Abstract

MATTERS OF STEEL:

ILLUSTRATING AND ASSESSING THE DETERIORATION OF THE

WORLDWAR II MERCHANT FREIGHTER *CARIBSEA*

By

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May 2015

Director: Dr. Nathan Richards
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The purpose of this thesis is to acquire historical and archaeological datasets for the illustration and interpretation of site formation processes affecting a World War II merchant shipwreck, and to use this data to develop a series of 3D models displaying sequential shipwreck disintegration. This thesis proposes to explore the potential of a) using archival sources (in particular ship builder's plans) to create the historical ship model and b) using archaeological resources to create an archaeological ship model, in order to visualize individual multi-stage deterioration. Additionally, by integrating structural deterioration assessments, as well as adding inferred environmental variables (including physical, biological, and chemical processes) into site formation models, resource managers and maritime archaeologists may forecast future site transformations. The interdisciplinary research will include historical and geo-spatially accurate data, combined with the understanding of cultural and environmental processes. It is hoped that an integrated explanatory model designed to visualize cumulative site formation data will contribute towards management actions regarding long-term stewardship of shipwrecks of this type.

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WORLD WAR II MERCHANT FREIGHTER *CARIBSEA*

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Master of Arts in Maritime Studies

By
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DEDICATION

This thesis is dedicated to the 21 merchant sailors of *Caribsea* who lost their lives on March 11, 1942 in the treacherous waters of the North Atlantic.

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CHAPTER ONE: INTRODUCTION

The Battle of the Atlantic is considered one of the longest, and arguably the most crucial, naval battles of World War II. It started in September of 1939, reaching its dramatic climax in the spring of 1943, and ended in May of 1945 (Rohwer 1977:25). The battle was fought over a vast expanse of ocean, from the warm waters of the Caribbean Sea and the Gulf of Mexico to the frigid waters of the Barents Sea. This area encompassed the shipping routes between the United States, Canada, and Great Britain. Germany focused its naval power primarily on this area to cut the Allies' supply lines, hoping to isolate Britain from supplies of food, ammunition, and war materials (Bunker 2012:2).

By the end of August 1942, German U-boats attacked over 285 Allied vessels in North American waters while only losing seven of their own (Wagner 2010:17). The losses prompted the United States Navy and Maritime Administrations to streamline their coastal protocols by arming the merchant fleets and utilizing the convoy strategy in 1943 (Billy and Billy 2008:69). These tactics drastically reduced the sinking of Allied vessels, and could be argued to be the turning point of the Atlantic warfront (Rohwer 1977:25). The Merchant Marine fought to gain passage through this surging warzone, dodging U-boat wolf packs, relying on creative military tactics and few guns, and desperately fighting to reach the war fronts overseas. Against all odds, the men and women who participated in the merchant marine provided fighting and provisional support to the Allied troops throughout the war, ultimately having a critical impact on the Allied victory of World War II.

Today, the remnants of World War II ship casualties are scattered across the ocean floor. The ongoing National Oceanic and Atmospheric Administration (NOAA) "Battle of the Atlantic" expedition is in the process of recording and documenting World War II German U-boats, Allied convoy vessels, merchant freighters, and tankers off the coast of North Carolina (NOAA 2008, 2009, 2010, 2011). Since 2008, a collaboration of NOAA's *Monitor* National Marine Sanctuary, the UNC-Coastal Studies Institute and East Carolina University, and other partners has been documenting the remains of North Carolina's submerged World War II heritage (Richards et al. 2011; Bright et al. 2012). Through the implementation of remote sensing surveys, high definition imagery, and biological surveys, these past expeditions have produced an extensive database of archaeological information on the historically significant shipwrecks tragically lost during World War II.

The waters of the United States are littered with a variety of World War II shipwrecks. However, limited historic preservation legislation in the United States applies to vessels located outside of state waters. While the Abandoned Shipwreck Act (1987) protects shipwrecks within a three-mile limit of the shoreline and the Sunken Military Craft Act (2005) covers sunken military craft irrespective of their distance from shore, these laws neglect the ubiquitous site type representing naval activities of the period—merchant shipwrecks. Merchant shipwreck sites tend to be ferrous-hulled (generally undergoing corrosion), large (in tonnage and dimensions), often highly disarticulated, frequently sitting high above the seabed, and adjacent to the convoy routes which guided them along American coastlines. Coupled with their commercial proprietorship, absent legal protection, and vessel characteristics, merchant shipwrecks remain exposed and vulnerable to salvage, looters, and destruction.

Their sheer number, lack of widely articulated historical and archaeological significance, legal ambiguity, and the absence of a standard framework for effectively monitoring and protecting them, make these shipwrecks a management challenge. In light of these challenges, there is constantly a need for methods by which maritime archaeologists and resource managers can collect data for use in the ongoing interpretation, assessment, and stewardship of these shipwreck sites. By using historical and archaeological data and an extensive understanding of the processes affecting the degradation of the shipwreck site, this study will aim to formulate a series of 3D site formation models of a World War II merchant shipwreck that can be used to better understand the transformation process taking place on these diminishing resources.

Research Questions

The primary objective of this study is to use comprehensive historical and archaeological datasets to develop a series of sequential 3D shipwreck models that illustrate the structural disintegration of a shipwreck site. These explanatory models provide illustrative, interpretive, and analytical capabilities that many archaeological resources lack.

Primary Research Question

- Can an analytical model, based on historically accurate data, current three-dimensional multibeam high-resolution imagery, and an understanding of the environmental and cultural processes affecting the shipwreck site, be used to develop a series of visual shipwreck models displaying sequential disintegration?

Secondary Research Questions

- What types of natural and cultural site formation processes are affecting ferrous World War II resources surrounding Cape Hatteras?
    - How are environmental forces such as sedimentary and hydrodynamic activities affecting the shipwreck site?
    - How are cultural forces such as the shipwrecking process, salvage, and fishing activities affecting the shipwreck site?

Regardless of the types of cultural or environmental factors affecting shipwreck sites, site formation processes have become a concern in cultural resource management, can influence decision making processes and recording methodologies. One of the challenges with cultural resource management involves sustaining the necessary resources to properly manage and preserve the site. The primary objective of this study includes utilizing acquired historical and archaeological datasets for the creation of 3D site formation models. This study provides the opportunity to apply and develop formerly acquired datasets or easily accessible data for a site formation study, providing an analytical tool for assessing and interpreting the collapse and disarticulation of a shipwreck site.

Previous Research

Understanding site formation processes and how they affect a specific type of shipwreck site requires a great deal of historical and archaeological research. The process of acquiring data for illustrating site formation processes affecting World War II, merchant shipwrecks off the coast of North Carolina demands research into the historical trajectory contributing specifically to the circumstances surrounding the shipwreck site in question. Moreover, emphasis on the development of the Merchant Marine and its role in the Battle of the Atlantic necessitates the analysis of histories surrounding the evolution of ship construction leading up to World War II. Comprehensive studies on ship construction have emphasized the critical importance the transitions from wood, to iron, to steel shipbuilding techniques have played on the progression of merchant shipping. Furthermore, specific histories on the development of modern ship construction and subsequent shipbuilding programs during World War I and World War II offer information on the progression of merchant shipbuilding techniques and design (Grantham 1868; Reed 1869; White 1900; Long 1902; Curr 1907; Carmichael 1918; Mattox 1920; Riegel 1921;

Carse 1942; Pursey 1942; Baker 1943; Manolis 1949; Lane 1951; Tyler 1958; Mitchell 1970; Gardiner 1994).

To fully understand the trajectory of modern ship construction requires a brief examination of the industry's origins. The steel vessels of the 20th century were the culmination of a long integration of metal into shipbuilding practices. The earliest histories of modern merchant ship construction stemmed from the work of engineers, shipwrights, naval architects, and professionals of the industry. During the transition from wood to iron shipbuilding at the end of the 19th century, there was an instant niche for discussion on ship construction materials and their influence on shipbuilding techniques and design (Grantham 1868; Reed 1869; White 1900). British and American shipbuilders relied on these early manuals, which described the methods of construction in early iron and steel shipbuilding and outlined the improvements leading up to existing methods.

With the turn of the century, historians discussed the implementation of these shipbuilding industrializations regarding American naval and merchant fleets. Historians often had different motivations; turn of the century recollections discussed the progression and specified utilization of ship construction, whereas later reminiscences provided regulation or informative literature for particular audiences. Early 20th-century literature on iron and steel ship construction operated under newfound knowledge. Where prior histories had discussed the development of the materials and potential for iron and steel vessels, these histories offered a look into the preliminary results of modern ship construction techniques (Long 1902; Curr 1907; Carmichael 1918; Mattox 1920; Riegel 1921).

Following World War I, and throughout World War II, the mid to late 20th-century historians were able to offer scholarship representing more focused subjects, including supplementary research and the benefit of additional hindsight (Carse 1942; Pursey 1942; Baker 1943; Manolis 1949). Studies, handbooks, memoirs, and histories written by historians and skilled professionals alike, still displayed antiquarian dispositions, but the manuals and histories of this era were expertly fixated on the merchant routine, shipbuilding practices, development, and design—replacing the novelty and ambiguity that previously accompanied the literature.

In retrospect of World War I and World War II, historians were able to piece together the history of merchant ship construction, shedding light on the progress and historical trajectory of the American merchant marine. Studies and histories were the result of post-war sources, memories, experiences, newspapers, interviews, and antiquarian studies that offered a glimpse into shipbuilding history that no secondary source provided. Historians chose their topics of expertise based on interest, passion, and accessibility, examining the wide range of standardized merchant ship design that ensued, including Hog Islanders, Lakers, Liberty Ships, and Victory tankers. With ample separation of time from their subject, historians (Lane 1951; Tyler 1958; Mitchell 1970, 1974; Gardiner 1994; Felknor 1998; Bunker 2006; Billy and Billy 2008) have continued to examine the development of the American merchant marine and its roles in World War II and in the broader progression of merchant shipping. This generation of literature utilized a wide range of sources including oral histories and vast collections from the National Archives. Professionals and historians continued to study the development of the American merchant marine, examining the evolving role of the merchant sailor and the changing design of the American merchant vessel.

