify post-depositional sediments (Curray 1960:234). General characteristics for the GOM were outlined by Curray (1960) and have been supplemented and refined by subsequent case-studies of specific micro-environments to determine the potential for sediment transport and scour under varying conditions (i.e., Suhayda 1977; Teague et al. 2006). Diurnal and mixed diurnal tidal fluctuations in the GOM typically average less than 0.3 m (1 ft); however, tidal ranges are highly variable during meteorological events and hurricane-induced tides in the GOM may exceed 3 m (10 ft) (Curray 1960:233). According to Curray (1960:231), average deepwater wave periods range from 3 to 8 seconds, and waves rarely exceed 1 m (3 ft) in height. Mean significant wave heights measured offshore of the Chandeleur Islands have been modeled from hindcast data and indicate wave heights of 0.8–1.0 m with a period of 5 seconds (Georgiou et al. 2005). Generally, these small-size waves are capable of moving sediment only in the shallow surf-zone (Curray 1960:231). Shallow water sediments are principally sands and coarser-grained material than that found on the continental shelf, because sands fall out of suspension before silts and clays and so are preferentially deposited along the coast (Masselink and Hughes 2003). Under bed stress and flow conditions, cohesionless sands "behave individually," while silts and clays (grain size less than 63 microns [μm]) are electro-statically charged and therefore cohesive (Masselink and Hughes 2003:124). According to Masselink and Hughes (2003:124), "the dynamic behavior of cohesive sediment depends less on single-grain properties and more on bulk-sediment properties (e.g., floc size and water content)." This has important repercussions for estimates of sediment scour.

Sediment that has been eroded from an area on the seabed through the effects of waves and/or currents is referred to as *scour* (Whitehouse 1998:9). Scour can occur locally (e.g., steep-sided holes), globally (e.g., a shallow or wide depression under or around features, also referred to as dishpan scour), or as overall seabed movement (Whitehouse 1998:9). Seafloor structures, including shipwrecks, create disturbances in the flow and direction of waves and currents through the water column, and create vortices emanating from the structure (Whitehouse 1998:9; Quinn 2006). With regard to shipwrecks, "the characteristics of the ambient flow depend on the size and shape of the structure and its orientation to the flow direction … angular or irregularly shaped structures will produce a more complex and turbulent flow than that formed around streamlined structures" (Whitehouse 1998:250-26). Sediment mobility can be predicted for specific locations, based on an analysis of waves, currents, wave-current interaction, and the specific sediment characteristics of the area (Whitehouse 1998:64).

Sediments on the continental shelf are generally considered to be at equilibrium, and fine-grained sediments correspond to areas with weaker currents (Whitehouse 1998:62). Hurricane waves and tidal currents disrupt this equilibrium and are largely responsible for reworking and modifying sediments on the shelf (Curray 1960:234). According to Curray (1960:233), "a velocity of 35cm/second is … the approximate mean velocity at 1 meter above the bottom which is required to pick up and move fine quartz sand," although actual net transport also requires a "velocity gradient to the bottom and unidirectional flow." Using hindcast wind and wave data for normal wave conditions in the GOM, Curray estimated that areas in water depths less than 10 fathoms (18.3 m or 60 ft) experienced bottom velocities greater than or equal to 35 cm/sec for more than 500 hours per year, or approximately 5% of the time (1960:233). Similar calculations using actual hurricane wave statistics indicated that areas in water depths between 10 and 15 fathoms (18.3 to 27.5 m or 60 to 90 ft) experienced this same velocity less than once every 18 months (Curray 1960:233). All of the shipwrecks in this study are located in areas that, according to Curray's estimates, experience bottom current velocities sufficient to result in transport and scour of fine, cohesionless, sands.

Wind- and wave-induced bottom pressures play a significant role in bottom sediment deformation and transport in water depths less than 150 m (500 ft) (Suhayda 1977:139). Wind and waves create bottom orbital velocities, whose tangential velocities create stress on the sediment surface in contact with the fluid plane. If the shear stress generated by the wave exceeds the cohesion of the sediments, then the sediments may become mobile, resulting in either transport or scour (Whitehouse 1998:67; Masselink and Hughes 2003:118). Wave height and period, and bottom depth will variably impact the amplitude of orbital velocity, and therefore the overall shear stress impacting potential scour (Whitehouse 1998:67). Wave heights and periods in the GOM are relatively low, but become exaggerated during hurricane events, contributing to increased instances of punctuated scour.

Based on data acquired by Forristall and Reece (1985), Teague et al. (2006) estimate that for every 3 m (9.8 ft) of wave height, approximately 1 cm of sediment displacement can be expected. According to Teague et al. (2006), Hurricane Ivan produced waves with significant heights of approximately 18 m (59 ft) (maximum wave height of 28 m or 92 ft) and near-bottom orbital wave velocities that were higher than 2 m/sec at 60 m (197 ft) of water depth, directly beneath the wave field. Following the estimates of Forristall and Reece (1985), they estimated 6 cm of sediment displacement in the areas with wave heights of 18 m. During Hurricane Ivan velocities recorded away from the center of the hurricane's path ranged between 0.4 to 1.2 m/sec, which were lower than velocities recorded under the maximum wave fields, but still above the threshold for sediment transport (as defined by Curray 1960). These water depths, though, are greater than at the present study sites and represent calculations based on data directly in the path of a specific hurricane. More important, these scour calculations and storm estimates do not differentiate between the types of sediments impacted by specific wave fields and current velocities.

A large percentage of scour studies are concerned with the coastline and nearshore areas because of the effects of shoreline erosion. For example, Keen et. al. (2004) documented large hurricanes' powerful capabilities in transporting sediments and forming event bed layers both seaward and shoreward of barrier islands in the northern GOM. These are the same high energy shallow zones in which Curray (1960) predicted higher sediment transport potential under normal wave and current conditions. Goff et. al. (2010) found that Hurricane Ike was capable of adding up to 2.5 m (8.2 ft) of sediment to a site north of Big Reef, offshore Texas. These authors also observed that shell-gravel ridges that were approximately 3 m (10 ft) high and 150 m (492 ft) wide before the storm were drastically degraded by the hurricane, and became up to 2 m (6.6 ft) shorter and migrated seaward by 40 to 50 m (131 to 164 ft). Even during lower energy events, with significant wave heights of 1 m and current speeds higher than 40 cm/sec in shallow water depths of 4 m, significant resuspension and bed reworking have resulted (Sahin et al. 2011). The work of Keen et al. (2004), Goff et al. (2010), and Sahin et al. (2011) demonstrate significant sediment transport and reworking in shallow water areas, such as those surrounding barrier islands, the surf-zone, and the inner shelf, which are characterized by sandy to muddy sediment and are much shallower than the current study sites.

According to Whitehouse (1998:4), "it is primarily the bed shear stress which causes scour regardless of whether the flow is wave-alone or current-alone, or the combined wave-current case." Bed shear stress is the force exerted per unit area, and resistance to shear stress is dependent on friction and sediment cohesion, which is a product of grain size and plasticity. Given uniform wave heights and currents, different bed types and configurations vary in their response to scouring conditions. Suhayda (1977) attempted to characterize bottom sediment movement responses for fine-grained clays in the GOM; bottom sediments in the northwestern GOM, where the study sites are located, are predominately silts and clays (MMS 1983). Suhayda (1977) tested sediments to a depth of 30 cm (12 inches) below the mud line (BML) in East Bay, Louisiana, in water depths of 10 to 12 m (33 to 39 ft). Under moderate waves (1 m high and period of 5 seconds), Suhayda (1977) measured a wave induced vertical displacement of approximately 1 mm in fine-grained clay. More relevant to the study sites, Suhayda (1977:146) found that muddy bottoms absorb and dissipate a high percentage of wave energy, and, when compared to sandy bottoms, "a relatively greater amount of wave energy is lost on a muddy coast at intermediate water depths than is dissipated along a sandy coast." As discussed by Komen et al. (1996:342), Forristall and Reece's research illustrated that the attenuation of wave heights measured between two study datums (as published in 1985) could largely be attributed to soft mud deposits, which dissipated significant wave energy.

Scour can be identified from geophysical remote sensing data, physical samples, and cores of sediment stratigraphy, and examination of topographic profiles and 3D digital elevation models of the seafloor around wrecks. Sub-bottom profiler data can detect eroded areas of seafloor and of sediment infill in which younger sediments have different densities than the surrounding sediments (Quinn 2006; Evans and Voisin 2011). Scour also leaves a unique physical signature within sediment stratigraphy, as evidenced by box cores collected on the inner continental shelf (8 to 13 m or 26 to 43 ft water depth) of the GOM after Hurricane Ivan. Research by Goff et al. (2010) resulted in the identification of an "event layer" stratigraphy that consisted of 5 to 8 cm (2 to 3 inches) of mud overlying 1 to 3 cm (0.4 to 1.2 inches) of sand and a shelly, bioturbated, Holocene sandy mud, with a basal hiatal surface in between. The observed event layer stratigraphy was interpreted as a direct result of disturbance caused by major hurricanes on the seabed (Goff et al. 2010:353), and has been correlated in other studies from previous hurricanes in the GOM (Allison et al. 2005). According to Goff et al. (2010) the basal hiatal surface of the event layer is formed by wave- and current-induced scour during the peak of the storm, and is overlain by sediments deposited as the storm weakens over the area. Allison et al. (2005) measured three stacked event layers down a box core collected from approximately 20 m (66 ft) BSL, offshore Louisiana. They found that the bottommost event layer, measuring approximately 7 cm (2.8 inches) thick, was attributable to Hurricane Ivan. The overlying two layers were produced by Hurricane Katrina and are about 19 cm (7.5 inches) thick, with the uppermost 9 cm (3.5 inches) representing sediment reworking as a result of Hurricane Rita.

Based on Curray's calculations, it is evident that only hurricanes and other extreme storm events occurring less than once every 18 months produce sufficient velocity to cause the mobilization of fine sands in water depths between 18 and 28 m (60 to 90 ft) in the GOM. While the seabed in water depths less than 18 m (60 ft) undergoes greater forces than deeper water, sufficient force is present only 5% of the time and sediment mobilization is therefore a rarity. Curray's calculations were specifically for sands, but the cohesive clays and silts that characterize the study sites typically require greater force for transport or scour than the cohesionless sediments discussed by Curray. For these reasons, it is expected that extreme storm events are the most likely cause of sediment transport at the study sites, although it must be noted that the impact of the wreck sites on flow velocity (and resultant localized scour) could not be quantified through this study and is therefore an unknown variable. Punctuated instances of sediment scour and redeposition may leave evidence in the form of an event layer that can be identified using sub-bottom profiler data and/or sediment cores from the survey area. Grain size measurements, both surficial and downcore, may lead to a better understanding of the differences in scour patterns at each site since sediment type has significant control over sediment mobilization potential. Combined with oceanographic modeling and radioisotope analysis, it is possible to discuss potential sediment scour and accretion rates across the study sites.

Subsidence is a separate and significant factor in the burial of shipwrecks. As discussed by Keith and Evans (2009), subsidence occurs as the result of, and immediately following, the wrecking event. One of the best ways to quantify the potential for subsidence is through shear strength measurements of seafloor sediments. These measurements provide an indication of the amount of force necessary for the sediments to shear, which allows for displacement and burial of the wreck site. As is discussed in Chapters 2 and 3, shear strength measurements were obtained from sediment cores when possible and used to supplement the interpretation based on the factors discussed above. Due to the limited amount of sediment acquired at each site and the number of samples acquired within those cores, shear strength measurements could not be conducted on every site; therefore, published data sets (McClelland 1979; Dunlap et al. 2004) were also used to provide supplemental interpretation. Figure 5.1 shows published shear strength measurements based on Dunlap et al. 2004.

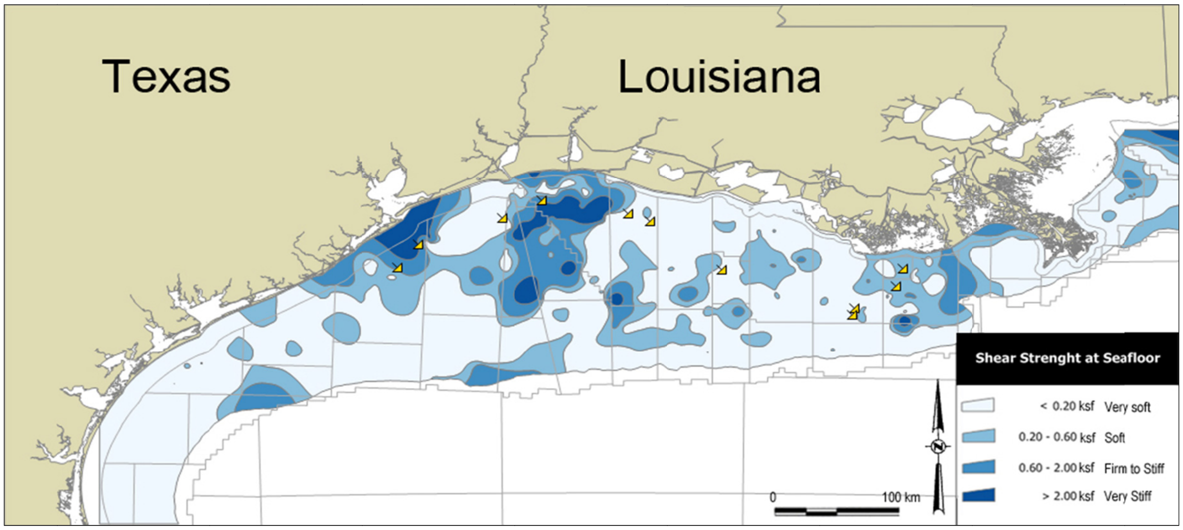


Figure 5.1. Shear strength measurements across the Northern GOM, in relation to study sites. (Data from Dunlap et al. 2004.)

5.1.2.1 Grain Size Data

Grain size is directly related to sediment cohesion, shear strength, and sediment transport potential. Cores acquired from the study sites were sampled and quantitative and qualitative grain size classifications made. Grain size measurements downcore were made to discern lithologic units and possible “event layers” or storm deposits, such as those indicated by Allison et al. (2005).

Published sediment morphology data for the GOM (MMS 1983) indicates that surficial sediments across most of the northwestern GOM consist of varying percentages of sand, silt, and clay. When compared with the published data, actual grain size measurements are generally within the same fraction (Table 5.1); however, divers noted significant grain size variability within some of the study sites. This suggests that estimates of sediment transport will vary in accuracy based on the difference between expected and actual grain sizes present, and that all estimates should be used with caution.

Table 5.1

Measured Surficial Grain Sizes for Study Sites

Site No.	Grain Size Classification	
	Graphic Mean Grain Size (µm)	Wentworth Classification[1]
433 (*R.W. Gallagher*)	48.6	Course silt
386 (*Heredia*)	n/a	n/a
373 (*Cities Service Toledo*)	12.5	Medium silt
15488 (Unknown wreck)	46	Coarse silt
15366 (Unknown wreck)	9.76	Medium/Fine silt
389 (*J.A. Bisso*)	173	Fine sand
236, paddlewheel area (*Hatteras*)	13	Medium silt
236, stern area (*Hatteras*)	343	Medium sand
15326 (Unknown wreck)	n/a	n/a
322 (Unknown wreck)	n/a	n/a

[1] Calculated graphic mean grain size from measured samples after Folk (1980) and Shackley (1975).

5.1.2.2 Oceanographic Data

As discussed previously, oceanographic modeling in this study focused on extreme storm events, due to their increased potential for inducing sediment transport and scour compared with non-storm conditions in the GOM (Section 5.1.2). Pre-existing data, including wave height and wave period, was available for recent storms, including Rita and Ike, and illustrate the oceanographic conditions likely to induce scour (Figures 5.2 and 5.3). In order to estimate sediment transport and scour potential across a multitude of study sites, three datum sites were selected and modeled (Rego et al. 2011). The results of the analysis at each datum were then used to model conditions at each of six study sites, as discussed in Chapter 2. Grain sizes were measured for each datum, because sediment type is a significant factor in determining sediment mobility potential, as discussed above (Section 5.1.2). The datums generally represent water depths and sediment types found across the study sites, and include both maximum scour and net scour (scour measured after redeposition of suspended sediments following the modeled storm event) (Table 5.2).

Table 5.2

Characteristics of Surface Sediments at Oceanographic Modeling Datums

Datum	**Depth (m)**	**Surficial Sediments**	
		Grain Size (µm) Graphic Mean	**Wentworth Classification**
1	26.0	12.5	Medium silt
2	15.5	88.7	Very fine sand
3	31.0	74.4	Very fine sand

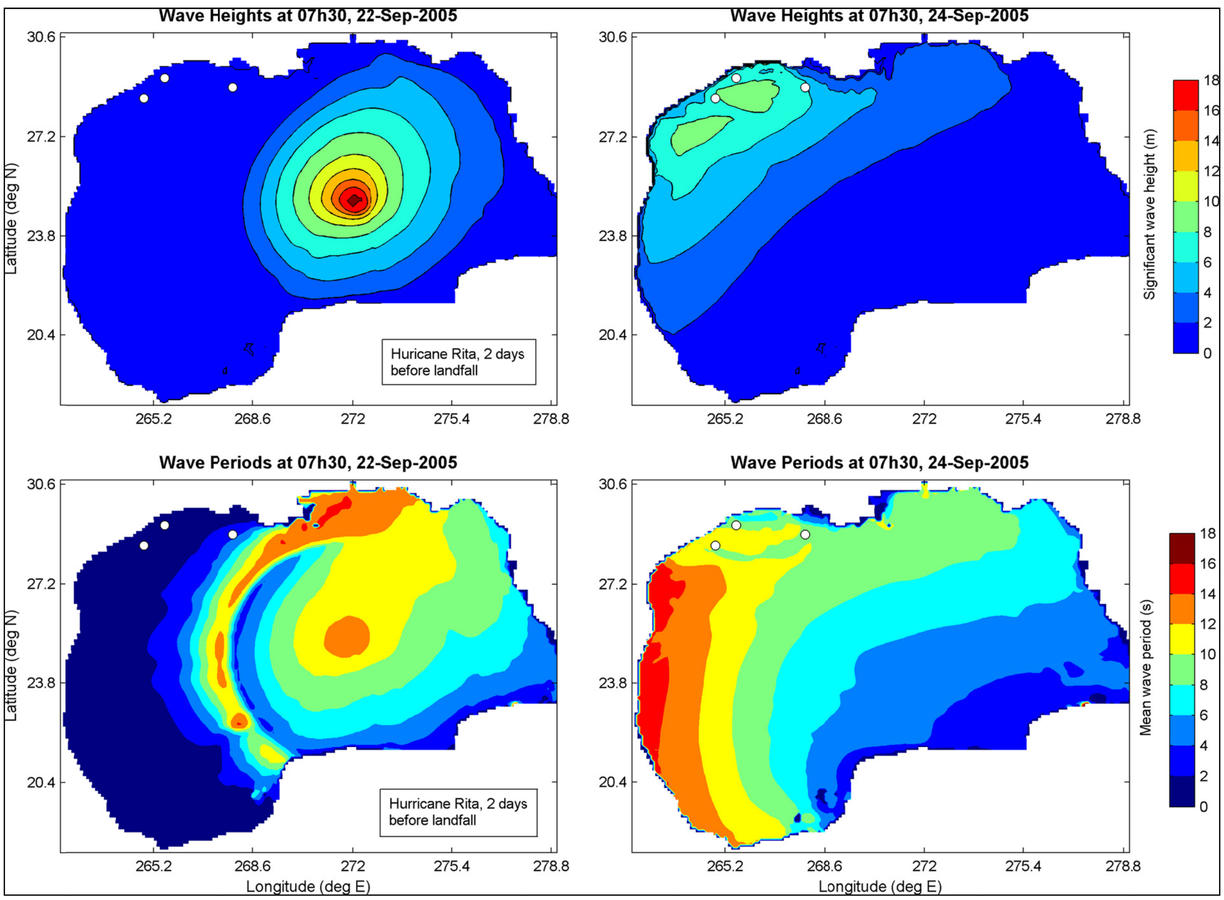


Figure 5.2. Significant wave height and mean wave-period during Hurricane Rita (results from regional model). The three white circles in the Northwestern GOM mark the three study Datums (Rego et al. 2011).

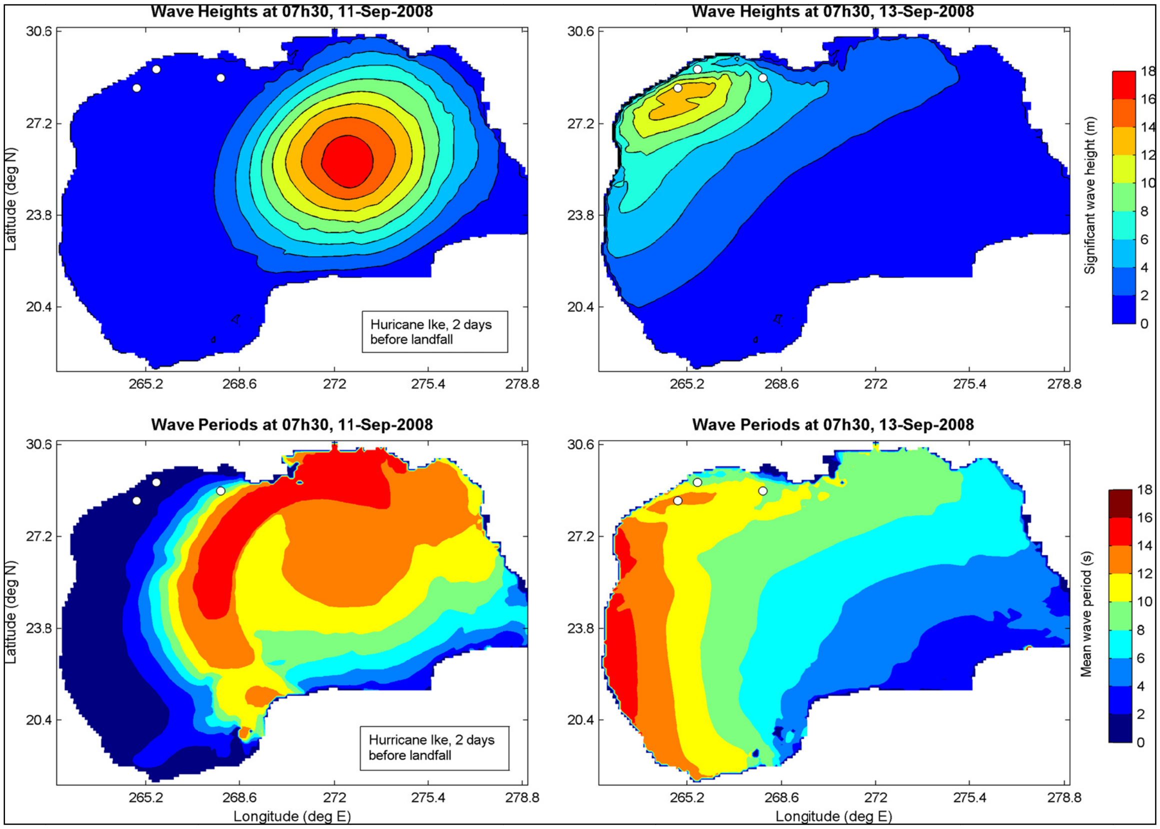


Figure 5.3. Significant wave height and mean wave period during Hurricane Ike (results from regional model). The three white circles in the Northwestern GOM mark the three study Datums (Rego et al. 2011).

Based on the results of the oceanographic datum modeling, each of the study sites should have experienced some degree of maximum scour (Table 5.3). As discussed in Chapter 2, sediment porosity and plasticity were not measured for the datum sites; therefore, to provide a range of expected conditions, both loose and consolidated bed scenarios were modeled for the specific grain sizes found at each datum point. For loose bed scenarios, maximum scour was reduced by between 70% and 91% following sediment redeposition (calculated 7 days after each modeled storm and reported as "net" scour; Table 5.3). At Datum 3 sediment redeposition actually resulted in net sediment accretion, but this was the only site to display accretion following a hurricane event. Under consolidated bed scenarios, maximum scour was reduced by 85% to 99% following sediment redeposition (Rego et al. 2011). This suggests that while scour is likely to occur at the shipwreck study sites, single instances of storm-related scour may not have a significant long-term effect on hull exposure rates. Scour is more likely to impact wreck sites when examined as a longer-term pattern of sediment movement, either through long-term or cumulative scour rates. Scour can and has been observed on the shipwreck sites through analysis of sub-bottom profiler data; however, there are limits to the resolution of near-surface scour patterns. The sub-bottom profiler system used in this study has published vertical resolution rates of 6 to 10 cm (2.4 to 3.9 inches) when using a 2 to 16 kHz range; however, the data acquired as a part of this study used a restricted 2 to 10 kHz frequency range that increased data resolution to approximately 6 to 8 cm (2.4 to 3.2 inch) range. Even using the higher frequency spectrum, based on hurricane scour estimates from hurricanes Ike and Rita, only scour in a loose bed scenario would be observed in the sub-bottom profiles. Consolidated-bed scour estimates are below the threshold for vertical resolution on sub-bottom data, and would only be detectable through physical sediment sampling and analyses, such as radioisotope analysis.

It should be understood that modeling estimates were based on flow conditions only. The estimates represent some, but not all of the possible scour scenarios during hurricane events. In particular, they do not account for the increased turbulence and local higher velocity flows and potential scour that would highly likely occur around the actual wrecks during storms and hurricanes.

Table 5.3

Scour Estimates Based on Oceanographic Modeling[1]

Hurricane	Bed Scenario	Scour Type	Scour Depth		
			Datum 1	Datum 2	Datum 3
Ike	Loose	Maximum	1.5 m	1.0 m	1.3 m
		Net	13 cm	30 cm	30 cm
	Consolidated	Maximum	0.3 cm	0.2 cm	0.24 cm
		Net	0.03 cm	0.03 cm	--
Rita	Loose	Maximum	1.5 m	84 cm	60 cm
		Net	21 cm	10 cm	+ 5 cm
	Consolidated	Maximum	0.3 cm	0.2 cm	0.10 cm
		Net	0.03 cm	~ 0 cm	--
[1] Rego et al. 2011					

5.1.2.3 Radioisotope Comparisons

Radioisotope analysis of ^{210}Pb and ^{137}Cs has had limited application in shipwreck archaeology. Previous examples of this type of data analysis include studies of *H.L. Hunley* (Murphy 1998) and USS *Housatonic* (Conlin 2005a). In the case of *Hunley*, analysis of ^{210}Pb and ^{137}Cs was done to determine sediment disturbance depth within the last 50 to 100 years (Lenihan and Murphy 1998:16). Radioisotope analysis conducted on sediments sampled above the buried vessel's hull indicated that there had not been any sediment disturbance within the last 100 years (Murphy et al. 1998:98). The results were correlated with biological data and used in further discussions of hull corrosion, because the radioisotopes demonstrated that the hull had been covered by a protective layer of sediment for at least 100 years, with an error margin of +/- 20 years (Murphy et al. 1998:98). Radioisotopes (^{210}Pb and ^{137}Cs) were used on the USS *Housatonic* shipwreck site for the intended purpose of delimiting the extent of post-depositional sediment disturbance, since two salvage efforts and one instance of dynamiting were known to have impacted the wreck (Conlin 2005a:47-48). *Housatonic* and *Hunley* wrecked in approximately the same area, and results from both sites were correlated and compared in the 2005 *Housatonic* study (Conlin 2005a). Unlike the hulls examined in the current study sites in the GOM, the hulls of both *Hunley* and *Housatonic* were completely buried under sediments; radiometric dating of sediments indicated averaged sedimentation rate estimates of 0.74+/-0.25

cm/yr at the *Hunley* site, and 0.89+/-0.3 cm/yr at the *Housatonic* site. Analysis did not identify any evidence of punctuated erosion (i.e., disturbance events in the downcore decay of ^{210}Pb) at either site, suggesting continuous burial that contributed to excellent states of preservation on both sites (Conlin 2005b:145).

For the purposes of the current study, radioisotope analysis was conducted at six shipwreck sites to determine approximate sedimentation rates in lieu of sediment traps or long-term monitoring. A secondary goal, developed during the analysis, focused on identifying a disturbance event layer in the sediment core. Unfortunately, the study budget allowed for only radioisotope analysis of a single core from each of six sites; therefore, it was understood that the sampling strategy was too coarse to make definitive statements about sediment disturbance based on one sample per site.

Following analysis of radioisotopic traces, all of the sampled sites showed excess ^{210}Pb and ^{137}Cs in surface (0-1 cm) sediment intervals (Table 5.4). This indicates that all core sites have sediments that have interacted with the marine water column in the last 56–100 years; the smaller interval represents the time since the onset of thermonuclear testing (1954), which released radiocesium into the atmosphere and resulted in ongoing fallout. Five of the six sites also show downcore decay in ^{210}Pb excess activity, indicating the seabed at those five sites is presently depositional (Table 5.5). The sixth site, Site 373, has variable activity downcore that may be a function of recent bioturbation by benthic macrofauna, coring/diver disturbance, or physical reworking (e.g., tropical storms). In none of the cores did downcore cesium profiles show a clear 1954 onset or 1963 peak testing time marker. This may be a function of overall low activities, and/or trends masked by downcore variability in grain size. Lead and cesium radiotracers are adsorbed preferentially onto clay mineral surfaces; therefore, variations in coarse fraction between sampled sediments, such as an increase in sand compared with coarse silt percentages in the sediments, serve to decrease activities. Grain size may also impact lead sediment accumulation rates, and therefore the potential impact of grain size was evaluated for each site using both direct measurements of grain size, and indirect measurement (e.g., sediment porosity).

Table 5.4

Sites Analyzed for Radioisotopes and the Number of Data Points Sampled from Each Site

Site No.	Core No.	Data Points
433 (*R.W. Gallagher*)	2	14
373 (*Cities Service Toledo*)	1	12
15488 (Unknown wreck)	1	11
15366 (Unknown wreck)	1	9
389 (*J.A. Bisso*)	2	9
236 (*Hatteras*)	1	13

Table 5.5

Linear Accumulation Rates (LAR) and Disturbance Event Date Ranges Indicated from Radioisotope Data

Site No.	**Distance Offshore (nm)**	**Disturbance Event Date Range**	**LAR (cm/yr)**
433 (*R.W. Gallagher*)	35	1921–1932	0.17
373 (*Cities Service Toledo*)	44	Indeterminate	Indeterminate
15488 (Unknown Wreck)	24	1947–1965	0.06
15366 (Unknown Wreck)	17	1925–1987	0.15
389 (*J.A. Bisso*)	21	1832–1960	0.08
236 (*Hatteras*)	21	1931–1949	0.14

At all five sites where a ^{210}Pbxs decay profile was observed in near surface sediments, there was also a point at depth where activities increased significantly. This is interpreted as a disturbance to the pattern of quasi steady-state sediment accumulation at the site, which can be interpreted as a disturbance event. The surficial sediment decay in Pb activity, therefore, represents a post-disturbance accumulation rate. Disturbances in the radioisotope data may be the result of extreme storm events that erode the seafloor and are followed by a resumption of accumulation rates, or the settling of a shipwreck onto the seafloor, that in turn impacts near-seafloor sediment transport. Without stratigraphic evidence like core x-radiographs of internal layers, it is not possible to differentiate these causations. However, it can be said that the fact that a disturbance layer was observed at all accumulating sites, including those near the maximum inner-shelf depths (40 m or 130 ft) where hurricane seafloor disturbance is less prevalent, points to a cause other than extreme storm events. The rate of sediment accumulation and depth of the disturbance interval can be used to arrive at an age range of the disturbance horizon. This age is presented as an interval in years, given that it is also a function of the sampling density with depth; denser sampling allows the depth of the disturbance interval to be better defined (Tables 5.4 and 5.5).

At four of the five accumulating-disturbance shipwreck core sites, the interval below the disturbance zone did not display a downcore decay of ^{210}Pbxs with depth. This may be an artifact of insufficient sampling density, variation in grain size, or disturbance of in situ sediments. At Site 236, there is sufficient evidence to assign an accumulation rate before the disturbance (e.g., pre-disturbance). The pre- versus post-disturbance difference in sediment accumulation rate provides a powerful analytical tool for examining the potential impact of the disturbance event (if identified) on site sediment accumulation or erosion.

On average, linear accumulation rates across the sampled shipwreck sites are 0.12 cm/yr. Absent of shipwreck subsidence, these low rates of sediment accretion indicate that the exposed hulls observed by divers during the 2010 field work will remain exposed for the foreseeable future; at current LARs, it will take 100 years to accumulate an average 12 cm (4.7 inches) of sediment at each site absent of any simultaneous scour. Due to the lack of significant sediment accretion, the hulls examined in this study will remain subjected to water column variables, and will likely suffer continued corrosion.

5.1.3 Water Quality

Metal-hulled shipwrecks in salt water environments are susceptible to corrosion, which occurs through oxidation, the electrochemical removal of atomic electrons from the exposed metal (Cronyn 1990:168; Keith 2004:24). Both extremely acidic and extremely alkaline environments accelerate active corrosion, in which soluble metal by-products dissipate into the water column (Keith 2004:24). Corrosion can also occur through a passive process during which various by-products, including carbonates, oxides, hydroxides, and sulphates, combine to form a concretion on the surface of the metal (Keith 2004:24). Oxygen is the primary agent in corrosion, but hydrogen, sulphide, and chloride ions also act to stimulate corrosion of submerged metal (Cronyn 1990:167-168). Corrosion is an important site formation process acting on modern steel-hulled wrecks because it ultimately weakens the integrity of the metal, contributing to structural failure over time. Ironically, more recent steel-hulled vessels deteriorate at a faster rate than their iron counterparts (Keith 2004). According to McCarthy (1985:222), "due to the lasting properties of wrought iron compared with steel, (iron ships) will remain with us … long after their steel contemporaries have disintegrated."

Corrosion occurs in both submerged and seabed-embedded structures. In both cases steel corrosion rates are affected by salinity, temperature, pH, and dissolved oxygen, carbonates, biological organisms, and pollutants (Matsushima 2000:545). Estimates indicate that corrosion results in an average loss of 0.1 mm/year per exposed surface; however, individual variable levels in seawater fluctuate seasonally and with depth, and evidence suggests that corrosion rates decrease over time (MacLeod 1989:13; Matsushima 2000:548). Corrosion is an important factor in considering the long-term preservation or structural stability of steel-hulled shipwrecks because instability can ultimately result in the collapse of all or part of the extant hull. Using finite element analysis on the USS *Arizona's* hull, Foecke et al. (2010) demonstrated that a 50% loss of hull steel through corrosion would result in localized collapse; a 60% loss would result in general collapse of the upper decks, adding significant stress to underlying decks. At the time the study was conducted, *Arizona* was estimated to be at 20% corrosion, with 50% corrosion projected to occur by the year 2120 (Foecke et al. 2010).

The passive corrosion of iron typically produces a remnant layer on the metal's surface that may protect it against further corrosion (Matsushima 2000:548). This remnant layer can also be a proxy for the original metal thickness, allowing archaeologists to compare measurements of the total original and reduced actual thicknesses (Russell et al. 2006:312). If the wrecking date is known, corrosion rates can be determined by calculating the change in thickness (amount of metal lost through corrosion) over the duration of submergence (Russell et al. 2006:313). Carbon steel, which is predominately used in shipbuilding, however, does not leave this remnant layer. Corrosion rates for steel hulls can be calculated only by subtracting the direct measurement of actual steel thickness from thicknesses specified in the documentary record, such as ship's plans (Russell et al. 2006:313). Actual measurements can be taken directly from sampled materials or through the use of ultrasonic measuring devices; however, both methods require the removal of metal samples from the hull (Russell et al. 2006:312-313). Despite the importance of corrosion for long-term site preservation and management, physical sampling of metal from the study sites was beyond the scope of this project; however, water samples were acquired during field operations at the depth of the actual wreck sites in order to provide baseline data on variables impacting corrosion and to provide comparative data for future research.

Published data exists for water quality in the GOM; it could be used in estimates of corrosion potential, but sampling intervals vary and may not accurately represent conditions present on individual wreck sites. Salinity data from NOAA's National Oceanographic Data Center (NODC) demonstrate both seasonal variability of water quality and variability with depth over a 1.0 degree grid (Figure 5.4 through Figure 5.7). Salinity values in the GOM are typically highest during the winter and lowest in summer at the surface (Figure 5.4), but remain relatively constant at depths of 20 and 30 m (66 and 98 ft) BSL, (Figures 5.6 and 5.7). Therefore, corrosion studies should use depth-appropriate data for salinity, considering both the maximum depth of the wreck and significant projection into the water column surrounding the hull.

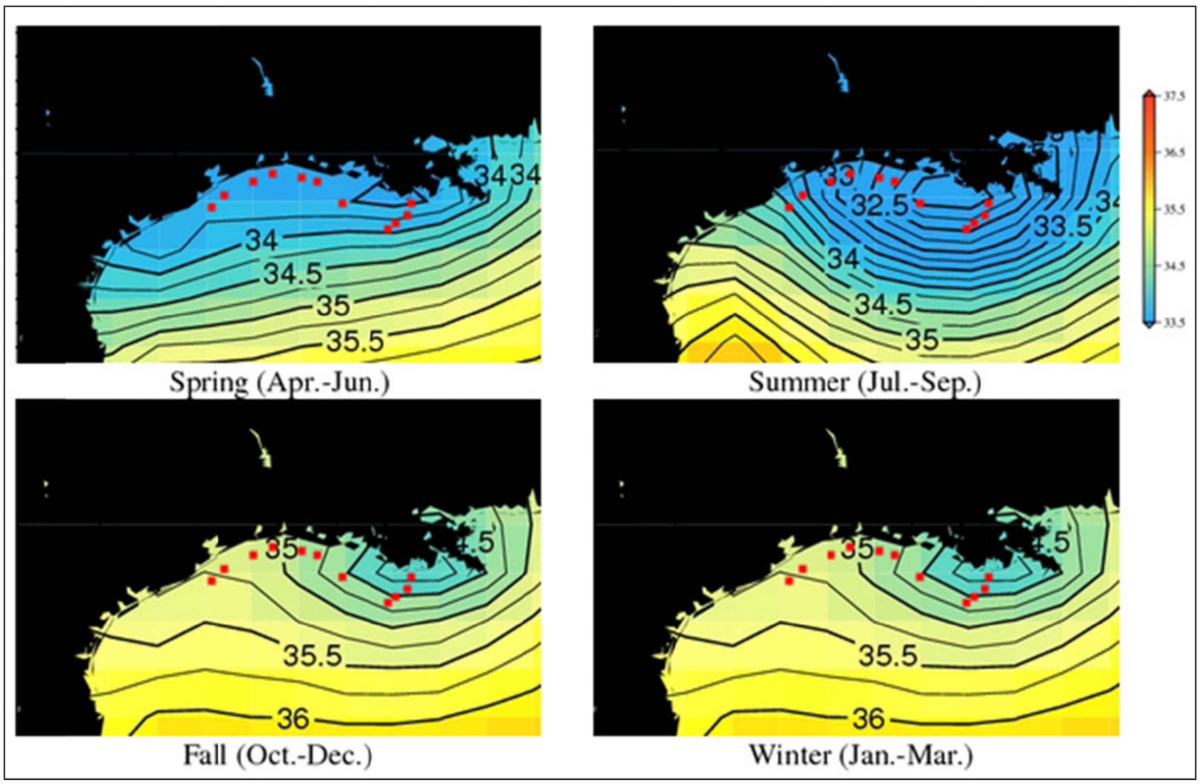


Figure 5.4. Seasonal average salinity measurements of surface water. Shipwreck study sites are indicated in red. (Data from NOAA NODC.)

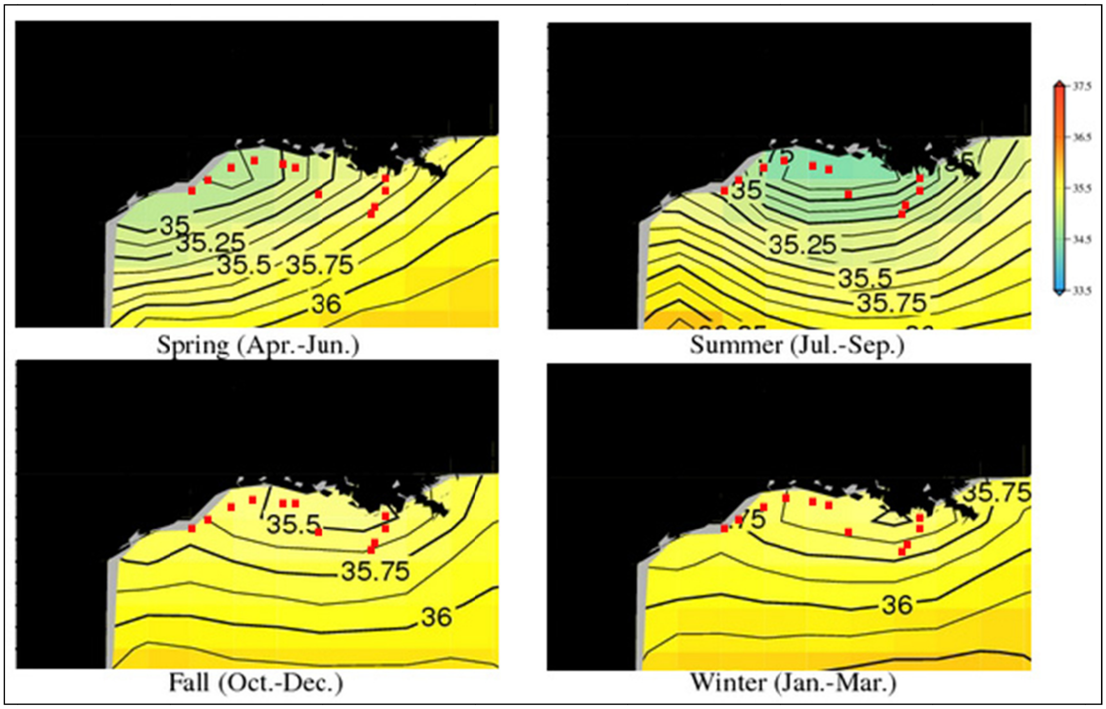


Figure 5.5. Seasonal average salinity measurements at a depth of 15 m BSL. Shipwreck study sites are indicated in red. (Data NOAA NODC.)

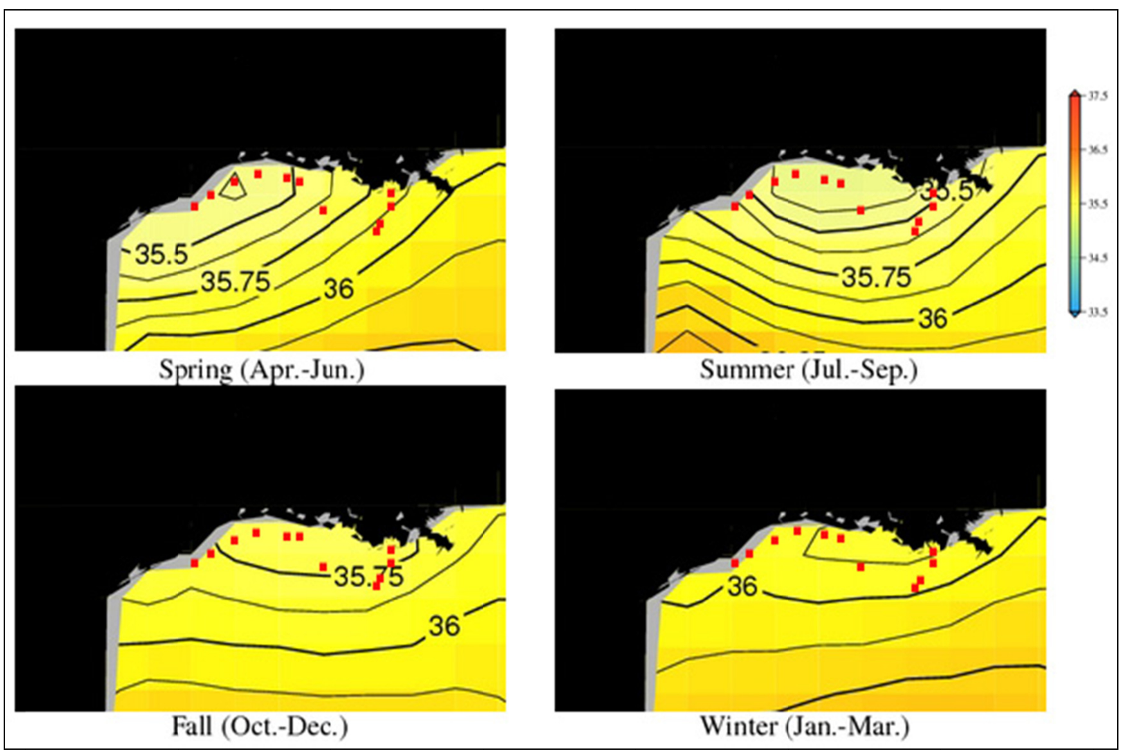


Figure 5.6. Seasonal average salinity measurements at a depth of 20 m BSL. Shipwreck study sites are indicated in red. (Data from NOAA NODC.)

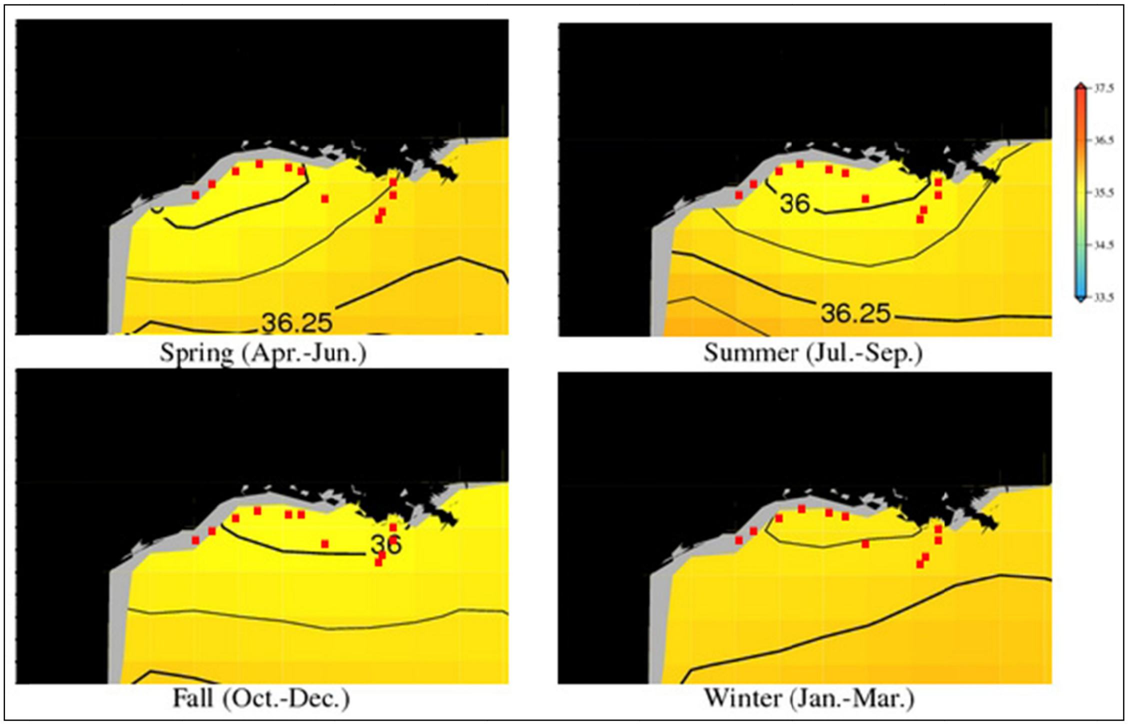


Figure 5.7. Seasonal average salinity measurements at a depth of 30 m BSL. Shipwreck study sites are indicated in red. (Data from NOAA NODC.)

Dissolved oxygen data acquired as part of a long-term GOM hypoxia study (Rabalais and Turner 2010) indicated that measured DO content of bottom-water ranged from < 1 mg/liter in hypoxic zones to approximately 7 mg/liter (Figure 5.8). Daily measurements of DO content at base stations in water depths of 15 and 20 m (49 and 66 ft) were recorded throughout the month of July 2010 in the GOM (Rabalais and Turner 2010). Although data from the hypoxia study does not extend as far west as Sites 15488, 15366, and 236, the data that was collected reflects bottom conditions and is an accurate assessment of conditions at a given point in time that would impact the remainder of the shipwreck sites. DO is the most important factor in measuring corrosion (Matsushima 2000:545; MacLeod 1989) but one-time measurements show only a myopic view.

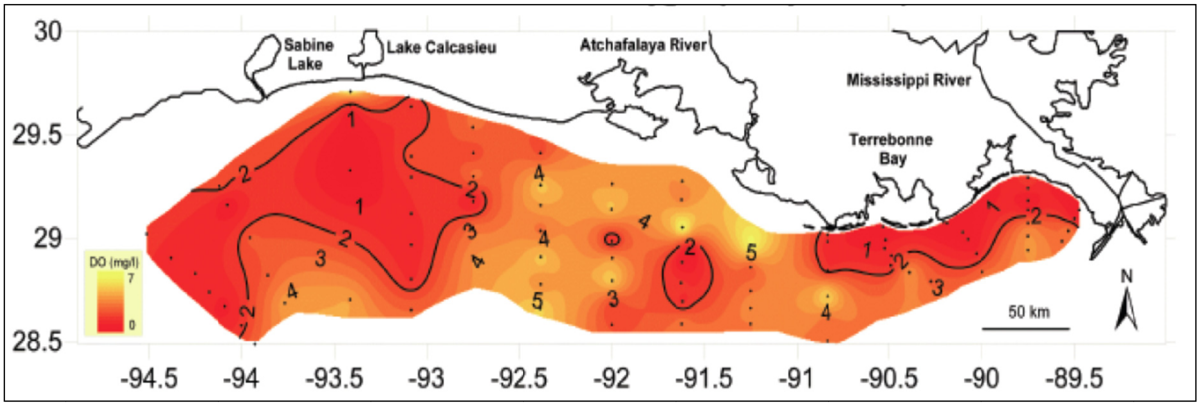


Figure 5.8. Dissolved oxygen content of bottom-water, as sampled July 25–31, 2010 (Rabalais and Turner 2010).

Water samples collected at each study site represent single data points within a pattern of seasonal fluctuation (Table 5.6). Data was plotted in several ways to aid in the identification of correlations, including by water depth (Appendix F; Figures F-1, F-4, and F-7), site location (Appendix F; Figures F-2, F-5, and F-8), and distance offshore (Appendix F; Figures F-3, F-6, and F-9). No discernible patterns were obvious in the plotted data across sites, but the range of salinity and DO measurements exceeded published data for the GOM. This suggests either variations due to methodology or greater variability at each site than expected, based on published averages for the region.

Table 5.6

Averaged Results of Water Quality Testing

Site No.	Sample No.	Distance Offshore (nm)	Water Temp. (°F)	Depth BSL (m)	Salinity (ppT)	pH	Dissolved Oxygen (mg/L)
380	1	11	86	11.3	31.6	7.240	6.747
389	1	21	86	20.1	31.4	7.496	7.017
433	1	35	77	30.8	32.7	7.767	6.795
433	2	35	77	27.4	32.1	7.837	6.980
386	1	41	83	21.3	33.6	7.563	6.780
373	1	44	83	24.7	30.8	8.013	7.450
15326	1	19	86	17.4	32.1	7.323	6.690
322	1	16	88	17.1	31.9	7.230	6.735
15488	1	24	88	14.3	31.5	8.020	6.915
15488	2	24	88	14.3	31.8	7.837	6.870
15366	1	17	88	18	33.2	8.097	7.455
15366	2	17	88	18	33.1	8.160	7.480
236	1	21	84	18.3	34.4	8.033	7.467

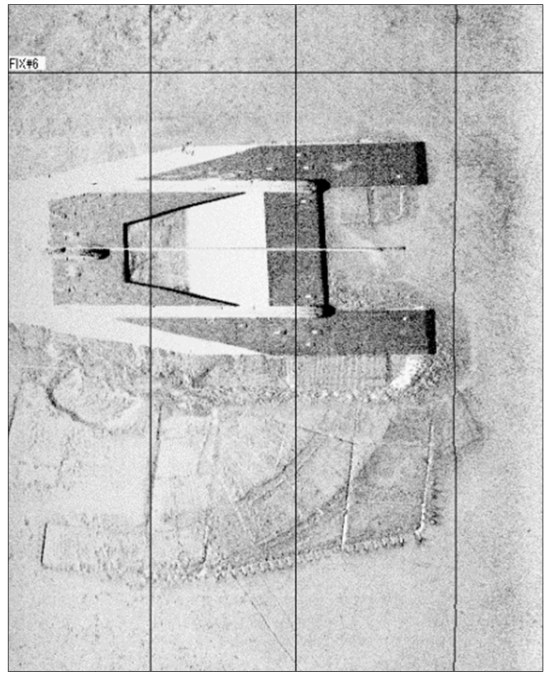
5.2 ANTHROPOGENIC PROCESSES

Anthropogenic processes of shipwreck site formation can occur during the wrecking event, such as through selective discard of materials during efforts to avert sinking. They can also occur as long-term, cumulative, or single-occurrence impacts at any time or for any duration after the wrecking event. Anthropogenic or cultural processes that can affect a site include construction, dredging, fishing, salvage, and the disposal of refuse (Stewart 1999).

As discussed in Chapter 1, BOEM is responsible for managing and regulating offshore energy development within the U.S.'s exclusive economic zone. The agency's primary concern in regard to cultural resources is ensuring that lease development has no adverse impacts on archaeological sites. Discussion in this section focuses primarily on the impacts of construction activities related to federally-permitted oil and gas development but also briefly addresses other anthropogenic impacts.

The primary impacts to the seafloor that can be expected from oil and gas operations are drilling and structure and pipeline installation and removal. Impacts associated with these activities are regulated by the Code of Federal Regulations and published Notices to Lessees (such as NTLs 2005-G07, 2008-G05, 2009-G39, and 2009-G40). These NTLs require, before lease development or pipeline installation, geophysical surveys or visual inspections of the seafloor to assess seafloor conditions, and identify any potential hazards, sessile biologic communities, and archaeological sites present in the area of potential effect. The reports prepared in compliance with the NTLs are reviewed by BOEM and, if compliance standards are met, the permitted activity is approved. Avoidance criteria or mitigation measures may be applied to certain magnetic anomalies, sonar targets, and subsurface features, identified on the geophysical data, which may represent potential archaeological resources. These avoidance criteria will be included in the notification of approval issued to the operator.

Jack-up rigs and submersible drilling rigs are the most common means of drilling in water depths equivalent to the study sites; jack-up rigs are the more prevalent. Both of these rigs result in setting the rig on the seafloor during drilling operations. The two most common types of jack-up rig are mat-supported and independent legged rigs. Typically, all jack-ups have three legs that support the rig, but the mat-supported rig also has a large A-shaped mat that distributes the weight across the legs (Figures 5.9 and 5.10). Although the permitted area of impact associated with drilling activities on the outer continental shelf is typically fairly restricted, the overall disturbance associated with drilling can extend beyond the footprint of the rig.



Figures 5.9 and 5.10. Left: Model of a mat-supported jack-up rig at Ocean Star Offshore Drilling Rig & Museum, Galveston, Texas. (Photo by authors 2009). Right: Side scan sonar image of a mat-supported jack-up rig on the seabed, showing imprints from previous mat-supported rigs. (Data Courtesy of Tesla Offshore.)

In addition to the bottom disturbance caused by the area of impact, drill cuttings and drilling mud may splay outward from the well site during drilling operations. Drill cuttings are fragments of earth produced during drilling and removed from the well hole through drilling fluid or "mud." There are three different types of drilling fluids: water-based, petroleum-based, and synthetic-based. In water depths deeper than the study area, drill cuttings have been observed to extend outward from the well site up to 50 m (164 ft) in diameter (Neff et al. 2000:15). If a well was drilled in proximity to a wreck site in equivalent water depths, the cuttings could obscure the site and/or make future investigation more difficult or expensive. Observations have also shown that in shallow waters similar to those of the study area, drill cuttings typically do not collect on the seabed but, instead, quickly dissipate because of the effects of currents and waves (Zingula 1977:548; Neff et al 2000:15). Though numerous studies have been conducted analyzing the impact of cuttings on biologic communities (NRC 1983; Boesch and Rabalais 1987; Neff et al. 2000; and UKOOA 2005), no known studies have been conducted that examine their impacts on shipwreck sites. Based on research conducted in the wake of the *Exxon Valdez* oil spill, contamination of radiocarbon samples were examined at ten different oiled sites. No adverse impacts to radiocarbon dating were identified from these samples; however, the issue of contamination impacts on radiocarbon dating is still under investigation (Reger et al. 1992). Without further study, though, it is unknown to what degree, if any, petroleum-based drilling fluid or additives in water-based or synthetic-based fluids could contaminate a site and adversely impact sample testing or data recovery. Certainly, burial under drilling splay would obscure an archaeological site and make documentation more difficult or time-consuming.

The installation of a permitted structure, such as a platform or caisson, typically takes place at the site of a successfully drilled well location. During drilling and subsequent platform operation phases, activities at a well site may include drilling additional wells with different rig footprints, the use of seafloor-mounted lift boats for maintenance or repair work, and anchoring associated with dive boats or other support vessels. Materials are frequently discarded from the rig or platform or from other service support vessels, usually through accidental loss. In addition to ancillary activities associated with resource extraction, platforms and well caissons often become popular sites for fishermen and recreational divers who can also produce impacts to archaeological sites. Despite the wide range of potential impacts associated with drilling a well, the area of impact is generally relatively localized, focused on the immediate vicinity of the well site.

If a well is successful, then product will need to be transported off-site for refining and distribution. The installation and use of subsea pipelines is the most common method for moving oil and gas from wells to production facilities. Pipelines in the GOM are required to be buried to a depth of at least 0.9 m (3 ft) BML in water depths under 61 m (200 ft). Within shipping fairways, pipelines are required to be buried 3 m (10 ft) below the seafloor, and within anchorage areas, 4.9 m (16 ft) to avoid incidental damage from anchoring (30 CFR 250.1003(a)(1)). The two most common methods for pipeline installation are through the use of anchored lay-barges (Figure 5.11) or dynamically positioned reel-barges. Although dynamically positioned pipeline installation can occur in water depths as shallow as 33 m (100 ft), it is generally not used in less than 61 m (200 ft) of water (Cranswick 2001). Anchored lay-barges are the most common pipeline installation method in water depths equivalent to those of the study area. Operational procedures for anchored lay-barges restrict their use to areas less than 300 m deep (1,000 ft) (Cranswick 2001), although the amount of anchor cable available on an individual vessel may restrict the operating depth to even shallower waters. Pipeline is buried during installation with the use of a jet-sled or plow. The lay-barge deploys the pipe from the surface through a device called a stinger and the jet-sled or plow digs a trench into the seabed in which the pipeline is laid. Jetting can cause substantial impacts to a shipwreck, but it should be noted that it is also in the installer's best interests to avoid impacting any wrecks, because the wrecks could damage the highly specialized and expensive equipment or cause considerable construction delays.

Figure 5.11. Pipeline lay-barge with anchors deployed (Shu 2011).

In addition to the impacts caused by jetting and laying the pipeline, substantial bottom-disturbing activities can also be caused by anchors and anchor chain used by the lay-barge during installation. A standard pipeline lay-barge extends anchors out a distance of five times the water depth. An anchored barge typically requires between eight and 12 anchors, each weighing between 30,000 to 50,000 tons (Cranswick 2001). The anchors are lifted onto anchor-handling support tugs which are used to deploy the anchors along the route. Winches aboard the lay-barge move the barge along the route by tightening up on the foreword anchors. Generally, after anchors are set, they need to be repositioned every 610 m (2,000 ft) along the pipeline route (Cranswick 2001). Ground disturbance is not limited to the actual anchor touch-down points. During barge movements, slack is placed on the stern lines before pulling the vessel forward along the bow anchor lines; this may allow portions of the chain to rest or drag on the bottom. The large diameter wire rope used to handle these massive anchors can cause substantial damage to a shipwreck site.

Ancillary activities, such as those conducted by lift boats and anchored vessels offering support (such as dive ships), are not explicitly regulated by BOEM. These vessels can produce fairly significant bottom disturbances but, due to the frequency with which they operate and the diverse number of companies, it would be difficult to regulate these bottom-disturbing activities on a case-by-case basis. Bottom-disturbing activities associated with lease development or pipeline installation are regulated under the permitted activity, so it is the operator's responsibility to ensure that contractors do not impact targets or anomalies that have been stipulated for avoidance. Off-lease bottom-disturbing activities are typically exempt from NTL requirements. These activities are usually risk-aversion activities that cannot be explicitly regulated, for example, anchoring a vessel or setting a platform on the seafloor during severe weather conditions to mitigate risk to the vessel and crew.