The ability to piece together the historical trajectory of American merchant shipbuilding throughout the 19th and 20th centuries is crucial for the full examination of the archaeological merchant shipwrecks left behind from the Battle of the Atlantic. These shipwrecks are symbolic of a time in America's history where merchant fleets were the epicenter of arguably the longest, deadliest, and most crucial battle ever conducted. The war required merchant vessels and crews of civilian seamen to continue transporting their cargoes through the U-boat infested waters of the North Atlantic. As a shipwreck, the construction and lifespan of these vessels are expectedly ordinary. The significance of these shipwrecks, however, lies within the extraordinary tasks, heroic actions, and massive obligation impressed upon the Merchant Marine throughout World War II.

In addition to the historical scholarship, archaeological methodologies and theories were of interest to the present study. Site formation theory assists in dictating the causes of what alters or moves a shipwreck site and its artifacts from their location in the archaeological record. There are two types of site formation processes: "initial human behavior (i.e. the phenomenon of a shipwreck which is culturally derived event) and subsequent transformational actions (effect of natural processes and subsequent human activities)" (Richards 2008:51). For the purposes of this study, both environmental and cultural activities affecting the collapse and assemblage of the shipwreck site will be taken into consideration.

There have been many changes in the scholarship of site formation throughout the development of maritime archaeology. Michael Schiffer (1973, 1987) and Keith Muckelroy (1976, 1978) are widely known for developing the concept of site formation processes. Their research and classification systems have since been widely followed with many archaeologists addressing similar topics and expanding on the theory (Ward et al. 1999:561; O'Shea 2002:211; Gibbs 2006:4; Martin 2012:51). Furthermore, these archaeological studies on site formation offer a theoretical framework that forms the foundation of this study.

Upon this foundation, preliminary research on the various 3D methods of virtual archaeology was necessary. The early 1990s introduced the idea of virtually illustrating archaeological concepts. While the mentioning of "virtual reality" often conveys visions of gaming, scientific representations, and entertainment, all three of these applications are beneficial towards the concept of virtual archaeology. 3D Computer Aided Drafting (CAD) applications and display tools have been further developed over the last fifteen years. The development of these tools has reaffirmed the broader scope of archaeological visualization as a mode for documentation, analysis, education, and dissemination (Sanders 2012:306; Earl 2013:239).

The development of virtual archaeology has enhanced traditional methods of interacting, analyzing, and interpreting underwater resources. In this respect, virtual technologies have opened the door to non-destructive public access, providing opportunities to discover and explore archaeological sites without irreparable damage. Resource managers cannot only study and protect the past, but they are now able to interact and assess change and structural collapse based on 3D platforms.

Before an archaeological model can be viewed, tested, interpreted, or analyzed, it must be created. Advances in digital technologies including computing capabilities and recording instrumentation have greatly influenced underwater fieldwork methodologies, thus affecting the ways the gathered data is captured, processed, and presented. Modeling, mapping, and visualization software have ultimately transformed the work of archaeologists (Monroy et al. 2012:329). A variety of techniques can be used to create 3D shipwreck models—harnessing historical and archaeological datasets into virtual displays. Models can be "built from scratch" using computer recreations based on 3D measurement systems (range-based modeling), captured through images (image-based modeling), or visualized through acoustic technologies.

Laser-scan modeling has been implemented to record, analyze, and reconstruct 3D ship models. A scaled, finite model is required to serve as a proxy and to assess hypothetical variations in symmetry. The to-scale model is then scanned using a laser or white light scanner to capture a series of coordinates. The model must be scanned numerous times to capture the details and angles of every surface. A range of 3D laser scanners are available, extending from small range scanners suitable for small objects or artifacts, to long range scanners suitable for buildings (Fernie and Richards 2003:17).

In 2002, Arizona State University's Partnership for Research in Spatial Modeling (PRISM) lab used the *Cyberware* 3030 Laser Scanner (with RGB color) to scan and capture a 3D model of a Viking ship. The 3D model was built from a total of 48 scans (4 sets of 12 rotational scans). The scans were merged to create one virtual model, illustrating the detail of the interior and exterior surfaces. The captured coordinates (3D point cloud) were then transferred into the *Cyberware,* which is similar to *Rhinoceros* or *AutoCAD,* where it produced a full interactive virtual model of the object. A model can be rotated in all directions for close examination of features on the interior or exterior surfaces (Indruszewski et al. 2004).

Another 3D modeling methodology combines traditional methods (measured drawings done by hand) and newer technologies (total station distance measuring equipment). Distance-based, electronic recording devices, acquires the coordinates of numerous points on the surfaces, curves, and features of an object or site. The numerous points are then transferred into 3D modeling software. Once these data have been compiled and interpreted, a 3D model can be visualized. This type of technology has been used for a variety of site types including terrestrial and maritime, although it is best suited for maritime sites on land, floating, or partially submerged (Campbell 2009:1).

The basic equipment required for this method includes a total station, computer, and 3D modeling software. While traditional documentation equipment can be helpful in the recording process, they do not provide an accurate 3D representation. The total station has a combination of theodolite and electronic distance capabilities, which captures the distance of points located on surfaces, edges, curves, and features located on the object or site. The total station measures these points and records 3D coordinates precisely relative to one another (Campbell 2009:2). Once the point cloud data has been captured, it is compiled and transferred into a CAD modeling software, which enables the 3D recreation of the data. The total station points will then be assembled into major construction features layer by layer, resulting in the primary deliverable—a 3D virtual site plan. Once the model is finished, additional textures and surfaces can be applied to improve realistic appearances (Campbell 2009:3; Carmo and Claudio 2013:224).

Image-based modeling techniques consist of several processes including sensor and network geometry, 3D measurements, structure and modeling, and texture visualization (Carmo and Claudio 2013:225). Provided you have adequate visibility, photogrammetric modeling exists as a useful technique for mapping and documenting an underwater site as opposed to tape-measure offsets or trilaterations, which have proven to be time consuming and problematic (Green et al. 2002:283). Photogrammetry includes extracting measurements and coordinates from a series of calibrated photographs to obtain geometric measurements for the creation of a 3D model of the photograph. It has been defined as, "the science or art of obtaining reliable measurements by means of photography" (Pollio 1969:1).

One method used for photogrammetric recording is phototriangulation. EOS *PhotoModeler* is one of the best programs for phototriangulation. It uses a calibrated camera to measure the "ray paths" from the camera, through the photographic image, to the various targeted points. The program triangulates the photos by measuring rays from the camera to points on the site, feature, or object. Images containing multiple views of the same points allow the program to calculate angles and complete geometric measurements creating a model of the photographed image (Green et al. 2002:284).

Faculty members and students of the Maritime Studies Department at East Carolina University have been implementing EOS *PhotoModeler* photogrammetry for understanding and preserving maritime heritage. In 2005, Dr. Nathan Richards taught a course titled HIST 5005: Deep Water and Advanced Survey Methods for Underwater Archaeology, where students developed 3D photogrammetric models of maritime objects. This modeling technique provided the students with a method for conducting research that might otherwise have been restricted or impossible (Richards et al. 2006:1–2).

Recent large-scale projects involving World War II iron-hulled shipwreck deterioration have involved the attention and resources of federal agencies including the National Park Service (NPS), the Bureau of Ocean Energy Management (BOEM), and the National Oceanic and Atmospheric Administration (NOAA). One of the most prominent shipwreck modeling efforts involves the USS *Arizona* deterioration study focused on understanding and characterizing the corrosion rates of structural elements on the ship. Finite Element Model (FEM), a progressive and demanding predictive model, is designed to calculate the vessel's structural deterioration and eventual collapse based on direct measurements of remaining steel thickness (Murphy and Russell 2008:123).

In 2007, BOEM (then Minerals Management Service) released a biological and archaeological study exploring seven World War II era shipwrecks located in the Gulf of Mexico. The project recorded and assessed the past and present conditions and any environmental factors affecting the deterioration of the shipwreck sites. The analysis includes a predictive model for the debris fields of metal-hulled shipwrecks lost through war efforts (Church et al. 2007). In 2011, BOEM (then Bureau of Ocean Energy Management Regulation and Enforcement) released another comprehensive study which included several World War II era casualties regarding hurricane impacts on shipwrecks in the Gulf of Mexico (Gearhart et al. 2011). These multi-disciplinary projects provide comprehensive analyses on the types of environmental and cultural factors influencing shipwrecks of similar consequence in the North Atlantic.

In 2013, NOAA released a study analyzing a broad variety of historical and environmental datasets relating to shipwrecks with potential environmental risk. The study provided a current assessment of the threat of hydrocarbon pollution from shipwrecks in United States waters, including predictive modeling of prospective oil spills from "priority" shipwrecks. Detailed analyses were conducted on shipwrecks including histories, condition assessments, and deterioration factors (NOAA 2013).

One method that has proven to be a successful and highly manageable technique is the modeling of objects with 3D CAD programs. Data based on evidence from archaeological, historical, or iconographical contexts are integrated and entered into the software to create lines and curves, or connecting coordinate data to create an extremely accurate 3D model. The object or site being modeled is not required. Moreover, the model is built according to acquired datasets including paintings, photographs, video, personal documents, builder's plans, recorded measurements, or any other resource that would supplement the recreation of the site or object. This method has proven time-consuming, but produces accurate modeling results with low costs (Carmo and Claudio 2013:224).

Alexis Catsambis (2006) outlined the reconstruction of vessels from 2D drawings to 3D models. Once accurate lines drawings of a vessel are obtained, the illustrations can be interpreted based on realistic proportions concerning details relating to the construction of the vessel, and developed into a 3D representation of the ship. Catsambis emphasized questions such as:

> Where did the information originate from [*sic*]? How was it conveyed to the author or artist? Is the author or artist someone knowledgeable in naval matters? Who is the intended audience and how much information is purposefully concealed or misrepresented (Catsambis 2006:13)?