Wreck-site impacts that are not related to oil and gas include fishing, recreational boating (including scuba diving), shipping, disposal, salvage, and dredging. Fishing and shrimping are perhaps the greatest bottom-disturbing activity on the seafloor across the northwestern GOM (Evans et al. 2009). Shrimp trawlers cover a great deal of seabottom while dragging nets weighted down with otter boards that scrape across the seabed. It is rare that a shipwreck site on the GOM's continental shelf is not covered in shrimp netting or fishing line. Recreational boaters and divers can also impact sites, either by disposing of refuse or by diving on known sites and removing artifacts. Debris disposal, both accidental and purposeful, is common on the OCS. In most cases, intrusive modern debris can easily be identified on a site and does not present a significant detriment to the archaeological record; however, military dumping of Unexploded Ordnance (UXO) and chemical weapons in the deepwater GOM presents a unique challenge in those areas (Samuel and Herbert 2007; Evans and Voisin 2011). Military testing grounds have also been known to cloud the archaeological record through the distribution of practice bombs and shells (Keith 2004; Keith and Skeist 2004). No known UXO dumping zones or military testing grounds are reported within the study area. Salvage, what Schiffer and Stewart refer to as "reclamation" (Schiffer 1987; Stewart 1999), can be categorized as either firsthand salvage or secondhand salvage. Firsthand salvage occurs when those involved in the wrecking process or with a stake in the vessel (i.e., investors or insurers) attempt to recover the entire wreck, recover usable gear from the wreck, or recover significant portions of the cargo. This is done with the technologies available at the time, and, though it disturbs the archaeological context, the act of salvage can provide information about the economic value ascribed to various items and available technologies used in salvage operations. Secondhand salvage is undertaken at a later date by those not affiliated with the vessel, usually for profit. The dredging of shipping channels is not common in the water depths examined for this study, and is generally restricted to the maintenance of existing channels. On-going dredging is therefore unlikely to impact new sites, although the dumping of dredge spoil could bury or obscure a site, making it difficult to identify. The most common types of dredging in water depths similar to those of the study sites are done for coastal restoration and sediment extraction. NTL 2009-G04 published by BOEM (2009a) specifies areas on the OCS that have been set aside for sand extraction.

5.3 Analysis of Shipwreck Site Formation Processes

The following sections discuss observations about the impact of site formation processes at each wreck site. This discussion builds directly on the methodology outlined in Chapter 2 and the data provided in Chapter 3.

5.3.1 Site No. 380, South Pelto Area, Reported Wooden Wreck

Because no wreck was identified, no soil or water samples were acquired and this site was not included in any modeling.

The reported location of Site 380 was 62.5 m (205 ft) from an existing pipeline. It appears that the pipeline installation pre-dates the record of the site.

5.3.2 Site No. 433, Ship Shoal Area, Probable *R. W. Gallagher*

5.3.2.1 Radioisotope Data

The wreck at Site 433 has been identified as the probable *R.W. Gallagher*, which was a victim of U-boat campaigns in the GOM in 1942 (Rohwer 1983; Wiggins 1995). Samples were obtained from Core no. 2 at a water depth of 27 m (90 ft). Core no. 2 was obtained in an interpreted area of ambient seafloor that was not influenced by significant seafloor scour. Radioisotope analysis indicates that normal sediment accretion was interrupted by a disturbance event that occurred 78 to 98 years before core acquisition, or between 1912 and 1932, with normal accretion resuming after the disturbance. The most likely cause of the disturbance is an extreme storm event, which could have disturbed the seafloor, and thus disrupted the LAR, through heavy wave and current activity. The wrecking event is not interpreted as the most likely cause of disturbance because it occurred in 1942, post-dating the disturbance by a minimum of ten years.

Between 1868 and 2008, 34 tropical systems, ranging from tropical depressions to category 4 hurricanes, have been centered within 37 km (20 nautical miles) of Site 433 (NOAA NHC). Of these storms, three occurred during the same time period as the disturbance event recorded in the radioisotope data; they include an unnamed tropical storm in 1931, an unnamed category 2 hurricane in 1926, and an unnamed category 1 hurricane in 1923 (Figure 5.12; NOAA NHC). The fact that no disturbances were recorded since the disturbance event 78 to 98 years ago may suggest that more recent, stronger hurricane events have not had a significant scouring effect on the seafloor at Site 433. Included in this time period are Hurricane Carmen, centered east of the site as a category 4 hurricane in 1974, and Hurricane Andrew, centered east of the site as a category 5 hurricane in 1992 (NOAA NHC). Although Carmen and Andrew were more intense than either the 1926 or 1923 hurricanes, they were centered to the east of the site; the 1926 and 1923 storms were centered to the west of the site, placing the wreck in the strongest quadrant of these storms. Site 433 was not within the swath of hurricane force winds associated with recent Hurricanes Katrina, Rita, Ike, and Gustav (Appendix D; Maps F-4 and F-5), although tropical storm strength winds associated with these storms could have impacted this area.

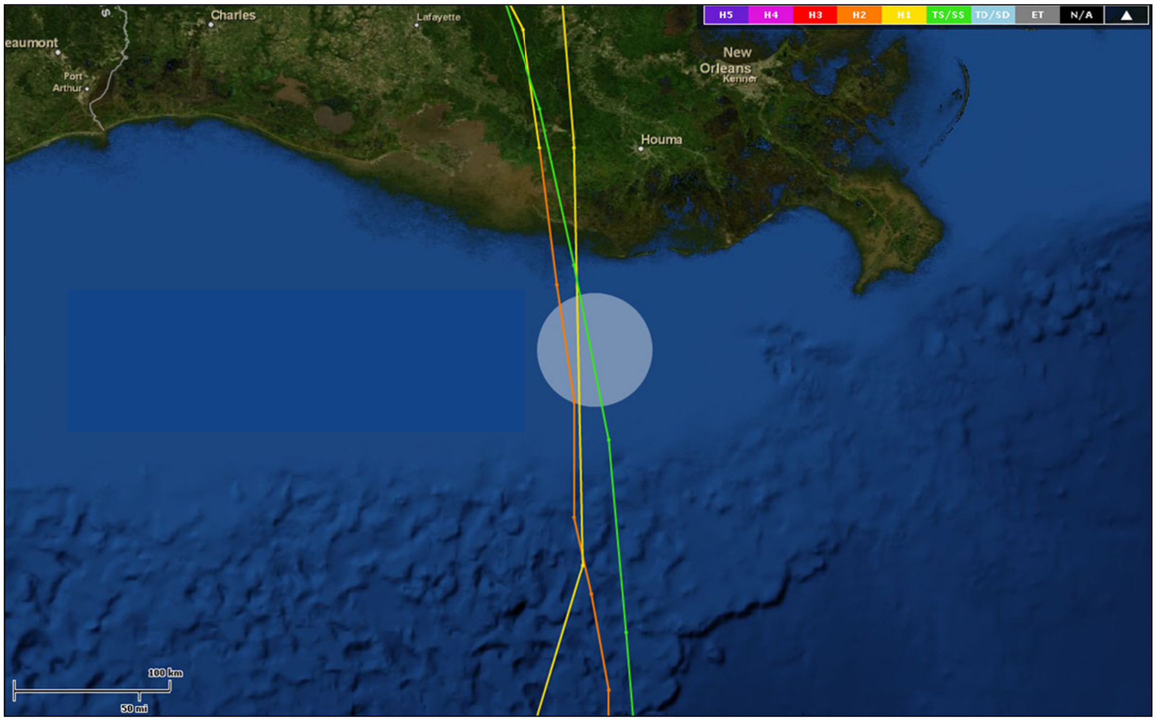


Figure 5.12. Individual tracks for all tropical systems centered within 37 km (20 nautical miles) of Site 433 between 1912 and 1932. (Image courtesy NOAA NHC.)

5.3.2.2 Scour

The wreck at Site 433 is oriented along a SSW heading, with the bow facing 204 degrees. A significant scour pattern, evident on the geophysical data, is oriented perpendicular to the axis of the wreck (Figures 3.2.5 and 5.13). The observed scour occurs in an asymmetrical pattern, with the predominant areas of global scour extending westward approximately 204 m (670 ft) away from the wreck. The observed pattern indicates wave- and current-induced scour being driven predominantly from the ESE and SE regions. Major local scour holes occur at the stern (north), bow (to the south), and at the breaches in the hull of the wreck. Additional scouring has occurred along the margins of the wreck. The degree of scouring may be attributed to the fact that the inverted hull projects prominently into the water column along the entire length of the keel; average relief for Site 433 is approximately 7.3 m (24 ft) above the mean seabed. Given prevailing currents from the ESE and SE, the up-current, or in this case east facing, side of the hull would experience greater development of helical, reversing vortices along the edge of the wreck, which would induce scour. The leeward face of the hull (the western side), would therefore exhibit greater development of reversing and horseshoe vortices, contributing to more pronounced local scour on this side of the wreck. Sub-bottom profiles indicate truncation of the sediment beds and stratigraphy within the scour, indicating very little accretion or infill within the scour surrounding the wreck (Figures 3.2.8 and 5.14).

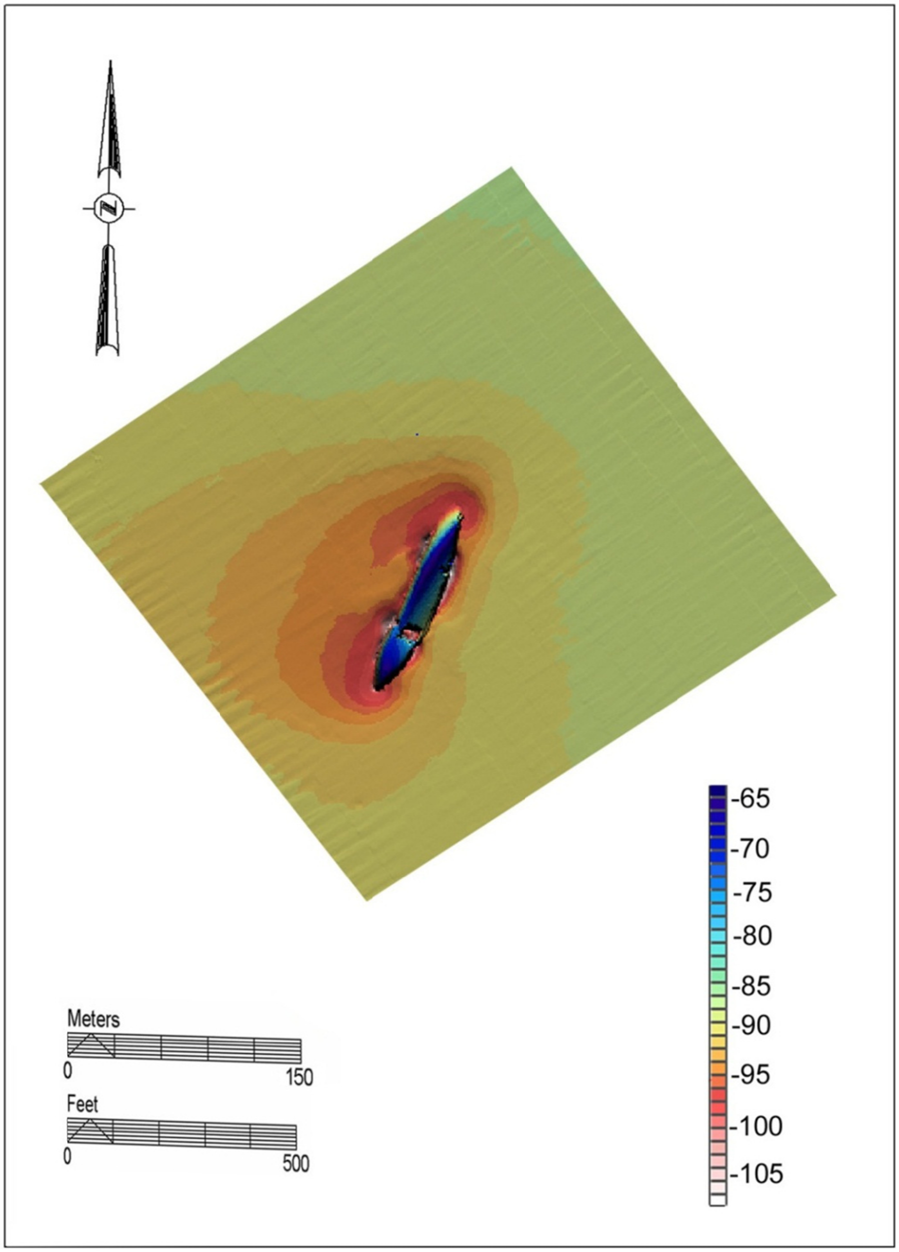


Figure 5.13. Multibeam bathymetry rendering at Site 433, highlighting seafloor scour.

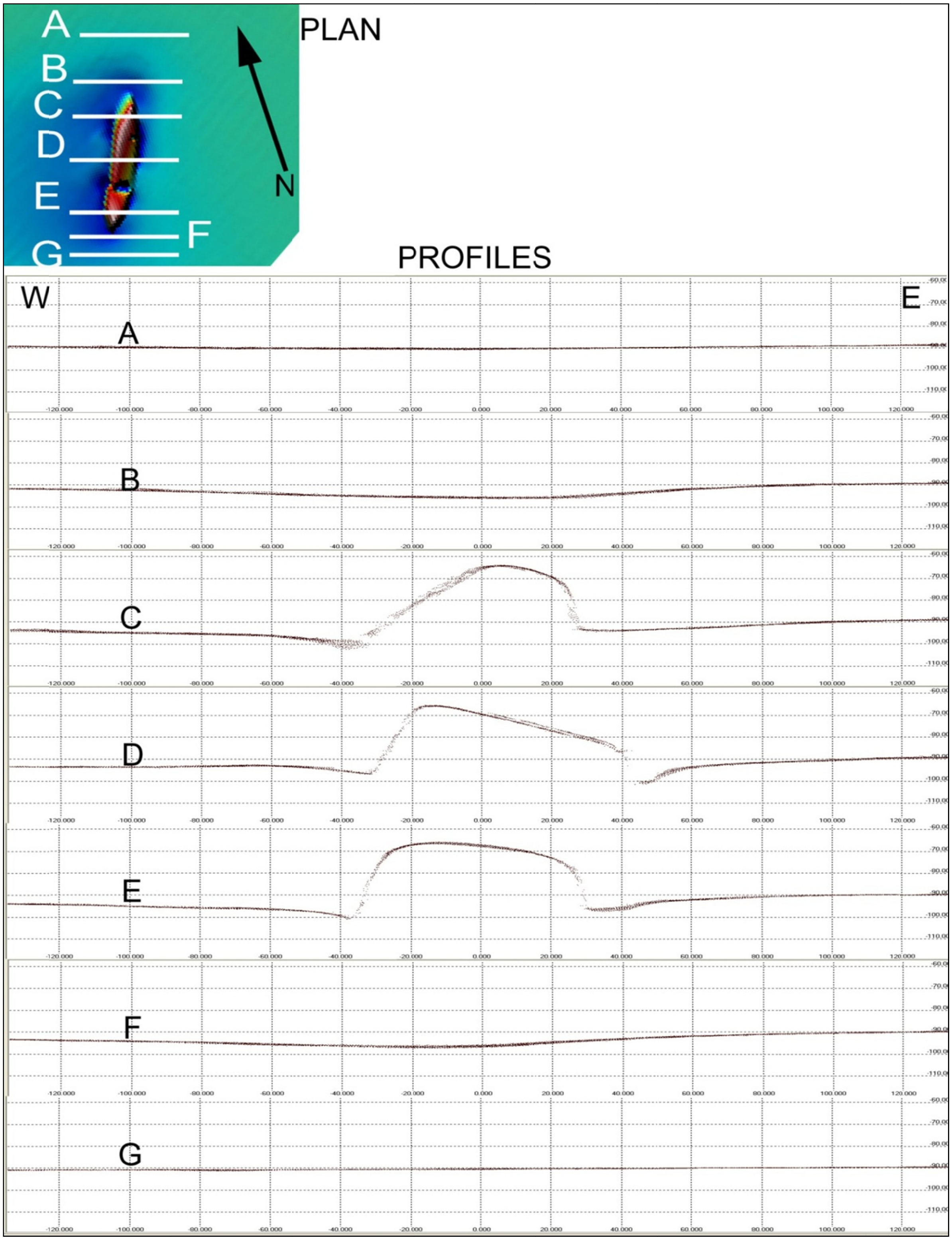


Figure 5.14. Profiles of seafloor surrounding Site 433.

Although radioisotope measurements are restricted to a single core from the site, when correlated with the lack of in-filled scour recorded on sub-bottom data, no evidence of recent scour and subsequent infill can be directly attributed to recent storms. This creates two distinct possibilities. On the one hand, the induced vortex effect that the wreck site has on prevailing currents may create sufficient force to exceed minimum requirements for bedload transport, resulting in ongoing scour at this site. On the other hand, if storm-induced scour exceeded the calculated linear accumulation rate, the lack of subsequent sediment accretion could account for the lack of a recent evident disturbance within the radioisotope decay curve. Calculated sediment LAR of 0.17 cm/yr suggests that little deposition is currently occurring in this area. The consolidated bed scenario for Datum 1 estimates that 0.03 cm of net scour occurred as the result of Hurricanes Ike and Rita. The loose bed scenario attributes between 13 and 21 cm (5.1 and 8.3 inches) of net scour to these two storms. According to Dunlap et al. (2004), shear strengths at the seafloor across this portion of the GOM are very soft (<0.2 ksf). Analysis of shear strength data from the single sediment core acquired on site (Table 3.3) confirmed this, providing a near-seafloor measurement of 0.032 ksf at 5 cm (2 inches) BML. Grain size indicates that surficial sediments at this site are coarse silts (48.6 μm) that fall beneath the 63 μm threshold for classification as cohesive sediments (Masselink and Hughes 2003:124). Based on the available data, either punctuated or ongoing flow, or a combination of the two, could be the cause of the observed scour on Site 433. Whether the scour is the result of normal currents, or punctuated events, the lack of sediment infill suggests that disturbed sediments are either compacted, or transported out of the surveyed area before they can settle out of suspension and redeposit within the scour zone.

5.3.2.3 Water Quality and Site Preservation

Water quality data acquired during diving operations indicate that average salinity at depth was 32.4 ppT, average pH was 7.802, and DO was 6.888 mg/L. Values for pH obtained within the core sediments produced an average reading of 7.938, although samples within the upper 10 cm exceeded pH values of 8. This is interesting because sulfate-reducing bacteria that can thrive in the anaerobic environment of the sediments typically require a pH level of 5.5 to 8 (Keith 2004:26). Sulfate-reducing bacteria are believed to cause the oxidation, and thus the corrosion, of iron and steel through the production of sulfide ions (Robinson 1981:6-7; Cronyn 1990:169; Kuang et al. 2007).

The inverted hull at Site 433 is relatively smooth, and a significant portion of the observed metal is covered by biofouling and organic growth. Trawlers or anchor lines associated with modern activities could potentially damage the extant hull, especially if they were to snag on already compromised metal near the torpedo holes. Active oil leakage observed on site and at the surface indicates that product remains trapped in the holds, but the amount of remnant bunker oil is unknown. The vessel is located on a soft, cohesive seafloor, and has experienced subsidence into surficial sediments. The hull, however, retains over 7 m (23 ft) of relief into the surrounding water column. The vessel is at risk of future deterioration of the exposed portions of the hull through the combined effects of chemical deterioration of the hull, metal fatigue, and changing current profiles and intensities. If the measured pH levels in the near-seafloor sediments are accurate indicators of the ambient acidity, higher pH levels within the soils may hinder the development of sulfate reducing bacteria within the near-seafloor sediments and thus help protect buried portions of the hull from oxidation. However, sediment samples were not tested for the presence of sulfate reducing bacteria as part of this study. Kuang et al. (2007) demonstrated in laboratory experiments that sulfate-reducing bacteria may alter the pH level of surrounding seawater by as much as 0.25. It is therefore unknown if the measured pH at Site 433 is an accurate indicator of sediment quality or a response to existing bacterial activity surrounding the wreck.

Sonar data at Site 433 revealed evidence of a large anchor scar measuring 53 m (173 ft) in length by an estimated 2.4 m (8 ft) in width. Although the cause of this scar cannot be attributed to a specific action, the size and location indicates probable oil and gas support. This scar was outside of the avoidance zone surrounding the site.

5.3.3 Site No. 386, Ship Shoal Area, Probable *Heredia*

The wreck at Site 386 is identified as the probable *Heredia*, which is known to have sunk in 1942 (Rohwer 1983; Wiggins 1995). The wreck's current condition is severely degraded, with large areas of disarticulated debris evident on sonar and multibeam data (Figures 3.35 and 5.15). *Heredia* was classified as a hazard to navigation after the wrecking event, and was scheduled for mitigation efforts, including controlled explosions on site to remove the uppermost wreck components to allow safe navigation over the site. According to records, however, the wreck site was not relocated and therefore demolition did not occur (Appendix E; Figure E-24-26). Given the condition of the site, it is possible that subsequent demolition did occur, but this is based purely on conjecture, as no documentary evidence has been found verifying site demolition.

5.3.3.1 Scour

No cores or diver observations of the seabed were conducted on site. The site is located 6.1 km (3.8 statute miles) SW of Site 433, and observed sub-bottom profiles were similar between the two sites. The environment at Site 386 is likely very similar to the conditions found at Site 433. Sub-bottom profiles recorded adjacent to and underneath the wreck show normal, parallel-bedded sediments. Scour zones, although not as prominent as those observed at Site 433, indicate truncation with no evidence of redeposition. Dunlap et al. (2004), indicate that shear strengths at the seafloor across this portion of the GOM are soft to very soft (0.6 to <0.2 ksf). No grain size data is available for this site, but it appears likely that sediments are similar to Site 433 where cores indicated that surficial sediments were cohesive coarse silts (48.6 μm).

Oceanographic modeling indicates relatively low rates of maximum and net scour occurring during hurricane events, but considered only flow conditions for sediment transport; it is unknown the degree to which smaller, disarticulated wreck components may be disturbed during hurricane-induced currents (Rego et al. 2011). Since the wrecking event, a total of 16 tropical systems, ranging from tropical depressions to a category 4 hurricane, have been centered within 37 km (20 nautical miles) of the site (NOAA NHC).

The wreck at Site 386 is oriented east-west, and lies along the path of greatest current and wave forces (Figures 3.3.3 and 5.16). The wreck is situated on its keel but is not completely upright; it lists to starboard. The highest portion of the wreck site is toward the stern, where the wreck sits approximately 7 to 7.3 m (23 to 24 ft) above the ambient seafloor (Figure 3.3.4). The most significant area of scour is located on the port side of the wreck, north of the bow. Less prominent scouring occurs around the stern and surrounding an ancillary component lying on the seafloor south of the stern aft of midships. The general zone of global scour extends north and east of the wreck, which is consistent with a pattern of larger and stronger vortices developing along the northern side of the wreck. It is anticipated that, over time, wave and current processes will contribute to the burial of wreck site components on the southern side of the site. This is because components of varying sizes and shapes sitting above the seafloor are likely to increase drag above the bed, thereby decreasing current velocities, which, in turn, may increase sediment deposition over this portion of the site. It is also anticipated that increased scour will occur along the northern margin of the wreck. The wreck's east-west orientation forms an acute angle to currents coming from the southeast, which is the predominant direction of severe storm events. It is possible that the wreck's axis could contribute to exaggerated storm related vortices, leading to increased storm-related impacts.

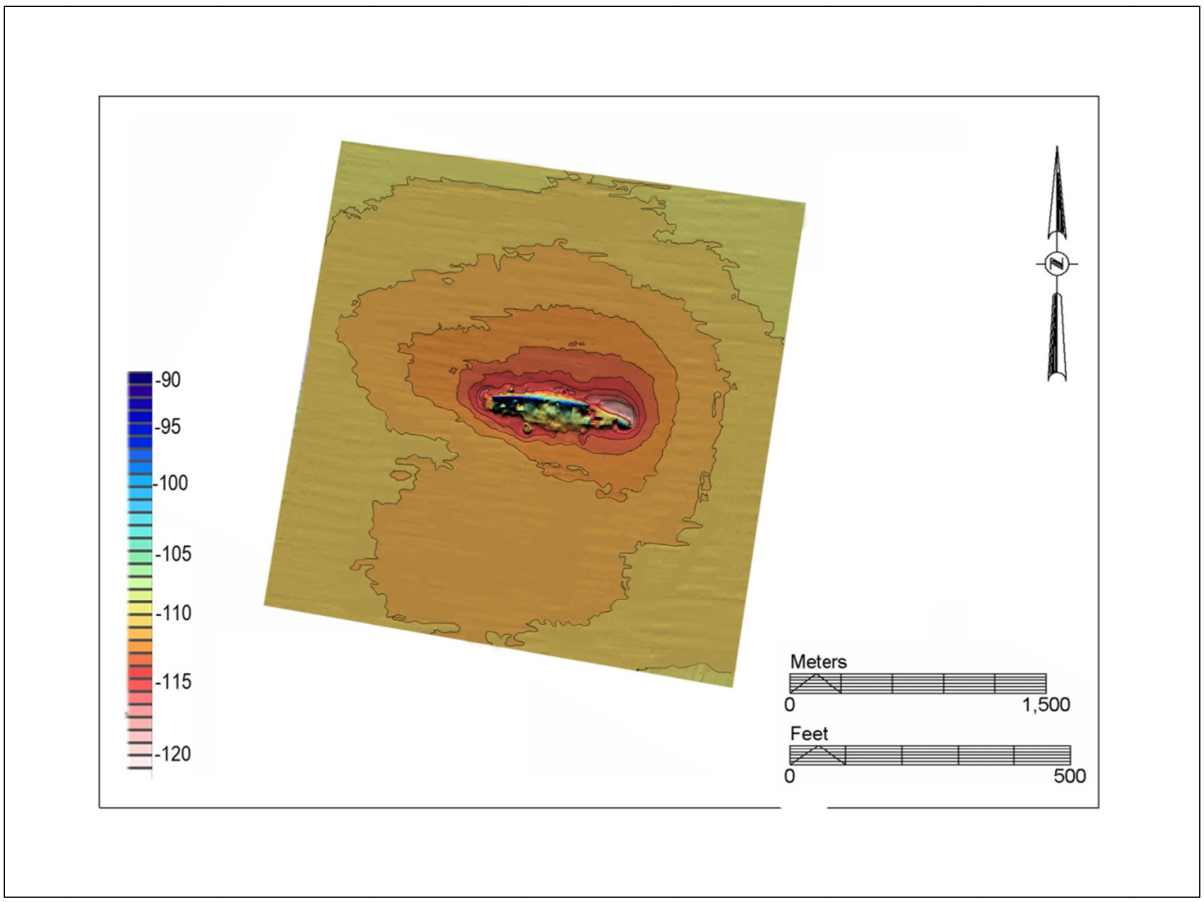


Figure 5.15. Multibeam rendering of the seafloor at Site 386.

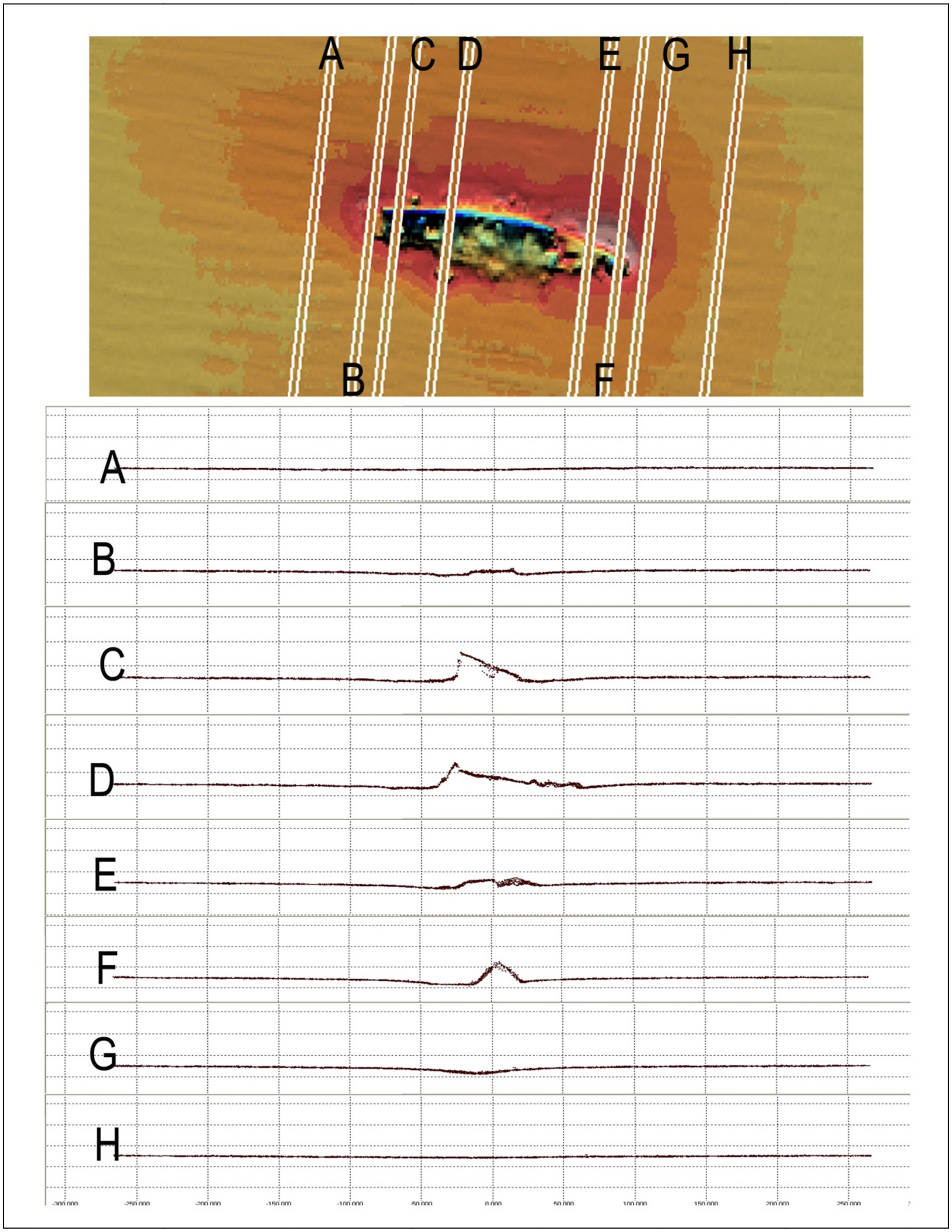


Figure 5.16. Profiles of the seafloor surrounding Site 386.

5.3.3.2 Water Quality and Site Preservation

A single water sample was obtained at 21 m (70 ft BSL) near the upper portion of the vessel's hull. Salinity measured 33.6 ppT, pH 7.563, and DO was 6.780 mg/L. No water samples were acquired at the seafloor.

It is possible that future hurricane or extreme storm events may damage disarticulated debris at the seafloor and/or extant portions of the site that extend into the water column, since dynamic current profiles and intensities could break or scatter features. The wreck is expected to experience continued chemical deterioration of exposed portions of the hull resulting in metal fatigue; however, portions of the wreck with less relief may become buried over time.

5.3.4 Site No. 373, South Marsh Island Area, Probable *Cities Service Toledo*

5.3.4.1 Radioisotope Data

The wreck at Site 373 has been tentatively identified as the tanker *Cities Service Toledo*; as a victim of U-boat campaigns in the GOM, it has a known wreck date of 1942 (Rohwer 1983; Wiggins 1995). Radioisotope analysis indicates that there is no discernible sediment accretion at the site. No evidence of sediment disturbances from tropical systems since the wrecking event were identified from the radioisotope data, supporting the minimal estimates of seafloor scour calculated from flow conditions for consolidated sediments during Hurricanes Rita and Ike. The lack of excess Pb activity downcore appears to indicate that a single disturbance event occurred, followed by a lack of subsequent sediment accretion. It is possible that the disturbance event may have been the wrecking event and settling of the ship onto the seafloor, which disturbed (mixed) in situ sediments. Combined with very low (or no) net sediment accumulation post-disturbance(s), no new isotopes have been introduced to the site's stratigraphy, resulting in the lack of a discrete disturbance layer.

Nine tropical systems, ranging from tropical depressions to category 1 hurricanes, have been centered within 37 km (20 nautical miles) of Site 373 since the wrecking event in 1942 (Figure 5.17; NOAA NHC). Site 373 was outside the swath of hurricane force winds related to Hurricanes Katrina and Gustav, and only nominally within the eastern extents of Hurricanes Rita and Ike (Appendix D; Maps D-4 & D-5). Radioisotope measurements are restricted to a single core from the site, but there is sufficient evidence to suggest that the observed scour at Site 373 is the cumulative result of the wrecking event, rather than of punctuated events such as past hurricanes.

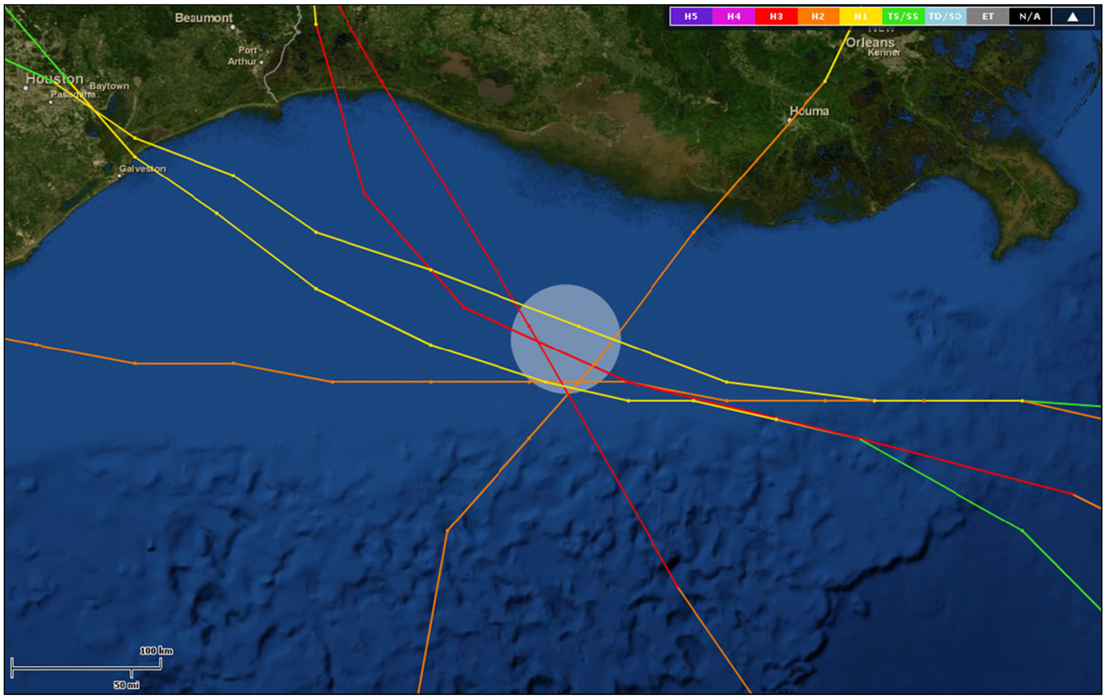


Figure 5.17. Individual tracks for tropical systems centered within 37 km (20 nautical miles) of Site 373 since 1942. (Image courtesy NOAA NHC.)

5.3.4.2 Scour

The wreck at Site 373 is oriented NNE/SSW, along an axis of 17 degrees. Prominent areas of scour occur at the bow, stern, and at the breach in the hull just south of midships. The wreck sits 6.7 m (22 ft) above the mean seabed. A shallower but broader scour zone extends to the west of the wreck site, but generally observable scour appears to be localized. The sub-bottom profiles indicate that accretion or reworked sediments have in-filled the most significant scour zones surrounding the wreck (Figure 3.4.3, Figure 5.18, Figure 5.19). The in-filled sediment appears to be dewatered and compacted, suggesting that the infill was not recently deposited and has been relatively undisturbed.

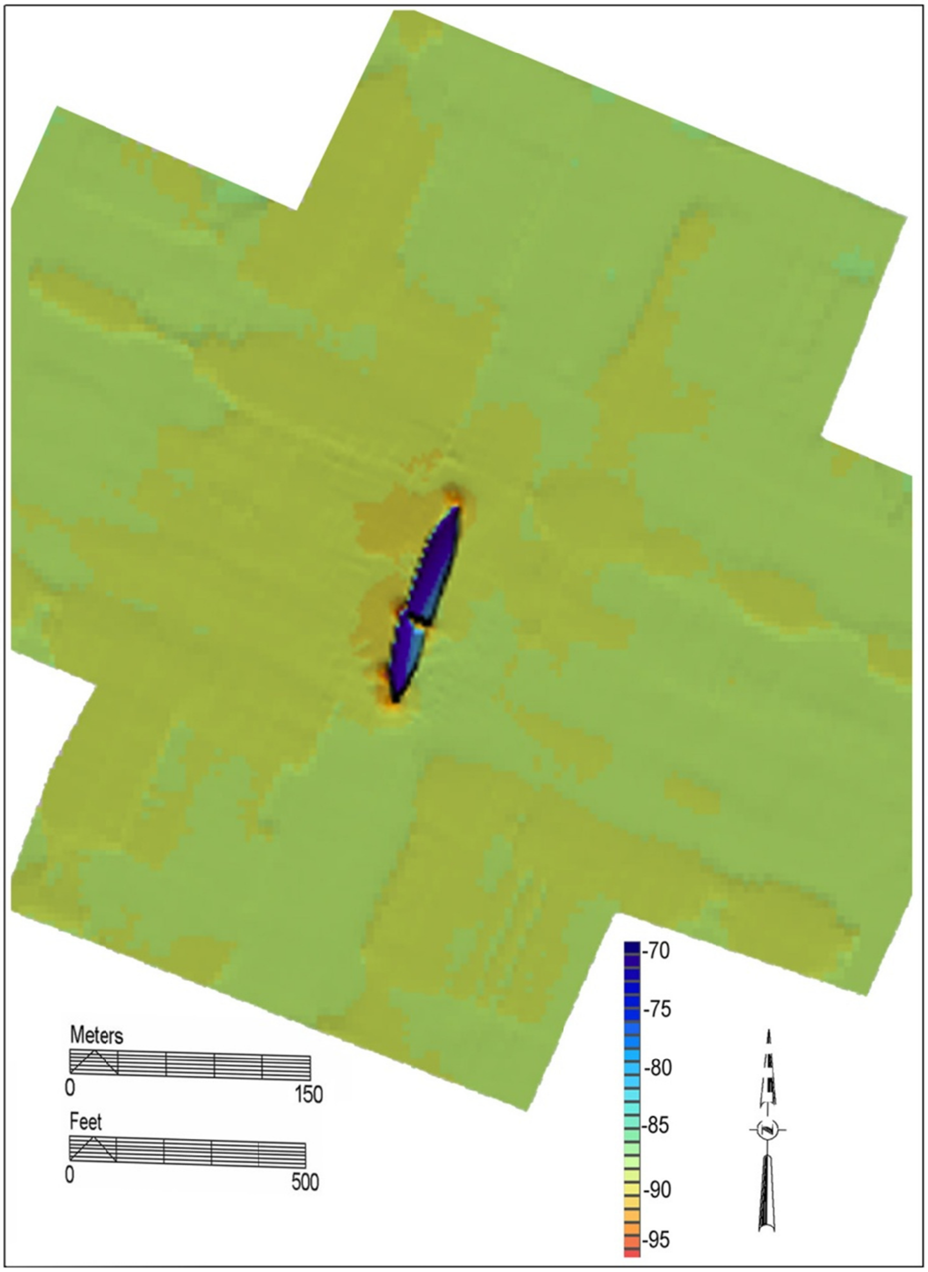


Figure 5.18. Multibeam bathymetry rendering at Site 373, highlighting seafloor scour.

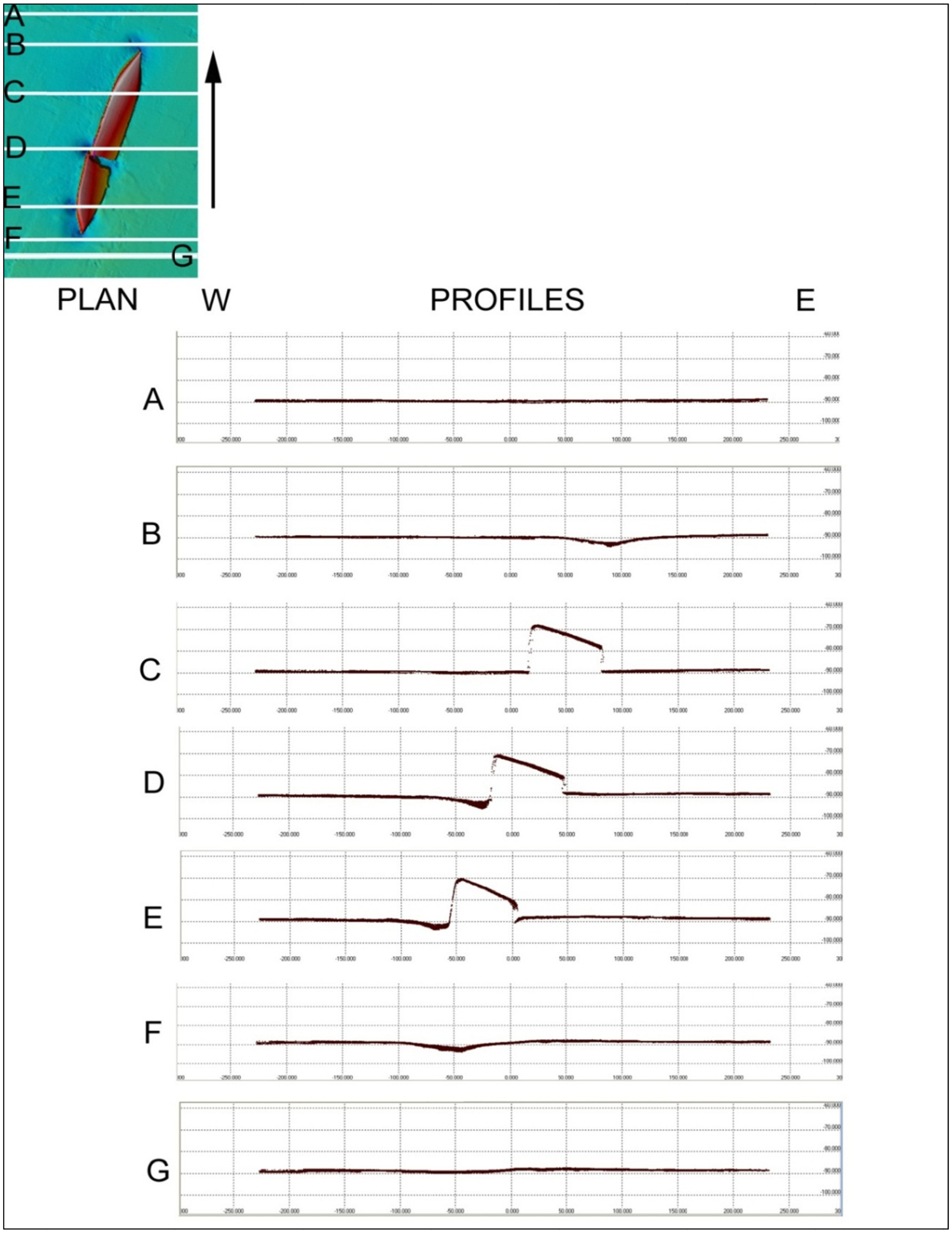


Figure 5.19. Profiles of the seafloor surrounding Site 373.

5.3.4.3 Water Quality and Site Preservation

The measured pH value (8.013) from water samples is slightly alkaline on the site. The measured DO on this site was 7.450 mg/L and salinity was 30.8 ppT. As MacLeod (1989) argues, DO content will have the greatest impact on the degradation of a steel hulled vessel. These measurements represent snapshots and are not part of a systematic or long term sampling strategy which would be required to properly study the chemical processes on site.

As with Site 433, the inverted hull at Site 373 is relatively smooth, with a significant amount of biofouling and organic growth. Trawlers or anchor lines associated with modern activities could potentially damage the extant hull, specifically if they were to catch on already compromised metal near the torpedo holes. Active oil leakage observed on site and at the surface indicates product remains trapped in the holds, but the amount of remnant crude oil is unknown.

It is not possible to quantify the potential for future deterioration of the exposed portions of the hull caused by the combined effects of chemical deterioration of the hull, metal fatigue, and changing current profiles and intensities based on data acquired as part of this study. Corrosion studies at Site 373 would require site-specific monitoring and acquisition of metal samples from the hull. Despite this, lacking discernible sediment accretion at the site, hull degradation is expected to continue due to prolonged exposure in the water column. The propeller and rudder have been removed from the site, so the most susceptible portions of the hull to mechanical forces and corrosion surrounds the large break in the vessel's hull near midships and the hole near the starboard bow.

5.3.5 Site No. 15488, High Island Area, Unknown Modern Wreck

5.3.5.1 Radioisotope Data

The wreck at Site 15488 is that of an unidentified modern vessel with an inverted hull. Radioisotope analysis indicates that normal sediment accretion was interrupted by a disturbance event at Site 15488 that occurred 45 to 63 years before core acquisition, or between 1947 and 1965, with normal accretion resuming at a rate of 0.06 cm/yr after the disturbance.

There are two likely explanations for the disturbance event: either excessive waves and/or currents caused by a hurricane or tropical storm passing in proximity to the site, or a seafloor disturbance caused during the wrecking event. Sixteen tropical systems, ranging from tropical depressions to category 4 hurricanes, have been centered within 37 km (20 nautical miles) of Site 15488 since record keeping began, including 11 that have occurred since 1947, the earliest date for the identified disturbance event (Figure 5.20; NOAA NHC). Only one tropical system occurred during the period of possible disturbance (1947 to 1965): the eye of Hurricane Audrey passed to the east of Site 15488 as a category 4 hurricane in 1957.

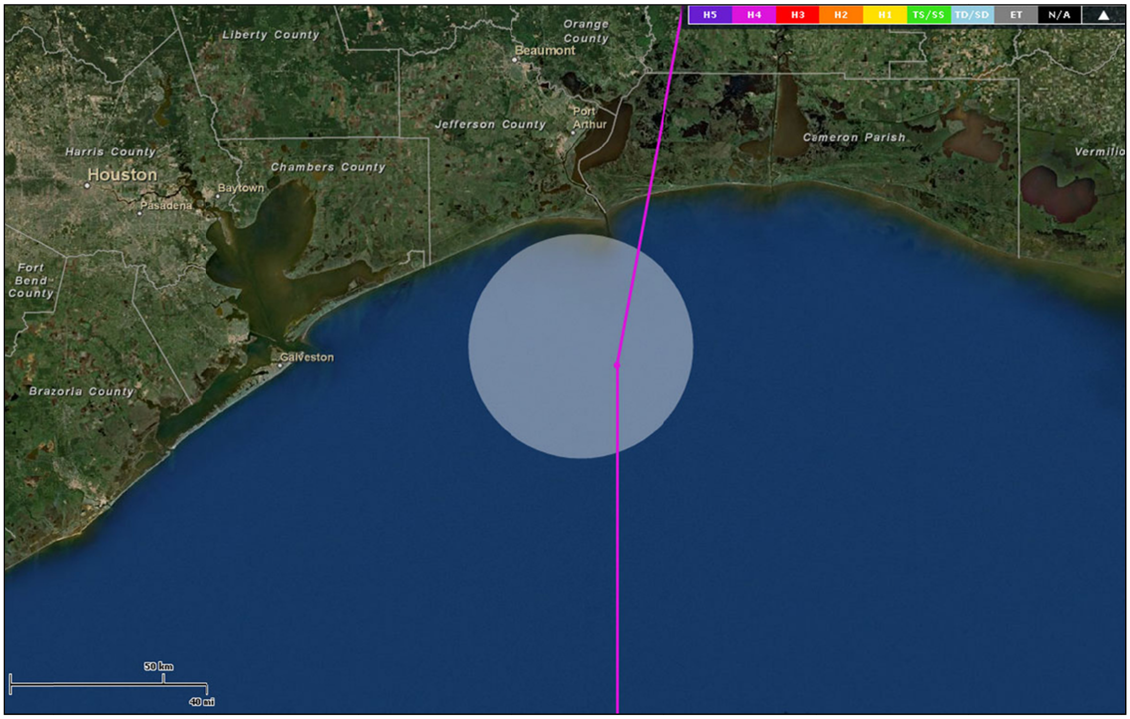


Figure 5.20. Individual tracks for tropical systems centered within 37 km (20 nautical miles) of Site 15488 between 1947 and 1965. (Image courtesy NOAA NHC.)

Given the low rates of maximum hurricane scour for consolidated beds during Hurricanes Ike and Rita at Datum 2 (Rego et al. 2011) and the observed seafloor compaction during the first coring attempt, it is unlikely that the disturbance at Site 15488 is hurricane-related. However, without further analyses or site specific oceanographic modeling, this is impossible to say with certainty. The fact that no disturbances were recorded since the disturbance event 43 to 65 years ago suggests that more recent hurricane events have not had a significant scouring effect on the seafloor at Site 15488. Included in this time period are Hurricanes Rita, which passed to the east of Site 15488, and Ike, which passed to the west of the site (Appendix D; Maps D-4-5).

No known study has been conducted to correlate seafloor impacts such as shipwrecks or ordnance with radioisotope measurements. It is theoretically possible that the impact of the wreck could be the cause of the disturbance event. As shown in Table 4.5, however, only one known wreck with dimensions similar to this shipwreck falls into the disturbance event period shown by the radioisotope data. The fishing vessel *Susan & Gretta* wrecked in 1956, which falls in the middle of the identified disturbance event date range of 1947 to 1965. *Susan & Gretta* is likely the same or a similar type of vessel as the unidentified wreck, but its reported dimensions are approximately 3 m (10 ft) shorter than the measured dimensions of Site 15488.

5.3.5.2 Scour

Dunlap et al. (2004) indicate that shear strength at this site is very soft (<0.2 ksf), although the area lies directly west of increased zones of shear strength associated with Beaumont clay outcrops. Grain size measurements at the seafloor obtained from the core indicate that the surficial sediments are coarse silts (46 µm). Seafloor sediments directly adjacent to the wreck were conducive to coring, but farther away from the wreck site, grain size and shear strength were sufficient to preclude successful core acquisition.

The wreck at Site 15488 is oriented along a WSW/ENE axis, oblique to the dominant storm waves and currents. The wreck has maximum observed relief of 2.4 m (8 ft). Minor instances of local scour are evident at the bow on the northern side and at the stern; less prominent scour zones occur along the northern and southeastern edges. The general scour zone is asymmetric to the NW. The observed pattern of scour indicates that waves and currents from both the NE and SE are probably affecting the site. Sub-bottom profiles of survey lines adjacent to and underneath the wreck recorded generally unstratified sediments (Figure 3.5.3); scour was restricted to the seafloor immediately surrounding the wreck, which has been in-filled; minimal scour zones are apparent at the seafloor (Figure 3.5.4). Based on sub-bottom profiles of the site, it is possible that the difference in seafloor resistance at the two core sites is a direct result of the wreck itself (i.e., finer-grained sediments settling around the wreck site), or could be associated with an underlying near-seafloor channel system. The wreck lies directly over a poorly-resolved channel system associated with the Deweyville Floodplain, which is located adjacent to the Sabine River valley (Pearson et al. 1986). Sub-bottom profiler data indicates that courser grained sediments are present throughout the area, the observed channel system appears to be around 3.7 to 4.6 m (12 to 15 ft) BML, but a significant sag zone overlies the channel reaching close to the seafloor. This sag zone indicates that sediments have not dewatered and compacted and may contribute to subsidence of the wreck site.

5.3.5.3 Water Quality and Site Preservation

The average measured pH value was 7.9285, the average DO was 6.8925 mg/L, and salinity was 31.65 ppT. These measurements represent snapshots and are not part of a systematic or long term sampling strategy which would be required to properly study the chemical processes on site.

There is not sufficient data to quantify the potential for future deterioration of the exposed portions of the hull through the combined effects of chemical deterioration of the hull, metal fatigue, and changing current profiles and intensities. Despite this, and lacking discernible sediment accretion at the site, hull degradation is expected to continue because of prolonged exposure to the water column.

Site 15488 lies 190 m (625 ft) from an existing pipeline. The pipeline was installed in 1999, two years before the wreck was first identified. This could indicate that the wreck occurred sometime between pipeline installation in 1999 and discovery in 2001. Because no record of a geophysical survey associated with the pipeline was discovered, it is not known if the wreck was identified and not reported/recorded, if the data was misinterpreted (as in the case of the 1981 Racal-Decca Survey over Site 389, which failed to identify *J.A. Bisso* [Hudson and Neurauter 1981]), or even if a survey was conducted in association with the pipeline. There were no evident impacts to the site that could be attributed to installation or maintenance of the nearby pipeline. Scars caused by shrimp trawling were evident on the seafloor surrounding the wreck site. During diving observations, netting was also observed on the site, verifying that shrimping has had an impact and likely will continue to affect the wreck.

5.3.6 Site No. 15366, Galveston Area, Unknown Modern Wreck

5.3.6.1 Radioisotope Data

The wreck at Site 15366 is that of an unidentified modern vessel with an inverted hull. Radioisotope analysis indicates that normal sediment accretion was interrupted by a disturbance event 23 to 85 years before core acquisition, or between 1925 and 1987, and that normal accretion resumed after the disturbance. A post-disturbance LAR was measured at 0.15 cm/yr.

There are two probable scenarios for the disturbance event at Site 15366. The recorded disturbance in the radioisotope data indicates either sediment displacement and mixing related to the wrecking event, or the sediment disturbance was caused by a tropical system that impacted the area between 1925 and 1987.

A total of 21 tropical systems, ranging from tropical depressions to category 4 hurricanes, have been centered within 37 km (20 nautical miles) of Site 15366 since recordkeeping began, including 11 that occurred between 1925 and 1987, the time period identified for the disturbance event (Figure 5.21; NOAA NHC). An unnamed category 4 hurricane passed just west of Site 15366 in 1934, and is the most intense storm to have passed within 37 km (20 nautical miles) of Site 15366 within the period of probable disturbance. Also, the eye of Hurricane Ike passed directly over Site 15366 in 2008 (Appendix D; Map D-5).

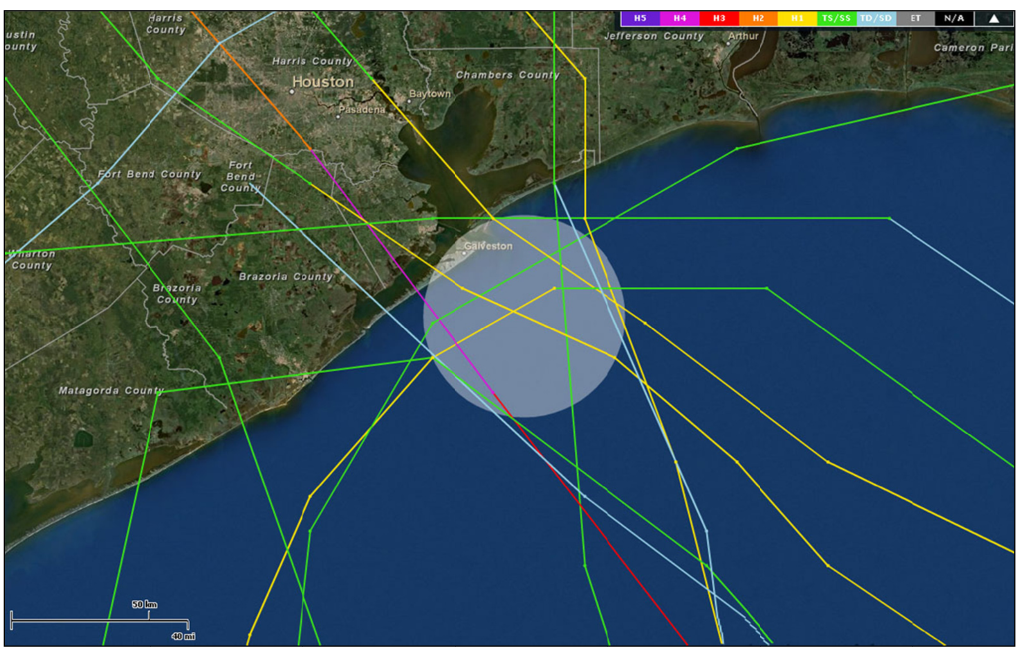


Figure 5.21. Individual tracks for tropical systems centered within 37 km (20 nautical miles) of Site 15366 between 1925 and 1987. (Image courtesy NOAA NHC.)

Given the low rates of maximum hurricane scour for consolidated beds during Hurricanes Ike and Rita at Datum 2, and the observed seafloor compaction during the first coring attempt it is unlikely that the disturbance at Site 15366 is hurricane-related; however, without further analyses or site specific oceanographic modeling, this is impossible to say with certainty.

No known study has been conducted to correlate seafloor impacts, such as shipwrecks or ordnance, with radioisotope measurements. It is theoretically possible that the impact of the wreck could be responsible for this disturbance. As shown in Table 4.6, three of the five vessels reported within 48 km (30 miles) of the site, and with similar dimensions, wrecked during this relatively broad window from 1925 to 1987. The fishing vessel *William Hayes* wrecked in 1957, the tugboat *Barbara D.* wrecked in 1983, and the fishing vessel *Keturah* wrecked in 1957. *William Hayes* and *Keturah* are closest in size to the measured dimensions of Site 15366. The results of the John E. Chance and Associates geophysical survey of this area could indicate a potential *terminus post quem* of 1986 for the formation of the wreck site. If this is the case and the vessel was not present at the time of the survey, then none of the above-referenced vessels can be Site 15366; however, it should be noted that the disturbance event still falls within this window, but the wrecking event would have had to occur within a year of the survey.

5.3.6.2 Scour

The wreck at Site 15366 is oriented on an approximate north-south axis, with the bow facing to the south. Relief at the wreck site varies from approximately 3 to 3.7 m (10 to 12 ft) above the ambient seafloor at the bow to approximately 1.7 to 2 m (6 to 7 ft) at the stern. There appears to be limited scour around the wreck; what scour is apparent occurs in a teardrop-shape, extending to the SSW (Figure 3.6.5). This pattern is consistent with scour caused by currents and waves coming out of the NNE, such as those produced during Hurricane Rita over this area. Sub-bottom data recorded minimal observable scour (Figure 3.6.4), although some possible minor accretion or infill was noted to the SSE near the bow of the wreck.

Dunlap et al. (2004) indicate that shear strength at this site is stiff to very stiff (1 to >2 ksf). Grain size at the seafloor obtained from the core indicates that the surficial sediments are medium fine silts (9.76 µm). Seafloor sediments directly adjacent to the wreck were conducive to coring, but farther away from the wreck site, grain size and shear strength were sufficient to preclude successful core acquisition. It appears likely that the difference in seafloor sediments between sediment cores is a direct result of the wreck itself, which may act as a sediment trap for finer grained particles.

5.3.6.3 Water Quality and Site Preservation

The average measured pH value was 8.129, the average DO was 7.468 mg/L, and salinity was 33.15 ppT. These measurements represent snapshots and are not part of a systematic or long term sampling strategy, which would be required to properly study the chemical processes on site.

There is not sufficient data to quantify the potential for future deterioration of the exposed portions of the hull through the combined effects of chemical deterioration of the hull, metal fatigue, and changing current profiles and intensities. Despite this, and lacking discernible sediment accretion at the site, hull degradation is expected to continue due to prolonged exposure in the water column.

No oil and gas infrastructure is located in immediate proximity to the wreck and no apparent impacts to the site caused by oil and gas development were evident. Scars caused by shrimp trawling were evident on the seafloor surrounding the wreck site.

5.3.7 Site No. 389, South Timbalier Area, Probable *J. A. Bisso*

5.3.7.1 Radioisotope Data

Although this site was not part of the original study, it was added to the scope of work; water samples and cores were acquired and analyzed as part of a contract amendment. The wreck at Site 389 has been identified as the tug *J.A. Bisso*, which sank in 1957. Radioisotope analysis indicates that normal sediment accretion was interrupted by a disturbance event that occurred 50 to 178 years before core acquisition in 2010, or between 1842 and 1960, with normal accretion resuming after the disturbance. Radioisotope data indicates that post-disturbance LAR is a relatively low 0.08 cm/yr, resulting in very little sediment accretion on site.

Samples obtained from Core no. 2 at a depth of 20 m (66 ft) reflect sediments immediately adjacent to the aft starboard hull. This area of the seafloor is devoid of observed scouring, and likely reflects the ambient seafloor including the most recently deposited sediments. Several possible causes of the disturbance are considered, principally the wrecking event, which falls within the time frame identified for the disturbance. Although the wrecking event is a strong candidate, an extreme storm event could also have caused the disturbance. A total of 28 tropical systems, ranging from tropical depressions to category 4 hurricanes, have been centered within 37 km (20 nautical miles) of Site 389 since 1842, when storms were first recorded systematically (Figure 5.22; NOAA NHC). Of these storms, 21 occurred during the same time period as the disturbance event recorded in the radioisotope data, including an unnamed category 3 hurricane that passed just west of the site in 1909 (NOAA NHC).

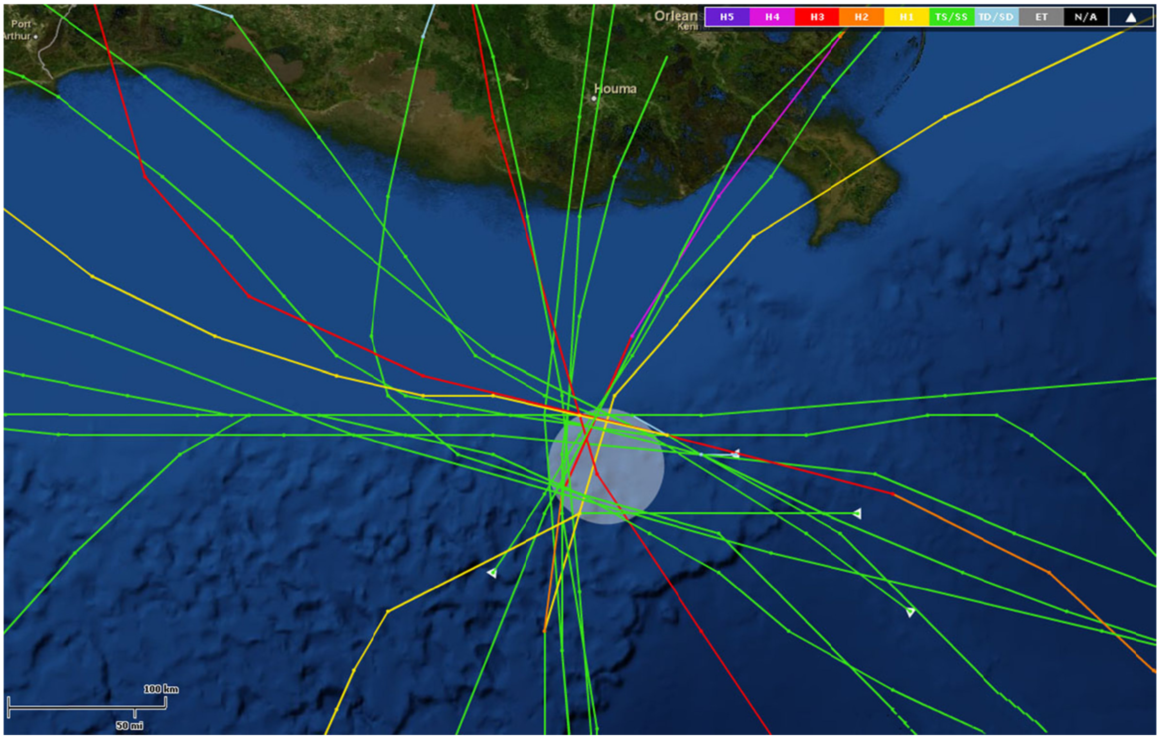


Figure 5.22. Individual tracks for tropical systems centered within 37 km (20 nautical miles) of Site 389 between 1842 and 1960. (Image courtesy NOAA NHC.)

More recent extreme storm events do not appear to have caused significant impacts to seafloor sediments at the wreck site, and do not appear as disturbance event markers in the radioisotope data, including Hurricanes Ivan (2004) and Gustav (2008) (NOAA NHC), which both passed east of the site (Appendix D; Maps D-4-5).

5.3.7.2 Scour

The wreck at Site 389 is oriented NNE to SSW, with the bow facing northward (Figure 5.23). The most pronounced area of scour occurs at the bow of the vessel, where significant local scour reaching depths of 3 m (10 ft) below the ambient seafloor were recorded. Additional areas of scour were observed on the geophysical data along the starboard, or eastern, side of the vessel extending approximately 400 to 450 m (1,300 to 1,475 ft) to the ESE, and to the port or western side of the hull, extending approximately 650 m (2125 ft) from the hull.

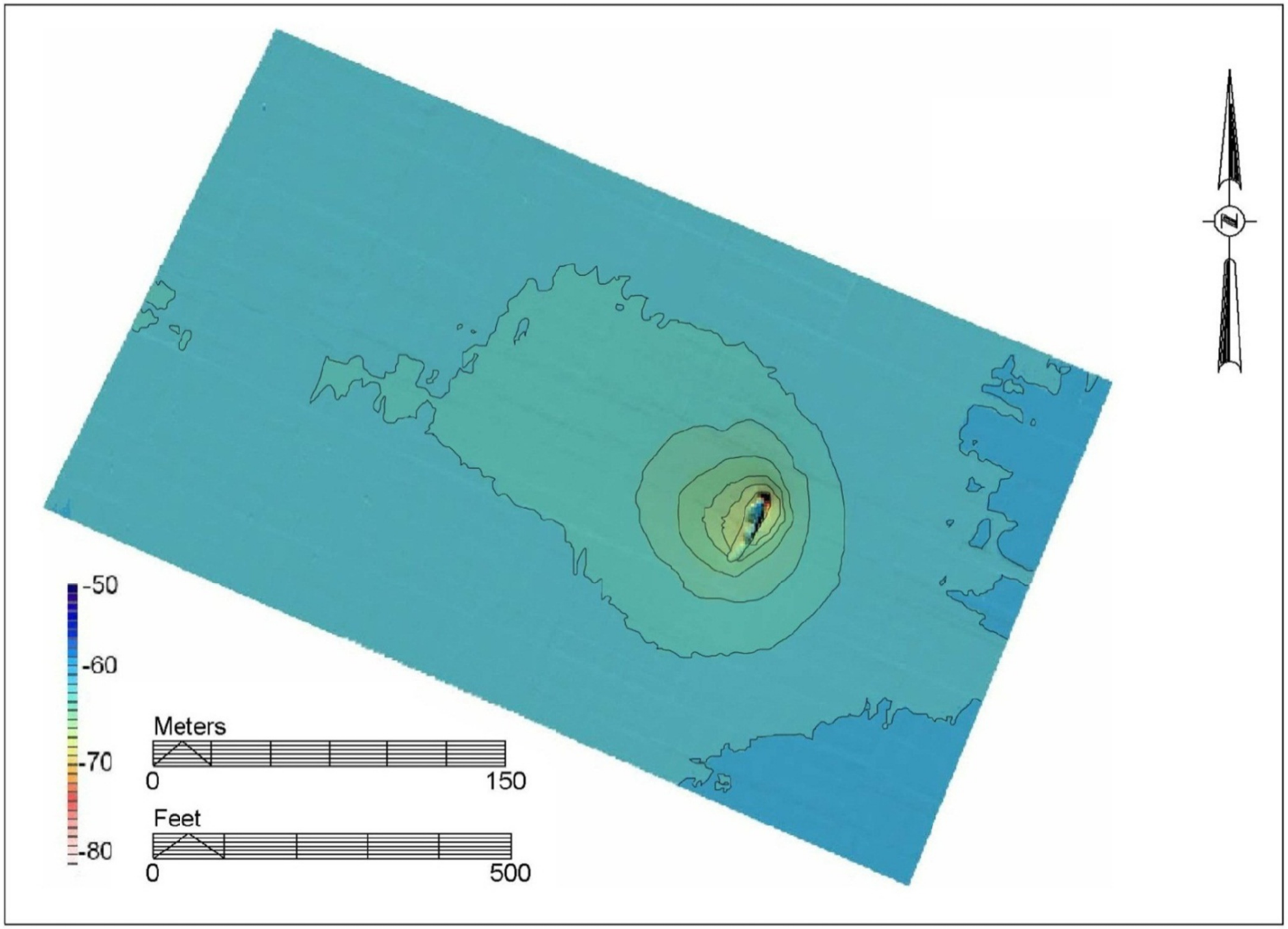


Figure 5.23. Multibeam rendering of Site 389, highlighting scour.

Scouring is most prominent at the bow because the vessel is upright on its keel and the bow has approximately 4.5 to 5.5 m (15 to 18 ft) of relief above the base of the observed scour hole. The bow protrudes significantly into the lower boundary layer of the water column, creating strong local jet flows and likely horseshoe vortices (e.g., Quinn 2006). On average, the scour zone adjacent to the wreck is slightly asymmetric on the eastern side of the hull, indicating that the higher, forward two-thirds of the wreck are impacting the degree of scour more than the lower and/or more buried southern aft end of the hull. The overall larger pattern of scour is circular and relatively asymmetric, suggesting that the dominant current/wave flow is from the ESE. Gearhart et al. (2011:19-21,130) indicate that maximum significant wave heights in the region of the wreck were approximately 6 to 8 m (20 to 26 ft) during Hurricane Katrina, with waves moving to the west, which is consistent with the orientation of the scour zones relative to the wreck.

Dunlap et al. (2004) indicate that shear strength at this site is soft (0.2 to 0.6 ksf). Grain size measurements at the seafloor obtained from the core indicate that the surficial sediments are fine sands (173 µm). Successful cores were acquired at the starboard stern of the vessel and at the bow within the large area of local scour. Sub-bottom profiles of survey lines adjacent to and underneath the wreck depict near-seafloor strata that are truncated by the observed scour zones; there is little to no evidence of sediment infill or redeposition (Figure 3.7.9).

5.3.7.3 Water Quality and Site Preservation

Water quality data acquired during diving operations indicates that average salinity at depth was 31.4 ppT, average pH was 7.496, and DO was 7.017 mg/L.

Calculated LAR of 0.08 cm/yr suggests that little sediment is currently deposited in this area and does not contribute significantly to site burial. This is confirmed by the results of the sonar imagery from 2005 to 2010, which indicate very little change to the seafloor at the wreck site. The lack of significant sediment accretion makes it unlikely that the ancillary object identified through previous sonar investigations has become buried over time. It is probable that the object was displaced either by Hurricane Katrina or as the result of anthropogenic activities. It is likely that, over time, the bow will continue to scour and the stern will continue to accrete slowly, likely through localized sediment movement around the wreck. If the scour continues, and has not stabilized at the current level, over time more of the bow region could be exposed. The scour zone could extend further under the ship toward the south. This scenario would have greater likelihood of occurring if strong waves and currents approached the ship from the northern quadrant. If this occurs, the current integrity of the wreck could be compromised; for example, the hull could break leeward of the bow. These scenarios reflect long-term formation processes based on sediment scour alone. Based on the available data, it is not possible to quantify the potential for future site burial through movement of existing sediments at the wreck site, or deterioration of the exposed portions of the hull, through the combined effects of chemical deterioration of the hull, metal fatigue, and changing current profiles and intensities.

As discussed in Sections 3.7.1 and 3.7.3, sonar data recorded over the site during previous surveys illustrates that disarticulated components at the wreck site have disappeared from the site and are believed to have been removed during recent hurricane activity. An object was evident off of the vessel's bow from the 1991 geophysical survey (Marmaduke 1991). The March 2005 survey identified an object off of the port side of the vessel, forward of midships (Floyd and Clemmons 2005a and 2005b). Surveys conducted in 2007 (Gearhart et al. 2011) and in 2010 (for the current study) found no evidence of any large ancillary wreck components. As noted by Gearhart et al. (2011:132-133), Hurricane Rita was the only major storm to cross through this area in the intervening time between the noted changes to the site (Appendix D; Map D-4).

No clear evidence of anthropogenic impacts to the wreck site was evident. While it is possible that portions of the superstructure and ancillary object identified through previous surveys may have been removed through salvage, it is just as probable that these impacts could be the result of natural processes. The presence of intact port-holes on site makes it unlikely that the site has been impacted by recreational divers.

5.3.8 Site No. 236, Galveston Area, USS *Hatteras*

5.3.8.1 Comparison with Previous Investigations

Although this site was not part of the original study, it was added to the scope of work; water samples and cores were acquired and analyzed as part of a contract modification. *Hatteras* is the most well-documented of the study sites. Results of previous archaeological investigations indicate that the wreck site has been fairly static in appearance over the course of investigations from the 1970s through 2004; however, site conditions were dramatically different during dive operations in 2010.

Initial archaeological investigations were conducted at Site 236 in the 1970s by the Bureau of Land Management (BLM) with the cooperation of the Texas Historical Commission (THC) and the Institute for Nautical Archaeology (INA) at Texas A&M University (Arnold and Hudson 1981). The site studies conducted in the 1970s resulted in geophysical data acquisition, specifically magnetometer survey data. A second series of investigations, conducted in the early 1990s by the MMS and THC for monitoring and mapping purposes, resulted in the generation of a preliminary site map (Figure 5.24; Arnold and Anuszkiewicz 1995).

Arnold and Anuszkiewicz (1995:85) state that a sediment meter was placed on site and that from 1992 to 1994 sediment levels remained fairly constant with no apparent disturbances. They also indicate that, based on imagery provided by Donald Keith, the only significant change to the site was a missing upright engine component (Arnold and Anuszkiewicz 1995:85). Site conditions observed during investigations conducted in the 1990s were described as follows:

> Little of the wreck is exposed above the sand. Paddlewheel hubs on both sides of the ship and some parts of the steam engine rise partially above the sand bottom. The only other remains showing above the bottom in 1992 and 1993 were a very small section of encrusted iron near the bow which was tentatively identified on the assumption that it was located forward of the paddlewheels and on its orientation and distance from other exposed remains. In 1994, the bow wreckage was buried. (Arnold and Anuszkiewicz 1995: 83)

An investigation conducted by PBS&J in 2004 indicates that site conditions were similar to those recorded in the 1970s and early 1990s site visits (Enright et al. 2006). Sonar imagery included in the PBS&J report shows that the starboard paddlewheel and connecting paddlewheel shaft were partially exposed (Figure 5.24). Only the top of the port paddlewheel was exposed; the remainder was buried under surficial sediments. A small portion of what was subsequently identified as a knuckle was recorded between the paddlewheel shafts, and cylindrical objects were identified south of the starboard paddlewheel. In effect, the wreck appeared to be in very similar condition to what was identified from the preliminary site plan published by Arnold and Anuszkiewicz.

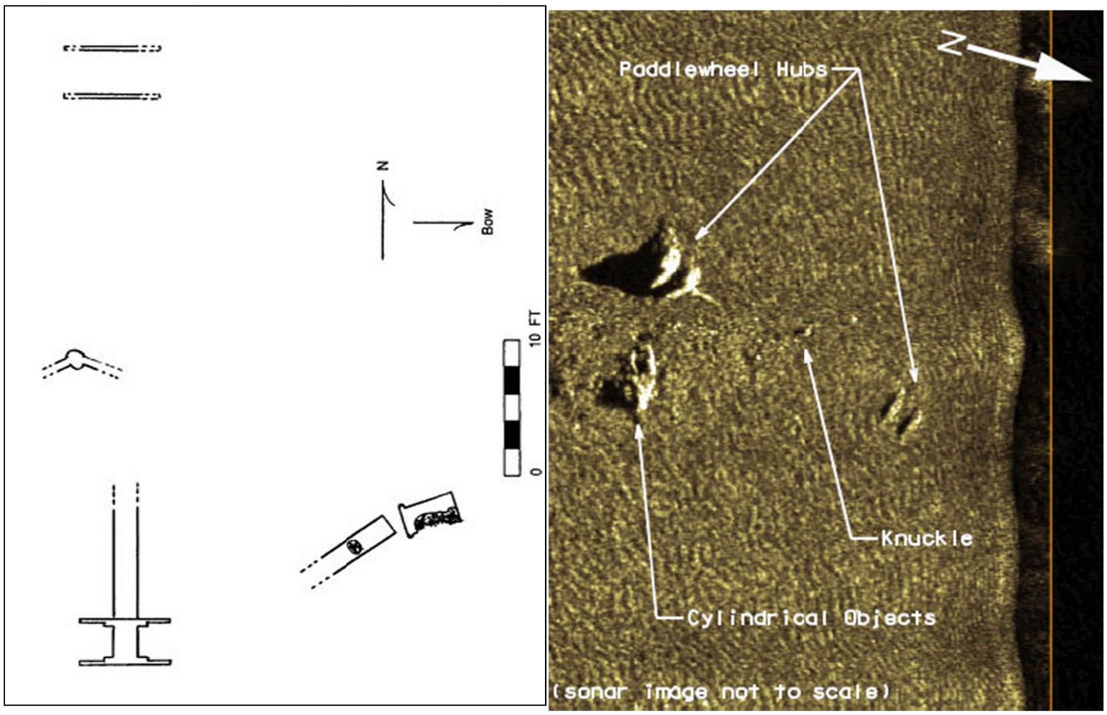


Figure 5.24 and 5.25. Left: Preliminary site plan, rotated and oriented north up (Arnold and Anuskiewicz 1995). Right: 500 kHz sonar image of *Hatteras* (Enright et al. 2006).

Inspections conducted in 2010 for this study indicated that the conditions at the site have changed significantly from previously published observations. Sector scanning sonar data (Figure 5.25) acquired in August, 2010 showed that, in addition to both paddlewheels, the paddlewheel shaft and walking beam were also exposed. The stern assemblage was exposed for what is believed to be the first time since archaeological monitoring has been conducted on site. Also, a large depression was evident on the seabed. This depression measures an estimated 9 m (30 ft) in diameter and, based on the shape and size, may be the result of anthropogenic activities on site. A detailed geophysical investigation was conducted in February 2011. This data indicates that the seafloor hole at the bow had in-filled with fine grained sediments. The area surrounding the hole was still evident, but appeared on multibeam renderings as a slight mound (Figure 5.30).

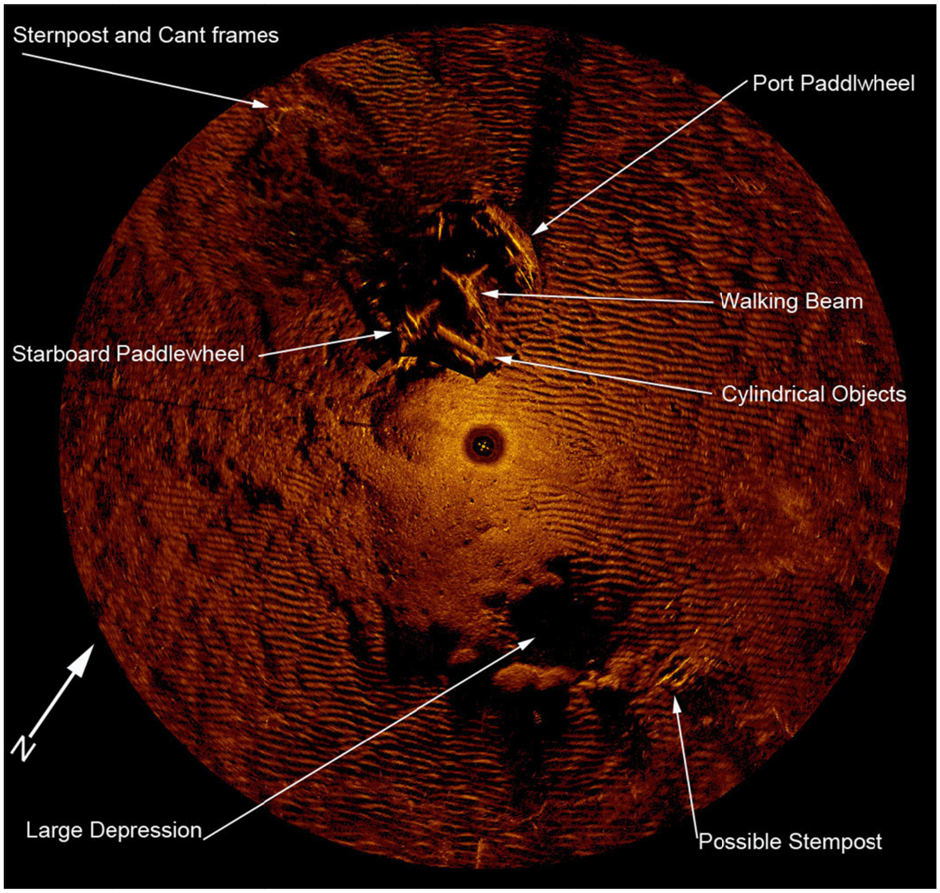


Figure 5.26. Composite of multiple Mesotech scans of USS *Hatteras* site; data was acquired at 150-ft range.

5.3.8.2 Radioisotope Data

Hatteras has a documented wrecking date in 1863. Radioisotope analysis indicates that normal sediment accretion was interrupted by a disturbance event 61 to 79 years before core acquisition in 2010, or between 1931 and 1949, with decreased sedimentation levels following the disturbance. Samples were obtained from Core no. 2 at a depth of 18 m (60 ft) and reflect sediments immediately adjacent to the port paddlewheel, amidships. Several possible causes of the disturbance are considered; however, the wrecking event occurred well before the observed disturbance. Although it is known that treasure hunters caused disturbances to the site, the time period of disturbance pre-dates the commercial availability of scuba diving gear, making it unlikely that this disturbance event can be attributed to on-site anthropogenic activities. It is more likely that an extreme storm event caused the identified disturbance.

Sediments at Site 236 display excellent pre- and post-disturbance ^{210}Pb trends with depth. Disturbance produced a sharp hiatus in excess activity at a depth somewhere between 8.6 and 11.1 cm (3.4 and 4.4 inches) in the seabed. Using the post-disturbance linear accumulation rate (LAR) of 0.14 cm/yr allows this disturbance to be dated in the range of 61 to 79 years before the 2010 core collection. While there are only three pre-disturbance excess points (r2=0.86), sufficient evidence exists to assign an LAR before disturbance of 0.33 cm/yr. This indicates that sediment LAR at Site 236 has decreased by almost 2 mm/yr since the disturbance event.

Twenty-three tropical systems, ranging from tropical depressions to category 4 hurricanes, have been centered within 37 km (20 nautical miles) of Site 236 since 1842, when storms were first recorded systematically (NOAA NHC). Of these storms, five occurred during the same time period as the disturbance event recorded in the radioisotope data, including an unnamed category 4 hurricane that passed almost directly over the site in 1932 (Figure 5.27; NOAA NHC).

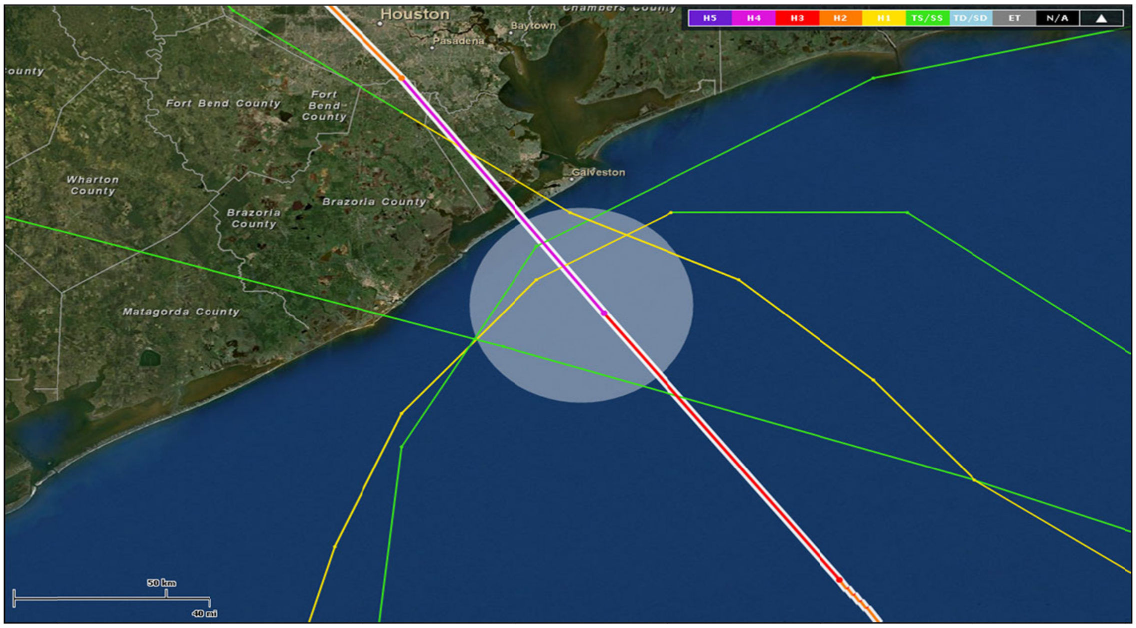


Figure 5.27. Individual tracks for all tropical systems centered within 37 km (20 nautical miles) of Site 236, between 1932 and 1949. (Image courtesy NOAA NHC.)

More recent extreme storm events did not produce disturbance event markers in the radioisotope data, including Hurricane Ike (Appendix D; Map D-5), which passed to the east of Site 236 as a category 2 storm, and Hurricane Alicia, which strengthened from a category 2 to 3 storm SW of the site in 1983 (NOAA NHC). This may be due to low rates of sediment accretion following earlier storm events.

5.3.8.3 Scour and Seafloor Morphology

Dunlap et al. (2004) indicate that the seafloor shear strength in this area ranges from stiff to very stiff (1 to >2 ksf). Geophysical data indicates that the seafloor at Site 236 is characterized by two distinct primary sediment zones; the southern region is characterized by medium to coarse sand and the northern region is characterized by finer-grained sediments (Figure 5.28). A third zone is evident from sonar backscatter, but this likely represents an admixture of the previous two sediment types. Two full sediment cores were taken adjacent to the starboard and port paddlewheel hubs, and two sediment plugs containing over 10 cm (4 inches) each of surficial sediment, were acquired at the vessel's stern. Grain size data from one full core and one sediment plug exhibit extreme variations between the two areas. Grain size at the paddlewheel exhibited medium/fine silts (13 μm) while grain size at the stern consisted of coarse/medium sands (343 μm). Sonar and sub-bottom profiler data highlight the areal extents of these near-seafloor sediment variations. Areas of decreased backscatter, indicative of finer grained sediments with greater sediment cohesion, were observed in the immediate vicinity of the paddlewheel, which corresponds with grain sizes measured from Core no. 2 (Figure 5.28). As is discussed in Section 3.8.3, sub-bottom profiles of survey lines adjacent to and underneath the wreck depict a moderately reflective seafloor underlain by amorphous sediments; acoustic attenuation was attributed to sand content within the near-surface sediments (Figure 5.29). The change in seafloor composition is also reflected in the bathymetry (Figure 3.8.3), which indicates that the courser grained sand deposits are part of a berm located south of the wreck and extending in an east-west direction. The wreck itself may be influencing the differential settlement of fine sediments observed across the site.

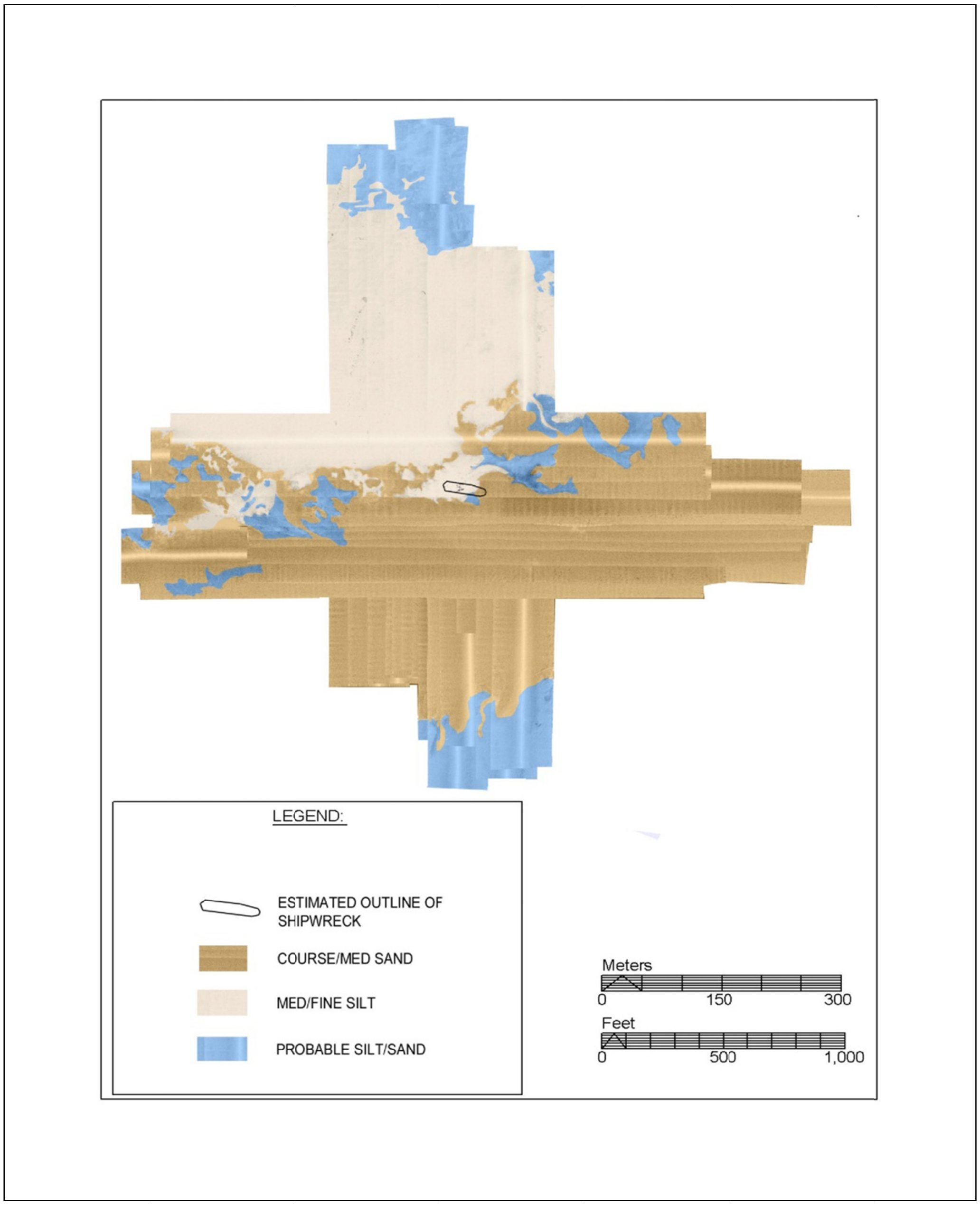


Figure 5.28. Sonar backscatter data highlighting changes in sediment grain size.

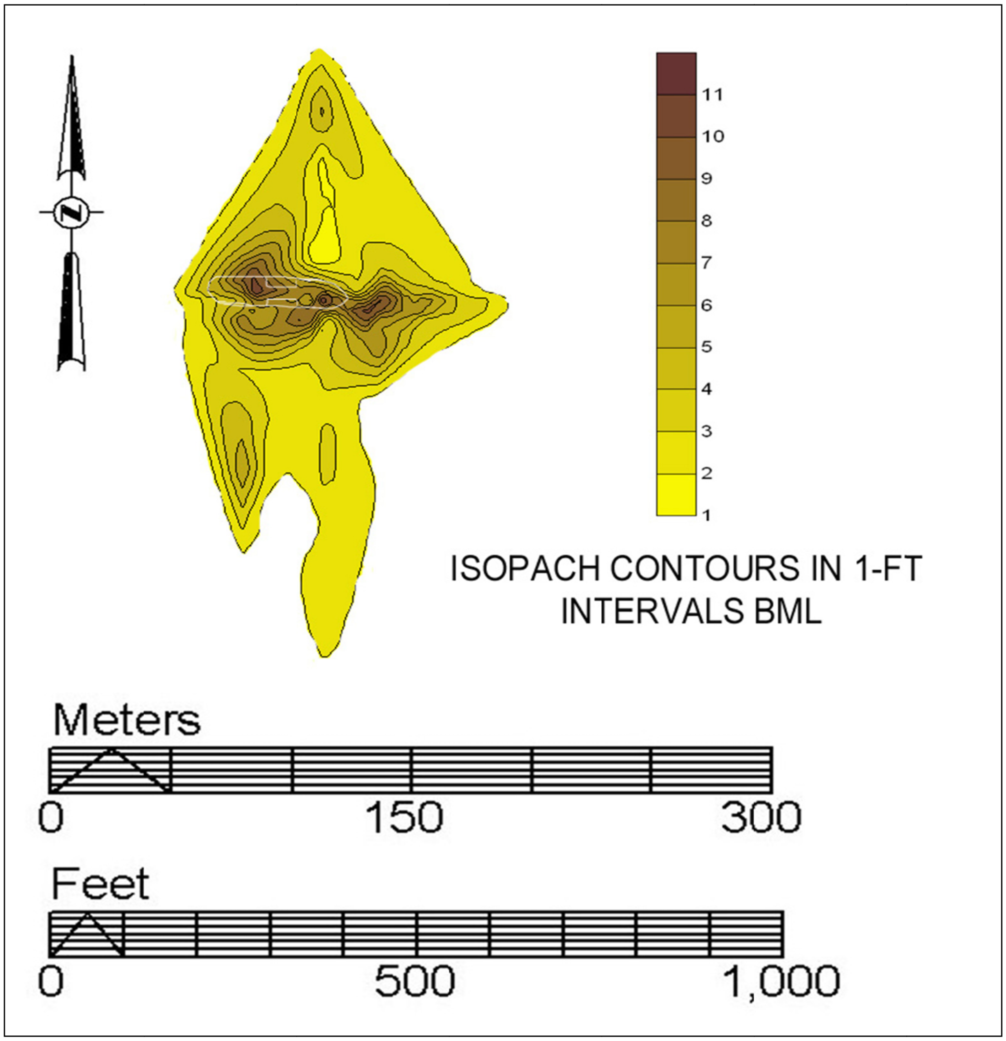


Figure 5.29. Sub-bottom scour contours.

The paddlewheel area of this ship is the most prominent portion of the wreck visible at the seafloor. It has been observed consistently during previous surveys of the site, although with varying degrees of exposure. During the 2010 survey, the paddlewheel assembly had a measured relief of approximately 1.5 to 1.8 m (5 to 6 ft) above the ambient seafloor (Figure 5.30). A circular scour zone extends around the paddlewheel area to a radius of approximately 15 m (50 ft), with more pronounced scour observed directly underneath and adjacent to the paddlewheel assembly (as illustrated in Chapter 3, Figure 3.8.8). A shallow area of minor scour extends around the wreck to an approximate radius of 70 m (236 ft).

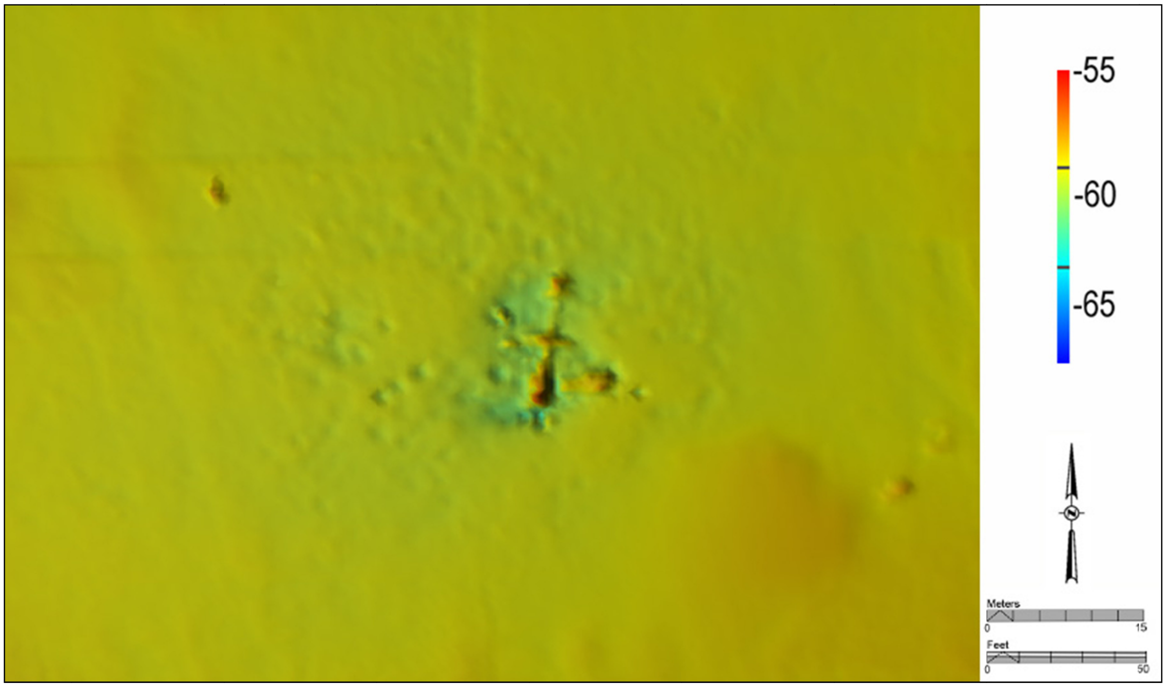


Figure 5.30. Multibeam rendering at Site 236.

Radioisotope measurements are restricted to a single core from the site, but there is evidence to suggest that scour at Site 236 is affected by extreme storm events, because the 2010 investigation documented greater rates of exposure following Hurricane Ike than had been previously observed on site. The observed increase in silt content near the wreck suggests that the hull acts as a sediment trap for finer-grained particles; however, the radioisotope analysis of Core no. 2 did not display any evidence of a disturbance event or a significant increase in LAR within the upper portion of the core. Bathymetry data acquired over the wreck site (Figure 5.30) depict a circular depression surrounding the paddlewheel assembly and, given the fine-grained sediments in this area, this part of the wreck appears to experience more dynamic episodes of scour and reburial as evidenced by the varying observations of surveys conducted since the 1970s. This dynamic accretion and scour is spatially restricted to the immediate area at the paddlewheel, suggesting that the remainder of the wreck experiences less scour and is more likely to remain buried.

The relatively low LAR of 0.14 cm/yr at the *Hatteras* site indicates that if natural sediment accretion rates over the last 61 to 79 years remain constant, accretion is not likely to have a substantial role in re-burying the exposed hull components on site. Despite this, evidence indicates that the large hole observed in August 2010 was in-filled with fine grained sediments within six months. As discussed above, pre- and post-disturbance ^{210}Pb trends indicate that LAR rates decreased by nearly 2 mm/yr following the observed disturbance event between 61 and 79 years before core acquisition. Because the only observations available are post-1970, the condition of the site before the disturbance is unknown. As stated above, it is possible that the wreck itself influences sediment accretion on site by disrupting natural flow. In this scenario, a significant storm (such as the 1932 Category 4 hurricane) may have impacted the site by reworking sediments that buried the hull. Once buried, the wreck would no longer project into the water column, and would not have a significant impact on sediment transport, or, more specifically, it would not create drag within the boundary layer. This profile reduction could have caused an observable decrease in LAR on site over the next 78 years.

Following this argument, oceanographic modeling indicates that loose bed scenarios at Datum 2 range from 10 to 84 cm (4 to 33 inches) of erosion from Hurricane Rita to 1 to 30 cm (0.4 to 12 inches) of erosion from Hurricane Ike. The mix of sands, silts, and clays at Site 236 suggests the presence of some cohesionless sediment, which is likely to have scoured away from the site, as is suggested in the loose bed scenario. Both storms occurred between the 2004 PBS&J investigation and the 2010 investigation for this study; they may be responsible for the significant amount of wreck exposure observed by divers in 2010. Wreck exposure at the paddlewheel assembly is not likely to remain static, because the hull is again projecting into the water column and impacting sediment transport by creating drag. It is hypothesized that the site will experience a temporary increase in LAR on site until a greater portion of the paddlewheel assembly is reburied. It is possible that the relatively short amount of time between Hurricanes Rita and Ike, and the 2010 investigation may account for the lack of significant increase in the post-disturbance LAR calculated from radioisotope data.

The *Hatteras* site represents an observably dynamic seafloor environment from which additional data could be collected to quantitatively monitor the inter-related processes affecting seabed morphology. During the 2010 diving operations, a makeshift erosion pin was placed on site adjacent to the starboard paddlewheel to facilitate future sediment change observations. The pin is located on the northeastern, inner side of the paddlewheel towards the bow of the vessel. A 1.8 m (5.9 ft) long length of rebar was hammered into the substrate so that 1 m (3.3 ft) was buried below the seafloor and the remaining 80 cm (32 in) were exposed in the water column. Yellow marine paint markings were scaled every 20 cm (8 in) down the length of the bar; redundant plastic cable ties were placed at every visual interval marking for tactile identification in case of poor visibility or biofouling. A double yellow line with cable ties distinguishes the seafloor as of 2010: sediment accretion will reduce bar exposure to less than 80 cm (32 in); sediment scour will fully expose the double yellow band and increase exposure to more than 80 cm (32 in).

The location of Site 236 within a designated fairway complicates the modeling of current flow regimes and velocities, which contribute to seafloor scour and sediment transport. It is recommended that current profilers and sediment traps be proactively deployed and monitored to develop a more complete set of variables acting on the site, and that can be used in site specific modeling and quantitative analysis.

5.3.8.4 Water Quality and Site Preservation

Water quality data indicate that salinity was 34.3 ppT, pH was 8.033, and DO was 7.467 mg/L.

Because *Hatteras* is located within a shipping fairway, it offers some additional protection from oil and gas development and possibly from trawling. Current regulations do not allow structures (caissons and platforms) within fairways; they also place more onerous requirements on pipeline installation, requiring them to be buried 4.6 m (15 ft) below the mudline, rather than the standard 0.9 m (3 ft). For this reason, many operators choose to avoid routing pipelines through fairways, if possible, but it is not prohibited. Pipelines do cross this fairway, and pipelines are present on either side of the *Hatteras* site, 2,743 m (9,000 ft) to the SW and 4,420 m (14,500 ft) to the NE. It is unknown at this point, but the authors speculate that preferential sediment accretion on Site 236 will rebury a large portion of the paddlewheel assembly, so that the site will resemble its pre-Hurricane Ike appearance in the next several years. Despite the influence of Ike, the anthropogenic impacts to the site are unknown. A large hole identified on the sector scanning sonar does not appear natural and could be the result of a prop-blower used to displace sediments to allow divers access to buried site components. If such activities were taking place on the site, there is no way to know, at this point, the extent and degree to which these processes are responsible for the condition of the site seen during diving operations and on the geophysical data. In most cases, due to the irregular nature of monitoring visits, there is no way to determine if these changes were brought on by natural processes or through anthropogenic means.

5.3.9 Site No. 15326, East Cameron Area, Unknown Barge

This site was not one of the original contract sites and was not included in modeling or analysis of site formation processes. Both water quality and cores were collected on site; the results are included in Section 3.9.3.1 and 3.9.3.2. Because the site was determined to have no obvious historical significance, it was decided that resources used for analysis be allocated to other sites.

Site 15326 lies 312 m (1,025 ft) from an existing pipeline. The wreck was identified through the pipeline route pre-lay survey; the pipeline route was subsequently re-designed to avoid the wreck by 300 m (1,000 ft). Numerous trawl scars attributed to shrimping were evident on the original sonar data, some of which appear to directly impact the site. No evidence of damage or scarring associated with pipeline installation was observed during diving operations; however, no post-installation sonar data was acquired at this site. Divers observed large quantities of shrimp netting covering the site.

5.3.10 Site No. 322, East Cameron Area, Unknown Modern Wreck

This site was not one of the original contract sites and was not included in modeling or analysis of site formation processes. Both water quality and cores were collected on site and the results are included in Section 3.10.3.1 and 3.10.3.2. Because the site was determined to have no obvious historical significance, it was decided that resources used for analysis would be allocated to other sites.

5.3.11 Site No. Pending, West Cameron Area, Modern Debris

This site was not one of the original contract sites and was not included in modeling or analysis of site formation processes. This site was determined to have no historical significance. Neither water quality nor sediment cores were acquired at this site.

5.4 COMPARISON OF OBSERVED SITE FORMATION PROCESSES

Eleven sites were investigated, and nine shipwrecks identified. All of the investigated shipwreck sites, with the exception of Site 236 (USS *Hatteras)*, consisted of metal-hulled (probable carbon steel) wrecks that project into the water column above the surrounding seabed. Of these, Sites 389 (*J.A. Bisso*), 433 (*R.W. Gallagher*), 373 (*Cities Service Toledo*), and 15366 (Unknown wreck) were oriented along a similar, north-south axis. Sites 15488 (Unknown wreck), 386 (*Heredia*), and 236 (*Hatteras*) were identified along an approximate east-west orientation. The remaining two wrecks, 15326 (Unknown barge) and 322 (Unknown wreck), were along a diagonal axis, approximately NE-SW (15326) and NW-SE (322). Of the nine steel-hulled study sites, the majority were upright, including Sites 389 (*J.A. Bisso*), 386 (*Heredia*), 236 (*Hatteras*), 15326 (Unknown barge), and 322 (Unknown wreck); the remaining hulls were all inverted. Sites 15488 (Unknown wreck), 15366 (Unknown wreck), 15326 (Unknown barge), and 236 (*Hatteras*) had the lowest profiles in the water column. Over their lifetimes, all of the wrecks will be subjected to minor current and wave action that can impact exposed portions of hull, and to larger scale impacts of major storms and hurricanes. The fact that many of the hulls are inverted will reduce the impact of these forces on the hull and limit resulting damages. As evidenced by Sites 389 and 386, the superstructure and disarticulated remains of upright wrecks are subject to greater risks and impacts, both natural and anthropogenic, which can cause greater degrees of site disarticulation and damage.

Radioisotope decay curves indicate that rates of sediment deposition are very low at all of the sampled study sites. Of the six sites sampled, Sites 236, 15366, and 433 exhibited the highest accumulation rates, at 0.14, 0.15, and 0.17 cm/yr, respectively. Sites 15488 and 389 exhibited the lowest rates at 0.06 and 0.08 cm/yr, respectively. At these rates, it will take 100 years to accumulate between 6 and 17 cm (2.4 to 6.7 inches) of sediment at the study sites, not even accounting for the effects of compaction and dewatering. This indicates that ongoing sediment accretion alone is unlikely to play a significant role in burying site components at any of the study sites.

All of the wreck sites had some degree of scour located directly adjacent to the shipwreck. These zones were typically larger and deeper surrounding the bow and stern of the wreck, and at breaks in the hull that create a zone where currents are locally accelerated and jet flows (high velocity localized flows) may be experienced. The majority of the sites also had broad shallow global scour zones that extended outward from the wreck site. The two exceptions to this were Sites 15488 and 373, where seafloor scour appeared to be restricted to the area directly surrounding the wreck site. In the case of Site 373, sub-bottom profiler data indicates that scour has been in-filled. This may indicate that the scour pattern was, at one point, similar to the other wreck sites, but sediment deposition has since filled in these scour zones. However, a lack of observed Pb downcore decay indicates that infill occurred close to the time of disturbance, as a lack of recent activity indicates little to no ongoing sediment accretion.

Site 386 is upright, oriented along a different axis than most of the other hulls, in deeper water, and is disarticulated to a greater extent producing a lower profile in the water column. Despite this, the site still exhibits a broad scour pattern similar to Sites 389, 433, and 15366. This appears to indicate that while the orientation of the wreck site will influence the orientation of the scour, it is not the most significant factor in determining extent or depth.

An interesting comparison can be made between *RW Gallagher* (Site 433) and *Cities Service Toledo* (Site 373). Both are similarly sized, inverted tankers that were sunk within a few months of each other. Both wrecks are oriented along virtually the same axis, and both have significant breaks in the hulls near midships. Both sites exhibit similar scour orientation surrounding the bow, stern, and at the break in the hull. Despite these similarities, *RW Gallagher* (Site 433) has a substantial, broad scour zone that extends outward from the wreck site to the west with no evidence of subsequent infill. *Cities Service Toledo* (Site 373) does not exhibit a prominent active scour zone, but evidence of in-filled scour is present. Both sites are located along the Louisiana continental shelf, in similar water depths; 26.5 m (87 ft) at Site 433 and 27 m (89 ft) at Site 373. Surficial sediments at Site 433 are coarse silts (48.6 µm) and those at Site 373 are medium silts (12.5 µm). While the pattern of average currents between Site 433 and Site 373 changes somewhat with the shoreline, the sites are relatively close together and the overall current direction across the two sites is from the ESE towards the WNW. Site 433 has slightly greater relief above the seafloor (7.3 m or 24 ft) than Site 373 (6.7 m or 22 ft).

The two most significant factors that differentiate the *RW Gallagher* (Site 433) and *Cities Service Toledo* (Site 373) sites appear to be seafloor sediment type/consistency and severe storm impacts. Although bulk density and plasticity are unknown, the sediments at Site 373 are finer grained, and would therefore be expected to travel further in suspension. This appears to be the opposite of what is observed at the two sites, where Site 373 appears to have experienced scour and immediate infill; no evidence of in-filled scour was evident on Site 433. For these reasons, storms appear to be the most likely culprit for the differing scour patterns at the two sites. Site 433 was located beyond the extents of hurricane force winds associated with Katrina, Rita, Gustav, and Ike (Appendix D; Maps D-4-5), while Site 373 was within the extents of hurricane force winds associated with Hurricanes Rita and Ike (Appendix D, Maps 4 & 5). Site 373 was modeled as Datum 2 and modeled net consolidated, or cohesive, bed scour rates are less than 0.03 cm (Rego et al. 2011; Table 5.3). When extrapolated to Site 433, Datum 2 results indicate that recent storm scour is unlikely to account for the differing observations when compared to Site 373.

It is evident that scour zones surrounding the wreck sites are variable, controlled by too many factors to quantify based on this study alone. However, there is a general pattern associated with wreck orientation. Wrecks oriented to the east (i.e., bow facing to the east) tend to display the most scour on the bow and stern regions, while those oriented across the dominant current flow direction tend to display more scour along the length of the ship, and have larger scour zones extending down-current of the wreck.

Further data is necessary to determine precisely the role of ongoing currents versus punctuated storm events within cohesive sediments. Despite this, observations of the extent and morphology of scour zones through geophysics and radioisotopes provided indications that scoured sediments were not typically falling back out of suspension and in-filling at the majority of the studied sites. This indicates that sediments were being shifted off site and modern accretion rates are insignificant. For this reason, it can be expected that these sites will continue to experience some degree of scour that could result in greater degrees of exposure over time and even reduce the stability of the wreck resulting in damage or collapse of the site.

Seafloor shear strength measurements at the wreck sites range from very soft to very stiff (<0.2 to >2.0 ksf). Although shear strength measurements were not acquired for the majority of the sites, some qualitative observations can be made based on the diving investigations. Resistance to coring was greater on sites off of Texas and closer to the LA-TX border, likely due to a lack of soft Holocene sediment overburden in this area. At Sites 15488 and 15366 coring away from the wreck site was unsuccessful due to shallow refusal, but successful cores were obtained directly adjacent to each of the wreck sites. This appears to indicate that the wreck sites have a significant impact on the composition of the seafloor. Radioisotope data did not provide any indication that these sediments are comprised of significant quantities of recently deposited sediment. This may indicate that the variability in seafloor strength was caused by the wrecking event, or that the effect may not be in the form of a disruption in sediment flow, but instead may result in a change in water content and plasticity.

As shown in Table 5.6, water quality samples indicate that pH values ranged from 7.230 to 8.160, salinity from 30.8 to 34.4 ppT, and DO from 6.690 to 7.480 mg/L. Water temperature was between 77 and 88 degrees at depth. The coldest temperatures were observed at the deepest samples on Site 433. Salinity readings were lower on the study sites than the published depth-specific seasonal averages (NOAA NODC), which range from 34.5 to 36 ppT; higher salinity rates are expected at the deeper sites. Published seasonal data trends indicate that surface salinity measurements are typically lowest in the summer, although salinity values do not change by more than a small margin from season to season at depths greater than 15 m (49 ft) BSL. Water quality data and measurements of sediment samples provide baseline data only. While these measurements provide an indication of conditions on site that impact corrosion of metal-hulled wrecks, they represent only a snapshot and not the cumulative impacts of time and seasonal variations. Tables in Appendix F demonstrate that no clear patterns were evident that can be correlated with water depth, latitude, longitude, or other natural variables. Supplemental data, such as that available through the NODC (NOAA NODC; Figure 5.4 – Figure 5.7), can be used to assist gross management strategies, but cannot substitute for onsite measurements for accurate site modeling.

Some evidence of anthropogenic impacts to the wreck sites was also observed. Both the rudder and the propeller are missing from Site 373, the probable *Cities Service Toledo*. Christ reports that the rudder was present in 1971 when he visited the site (Christ 2005), so the removal was not part of any initial salvage to the wreck site immediately following the sinking in 1942. It remains unknown when or how the rudder was removed but the clean and precise nature of the cut on the propeller shaft suggests intentional and planned removal. Site 389, *J.A. Bisso*, lacks a pilot house or other superstructure, even though the vessel is right-side up on the seafloor. Geophysical data obtained over the site in 2005 showed a large ancillary object just off of the port side of the vessel. Two subsequent geophysical surveys, coupled with diver investigations in 2010, failed to find any evidence of this object. These components of the wreck could have been removed or damaged by human impacts to the sites, through shrimp trawling or purposeful deconstruction or salvage, or they could have been the result of natural processes (Hurricanes Gustav and Katrina came through this area after the initial sonar imagery). *Hatteras* is the most well documented of the study sites. Results of previous archaeological investigations indicate that the wreck site has been fairly constant in appearance over the course of investigations from the 1970s through 2004. It would appear that the condition of the site was fairly stable; however, site conditions were dramatically different during dive operations in 2010. An examination of storm history over the *Hatteras* site indicates that the only significant storm to cross near Site 236 since the monitoring began in the 1970s was Hurricane Ike, which occurred less than one year before the 2010 field work. It is unknown at this point, but the authors speculate that preferential sediment accretion on Site 236 will rebury a large portion of the paddlewheel assembly, so that, within the next several years, the site will resemble its pre-Ike appearance. Despite the influence of Hurricane Ike, the anthropogenic impacts to the site are unknown, although possible evidence of sediment removal was identified on the sector scanning sonar data (Section 5.8.3.4). If such activities were taking place on the site, at this point there is no way to know to what extent and to what degree these processes are responsible for the condition of the site seen during diving operations and on the geophysical data.

Through the accumulation of more data and through a better understanding of how natural processes impact these sites, archaeologists can learn to identify when the impacts to sites are cultural and when they are the result of natural events. Often the most significant processes that impact a shipwreck site involve the movement of the seabed. This movement may be in the form of sediment removal (erosion/scour) and addition (accretion/deposition), or may be the result of mass sediment mobilization (mudflows or liquefaction). Scour is one of the most notable and universally present impacts to a shipwreck site; it occurs in one of two ways: natural or induced. Natural scour can result from ongoing wave and current processes or can be sudden, related to severe storm events. An object that sits proud above the seafloor (such as a shipwreck) can induce scour by impacting and re-directing natural wave and current patterns. The geophysical data acquired at each of the primary study sites indicates that scour is prevalent surrounding these wreck sites, but varying scour patterns and degrees are evident from site to site. Because of significant hull exposure on the majority of the wreck sites, coupled with low sediment accretion rates, corrosion is the most significant long-term site formation process expected to impact the studied shipwreck sites.

6. CONCLUSIONS AND RECOMMENDATIONS

The primary goal of this study was to investigate possible shipwreck sites and make a determination of their potential historical significance using eligibility criteria for the NRHP. Of the 11 sites investigated, five are considered eligible for listing on the NRHP: *RW Gallagher* (Site 433), *Heredia* (Site 386), *Cities Service Toledo* (Site 373), *JA Bisso* (Site 389), and *Hatteras* (Site 236). Each of these sites may eligible under multiple criteria, as is discussed in Chapter 4. The site of the USS *Hatteras* (Site 236) is already listed on the National Register and was added to the scope of work for monitoring purposes. Nomination forms have been prepared for Sites 433 (*R.W. Gallagher*), 386 (*Heredia*), 373 (*Cities Service Toledo*), and 389 (*J.A. Bisso*) and were submitted under this contract's scope of work. The four remaining shipwrecks verified as part of this study represent relatively modern vessels that did not display any unique qualities or apparent historical significance and include Sites 15488 (Unknown wreck), 15366 (Unknown wreck), 15326 (Unknown barge), and 322 (Unknown wreck). No shipwreck was identified at the reported location of Site 380. The feature investigated in the West Cameron area (no site number available), was determined to represent modern industry-related debris rather than a shipwreck site, and was not interpreted as eligible for listing on the National Register.

A secondary goal of the study was to provide an assessment of shipwreck site formation processes. Because of the number of sites, contract specifications, and the fiscal and temporal constraints of the study, the methodology focused on three primary investigative techniques: the acquisition of sediment cores, oceanographic modeling (using the grain size analysis results from the cores), and water sampling. The results of the site formation data are provided to help BOEM with the ongoing management and protection of submerged cultural resources on the OCS. As discussed in Chapter 1, the most common management strategy is the designation of avoidance zones to known wrecks, targets, and anomalies to ensure that these areas are not impacted by development.

6.1 Management Strategies

6.1.1. Regulatory Practice

In situ preservation is a recognized management strategy used by archaeologists all over the world (UNESCO 2001) and is best used in combination with avoidance zones. In the GOM, BOEM enforces avoidance zones around shipwreck sites during permitted activities on the OCS.

Other agencies throughout the world that regulate bottom-disturbing activities and their potential impacts on archaeological resources have developed their own ways to ensure that archaeological and potentially archaeologically significant materials are avoided. The state of Texas is one of the few U.S. states with substantial offshore oil and gas development and archaeological survey requirements designed to ensure that historic resources are not impacted by offshore development. Texas maintains economic rights within 15 km (9 mi) of the coast rather than the 5 km (3 mi) identified as state waters in Louisiana, Mississippi, and Alabama.

Texas' avoidance criteria apply to any sonar target or magnetic anomaly deemed archaeologically significant by the project archaeologist, and are determined by the target's distance offshore. Avoidance zones of 50 m (164 ft) are used for targets within 5 km (3 nautical miles) of shore and 150 m (492 ft) surrounding sites or objects located between the 3 and 9 nautical mile limit (Texas Administrative Code Title 13, Part 2, Chapter 28, Rule §28.1). Similar to the BOEM requirements, if the avoidance can be adhered to during construction, the archaeological permit is generally approved by the State of Texas and construction can commence. If avoidance is not possible, an investigation of the target or anomaly may be required. One significant difference from BOEM is that Texas does not require surveys in all areas; instead, it assigns survey requirements only to tracts with known shipwrecks or high potential.

Agencies in other states that require archaeological surveys may not necessarily deal with oil and gas development, but regulate other bottom-disturbing activities. South Carolina, for instance, regulates disturbance activities associated with dredging, construction, and aggregate extraction (Chris Amer 2011 pers. comm.). Although the South Carolina Institute for Archaeology and Anthropology (SCIAA) is not the permitting agency, by law they must be consulted by the permitting agency as part of the permitting and review process. When an activity is planned, SCIAA reviews the proposed activity and recommends to the permitting agency (such as the U.S. Army Corps of Engineers) whether a survey is necessary. Once the survey is completed, SCIAA reviews the report and may recommend either further investigation of targets to determine National Register potential, mitigation, or avoidance by a distance of 100 m (328 ft) or greater. Avoidance zones use either a centerpoint and radius, or an oval, defined to the operator by three points including the target's centerpoint and two offsets (Chris Amer 2011 pers. comm.).

In the U.K., the Crown Estate manages the seabed out to the 22 km (12 nautical miles) territorial limit (Crown Estate 2011). The crown maintains rights only to submerged bottom lands within the territorial limit; oil and gas production are specifically excluded from these regulations (BMAPA & English Heritage 2003). A more common bottom disturbance activity within the territorial limit is marine aggregate extraction. The British Marine Aggregate Producers Association (BMAPA) and English Heritage have published a guidance note that details measures to mitigate effects of dredging on historic resources (BMAPA & English Heritage 2003). This document indicates that avoidance is the preferred method of mitigation. When sites are identified during dredging activities, English Heritage is notified and a temporary exclusion zone is provided to the site. The operator is then directed to contract an archaeological investigation to determine the extent and nature of the site. Depending on the results of the archaeological assessment, a permanent archaeological exclusion zone may be applied to the site.

BOEM has maintained survey guidelines for submerged archaeological resources since the 1970s, and has continually evaluated and updated these strategies by conducting and/or funding studies that inform their management strategies. The development of archaeological survey and management guidelines in other regions has happened differently in response to other pressures and influences. Recommendations have been made previously to require tighter survey grid intervals in the GOM (e.g., 30 m or 98 ft or tighter) over all potential areas of impact (Garrison et al. 1989; Pearson et al. 2003; Enright et al. 2006). The effectiveness of various line spacing intervals was discussed extensively in these previous BOEM studies; therefore, this study does not address magnetometer line spacing recommendations. Existing survey requirements have been developed by the predecessor agencies to BOEM in order to balance responsible site protection with economic development of the OCS, and avoid unduly restricting energy production. Archaeological survey requirements and management strategies in different regions appear to be very similar; survey line spacing is one of the primary differences.

When determining an avoidance zone around a shipwreck site, there are two primary considerations. The first is the extent of the wreck site itself. This constitutes the main component of the ship and any ancillary materials that may have become separated during the wrecking event or as the result of subsequent secondary scattering processes. The second includes bottom disturbing activities that may occur near the wreck, especially the footprint of the activity and operators' ability to adhere to the prescribed avoidance zones, given real-world operating conditions (see section 5.2 for a discussion of activities typically associated with oil and gas industry development).

6.1.2 Determining Avoidance Zones

When establishing an avoidance zone, the size of the wreck, water depth, and maximum extent of ancillary wreck components all need to be taken into account (Church et al. 2007; Enright et al. 2006). Broader avoidance zones up to 610 m (2,000 ft) are often used in deep water; in shallower depths, 300 m (1,000 ft) avoidance zones are fairly standard. This is, in part, because it has been demonstrated that debris fields associated with deep water wrecks can extend significant distances from the wreck site (Church et al. 2007). In shallower water, objects freefall a shorter distance through the water column, generally producing a denser scatter of objects. Shallow water sites are more likely to suffer from site disturbances and scattering. The more dynamic shallow water current and wave processes, coupled with anthropogenic activities (such as trawling), may contribute to significant movement of wreck components. In certain areas of the GOM, mud-flows or other mass sediment mobilization events could not only disrupt the site matrix, but relocate either an entire wreck site or individual site components a significant distance (Church et al. 2007:28).

Shipwrecks must be located before they can be avoided. Deepwater wreck sites are likely to be observed at the seafloor, with minimal sediment overburden, because the low energy deep-water environment typically contains moderate to well-consolidated bottom sediments. Unlike in deepwater, shallow water sediments of the GOM have a high silt content, and are within a higher energy environment that contributes to sediment deposition and reworking. These conditions can result in the burial of secondary site components or, in some cases, such as wooden shipwrecks, obscure the site and make it more difficult to identify through acoustic imaging and diving. The GOM's unique environment reduces the effectiveness of many strategies that are typically used in marine archaeology that rely on visual inspections.