Once the drawings are carefully transcribed and thoroughly interpreted, the 3D construction of the vessel's lines and structural components begins. The digitizing and virtual reconstructions of the drawings are completely assembled through various tools accessible in the interface of a program.

For the purpose of this study, the development of 3D site formation models were developed using the capabilities of the CAD program *Rhinoceros* 4.0 This particular method was chosen because of its accessibility, user-friendly interface, and applicability to the modeling objective. The development process, results, and analysis of the subsequent 3D models are discussed in detail throughout the extent of this study.

Thesis Structure

The current study is a compilation of historical and archaeological approaches regarding the 3D illustration of a World War II shipwreck and the subsequent site formation processes affecting the site. Chapter One is an introduction, defining the main objective of the project: outlining the research questions and introducing the historical and archaeological framework of the study. Chapter Two examines the theoretical framework for the archaeological investigation of a shipwreck site. This provides a foundation for understanding the types of environmental and cultural processes affecting a shipwreck. Chapter Three provides the historical trajectory of the shipwreck candidate that was eventually chosen for this project: the Laker freighter *Caribsea*. This chapter outlines the historical circumstances leading to the wrecking event of the ship. The historical context of *Caribsea* is discussed in detail, including factors contributing to the construction of the ship and reference data relevant to the Battle of the Atlantic and the ultimate sinking of *Caribsea*.

Chapter Four outlines the methodology used in this study, including the process of choosing a shipwreck site, the acquisition of historical and archaeological datasets, and the 3D modeling process. Chapter Five serves as a more detailed discussion on the 3D modeling process. This chapter further explores the types of historical and archaeological data that contributed to the development of the models, also displaying the results of the modeling process. Chapter Six revisits the original research questions of the study and discusses how the 3D models accurately illustrated and further assessed site formation processes affecting *Caribsea*. Lastly, Chapter Seven provides concluding statements on this study.

CHAPTER TWO: SITE FORMATION THEORY

The archaeological record is an unorganized consequence of circumstances, making it difficult to appreciate and observe as an archaeologist in a contemporary environment. This perspective advocates discussion regarding the reconstruction of the past:

> Every living community is in the process of continuous change with respect to the materials which it utilizes. At any point in its existence some proportion of materials are falling into disuse and decomposing, while new materials are being added as replacement. In a certain sense a part of every community is becoming, but is not yet, archaeological data (Ascher 1961:324).

This type of process-oriented theory is referred to as site formation—a philosophy of material context explaining the evolution of the archaeological record (Shott 1998:301). Understanding site formation processes and how they affect a shipwreck site is critical when assessing the archaeological record. Site formation assists in dictating the causes of what is altering or moving the shipwreck site and its artifacts from their original locations.

Unlike terrestrial sites, whose locations often reflect choice or reason, shipwrecks and underwater sites are likely to be "fortuitous, unintended, and very possibly far from [their] original provenance" (Martin 2012:47). While the primary task of the maritime archaeologist is to reconstruct the maritime past through the study of the archaeological record, in order to corroborate the remains of a shipwreck with the historical record, the physical context of the site must also be taken into account. Thus, the shipwreck and its environment must be interpreted as one interconnected entity.

Understanding site formation processes and how they affect a shipwreck site is critical when assessing historical and archaeological datasets for a series of shipwreck models. Site formation theory assists in dictating the causes of what is altering or moving the shipwreck site and its artifacts from their location in the archaeological record. The challenge to understanding site formation theory exists in observing and accurately interpreting their effects for predicting future degradation on the shipwreck site. For the purposes of this thesis, the primary focus will revolve around the pre-depositional and post-depositional environmental and cultural processes affecting the deterioration and assemblage of a shipwreck site.

Keith Muckelroy (1975) recognized that accurate recording of a site does not reflect the state of the ship before it wrecked, and does not reflect the state of the shipwreck for future reference. He did, however, suggest the possibility of predictability hidden beneath the historical, natural, and cultural properties affecting the shipwreck site. Furthermore, Ward, Larcombe, and Veth (1999:562) noted that, “Models are helpful with the predicted circumstance of shipwreck formation, and to better manage, assess, excavate, preserve archaeological remains.” The development of an explanatory site formation model could potentially assist with management actions regarding long-term stewardship of ferrous-hulled shipwreck sites. This could improve and expand upon archaeological methodologies that are conducive with resource management, resulting in the better evaluation, preservation, and protection of our maritime cultural resources.

This chapter discusses site formation theory and the process of identifying and interpreting cultural and environmental factors affecting North Carolina World War II shipwreck sites. After identifying the site formation factors affecting the shipwreck site, their effects are illustrated using 3D capabilities. The historical and archaeological data depicts a sequence of shipwreck models, each one with structural change. The identification, interpretation, and illustration of site formation processes is required for projecting the probable state of the shipwreck at any point in time. This site formation study will highlight the cultural and environmental factors altering a shipwreck site, and will serve as a useful tool in facilitating ongoing data analysis.

The first half of this chapter explores the background of site formation theory and its development over the last forty years. The primary contributors of site formation theory are discussed including Lewis Binford (1977, 1981), Michael Schiffer (1973, 1976, 1987), and Keith Muckelroy (1976, 1978). An overview of site formation development, models, and applications is also discussed. The second half of the chapter summarizes the types of site formation processes affecting shipwreck sites including pre-depositional and post-depositional factors. The factors affecting the transformation of the vessel from the systemic context to the archaeological record will be identified, as well as the cultural and natural formation processes influencing the deterioration of the shipwreck site.

Theoretical Background

To a casual visitor or bystander, terrestrial and underwater archaeological sites often appear to be timeless and unchanging—representing a captured point in time. This "time capsule" perspective was known as the "Pompeii premise," or the idea of viewing the archaeological record as a frozen moment of time (Binford 1981:25). On the contrary, archaeological sites are dynamic entities reflecting not only the past but the corresponding natural and cultural circumstances consistently affecting the site.

In his 1977 essay, Lewis Binford (1977:7) concluded that once a plausible philosophy regarding the processes affecting the archaeological record is understood, the tangible significance can be applied towards the material record. Binford further popularized the term "middle-range theory," emphasizing cultural factors and circumstances that influenced the archaeological record, claiming, "the material record cannot be read as a straightforward, let alone nearly complete, account of past cultures and transformations" (Shott 1998:304). Similarly, David Clarke (1973:8) and Michael Schiffer (1976) also proposed a type of interpretative site formation theory.

Michael Schiffer, a terrestrial archaeologist, theorized that the cultural past is comprehensible, but only when the archaeological record is thoroughly investigated (1973, 1987). Schiffer's focus on the cultural (C-transforms) and non-cultural (N-transforms) processes revolved around two important aspects: causes and consequences. He claimed the causative variables of specific formation processes made the transformation highly predictable. For example, underwater ferrous materials such as an iron shipwreck react with the aqueous environment and eventually corrode. The effects or traces of the specific processes are usually predictable (Schiffer 1987:21).

In particular, Schiffer emphasized two basic types of formation processes: cultural and non-cultural. Cultural formation processes are defined as the processes of human behavior that affect or transform the archaeological record after its original period of use. Cultural behaviors include reusing items in systemic context, depositing artifacts thus creating or adding to the archaeological record, and any type of subsequent activity in the past or present that alters or modifies the systemic or archaeological record. Non-cultural formation processes are the environmental processes influencing the formation of the archaeological record, therefore producing a modified artifact or archaeological site. Schiffer claimed N-transforms were the "least autonomous domain," meaning the processes affecting environmental transformation were established by other disciplines such as geology, biology, and chemistry (Schiffer 1988:473).

Keith Muckelroy (1976, 1978) identified the underwater processes affecting the assemblage of maritime sites. His 1978 book, *Maritime Archaeology*, remains one of the most formative studies on underwater site formation processes to date. This research was strongly influenced by David Clarke (1968), who created a system for identifying and interpreting the continual transformations of an archaeological site. Muckelroy built upon this system through the adaptation of underwater influences. He explored well-documented archaeological sites, identifying the site transformations from those ships to assist in interpreting undocumented, less coherent shipwreck sites (Muckelroy 1978:158). Muckelroy paved the way for underwater site formation theory, investigating how shipwrecks are influenced by site formation processes. He identified features common to shipwreck and the implications of disintegration factors (Figure 2.1).

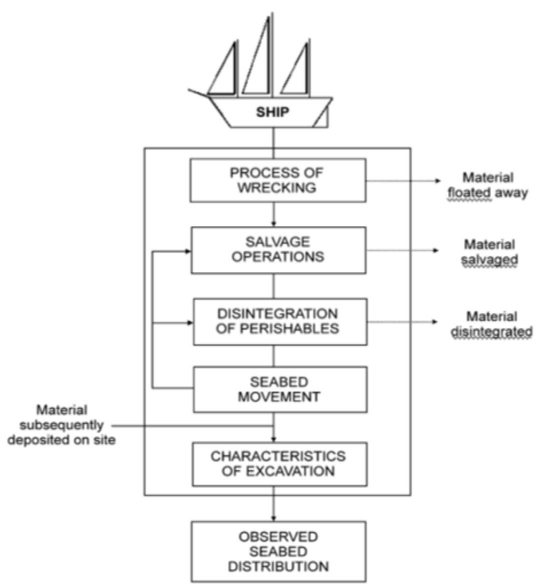

FIGURE 2.1. Diagram showing the development of a shipwreck site (Muckelroy 1976:282).

Muckelory's research utilized methods from coastal morphology when analyzing the environment of shipwreck sites. His ability to gauge the shifting multi-disciplinary trends was shared by Clarke (1968) through the application of ecological, geographical, and biological sciences and Binford's (1977) practice of integrating social sciences. Muckelroy shed light on the differences between the types of processes that disturb terrestrial sites, as compared to the processes affecting underwater sites. Compared with the human accessibility in a terrestrial context, cultural factors underwater are limited to a few identifiable activities. Thus, the conversation began, moving towards identifying these outlining underwater processes (Muckelroy 1978:158).