Another problem with identifying smaller wreck components through acoustics is the use of low frequency (typically 100 kHz) sonar data. As discussed in Chapter 2, low frequency data provides coverage of a wide swath of the seafloor but with reduced detail; low frequency data is a compromise between survey detail and logistics and is often used for large-scale reconnaissance surveys conducted on the behalf of industry. The current study sites were surveyed using both low and high frequency sonar grids, and, although the low frequency grids produce adequate data for identifying many wreck sites, resolution is typically insufficient to resolve specific hull details and smaller components on the seabed. The Edgetech 120/410 kHz sonar that was used for this study is one of the side scan sonar devices most commonly used for BOEM-compliant surveys on the OCS. At 120 kHz, the sonar has an advertised across-track frequency of 8 cm (3 inches) but an along-track resolution of 5 m (16.4 ft). At 410 kHz, the sonar has an advertised across-track resolution of 2 cm (0.787 inches) but an along-track resolution of 0.6 m (2 ft) (Edgetech 2011). The use of high frequency sonar imagery over wreck sites may facilitate the identification of smaller pieces of debris, but it decreases sonar range and therefore increases the time and cost involved in conducting surveys. No matter the frequency, sonar data has its limitations. Even when a target is identified in proximity to a wreck site, without visual inspection (usually by a diver or ROV), it still may not be possible to determine if it is associated with the wreck or if it represents intrusive debris from another source. To ground truth such sonar targets and magnetic anomalies, visual inspections are typically necessary; however, the generally poor visibility in the northwestern GOM makes this a difficult, time consuming, expensive, and sometimes dangerous undertaking.

All of the wreck sites investigated as part of this study appear to be relatively consolidated. No site components that could be definitively associated with any of the study sites were identified beyond the 300-m (1,000-ft) avoidance zone surrounding each site. The largest wreck scatter was associated with Site 386, the upright and heavily damaged hull of *Heredia*; however, even this site exhibited a generally tight pattern of debris scatter. Small quantities of unidentifiable debris were observed surrounding some of the sites, but these appeared as discrete, isolated sonar and or magnetometer targets, and did not represent scattered debris fields, such as those that had been identified as part of the 2006 deepwater shipwreck study (Church et al. 2007). Attempts to locate small, isolated features evident from geophysical data at the current study sites during diving operations were unsuccessful because of poor visibility at the seafloor and time constraints.

The purpose of this project was not to develop universal avoidance zones, but to determine the nature of site formation, particularly site change over time. The scope of this study was not intended to predict the extents of debris associated with all shipwrecks located at depths of 9 to 37 m (30 to 120 ft) BSL. However, it is possible to discuss the effectiveness of avoidance zones at each of the individual sites and make recommendations for the overall use of avoidance as a mitigation strategy and management tool.

6.1.3 Evaluating Effectiveness of Avoidance Zones

As discussed in Section 5.3, seafloor impacts caused by oil and gas lease development activities regulated by BOEM can be considerable. The onus is on the operator to ensure that their contractors and subcontractors comply with these avoidance zones regulations. After operations are completed, the operator is required to submit to BOEM a diagram, or plat, that details areas of bottom disturbing activities, to ensure that no avoidances were compromised. When an avoidance zone is not adhered to, an incident of non-compliance can be issued; this may require an investigation of the target to determine historic significance. If a Section 106 consultation deems the target to be historically significant, mitigative actions may be required and, in some cases, civil penalties imposed.

Although BOEM has strategies in place to ensure that avoidance zones are properly observed, these are based primarily on self reporting and a real-time awareness by the operator of bottom disturbance locations relative to the avoidance zone. Identifying potential unreported impacts is a more difficult endeavor. In deeper water, consolidated seafloor sediments, low accretion rates, and minimal current and wave impacts create conditions in which anchor scars, mat imprints, and other seafloor disturbances can be seen on the seafloor for extended lengths of time. Seafloor scars recorded by sonar or video data can provide information about industry impacts to that area, but the data alone can't determine the age of the seafloor disturbance. Along the shallow Continental Shelf where the study took place, depending on the type of sediment, seafloor imprints may be eroded and reworked within a higher energy environment or in-filled by new or reworked sediments. In these cases, evidence of previous seafloor impacts is unlikely to be recorded and may go completely unnoticed unless obvious damage is present, and/or the source of the damage remains behind (such as a lost anchor). An example of this was observed on *Hatteras* (Site 236). An approximately 10-m (33-ft) diameter hole, believed to be of anthropogenic origin, was observed near the bow of the vessel in August of 2010, but, by the time the geophysical data was recorded over the site in February 2011, less than six months later, it had been filled in with sediment.

All of the sites within this study have active avoidance zones. No evidence identified at any of the study areas indicated that the wrecks had been impacted recently by industry activities. *J.A. Bisso* (Site 389) had the most apparent post-depositional impacts, consisting of missing superstructure and loss of the port side ancillary component noted from the 2005 data, but it is not known if these were the result of natural or anthropogenic processes. Two of the study sites contained pipelines within the 300-m (1,000-ft) avoidance zone surrounding the site and another had a pipeline installed in close proximity to the avoidance zone. Only in the case of the unknown barge at Site 15326 is it known for certain that the pipeline post-dates the shipwreck. In this case the pipeline route was designed to avoid the wreck by a distance greater than the assigned 300-m (1,000-ft) avoidance zone. No subsequent geophysical survey was conducted at this site. Divers found no evidence of obvious damage to the wreck itself; however, visibility on the site was poor and these results are not definitive. Although a number of the sites exhibited damage to the hulls or superstructure, it was typically not possible to determine if the damage occurred as part of the wrecking event or was post-depositional, through either anthropogenic or natural causes.

Netting and remnants of trawling gear were evident on a number of the study sites. Parallel scars consistent with trawling were evident on the sonar data in the vicinity of the unknown barge (Site 15326) and the unknown wrecks at Sites 15366, and 15488. Based on the study results, either trawling has had a greater impact on the study sites than oil and gas development, or the remnants of trawling are simply more evident. It should also be noted that trawl scars were not prevalent on any of the sites east of *R.W. Gallagher* (Site 433), but were evident on most of the sites west of this location. Although trawling territories and seasons may have a part in this, the higher clay content across the seafloor in the western portion of the GOM, combined with low sediment accretion and limited reworking, better preserve the impression of such scars.

Trawlers were observed during diving operations in 2010 in the High Island and Galveston Areas, but it is unknown how recent the observed trawl scars were in relation to the acquisition dates for geophysical data.

Although no clear evidence of oil and gas industry damage to any of the study sites was observed, these sites are part of a dynamic environment susceptible to both natural and anthropogenic impacts that have occurred and will continue to occur, regardless of oil and gas industry regulations. The impacts of shrimping and fishing are evident on many of the sites, through the presence of netting and line on many of the sites, and known visits by the U.S. Coast Guard and others to the World War II sites have resulted in secondary modifications and content removal. Changes will occur to offshore shipwreck sites, but the application of avoidance zones can protect shipwrecks against egregious damage.

Enright et al. (2006) argue that when designing an avoidance zone, in addition to ensuring that construction activities do not impact sites, it is also necessary to consider the proximity of infrastructure that could potentially shift or move, such as during a storm, and adversely impact the shipwreck site. While this is a valid point, it is also necessary to consider the likelihood that adjacent infrastructure would be impacted to such a degree that it would move and cause damage to a shipwreck within an avoidance zone. Based on extensive experience conducting post-hurricane geophysical inspections of pipelines and platforms in the GOM, we can make the following observations:

- Buried pipelines were most likely to shift or move when sediments became liquefied and slump during mass sediment transport events. Documented mudflow areas surrounding the modern Mississippi River delta lobe have been identified (Coleman et al. 1980) and updated maps (Hitchcock et al. 2006) showed little change to the extent of the mudflow zones over time. Pipelines outside of this mudflow zone in shallow water depths are unlikely to be subjected to mass sediment movement. Therefore, known wrecks and sites susceptible to these processes can be cross referenced with existing data to determine the likelihood of pipeline movement.

- Buried pipelines outside of mudflow areas are generally unlikely to be impacted by hurricanes unless the riser at the platform or well is damaged, causing the attached pipeline to shift (as noted by Enright et al. 2006).

- Anchors from ships and moored semisubmersible drill rigs are a common cause of damage and displacement to unburied pipelines during severe storm events. These same impacts can also result in damage to shipwrecks or potential shipwreck sites, but it is not possible to model every path along which a rogue anchor may be dragged on the seafloor.

6.1.4 Observations and Recommendations

Despite almost 40 years of survey and regulation in the GOM, there are recognized complications in current survey requirements and avoidance zone strategies. Archaeological surveys are one small requirement in the overall permitting and planning process required of operators. A BOEM-provided checklist of well plan document requirements includes over 175 different possible items, depending on the location and type of plan being submitted, not including the various state-specific requirements. Of these possible plan requirements, archaeology is mentioned only twice. Despite this relatively minor role of archaeology, in terms of plan documents and required actions, archaeological avoidance zones, like biological stipulations and safety issues, can significantly impact permit approval. It is essential that operators understand early on that the presence of an archaeological resource may require that they move their planned location in order to observe possible avoidance zones, for the protection of the resource and the safety of offshore personnel. In areas of anticipated resources, it is the operator's responsibility to ensure that the survey design provides sufficient coverage to allow for possible re-routes and movement of proposed locations. When unanticipated discoveries are made, however, avoidance zones suggested by the operator's contracting archaeologist could be revised by BOEM. Coordination between contracting and reviewing archaeologists before the official review can prevent some of this confusion. It is necessary for all archaeologists working with avoidance zone assignments to develop the zone sizes based on accurate understandings of the unique site formation processes acting on a site and the primary threats to site preservation.

The World War II-era wrecks in this study measure between 121 and 152 m (400 and 500 ft) in length, with limited amounts of discrete material identified in the survey grid. These sites have been assigned 300-m (1,000-ft) avoidance zones, which are equal in size to those assigned to wrecks measuring as small as 15 m (50-ft) in length. As suggested by Enright et al. (2006:144), polygon type avoidances would be preferable to single point and radii in cases such as these. For example, the World War II wrecks have an average length to beam ratio of over 1:6, which creates ample distance between the perimeter of the avoidance zone and the sides of the hull, but significantly less distance between the avoidance zone perimeter and the bow and stern areas. This practice has not been adopted in the GOM, likely because of the difficulty of expressing this data to operators; however, the South Carolina strategy detailed in Section 6.1.1 may be a relatively straightforward way to implement a version of polygon or oval avoidances in the GOM.

The results of this study did not provide any quantitative data to support or challenge the effectiveness of BOEM-mandated avoidance zones. Ultimately, the operator is responsible for ensuring that their activities do not impact any known or potential sites. Because impacting a site can result in expensive mitigation measures and possible civil penalties, it is in the operator's best interest to ensure that avoidance zones are adhered to during primary construction activities and also during ancillary activities conducted by subcontractors. The most effective way to avoid site damage is to place installations well outside the avoidance zones. When well locations are selected, the location should exceed the recommended avoidance zone provided by BOEM, with the understanding that successful wells, as discussed above, are accompanied by ancillary installations. If the well is installed the minimum distance specified by the avoidance, the placement of subsequent pipelines, manifolds, or platforms will be limited due to the need to maintain the avoidance zone, and risk possible inadvertent site impacts. For pipeline routes, it is necessary to ensure that the survey corridor width is adequate to account for any necessary re-routes to the pipeline that may be required if targets or anomalies are located along the proposed route. Operators and regulators should also be aware that real-world operating conditions may require anchor patterns to differ from pre-planned designs, and these may result in anchors extending beyond the extents of a survey grid designed to meet minimum requirements.

No avoidance criteria can predict or protect against all potential threats to a site. During installation, sites can be avoided by vessels, anchors, and the actions of offshore personnel, but post-installation industry presents few threats to submerged archaeological resources. The greatest industry-related threats to shipwreck sites occur in charted mudflow zones, areas in close proximity to platforms (due to associated vessel traffic and potential damage from the structure impacting the site), and drifting or dragged anchors moving across the site. The most practical way to protect sites against impacts related to future infrastructure is to ensure that the location is selected in consideration of the current avoidance zone and potential placement of subsequent installations.

6.2 Further Research

6.2.1 Historic Research

The GOM is home to some of the oldest known shipwrecks in the Western Hemisphere, but its shipwrecks are often overshadowed by those in the Atlantic and Caribbean regions. As demonstrated in this study, many wrecks in the GOM are relatively modern in origin. Modern wrecks, however, represent the unique culture of the Gulf Coast. Although the wrecks of oil and gas industry vessels and fishing boats may not excite today's archaeologist, these vessels are intrinsically tied to the culture of the region and are reflected in all parts of daily life. Because of the prevalence of museum-quality examples (such as those housed at the Louisiana State Museum and the Center for Traditional Louisiana Boatbuilding), the modern offshore wrecks were not interpreted as historically significant, but future archaeologists or historians may have questions about these industries and their place in U.S. culture. Offshore oil and gas exploration represents significant and rapid technological innovations; in fewer than sixty years, oil and gas wells moved from just out of sight of land to ultra deepwater.

The World War II-era wrecks identified as part of this study represent a time of intense innovation. Refrigerated cargo compartments and the transition from steam to oil are just some examples of changes within global shipping represented by these wrecks. Each was a unique vessel with its own story, but all ended as casualties of German incursion into U.S. waters. Their histories highlight both military and civilian responses to the attack on shipping. It cannot be overlooked that while tankers and commercial vessels were targeted by German U-boats, the smaller fishing craft and trawling vessels operating in the GOM went largely ignored.

Historical research conducted for this study was extensive; it encompassed numerous archival institutes and uncovered previously unpublished documents, such as the plans for *J.A. Bostwick*. Despite this, a wealth of information is available on each of the study sites and additional research could prove valuable. For instance, *Heredia* was built in Belfast, Ireland.

Although museums and archival collections in Belfast were contacted, an onsite trip would be necessary to properly search for information, such as plans for *Heredia*. Because of the number of study sites, this was not deemed a priority. Future studies could benefit by limiting the number of sites investigated, which would result in more extensive and in-depth research on fewer wrecks.

6.2.2 Long-term Monitoring

Today, the shipwrecks of the GOM, both the modern and the historically significant, function as artificial reefs on the seabed. As such, these wrecks are independent laboratories at which a number of different experiments can be conducted. Part of this study was to identify the processes impacting each site, but more can be done. The initial contract solicitation read, "Sediment cores will be collected at each site in order to conduct sedimentary analysis of the local area." A contract clarification was issued which stated, "At a minimum, sediment type and size analysis should be completed to address site formation and sedimentation rates. However, the offeror is encouraged to propose additional analysis of sediment cores." While sediment cores can provide information about sediment type, consolidation, plasticity, water content, etc., this data does not provide any information about sediment movement, including accretion, erosion, compaction, mass transport, and scour. To use this data for these purposes, oceanographic modeling that accounts for factors, such as currents, waves, seafloor slope, and morphology, is necessary. Even then, this data represents only a model and is not a replacement for direct empirical data specific to each site. To address sediment movement at an individual site, including deposition, scour, and reworking, empirical data at the shipwreck sites should be obtained with on-site measurement tools to accurately record current flow over and around the wreck, tidal currents, seasonal fluctuation of water chemistry, and sediment accretion rates at different places on site. Collected using current meters, erosion pins, sediment traps, or other meters, these data sources would provide more detailed information about the interrelated processes that impact the individual shipwreck site. Because of the complexity of these interrelated processes, a study of this type would require intensive investigation and long-term monitoring to obtain sufficient data. The present study, limited in time and budget, did not have the resources to do this, but did collect baseline data and develop interpretations of site conditions which can be tested and expanded upon by future studies. The present results illustrate conditions on a multitude of wrecks, any of which could form the basis of unique and meaningful research questions regarding in-depth site formation processes, either through long-term study or comparison of two sites. A multiyear intensive study that looks at a limited number of sites (two to four) or an ongoing monitoring program at a single site would be more effective in examining natural site formation processes.

6.2.3 Core Analysis

Based on the results of this study, geophysical data appears to show higher rates of sediment movement than are suggested by hurricane sediment transport modeling or disturbance events as identified in the radioisotope data. The radioisotope analysis was implemented in an attempt to determine the age of sediments at the sites and, therefore, to be a proxy for sediment accretion and erosion rates. Linear accumulation rates (LAR) could be calculated for five of the six sites. Although not a goal of the research design, results from this study indicate that the wrecking event may cause severe enough seafloor disturbance to influence the radioisotope count and therefore provide a date range for the wrecking event. The coring and sampling strategy utilized by the current study was not sufficient to fully test this hypothesis, which may be a viable study in and of itself.

6.2.4 Local Knowledge

Interviews with Cappy Bisso, C.J. Christ, and Avery Munson provided a great deal of information and also indicated that many of these wrecks have been investigated previously by multiple teams of avocational divers. Interviews also revealed that the identities of many of these wrecks have been known for some time. Some of this information has been published, but some has not. Charter captains, fishermen, and shrimp trawlers are well known as sources of information about offshore hangs, obstructions, and wreck locations. Some of these informants may be willing to share their knowledge of the shipwrecks of the GOM, and such interviews could provide invaluable data and perspective. Veterans of World War II, and especially survivors of German U-boat attacks in the GOM, could provide previously undocumented information on the war in the GOM, about which many Americans outside of the region are unaware.

6.2.5 The Future of Shipwrecks on the OCS

Shipwrecks are a non-renewable resource, and, as such, are protected by both state and federal laws. Collectively, they represent the intangible heritage of a nation, but individually they represent stories of culture, trade, travel, economics, innovation, and, ultimately, loss. Each vessel investigated in this study represents the history and culture of the GOM region. BOEM has a role in protecting the nation’s historically significant submerged cultural resources for the enjoyment and education of future generations. Avoidance zones enforced by BOEM help to protect the sites against anthropogenic or human-made impacts resulting from its permitted actions, which present the most immediate threats to the sites, as identified by the results of this study. Site formation processes identified as part of this study indicate that the sites are relatively stable, even in light of recent extreme storm events and hurricanes. While these examples of history are often out of sight, they should never be out of mind.

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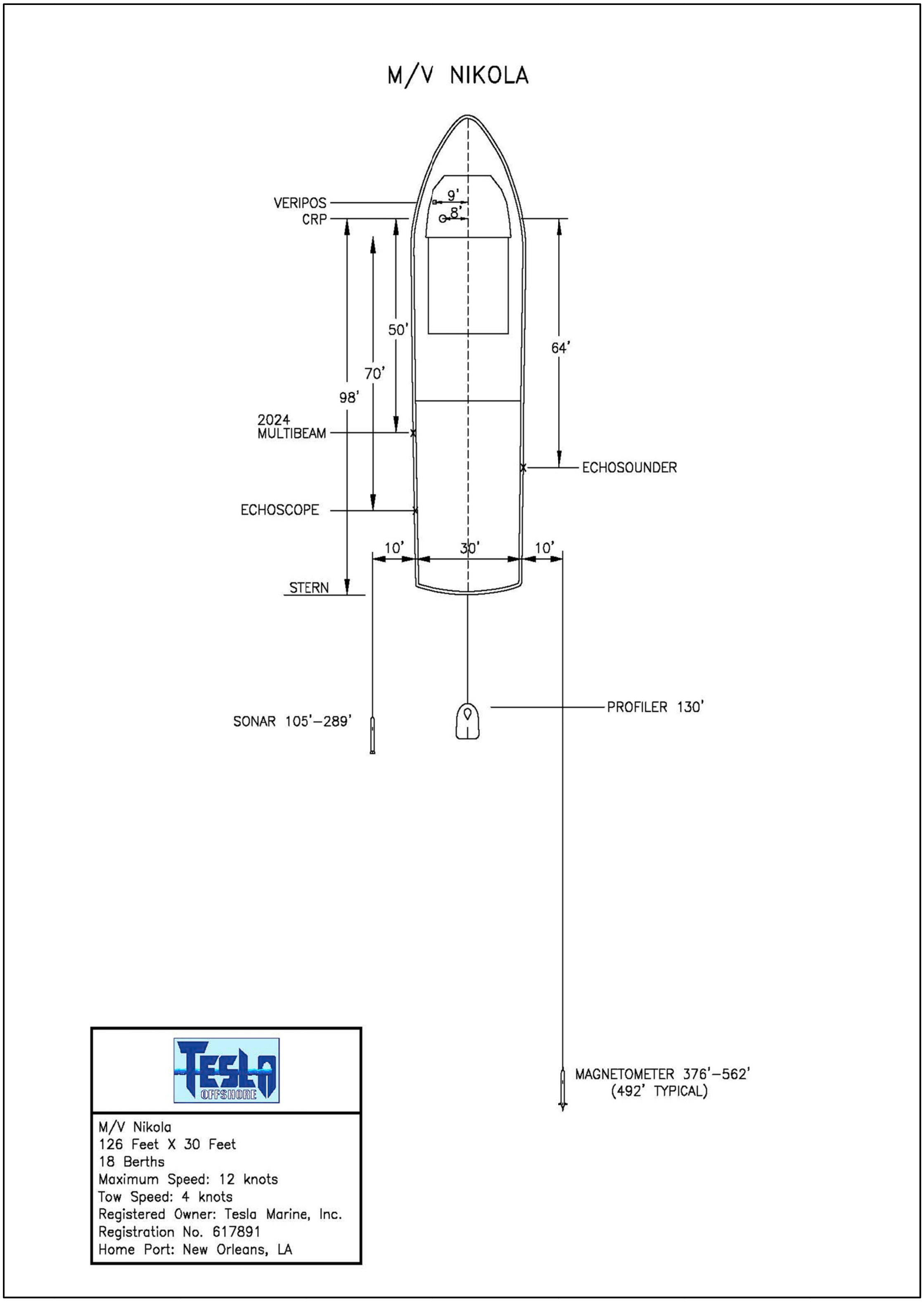
Appendix A

M/V *Nikola* Boat Diagram and Geophysical Equipment Specifications


M/V NIKOLA
VERIPOS
CRP
9'
8'
50'
70'
98'
64'
2024
MULTIBEAM
ECHOSOUNDER
ECHOSCOPE
10'
30'
10'
STERN
PROFILER 130'
SONAR 105'–289'
MAGNETOMETER 376'–562'
(492' TYPICAL)
M/V Nikola
126 Feet X 30 Feet
18 Berths
Maximum Speed: 12 knots
Tow Speed: 4 knots
Registered Owner: Tesla Marine, Inc.
Registration No. 617891
Home Port: New Orleans, LA

EZNAV NAVIGATION SYSTEM

EZNav Geophysical is a comprehensive system for the control of most types of geophysical surveys and site investigations. Used in conjunction with the microprocessor-controlled SSC 03 event controller, EZNav produces event timing independent of the PC clock or operating system timing restrictions. Like all EZNav software versions, this is designed to be as simple to use in the field as possible, while retaining the capabilities necessary to get the job done. EZNav Geophysical is the easiest tool for all types of offshore geophysical survey. With EZNav Geophysical, it is easy to use controls, configure, store and recover data connect devices, use with AutoCAD DXF files, send contact closures, run lines or go from point to point or integrate with Nobeltec ECDIS.

EZNav GEOPHYSICAL SPECIFICATIONS	
Key Features	Wizards to aid setup of key parameters such as geodetics and offsets.
	Single directory structure for all setup and data for each project, resulting in easy import and export from the ship.
	Interfaces to most industry standard sonar and magnetometer recording systems.
	Supports up to 16 channels of I/O including dual GPS, offset telemetry and USBL
	Accurate twin event generation channels, based on distance down line, distance traveled or time.
	Flexible, simple line control, or point to point navigation.
	DXF support for background graphics and line import.
	For Gulf of Mexico work, import of MMS platform, block and pipeline databases.
	Dedicated helmsman's display with line or chart graphics.
	Nobeltec ENC support for line and data export, including 3D depth data displays and radar overlays.
	User friendly tools for quality control and survey operations such as: on screen measurement, geodetic conversions, GPS and Gyro comparison.
	Comprehensive data logging options for events and all offsets.
	Post mission software to edit and/or convert data to Excel or DXF formats.

QPS QINSY SURVEY

QINSy is a hydrographic software suite capable of producing almost final results and images for real time quality control. The system makes use of a project template database which contains all survey configuration parameters pertinent to the project. QINSy supports most of the world's datums and projections, multiple units and geoidal models used world-wide. Together with real-time depth measurements, sound velocity profiles, tide levels, RTK height, etc,. QINSy calculates in real time final footprint positions and images this on the various displays. QINSy key technology is based on collection, visualization and storage of large volumes of navigation, depth and other sensor data, producing almost final result in real time.

QPS QINSy Specifications	
Key Features	Real-time calculation of footprint positions and DTM production
	Combination of ring buffers and PPS provide a proven accuracy of 1msec.
	Storage of Raw sensor data enables total replay of performed survey in-office with different settings if required
	Total Propagated Uncertainty (error budget) calculation in real-time for on-line data clipping
	Multilayer sounding grid used for online imaging of DTM, layer difference ,etc.
	Imaging of project using 2D and 3D imaging techniques together with flexible alpha numerical information displays
	2D/3D XYZ Data Cleaning (line by line method) with 3D Grid Display (including 3DS Object Support)
	All incoming and outgoing data is stamped with an UTC time label
Also Includes	Complex Tidal Reduction Models
	Digital Chart Display (ENC) Support
	Enhanced Multilayer Navigation Display
	Extensive Filter Methods (on-line and post process)
	Heading sensors
	Pipeline Detection and Eventing
	Position Navigation Systems (GNSS)
	Sound Velocity Management/Modeling with Sound Velocity Profiler Support (File input and on-line).
	Surface Navigation Systems
	Tide Gauge Support (File input and on-line)
	USBL and LBL Support
	X-Section View and Profile Display

VERIPOS LD2 INTEGRATED MOBILE POSITIONING UNIT/VERIPOS ULTRA POSITIONING SERVICE

The Veripos Ultra service is a precise positioning service designed to deliver decimeter level position accuracy, globally. The service is based around Precise Point Positioning (PPP)- a technique where all GPS system errors are removed or minimized by direct calculation, precise modelling or estimation. The positioning service is received through the LD2 Integrated Mobile Positioning Unit which uses a compact high-gain omni-direction antenna and works with an L-Band input within the range 1225 to 1559 MHz.

Veripos Specifications		
LD2 Integrated Mobile Positioning Unit Features	Input Voltage:	90v to 265v AC
	Consumption:	20W
	Onboard PC/104 Processor:	300 MHz Geodeprocessor, 64 Mb SDRAM, 64Mb
		Linux Operating System
	Veripos L-band	Frequency input 1525 to 1559MHz
		Data rates 600, 1200, 2400, 4800 baud
	Receiver:	Magellan 3011 HF/MF dual channel receiver
Ultra Positioning Service	Process type:	Precise Point Positioning
	Orbit and clock corrections:	JPL
	Observations used:	L1/L2 carrier phase
	Availability:	worldwide
	HP satellites:	Inmarsat 25E, 98W, 109E, AORE, AORW, IOR
	LP satellites:	Inmarsat POR
	Data format:	Proprietary
	Typical correction update	30 seconds
	Typical latency:	2 seconds
	Normal horizontal accuracy:	10cm (95%)
	Normal vertical accuracy:	20cm (95%)
	Co-ordinate reference frame:	ITRF05

CODA DA ACQUISITION SYSTEM

The Coda DA is a digital data acquisition system that can accept input from sidescan sonar, subbottom profiler, boomer or archived analogue data. CODA systems are designed to meet Minerals Management Service requirements for digital data recording in a standardized format for both seismic and sonar systems. This system also reduces processing and reporting time.

CODA DA TECHNICAL SPECIFICATIONS					
System	**Triggers**	**Channels**	**Serial**	**Interfaces**	**Additional**
DA	1	2	2	SSS or SBP	19" rack-
INPUTS & OUTPUTS					
Analogue inputs	Adjustable input-range analogue inputs compatible with all analogue sidescan sonar outputs and sub-bottom profilers including direct hydrophone connection. Improved low voltage performance.				
Trigger inputs & outputs	Standard TTL input & output. Up to 2 independent/asynchronous triggers.				
Navigation & fix data	Multiple serial ports for NMEA compatible navigation data and other proprietary format navigation, fix and annotation strings.				
Network	2 Ethernet interfaces (1 x 1Gb, 1 x 10/100Mb) for data transfer and interface to digital sonars.				
DATA RECORDING					
Recording devices	Internal hard disk, external hard disk (via USB 2.0 or IEEE 1394), DVD RAM and remote network devices. Automatic continuous recording switch-over. Raw or processed data recording and copying. Post-acquisition data back-up to DVD-R and CD-R disks.				
Recording formats	CODA, SEGY, XTF, QMIPS				
DISPLAY MODES					
Sonar	Vertical and horizontal scrolling waterfall, A-scan/oscilloscope, dual or single channel.				
Sub-bottom	User-defined seismic zoom windows, left/right, up/down, scroll directions.				
Navigation	On screen real-time nav. updates, track plot, corrected nav, navigation smoothing, speed correction etc.				
PROCESSING					
Sidescan	Real-time sonar gain correction and colour palette display enhancement facilities, cross-track smoothing, speed correction. Extensive real-time and post-processing modules including Pipeline Inspection, Mosaicing and GeoKit interpretation tools.				

Sub-bottom	Extensive real-time signal processing and gain correction for sub-bottom profiler together with display enhancement facilities. User-defined depth and time based filters and gain controls. Stacking, auto seabed tracking, speed correction. Extensive post processing modules for reprocessing and interpretation. Supports heave sensor input for real-time heave correction.
PHYSICAL	
Description	19" rack-mountable system - 1U, slim-line ruggedized industrial
Dimensions	17" wide x 1.75" high x 14" deep (19" wide x 1.75" x 14" deep
Power	100-240 Volts AC
Processor	Pentium M 1.8GHz or better
Memory	512Mb as standard
Hard Disk	300 gigabyte
Display	Compatible with single or dual screens (optional)

EDGETECH 4200-FS (SP) 100/ 410 KHZ SIDE SCAN SONAR

The EdgeTech 4200 Series Side Scan Sonar System provides a unique advantage over conventional dual frequency side scan systems by combining EdgeTech's Full Spectrum and MulitPulse technologies into one unit. The 4200 Series uses EdgeTech's Full-Spectrum chirp technology to deliver wide band, high energy transmit pulses, coupled with high-resolution and superb signal to noise ratio echo data. The 4200 Series sets new standards in the industry for seafloor mapping by integrating key performance and safety features, the dual mode feature along with EdgeTech's Secondary Recovery System, Standard Heading, Pitch & Roll, optional Depth, Magnetometer interface and Acoustic responder for accurate towing positioning

4200-SP SPECIFICATIONS	
Frequency (dual simultaneous)	100 / 400 kHz
Horizontal Beam Width	100 kHz – 1.5°, 400 kHz – 0.4°
Optional CW Pulse Short	100 kHz – 100us, 410 kHz – 30us
Operating Range (max)	100 kHz: 500 meters/side; 400 kHz: 120 meters/side
Towing Speed (max safe)	12 knots
Towing Speed *	4.8 knots
Towfish Material	Stainless Steel
Towfish Diameter	11.4 cm. (4.5 inches)
Towfish Length	125.6 cm. (49.5 inches)
Weight (in air)	30 kg (66 lbs.)
Weight (in sea water)	18 kg (40 lbs.)
Operating Depth (max)	1000 m
Tow Cable Type	Coaxial
Options	Pressure, Temperature, Magnetometer, USBL Acoustic Tracking System, Acoustic Responder, Depressor and Custom Sensors

* Meets NOAA Shallow Water Survey Specification- Min 3 pings on a 1-meter target at 100 m range.

EDGETECH 3200-XS CHIRP SUB-BOTTOM PROFILING SYSTEM

The SB-216S tow fish operates from 2-16 kHz and utilizes special design transmitters with low Q wideband characteristics, best suited for “chirp” transmissions. At least two hydrophones are installed in the tow vehicle to reduce acoustic scattering from the sides. This results in a narrower across track beam pattern. Preserved in the output of the Full Spectrum chirp processing is the signal phase. This phase information is also recorded to the mass storage device. This phase information is required for sub-surface sediment classification. Phase is used to determine if the impedance is increasing or decreasing. The system separates the Full Spectrum signal processing and the signal amplifier out into separate housings. This lets a user interface to his own or a third party topside display processors such as the CODA 50, for command, control, display, printing and data storage.

SPECIFICATIONS	
Towfish model	SB-216S
Frequency range	2 - 16 kHz
Pulses (user selected)	2-16 kHz, 2-12 kHz, 2-10 kHz
Vertical resolution (depends on pulse selected)	6 - 10 cm
Penetration (typical) in coarse calcareous sand(meters) in clay (meters)	6
Beam width	17° - 24°
Size (cm)	105L x 67W x 40H
Weight	76 kg
Calibration	Each system is calibrated for reflection
Cable requirements	3 shielded twisted pairs (5 used)
Maximum Towfish Operating Depth	300 m (1,000 ft)
Optimum tow height	3 to 5 m above seafloor
Tow Speed	3-4 knots optimal, 7 knots maximum safe
Options	Integrated depth sensor, 4 kW amplifier, USBL acoustic tracking system

R2 SONIC BROADBAND MULTIBEAM ECHOSOUNDER

The Sonic 2024 Broadband Multibeam Echosounder system networks the modules, and embeds the processor/controller in the sonar head. With a wide operating frequency band, the user has unparalleled flexibility in trading off resolution and range and controlling interference from other active acoustic systems. Commands are transmitted through an Ethernet interface to the Sonar Interface Module which supplies power to the sonar heads, synchronizes multiple heads, time tags sensor data, and relays data to the applications workstation and commands to the sonar head. Features include: 60 kHz wideband signal processing, 150-m range, embedded processor/controller.

System Specifications	
Frequency	200 kHz – 400 kHz
Beamwidth, across track	0.5°
Beamwidth, along track	1.0°
Number of beams	256
Swath sector	Up to 160°
Max Range setting	500 m
Pulse Length	10 µs – 1ms
Pulse Type	Shaped CW
Depth rating	100 m
Operating Temperature	0° C to 40° C
Storage Temperature	-30° C to 55° C
Electrical Interface	
Mains	90-260 VAC, 45-65 Hz
Power Consumption	< 50 W
Uplink/Downlink	10/100/1000 Base-T Ethernet
Data Interface	10/100/1000 Base-T Ethernet
Sync In, Sync Out	TTL
GPS	1PPS, RS-232
Auxiliary Sensors	RS-232
Deck Cable Length	15 m
Mechanical	
Receiver Dim (LWD)	480 x 109 x 190 mm
Receiver Mass	12 kg
Projector Dim (LWD)	273 x 108 x 86 mm
Projector Mass	6 kg
Sonar Interface	280 x 170 x 60 mm
Module Dim (LWH) Sonar	3 kg

ODOM ECHOTRAC DF MK III DIGITAL PRECISION DUAL FREQUENCY ECHO SOUNDER &TSS CMS25 MOTION SENSOR

The MK III Echotrac is recorded at 24/200 kHz and interfaced into a TSS Compact Motion Sensor. The CMS25 allows for real-time heave compensation of the sounder data and can provide heave data in analogue and digital format.

ECHO SOUNDER SPECIFICATIONS	
AC power	110 or 220 VAC
Number of channels	2
Agile Frequency Board	Broadband
Channel 1:Broadband High Frequency Board	100 kHz to 1MHz
Channel 1:Broadband Low Frequency Board	3-50 kHz
Channel 2:Broadband Low Frequency Board	3-50 kHz
Channel 2:Broadband High Frequency Board	100 kHz to 1 MHz

TSS CMS25 MOTION SENSOR	
Accuracy	Heave: ±5cm or 5% whichever is greater Roll & Pitch for ±30° Vessel Motion: +0.25°
Range	Heave: ±10cm Pitch and Roll: ±30°
Resolution	1cm; Digital - 0.01°; Analogue - 12 bit
Bandwidth	0.05 to > 10Hz 0 to > 10 Hz
Update rate	Digital - Up to 200Hz Analogue - Up to 500Hz
Power	10 - 36V dc, <6.5W
Velocity input packet formats	NMEA 0183 (requires VTG & GLL or GGA); TSIP: Doppler Speed Log
Heading input packet formats	NMEA 0183; SGB; Robertson, Sperry LR40/60
Depth rating	3000m standard Up to 6000m optional
Tilt	Operating +45° any plane; Transit - No limit
Yaw immunity	10° per second with 30° roll & pitch Available outputs formats Standard TSS and other manufacturer's data strings in addition to a user configurable menu can be viewed and selected with DMSView for Windows.

SBE 19PLUS V2 SEACAT PROFILER CONDUCTIVITY, TEMPERATURE AND PRESSURE RECORDER WITH RS-232 INTERFACE

The SBE 19*plus* V2 SEACAT Profiler is designed to measure conductivity, temperature, and pressure in marine or freshwater environments at depths up to 7,000 m (22,900 ft).

General Specifications	
Measurement Range	
Conductivity	0 to 7 Siemens/meter (0-70 mmho/cm)
Temperature	-5 to +35° C
Pressure	0 to full scale – 2000/3000/6000/10,000/15,000 psia
A/D inputs	0 to +5 volts
Initial Accuracy	
Conductivity	0.0003 S/m (0.003 mmho/cm)
Temperature	0.001° C
Pressure	0.015% of full scale
A/D inputs	0.005 volts
Typical Stability	
Conductivity	0.00004 S/m (0.0004 mmho/cm)
Temperature	0.0002° C
Pressure	0.0015% of full scale
A/D inputs	0.001 volts
Resolution (at 24 Hz)	
Conductivity	0.00004 S/m (0.0004 mmho/cm)
Temperature	0.0002° C
Pressure	0.001% of full scale
A/D inputs	0.0012 volts
Time Response (1)	
Conductivity	0.065 second
Temperature	0.065 second
Pressure	0.015 second
A/D inputs	5.5 Hz 2-pole Butterworth Low Pass Filter
Master Clock Error Contribution (2)	
Conductivity	0.00005 S/m
Temperature	0.00016° C
Pressure	0.3 dbar (for 6800m [10,000 psia] pressure sensor)

SEA SPY OVERHAUSER MAGNETOMETER

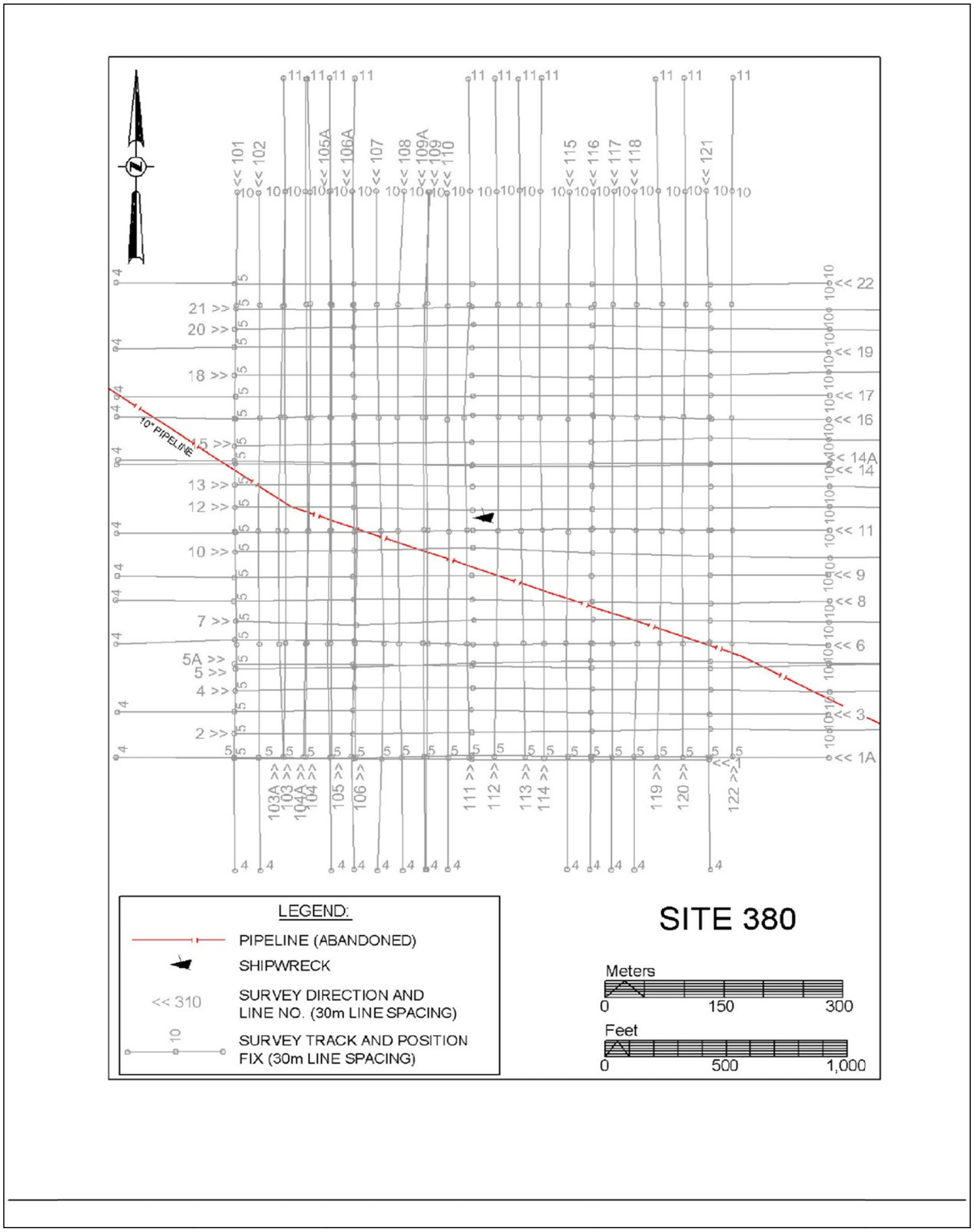
The Marine Magnetics SeaSPY is the latest and most accurate magnetometer on the market today. This system addresses the limitations associated with other marine magnetometers; such as orientation restrictions, sensor realignment, time and temperature drift and poor absolute accuracy. The SeaSPY magnetometer measures the ambient magnetic field using a specialized branch of nuclear Magnetic Resonance technology, applied specifically to hydrogen nuclei. The SeaSPY sensor is entirely omni directional. The amount of signal produced by the sensor is completely independent of magnetic field direction and optimized to work around the world. No matter what the magnetic field strength is, the SeaSPY sensor will continue to provide a strong signal and accurate data.

SEA SPY SPECIFICATIONS	
Operating Zones	No Restrictions (SeaSPY will perform exactly according to spec throughout the entire range)
Absolute Accuracy	0.1nT
Sensor Sensitivity	0.01nT
Counter Sensitivity	0.001nT
Resolution	0.001nT
Dead Zone	NONE
Heading Error	NONE
Temperature Drift	NONE
Power Consumption	1W standby, 3W maximum
Timebase Stability	1ppm, -45°C to +60°C
Range	18,000nT to 120,000nT
Gadient Tolerance	Over 10,000nT/m
Sampling Range	4Hz-0.1Hz
External Trigger	By RS-232
Communications	Rs-232, 9600bps
Power Supply	15VDC or 100-240VAC
Operating Temperature	-45°C to +60°C
Operating Depth	300 m
Temperature Sensor	-45°C to +60°C, 0.1 step

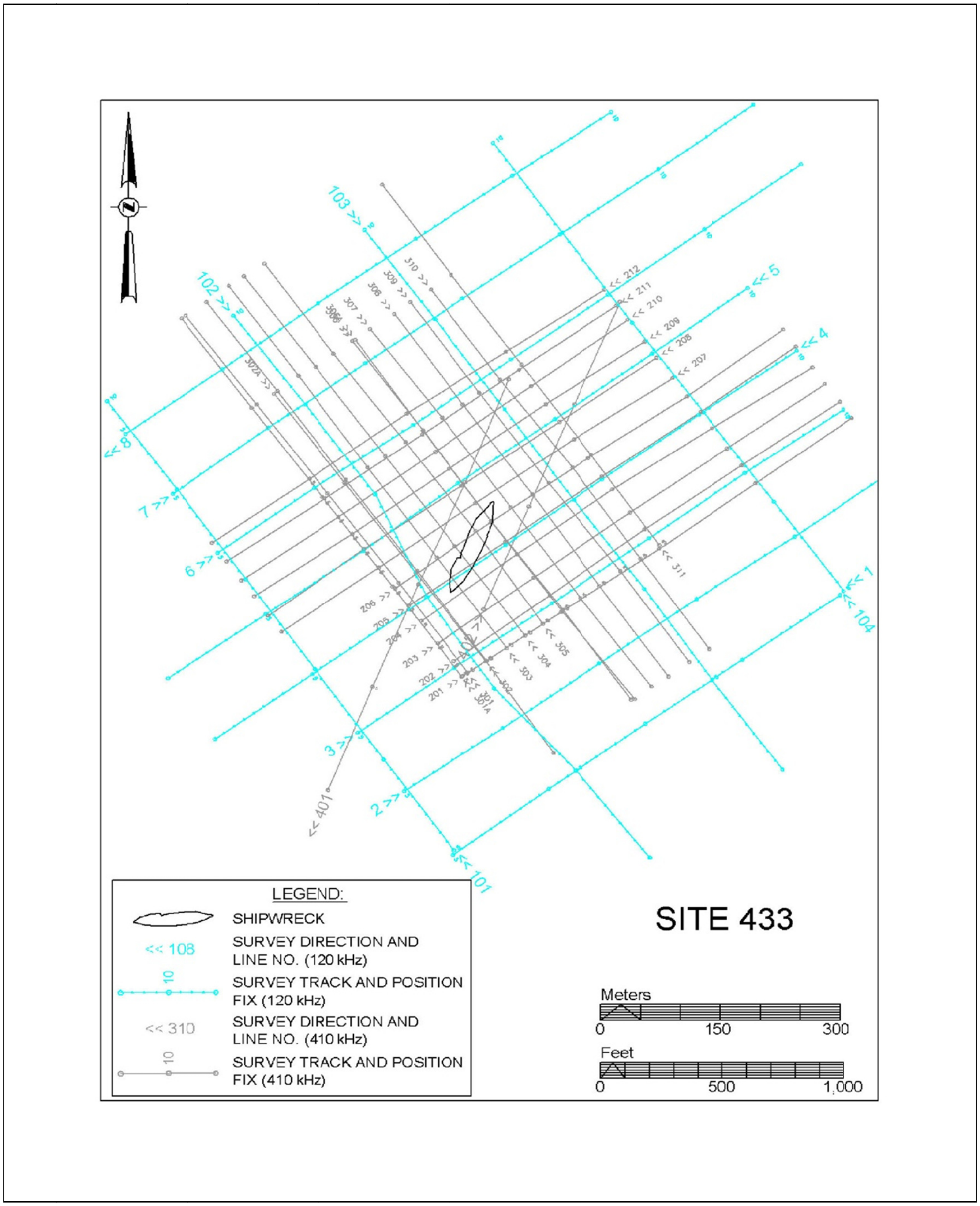
Towfish	
Length	124 cm (49 inches)
Diameter	12.7 cm (5 inches
Weight in air	16 kg (35 lbs)
Weight in water	2 kg (4.4 lbs)

Appendix B

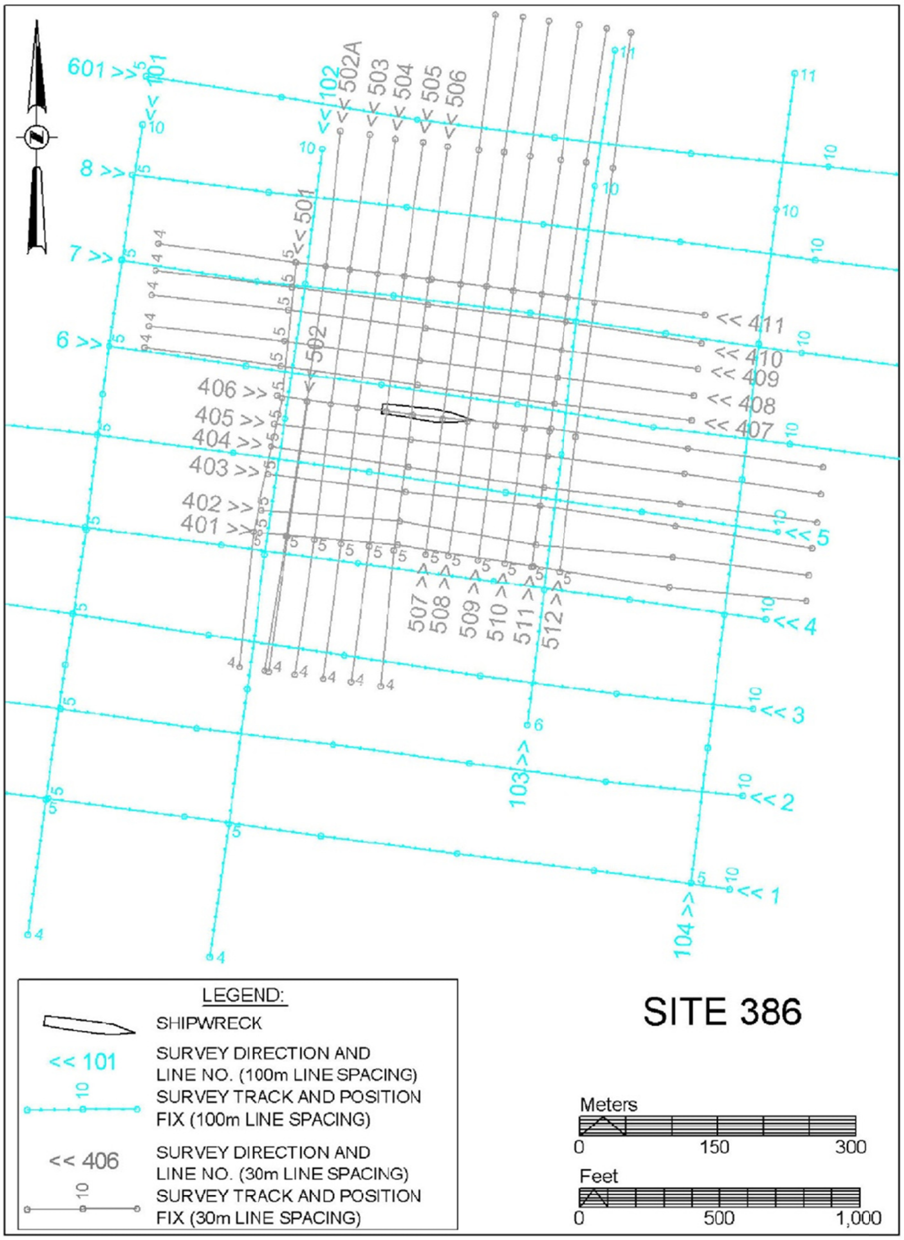
Geophysical Survey Post-Plots



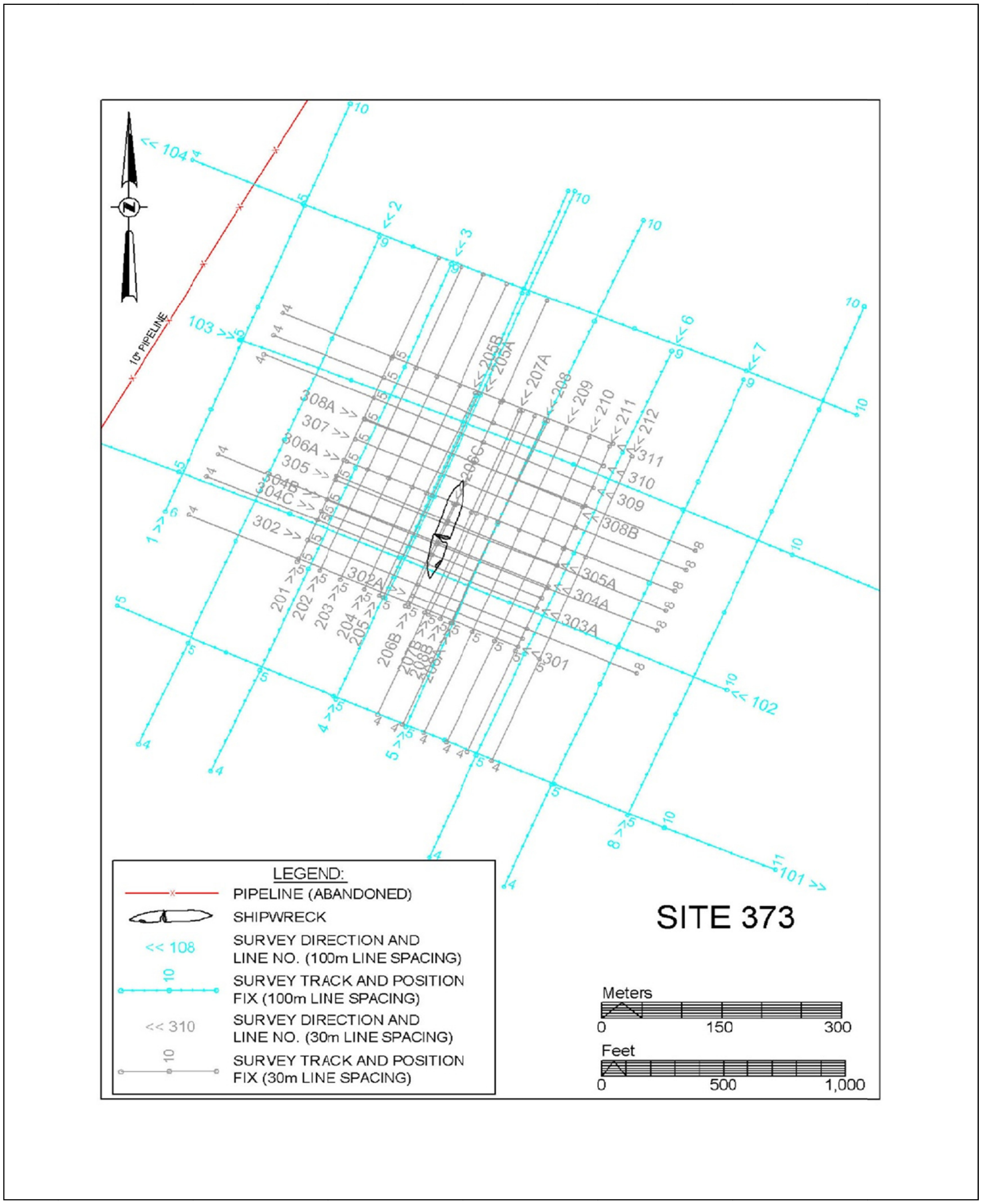
Map B-1. Survey post-plot. Site 380, reported wooden wreck, South Pelto area.



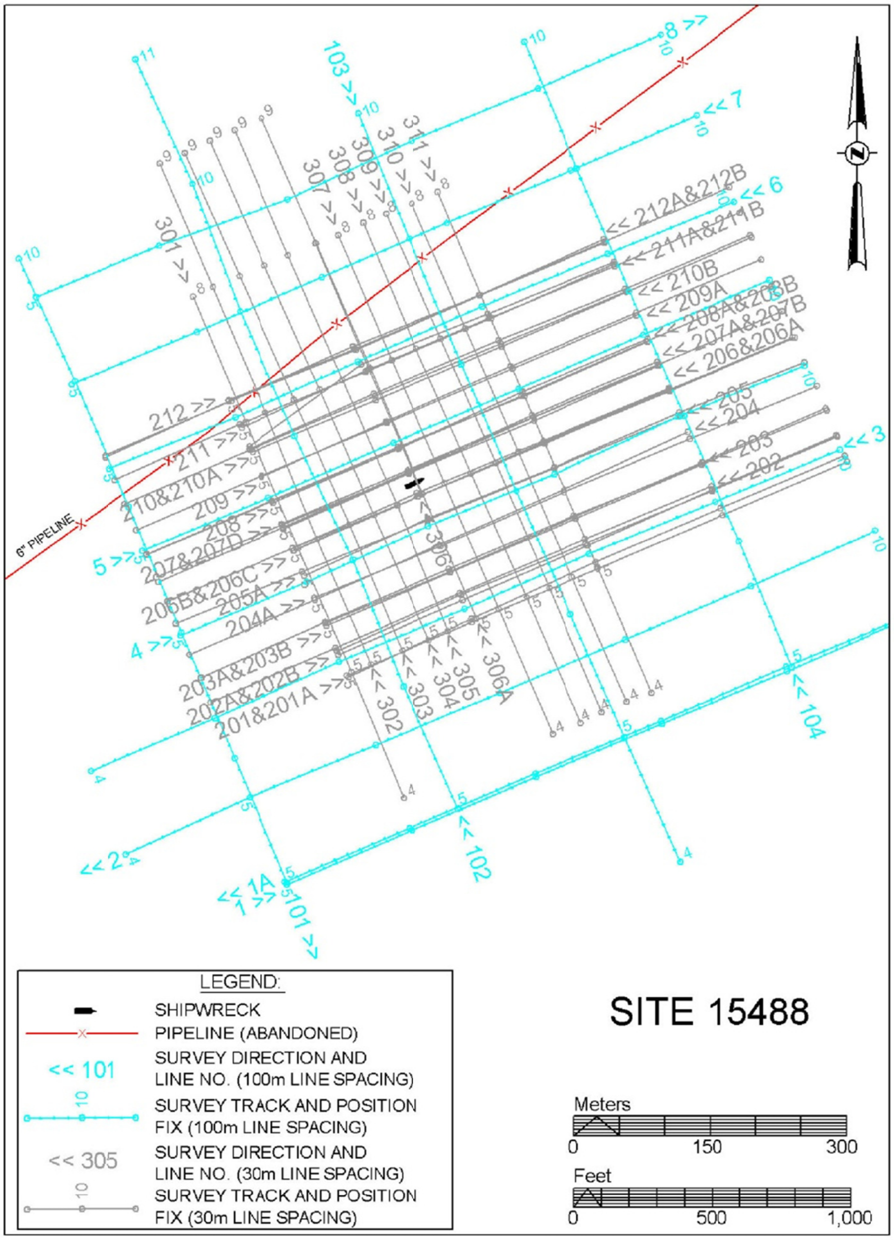
Map B-2. Survey post-plot. Site 433, probable *R.W. Gallagher,* Ship Shoal area.



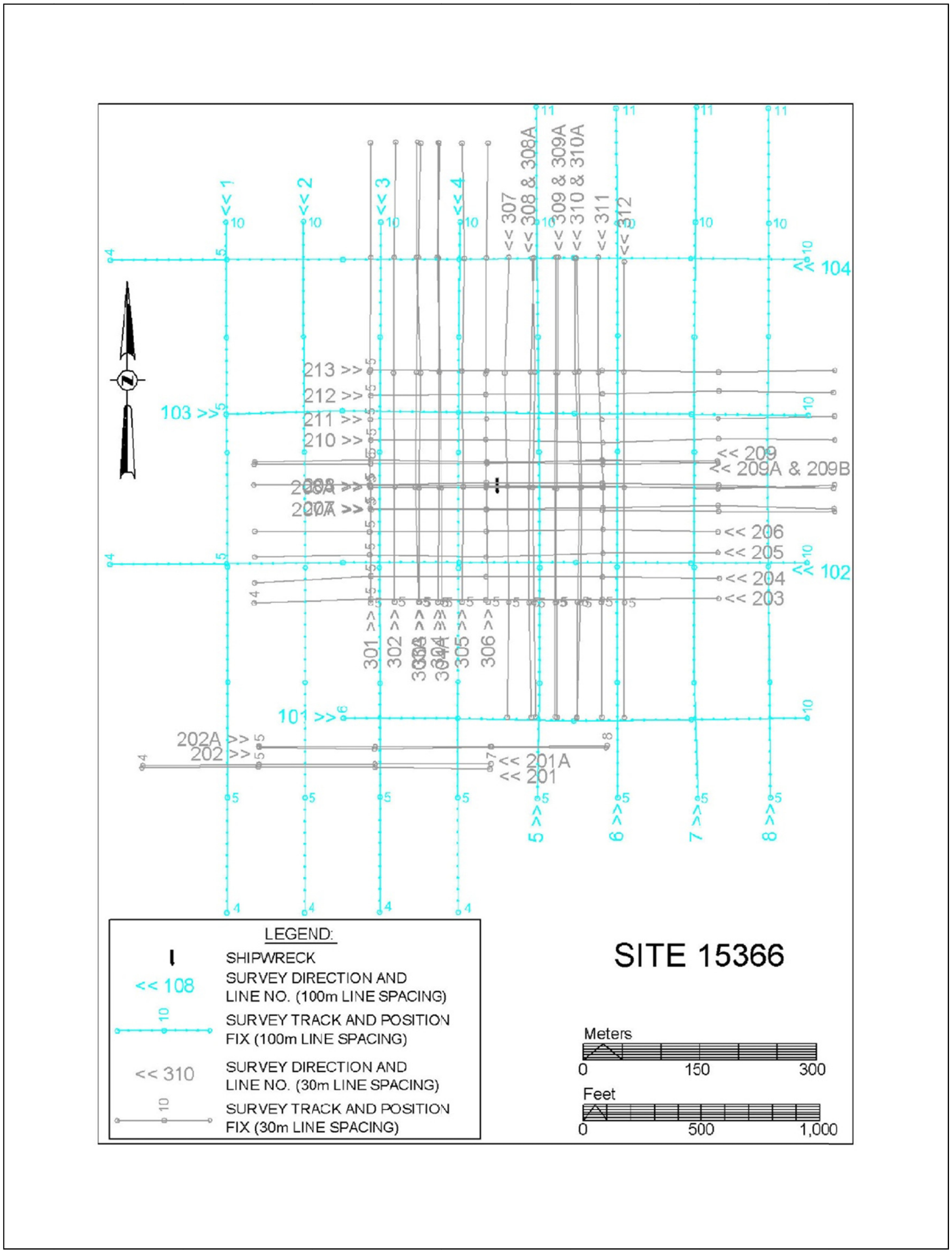
Map B-3. Survey post-plot. Site 386, probable *Heredia*, Ship Shoal area.



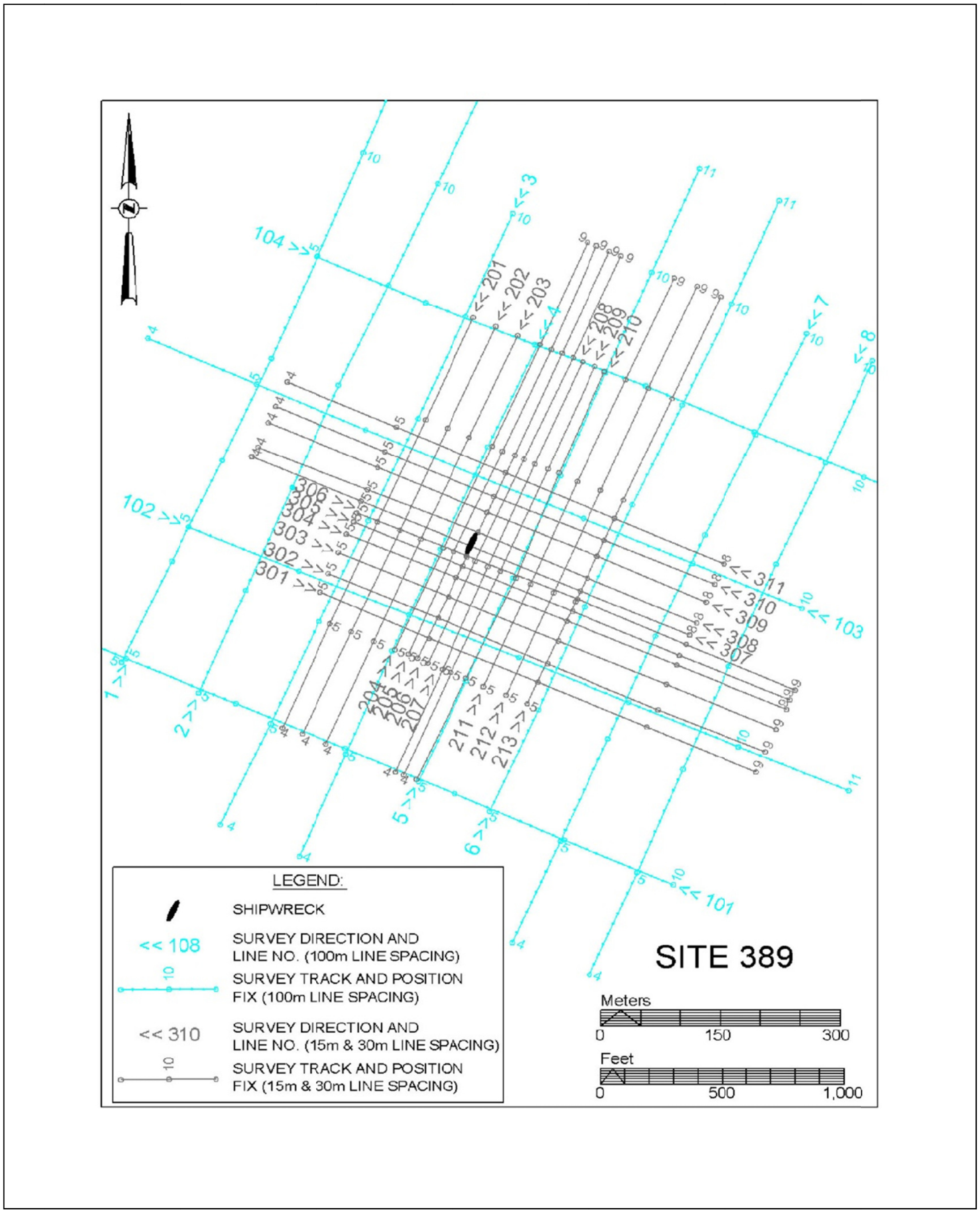
Map B-4. Survey post-plot. Site 373, probable *Cities Service Toledo*, Ship Shoal area.



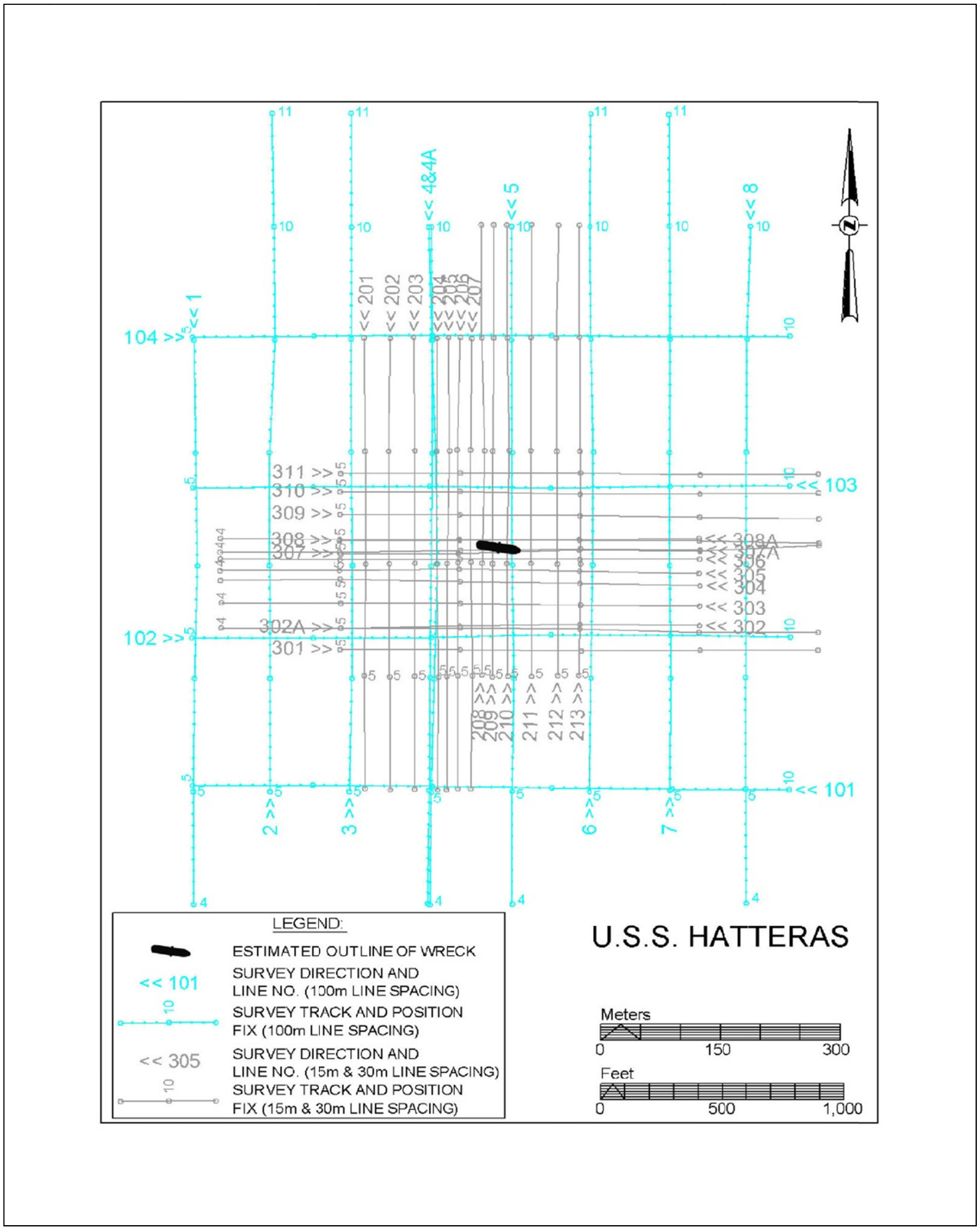
Map B-5. Survey post-plot. Site 15488, unidentified wreck, High Island area.



Map B-6. Survey post-plot. Site 15366, unidentified wreck, Galveston, Texas, area.



Map B-7. Survey post-plot, Site 389, probable *J.A. Bisso*, South Timbalier area.



Map B-8. Survey post-plot. Site 369, USS *Hatteras*, Galveston area.

Appendix C

Tabulated Magnetic Anomalies

SITE 380 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT (FT)	SIG-NATURE	nT	DURA-TION (FT.)
1	UNKNOWN	1A	7.4	13	D	14	107
2	UNKNOWN	1A	6.7	13	-	5	38
3	PIPELINE	3	10.2	15	D	194	596
4	UNKNOWN	4	4.7	11	D	9	80
5	UNKNOWN	5A	5.3	11	D	6	75
6	PIPELINE	5A	9.7	11	D	372	346
7	PIPELINE	6	9.1	14	D	204	1110
8	UNKNOWN	6	7.7	13	D	15	109
9	PIPELINE	7	8.7	12	D	961	848
10	UNKNOWN	8	9.9	12	+	6	74
11	UNKNOWN	8	8.8	11	D	53	293
12	PIPELINE	8	7.7	11	D	315	511
13	PIPELINE	10	6.6	10	D	830	912
14	UNKNOWN	10	8	10	D	17	91
15	UNKNOWN	10	9.9	12	-	9	76
16	UNKNOWN	11	7.1	10	D	37	237
17	PIPELINE	11	5.8	11	D	2907	384
18	PIPELINE	12	5.8	9	D	3453	484
19	UNKNOWN	12	6.9	10	-	9	61
20	UNKNOWN	12	7.2	10	D	252	137
21	UNKNOWN	12	8.5	10	-	4	68
22	PIPELINE	15	4.9	9	C	187	347
23	UNKNOWN	16	6.4	9	D	40	105
24	PIPELINE	101	7.5	6	+	312	324
25	PIPELINE	102	7.4	10	+	183	165
26	UNKNOWN	102	7.1	10	+	0	38
27	PIPELINE	103	7.2	7	-	681	301
28	PIPELINE	104	7.1	7	D	2087	506
29	UNKNOWN	104	9.7	6	-	10	50
30	PIPELINE	105	7	10	-	1722	514
31	PIPELINE	106	6.9	5	-	597	364
32	UNKNOWN	107	10.5	10	D	10	150
33	PIPELINE	107	6.8	13	D	161	444

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT (FT)	SIG-NATURE	nT	DURA-TION (FT.)
34	PIPELINE	108	6.7	14	+	190	313
35	UNKNOWN	108	5.4	15	-	4	59
36	PIPELINE	109	6.7	16	-	211	220
37	PIPELINE	110	6.7	11	+	164	195
38	UNKNOWN	110	5	12	+	15	75
39	PIPELINE	111	6.7	8	+	304	315
40	UNKNOWN	111	7.1	9	C	89	154
41	UNKNOWN	112	4.7	13	D	7	98
42	UNKNOWN	112	6.3	10	D	20	92
43	PIPELINE	112	6.6	10	+	256	169
44	UNKNOWN	112	7.2	9	D	6	57
45	PIPELINE	113	6.5	16	D	66	296
46	UNKNOWN	114	6	10	-	19	80
47	PIPELINE	114	6.4	11	-	314	194
48	UNKNOWN	114	8.4	8	D	37	132
49	UNKNOWN	115	10.3	10	D	10	64
50	PIPELINE	115	6.3	15	D	226	316
51	UNKNOWN	116	8.9	11	-	6	67
52	PIPELINE	116	6.3	14	+	282	322
53	UNKNOWN	117	6.9	16	-	5	72
54	PIPELINE	117	6.2	17	+	139	242
55	UNKNOWN	118	8.1	11	D	98	183
56	PIPELINE	118	6.2	12	D	78	437
57	PIPELINE	119	6.2	11	-	1073	400
58	UNKNOWN	119	8.4	7	-	2	31
59	UNKNOWN	119	8.7	7	D	5	44
60	PIPELINE	120	6.1	9	-	414	278
61	UNKNOWN	120	6.4	8	D	65	46
62	UNKNOWN	120	8.5	5	-	8	61
63	PIPELINE	121	6	13	-	199	358
64	PIPELINE	122	5.9	9	-	287	256
65	UNKNOWN	122	9.5	9	D	33	112

Shaded cells represent anomalies located in close proximity to the reported location of #380.

SITE 433 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DUR-ATION (FT.)
1	UNKNOWN	4	6.3	45	+	14	34
2	UNKNOWN	5	9.4	18	-	315	205
3	UNKNOWN	6	6	16	D	8	58
4	UNKNOWN	7	8.8	9	+	3	107
5	UNKNOWN	8	7.6	13	+	3	33
6	UNKNOWN	104	8	11	D	28	148
7	UNKNOWN	104	9.6	9	+	9	49
8	UNKNOWN	201	7.7	11	+	10	64
9	UNKNOWN	202	5.8	11	+	48	24
10	UNKNOWN	202	7.8	16	-	51	111
11	UNKNOWN	208	8.3	16	D	153	153
12	UNKNOWN	209	8.2	14	-	157	220
13	UNKNOWN	210	8.1	12	+	10	99
14	UNKNOWN	212	5.3	11	-	5	38
15	UNKNOWN	212	4.8	12	D	3	52
16	UNKNOWN	302	7.4	8	D	27	49
17	UNKNOWN	304	9	36	-	9	104
18	WRECK	1	7.6	11	-	16	1607
19	WRECK	2	7.3	9	D	41	2225
20	WRECK	3	6.3	4	D	260	2008
21	WRECK	4	7.1	36	D	12761	1619
22	WRECK	5	7.2	13	D	504	1742
23	WRECK	6	7.5	12	D	80	2107
24	WRECK	7	7.4	11	+	22	937
25	WRECK	103	6.9	12	D	221	1847
26	WRECK	201	5.3	11	+	199	1556
27	WRECK	202	5.3	16	+	354	1605
28	WRECK	203	5.4	15	+	1152	1687
29	WRECK	204	5.4	30	D	25138	1554
30	WRECK	205	5.5	33	D	63512	1453
31	WRECK	206	5.8	34	D	11426	1247
32	WRECK	207	5.9	40	-	1045	1333
33	WRECK	208	6.2	18	D	458	1434
34	WRECK	209	6.3	19	-	232	1268
35	WRECK	210	5.3	10	D	124	1323

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DUR-ATION (FT.)
36	WRECK	211	6.4	19	-	76	1253
37	WRECK	212	6.5	12	-	43	1128
38	WRECK	301	5.6	6	D	949	1617
39	WRECK	302	5.9	9	D	9402	1237
40	WRECK	303	5.8	34	D	25628	1435
41	WRECK	304	6	37	D	9816	1078
42	WRECK	305	5.8	36	C	10402	1200
43	WRECK	306	5.8	41	C	6456	1020
44	WRECK	307	6.1	41	-	6284	1364
45	WRECK	308	6.3	14	D	641	1337
46	WRECK	309	5.6	16	D	273	1334
47	WRECK	310	6.5	16	D	123	1378
48	WRECK	311	5.4	11	D	61	1533
49	UNKNOWN	101	4.7	9	D	64	65
50	WRECK	101	6.8	11	-	30	1090
51	WRECK	102	6.8	9	D	1207	1693
52	WRECK	401	6.3	11	-	1173	1729
53	UNKNOWN	402	4.9	15	+	12	30
54	WRECK	402	6.7	13	-	1706	1469

SITE 386 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
1	UNKNOWN	3	4.7	17	+	11	157
2	UNKNOWN	4	9.4	17	+	5	39
3	UNKNOWN	6	5.3	10	D	26	79
4	UNKNOWN	6	6.7	10	-	27	37
5	UNKNOWN	6	7.4	16	-	94	23
6	UNKNOWN	6	7.6	18	+	121	47
7	UNKNOWN	7	4.4	15	-	15	15
8	UNKNOWN	7	4.6	12	C	8	48
9	UNKNOWN	7	5.3	13	-	62	145
10	UNKNOWN	7	5.4	12	-	9	71
11	UNKNOWN	8	8.7	11	D	19	77
12	UNKNOWN	403	6.8	13	+	43	23
13	UNKNOWN	404	5.6	15	+	25	66
14	UNKNOWN	404	5.7	14	+	8	23
15	UNKNOWN	407	8.9	5	D	14	41
16	UNKNOWN	407	6.3	12	-	29	29
17	UNKNOWN	408	5.9	13	+	22	60
18	UNKNOWN	409	6	8	-	13	29
19	UNKNOWN	504	8.1	14	-	10	84
20	UNKNOWN	504	5.5	15	-	215	40
21	UNKNOWN	601	7	16	-	3	93
22	UNKNOWN	601	10.4	18	D	12	69
23	WRECK	4	7.6	18	D	25	1387
24	WRECK	5	7.6	17	D	4778	1311
25	WRECK	6	7.7	9	C	1335	1435
26	WRECK	7	8.1	5	D	47130	1505
27	WRECK	401	6.6	10	D	30	1043
28	WRECK	402	6.5	13	+	53	983
29	WRECK	403	6.5	12	+	134	1312
30	WRECK	404	6.4	9	D	346	1295
31	WRECK	405	6.2	28	+	2797	1567
32	WRECK	406	6.2	32	C	6714	1587
33	WRECK	407	6.5	9	-	355	1043
34	WRECK	408	6.5	13	-	141	1206
35	WRECK	409	6.7	9	D	60	1149

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
36	WRECK	410	6.7	14	+	29	1057
37	WRECK	411	6.7	14	D	19	1385
38	WRECK	501	5.8	10	-	24	777
39	WRECK	502A	5.8	14	-	45	790
40	WRECK	503	5.8	13	-	88	756
41	WRECK	504	5.9	18	-	267	711
42	WRECK	505	6	32	-	3221	806
43	WRECK	506	6	35	D	11856	734
44	WRECK	507	5.9	28	D	15327	1170
45	WRECK	508	6	29	D	11907	1213
46	WRECK	509	6.1	29	D	1943	1164
47	WRECK	510	6.1	11	-	205	1343
48	WRECK	511	6.2	15	-	74	1228
49	WRECK	512	6.3	7	-	35	979
50	UNKNOWN	101	8.8	14	-	9	145
51	UNKNOWN	101	6.3	15	D	17	124
52	UNKNOWN	102	8.6	16	+	9	47
53	WRECK	102	7.9	16	-	25	952
54	UNKNOWN	103	5.5	10	D	5	59
55	WRECK	103	8.4	11	-	62	1000
56	UNKNOWN	104	10.5	10	D	11	84

SITE 373 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
1	UNKNOWN	2	7.7	11	D	13	67
2	UNKNOWN	3	7	18	-	30	139
3	UNKNOWN	4	5.4	16	+	16	42
4	UNKNOWN	4	6.7	16	+	154	44
5	UNKNOWN	4	6.9	15	+	30	44
6	UNKNOWN	6	6.5	11	D	36	74
7	UNKNOWN	102	10.2	12	D	8	56
8	UNKNOWN	102	8.3	29	D	5	56
9	UNKNOWN	103	5.1	9	+	22	43
10	UNKNOWN	103	5.6	10	D	15	150
11	UNKNOWN	103	8	11	D	6	36
12	UNKNOWN	103	8.8	11	D	25	64
13	PIPELINE	104	5.4	12	+	404	153
14	UNKNOWN	104	5.2	11	+	69	72
15	UNKNOWN	104	5	11	D	15	51
16	UNKNOWN	201	5.9	11	+	16	93
17	UNKNOWN	202	5.9	10	D	48	149
18	UNKNOWN	204	7.5	14	-	18	50
19	UNKNOWN	208	6	14	+	22	46
20	UNKNOWN	6A	5	26	+	162	78
21	UNKNOWN	309	7.5	11	-	18	52
22	WRECK	2	6.6	12	-	31	1594
23	WRECK	3	6.7	18	-	128	1372
24	WRECK	4	6.7	18	C	6617	1819
25	WRECK	5	7	13	-	900	1526
26	WRECK	6	7	11	-	125	1227
27	WRECK	7	7.1	12	-	28	1448
28	WRECK	101	7.5	12	+	26	1610
29	WRECK	102	7.4	30	D	50870	782
30	WRECK	103	7.1	11	+	393	1036
31	WRECK	201	5.6	11	-	123	1249
32	WRECK	202	5.7	10	-	243	1101
33	WRECK	203	5.7	10	-	463	978
34	WRECK	204	5.8	12	-	1219	1482
35	WRECK	205	6.1	24	D	6185	1672

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
36	WRECK	206B	5.6	29	D	55938	1141
37	WRECK	207A	5.8	26	D	54106	1123
38	WRECK	208	6	14	-	2536	1375
39	WRECK	209	6	16	-	813	926
40	WRECK	210	6	15	-	335	1117
41	WRECK	211	6	15	-	183	1222
42	WRECK	212	6.1	13	-	99	1217
43	WRECK	301	6.1	13	+	1407	996
44	WRECK	302	6.1	14	+	2320	822
45	WRECK	303A	5.8	29	D	51614	997
46	WRECK	304B	5.9	28	C	55408	900
47	WRECK	305	5.9	32	C	40808	1202
48	WRECK	306A	6.1	28	C	9281	953
49	WRECK	307	6	27	C	34754	1032
50	WRECK	308A	5.9	14	D	1695	954
51	WRECK	309	5.9	12	+	335	857
52	WRECK	310	6	12	+	174	1040
53	WRECK	311	5.8	12	+	85	1015

SITE 15488 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
1	UNKNOWN	4	4.5	10	+	2	53
2	UNKNOWN	4	5.3	10	+	2	73
3	WRECK	4	7	10	C	21	462
4	WRECK	5	6.9	11	D	26	399
5	PIPELINE	6	6	13	D	348	1045
6	PIPELINE	7	8.6	13	D	548	848
7	PIPELINE	101	8.1	11	+	160	208
8	PIPELINE	102	8.5	12	+	520	334
9	PIPELINE	103	8.8	9	+	1036	340
10	UNKNOWN	103	7.9	9	+	12	56
11	UNKNOWN	103	7.2	9	+	4	88
12	PIPELINE	104	9.2	11	-	270	202
13	UNKNOWN	203B	5.5	10	+	3	129
14	UNKNOWN	203B	7.5	10	+	2	121
15	UNKNOWN	204A	7.4	12	+	5	96
16	WRECK	205A	6	14	D	30	438
17	WRECK	206C	6.1	10	D	642	491
18	WRECK	207D	6.1	7	-	6259	607
19	UNKNOWN	207D	6.9	7	+	5	31
20	WRECK	208B	5.8	12	-	14	354
21	PIPELINE	211B	5.2	12	C	101	329
22	UNKNOWN	212B	8.7	12	-	18	20
23	PIPELINE	212B	5.5	11	D	1204	698
24	PIPELINE	301	7.1	15	D	116	288
25	PIPELINE	302	7.3	16	D	138	229
26	UNKNOWN	303	6.2	17	-	11	294
27	PIPELINE	303	7.3	17	-	1291	241
28	WRECK	304	6.2	16	D	77	544
29	PIPELINE	304	7.4	17	+	962	342
30	WRECK	305	6.2	18	D	3727	497
31	PIPELINE	305	7.4	17	-	694	245
32	WRECK	306A	6.1	18	-	639	295
33	PIPELINE	306A	7.4	18	D	36	354
34	PIPELINE	307	7.4	16	C	43	194
35	WRECK	307	6	16	-	92	394
36	PIPELINE	308	7.5	14	-	471	201

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
37	WRECK	308	6	14	-	14	337
38	PIPELINE	309	7.5	16	+	73	291
39	UNKNOWN	309	5.9	15	+	3	73
40	PIPELINE	310	7.6	17	-	261	162
41	PIPELINE	311	7.6	14	-	115	180

SITE 15366 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
1	UNKNOWN	1	7.8	17	D	8	80
2	WRECK	4	7.5	19	-	34	397
3	WRECK	5	7.5	12	-	7	461
4	UNKNOWN	101	6	13	-	243	158
5	WRECK	102	7.3	18	+	28	328
6	WRECK	204	6.1	19	+	8	361
7	WRECK	205	6.1	18	+	47	312
8	WRECK	206	6.1	19	+	5135	642
9	UNKNOWN	207	5.1	10	D	28	62
10	WRECK	207	6	10	-	28115	591
11	UNKNOWN	208	5.2	9	+	40	89
12	WRECK	208	6	9	-	27	579
13	UNKNOWN	209	6.5	19	D	8	104
14	WRECK	303	5.8	15	-	9	354
15	WRECK	304	5.9	16	-	25	415
16	WRECK	305	5.9	18	-	299	508
17	WRECK	306	5.9	17	D	2687	477
18	WRECK	307	5.8	17	-	119	368
19	UNKNOWN	308	6.3	18	D	10	47
20	WRECK	308	5.8	17	-	11	286

SITE 389 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
1	UNKNOWN	2	5.6	15	-	3	51
2	UNKNOWN	2	7	15	D	8	58
3	WRECK	3	8.9	15	+	2	1158
4	WRECK	4	7.1	16	-	111	460
5	WRECK	5	7.3	15	-	17	654
6	UNKNOWN	7	4.7	14	+	4	59
7	UNKNOWN	8	5.6	12	+	3	56
8	WRECK	103	7.2	16	+	6	300
9	WRECK	202	5.9	14	-	7	627
10	WRECK	203	6.3	14	+	226	606
11	UNKNOWN	203	6.2	15	+	16	38
12	WRECK	204	6.2	17	-	210	389
13	WRECK	205	6.2	17	-	972	482
14	UNKNOWN	206	5.2	17	+	22	75
15	WRECK	206	6.3	19	D	9831	486
16	UNKNOWN	206	7.2	18	+	20	89
17	UNKNOWN	207	5.2	14	-	17	65
18	WRECK	207	6.3	16	D	2160	504
19	UNKNOWN	207	7.2	15	-	47	59
20	UNKNOWN	208	7	13	-	55	66
21	WRECK	208	6.1	13	D	2634	565
22	UNKNOWN	208	5.1	13	-	8	87
23	WRECK	209	6.1	13	C	329	634
24	WRECK	210	6.1	12	-	64	636
25	WRECK	211	6.3	16	-	11	633
26	WRECK	212	6.3	16	-	5	609
27	UNKNOWN	212	7.2	16	+	2	30
28	UNKNOWN	301	6.2	14	D	9	121
29	WRECK	302	6.2	12	+	3	449
30	WRECK	303	6.2	12	+	8	484
31	UNKNOWN	303	7.4	12	+	7	55
32	WRECK	304	6.1	14	+	33	464
33	WRECK	305	4.6	15	+	4	51
34	WRECK	305	6.1	16	+	113	646
35	WRECK	306	6.1	14	+	766	878

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIG-NATURE	nT	DURATION (FT.)
36	WRECK	307	5.9	15	-	7758	874
37	WRECK	308	5.9	19	-	1049	837
38	UNKNOWN	308	5.5	19	D	87	136
39	WRECK	309	6.1	15	D	26	657
40	WRECK	310	6.2	16	D	11	868

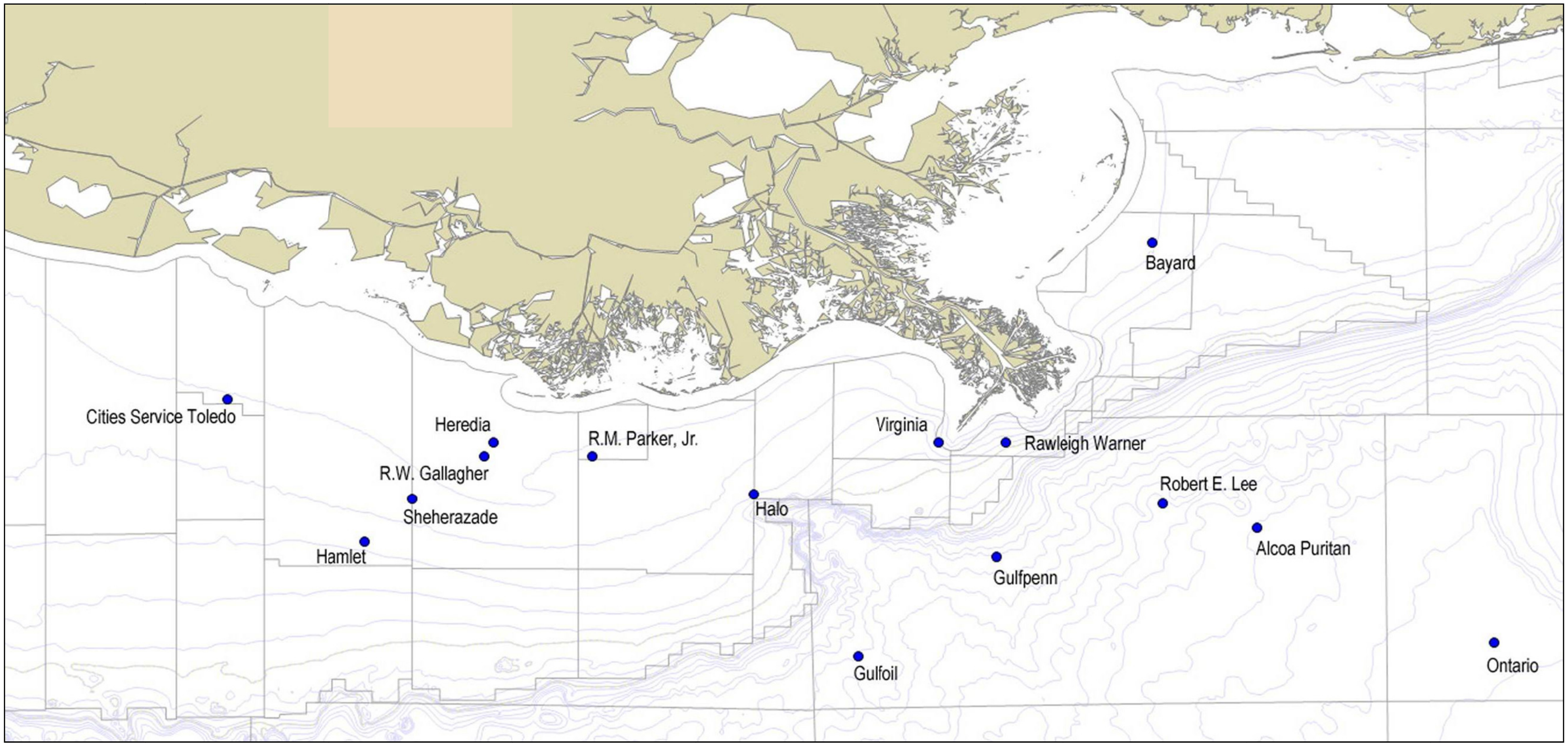
SITE 236 MAGNETIC ANOMALIES

ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIGNA-TURE	nT	DURATION (FT.)
1	UNKNOWN	1	6.7	14	+	10	106
2	UNKNOWN	3	6.3	13	-	15	51
3	UNKNOWN	3	6.9	15	-	2	24
4	WRECK	4A	7.2	14	-	11	785
5	UNKNOWN	4A	7.1	16	+	5	23
6	UNKNOWN	4A	6.3	13	D	4	77
7	UNKNOWN	5	8.2	16	+	4	28
8	WRECK	5	7.1	15	D	14641	819
9	UNKNOWN	6	6.8	15	D	11	52
10	WRECK	6	7.3	16	-	35	592
11	UNKNOWN	8	9.8	9	D	40	172
12	UNKNOWN	102	6.7	14	-	4	49
13	WRECK	103	7.6	14	D	47	1054
14	UNKNOWN	201	5.6	6	-	9	37
15	UNKNOWN	201	5	6	D	15	72
16	UNKNOWN	202	5.1	8	+	7	45
17	WRECK	203	6.2	10	-	7	626
18	UNKNOWN	204	7.4	8	D	5	47
19	UNKNOWN	204	7.1	9	D	12	51
20	WRECK	204	6.2	8	-	24	694
21	UNKNOWN	204	5.9	8	-	4	29
22	UNKNOWN	204	5.4	7	D	4	59
23	WRECK	205	6.2	7	-	42	581
24	WRECK	206	6.2	7	D	79	855
25	WRECK	207	6.2	11	D	323	696
26	WRECK	208	6.4	16	D	6935	693
27	WRECK	209	6.3	11	D	19216	789
28	UNKNOWN	209	7.4	12	D	18	79
29	WRECK	210	6.3	14	-	1760	878
30	WRECK	211	6.1	13	D	10362	947
31	WRECK	212	6.3	13	-	497	761
32	WRECK	213	6.2	11	-	83	520
33	UNKNOWN	301	4.4	14	D	20	59
34	UNKNOWN	301	5.3	13	-	3	33
35	WRECK	302A	6.5	12	-	8	852

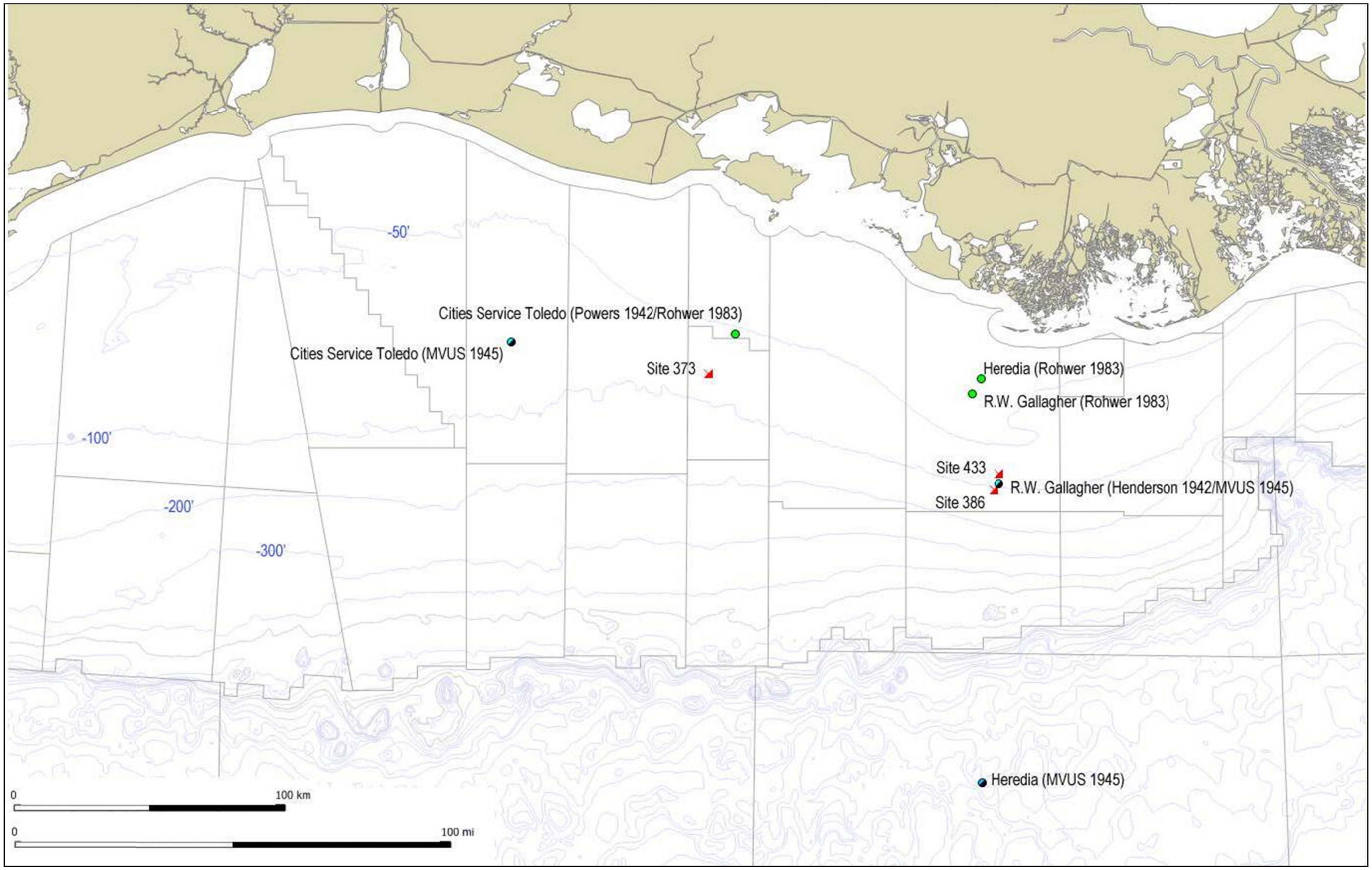
ANOMALY NO.	SOURCE	LINE	FIX	SENSOR HT(FT)	SIGNA-TURE	nT	DURATION (FT.)
36	WRECK	303	6.3	18	+	24	848
37	UNKNOWN	303	5.6	18	D	12	59
38	WRECK	304	6.5	17	+	78	830
39	WRECK	305	6.5	18	+	251	870
40	UNKNOWN	305	6	18	-	52	101
41	WRECK	306	6.5	16	+	1175	978
42	WRECK	307A	6.3	10	C	11352	879
43	WRECK	308A	6.4	10	C	16253	835
44	UNKNOWN	308A	5.5	10	+	11	43
45	WRECK	309	6.6	17	C	6839	935
46	WRECK	310	6.5	16	C	106	823
47	WRECK	311	6.6	15	D	37	926

Appendix D

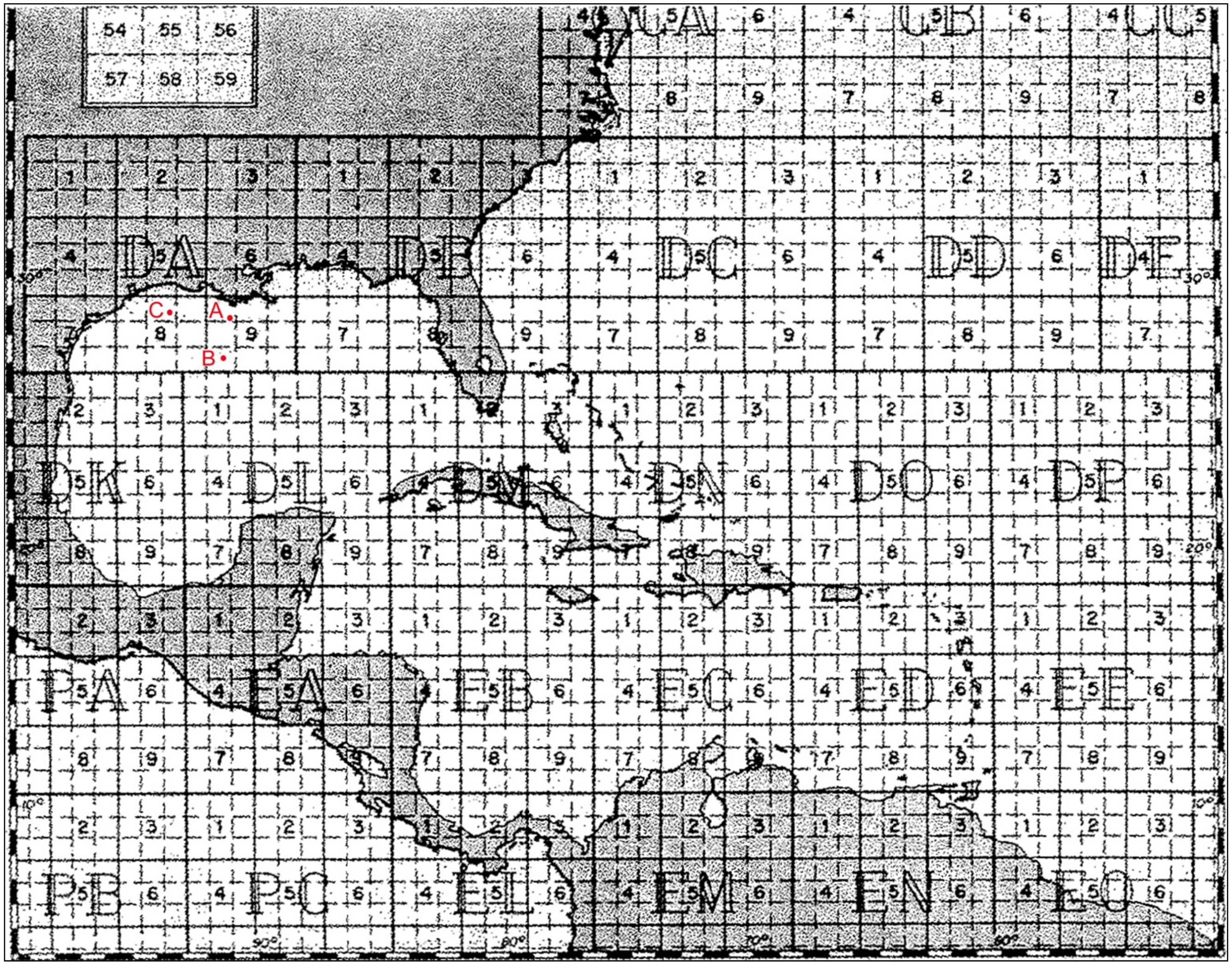
Supplemental Maps



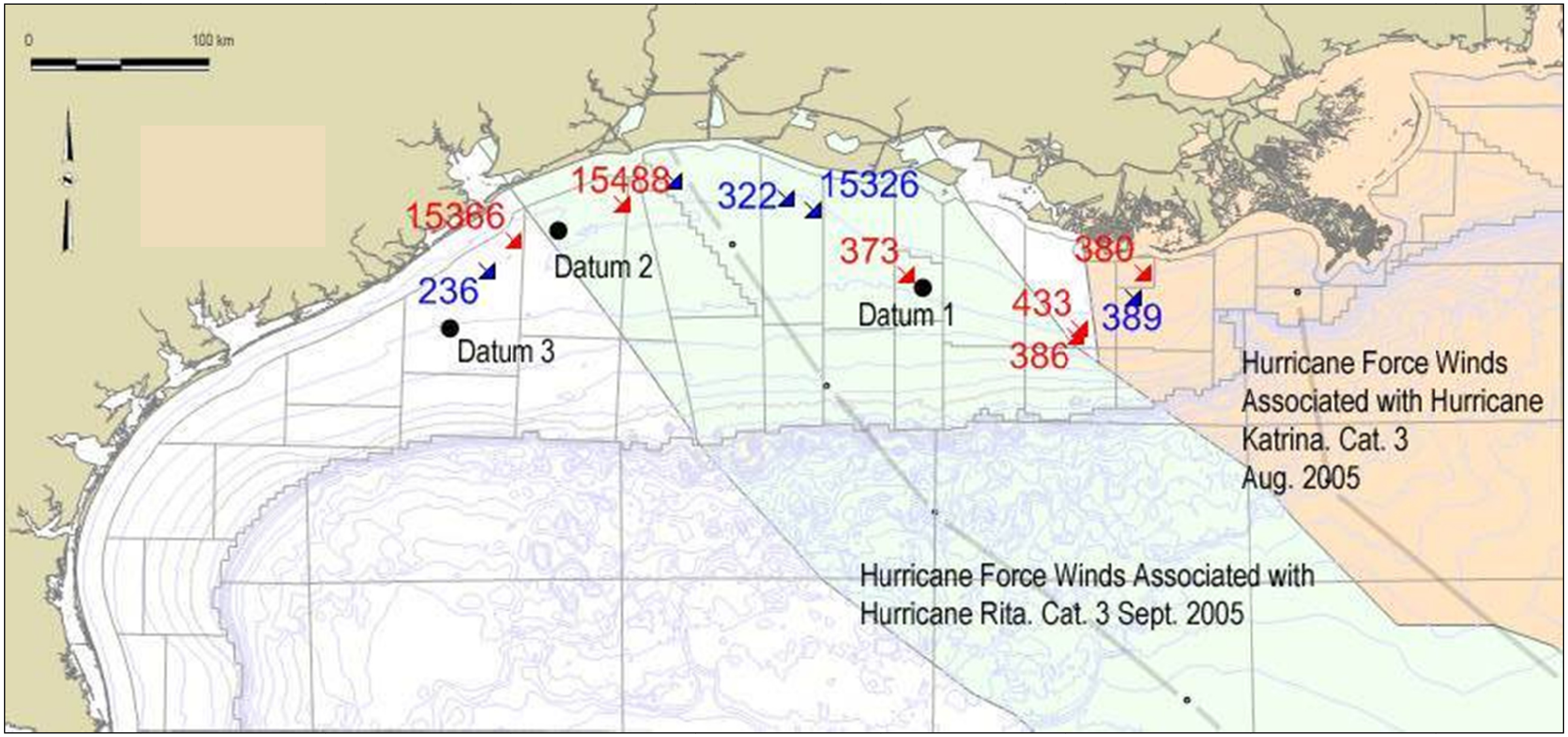
Map D-1. Reported location of U-boat victims in the north central GOM (based on coordinates from Rohwer 1983).



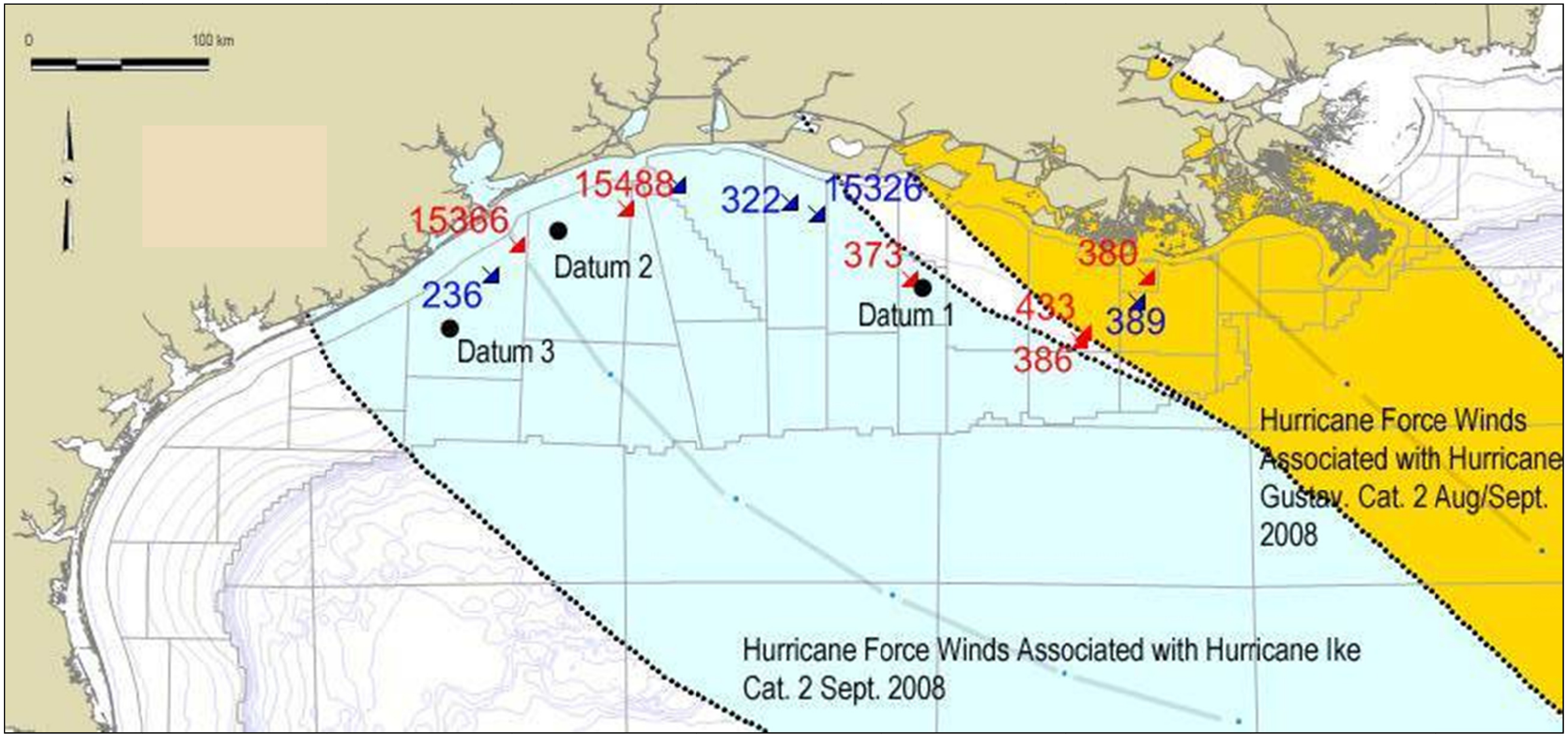
Map D-2. Comparison of reported locations of designated study sites and World War II-era tankers.



Map D-3. German grid system map showing reported locations of World War-II-era study sites, based on German U-boat accounts (Rowher 1983). **A.** *R.W. Gallagher*, **B.** *Heredia*, **C.** *Cities Service Toledo*.



Map D-4. Locations of study sites and datums in relation to 2005 hurricanes (hurricane tracks from NOAA).



Map D-5. Locations of study sites and datums in relation to 2008 hurricanes (hurricane tracks from NOAA).

Appendix E

Supplemental Documents

SITE 433 ***R. W. GALLAGHER***

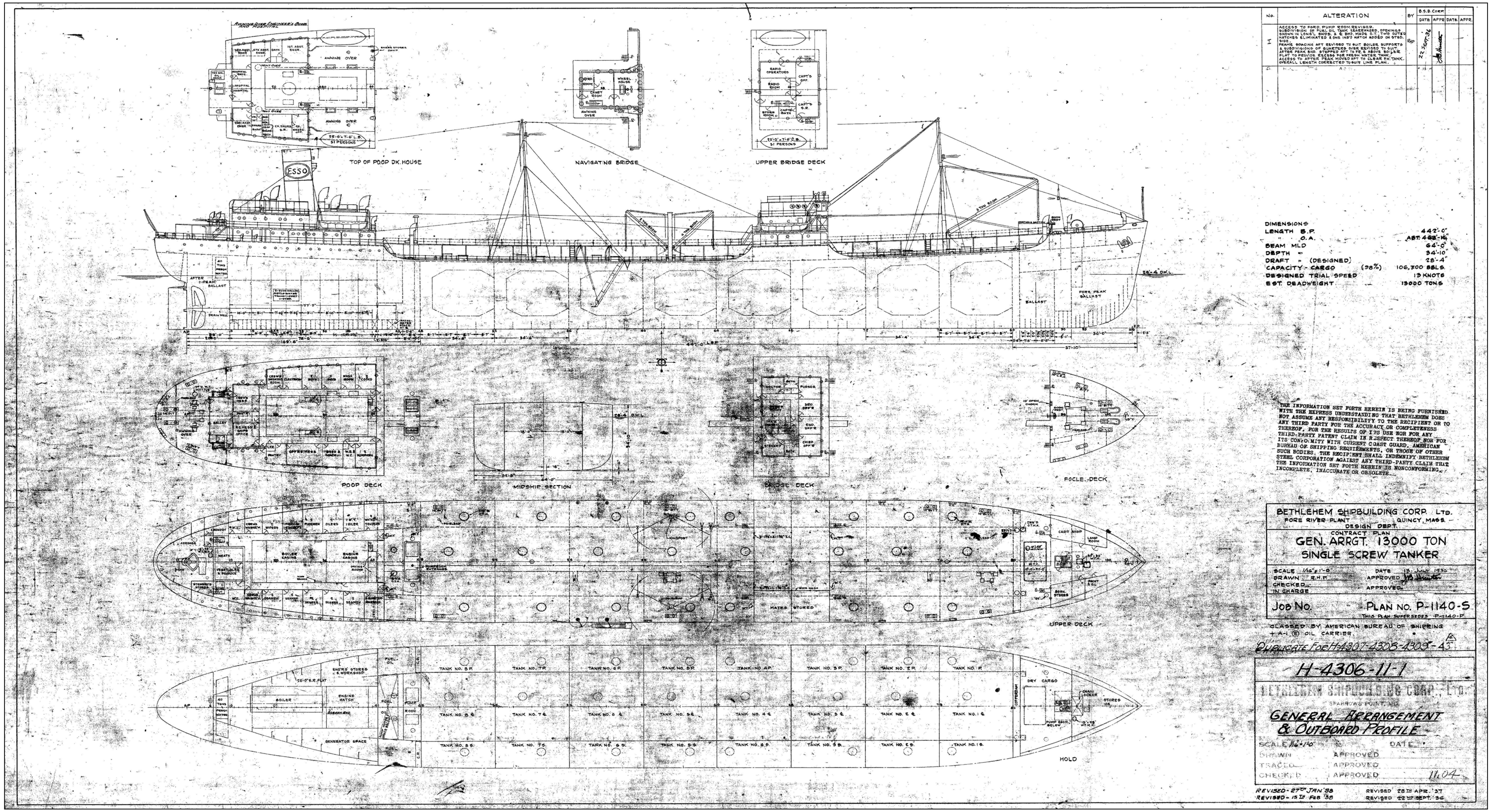


Figure E-1. General arrangement and outboard profile plans for Hull 4306 (duplicate plans were made for Hull 4307-*R.W. Gallagher*) 1936 (last revised 1938), Bethlehem Shipbuilding Corp. Ltd. (Courtesy of Avery Munson).

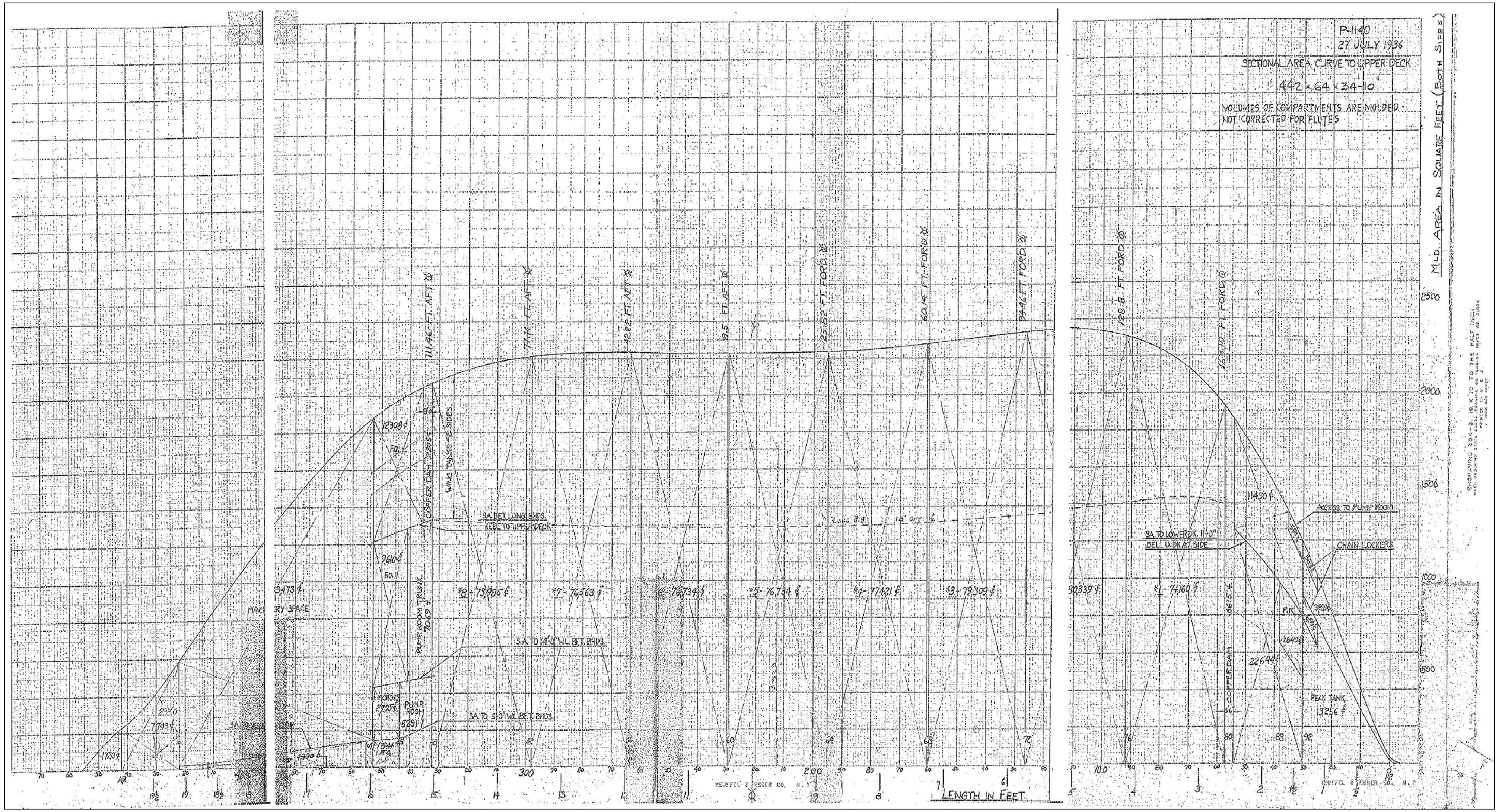


Figure E-2. Engineering plans for Hulls 4306-4309 (*R.W. Gallagher*–Hull No. 4307) 1936. Courtesy of William A. Baker Collection, MIT Museum (Catalog No. Box XVII, Folder B155)

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acc. 1699 Box 170
Bethlehem Steel

SHIPS BUILT — BETHLEHEM-SPARROWS POINT SHIPYARD, INC.

Hull Number	4305	4306	4307	4308	4309	4310	4311	4312
Name	GULFTIDE	ESSO BATON ROUGE	R.W. GALLAGHER	ESSO BALTIMORE	ESSO CHARLESTON	FRONTIER NO.2	FRONTIER NO.3	---
Type	Tanker	Tanker	Tanker	Tanker	Tanker	Oil Barge	Oil Barge	Derrick Barge
Owner	Gulf Oil Corp.	Std.Oil Co. of N.J.	Std.Oil Co. of N.J.	Std.Oil Co. of N.J.	Std.Oil Co. of N.J.	Frontier Fuel Oil Co.	Frontier Fuel Oil Co.	Std.Oil Co. (Venezuela)
Date Contracted	17 Jan 36	16 Jul 36	16 Jul 36	23 Dec 36	23 Dec 36	21 Dec 36	21 Dec 36	5 Nov 36
Date Keel Laid	27 Apr 36	22 Dec 36	11 Jan 37	20 Oct 37	18 Nov 37	3 Feb 37	4 Feb 37	Fabricated
Date Launched	23 Jan 37	13 Nov 37	22 Jan 38	4 Jne 38	23 Jul 38	31 Mar 37	31 Mar 37	for export
Date Delivered	13 Apr 37	18 Jul 38	10 Aug 38	21 Sep 38	19 Oct 38	15 Apr 37	27 Apr 37	
L.O.A.	Same as hull 4304	463'-1¼"	Same as hull 4306	Same as hull 4306	Same as hull 4306	203'-0"	Same as hull 4310	80'-0"
L.B.P.		442'-0"						
Breadth, Maximum Mld.		64'-0"				43'-0"		40'-0"
Breadth, Extreme								
Depth, Mld.		34'-10"				12'-0"		6'-6"
Draft, Mld.		28'-4"				8'-4"		
Displacement, Tons		16,970				1924		
Deadweight, Tons		12,950		12960	12951	1500		
Gross, Tonnage		7989		7949	7949	934		
Net Tonnage		4738		4711	4711	928		
Cargo Cap. Gen. CF Bale		10,958						
Ref. CF Bale		---				---		
Liquid, Bbls		108,895				14000 (abt)		
No. Passengers		---				---		
Speed, Knots		13						
Machinery, Engine		Sgl.Screw DRGT				Non-propelled		Non-propelled
SHP/RPM		4000/92						
Boilers		2 WT, oil 400#/750°F						

(4305---4312)

Figure E-3. List of Hull Nos. 4305-4312 specifications, built at Bethlehem Sparrow's Point, Maryland Shipyard. Accession 1699, Bethlehem Steel Collection, Box 170, Hagley Museum & Library.

COUNTERPART I

FORM NO. 102
WARSHIPOILTIME
5/22/42
Part I

WAR SHIPPING ADMINISTRATION

REQUISITION TIME CHARTER
FOR TANK VESSEL

Contract No. WSA-2122-R

TIME CHARTER as of **April 20**, 1942, between **Standard Oil Company of New Jersey**
Address **30 Rockefeller Plaza, New York, New York**
OWNER of the good **United States** SS/[redacted] "**R.W. GALLAGHER**"
(herein called the "Vessel"), with hull, machinery and equipment in a thoroughly efficient state, as far as the exercise of due diligence can make her so, and UNITED STATES OF AMERICA, CHARTERER, particulars as follows:

DEADWEIGHT capacity for cargo, fresh water and stores about **12950** tons
(2240 lbs.), including Permanent Bunkers for fuel **615** tons/[redacted]
ON MEAN DRAFT (Assigned Summer Freeboard, 1930 Convention) **28** feet **6-1/4** inches
CLASSED **✠ A 1 (E) American Bureau**
SPEED about **12.1** knots fully laden under good weather conditions
CONSUMPTION per 24 hours about **25** tons/[redacted]
BULK CARGO CAPACITY (less 2% for expansion and excluding permanent bunkers) **106,715 barrels**
DISCHARGE CAPACITY all pumps per hour **6000** [redacted]/barrels
TANKS COILED **- Yes**

LAST TWO SUCCESSIVE CARGOES **- Fueloil, Crude**
PANAMA CANAL TRANSIT highest grade products under current regulations Grade **- A** supplement No. **18**
CONSTRUCTED AND EQUIPPED SUEZ CANAL TRANSIT with crude petroleum or products in bulk **- Yes**

****

OWNER agrees to let and CHARTERER agrees to hire the VESSEL, from time of delivery for trading subject to the following terms:

Part I

A. PERIOD OF CHARTER: From the time of delivery to the time of expiration of the voyage current at the end of the emergency proclaimed by the President May 27, 1941; PROVIDED, That after September 1, 1942 either party may sooner terminate this Charter (the Vessel to be redelivered as hereinafter provided) upon not less than 30 days' written or telegraphic notice.
B. TRADING LIMITS: World-wide.
C. RATE: Option I - A basic rate of $ **3.60** per deadweight ton per month computed in accordance with the Charterer's General Order No. 8, Supplement No. 1, together with any appropriate adjustments or premiums in accordance with such Supplement No. 1 to General Order No. 8, which full rate shall be subject to revision not more often than once in every 120 days as in paragraph D below provided; or

Option II - 75 percentum of the full rate payable in accordance with Option I above and such further sum, if any, adjudicated to be necessary to make up just compensation for the use of the Vessel and the services required in connection therewith under the terms of this Charter, pursuant to the provisions of Section 902 of the Merchant Marine Act, 1936, as amended.