In Muckelroy's (1978) site formation representation, cultural and natural forces affecting the condition of the site are divisible into either "extracting filters" or "scrambling devices." Extracting filters include forces removing materials from the shipwreck site, including loss by flotation, in situ deterioration, or contemporary salvage. Scrambling devices, such as the wrecking process and natural factors, represent the forces that are continually disorganizing the ship and its contents (Martin 2012:53). By deconstructing and interpreting the characteristics of natural and cultural processes affecting underwater sites, Muckelroy hypothesized the recreation of the original composition of a vessel (Harpster 2009:69). Site formation theory, therefore, was an interpretive tool, a potential method for analyzing underwater shipwreck sites and possibly predicting future deterioration.

Once site formation theory was further acknowledged and practiced within the field, an assortment of models started appearing to organize and exemplify the various components of site formation theory. Ward, Larcombe, and Veth (1999) outlined a process-based model for shipwreck disintegration using hydrodynamic and sedimentary data from the study or excavation of HMS *Pandora*. By accounting for the physical, biological, and chemical breakdown of the shipwreck, they hypothesized a four-stage process of shipwreck formation. This study generated discussion on the various ways to understand and illustrate shipwreck formation. Additionally, Ward, Larcombe, and Veth (1999) introduced a model focusing solely on the natural processes of maritime environments affecting shipwreck site deterioration (Figure 2.2).

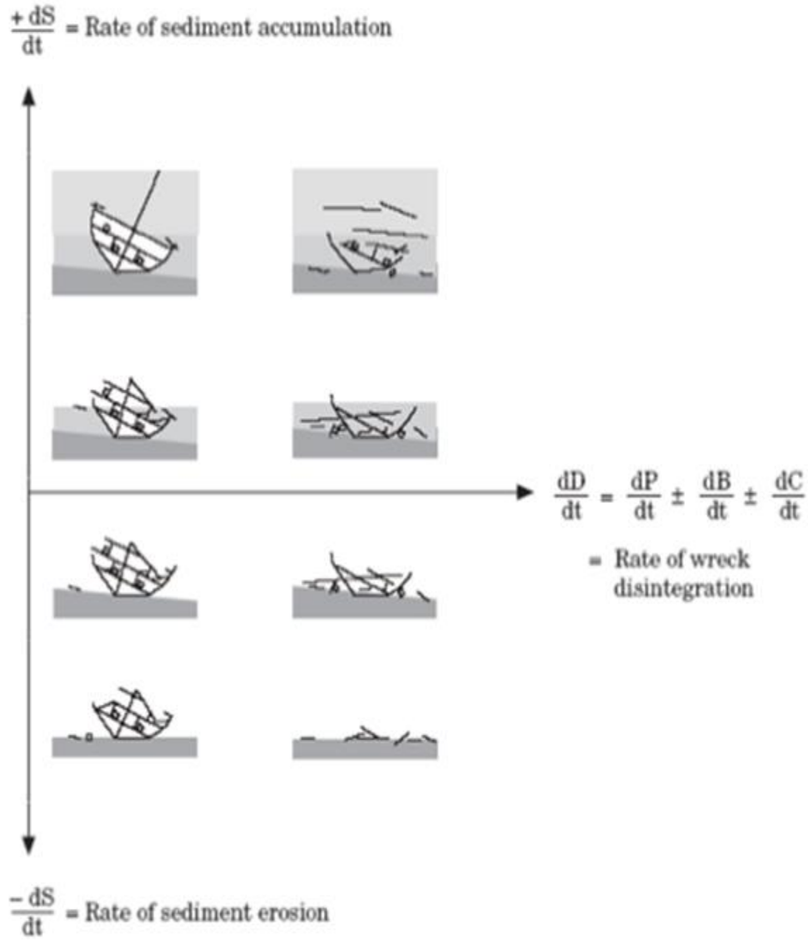

FIGURE 2.1. Diagram showing the disintegration of a shipwreck site (Ward et al. 1999:567).

The Ward, Larcombe, and Veth model effectively linked the physical anomalies of the shipwreck site with the processes controlling the actual shipwreck formations. This clearly defined the multidisciplinary approach that is required for site formation theory, outlining the necessity of future assessment of physical processes affecting the conditions of shipwreck sites.

David Stewart (1999) focused on the depositional and post-depositional formation processes affecting the condition of a shipwreck. He discussed topics such as the nature of the shipwrecking event, differential preservation between periods, and cultural and natural transformation factors affecting the shipwreck site. He stressed the importance of identifying the destructive factors contributing to the deterioration of a shipwreck site, and the opportunity to expand on this site formation research specifically post-depositional processes including dredging, construction, and bioturbation (Stewart 1999:565).

In contrast, John O'Shea (2002) assessed site formation theory through a more theoretical approach. O'Shea used stranded wooden vessels in Lake Huron to outline the behavioral, cultural, and natural stages of site formation processes. He placed emphasis on two questions: how materials pass from a cultural and systemic context into a static archaeological context, and what happens to the material remains between the time they are deposited and the time they are discovered and recovered by archaeologists. He included an evaluation of "depositional" and "post-depositional" processes, making significant advances towards a more modern understanding of archaeological deposition and distribution.

John Riley (1988), an avocational maritime archaeological expert, observed the deterioration of iron shipwrecks. Riley investigated and recorded shipwreck sites, subsequently developing to-scale cardboard shipwreck models. Riley's observations led him to conclude that when vessels sank, they settled into the sediment up to their natural waterline. This observation developed into "The Waterline Theory." The burial of the shipwreck acting as a preventative measure, keeping material from the hull from being moved or disturbed (McCarthy 2000:97).

Martin Gibbs (2006) recognized both cultural and natural processes in site formation, especially the role of cultural and behavioral factors in the process of accessing information. According to Gibbs, to thoroughly understand the pre-wreck and wreck-site nature, the relationships between historical records, archaeological, and oral data sets must be taken into account (Gibbs 2006:4). Through the creation of an effective model, Gibbs analyzed the relevant behaviors affecting the shipwrecking event and shipwreck site condition (Figure 2.3).

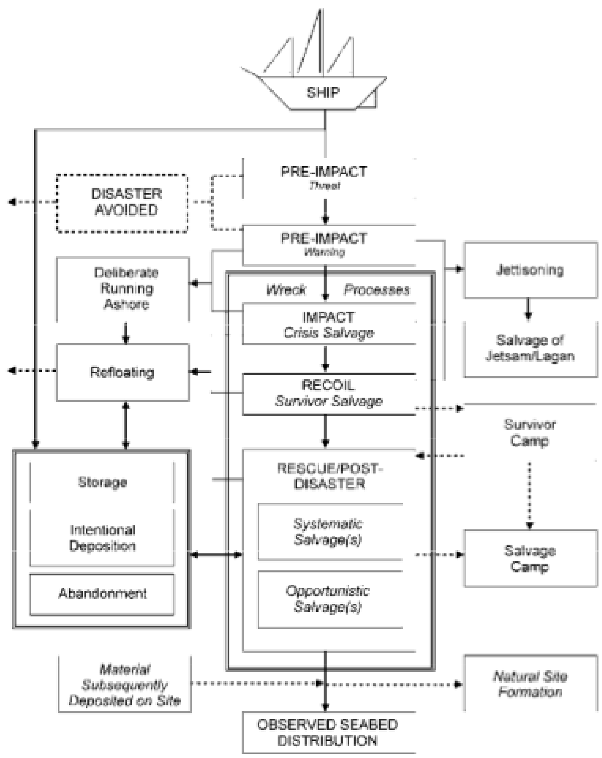

FIGURE 2.3. Diagram showing cultural factors in shipwreck disintegration (Gibbs 2006:16).

In an effort to examine the framework behind site formation theory, Nathan Richards (2008) discussed how the research of Muckelroy (1978) and Schiffer (1973, 1987) is comparable: “Muckelroy’s ‘extractive filters,’ for example, resemble Schiffer’s ‘transformation processes,’ and both researchers describe processes that are factors involved in the creation of the historic and archaeological record” (Richards 2008:51). Richards examined and described the impact of C-transform processes on the archaeological record, indicating behavioral activity such as reuse, discard, loss, abandonment, reclamation, and disturbance (Richards 2008:54).

In order to make inferences about the underwater archaeological record, maritime archaeologists must take into account the different processes that have impacted or changed the shipwreck site. There are two phases of site formation, the creation of a shipwreck site (pre-depositional processes), usually resulting from human behavior or unforeseen circumstances prior to the shipwreck being deposited onto the seafloor; and shipwreck site alteration (post-depositional processes), subsequent processes or actions affecting the shipwreck site following its deposit on the seafloor.

Pre-Depositional Processes: Shipwreck Creation

According to Muckelroy (1978), site formation begins with the actual ship itself, considering the site formation processes affecting a ship as it passes from a systemic context into an archaeological context. These processes are also known as pre-depositional processes. Pre-depositional processes are circumstances, processes, and conditions affecting the creation of the archaeological material before deposition (Souza 1998:69). The factors affecting the way an item becomes incorporated into the archaeological record has a crucial impact on the potential meaning eventually attached to it by archaeologists.

By establishing the circumstances and events leading up to a shipwreck, archaeologists' understanding of sites invariably increases. As a starting point, consider the circumstances surrounding the vessel prior to the wrecking event. The classification will identify the cultural or social aspects affecting the context of the shipwreck site (O'Shea 2002:213; Gibbs 2006:8).