D. RATE REVISION (Option I only): At any time after September 1, 1942, but not more often than once every 120 days, either party may request a redetermination of the rate of charter hire upon 30 days' written or telegraphic notice to the other. If a revised rate is determined and agreed upon within such 30-day period, it shall become effective as of the date specified in the determination and shall continue for the balance of the period of this Charter subject to further redetermination in accordance with the provisions of this paragraph. If a revised rate is not determined or agreed upon within such 30-day period, then the rate of hire in effect at the time of such notice shall apply only until noon (EWT) of the day after the end of such 30-day period, and charter hire for the balance of the period of this Charter shall be just compensation within the meaning of Section 902 of the Merchant Marine Act, 1936, as amended, and shall

Figure E-4. War shipping administration requisition time charter for *R.W. Gallagher* 1942, p.1 (USMC 1942b).

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(WARSHIPOILTIME Part I)

be established and paid as therein provided. In such latter event, the use of the Vessel, if not theretofore requisitioned, shall be deemed to have been requisitioned pursuant to Section 902 as of noon (EWT) of the day after the end of such 30-day period. This paragraph shall not operate so as to terminate the period of or otherwise modify the provisions of this Charter, notwithstanding any such modifications, adjustments, or terminations of the charter hire provisions of this Charter by operation of this paragraph.

E. WAR RISK INSURANCE VALUATION:
<u>Option I</u> - The sum of $ **None** per deadweight ton computed in accordance with General Order No. 9 of the Charterer together with any premiums or adjustments, or any assumption of war risk, general average, collision or salvage risks or liabilities as may be provided for in said General Order and which are applicable to the Vessel by the terms of said General Order; PROVIDED, That if said General Order No. 9 does not set forth a formula for ascertaining such valuation, then Option II below shall apply unless otherwise agreed in the Special Provisions hereinbelow; or

<u>Option II</u> - Just compensation to be determined in accordance with Section 902 of the Merchant Marine Act, 1936, as amended, for any loss or damage due to the operation of a risk assumed by the Charterer under the terms of this Charter to the extent the person entitled thereto is not reimbursed therefor through policies of insurance against such loss or damage.

F. PORT OF DELIVERY: **Newport News, Virginia - April 20, 1942**
G. PORT OF REDELIVERY: Not less favorable to either party than the port of delivery, unless otherwise agreed.
H. NOTICE OF REDELIVERY: Fifteen (15) days
I. UNIFORM TERMS: This Charter consists of this Part I and Part II, the Uniform Time Charter Terms and Conditions for Tank Vessels, published in the Federal Register of June 19, 1942. Unless in this Part I otherwise expressly provided, all of the provisions of said Part II shall be part of this Charter as though fully incorporated herein.

J. SPECIAL PROVISIONS:
1. Unless the Owner otherwise indicates in the execution hereof, or unless the proviso in War Risk Insurance Valuation Option I applies to the Vessel which will be indicated if the sum in said Option I is written "$none", Rate Option I and War Risk Insurance Valuation Option I shall apply and in such event, in consideration of the compensation provided and the other obligations assumed by the Charterer hereunder, the Owner accepts this Charter in full satisfaction of any and all claims he has or may have against the Charterer arising out of the requisition of the Vessel and accepts the compensation herein provided for as the compensation required by law. If the Owner in the execution hereof elects Rate Option I and War Risk Insurance Valuation Option II, then the Owner shall accept this Charter and such hire in full satisfaction of any and all claims he has or may have against the Charterer arising out of the requisition of the Vessel and as the compensation required by law except as to any loss or damage due to the operation of a risk assumed by the Charterer under the terms of this Charter to the extent the person entitled thereto is not reimbursed therefor through policies of insurance against such loss or damage.

2. (a) If at the time of requisition the Vessel had cargo on board, then charter hire for the Vessel's first voyage shall be adjusted on such fair and equitable accounting basis as the Charterer shall determine.

(b) If redelivery is made at a port that is more favorable to the Owner, then the Owner shall make the Charterer a proper allowance of any savings to the Owner thereby; if the port of redelivery is less favorable to the Owner, then the Charterer shall pay the Owner a proper allowance to cover the additional cost required to put the Owner in the same position as if the Vessel had been redelivered at the port of original delivery.

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(WARSHIPOILTIME Part I)

(J. SPECIAL PROVISIONS, continued)

3. (a) Based on the Owner's representations, the aggregate rate of the monthly charter hire under Rate Option I (excluding any allowances under sub-paragraph c of section 2 of Charterer's General Order No. 8, Supplement No. 1) is computed as follows (subject to verification):

This Vessel			Vessel next higher class	
Basic Rate	$ 3.60x 12950	$ 46,620.00	$ 3.45x 14000	$ 48,300.00
Speed Premium 2 x	$ .10x 12950	$ 2,590.00	2x $ .10x 14000	$ 2,800.00
Age Adjustment	$ .50x 12950	$ 6,475.00	$ .50x 14000	$ 7,000.00
M/S Premium	$ .35x	$ None	$ .35x	$ None
TOTAL RATE	(i)	$ 55,685.00	(ii)	$ 58,100.00

[lower amount of (i) or (ii)]

(b) Satisfactory c[...] ng as to Vessel's deadweight, or spee[...] epresentations and without further ver[...] pertinent changes.

(c) The total loss[...] subject to modification by mut[...] ption of this charter, and such modified v[...] arily or by replacement agreement.

Figure E-5. War Shipping Administration requisition time charter for *R.W. Gallagher* 1942, p.2 (USMC 1942b).

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(WARSHIPOILTIME Part I)

(J. SPECIAL PROVISIONS, continued)

3. (a) Based on the Owner's representations, the aggregate rate of the monthly charter hire under Rate Option I (excluding any allowances under sub-paragraph c of section 2 of Charterer's General Order No. 8, Supplement No. 1) is computed as follows (subject to verification):

	This Vessel		Vessel next higher class	
Basic Rate	$ 3.60x 12950	$ 46,620.00	$ 3.45x 14000	$ 48,300.00
Speed Premium 2 x	$ .10x 12950	$ 2,590.00	2x $ .10x 14000	$ 2,800.00
Age Adjustment	$ .50x 12950	$ 6,475.00	$ .50x 14000	$ 7,000.00
M/S Premium	$ .35x	$ None	$ .35x	$ None
TOTAL RATE	(i)	$ 55,685.00	(ii)	$ 58,100.00

[lower amount of (i) or (ii)]

(b) Satisfactory certificate of American Bureau of Shipping as to Vessel's deadweight, or speed will be accepted in lieu of Owner's representations and without further verification except in case of subsequent pertinent changes.

(c) The total loss valuation herein provided for shall be subject to modification by mutual agreement effective as of the inception of this charter, and such modified valuation may be expressed either monetarily or by replacement agreement.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement in triplicate the day and year first above written, and the Owner has elected Rate Option I and War Risk Insurance Valuation Option II.

As to execution for OWNER
ATTEST:

ASST. SECRETARY

Or if not incorporated

In the presence of:

Witness

and

Witness

STANDARD OIL COMPANY OF NEW JERSEY

By:
VICE PRESIDENT

UNITED STATES OF AMERICA
By: E. S. LAND, ADMINISTRATOR
WAR SHIPPING ADMINISTRATION

By:
For the Administrator

Figure E-6. War Shipping Administration requisition time charter for *R.W. Gallagher* 1942, p.3 (USMC 1942b).

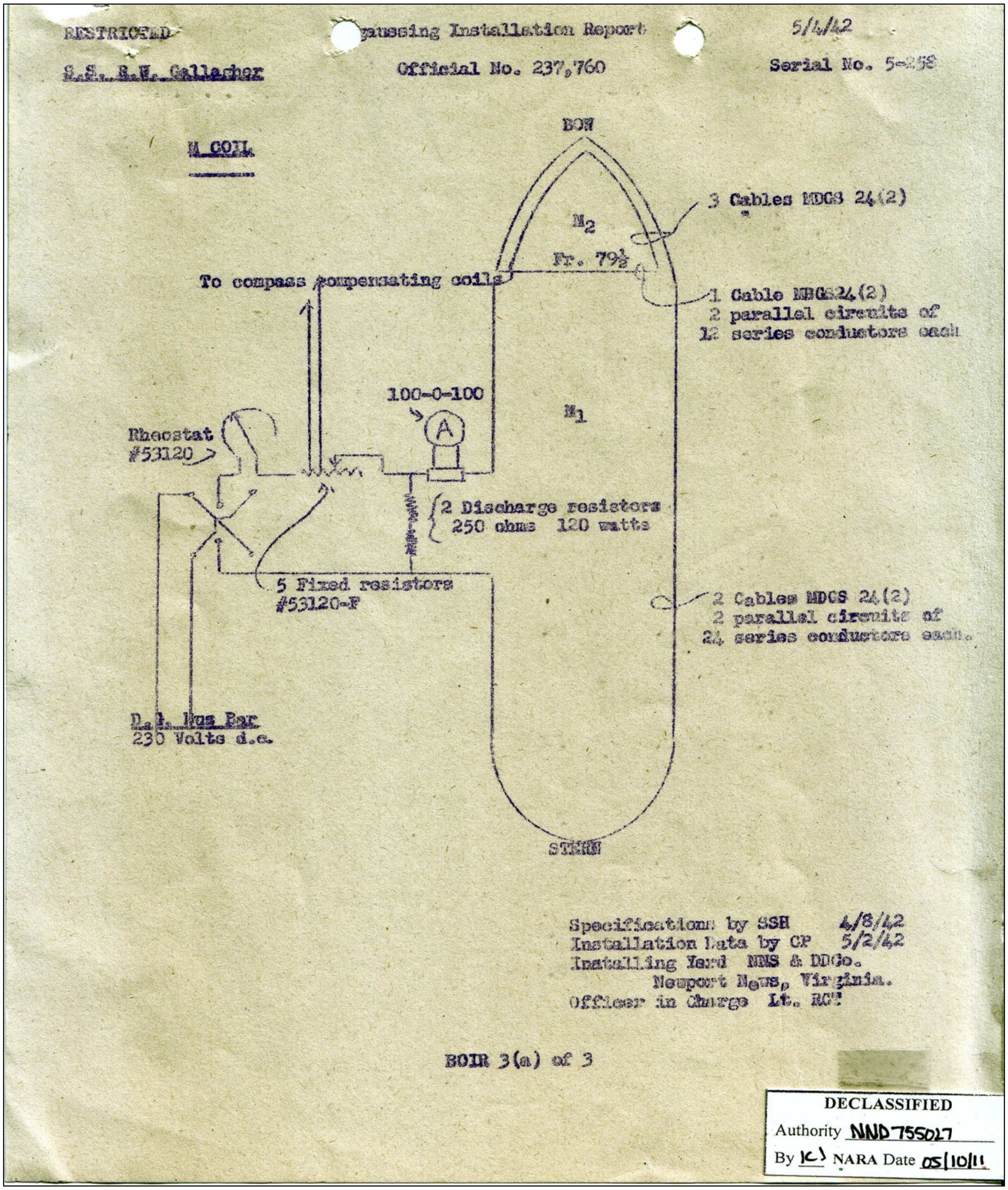


Figure E-7. Degaussing installation report for *R.W. Gallagher* 1942, p.1 (Bureau of Ordnance).

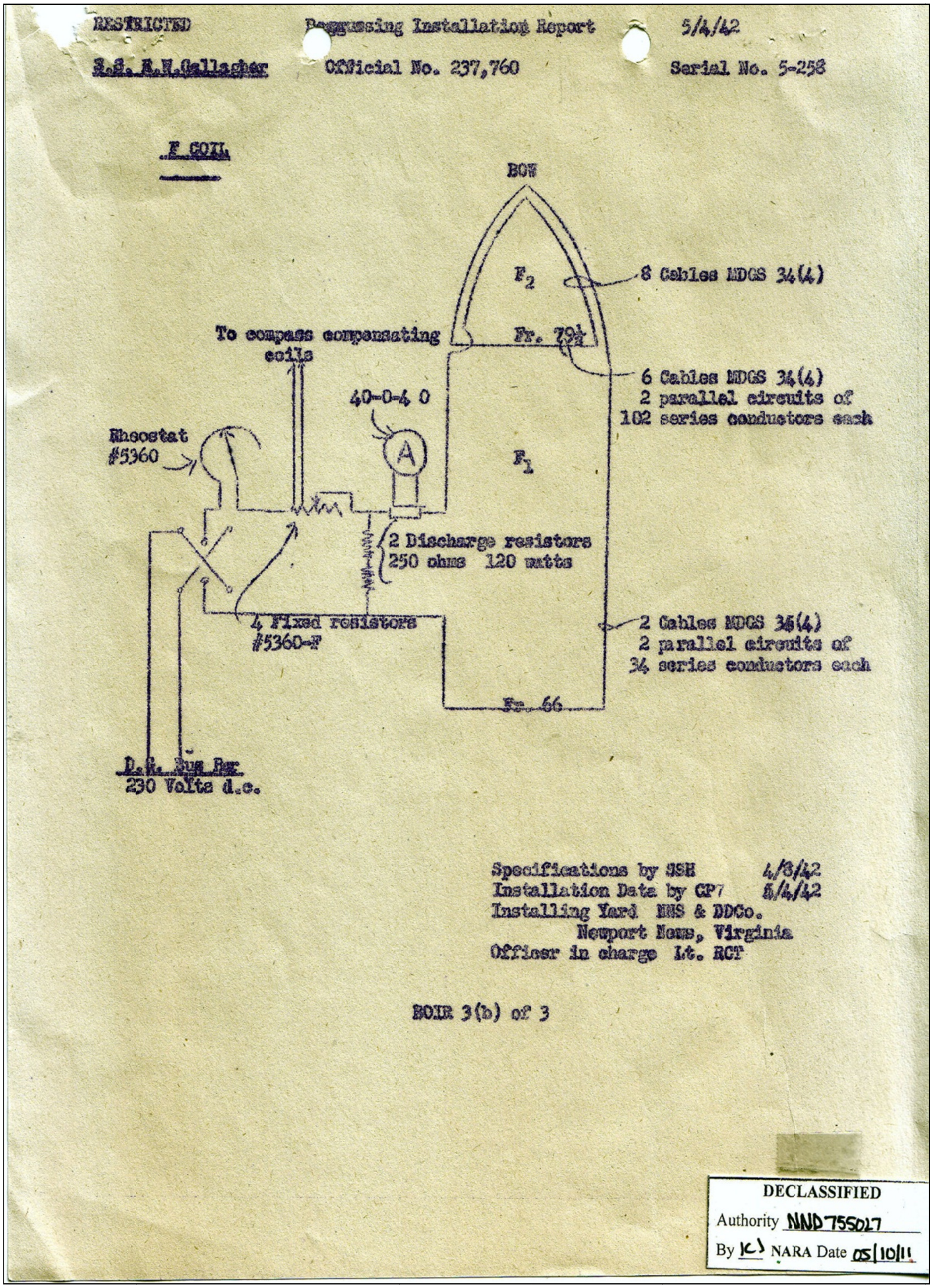
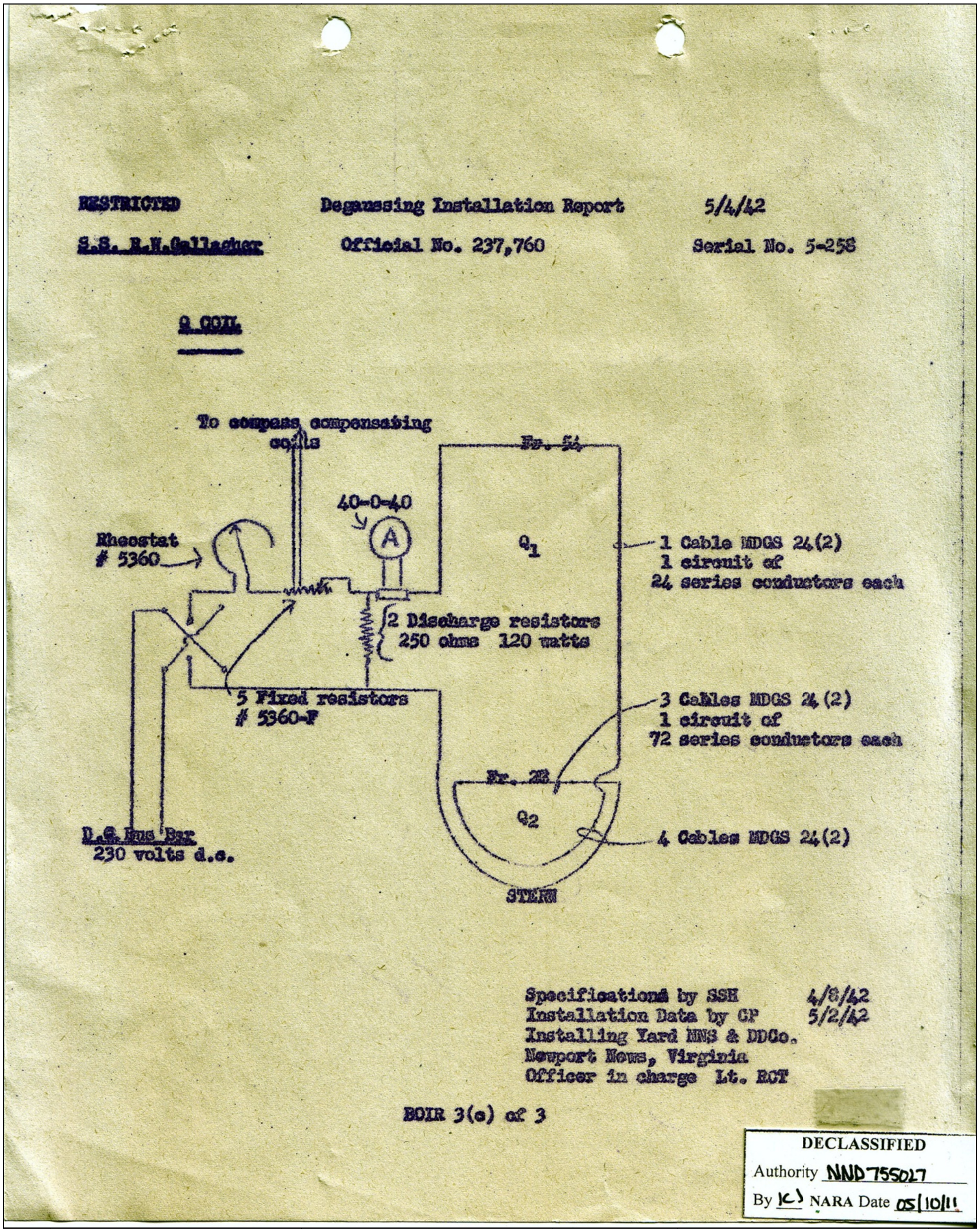


Figure E-8. Degaussing installation report for *R.W. Gallagher* 1942, p.2 (Bureau of Ordnance).



RESTRICTED Degaussing Installation Report 5/4/42

S.S. R.W.Gallagher Official No. 237,760 Serial No. 5-258

Q COIL

Specifications by SSH 4/8/42
Installation Data by CP 5/2/42
Installing Yard NNS & DDCo.
Newport News, Virginia
Officer in charge Lt. RCT

BOIR 3(c) of 3

Figure E-9. Degaussing installation report for *R.W. Gallagher* 1942, p.3 (Bureau of Ordnance).

RESTRICTED BUREAU OF ORDNANCE Sheet No. 1 of 3

DEGAUSSING INSTALLATION REPORT Date May 2, 1942

22

Name S.S. R.W. GALLAGHER ABS # 237,760 Serial No. 5-258

Generators (D.C.)

No.	Voltage	Power
2	230	300 KW

Type of installation Permanent

Normal load 60 KW Max. Load 420 KW

D.G. Design Memo. BuOrd Manual #2 of 28 Aug. 1941 & Revision

Reference Plans Bethlehem S.B. Corp. DR #P-1140-S

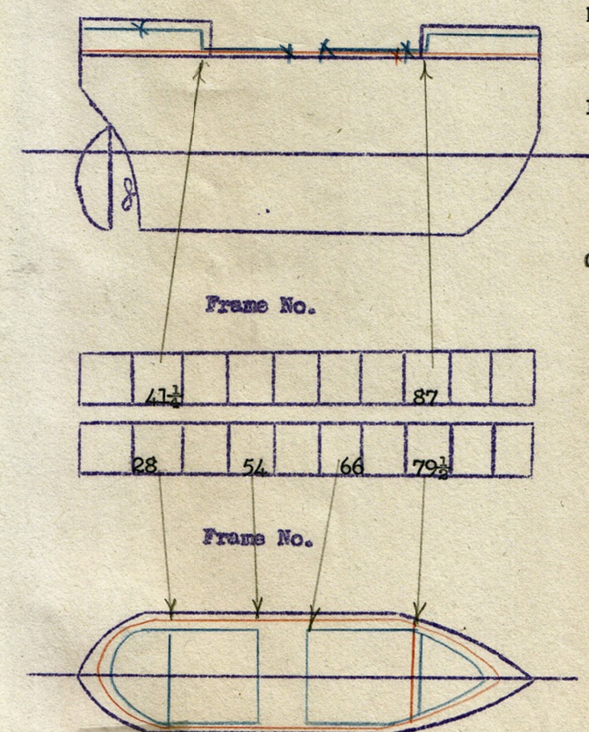
Material of: (a) Hull Steel (b) Superstructure Steel

Mean ht. of ship (with superstructure properly weighted) 44' Ft.

Length over all 442' Ft. Beam 64' Ft. Mean Displacement ______ tons

COIL LOCATIONS

Show Superstruct. & Draft & Label Ref. Dks.



	Frame	Ht. (Ft.)	Level of Coils Above or below Reference Decks
M	B-S	0'	Above upper deck.
F	B-87	1'	Below focsle deck
	87-66	0'	Above upper deck
Q	54-41½	0'	Above upper deck
	41½-St	3'.75	Below poop deck

Crossover Frames

Coil	For'd Frame	Aft Frame	Remarks
M1	Bow	Stern	-
M2	Bow	79½	Fwd of winch
F1	Bow	66	Fwd of Bulkhead
F2	Bow	79½	Fwd of winch
Q1	54	Stern	Fwd of mast
Q2	28	Stern	Under catwalk

BOIR-1-1

DECLASSIFIED
Authority NND 755027
By KJ NARA Date 05/10/11

Figure E-10. Degaussing installation report for *R.W. Gallagher* 1942, p.4 (Bureau of Ordnance).

Authority NND750161
By KS NARA Date 05/10/11

PORT DIRECTOR'S REPORT ARMING MERCHANT VESS

CONFIDENTIAL

SERIAL PD 279 **NAME OF SHIP:** ~~MS~~ SS R. W. GALLAGHER

OWNER: Standard Oil Co. of N.J. OPERATOR or AGENT: Same

REGISTRY U.S. CLASS (pass. Cargo or Tank Ship) Tanker

ITINERARY : Sailing Date: 5/9/42 From: Norfolk, Va. To: Port Au La Cruz, Columbia.

Via:

SHIP'S CREW **Commissioned Rank**

MASTER: A. Petersen — None

OFFICERS: (Listed by name only if Commissioned)

Deck Department		Engineering Department		Steward's Department	
Chief Mate	1	Ch. Engineer	1	Ch. Steward	1
2nd Mate	1	1st Engineer	1	Ch. Cook	1
3rd Mate	1	2nd Engineer	1	2nd Cook	1
Quartermaster	0	3rd Engineer	1	3rd Cook	0
Boatswain	1	4th Engineer	0	Messman	5
Seamen — Able	7	Firemen	0	Utilitymen	0
Seamen — Ord	3	Oilers	3	Pumpman	1
Radio Operator	1	Wipers	2	Machinist	1
Electrician	1	Watertenders Fire	3		
Storekeeper	1				

Total Crew Including Master 40

PASSENGERS—Number on Board None

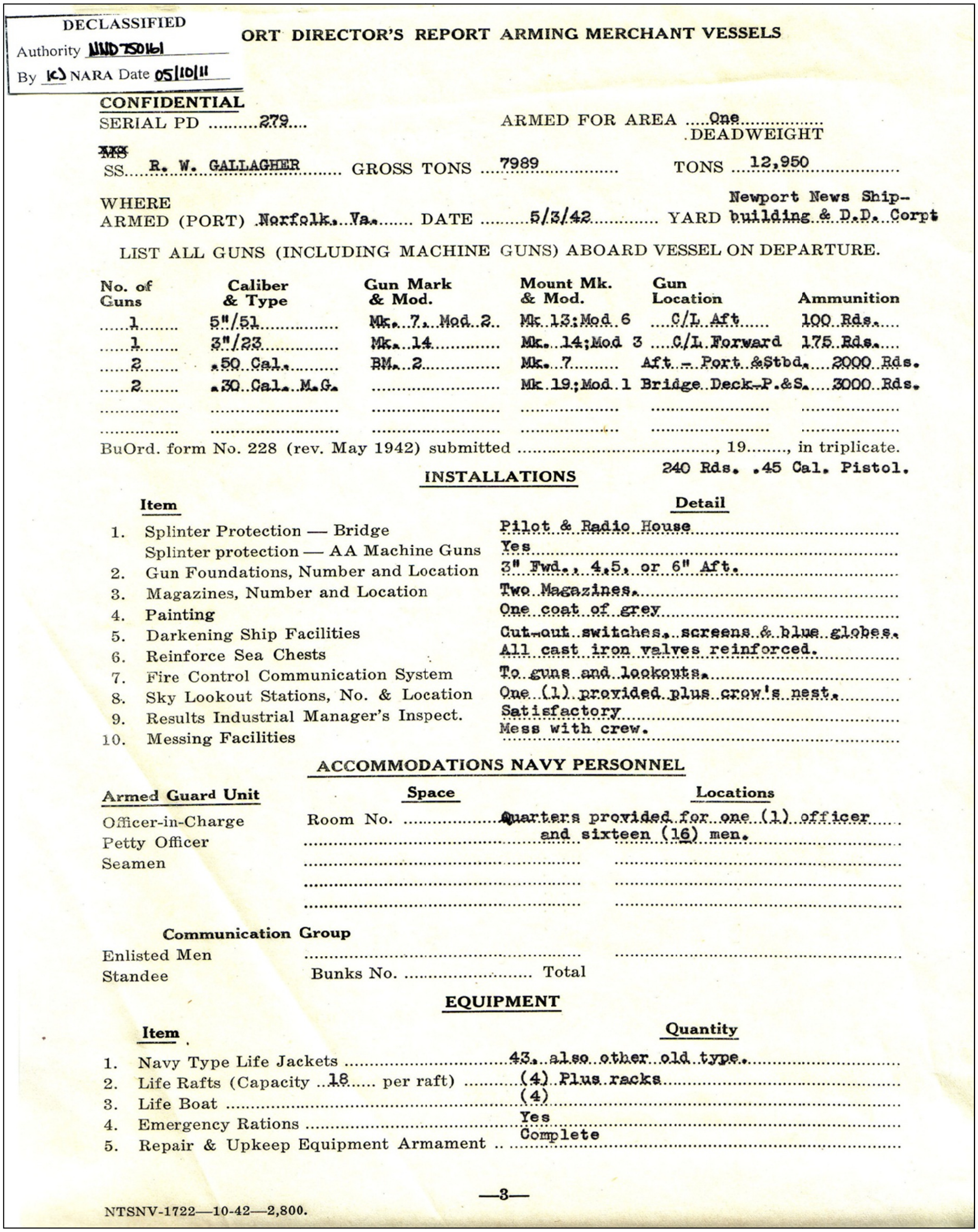
U. S. NAVY PERSONNEL

Armed Guard Unit	Name	Rating	Branch	Service No.
Officer in Charge:				
Enlisted Men:	NIBOUAR, John	GM 3/c	USNR V-6	124 11 10
	TIMPANO, V. P.	A.S.	USNR V-6	602 11 89
	~~SUTTON, George V.~~	~~A.S.~~	~~USNR V-6~~	~~656 31 81~~
	THOMAS, Arthur C.	A.S.	USNR V-6	552 64 17
	THOMAS, Curtis W.	A.S.	USNR V-6	552 62 32
	~~TAYLOR, Bennie B.~~	~~A.S.~~	~~USNR V-6~~	~~636 28 15~~
	TAYLOR, Henry F.	A.S.	USNR V-6	656 32 05
	THOMAS, James C.	A.S.	USNR V-6	552 00 07
	~~THOMAS, Roy E.~~	~~A.S.~~	~~USNR V-6~~	~~552 64 16~~
Communication Group				

—2—

NTSNV-1721—10-42—2,800.

Figure E-11. Port director's report arming merchant vessels for *R.W. Gallagher* 1942, p.2 (OCNO 1942b).



DECLASSIFIED
Authority NND750161
By KJ NARA Date 05/10/11

ORT DIRECTOR'S REPORT ARMING MERCHANT VESSELS

CONFIDENTIAL

SERIAL PD 279 — ARMED FOR AREA One

SS R. W. GALLAGHER — GROSS TONS 7989 — DEADWEIGHT TONS 12,950

WHERE ARMED (PORT) Norfolk, Va. — DATE 5/3/42 — YARD Newport News Shipbuilding & D.D. Corp

LIST ALL GUNS (INCLUDING MACHINE GUNS) ABOARD VESSEL ON DEPARTURE.

No. of Guns	Caliber & Type	Gun Mark & Mod.	Mount Mk. & Mod.	Gun Location	Ammunition
1	5"/51	Mk. 7, Mod 2	Mk 13;Mod 6	C/L Aft	100 Rds.
1	3"/23	Mk. 14	Mk. 14;Mod 3	C/L Forward	175 Rds.
2	.50 Cal.	BM. 2	Mk. 7	Aft - Port &Stbd.	2000 Rds.
2	.30 Cal. M.G.		Mk 19;Mod 1	Bridge Deck-P.&S.	3000 Rds.

BuOrd. form No. 228 (rev. May 1942) submitted ..., 19..., in triplicate.

240 Rds. .45 Cal. Pistol.

INSTALLATIONS

Item	Detail
1. Splinter Protection — Bridge	Pilot & Radio House
Splinter protection — AA Machine Guns	Yes
2. Gun Foundations, Number and Location	3" Fwd., 4.5, or 6" Aft.
3. Magazines, Number and Location	Two Magazines.
4. Painting	One coat of grey
5. Darkening Ship Facilities	Cut-out switches, screens & blue globes.
6. Reinforce Sea Chests	All cast iron valves reinforced.
7. Fire Control Communication System	To guns and lookouts.
8. Sky Lookout Stations, No. & Location	One (1) provided plus crew's nest.
9. Results Industrial Manager's Inspect.	Satisfactory
10. Messing Facilities	Mess with crew.

ACCOMMODATIONS NAVY PERSONNEL

Armed Guard Unit	Space	Locations
Officer-in-Charge	Room No. Quarters provided for one (1) officer	
Petty Officer	and sixteen (16) men.	
Seamen		

Communication Group

Enlisted Men ...

Standee — Bunks No. ... Total

EQUIPMENT

Item	Quantity
1. Navy Type Life Jackets	43, also other old type.
2. Life Rafts (Capacity 18 per raft)	(4) Plus racks
3. Life Boat	(4)
4. Emergency Rations	Yes
5. Repair & Upkeep Equipment Armament	Complete

—3—

NTSNV-1722—10-42—2,800.

Figure E-12. Port director's report arming merchant vessels for *R.W. Gallagher* 1942, p.3 (OCNO 1942b).

CONFIDENTIAL

Serial PD ...279...........

PORT DIRECTOR MATERIAL REPORT
FOR ARMED GUARD UNIT

xMSx

ON BOARD SS ......R. W. GALLAGHER.............

DECLASSIFIED
Authority NND 750161
By KJ NARA Date 05/10/11

Item No.	Quantity No.	Unit	Description	Stock Number	Title
1.	1	Each	BAG, canvas, weighted No. C&R 434791	24-B-60	C
2.		Cell	BATTERIES, Blinker Signal Gun	17-B-7040	C
3.	60	Cell	BATTERIES, Flashlight	17-B-7210	C
4.	12	Cell	BATTERIES, Dry, hand lantern	17-B-7600	C
5.	4	Each	BELTS, pistol, automatic	A-2-B-1490	B
6.	2	Pair	BINOCULARS, 6 x 30	18-B-1135	B
7.		Pair	BINOCULARS, 7 x 35	18-B-1138	B
8.		Each	BLINKER, Signal Gun, battery type.	17-B-1600	B
9.	4	Each	BOTTLES, vacuum, 1 quart	13-B-500	B
10.	1	Each	CASE, first-aid (armed guard)	S2-510	
11.	1	Misc.	CLEANING, supplies (brushes, soap, buckets, rags, etc.)		
12.		Set	FLAGS, alphabet code No. 4	5-F-255-80	C
13.		Set	FLAGS, numeral No. 4	5-F-4375 to 4384	C
14.		Set	FLAGS, semaphore	5-F-4375 to 4384	C
15.	10	Each	FLASHLIGHTS, 2 cell pocket type	17-F-13452	C
16.	49	Each	GAS MASKS		B
17.		Each	GLOBES, hand lantern	31-G-270	C
18.	4	Pair	GOGGLES, for lookout, light density	37-G-3555	C
19.	2	Pair	GOGGLES, for lookout, dark density	37-G-3450	C
20.	9	Each	HELMETS, steel standard	37-H-	B
21.		Each	HELMETS, steel to wear with headphone	37-H-	B
22.	4	Each	HOLSTERS, automatic pistol (colt)	A-2-H-1435	B
23.		Each	LAMPS, blinker signal gun	17-L-6300	C
24.	20	Each	LAMPS. flashlight	17-I-6320	C
25.	2	Each	LANTERNS, hand, portable, type "J"	17-L-7760	B
26.	1	Each	MEDICAL GUN BAG, equipment	S-2-03	
27.	1	Each	MEGAPHONE, 18" small	37-M-330	C
28.	1	Each	MEGAPHONE, 32" large	37-M-335	C
29.		Pair	MITTENS, ammunition-handling asbestos	A (L) 2-G-48116	C
30.	4	Each	PISTOLS, automatic, colt, 45, No. 1911	A-2-P-3415	B
31.		Gal.	PAINT, dark gray, formula 5D	52-P	C
32.		Each	ROPE, 125 fath. 3" manila, for spar	21-R-413	C
33.		Each	SEARCHLIGHT, signal 8" (Crouse-Hinds)	17-S	B
34.		Each	SPAR, towing	23-S-180	B
35.		Each	SPY GLASS, quartermaster, 16 power	18-S-2255	B
36.	1	Misc.	STATIONARY (No. 53 items) (not over $30)		C
37.	8	No.	Magazines, pistol		
38.	4	No.	Carriers, magazine, pistol		
39.	2	No.	Brushes, paint, Gr. B.	B-2617	
40.	2	No.	Brushes, varnish, 1"	B-5220	
41.	2	No.	Brushes, varnish, 2½"	B-5225	
42.	6	No.	Lamps, hand lantern	17-L-6390	
43.	16	Yds.	Bunting, yellow	5B238	
44.		Set	CONVOY LIGHTS, Colored		B
45.	1	Each	WAKE LIGHT, Screened, Type No. 2	Maritime Commission	B

DEGAUSSING OPERATION

Type of Coils ....M.....F.....&.....Q................ (M only; MF & Q: MF, Q & A)   Compass Compensated ....Yes..........

If not Coiled — Date Wiped ....or Date Flashed ....

Date Calibrated ....5/5/42........................   Range ....Wolf Trap.................................. (Wolf Trap, Newport, etc.)

Degaussing Factor ...72'... (From Range)

Date Depermed .... (If shown necessary by range)

—4—

Figure E-13. Port director's material report for Armed Guard Unit for *R.W. Gallagher* 1942, p.4 (OCNO 1942f).

(COPY)

18 January 1944.

From: Paul W. Kraemer, Lt.(jg) USNR, USS YP-191

To: The Commandant, 8th Naval District
Naval Industrial Manager, 8th Naval District
Commanding Officer, NTSch(Salvage), Pier 88, NY, NY.

Subject: R.W.GALLAGHER (Tk), Wreck No. 628, Determination of depth of water above the wreck of.

1. Information regarding the subject vessel as compiled by the U.S.Hydrographic Office in the Wreck Information List published 1 January, 1943, is as follows: the R.W. GALLAGHER, an American tanker, was sunk 13 July, 1942 and was reported to be in position 28-32 N; 90-59 W with the tops of her masts showing. She was later reported to be totally submerged in position 28-32-30 N; 90-58-24 W as marked by a Lighted Buoy 200 yards to the north. The ship dimensions are 445.5 x 64.2 x 35.2 The cargo being carried was 83,000 bbls. of bunker fuel.

2. Upon reporting to the site of the wreck, it was noticed that considerable oil slicks were present several hundred yards north of the Wreck Buoy. The wreck was then contacted by grapnelling in the vicinity of the oil slicks, and the position of contact was marked with a can buoy. The surrounding depth of water was 90 feet.

3. After mooring next to the marker buoy, divers, N.Badovinatz SF1c and the writer, descended on the wreck for an inspection and so as to attach marker buoys to the foremost and after-most extremities of the hulk. While accomplishing this, the divers reported the ship to be turned over on her beam ends and well buried in the soft muddy bottom.

4. Two methods of sounding were carried out simultaneously between and in the vicinity of the marker buoys. Lead line readings were taken over the side of the salvage ship, while a drag-sounding method, as described below, was also employed. In employing the drag-sounding method, a 12-foot steel bar 1 1/2 inches in diameter and having a 100-pound concrete weight secured to each end, was hung 50 feet below the surface of the water at the stern of the salvage ship by means of two wire rope straps. Forces on the bar were "felt" by means of a length of 21-thread secured to either end of the bar and held by hand on topside. The salvage ship was allowed to drift between and in the vicinity of the marker buoys. Ideal weather conditions prevailed during the soundings.

1290645
MET

Figure E-14. *R.W. Gallagher* (Tk), Wreck No. 628, Determination of depth of water above the wreck of, pg. 1 (Kraemer 1944, courtesy of J. Avery Munson Collection).

(COPY)

- 2 -

Subj: R.W.GALLAGHER, (Tk), Wreck No. 628, Determination of depth of water above the wreck of.

- -

5. The minimum depth of water over the wreck as found by the sounding lead was 59 feet. There were no contacts made by the drag sounding-bar. The soundings were taken approximately midway between high and low water during the ebb tide of the afternoon of 10 January, 1944; the mean range of tide in the vicinity of the wreck or its reference station, is not listed in the Tide Tables. Notwithstanding the mean tidal range, it was thus found that a minimum depth of water over the wreck of the R.W.GALLAGHER is greater than 50 feet. It was for this reason that no demolition work was carried out on the hulk.

/s/ P.W. KRAEMER

P.W. Kraemer.

Figure E-15. *R.W. Gallagher* (Tk), Wreck No. 628, Determination of depth of water above the wreck of, pg. 2 (Kraemer 1944, courtesy of J. Avery Munson Collection).

SITE 386 *HEREDIA*

Figure E-16. Timetable cover from States Steamship Company highlighting *General Pershing* and her sister ships, 1932. Image courtesy of Bjorn Larsson.

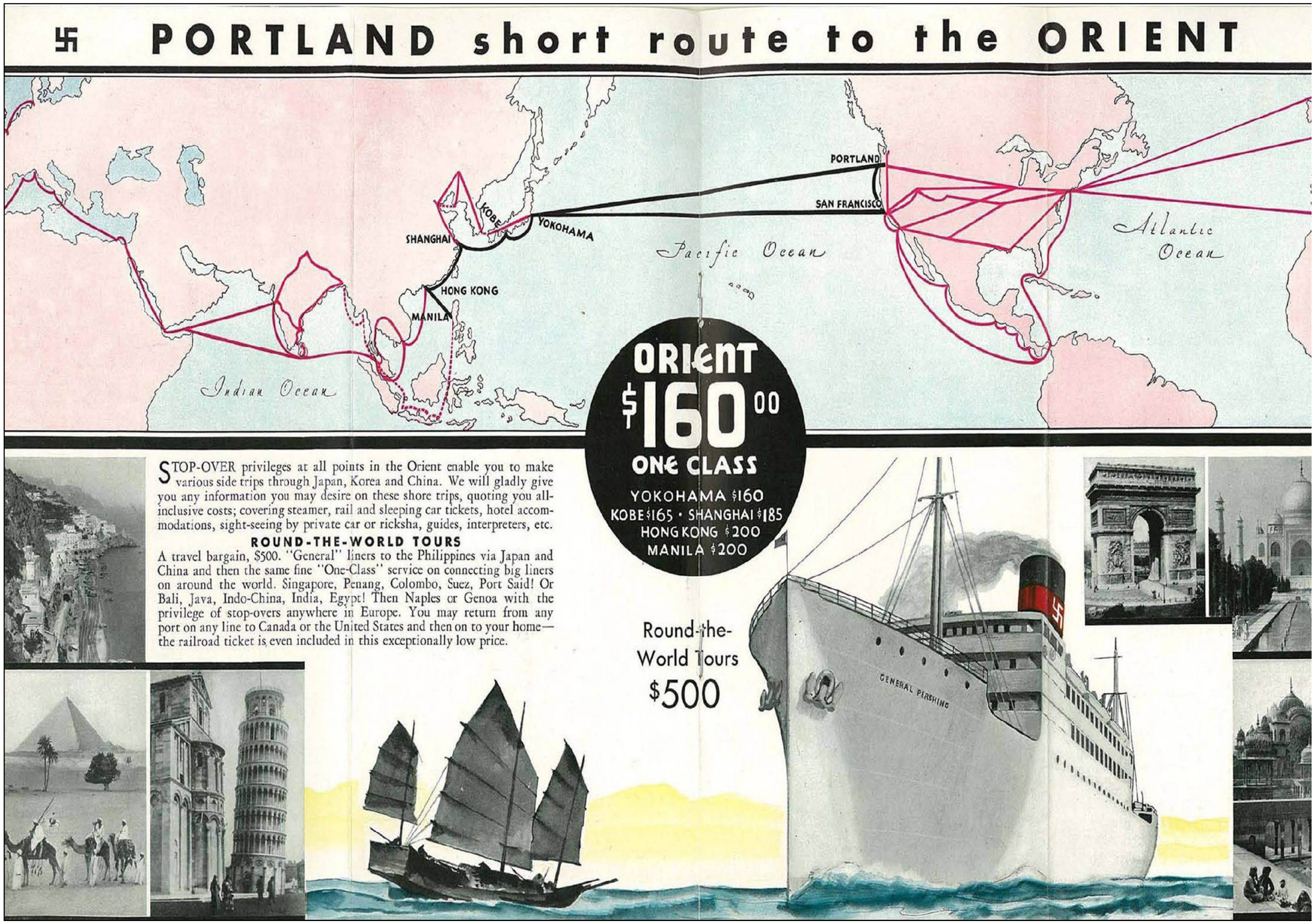


Figure E-17. Timetable pages from States Steamship Company, showing drawing of *General Pershing*, 1932. Image courtesy of Bjorn Larsson.

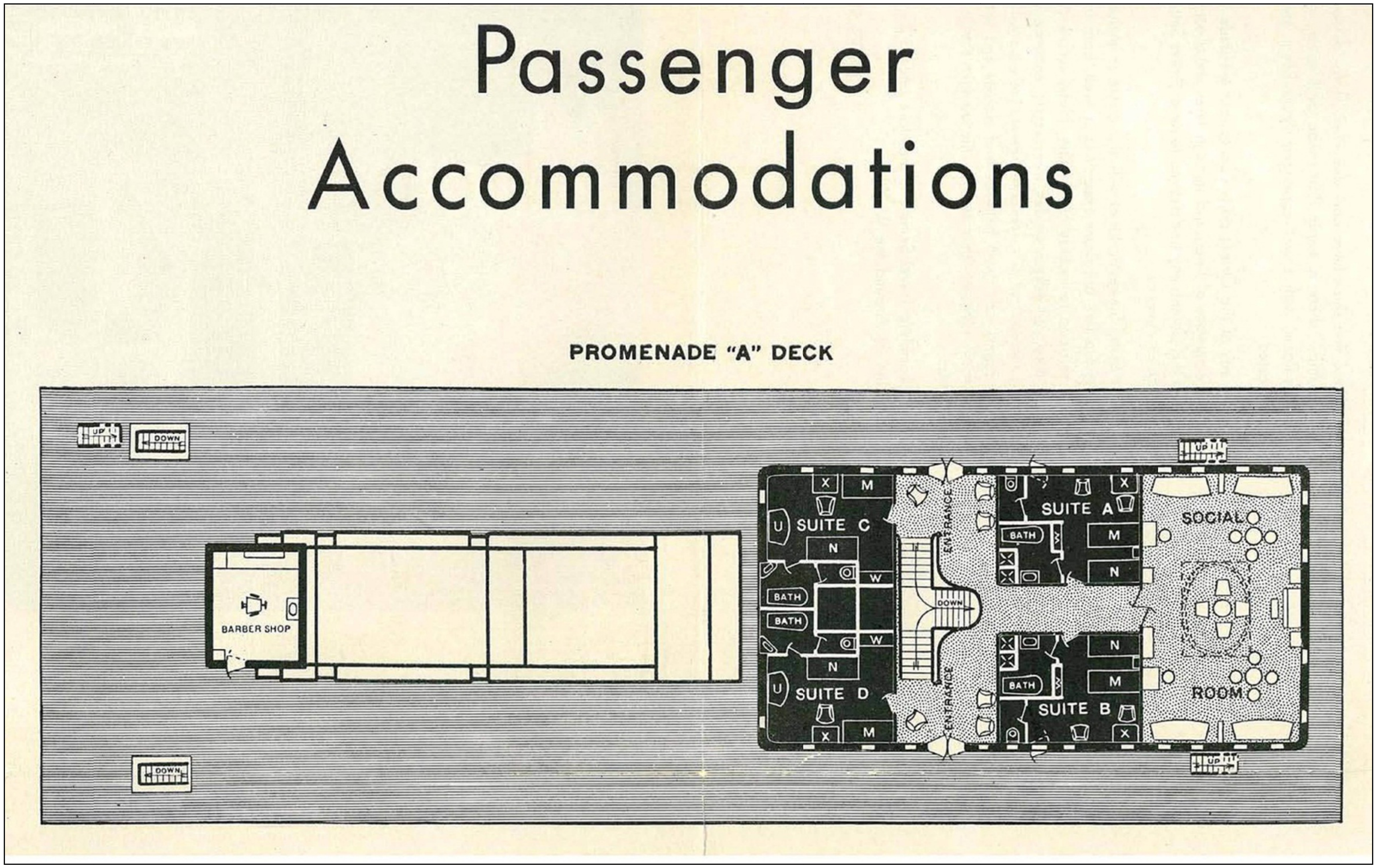


Figure E-18. Pages of timetable from States Steamship Company, illustrating cabin plans for the General Liners, 1934. Image courtesy of Bjorn Larsson.

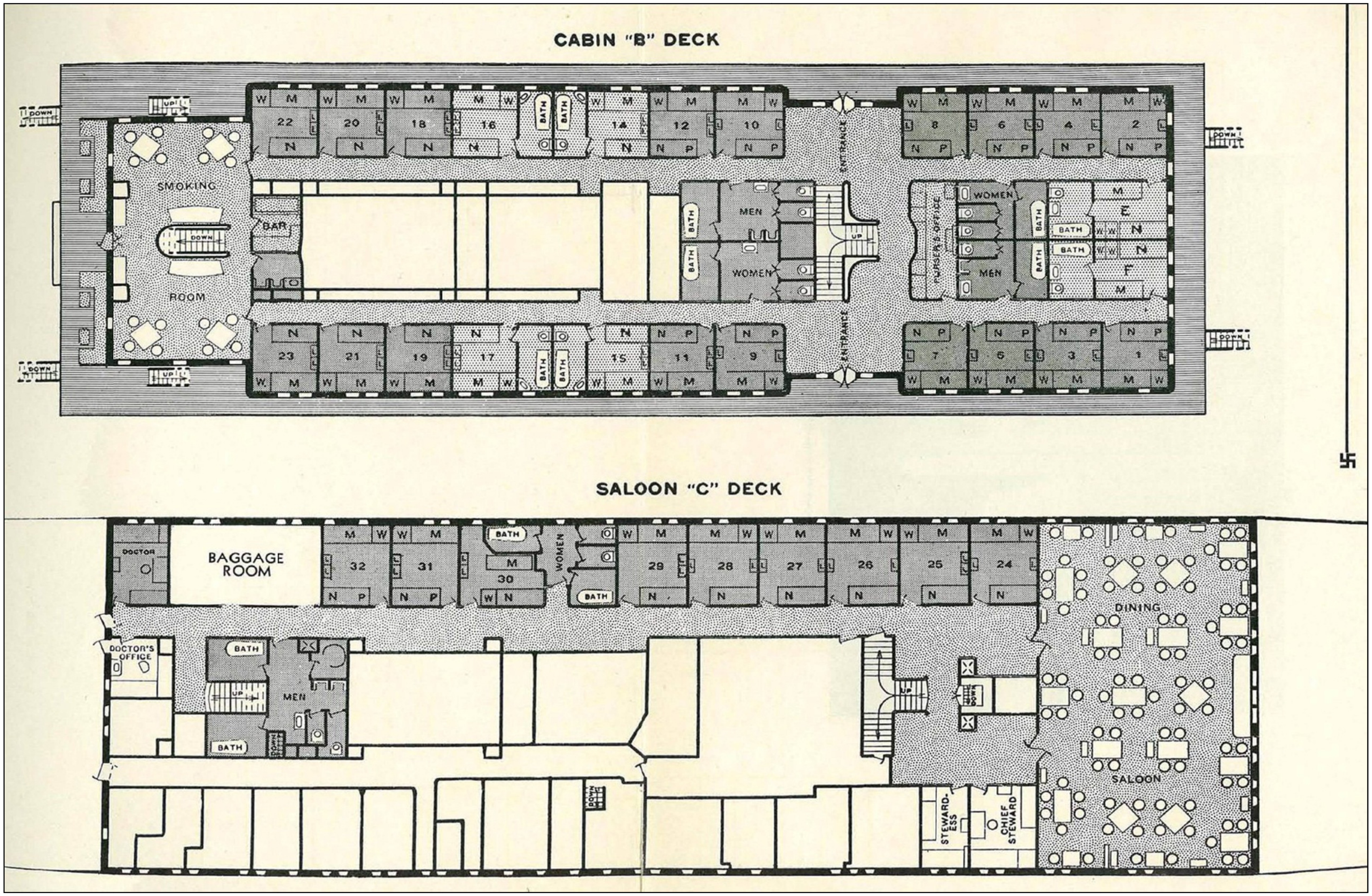


Figure E-19. Page of timetable from States Steamship Company, illustrating cabin plans for the General Liners, 1934. Image courtesy of Bjorn Larsson.

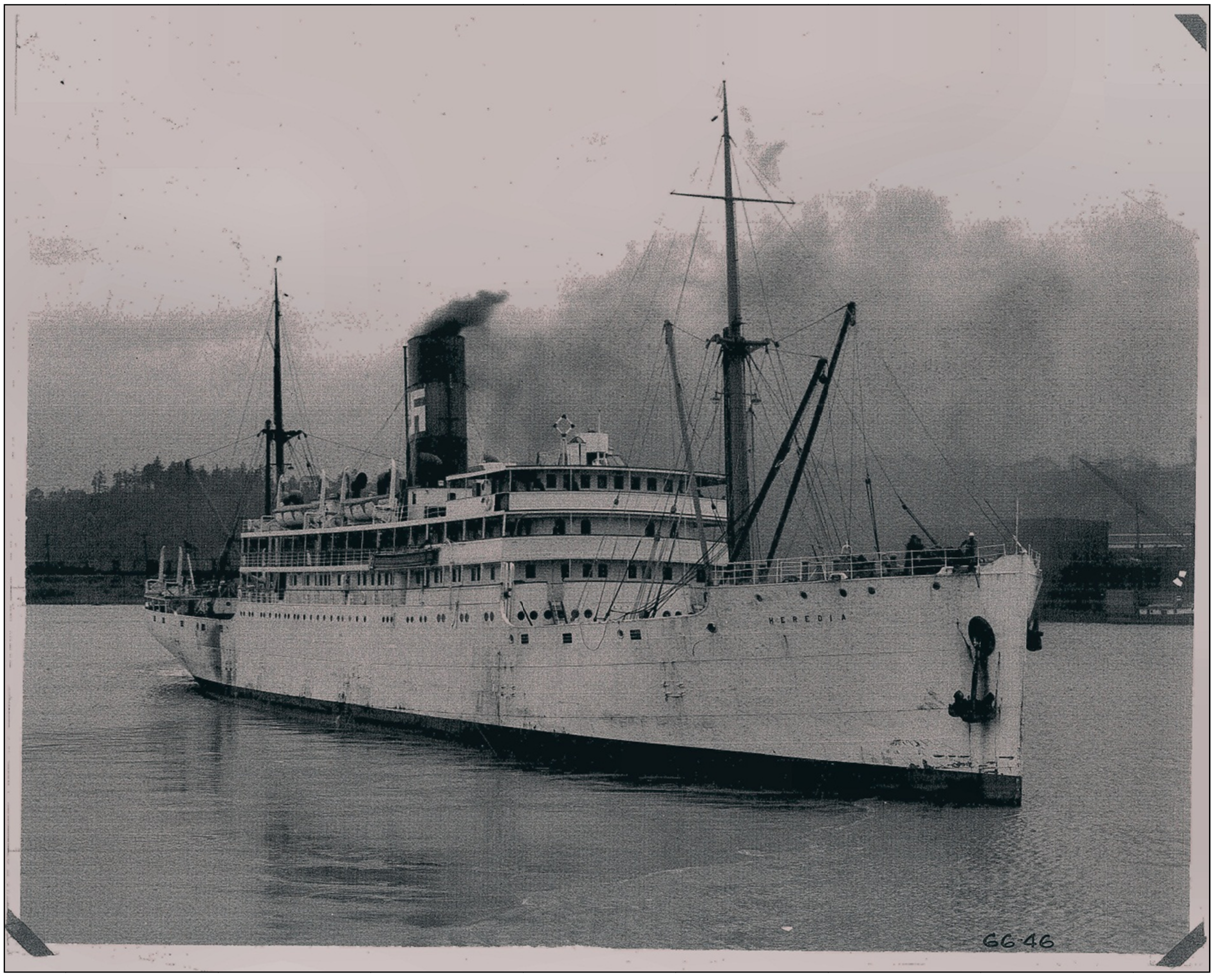


Figure E-20. Image of *Heredia* in Portland, Oregon, December 23, 1932, upon commencement of the charter to States Steamship Service. Image courtesy of the Oregon Historical Society.

SERIAL PD 0755

MS
SS HEREDIA

AREA OF OPERATION 2

GROSS TONNAGE 3/26/42

COMPLETED ARMAMENT DATE 3/26/42

WHERE ARMED Bethlehem, 56th St., Bklyn.

ARMAMENT

GUN SIZE	LOCATION
1-23 cal. 3" Mk XIV	Poop deck

MACHINE GUNS	LOCATION
1-.30 Lewis	Starboard deck house
1-.30 Lewis	Port deck house
	Not mounted

INSTALLATIONS

ITEM	DETAIL
1. Splinter Protection	Steel
2. Gun Foundations & Magazines	Magazine starboard; shelter deck
3. Painting	Dark gray
4. Darkening Ship Facilities	Installed
5. Reinforce Sea Chests	Yes
6. Fire Control Communi'ion System	Installed for after gun
7. Sky Look Out Stations	Being installed now.
8. Results D.M.O.	-
9. Messing Facilities	Separate.

ACCOMMODATIONS NAVY PERSONNEL

ARMED GUARD UNIT	SPACE	LOCATION
Officer in Charge	Room # Spare room	Bridge, port deck
Petty Officer		
Seamen	12 men in three rooms 4 bunks each	Main deck forward port

DECLASSIFIED
Authority NND79016
By NARA Date 5/1/41

COMMUNICATION GROUP

Enlisted Men (3) ________

Standee: Bunks No.________

EQUIPMENT

ITEM	QUANTITY
1. Navy - Type Life Jackets..........	24 on board
2. Life Rafts (Capacity 18 per raft)..	4 on board
3. Life Boat........................	4; 46 persons each
4. Emergency Rations.................	On board

Figure E-21. Port director's report arming merchant vessels for *Heredia* 1942, p.2 (OCNO 1942a).

CONFIDENTIAL

PORT DIRECTOR'S MATERIEL REPORT
FOR ARMED GUARD UNIT

Serial PD 0755

[redacted]

ON BOARD SS HEREDIA

ITEM NO.	QUANTITY NO.	UNIT	DESCRIPTION	STOCK NUMBER	TITLE
1.	1	Each	BAG, canvas, weighted #C&R 434791	24-B-60	C
2.	-	Cell	BATTERIES, Blinker Signal Gun	17-B-7040	C
3.	36	"	BATTERIES, flashlight	17-B-7210	C
4.	8	"	BATTERIES, dry, hand lantern	17-B-7600	C
5.	4	Each	BELTS, pistol, automatic	A-2-B-1490	B
6.	2	Pair	BINOCULARS, 6 x 30	18-B-1135	B
7.	-	"	BINOCULARS, 7 x 35	18-B-1138	B
8.	-	Each	BLINKER, Signal Gun, battery type	17-B-1600	B
9.	1	"	BOTTLES, vacuum, 1 quart	63-B-500	B
10.	1	"	CASE, first-aid (armed guard)	S2-510	
11.	Yes	Misc.	CLEANING, supplies(brushes,soap,buckets,rags, etc.		
12.	-	Set	FLAGS, alphabet code # 4	5-F-255-80	C
13.	-	Set	FLAGS, numeral # 4	5-F-4375to 4384	C
14.	-	Set	FLAGS, semaphore	5-F-5100to 5110	C
15.	7	Each	FLASHLIGHTS, 2 cell pocket type	17-F-13452	C
16.	-	"	GAS MASKS		B
17.	4	"	GLOBES, hand lantern	31-G-270	C
18.	6	Pair	GOGGLES, for lookout,light density	37-G-3555	C
19.	6	"	GOGGLES, for lookout,dark density	37-G-3450	C
20.	35	Each	HELMETS, steel standard	37-H-	B
21.	-	"	HELMETS, " to wear with headphone	37-H	B
22.	4	"	HOLSTERS, automatic pistol(colt)	A-2-H-1435	B
23.	-	"	LAMPS, blinker signal gun	17-L-6300	C
24.	14	"	LAMPS, flashlight	17-I-6320	C
25.	2	"	LANTERNS, hand, portable, type "J"	17-L-7760	B
26.	3	"	MEDICAL GUN BAG, equipment	S-2-03	
27.	1	"	MEGAPHONE, 18"small	37-M-330	C
28.	1	"	MEGAPHONE, 32" large	37-M-335	C
29.	4	Pair	MITTENS,ammunition-handling asbes.	A(L)2G-48116	C
30.	4	Each	PISTOLS,automatic,colt,45,# 1911	A-2-P-3415	B
31.	1	Gal.	PAINT, dark gray, formula 5D U	52-P-5333	C
32.	1	Each	ROPE,125fath.3"manila,for spar	21-R-413	C
33.	-	"	SEARCHLIGHT,signal8"(Crouse-Hinds)	17-S	B
34.	-	"	SPAR, towing	23-S-180	B
35.	-	"	SPY GLASS, quartermaster,16power	18-S-2255	B
36.	Yes	Misc.	STATIONARY(#53 items)(not over$30)		C
37.	1	Qt.	Tinting material, Formula 5-T-M	52-T-841	C
38.					
39.					
40.					
41.					
42.					
43.					
44.		Set	CONVOY LIGHTS, Colored		B
45.		Each	WAKE LIGHT, Screened, Type # 2		B

DEGAUSSING OPERATION

A. Coiled Yes

B. Wiped

C. Calibrated

D. Flashed

E. Depermed

F. Compass C

REMARKS

Figure E-22. Port director's material report for Armed Guard Unit for *Heredia* 1942, p.1 (OCNO 1942d).

ARMED GUARD CENTER REPORT OF MATERIALS
FURNISHED TO ARMED GUARD UNITS.

CONFIDENTIAL
SERIAL PD 0755

INSTRUCTIONS ISSUED TO ARMED GUARD OFFICER--SS ~~MS~~ HEREDIA .