This "pre-wreck nature" was derived by Keith Muckelroy (1978) and can include classification, route, equipment, cargo, how the vessel was loaded, construction details of the vessel, life-history, social, economic, and technological contexts, final voyage, and the composition of the crew. Martin Gibbs (2006) and Colin Martin (2012) further expanded these types of "inputs" or "defining characteristics." Gibbs delineated depositional processes as "pre-impact" phases, concluding "the potential for a shipwreck to occur, and the cultural factors that influenced site formation, could emerge long before the actual shipwreck event" (Gibbs 2006:8). These types of factors might be articulated within historical datasets, leading to their possible impacts or implication on the archaeological record. Deducing these types of factors can assist in the accurate interpretation of the shipwreck site.

Whether a vessel was military, commercial, or passenger contributes to the probability of a wrecking event and the consequent assemblage. The classification can also allude to other "pre-wreck" aspects including cargo type, construction details, and crew composition. The shipwreck assemblage will often indicate the vessel's behavior or circumstance prior to the wrecking event. Wreck-site assemblages can demonstrate responses including radical changes in course, attempting to slow down, dropping anchors, signaling for help, jettisoning heavy cargo, abandoning the ship, and early intervention by external representatives (Gibbs 2006:10). These types of circumstances are best understood in terms of "observed archaeological associations that represent actions taken by individuals in order to minimize risk while operating under hazardous conditions or in treacherous areas" (Souza 1998:47). These types of connections are important because they constitute the organization of the material record before the wrecking event.

Similarly, the context surrounding the shipwreck will have a severe implication on the trajectory for the final deposition of the shipwreck site. Was the vessel abandoned, lost, or stranded? Was the vessel sunk due to fire, collision, hostile action, or scuttling? A vessel that is subject to grounding would subsequently suffer from a dynamic shore environment and will likely succumb to severe disarticulation. Whereas a vessel subject to a collision would most likely involve deeper water and would exist on the bottom as a continuous site (O'Shea 2002:213).

Schiffer outlined the cultural transformation processes affecting materials prior to deposition. Many of these C-transforms refer to the human effects processes or behaviors influencing an artifact after their initial use in the systemic context before forming the archaeological record. These can be applied to underwater archaeology. Schiffer proposed that artifacts begin as raw materials produced from the natural environment. During manufacturing, the artifact is modified through a variety of processes resulting in the desirable product.

Schiffer recognized that once an artifact was available for use, it could potentially undergo three major artifact functions: techno-function, meaning a practical application; socio-function, meaning a social role; or ideo-function, meaning a symbolic purpose. Artifacts can be utilized for more than one function or they can be discarded and enter into the archaeological record. Upon entering the archaeological record, artifacts might interact with the natural environment, or they might return to the cultural, systemic context (Schiffer 1987:14).

According to Schiffer, artifacts undergo C-transforms at every stage in their life cycle. These transformations were further evaluated through reuse, deposition, and abandonment processes (Smith 2010:24). Reuse is a significant component of every society, retaining artifacts within the systemic context in either its usual form, or altered form—rather than being discarded into the archaeological record (Schiffer 1987:28–35; Richards 2008:55). Cultural deposition includes the discard or transfer of materials from the systemic context into the archaeological record (Schiffer 1987:47–48). Evidence of these behavioral processes appears in the deposited archaeological context, and can be recorded and interpreted to assist in further identifying and corroborating the historical record with the physical archaeological record (Schiffer 1987:47–48).

Likewise, Richards (2008) refers to the depositional processes distinguished from the archaeological record as an "archaeological signature." Richards (2008:51) noted:

> Formation processes are the causal mechanisms that facilitate the movement of artifacts from their systemic or use context (where an artifact is participating in a behavioral

system) to their archaeological context (where an artifact is only interacting with the natural environment).

Richards highlights the importance of observing the transition of artifacts from an active cultural context into the archaeological context, or back into a systemic, cultural environment. Other than acknowledging that pre-depositional processes affect the condition and interpretation of cultural materials within the archaeological record, this study primarily focuses on post-depositional processes altering the shipwreck site following deposition.

Post-Depositional Processes: Shipwreck-Site Alteration

Post-depositional processes are changes a shipwreck site undergoes once deposited on the ocean floor. Understanding the environmental and cultural processes and conditions affecting a shipwreck site assists archaeologists in effectively interpreting and managing underwater cultural resources. This process is a necessary step in assessing and interpreting an archaeological site, as Gould (2000:48) noted, "In looking at general relationships between behavior and material residues, the first thing to consider is the total ecosystem in which this behavior takes place." Furthermore, maritime archaeologists must understand the degradation processes to assess the shipwreck assemblage—differentiating the current archaeological material from the post-depositional processes actively or passively transforming it.

Much of this work was established by Muckelroy's (1978) attempts to identify wreck-site altering processes, which he has termed "extracting filters" and "scrambling devices." Likewise, Schiffer's (1987) cultural and noncultural site formation model discusses the processes affecting archaeological materials following deposition, with an exclusive focus on terrestrial-based processes.

These studies, however, have failed to effectively link the physical attributes of underwater shipwreck sites with the processes that control site formation. Recently, a series of concentrated studies (Ward et al. 1998, 1999; McCarthy 2002; Oxley 2002; Wheeler 2002; McNinch and Wells 2006; Quinn 2006, Church et al. 2007; Gearhart et al. 2011) are providing cumulative data on the post-depositional processes affecting shipwreck sites. Over time, physical, biological, and chemical parameters will work together to transform and ultimately destroy a shipwreck site—it is important to identify and understand these processes.

Environmental Processes

When assessing the challenges of site formation, environmental forces such as sedimentary and hydrodynamic activities play a major role in the continued disintegration of a shipwreck site. Movement of the seabed including tides, currents, wave action, and storms may all contribute to the physical deterioration of a shipwreck site. It is important to examine these processes and be able to illustrate their potential effects on a 3D shipwreck model.

Studies on site formation processes have outlined the connection between shipwreck sites and their physical environment (Muckelroy 1978; Robinson 1981; Schiffer 1987; Ward et al.1999; Wheeler 2002; and Quinn 2006). Hydrodynamic and sedimentation processes can cause physical damage to shipwrecks directly or in conjunction with seabed mobility including erosion, burial, abrasion, or scouring (Wheeler 2002:1150). The physical processes affecting a shipwreck site are mostly likely to be the most prominent, while the biological and chemical processes become more active as the shipwreck disintegrates (Ward et al. 1999:565).

The effects of the seabed have been analyzed by Muckelroy (1978), in particular the scrambling devices of sediment disturbances through tidal currents or wave action. Muckelroy highlighted wave energy depending on the speed, distance, and duration of onshore wind and the suspended sediment moving through these currents. Depending on the location, depth, and seabed landscape, the wave activity surrounding a shipwreck site can vary (Muckelroy 1978:176; Wheeler 2002:1150). A study of the Pulaski Site (Souza 1998) located in the Dry Tortugas, captured the effects of a shallow depth (19 to 24 ft.), exposed, high-energy (edge of a major reef) environment. The fast moving currents consistently moving the coralline sediment through the exposed site has subjected the shipwreck to major site deterioration (Souza 1998:38–39).

When a vessel is deposited into a marine environment, the presence of its structure changes the flow pattern of its new environment. This disruption causes the following phenomena: contraction of hydrodynamics, generation of turbulence, reflection and diffraction of waves, wave breaking, and pressure in the surrounding sediment. These changes influence the sediment pattern and can lead to scouring. Rory Quinn (2006:1420) made the following observation:

> …wreck sites act as open systems, with the exchange of material (sediment, water, organics, and inorganics) and energy (wave, tidal, storm) across system boundaries. Shipwreck are therefore generally in a state of dynamic (not steady state) equilibrium with respect to the natural environment, characterised [*sic*] by negative disequilibrium, ultimately leading to shipwreck disintegration.

The suspended sediment in strong currents can "sand-blast" features standing upright in the seabed, causing rapid erosion. The hydrodynamics of a seabed can facilitate continual scouring, exposure, and burial of shipwreck sites that can encourage or deter deterioration.

The forces of storms and hurricanes also can have a dramatic impact on a site: further distributing, moving, or breaking up a shipwreck. Based on a recent study observing the impact of hurricane activity on historic shipwrecks located in the Gulf of Mexico, shipwreck damage including structural failure, lateral displacement, rolling, and vertical displacement has been reported in water depths ranging from 31 to 178 ft. (Gearhart et al. 2011:9–10). One example exhibiting shipwreck movement due to hurricane activity includes the well-publicized case of *Spiegel Grove*. The 510 ft. vessel was sunk as an artificial reef in 2002, unintentionally coming to rest on its starboard side in approximately 133 ft. of water with the port side of the ship in approximately 50 ft. of water. In 2005, the waves of Hurricane Dennis struck the top of the ship's broadside, rolling the ship into a fully upright position and settling into a scour that had formed along the shipwreck's hull (Gearhart et al. 2011:10). Deeper water depths may also cause extensive damage through hydrostatic pressure. Depending on the depth (extreme depths beyond the continental shelves), the weight of the overlying water pressure combined with ship construction limitations and structural collapse due to corrosion can ultimately crush a shipwreck (Wheeler 2002:1150).

Biological deterioration processes include the direct impact (boring, encrustation, or biological decay) of marine organisms on a shipwreck. These processes involve the deterioration of organic materials forming a microscopic layer, eventually accompanied by the attachment and growth of micro and macro organisms. Shipwrecks offer a hard substrate that can act as a surrogate for artificial reef systems. The growth of organisms around a shipwreck structure can also provide protection from the elements of physical and chemical degradation (Ward et al. 1999:566, Wheeler 2002:1150–1151).

Following the wrecking event, biological activity will increase rapidly because the presence of the shipwreck offers increased food and habitat resources. Depending on the materials composing the shipwreck site, elements existing in the environment and the physical processes influencing the environment, erosion and exposure will increase or decrease biological activity due to the availability of food resources. Elements for biological productivity include the nutrient content of seawater (phosphate or dissolved oxygen concentrations), temperature, and salinity (Robinson 1981:4; Wheeler 2002:1151). The nature and rate of biological activity affecting the shipwreck site will depend on the shipwreck assemblage and fluctuating relationship with the surrounding environment (Ward et al. 1999:566).

In addition to the physical transformation of a shipwreck site due to seabed movement, Muckelroy (1978) also discussed the activities of marine creatures and their possible impact on shipwreck sites. Muckelroy noted the instincts of crabs and octopi to accumulate and move through shipwreck assemblages, suggesting the possibility that marine life might have similar archaeological consequences comparable to the terrestrial burrowing of moles and rabbits (Muckelroy 1978:181). The biological activity associated with shipwrecks actively influences the food chain in regards to commercially valued fish. This factor may encourage cultural processes and ongoing site transformation and disarticulation through scuba diving, spear fishing, trawling, and commercial fishing.

Muckelroy considered corrosion processes a major scrambling effect, outlining a variety of environmental attributes such as depth, current, and underwater topography, which play a role into the deterioration of a shipwreck site (Muckelroy 1977:51). Chemical deterioration processes include the direct reaction (corrosion) of ferrous shipwreck materials to the marine environment (seawater). The marine environment will dictate the nature and rate of corrosion, while physical and biological site formation processes are intimately associated with this process. The variables affecting the nature and rate of chemical processes affecting shipwrecks includes the pH, temperature, salinity, and dissolved oxygen mass found in the water (Wheeler 2002:1151).

According to Neil North (1982), the submersion of an iron shipwreck in a marine environment will undergo four distinct stages including: initial immersion, corrosion, equilibrium state, and disturbed state (North 1982:76–78). North found that corrosion products (concretion) form on iron materials such as shipwrecks within the first few months of wrecking. The process of corrosion is often affected, and disguised, by the presence of concretions. Concretions form due to coralline algae, which have a partial exoskeleton of calcium carbonate. As the algae dies, the exoskeleton is left behind subsequently overlaid with continuing growths of the same material. This continual buildup attracts the growth of seaweed, mollusks, and coral. This outer layer then traps sand particles, coral fragments, and debris (McCarthy 2002:90–91).

Cultural Processes

Post-depositional cultural processes include human actions that have influenced the shipwreck site after its deposition into the archaeological record. These behaviors can include but are not limited to salvage, scuba diving, fishing, trawling, dredging, and construction. In some cases, this type of interaction with a shipwreck site can be intentional such as taking artifacts from a shipwreck site for personal profit. Other human disturbances remain inadvertent, such as fishing gear getting snagged on shipwreck sites or dredging activities within a harbor unintentionally exposing a nearby shipwreck (O'Shea 2002:214). Regardless of the intent, however, human interaction has a major impact on the remains of a shipwreck, how it is distributed, preserved, or even located. It is important to assess and interpret these types of post-depositional cultural site formation processes for their effects on the continued disintegration of a shipwreck site. These types of processes will be thoroughly examined and illustrated on the 3D shipwreck model.

Schiffer (1987:99) noted that once artifacts are deposited into the archaeological record, they do not always remain there. He went on to define salvage as the "process of reclaiming artifacts, including structures, from occupations by earlier peoples at a site…" (Schiffer 1987:104). Salvage behavior has since been further studied, and refined into various salvage classifications. Whether its commercially funded treasure salvage companies, recreational treasure hunting, or sport divers collecting artifacts from shipwrecks as souvenirs, salvage efforts pose a serious threat to the disruption and destruction of a shipwreck site. These types of behaviors lead to loss or movement of a shipwreck's assemblage, even causing the destruction of entire shipwrecks through specialized equipment or dynamite to access interior cargoes (Stewart 1999:575).

The removal of artifacts by treasure hunters or commercial treasure salvage operators is a frequent problem on any type of shipwreck site. Nevertheless, the effects of professional maritime archaeologists often also have an impact on the destruction of shipwreck sites. Maritime archaeology sometimes involves the complete excavation or recovery of a shipwreck site—employing a wide range of specialized equipment and processes (Stewart 1999:574). Regardless of who has been influencing a shipwreck site, it is important to keep in mind that any type of human access to a shipwreck site has most likely distorted the archaeological record in some way.

Many studies (Stewart 1999; O'Shea 2002; Kingsley 2009; Steinmetz 2010) suggest the commercial fishing industry has a major detrimental impact on shipwreck sites. Over the last 60 years, the wake of widespread overexploitation of fishing resources has been examined. Commercial fishing has not only resulted in a dramatic fishery collapse, also decimating reef systems, but has, and will continue, to damage shipwreck sites. Deep-sea fishing impacts including scavenging, trawling, navigational dredging, piling construction, recreational fishing, and even unintentional disturbances from snagged fishers' nets have adversely affected shipwrecks site's coherence and continues to be a severe threat of direct physical disturbance.

In 2009, Sean Kingsley compiled the first regional study of fishing impacts on deep-water shipwrecks. The three-year project focusing on the English Channel and Western Approaches surveyed 267 shipwreck sites dating between mid-17th century and today. Remote sensing capabilities revealed 42% of these sites showed evidence of fishing disturbances ranging from dragging signatures, trawling and dredging furrows, snagged nets and fishing cables, and chipped and dispersed cargo. Ultimately, Kingsley revealed the physical disturbances of fishing impacts, resulting in loosening archaeological material, deteriorating organic remains, de-contextualizing assemblages, broken hull structure, and loss or destruction of artifacts (Kingsley 2009; Steinmetz 2010:16–17).

Lastly, a wide variety of construction activities can influence shipwreck sites. Examples of these activities include, but are not limited to, dredging in rivers and harbors, discharging sediment and materials into a waterway, constructing bridges and piers, the development of oil and gas structures, renewable energy efforts, removing shipwreck materials that pose a navigational hazard, and shoreline and channel improvements. Although these types of activities are usually undertaken, funded, licensed, or permitted by Federal agencies, they often have the potential to affect submerged resources. Therefore, these activities require an assessment under Section 106 and the National Environmental Policy Act (NEPA) prior to permit/license approval, which minimizes the potential impacts to these resources. Unfortunately, many states do not consider applying Section 106 to underwater scenarios.

Conclusion

This chapter discusses the types of site formation processes affecting submerged ferrous hulled shipwreck sites. The interpretation and identification of these processes offers the opportunity for observing, preserving, and possibly predicting future degradation of shipwreck sites. Ward, Larcombe, and Veth (1999:562) noted that, "Models are helpful with the predicted circumstance of shipwreck formation, and to better manage, assess, excavate, preserve archaeological remains." Furthermore, Muckelroy (1975:174) suggested the possibility of residual patterning hidden beneath the historical, natural and cultural properties affecting the shipwreck site, which could be recoverable and practical. While a site formation analysis may or may not lead to predictive abilities, it serves as an explanatory tool: providing comprehensive data on the deterioration factors affecting World War II shipwreck sites off the North Carolina coast.

Regardless of the types of cultural or environmental factors affecting shipwreck sites, identifying, avoiding, and monitoring impacts to underwater resources has become a primary concern in cultural resource management. By noting foundational theories of site formation, and discussing the effects of pre-depositional and post-depositional site formation processes on the continued disintegration of shipwreck sites, this chapter offers direct insight into the behaviors and processes constantly influencing the archaeological record.This information is taken into consideration as cultural and environmental datasets are integrated into the 3D explanatory shipwreck model.

CHAPTER THREE: THE HISTORICAL TRAJECTORY OF THE MERCHANT FREIGHTER *CARIBSEA*

The Battle of the Atlantic, the longest and arguably the most pivotal battle of World War II, was not fought between two equivalent adversaries, but was waged over the unarmed, civilian merchant men and women who braved the treacherous shipping routes through the North Atlantic. The passageway through the North Atlantic, more commonly referred to as "Torpedo Alley," was the area of ocean most severely attacked by German U-boats. Hitler considered this area the "key to all the war," marking shipping routes to Great Britain, Canada, Africa, and the bitter voyage to Russia (Carse 1943:22). For the eight months following Pearl Harbor, German U-boats successfully hunted down Allied merchant ships and scores of convoys, littering the ocean floor with people, ships, and their cargoes.

In 1942, between January and July, the German U-boats stalking the eastern seaboard sank or damaged 397 Allied vessels. Approximately 5,000 people, including armed military forces and civilian sailors were burned to death, crushed, drowned, or vanished into the sea (Duffus 2012:23). The majority of these attacks occurred in the war zone off North Carolina's Outer Banks, forcing the residents of the Outer Banks to stand by and watch as war was waged off their front porches.

One loss in particular hit the people of the Outer Banks especially hard. Jim Baughm Gaskill, a local resident who grew up on the Ocracoke Island, eventually left to pursue the Merchant Marine. As the United States got involved in World War II, Jim received his master's license and shipped out on the merchant freighter, *Caribsea* (Ballance 1989:196). On 14 March 1942, the unarmed freighter was torpedoed and sank in less than two minutes, killing 21 men onboard, including beloved Ocracoke native, third mate Jim Gaskill (*Washington Post* 1942:3).

This tragic ending is just part of the vessels' story. The lifespan of *Caribsea* bridged both world wars, encompassing the progression of ferrous-hulled ship construction, the development of the Merchant Marine, and the Allied victory of World War II.

Caribsea, was a freighter steamship built in 1919 for the Emergency Fleet Corporation (Figure 3.1). Originally launched as *Lake Flattery*, the steel-built bulk carrier was one of a series of standard "Laker" vessels built on the Great Lakes under a contract for the United States Shipping Board (*Wall Street Journal* 1918:7). While this vessel was not necessarily a technological achievement itself, the industrialized steel building techniques, integrated technologies, and substantial lifespan of *Caribsea* represents a dynamic period of shipbuilding modernizations.