1. Ordnance and Gunnery Instructions for Armed Guards.....YES

2. General Instructions for Commanding Officer of Naval Armed Guards on Merchant Ships, Nov. 15, 1941..........YES

3. Instructions for operating Naval Transports and Merchant Vessels in Time of War - Part I.................YES

4. Test Firing of Guns After Leaving Port -- (CNO ltr. No. 396123 of 1 December, 1941 -- Attach to Orders.....YES

5. SAFETY PRECAUTIONS--(Condensed from Naval Regulations for Armed Guard Officers)............................YES

6. SILHOUETTES.......................Surface Raiders......YES
.......................Aircraft.............YES

7. Signals for Control of Merchant Vessels by Aircraft....YES

8. Publication of German Raider Tactics..................YES

9. Anti-Aircraft Machine Gun Training Centers............YES

MOVABLE EQUIPMENT ISSUED TO ARMED GUARD UNIT

	ITEM	QUANTITY	SPECIFICATION NUMBER	DESCRIPTION
SPECIAL	1		72-A	Arctics, 4 buckle, cashmerette
	2		37-C-4	Coats, balloon cloth (Spec.)
WINTER	3		37-C-4	Trousers " " (Sub.)
	4		37-C-5	Coats, woolen (clothing)
CLOTHING	5		37-C-5	Trousers, " (
	6		N.37-G-15	Gloves, leather, not lined
	7		N.72-C-1	Sou'westers, balloon cloth
	8			Coat, Sheepskin
	9		N.27-B-7 Spr-11	Blankets, Regular Navy
	10	6	N.72-C-1	Overalls (Type C)
FOUL	11	6	N.72-C-1	Coats, short (Type B)
WEATHER	12	-	N.72-C-1	Coats, long (Type A)
CLOTHING	13	6	N.72-C-1	Sou'westers, balloon cloth

WELFARE AND RECREATIONAL EQUIPMENT

As furnished by the Supply Officer, ARmed Guard Center and by the Red Cross.

COMMENTS:

DECLASSIFIED
Authority NND 790161
By [illegible] NARA Date 5/11/11

Figure E-23. Armed Guard Center report of materials furnished to Armed Guard Units for *Heredia* 1942, p.2 (OCNO 1942e).

ADDRESS NAVY DEPARTMENT,
BUREAU OF SHIPS. REFER TO
FILE No.

H3-8 (880)

NAVY DEPARTMENT
BUREAU OF SHIPS
WASHINGTON, D. C.

19 FEB 1944

To: The Chief of Naval Operations, Hydrographic Office, Suitland, Md.

Subj: Menaces to Navigation, Removal Of.

1. Facilities operating under the supervision of the Bureau have been engaged in removing wrecked vessels constituting menaces to navigation. The following vessels have been demolished and there is now an acceptable depth of water over them.

Name	Wreck No.	Removed By
H.M.S PENTLAND FIRTH	577	Navy Salvage Service
S.S. TOLTEN	215	Navy Training School (Salvage)
S.S. GULF TRADE (Stern)	217	" " " "
S.S. PERSEPHONE	219	" " " "
S.S. R.P.RESOR	218	" " " "
S.S. LEMUEL BURROWS	232	" " " "
S.S. J.R. WILLIAMS	244	" " " "
S.S. DAVID MCKELVY	487	" " " "
S.S. SANTORE	274	Navy Salvage Service
S.S. W.E. HUTTON	366	Navy Salvage Service
S.S. OCEAN VENUS	443	Navy Salvage Service

2. Demolition operations were planned on the following vessels but sweeping over their buoyed or charted positions disclosed that they had either disappeared or that there was an acceptable depth of water over them.

Name	Wreck No.	Survey Made By
EVENING STAR	None Assigned. Position: 38-51-05N 74-36-06W	Navy Training School (Salvage)
S.S. SCHEHERAZADE	493	" " " "

Figure E-24. Letter to the Chief of Naval Operations, Hydrographic Office, regarding the removal of menaces to navigation, p.1. U.S. Navy Department, Bureau of Ships 1944. Courtesy of the J. Avery Munson Collection.

H3-8(426366)

H3-8 . (880)

Name	Wreck No.	Survey Made By
S.S. VIRGINIA	490	Navy Training School(Salvage)
S.S. HEREDIA	498	" " " "
S.S. R.W. GALLACHER	628	" " " "
S.S. R.H. PARKER	535	" " " "

3. The Hydrographic Office will be advised when additional demolition work on wrecked vessels has been accomplished.

FEB 22 1944

B Mansean

Chief of Bureau

By Direction of Chief of Bureau

Copy to:
COM 3
COM 4
COM 5
COM 7
COM 8
COMEASEAFRON
COMGULFSEAFRON
CO NTS(S), Pier 88, North River, New York.
SUPSALV., 17 Battery Pl., New York.

MARITIME SECURITY

MAR 10 1944

- 2 -

Figure E-25. Letter to the Chief of Naval Operations, Hydrographic Office, regarding the removal of menaces to navigation, p.2. U.S. Navy Department, Bureau of Ships 1944. Courtesy of the J. Avery Munson Collection.

GE SPEWR

Subject: Menaces to Navigation,
Removal of.

1st Ind.

Office, C. of E., 2 February 1944.

To: The Chief of the Bureau of Ships, Navy Department, Washington, D.C.

1. By authority of the Secretary of War, removal of the following wrecks is authorized under the provisions of Section 19 of the River and Harbor Act of 3 March 1899 (30 Stat. 1154; U.S. C. 414):

Item	Name	LOCATION
30	SCHEHERAZADE	28-42-15 N, 91-23-00 W About 32 miles southwest of Caillou Bay, Louisiana.
35	EMPIRE MICA	29-18-43 N, 85-21-10 W About 17 miles south of Cape San Blas, Florida.
37	OAXACA	28-23-00 N, 96-11-00 W About 10 miles east of Pass Cavallo, Texas.

2. Reimbursements for the costs of removing the wrecks will be made upon submission of Form 1080.

3. The District Engineer at New Orleans reports that the S.S. HEREDIA (Item 32) has not been found in sweeping by wire drag over the position of the wreck: the S.S. R.W. GALLAGHER (Item 33) is lying on its side and iesettling in soft mud with a minimum depth of 10 fathoms over the wreck; and the S.S. R.H. PARKER, JR. (Item 34) has been flattened by recent bombing operations and the wreck buoy has been removed from the site. It is therefore suggested that removal operations on these wrecks be deferred.

4. In accordance with paragraph 2 of basic letter Item 31, the S.S. VIRGINIA, which has not been located, has been stricken from the wreck list.

Enc. A

Figure E-26. Letter to the Chief of the Bureau of Ships, Navy Department, regarding the removal of menaces to navigation, p.2. Office of the Chief of Naval Operations 1944, Courtesy of the J. Avery Munson Collection.

SITE 373 *CITIES SERVICE TOLEDO*

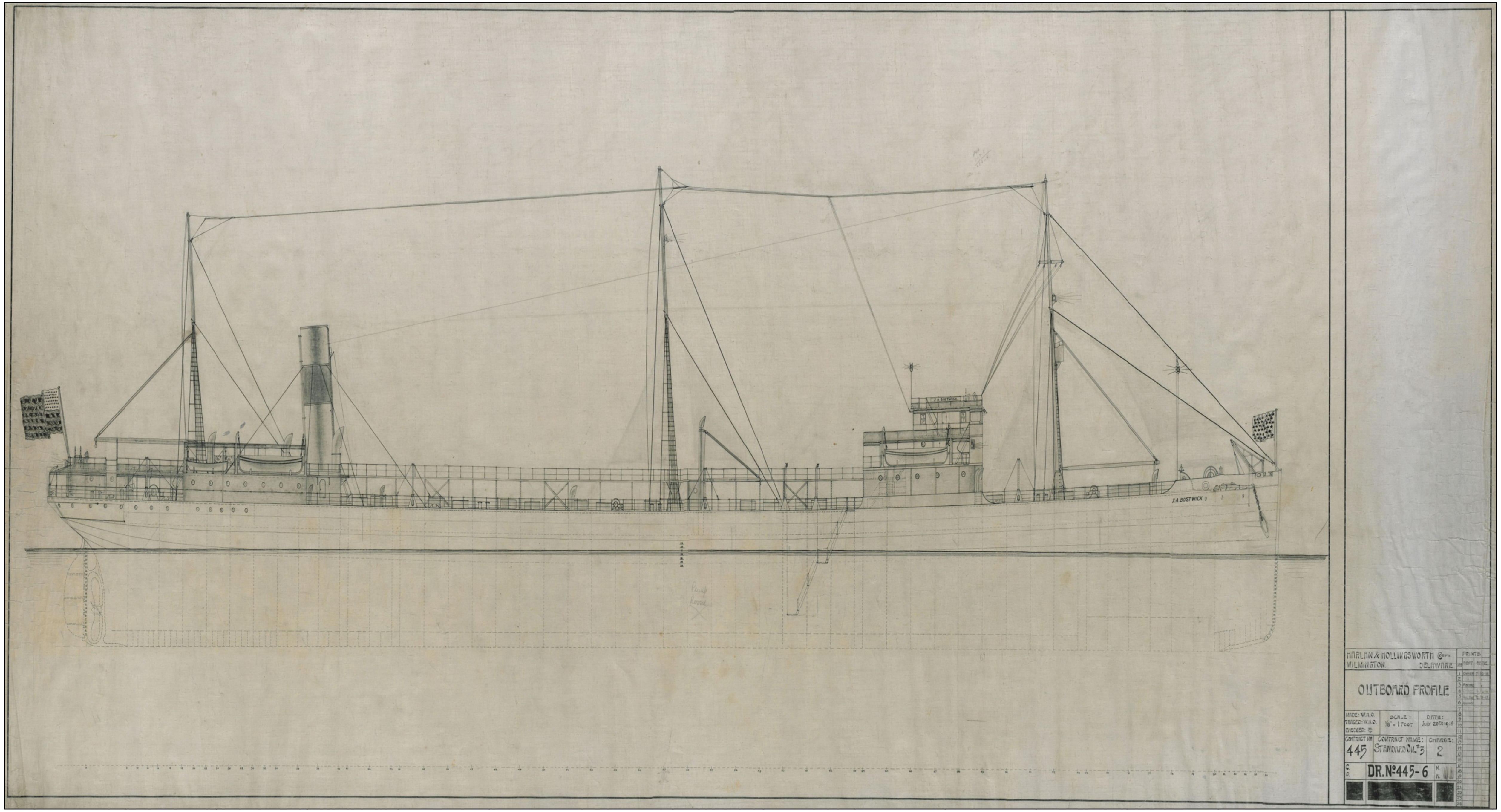


Figure E-27. *J. A. Bostwick* outboard profile plan, Hull No. 445, Harlan and Hollingsworth Corp., Wilmington, Delaware, 1916. Courtesy of Hagley Museum and Library, Accession 1699, Bethlehem Steel Company Archive.

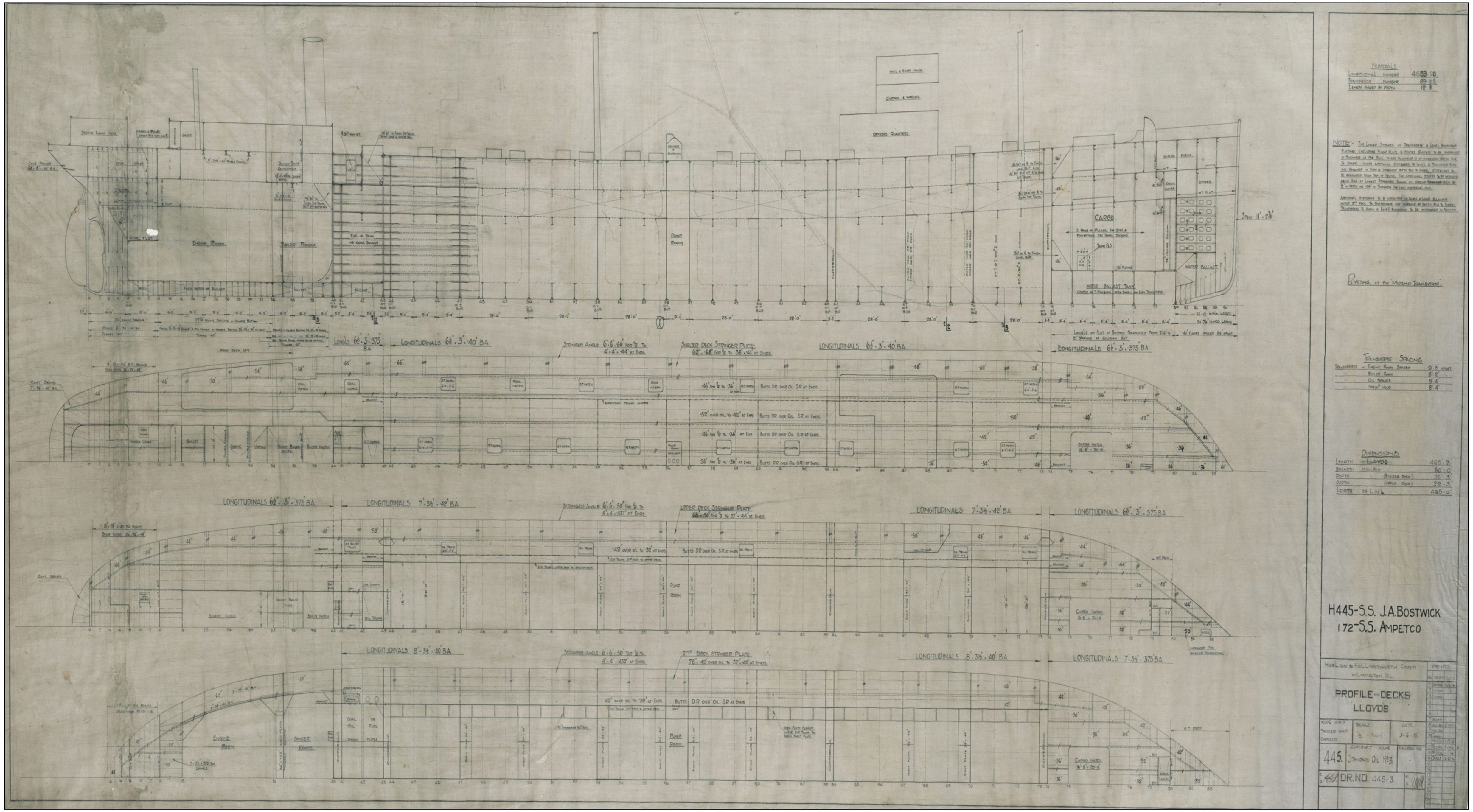


Figure E-28. *J. A. Bostwick* profile and deck plans, Hull No. 445, Harlan and Hollingsworth Corp., Wilmington, Delaware, 1916. Courtesy of Hagley Museum and Library, Accession 1699, Bethlehem Steel Company Archive.

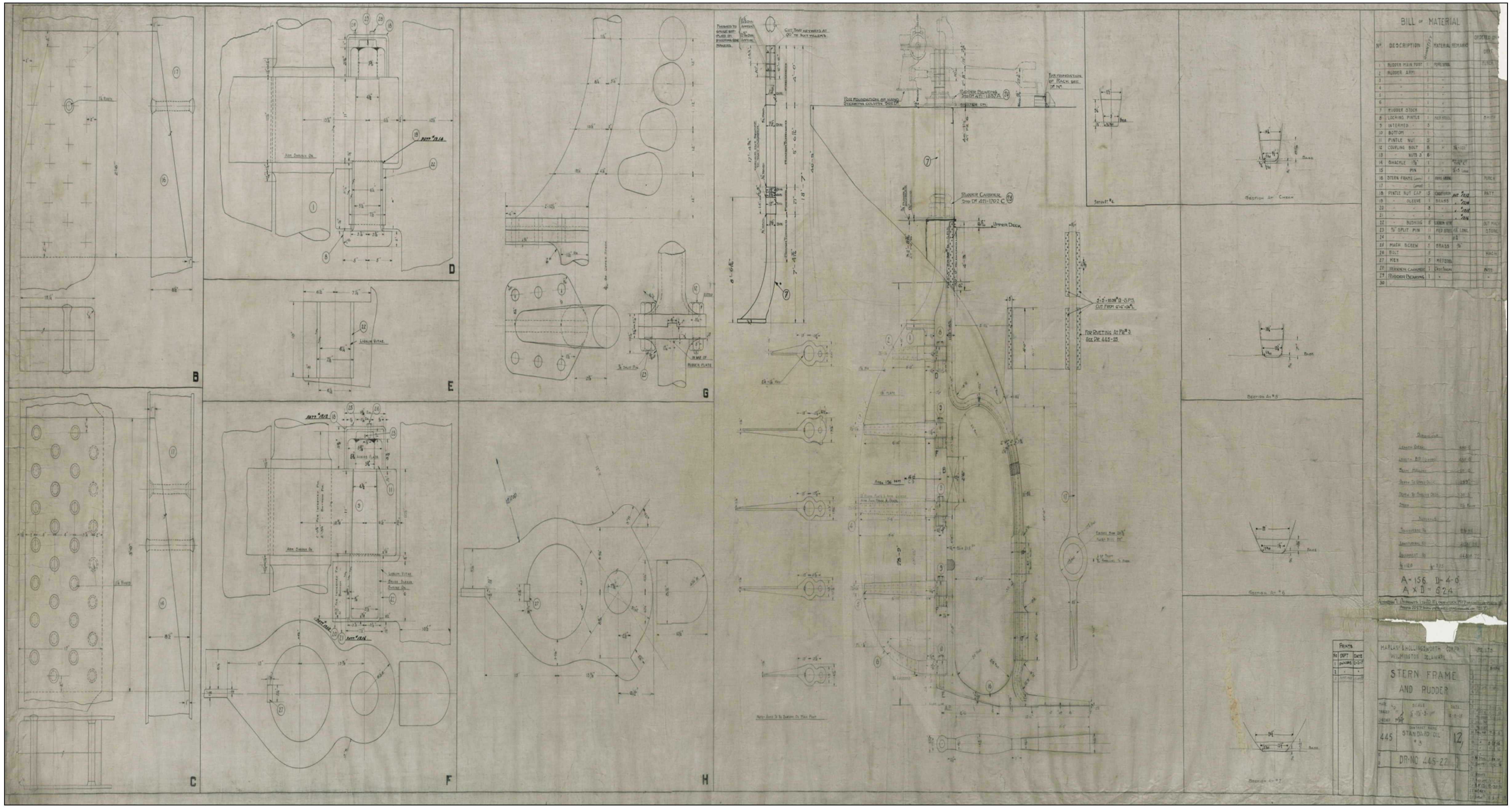


Figure E-29. *J. A. Bostwick* stern frame and rudder plans, Hull No. 445, Harlan and Hollingsworth Corp., Wilmington, Delaware, 1916. Courtesy of Hagley Museum and Library, Accession 1699, Bethlehem Steel Company Archive.

COUNTERPART I

FORM NO. 102
WARSHIPOILTIME
5/22/42
Part I

Contract No. WSA-1611-

WAR SHIPPING ADMIN[illegible]TION

REQUISITION TIME CHARTER
FOR TANK VESSEL

TIME CHARTER as of **April 20**, 1942, between **Cities Service Oil Company**

Address **60 Wall Tower, New York, New York**
OWNER of the good **United States** [redacted]**"CITIES SERVICE TOLEDO"**
(herein called the "Vessel"), with hull, machinery and equipment in a thoroughly efficient state, as far as the exercise of due diligence can make her so, and UNITED STATES OF AMERICA, CHARTERER, particulars as follows:

DEADWEIGHT capacity for cargo, fresh water and stores about **12615** tons
(2240 lbs.), including Permanent Bunkers for fuel **1250** tons/[redacted]
ON MEAN DRAFT (Assigned Summer Freeboard, 1930 Convention) **27** feet **6-1/4** inches
CLASSED **✠ 100 A 1 British Lloyds**
SPEED about **10.1** knots fully laden under good weather conditions
CONSUMPTION per 24 hours about **30** tons/[redacted]
BULK CARGO CAPACITY (less 2% for expansion and excluding permanent bunkers)
95,000 barrels
DISCHARGE CAPACITY all pumps per hour **4000** [redacted]/barrels
TANKS COILED **All Main Tanks**

LAST TWO SUCCESSIVE CARGOES - **Crude and #5 oil**
PANAMA CANAL TRANSIT highest grade products under current regulations Grade **B**
supplement No. **18**
CONSTRUCTED AND EQUIPPED SUEZ CANAL TRANSIT with crude petroleum or products in bulk-**Ye**

****

OWNER agrees to let and CHARTERER agrees to hire the VESSEL, from time of delivery for trading subject to the following terms:

Part I

A. PERIOD OF CHARTER: From the time of delivery to the time of expiration of the voyage current at the end of the emergency proclaimed by the President May 27, 1941; PROVIDED, That after September 1, 1942 either party may sooner terminate this Charter (the Vessel to be redelivered as hereinafter provided) upon not less than 30 days' written or telegraphic notice.

B. TRADING LIMITS: World-wide.

C. RATE: Option I - A basic rate of $ **3.60** per deadweight ton per month computed in accordance with the Charterer's General Order No. 8, Supplement No. 1, together with any appropriate adjustments or premiums in accordance with such Supplement No. 1 to General Order No. 8, which full rate shall be subject to revision not more often than once in every 120 days as in paragraph D below provided; or

Option II - 75 percentum of the full rate payable in accordance with Option I above and such further sum, if any, adjudicated to be necessary to make up just compensation for the use of the Vessel and the services required in connection therewith under the terms of this Charter, pursuant to the provisions of Section 902 of the Merchant Marine Act, 1936, as amended.

D. RATE REVISION (Option I only): At any time after September 1, 1942, but not more often than once every 120 days, either party may request a redetermination of the rate of charter hire upon 30 days' written or telegraphic notice to the other. If a revised rate is determined and agreed upon within such 30-day period, it shall become effective as of the date specified in the determination and shall continue for the balance of the period of this Charter subject to further redetermination in accordance with the provisions of this paragraph. If a revised rate is not determined or agreed upon within such 30-day period, then the rate of hire in effect at the time of such notice shall apply only until noon (EWT) of the day after the end of such 30-day period, and charter hire for the balance of the period of this Charter shall be just compensation within the meaning of Section 902 of the Merchant Marine Act, 1936, as amended, and shall

Figure E-30. War Shipping Administration requisition time charter for *Cities Service Toledo* 1942, p.1 (USMC 1942e).

-2-

(WARSHIPOILTIME Part I)

be established and paid as therein provided. In such latter event, the use of the Vessel, if not theretofore requisitioned, shall be deemed to have been requisitioned pursuant to Section 902 as of noon (EWT) of the day after the end of such 30-day period. This paragraph shall not operate so as to terminate the period of or otherwise modify the provisions of this Charter, notwithstanding any such modifications, adjustments, or terminations of the charter hire provisions of this Charter by operation of this paragraph.

E. WAR RISK INSURANCE VALUATION:

Option I - The sum of $ **65.00** per deadweight ton computed in accordance with General Order No. 9 of the Charterer together with any premiums or adjustments, or any assumption of war risk, general average, collision or salvage risks or liabilities as may be provided for in said General Order and which are applicable to the Vessel by the terms of said General Order; PROVIDED, That if said General Order No. 9 does not set forth a formula for ascertaining such valuation, then Option II below shall apply unless otherwise agreed in the Special Provisions hereinbelow; or

Option II - Just compensation to be determined in accordance with Section 902 of the Merchant Marine Act, 1936, as amended, for any loss or damage due to the operation of a risk assumed by the Charterer under the terms of this Charter to the extent the person entitled thereto is not reimbursed therefor through policies of insurance against such loss or damage.

F. PORT OF DELIVERY: **Petty's Island, N. J. - April 20, 1942**
G. PORT OF REDELIVERY: Not less favorable to either party than the port of delivery, unless otherwise agreed.
H. NOTICE OF REDELIVERY: Fifteen (15) days
I. UNIFORM TERMS: This Charter consists of this Part I and Part II, the Uniform Time Charter Terms and Conditions for Tank Vessels, published in the Federal Register of June 19, 1942. Unless in this Part I otherwise expressly provided, all of the provisions of said Part II shall be part of this Charter as though fully incorporated herein.

J. SPECIAL PROVISIONS:

1. Unless the Owner otherwise indicates in the execution hereof, or unless the proviso in War Risk Insurance Valuation Option I applies to the Vessel which will be indicated if the sum in said Option I is written "none", Rate Option I and War Risk Insurance Valuation Option I shall apply and in such event, in consideration of the compensation provided and the other obligations assumed by the Charterer hereunder, the Owner accepts this Charter in full satisfaction of any and all claims he has or may have against the Charterer arising out of the requisition of the Vessel and accepts the compensation herein provided for as the compensation required by law. If the Owner in the execution hereof elects Rate Option I and War Risk Insurance Valuation Option II, then the Owner shall accept this Charter and such hire in full satisfaction of any and all claims he has or may have against the Charterer arising out of the requisition of the Vessel and as the compensation required by law except as to any loss or damage due to the operation of a risk assumed by the Charterer under the terms of this Charter to the extent the person entitled thereto is not reimbursed therefor through policies of insurance against such loss or damage.

2. (a) If at the time of requisition the Vessel had cargo on board, then charter hire for the Vessel's first voyage shall be adjusted on such fair and equitable accounting basis as the Charterer shall determine.

(b) If redelivery is made at a port that is more favorable to the Owner, then the Owner shall make the Charterer a proper allowance of any savings to the Owner thereby; if the port of redelivery is less favorable to the Owner, then the Charterer shall pay the Owner a proper allowance to cover the additional cost required to put the Owner in the same position as if the Vessel had been redelivered at the port of original delivery.

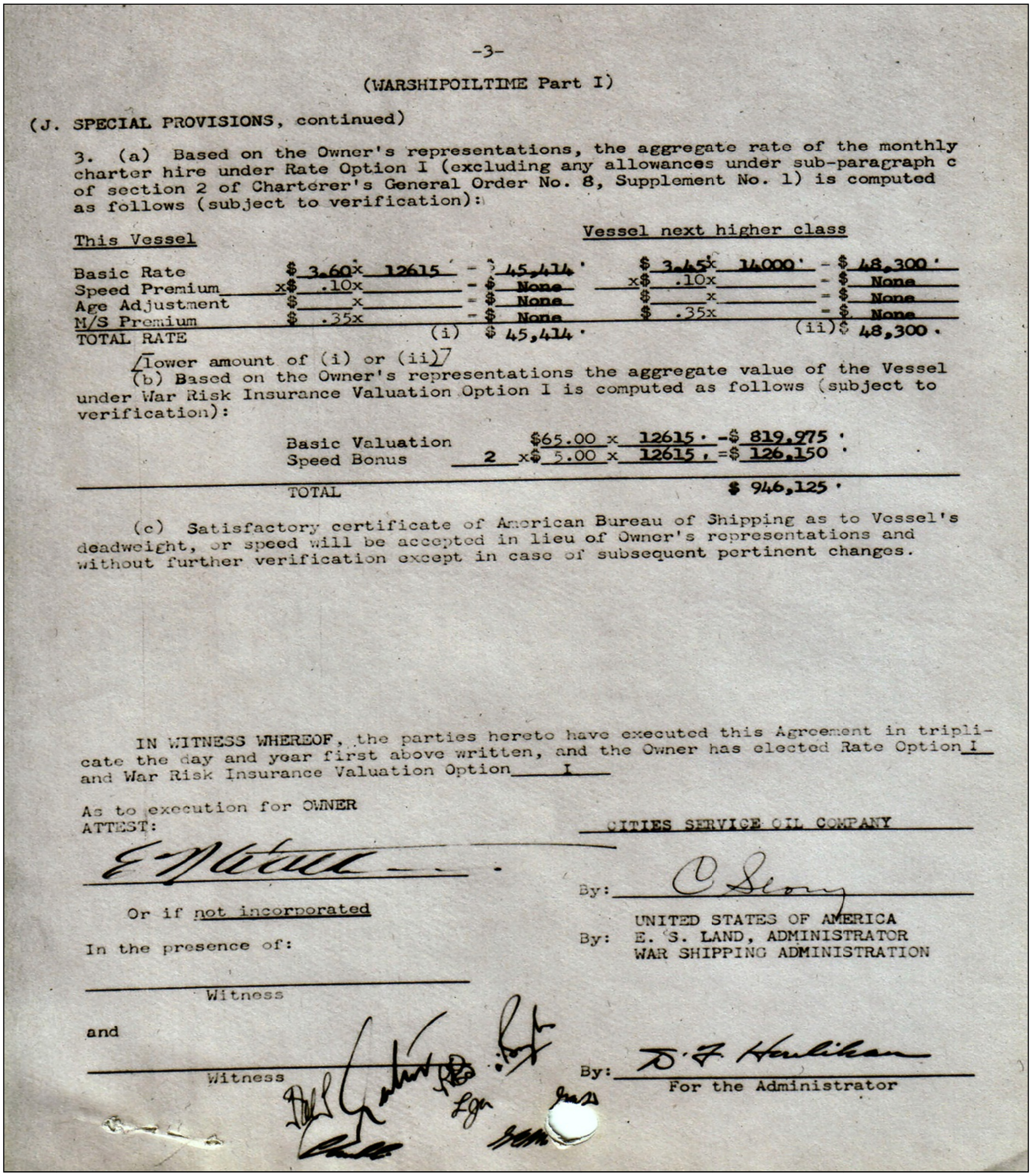
-3-

(J. SPECIAL PROVISIONS, conti...

3. (a) Based on the Own... of the monthly charter hire under Rate O... sub-paragraph c

DECLASSIFIED
Authority DODDIR: 52003.0 Date March 1983
By EU NARA Date 5/11/11

Figure E-31. War Shipping Administration requisition time charter for *Cities Service Toledo* 1942, p.2 (USMC 1942e).



-3-

(WARSHIPOILTIME Part I)

(J. SPECIAL PROVISIONS, continued)

3. (a) Based on the Owner's representations, the aggregate rate of the monthly charter hire under Rate Option I (excluding any allowances under sub-paragraph c of section 2 of Charterer's General Order No. 8, Supplement No. 1) is computed as follows (subject to verification):

This Vessel				Vessel next higher class		
Basic Rate	$ 3.60x	12615	= $ 45,414	$ 3.45x	14000	= $ 48,300
Speed Premium	x$ .10x		= $ None	x$ .10x		= $ None
Age Adjustment	$ x		= $ None	$ x		= $ None
M/S Premium	$ .35x		= $ None	$ .35x		= $ None
TOTAL RATE		(i)	$ 45,414		(ii)	$ 48,300

[lower amount of (i) or (ii)]

(b) Based on the Owner's representations the aggregate value of the Vessel under War Risk Insurance Valuation Option I is computed as follows (subject to verification):

Basic Valuation		$65.00 x	12615	= $ 819,975
Speed Bonus	2	x$ 5.00 x	12615	= $ 126,150
TOTAL				$ 946,125

(c) Satisfactory certificate of American Bureau of Shipping as to Vessel's deadweight, or speed will be accepted in lieu of Owner's representations and without further verification except in case of subsequent pertinent changes.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement in triplicate the day and year first above written, and the Owner has elected Rate Option I and War Risk Insurance Valuation Option I

As to execution for OWNER
ATTEST:

CITIES SERVICE OIL COMPANY

By:

Or if not incorporated

In the presence of:

UNITED STATES OF AMERICA
By: E. S. LAND, ADMINISTRATOR
WAR SHIPPING ADMINISTRATION

Witness

and

Witness

By: D. F. Houlihan
For the Administrator

Figure E-32. War Shipping Administration requisition time charter for *Cities Service Toledo* 1942, p.3 (USMC 1942e).

DECLASSIFIED
Authority NND790161
By [initials] NARA Date 5/11/11

PORT DIRECTOR'S REPORT ARMING MERCHANT VESSELS

CONFIDENTIAL

SERIAL PD 328 ARMED FOR AREA Two

SS Cities Service Toledo GROSS TONS 8192 DEADWEIGHT TONS 12575

WHERE ARMED (PORT) Balto. Md. DATE 5-19-42 YARD Bethlahem Key Highway

LIST ALL GUNS (INCLUDING MACHINE GUNS) ABOARD VESSEL ON DEPARTURE.

No. of Guns	Caliber & Type	Gun Mark & Mod.	Mount Mk. & Mod.	Gun Location	Ammunition
1	5" 51 Cal.	Mk. 8	Mk. 8 Mod. 1	Platform Aft Platform Forward	100 Rds.
2	.50 Cal. BAM	Mk. 2	Mk. 9	Pill Boxes, aft	2000 Rds.
2	.30 Cal. Colt	Mk. 3	Mk. 19-1	Pill Boxes, bridge	3000 Rds.

BuOrd form No. 228 (rev. May 1942) submitted ______ 19__, in triplicate.

240 Rds. .45 Cal. pistol

INSTALLATIONS

ITEM	DETAIL
1. Splinter Protection - Bridge	Yes
Splinter Protection - AA Machine Guns	Yes
2. Gun Foundations, Number and Location	Steel - (2) platform forward & aft
3. Magazines, Number and Location	Steel
4. Painting	Grey
5. Darkening Ship Facilities	Blackout switches on doors All ports painted
6. Reinforce Sea Chests	Concrete - sealed
7. Fire Control Communication System	Telephone to after gun, all Pill Boxes and Crows Nest
8. Sky Lookout Stations, No. & Location	Crows Nest (Foremast)
9. Results Industrial Manager's Inspect.	Satisfactory
10. Messing Facilities	In Crews Mess room at separate times

ACCOMMODATIONS NAVY PERSONNEL

ARMED GUARD UNIT	SPACE	LOCATIONS
Officer-in-Charge	Room# 1	Amidships
Petty Officer		
Seamen	1 Room - 12 persons	Aft

COMMUNICATION GROUP

Enlisted Men

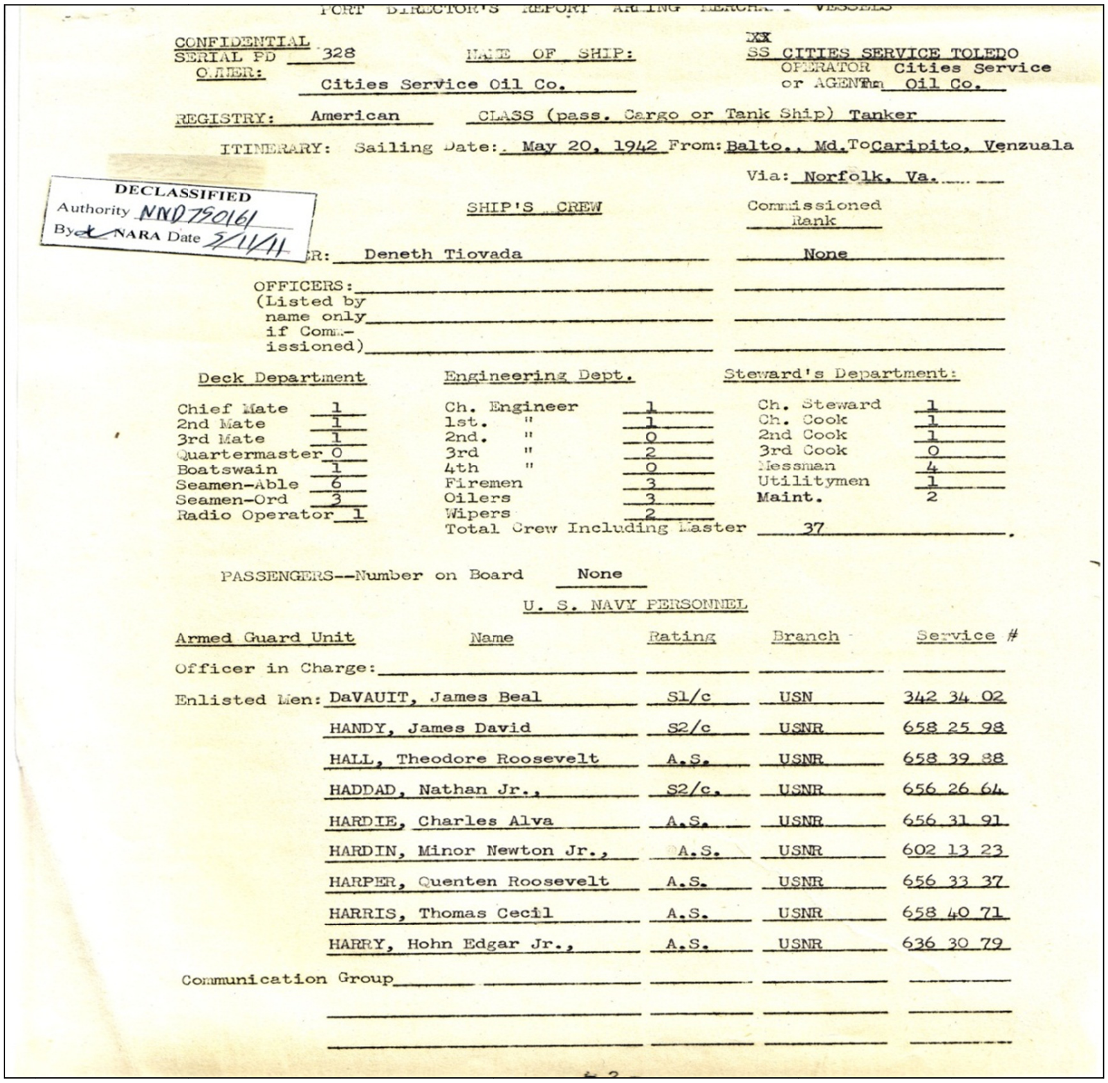
Standee Bunks No. 6 Tiers Total 12 Bunks

EQUIPMENT

ITEM	QUANTITY
1. Navy - Type Life Jackets	32 also 45 old type
2. Life Rafts (Capacity 18 per raft	4 Rafts
3. Life Boat	4 - 40 persons each
4. Emergency Rations	Yes
5. Repair & Upkeep Equipment Armament	Complete

(200-3/18/42 - Revised 6/8/42)

Figure E-33. Port director's report arming merchant vessels for *Cities Service Toledo* 1942, p.2 (OCNO 1942c).



PORT DIRECTOR'S REPORT ARMING MERCHANT VESSELS

CONFIDENTIAL
SERIAL PD 328 NAME OF SHIP: SS CITIES SERVICE TOLEDO
OWNER: Cities Service Oil Co. OPERATOR or AGENT: Cities Service Oil Co.

REGISTRY: American CLASS (pass. Cargo or Tank Ship) Tanker

ITINERARY: Sailing Date: May 20, 1942 From: Balto., Md. To Caripito, Venzuala

Via: Norfolk, Va.

SHIP'S CREW — Commissioned Rank

MASTER: Deneth Tiovada — None

OFFICERS: (Listed by name only if Commissioned)

Deck Department		Engineering Dept.		Steward's Department:	
Chief Mate	1	Ch. Engineer	1	Ch. Steward	1
2nd Mate	1	1st. "	1	Ch. Cook	1
3rd Mate	1	2nd. "	0	2nd Cook	1
Quartermaster	0	3rd "	2	3rd Cook	0
Boatswain	1	4th "	0	Messman	4
Seamen-Able	6	Firemen	3	Utilitymen	1
Seamen-Ord	3	Oilers	3	Maint.	2
Radio Operator	1	Wipers	2		

Total Crew Including Master 37.

PASSENGERS--Number on Board None

U. S. NAVY PERSONNEL

Armed Guard Unit	Name	Rating	Branch	Service #
Officer in Charge:				
Enlisted Men:	DaVAUIT, James Beal	S1/c	USN	342 34 02
	HANDY, James David	S2/c	USNR	658 25 98
	HALL, Theodore Roosevelt	A.S.	USNR	658 39 88
	HADDAD, Nathan Jr.,	S2/c.	USNR	656 26 64
	HARDIE, Charles Alva	A.S.	USNR	656 31 91
	HARDIN, Minor Newton Jr.,	A.S.	USNR	602 13 23
	HARPER, Quenten Roosevelt	A.S.	USNR	656 33 37
	HARRIS, Thomas Cecil	A.S.	USNR	658 40 71
	HARRY, Hohn Edgar Jr.,	A.S.	USNR	636 30 79
Communication Group				

Figure E-34. Port director's report arming merchant vessels for *Cities Service Toledo* 1942, p.3 (OCNO 1942c).

FOR AR[illegible] GUARD UNIT

Serial PD **328**

ON BOARD SS **Cities Service Toledo**

DECLASSIFIED
Authority NND 790161
By [illegible] NARA Date 5/11/11

ITEM NO.	QUANTITY NO.	UNIT	DESCRIPTION	STOCK NUMBER	
1.		Each	BAG, canvas, weighted #C&R 434791	24-B-60	C
2.		Cell	BATTERIES, Blinker Signal Gun	17-B-7040	C
3.	49	"	BATTERIES, Flashlight	17-B-7210	C
4.	12	"	BATTERIES, Dry, hand lantern	17-B-7600	C
5.	4	Each	BELTS, pistol, automatic	A-2-B-1490	B
6.	1	Pair	BINOCULARS, 6 x 30	18-B-1135	B
7.		"	BINOCULARS, 7 x 35	18-B-1138	B
8.		Each	BLINKER, Signal Gun, battery type	17-B-1600	B
9.	2	"	BOTTLES, vacuum, 1 quart	63-B-500	B
10.	1	"	CASE, first-aid (armed guard)	S2-510	
11.	1	Misc.	CLEANING, supplies (brushes, soap, buckets, rags, etc.		
12.		Set	FLAGS, alphabet code # 4	5-F-255-80	C
13.		Set	FLAGS, numeral # 4	5-F-4375 to 4384	C
14.		Set	FLAGS, semaphore	5-F-4375 to 4384	C
15.	8	Each	FLASHLIGHTS, 2 cell pocket type	17-F-13452	C
16.	48	"	GAS MASKS		B
17.		"	GLOBES, hand lantern	31-G-270	C
18.	2	Pair	GOGGLES, for lookout, light density	37-G-3555	C
19.	1	"	GOGGLES, for lookout, dark density	37-G-3450	C
20.	8	Each	HELMETS, steel standard	37-H-	B
21.		"	HELMETS, " to wear with headphone	37-H	B
22.	4	"	HOLSTERS, automatic pistol (colt)	A-2-H-1435	B
23.		"	LAMPS, blinker signal gun	17-L-6300	C
24.	16	"	LAMPS, flashlight	17-1-6320	C
25.	2	"	LANTERNS, hand, portable, type "J"	17-L-7760	B
26.	1	"	MEDICAL GUN BAG, equipment	S-2-03	
27.		"	MEGAPHONE, 18" small	37-M-330	C
28.		"	MEGAPHONE, 32" large	37-M-335	C
29.		Pair	MITTENS, ammunition-handling asbes.	A(L)2-G-48116	C
30.	4	Each	PISTOLS, automatic, colt, 45, # 1911	A-2-P-3415	B
31.		Gal.	PAINT, dark gray, formula 5D	52-P	C
32.		Each	ROPE, 125 fath. 3" manila, for spar	21-R-413	C
33.		"	SEARCHLIGHT, signal 8"(Crouse-Hinds)	17-S	B
34.		"	SPAR, towing	23-S-180	B
35.		"	SPY GLASS, quartermaster, 16 power	18-S-2255	B
36.	1	Misc.	STATIONARY (#53 items) (not over $30)		C
37.	**8**	**No.**	**Magazines, pistol**		
38.	**4**	**No.**	**Carriers, pistol, magazine**		
39.	**1**	**No.**	**Brushes, Paint gr. B.**	**B-2617**	
40.	**1**	**No.**	**" Varnish 1"**	**B-5220**	
41.	**1**	**No.**	**" " 2½"**	**B-5225**	
42.	**6**	**No.**	**Lamps, hand lantern**	**17-L-6390**	
43.	**16**	**Yds.**	**Bunting, yellow**	**5B238**	
44.	1	Set	CONVOY LIGHTS, Colored	Balto, Md.	B
45.	1	Each	WAKE LIGHT, Screened, Type # 2	" "	B

DEGAUSSING OPERATION

Type of Coils **M only** Compass Compensated **Yes**
(M only; MF & Q: MF, Q & A)

If not Coiled -- Date Wiped ________ or Date Flashed ________

Date Calibrated **5-24-42** Range **Wolf Trap**
(Wolf Trap, Newport, etc.)

Degaussing Factor **70'**
(From Range)

Date Depermed **5-22-42**
(If shown necessary by range)

Figure E-35. Port director's material report for Armed Guard Unit for *Cities Service Toledo* 1942, p.1 (OCNO 1942g).

DECLASSIFIED
Authority NND750161
By NARA Date 5/1/11

Restricted

Name of Ship:	S.S. CITIES SERVICE TOLEDO
Owner	Cities Service Oil Company
Operator or Charterer	Cities Service Oil Company
Usual Operating Area:	Two
Shipyard Installing Armament	Bethlehem-Upper Yard
Date of Installation	May 18, 1942
Gross Tonnage	8,192
Deadweight Tonnage	13,500

1	5" 51 Cal.	Gun.	Mk. VIII	Mod.	Serial	493
1	" " "	B/M	" VII	" 9	"	493
1	" " "	Yoke	" VII	" 1	"	2459
1	" " "	Mount	" XIII	" 1		
1	" " "	Stand	" IX		"	413
1	" " "	Carriage	" XIII	" 1	"	445
1	" " "	Slide	" XIII		"	418
1	" " "	Sight	" XXI		"	6570
1	" " "	Telescope	" XXVII	" 1	"	2522
1	" " "	Telescope	" XXVIII		"	306

1 Projectile Ready Service Box
1 Powder Ready Service Box
1 Loading Tray
1 Sponge Bristle Head
1 Tompion
1 Extractor
10 Sight Lamps
1 Gun Cover
5 Sectional Handles
1 Bale Rags
2 Boxes Cleaning Gear
1 Battery Box, 1 battery
1 Thermometer (Maximum-Minimum)
3 .50 Cal.Ready Service Boxes and Locks

2	.50 Cal. Browning Machine Guns	Mk.2	Serials	42071-42072
2	" " " Mounts	" 9	"	48311-83093
2	" " " Sights	" 6	"	40073-40071

2 Spare Barrels
2 Boxes, ammunition
1 Loading Machine

2	.30 Cal. Colt Machine Guns	Mk.3	Serials	3262-3408
2	" " " Mounts	" 19-1	"	3785-3816

12 Feed Boxes wood
1 Belt filling machine
12 Feed Belts
2 Yokes, adapter for mounting .30 caliber Colt Gun in Stand, Mk. 22

No ammunition placed on board by Assistant Industrial Manager, USN, Baltimore.

Figure E-36. Port director's material report for Armed Guard Unit for *Cities Service Toledo* 1942, p.2 (OCNO 1942g).

SITE 389 *J. A. BISSO*

Figure E-37. Photograph of *J. A. Bisso,* date unknown. Courtesy of William “Cappy” Bisso.

Figure E-38. Photograph of *J. A. Bisso*, far right, reportedly on the job it was on when it sank. Verso inscribed “McDermott 800 ton Derrick #9 Bisso 400 ton derrick Cairo with Tug J. A. Bisso alongside Sunken American Tideland Rig #101.” Courtesy of William “Cappy” Bisso.

SITE 236 USS *HATTERAS*

Figure E-39. Drawing of the engine for *St. Mary's*, Hull No. 41, date unknown, from the Harlan & Hollingsworth Collection, Mariner's Museum, Newport News, Virginia.

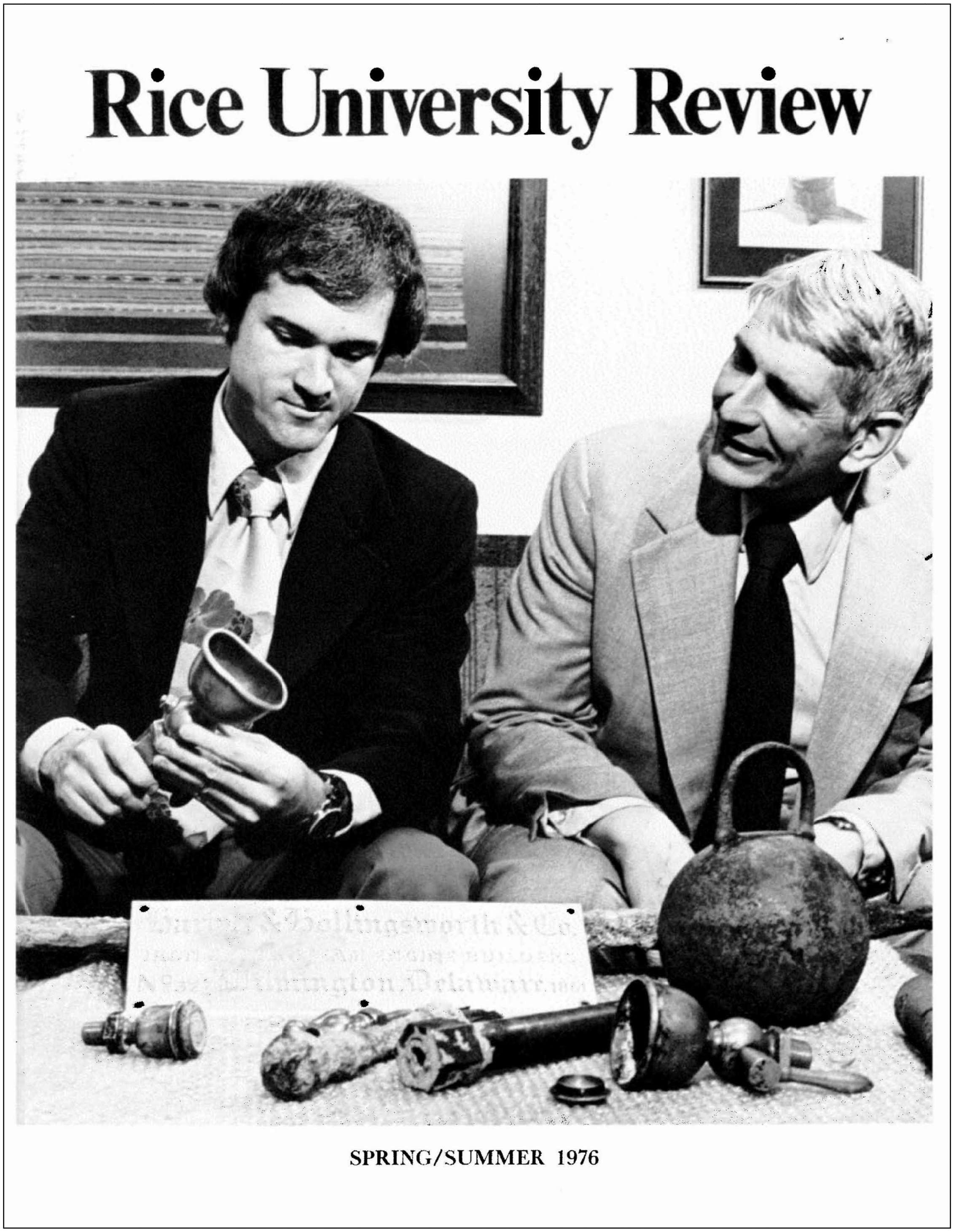


Figure E-40. Paul A. Cloutier and Frank E. Vandiver shown with artifacts recovered from the *Hatteras* site. Cover image, Rice University Review, 1976.

Figure E-41. Iron ball, shown from above, recovered from USS *Hatteras* site, housed at the Corpus Christi Museum of Science and History. Image courtesy of the Naval History & Heritage Command Underwater Archaeology Branch, Department of the Navy.

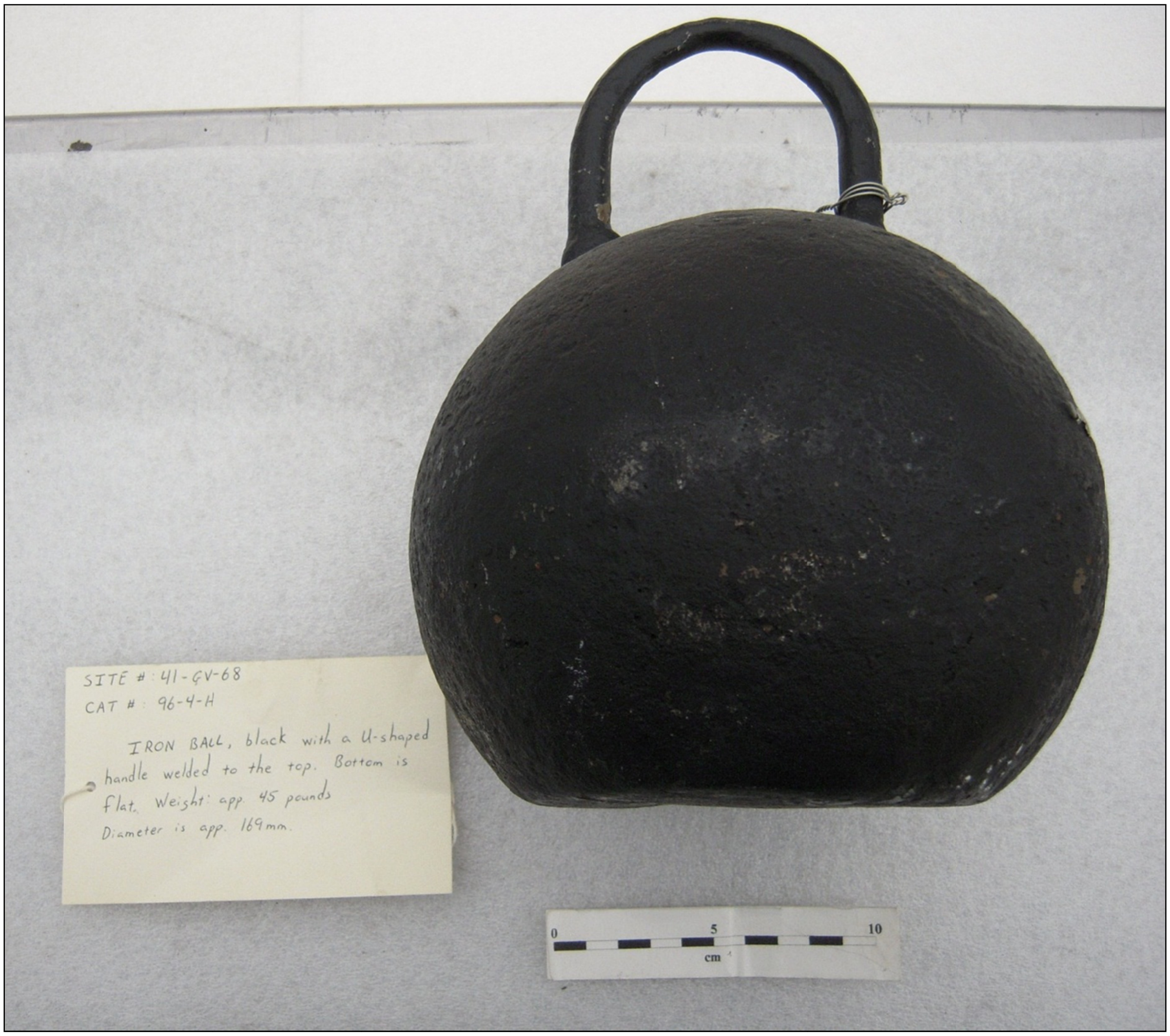


Figure E-42. Iron ball, side view, recovered from USS *Hatteras* site, and housed at the Corpus Christi Museum of Science and History. Image courtesy of the Naval History & Heritage Command Underwater Archaeology Branch, Department of the Navy.

Appendix F

Water Quality and Radioisotope Tables

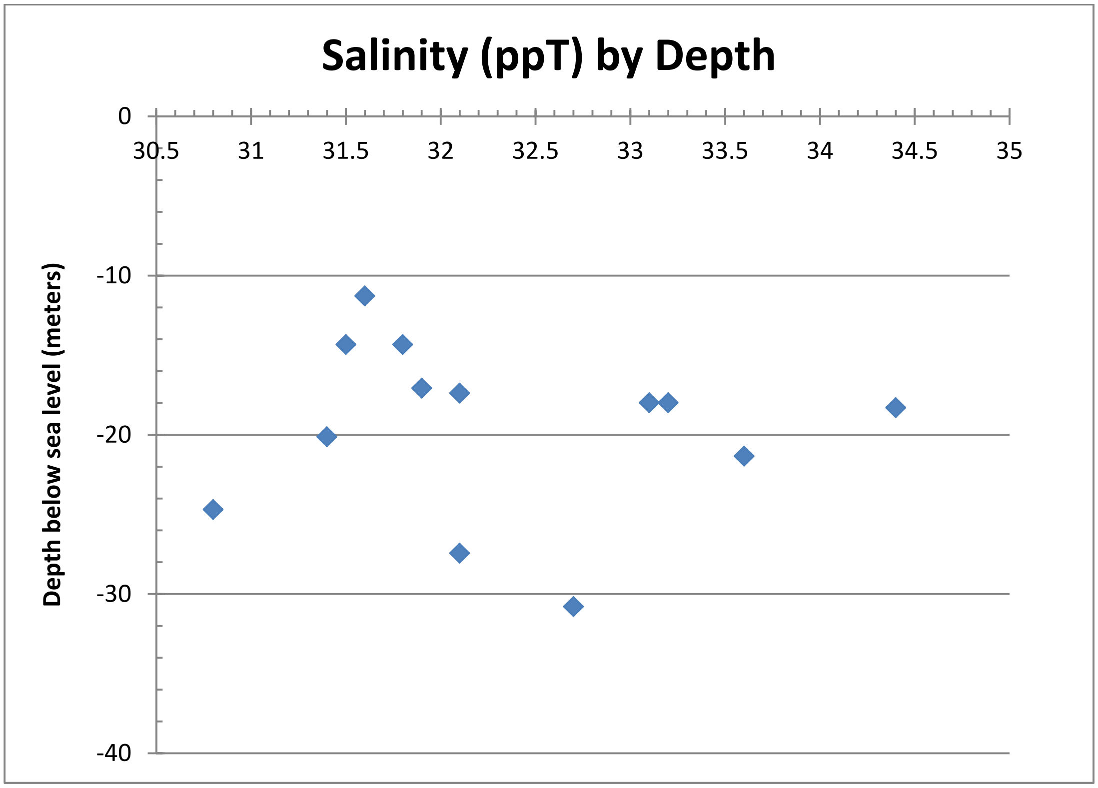


Figure F-1. Salinity measurements compared by depth of sample.

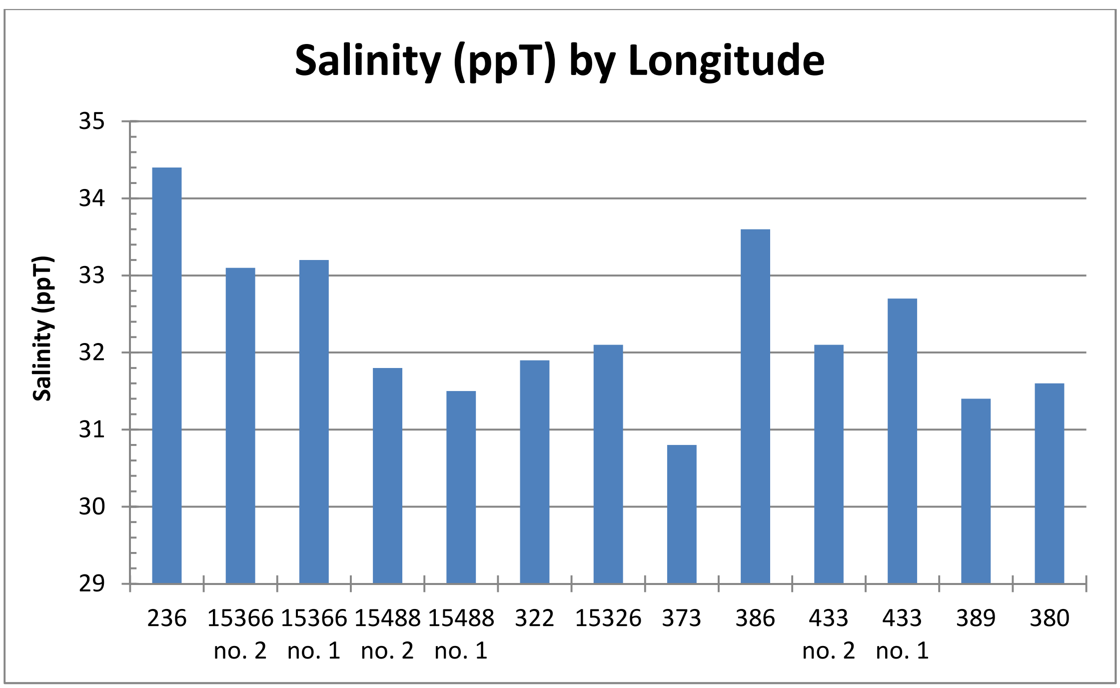


Figure F-2. Salinity measurements displayed west (left, Site 236) to east (right, Site 380).