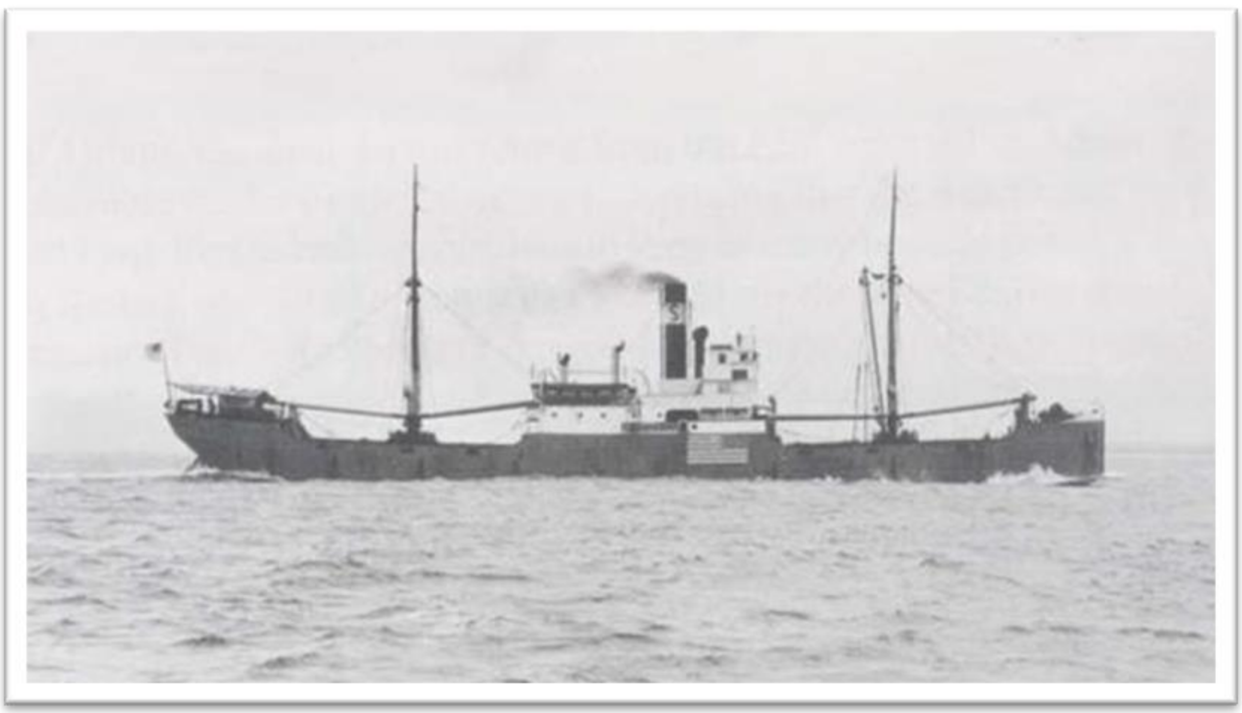

FIGURE 3.1 *Caribsea* prior to World War II (University of Wisconsin Digital Collections, Great Lakes Maritime History Project, October 2013).

The purpose of this chapter is to survey the background of *Caribsea*, discussing chronological ship construction leading up to the Battle of the Atlantic of World War II, and then examine the subsequent sinking of *Caribsea*. Because the purpose of this study involves acquiring and interpreting data for illustrating the site formation processes affecting World War II merchant shipwrecks, it is important to understand the historical trajectory contributing to this process. The first part of the chapter addresses the progression of iron and steel ship construction leading up to World War I. Changes and improvements including construction techniques, metallurgy, and ship design provide contextual information regarding iron and steel shipbuilding in American shipyards during the 19th and the early part of the 20th centuries. The second part, and the primary focus of this chapter, examines the history of *Caribsea*, including the details surrounding the construction, lifespan, and sinking of the ship.

Background of Steel Ship Construction

To fully understand the background of modern shipbuilding techniques requires a brief examination of the industry's origins. The iron vessels of the late 19th century were the culmination of a long integration of metal into shipbuilding practices. During the early stages of iron shipbuilding, American techniques were inextricably linked to the iron shipbuilding developments imported from Europe. As Britain's supply of timber dwindled, a new shipbuilding method became a necessity rather than the progression of industrialization. Britain's transition into iron shipbuilding during the first half of the century attracted American shipbuilders who were impressed by the reputed qualities of the iron vessels. The timber shortage that Europe faced, however, would not affect the United States until the turn of the century, largely inhibiting the market for ferrous-hulled ships until their usefulness and low costs were proven (Rodgers 1999:8).

The American shipbuilding industry and the United States Navy were slow to accept iron as a reliable building material in shipbuilding for many reasons, including the longstanding ideology of traditional wooden shipbuilding methods, difficulties with bottom fouling, compass deviation, high insurance premiums, seemingly unlimited timber resources, and inaccessibility to iron materials (Rodgers 1999:35). Additionally, the fundamental reason behind American shipbuilders' resistance towards using iron as a shipbuilding material was skepticism as to the capabilities of iron compared to wood. Although the transition from wood to iron was technically only a change in building materials, the shift had a revolutionary effect upon the shipbuilding industry. David Tyler (1958:4) noted:

> Wooden beams and planks could be shaped with an adz, fastened with spikes, and moved about on men's shoulders, but iron beams and plates required the use of cranes for moving, furnaces and steam hammers for shaping, and mechanical punches and cutters preparatory to riveting. The exact placement of rivet holes required the use of accurate drawings and patterns. These requirements called for a considerable outlay of capital.

American shipbuilders gravitated towards wooden ship construction because it was familiar and cheap. Additionally, it was reported that, "Many observers failed to realize that an airtight vessel built of iron could float even though the new building material by itself could not" (Thiesen 2000:89). It was not until the late 19th century, when time and experience had taken its toll to test and prove the advantages of iron ship construction, that the general American shipbuilding population accepted iron as a suitable material for the fabrication of ships. As a result, shipbuilders avoided using iron, and experimentation with iron in shipbuilding was left to mechanics and boilermakers who had the proficiency in iron design and unlimited access to materials (Tyler 1958:3–4; Thiesen 2000:89; Piero 2004:22).

The boilermakers, ironworkers, and mechanics were the first groups in the United States to design and produce watertight, iron vessels in the early 1820s. While the very first ocean-going iron vessel, *Aaron Manby*, was built in Britain in 1818, the first recorded American iron vessel, *Cordorus*, was built in 1825 by a Pennsylvania boilermaker, John Elgar. In the early 1840s, the development of the anthracite furnace design kick-started the iron industry, making iron cheap enough for use in experimentation with iron shipbuilding. This process had the effect of doubling the production of iron, while also reducing the price for the material and for shipbuilding. As iron became more accessible and iron ship experimentation more prevalent, iron shipbuilding in the United States slowly started to take form (Tyler 1858:4–7; Gratham 1858:13; Thiesen 2000:94).).

With the development of steam power and the gradual increase in the size and capabilities of vessels, the defects of wood as the primary shipbuilding material became more obvious. Iron was stronger and more durable, providing the infrastructure needed to expand and experiment with the iron and steam ship design. Iron hulls promoted the use of steam power by providing rigidity and durability for the constant vibration of the engines and movement from the propellers. This was a great improvement compared to wooden hulls, which would weaken and flex from the perpetual vibration, causing faster deterioration and repair turnarounds (Thiesen 2000:91). Iron vessels required less material to attain equivalent strength and durability, which provided more available cargo and fuel space and carrying power. Additionally, iron vessels were superior compared to the three worst threats to the survival of a wooden vessel: fire, grounding, and collision (Riegel 1921:21–24, Rodgers 1999:25).

The designs of the first iron ships were similar to wooden ships. Early iron shipbuilders naturally adopted wooden shipbuilding techniques, because their knowledge and understanding of the capabilities of iron materials was limited. Wooden ships required the traditional transverse framing system where the frames were closely spaced to receive the fastenings of the planking, to bind various strakes together, and to provide the strength of the ship's structure (Reed 1872:75; Piero 2004:27). Furthermore, transverse framing was necessary for ships that required transverse strength to enable resistance against racking stresses caused by masts, rigging, and cargo. Thus far, longitudinal strength was less important because ships were comparatively smaller. Iron shipbuilders adopted this type of framing system, noting that the system was cheap to build and served its purpose. However, as the strength and capabilities of iron became more widely understood, shipbuilders began implementing modifications to their designs (Pursey 1942:34).

As ships became longer and larger, they were subject to severe hogging or sagging strains. Shipbuilders began to notice the worst strains were breaking along the transverse sections of the ship, altering the longitudinal form of the vessel. By the 1870s, it became apparent that a new framing system was required that supported the longitudinal pieces, such as the keelsons, stringers, ties, clamps, and plate rails. Instead of adding additional strengthening pieces to the already heavy transverse system, shipbuilders improved the system of framing by adopting a longitudinal system (running primarily fore and aft of the vessel) that would be accompanied by ample transverse frames. The weight and number of transverse frames were largely reduced, using the saved material for additional longitudinal framing. This reduced the weight of the hull and increased the strength, saving shipbuilding costs, increasing cargo-carrying power, and proved larger shipping earnings (Reed 1872:76).

As iron shipbuilding became more prevalent, and shipbuilding techniques more streamlined, a new material came to the forefront of shipbuilding technology. Once shipbuilders had accepted iron's shipbuilding capacity over that of wood, attention was directed towards steel, with the hopes of further strengthening ships while diminishing the weight of the hull. Following the invention of the Bessemer process in 1856, a method that modernized and accelerated the steel-making process, steel soon began to replace iron as the primary building material used in railroads, bridges, buildings, and ships. The advantages of steel were that it was stronger and weighed less than iron, it also provided improved protection and permitted the increased weight of additional armor for warship building. Additionally, it was also beneficial for commercial shipping, since the reduction in weight permitted the transport of heavier cargoes (Tyler 1958:73). In 1869, Edward James Reed emphasized steel's shipbuilding characteristics and potential in his book, *Shipbuilding In Iron and Steel*. Reed went on to identify steel's greater ductility and strength than that of iron, further highlighting the capabilities of steel and predicting that it would soon displace iron as the primary shipbuilding material (Reed 1869:297; Piero 2004:40). In 1881, one writer calculated the gross comparison of cost and capacity for a steel steamer of 4000 tons carrying passengers and cargo, claiming, "Although the cost was originally greater, the increased cost was compensated for by the augmented capacity" (Riegel 1921:25).