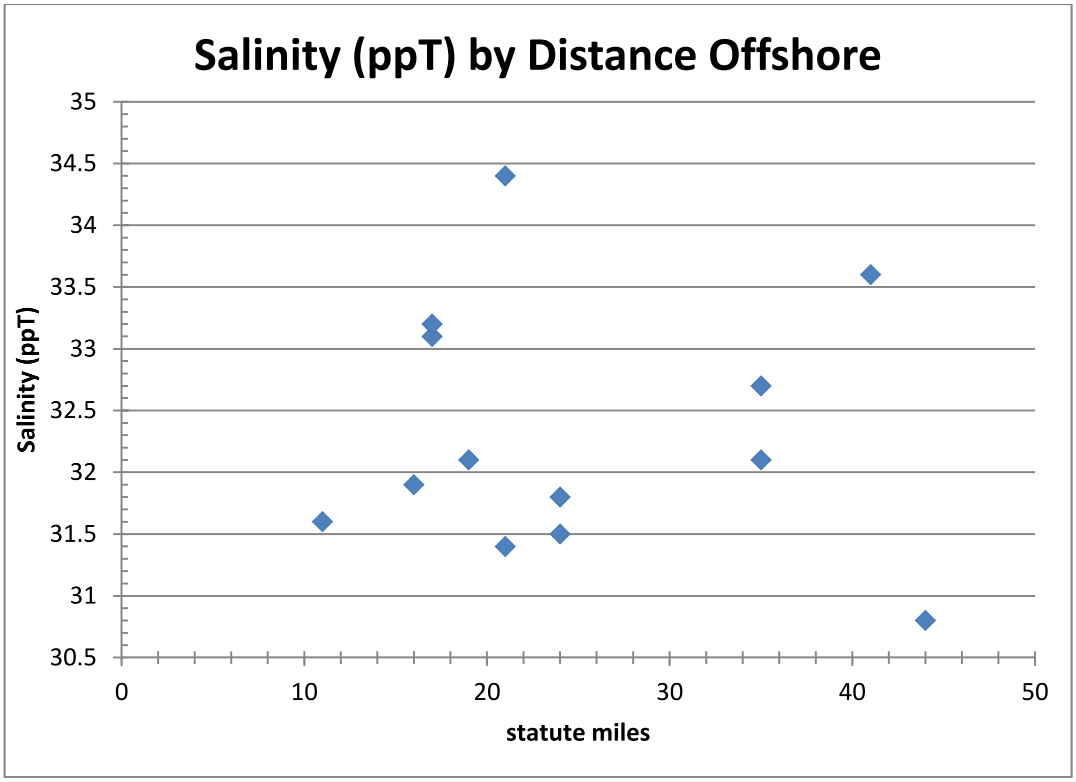


Figure F-3. Salinity measurements displayed by distance offshore.

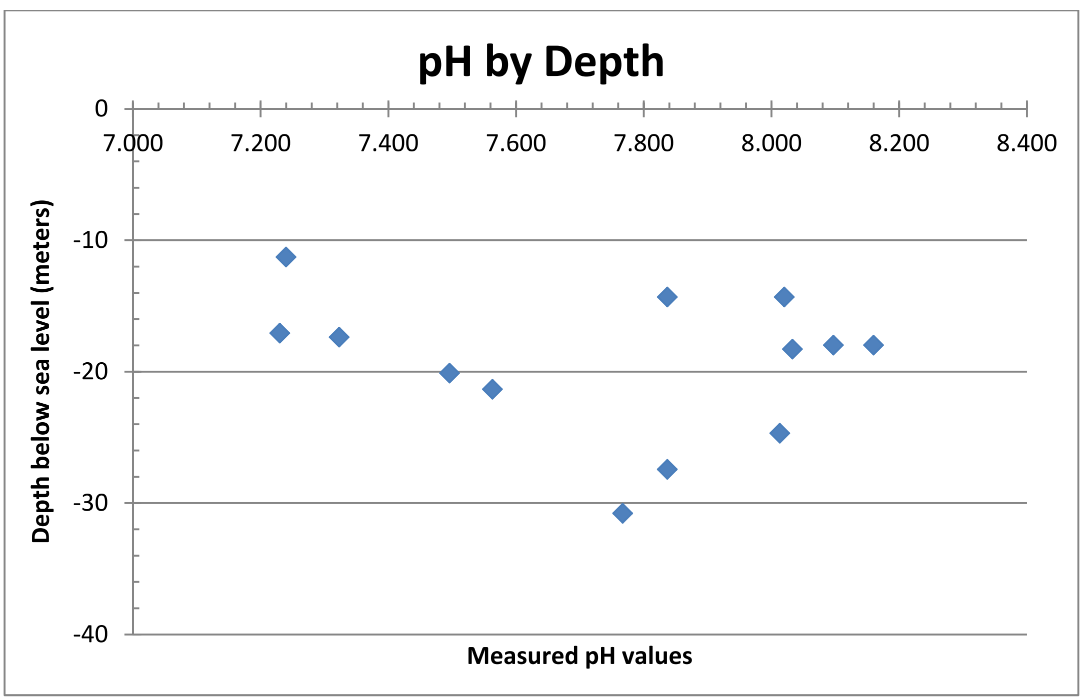


Figure F-4. Averaged pH values compared by depth of sample.

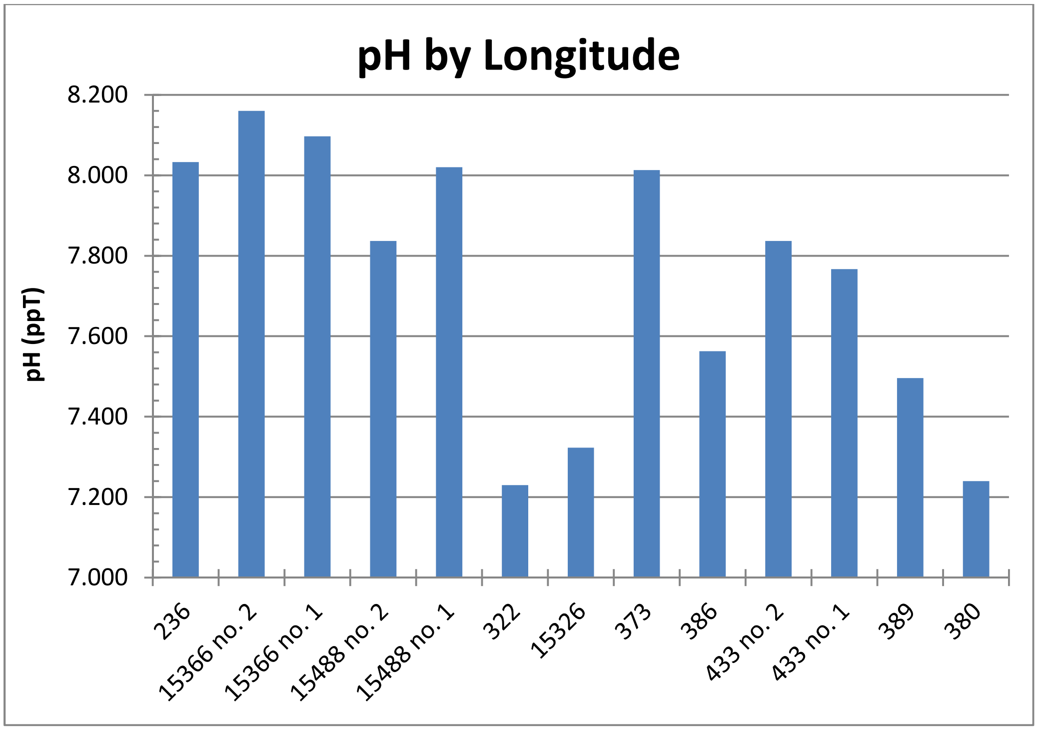


Figure F-5. Averaged pH values displayed by longitude west (Site 236) to east (Site 380).

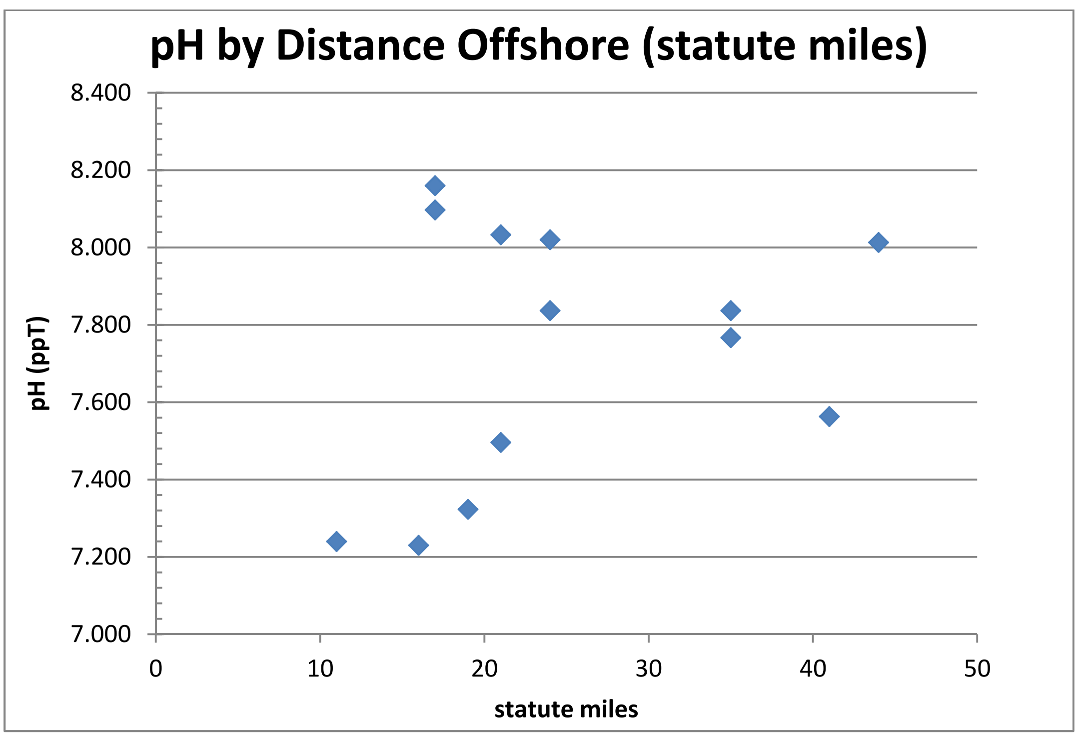


Figure F-6. Averaged pH values displayed by distance offshore.

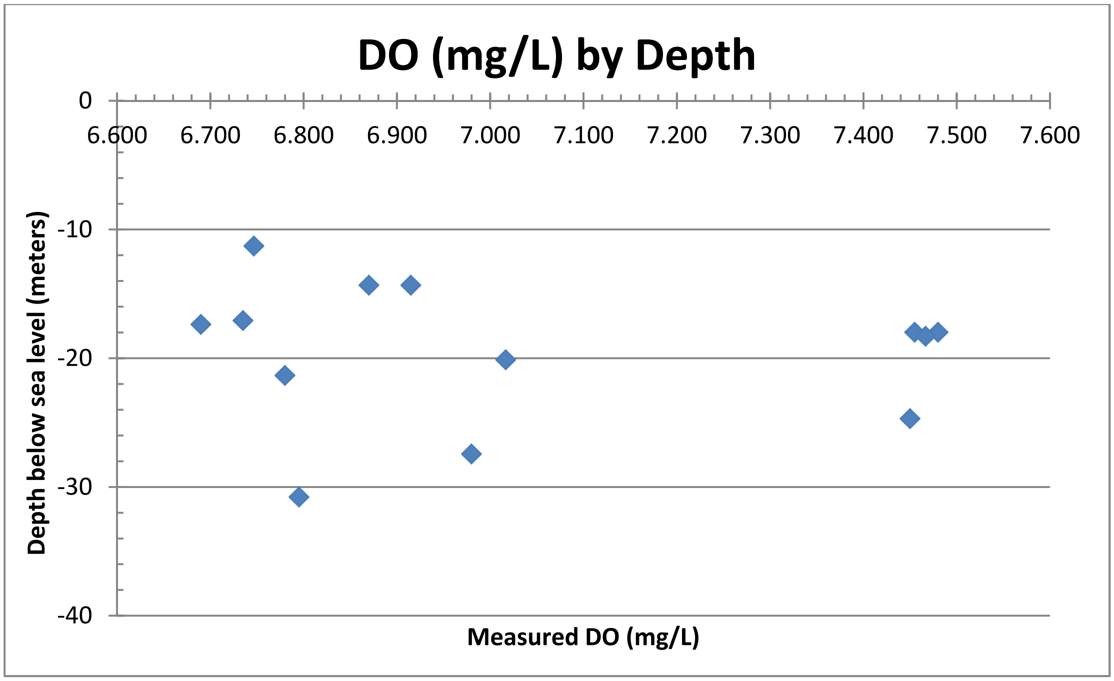


Figure F-7. Averaged DO measurements compared by depth of sample.

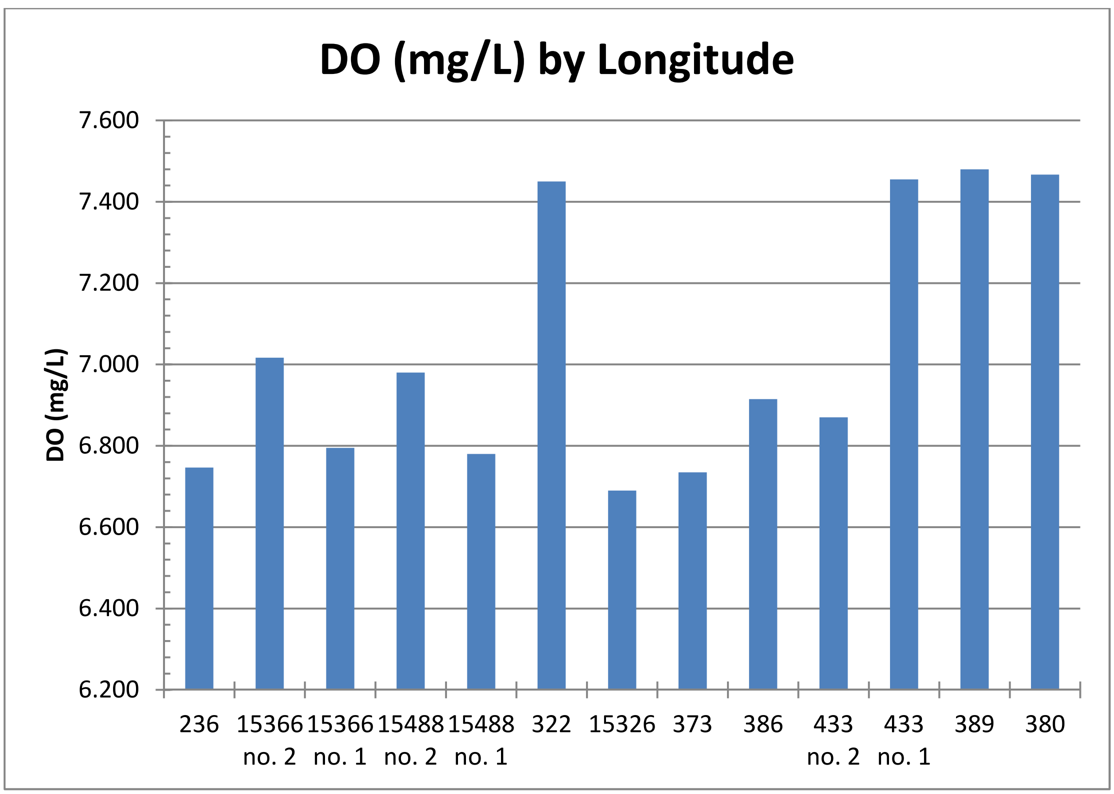


Figure F-8. Averaged DO values displayed west (left, Site 236) to east (right, Site 380).

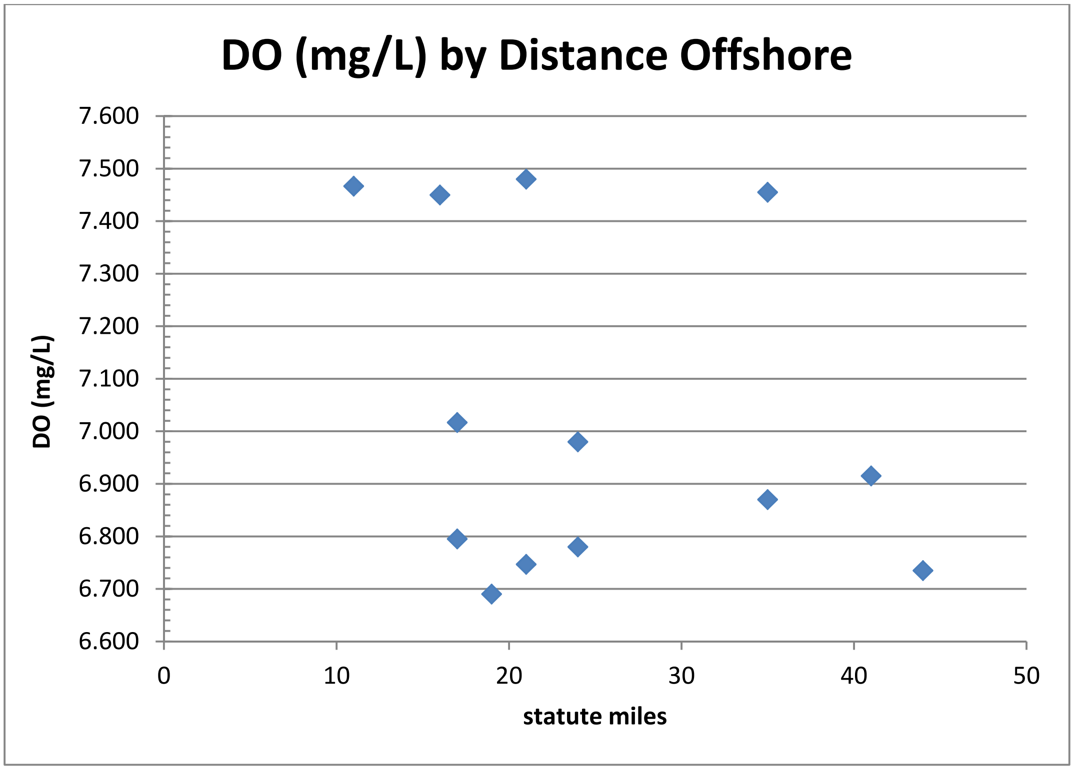


Figure F-9. Averaged DO measurements displayed by distance offshore.

Table F-1

Radiochemical and Porosity Data for Site 433

Sample Depth (cm)	xs Pb-210	xs err	Ra-226	Ra err	Cs-137	Cs err	Porosity	75% porosity consolidated depth
0–1	1.54	0.82	1.28	0.22	0.08	0.09	0.75	0.59
1–2	1.74	0.81	1.20	0.09	0.03	0.08	0.59	
2–3	0.34	0.67	1.42	0.10	0.05	0.07	0.59	2.08
3–4	0.64	0.76	1.45	0.32	0.00	0.00	0.59	3.86
4–5	0.53	0.71	1.36	0.20	0.00	0.08	0.61	5.63
5–7	0.34	0.66	1.28	0.02	0.00	0.00	0.62	7.37
7–9	0.00	0.69	1.66	0.18	0.00	0.08	0.64	9.90
9–11	0.10	0.66	1.35	0.16	0.00	0.00	0.53	13.16
19–21	1.11	0.79	1.14	0.39	0.00	0.00	0.65	16.74
No activity reported for remaining samples, taken at depths of 29–31, 39–41, 49–51, 59–61, and 69–71 cm								

Table F-2

Radiochemical and Porosity Data for Site 373

Sample Depth (cm)	xs Pb-210	xs err	Ra-226	Ra err	Cs-137	Cs err	Porosity	75% porosity consolidated depth
0–1	2.95	0.95	1.20	0.07	0.00	0.00	0.84	0.39
1–2	3.75	0.95	1.24	0.15	0.05	0.08	0.82	1.21
2–3	3.37	0.78	1.30	0.21	0.13	0.06	0.81	2.10
3–4	5.13	1.22	1.63	0.52	0.00	0.00	0.83	2.96
4–5	4.55	1.05	1.57	0.24	0.00	0.08	0.80	3.85
5–7	5.03	1.04	1.20	0.15	0.00	0.00	0.80	5.31
7–9	3.93	1.03	1.46	0.30	0.05	0.09	0.75	7.44
9–11	4.24	0.94	1.29	0.04	0.01	0.08	0.75	9.76
19–21	3.18	0.99	1.47	0.20	0.00	0.00	0.75	21.38
29–31	3.00	0.93	1.36	0.31	0.24	0.08	0.68	34.50
39–41	5.66	1.05	1.15	0.03	0.10	0.08	0.73	48.01
49–51	4.98	1.03	1.16	0.14	0.16	0.08	0.72	60.58

Table F-3

Radiochemical and Porosity Data for Site 15488

Sample Depth (cm)	xs Pb-210	xs err	Ra-226	Ra err	Cs-137	Cs err	Porosity	75% porosity consolidated depth
0–1	4.66	1.04	1.06	0.12	0.24	0.09	0.86	0.33
1–2	3.90	1.05	1.24	0.33	0.00	0.10	0.86	1.01
2–3	2.37	0.89	1.11	0.24	0.00	0.00	0.83	1.77
3–4	1.47	0.81	0.88	0.22	0.00	0.00	0.77	2.74
4–5	3.06	0.98	1.02	0.11	0.10	0.10	0.79	3.78
14–16	3.52	0.97	1.22	0.14	0.00	0.00	0.78	14.35
24–26	4.56	1.06	1.29	0.31	0.07	0.09	0.74	25.52
34–36	4.27	1.03	1.11	0.24	0.08	0.09	0.78	36.66
44–46	4.45	0.99	1.27	0.15	0.05	0.08	0.75	47.65
54–56	4.95	1.09	1.29	0.29	0.00	0.00	0.74	59.60
64–66	4.54	1.02	1.45	0.17	0.01	0.08	0.72	72.19

Table F-4

Radiochemical and Porosity Data for Site 15366

Sample Depth (cm)	xs Pb-210	xs err	Ra-226	Ra err	Cs-137	Cs err	Porosity	75% porosity consolidated depth
0–1	5.70	1.21	1.04	0.17	0.00	0.11	0.85	0.37
1–2	5.34	1.12	1.32	0.08	0.07	0.09	0.85	1.09
2–3	4.37	1.16	1.06	0.20	0.00	0.00	0.83	1.85
3–4	3.44	1.01	1.07	0.12	0.05	0.10	0.83	2.66
4–5	3.21	0.94	1.02	0.32	0.00	0.00	0.84	3.47
14–16	6.03	1.34	1.36	0.43	0.14	0.11	0.80	12.66
24–26	5.88	1.09	1.15	0.15	0.12	0.08	0.79	22.38
34–36	2.76	0.74	0.80	0.04	0.00	0.07	0.56	36.85
44–46	4.76	0.88	1.18	0.19	0.14	0.06	0.77	51.83

Table F-5

Radiochemical and Porosity Data for Site 389

Sample Depth (cm)	xs Pb-210	xs err	Ra-226	Ra err	Cs-137	Cs err	Porosity	75% porosity consolidated depth
0–1	1.93	0.72	0.82	0.27	0.00	0.00	0.62	0.40
1–2	2.16	0.71	1.10	0.22	0.12	0.07	0.65	1.24
2–3	1.77	0.87	1.58	0.41	0.00	0.00	0.53	2.12
3–4	0.63	0.57	0.76	0.12	0.00	0.00	0.49	3.02
4–5	0.62	0.44	0.81	0.09	0.00	0.00	0.46	3.95
14–16	2.28	0.80	1.00	0.37	0.00	0.00	0.53	14.18
24–26	3.52	0.84	1.72	0.24	0.07	0.06	0.78	24.57
34–36	4.27	1.01	1.56	0.20	0.04	0.09	0.77	35.82
44–46	1.77	0.75	1.49	0.17	0.03	0.07	0.63	47.32

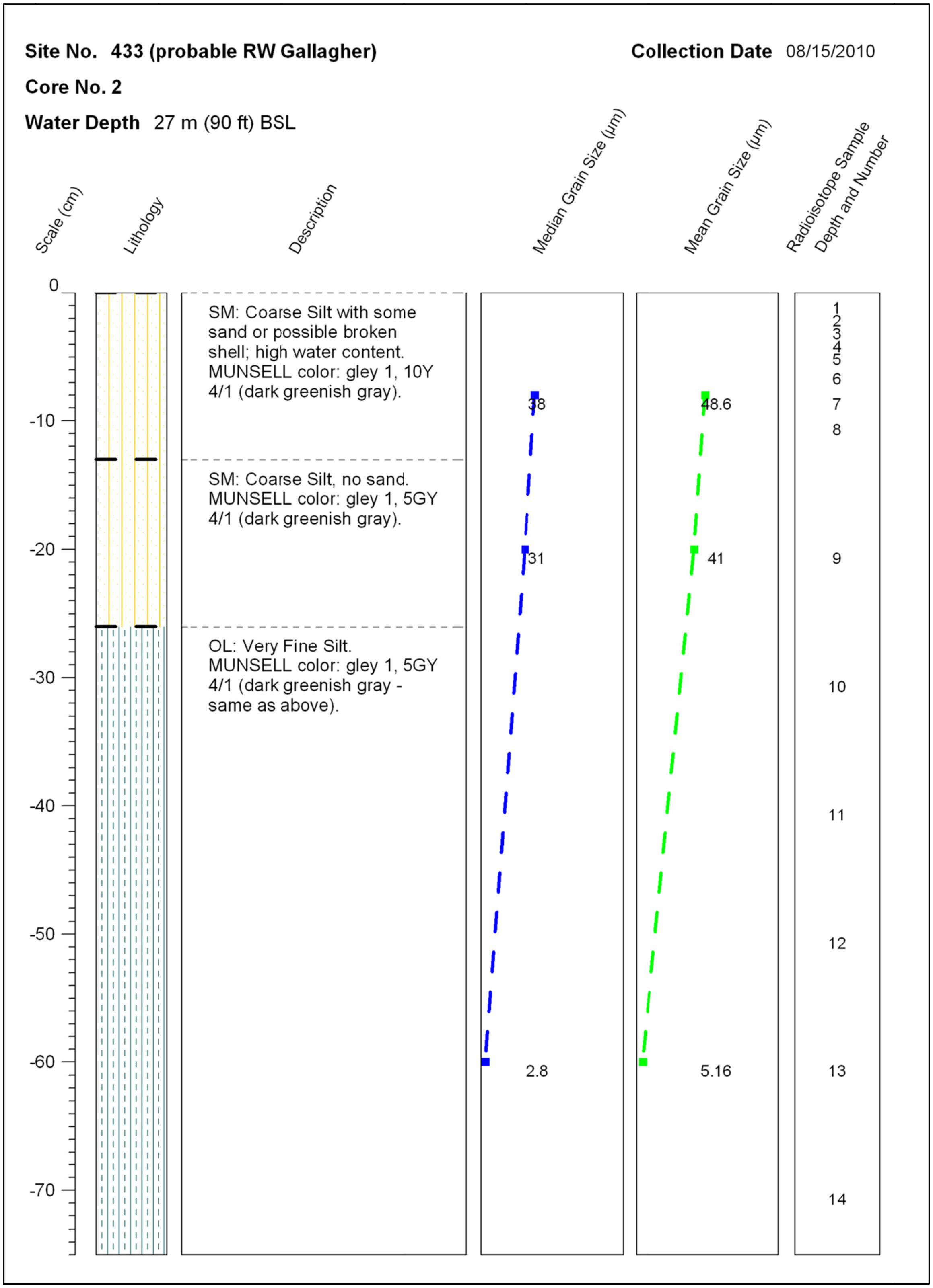
Table F-6

Radiochemical and Porosity Data for Site 236

Sample Depth (cm)	xs Pb-210	xs err	Ra-226	Ra err	Cs-137	Cs err	Porosity	75% porosity consolidated depth
0–1	6.15	1.23	1.25	0.17	0.11	0.1	0.88	0.31
1–2	6.00	1.19	1.28	0.24	0.1	0.09	0.85	0.97
2–3	4.42	1.03	1.31	0.32	0.02	0.08	0.83	1.73
3–4	4.37	0.87	0.99	0.27	0.04	0.06	0.82	2.56
4–5	3.38	0.92	1.24	0.11	0.06	0.08	0.81	3.45
5–7	2.46	0.77	0.8	0.16	0	0	0.63	5.53
7–9	0.93	0.73	1.06	0.18	0	0	0.69	8.58
9–11	4.60	1.13	1.25	0.33	0.07	0.09	0.76	11.12
19–21	3.61	0.96	1.38	0.43	0.07	0.07	0.74	22.82
29–31	0.42	0.52	1.13	0.2	0.02	0.05	0.64	36.94
39–41	0.78	0.72	1.11	0.23	0.01	0.08	0.68	52.13
49–51	0.32	0.63	1.05	0.14	0	0	0.61	67.8
59–61	0.50	0.67	0.84	0.3	0.05	0.07	0.48	87.09

Appendix G

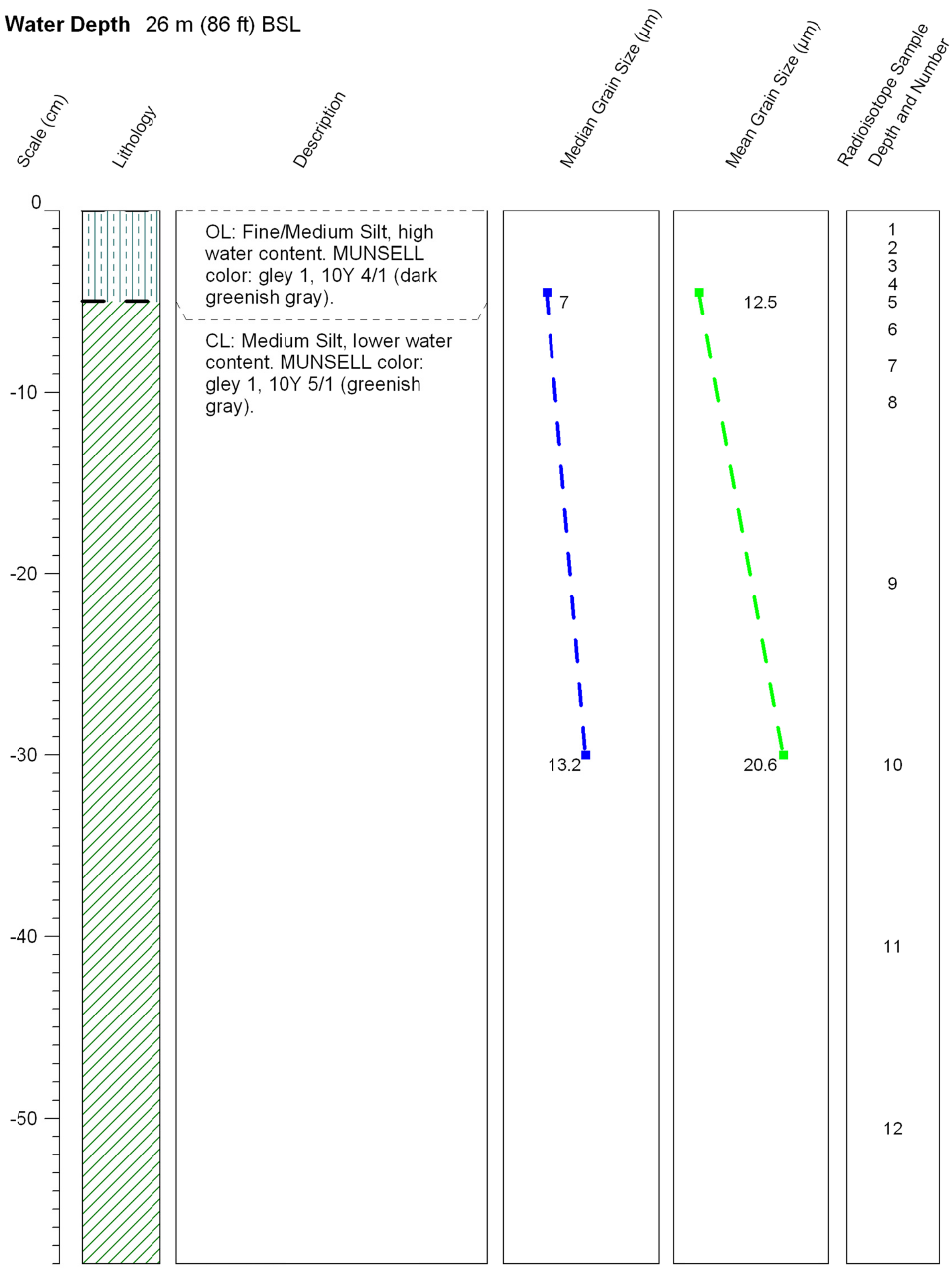
Core Logs

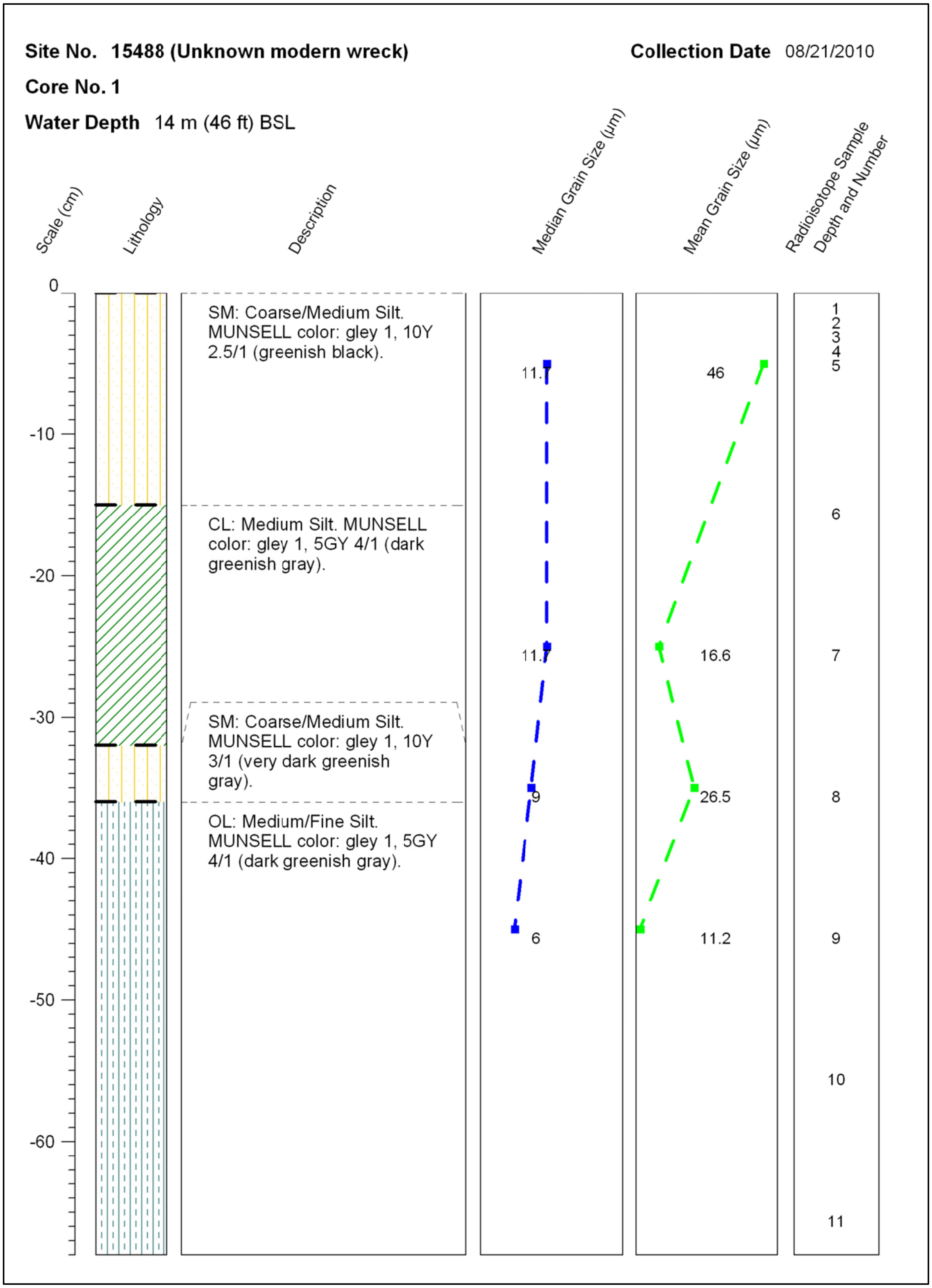

Site No. 433 (probable RW Gallagher)
Collection Date 08/15/2010
Core No. 2
Water Depth 27 m (90 ft) BSL
Scale (cm)
Lithology
Description
Median Grain Size (µm)
Mean Grain Size (µm)
Radioisotope Sample Depth and Number
0
-10
-20
-30
-40
-50
-60
-70
SM: Coarse Silt with some sand or possible broken shell; high water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).
SM: Coarse Silt, no sand. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
OL: Very Fine Silt. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray - same as above).
38
31
2.8
48.6
41
5.16
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Site No. **373 (probable Cities Service Toledo)** **Collection Date** 08/19/2010

Core No. 1

Water Depth 26 m (86 ft) BSL



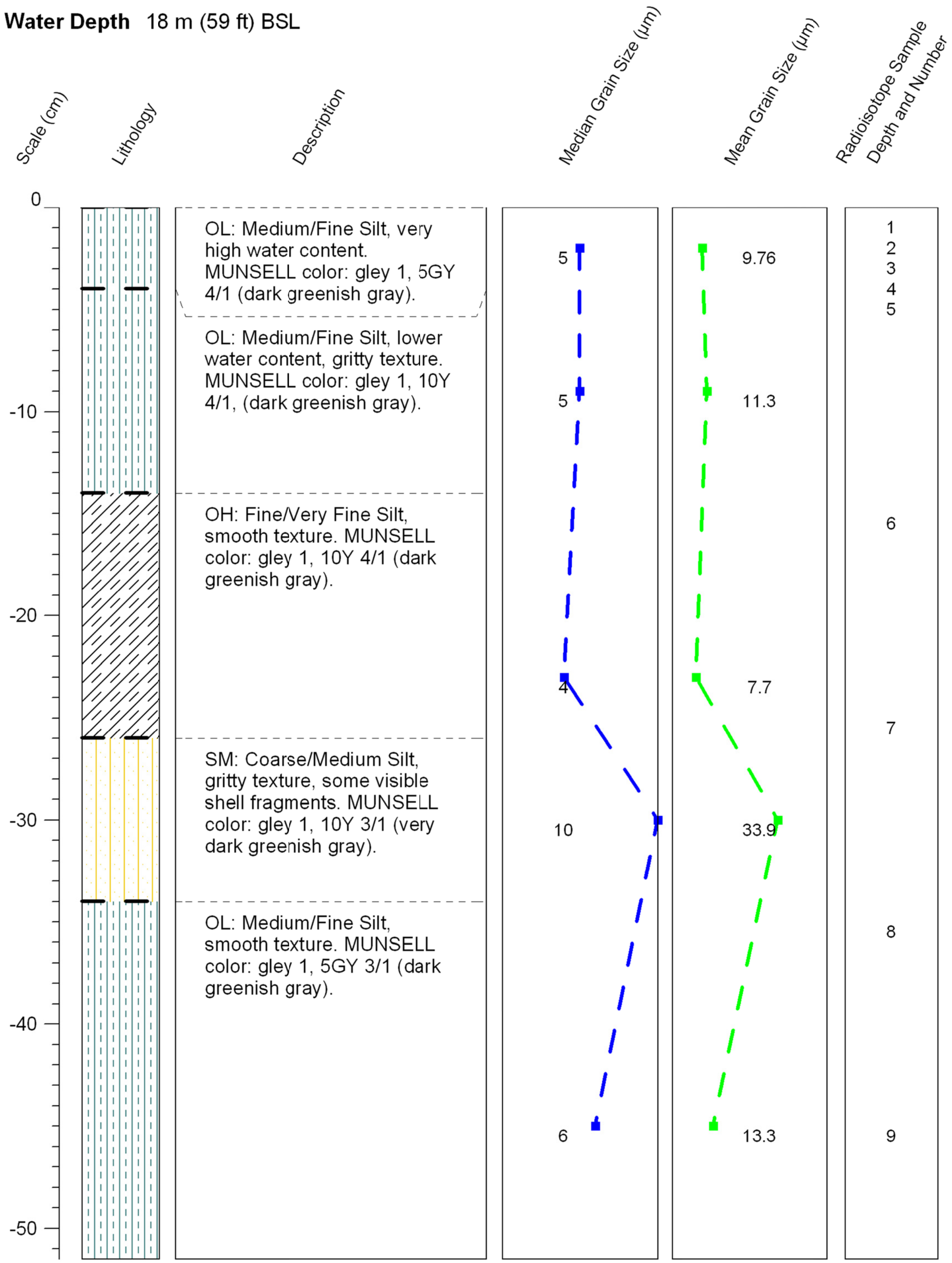


Site No. 15488 (Unknown modern wreck)
Collection Date 08/21/2010
Core No. 1
Water Depth 14 m (46 ft) BSL
Scale (cm)
Lithology
Description
Median Grain Size (μm)
Mean Grain Size (μm)
Radioisotope Sample Depth and Number
0
-10
-20
-30
-40
-50
-60
SM: Coarse/Medium Silt. MUNSELL color: gley 1, 10Y 2.5/1 (greenish black).
CL: Medium Silt. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
SM: Coarse/Medium Silt. MUNSELL color: gley 1, 10Y 3/1 (very dark greenish gray).
OL: Medium/Fine Silt. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
11.7
11.7
9
6
46
16.6
26.5
11.2
1
2
3
4
5
6
7
8
9
10
11

Site No. **15366 (Unknown modern wreck)** **Collection Date** 08/23/2010

Core No. 1

Water Depth 18 m (59 ft) BSL

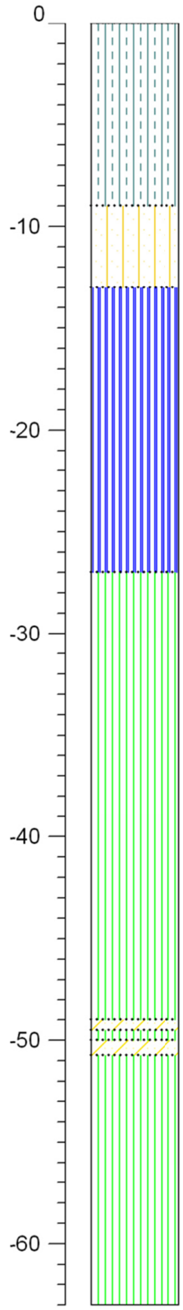


Site No. **389 (probable JA Bisso)** **Collection Date** 08/14/2010

Core No. 1

Water Depth 20 m (66 ft) BSL

Scale (cm) Lithology Description



OL: Soft texture, very high water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

SM: Gritty texture, high water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

MH: Gritty texture. MUNSELL color: gley 1, 5GY 2.5/1 (greenish black).

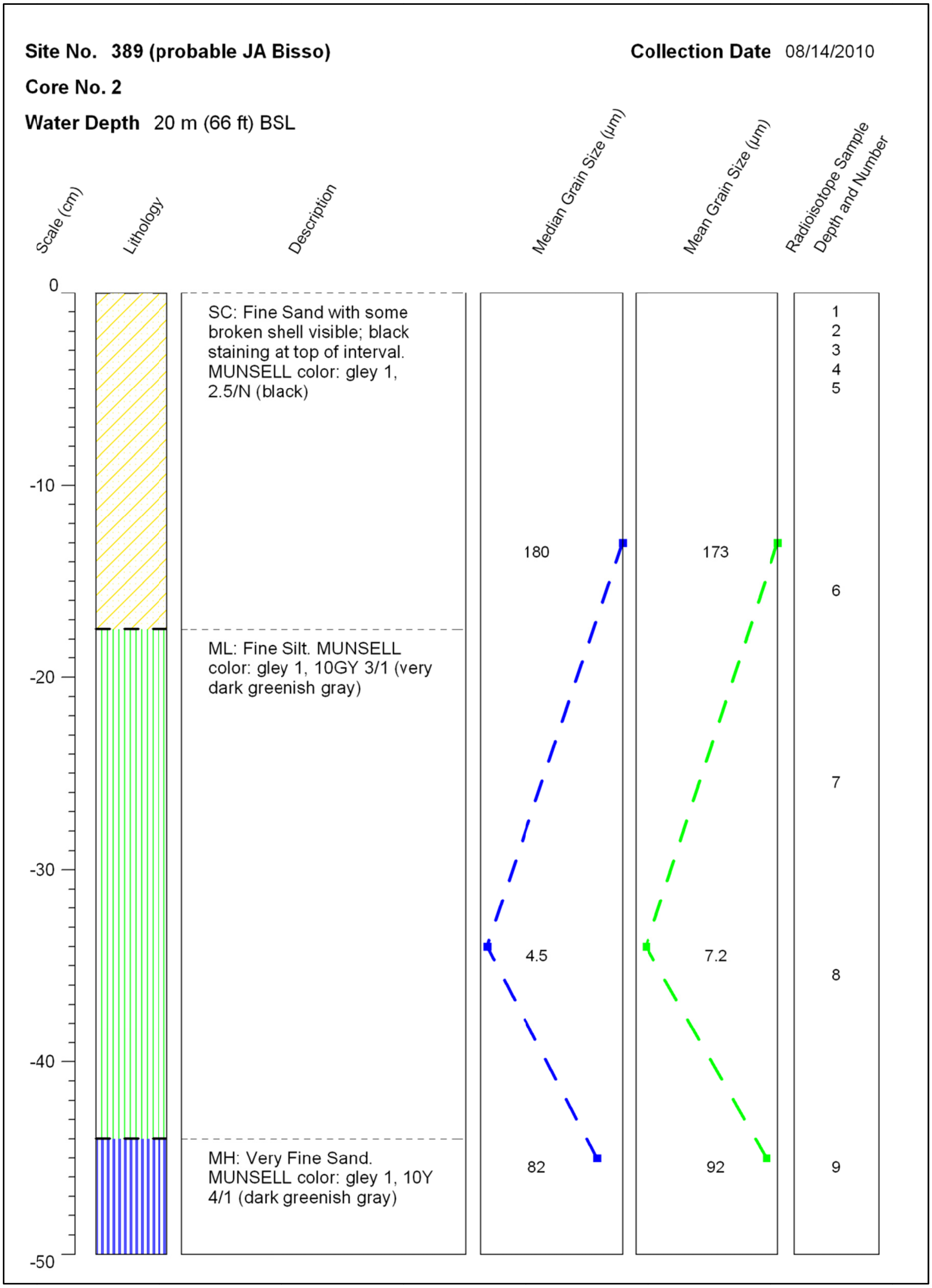
ML: Soft texture. MUNSELL color: gley 1, 10Y 3/1 (dark greenish gray).

SC: Sand lens.

ML: Soft texture. MUNSELL color: gley 1, 10Y 3/1 (dark greenish gray).

SC: Sand lens.

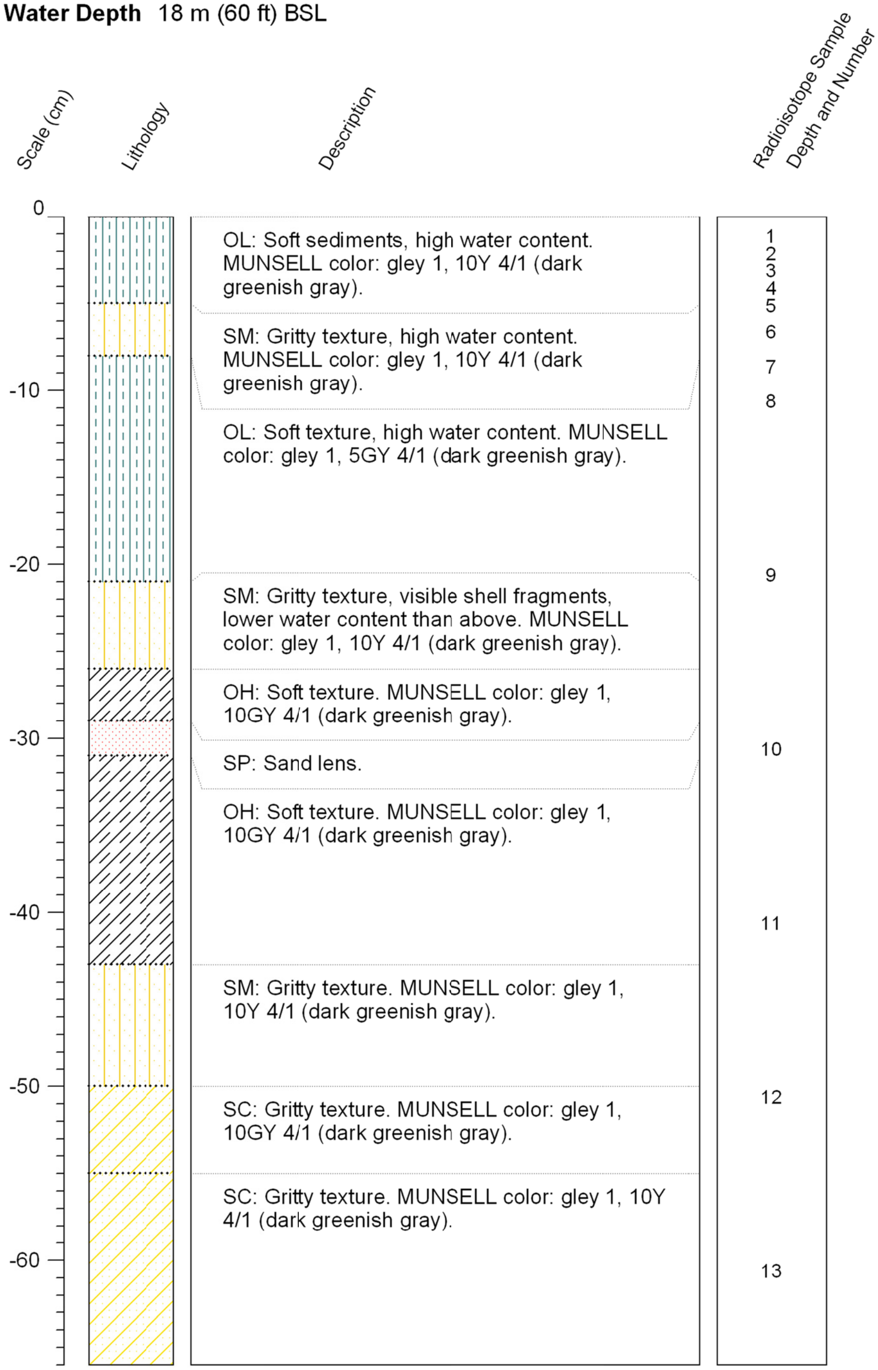
ML: Soft texture. MUNSELL color: gley 1, 10Y 3/1 (dark greenish gray).

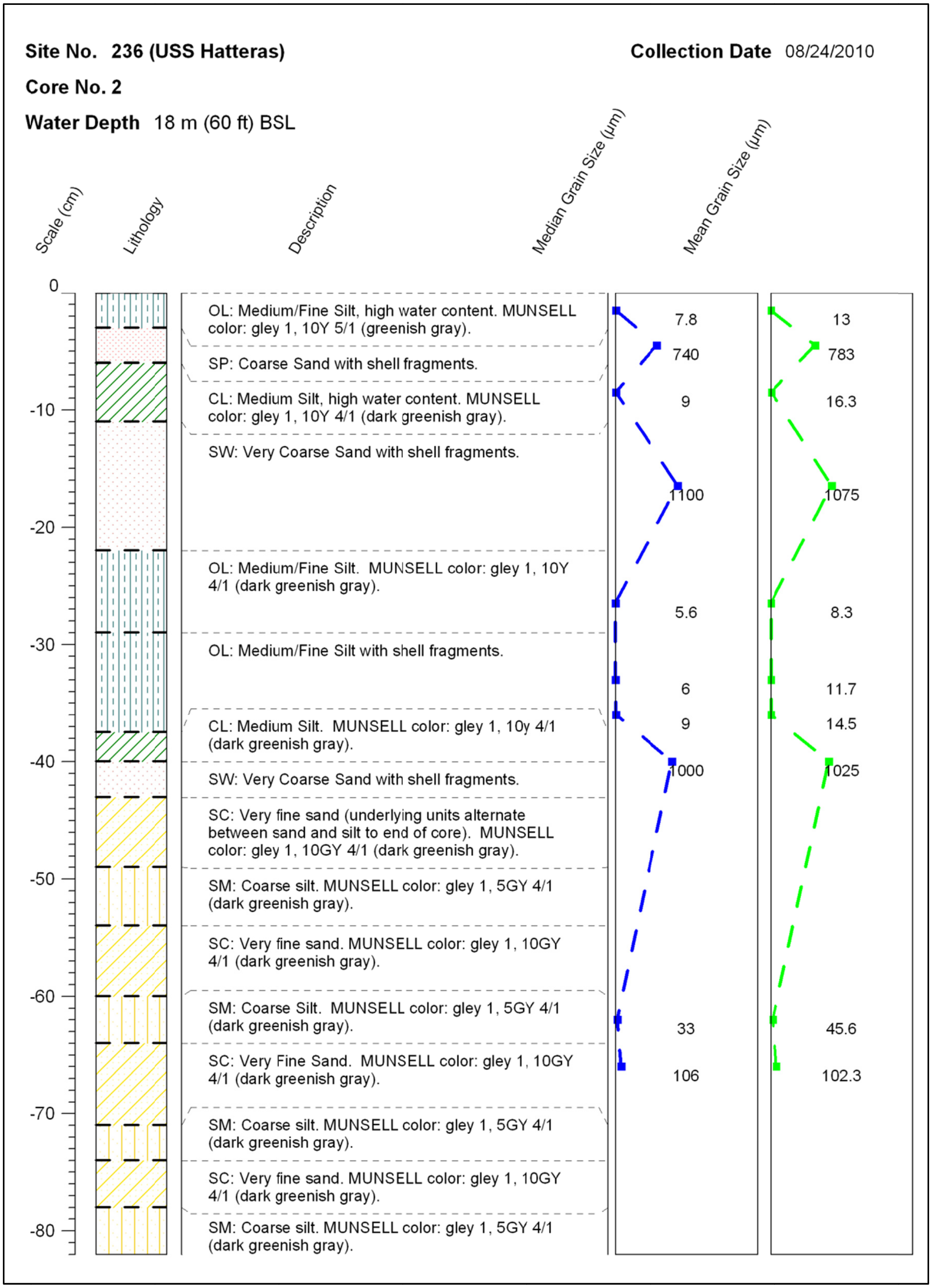

Site No. 389 (probable JA Bisso)
Collection Date 08/14/2010
Core No. 2
Water Depth 20 m (66 ft) BSL
Scale (cm)
Lithology
Description
Median Grain Size (µm)
Mean Grain Size (µm)
Radioisotope Sample Depth and Number
0
-10
-20
-30
-40
-50
SC: Fine Sand with some broken shell visible; black staining at top of interval. MUNSELL color: gley 1, 2.5/N (black)
ML: Fine Silt. MUNSELL color: gley 1, 10GY 3/1 (very dark greenish gray)
MH: Very Fine Sand. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray)
180
4.5
82
173
7.2
92
1
2
3
4
5
6
7
8
9

Site No. **236 (USS Hatteras)** **Collection Date** 08/24/2010

Core No. 1

Water Depth 18 m (60 ft) BSL



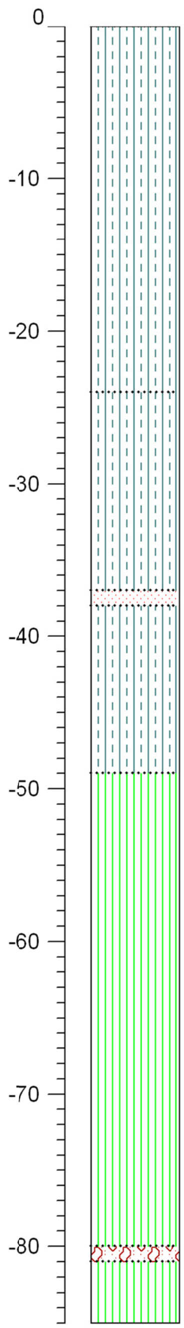

Site No. 236 (USS Hatteras)
Collection Date 08/24/2010
Core No. 2
Water Depth 18 m (60 ft) BSL
Scale (cm)
Lithology
Description
Median Grain Size (µm)
Mean Grain Size (µm)
0
-10
-20
-30
-40
-50
-60
-70
-80
OL: Medium/Fine Silt, high water content. MUNSELL color: gley 1, 10Y 5/1 (greenish gray).
SP: Coarse Sand with shell fragments.
CL: Medium Silt, high water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).
SW: Very Coarse Sand with shell fragments.
OL: Medium/Fine Silt. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).
OL: Medium/Fine Silt with shell fragments.
CL: Medium Silt. MUNSELL color: gley 1, 10y 4/1 (dark greenish gray).
SW: Very Coarse Sand with shell fragments.
SC: Very fine sand (underlying units alternate between sand and silt to end of core). MUNSELL color: gley 1, 10GY 4/1 (dark greenish gray).
SM: Coarse silt. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
SC: Very fine sand. MUNSELL color: gley 1, 10GY 4/1 (dark greenish gray).
SM: Coarse Silt. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
SC: Very Fine Sand. MUNSELL color: gley 1, 10GY 4/1 (dark greenish gray).
SM: Coarse silt. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
SC: Very fine sand. MUNSELL color: gley 1, 10GY 4/1 (dark greenish gray).
SM: Coarse silt. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
7.8
740
9
1100
5.6
6
9
1000
33
106
13
783
16.3
1075
8.3
11.7
14.5
1025
45.6
102.3

Site No. 15236 (Unknown barge) **Collection Date** 08/20/2010

Core No. 1

Water Depth 17 m (57 ft) BSL

Scale (cm) Lithology Description



OL: Soft texture, high water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

OL: Soft texture, lower water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

SP: Sand lens with visible shell fragments.

OL: Soft texture, lower water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

ML: Gritty texture. MUNSELL color: gley 1, 5Y 4/1 (dark gray).

GW: Shells.

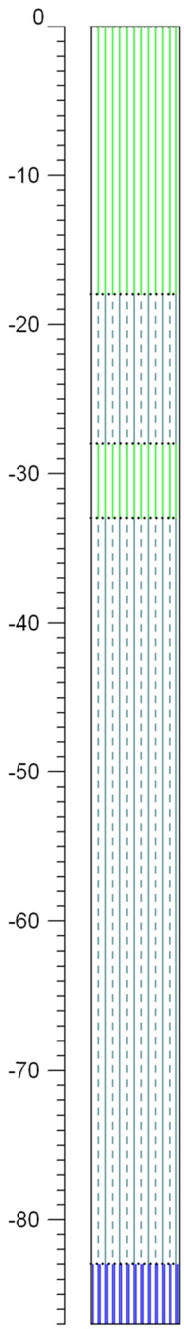
ML: Gritty texture. MUNSELL color: gley 1, 5Y 4/1 (dark gray).

Site No. 15236 (Unknown barge) **Collection Date** 08/20/2010

Core No. 2

Water Depth 17 m (56 ft) BSL

Scale (cm) Lithology Description



ML: Gritty texture, very high water content. MUNSELL color: gley 1, 5Y 4/1 (dark gray).

OL: Soft texture, lower water content. MUNSELL color: gley 1, 5Y 4/1 (dark gray).

ML: Gritty texture, some visible shell. MUNSELL color: gley 1, N 4/0 (dark gray).

OL: Soft texture. MUNSELL color: gley 1, 5Y 4/1 (dark gray).

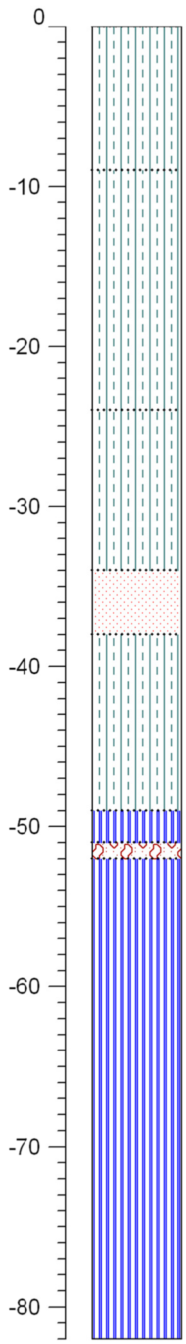
MH: Gritty texture, dense sediments. MUNSELL color: gley 1, n 4/- (dark gray).

Site No. **322 (Unknown modern wreck)** **Collection Date** 08/20/2010

Core No. 1

Water Depth 17 m (56 ft) BSL

Scale (cm) Lithology Description



OL: Soft texture, very high water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

OL: Soft texture, medium water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

OL: Soft texture, low water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

SP: Sand lens with visible shell fragments.

OL: Soft texture, low water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).

MH: Gritty texture, dense sediments. MUNSELL color: 5GY 4/1 (dark greenish gray).

GW: Shell inclusion.

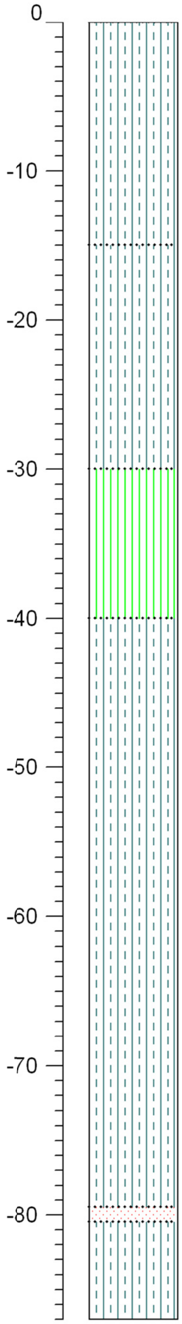
MH: Gritty texture, dense sediments. MUNSELL color: 5GY 4/1 (dark greenish gray).

Site No. **322 (Unknown modern wreck)** **Collection Date** 08/20/2010

Core No. 2

Water Depth 17 m (57 ft) BSL

Scale (cm)	Lithology	Description
0 to -15		OL: Soft texture, very high water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).
-15 to -30		OL: Soft texture, medium water content. MUNSELL color: gley 1, 10Y 4/1 (dark greenish gray).
-30 to -40		ML: Gritty texture, some visible shell fragments. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
-40 to -79		OL: Soft texture. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).
-79 to -80		SP: Sand lens with visible shell fragments.
-80 to bottom		OL: Soft texture. MUNSELL color: gley 1, 5GY 4/1 (dark greenish gray).



The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management Mission

The Bureau of Ocean Energy Management (BOEM) promotes energy independence, environmental protection, and economic development through responsible, science-based management of offshore conventional and renewable energy.