While the ferrous-hulled ideology had been tried and proven, very few iron or steel ships were built in the United States prior to the 1880s. European builders originally turned to iron and steel shipbuilding out of necessity, learning to cultivate and streamline this new industrial infrastructure into a booming industry. American shipbuilders still largely relied on wooden construction, refusing to compete with British metal shipbuilding while seemingly unlimited supplies of timber were available. In 1883, however, the inefficiency of the United States Navy, coupled with the advancement of the European fleets, prompted the birth of the new American Navy and the construction of four steel cruisers: *Atlanta*, *Boston*, *Chicago*, and *Dolphin*. While rudimentary and unarmored, these ships launched new era for American shipbuilding and represented the beginning of steel ship construction in the United States (Long 1902:24; Tyler 1958:71; Piero 2004:45).

The adoption of steel ship construction for the development of the new and improved United States Navy launched American shipyards full speed ahead. Coincidentally, mature shipyards along the Delaware River transitioned into updated techniques and upgraded their facilities and machinery, while new shipyards began to appear up the eastern seaboard and throughout the Great Lakes area. The discovery of unlimited supplies of raw ore materials in the Lake Superior area was largely responsible for the development of a considerable steel shipbuilding industry in the Great Lakes. Since few iron ships had been built there due to the easy access to timber materials, the shipbuilding shift was, for the most part, directly from wood to steel. This enabled the Great Lakes shipyards to immediately adopt some of the most advanced methods of steel ship construction (Gregory 1907:255; Tyler 1958:73).

Towards the end of the 19th century, metallurgy, hull design, and engine innovation had produced vastly improved steel-hulled merchant and naval vessels. In the late 1880s, the first tankers and freighters emerged as the beginning of specialized cargo vessel types offering an array of increased capacity, and/or lower registered tonnages, as well as multi-deck ships. By 1900, two types of engines started appearing in merchant ships: the oil burning engine, which except in regards to fuel, was identical to a coal-burning engine and the internal-combustion engine, which operated on the same principle as the steam engine. These engines eliminated the need for coal bunkers taking up valuable cargo space, and also enabled the vessels to carry more fuel on the voyage, prolonging the journey and reducing the number of stops (Riegel 1921:119–134; Gardiner 1994:139–140).

At the turn of the century, steel ship construction had become an established, strong, cheap, and reliable shipbuilding technique. This not only permitted larger and lighter hulls, but offered higher boiler pressures, more efficient engines, and improved ballast procedures. Merchant ships were often equipped with triple expansion steam reciprocating engines. These engines provided economical and dependable propulsion, but had limited power output and modest fuel efficiency. Ships were outfitted with seawater ballast in double bottom tanks instead of the use of expensive and inconvenient materials including sand or gravel. This development improved seaworthiness, also speeding up the loading and discharging process. Furthermore, electricity and upgraded machinery was introduced to merchant ships, improving safety standards and speeding up port turn-rounds (Gardiner 1994:139).

The first decade of the new century saw a number of improvements, which further paved the way for modern merchant ship design and construction. Joseph Isherwood, a former Lloyd’s Register surveyor, introduced a new system of longitudinal framing (Gardiner 1994:140). As opposed to the traditional transverse system which placed a frame nearly 2 ft. apart, emphasis was placed on the longitudinal frames of the hull running fore to aft, and the transverse frames were placed at widely spaced intervals of about 12 ft. The new Isherwood system increased deadweight by reducing the number of transverse frames, beam knees, and bilge brackets, while additionally increasing longitudinal strength, improving ventilation, lessening vibration, enhancing accessibility to structural components, and strengthening the bottom of the vessel (Riegel 1921:39–41). Furthermore, the multitude of merchant ship designs was consolidated into three simpler concepts. The simplest was the three island ship, a single deck ship with a forecastle forward, a bridge amidships covering the engine and boiler room and offering officers’ accommodation, and a poop deck aft, which was also used for crew accommodation. If more decks were required (generally used for less dense cargo), a second or third deck could be added for extra capacity. This design resulted in a shelter decker concept. For smaller vessels with machinery aft, the vessel design was considered a raised quarterdeck concept (Riegel 1921:69–75; Gardiner 1994:140).

Irrespective of the shipbuilding advancements, in the years leading up to the First World War, the United States was slow to build up its merchant marine. At the beginning of the war in 1914, foreign governments readily used their merchant vessels for war activities, and U-boat warfare began to drastically limit the number of vessels available for neutral cargoes. It was not until German U-boats were threatening to deplete worldwide shipping that the United States began to take the shipping industry and the status of the American merchant marine more seriously.

War-built Merchant Fleet

On 7 September 1916, Congress passed the Shipping Act of 1916 producing the United States Shipping Board. The Shipping Board's main initiative was to regulate shipping and to promote the development of the American merchant marine. Upon the United States' entry into World War I in April 1917, the Shipping Board called for the organization of the Emergency Fleet Corporation. While a preemptive move, the organization of the Emergency Fleet instigated funding, shipping operations, and ultimately the urgency for a stronger merchant marine (Mattox 1920:2–3).

During World War I, the steadily mounting losses of shipping due to German U-boat warfare placed constant pressure upon the Shipping Board. By the time the armistice was signed in November 1918, there were 898 contracted shipways in use, capable of building ocean-going ships (Mattox 1920:31). There was no uniformity between the yards, and beyond steel, ocean-going construction, ships were of every size and type. From Maine to Florida, around the gulf, the Pacific coast, and the Great Lakes, there were hundreds of different types of vessels, "Each type called for a different design, not only for the hulls but for propelling machinery, boilers, rigging, cables, galley outfits, plumbing, propellers, ect. [*sic*]" (Mattox 1920:49). The war was the perfect excuse for the United States to build and expand the merchant marine, and continue even after the war had ended.

In May 1918, Charles Schwab, Director General of the shipbuilding program, reached an agreement amongst the Great Lakes shipbuilding companies for 130 vessels at approximately $800,000 each. The ships would be up to 4,200 gross tons of dead weight and be full "Welland Canal size," meaning a depth of a little more than 28 ft. Schwab visited the shipyards (Figure 3.2), pleading with the workers to complete the ships on schedule:

> The nation must have 1,000,000 tons more ships than it had last year. I know we will get them. You men and the rest of the ship workers in the country will produce the ships. Every blow you strike at a rivet is a blow struck at the Kaiser. The United States never lost a war, and we are not going to lose this one.

Shipbuilding firms from Duluth to Cleveland were awarded contracts for standard lake-type steel vessels, including McDougall-Duluth Shipbuilding Company. (*Washington Post* 1918:3). McDougall-Duluth Shipbuilding Company was a company located in West Duluth, Minnesota. Alexander McDougall, inventor of the whaleback-type ship and owner of McDougall-Duluth Shipbuilding Company, was the ingenuity behind the shipyard (*New York Times* 1900:21). Although his creation of the whaleback, a steel boat with a flat bottom, rounded top, and a spoon-shaped bow, "designed to carry the greatest cargo on the least water," was not successful, the McDougall-Duluth Company slowly began to gain momentum through additional iron and steel ship contracts (Castle and Sanborn 1968:32).

FIGURE 3.2. McDougall-Duluth shipyard workers in 1918 (University of Wisconsin Digital Collections, Great Lakes Maritime History Project, October 2013).

By the end of May 1918, the Emergency Fleet Corporation had apportioned over 36 McDougall-Duluth contracts for "standard lake type" steel vessels (*Wall Street Journal* 1918:7). The capacity at the McDougall-Duluth shipyard was more than doubled, increasing the number of shipping births to 10 (Figure 3.3) (*Christian Science Monitor* 1918:7).

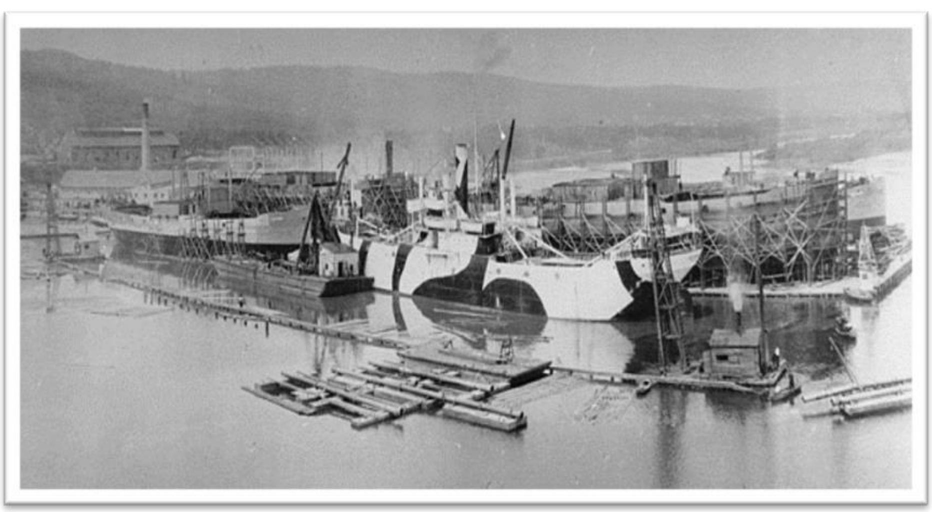

FIGURE 3.3 McDougall-Duluth shipyard during World War I (University of Wisconsin Digital Collections, Great Lakes Maritime History Project, October 2013).

Laker Freighters

The "Laker" style ships were a modified version of an earlier McDougall-Duluth design built shorty before the war. This "Fredrickstad" vessel was prominent as an "economical medium-sized freighter," built of steel with two full-length decks and a top boat deck. These vessels were known as "three island types" because of the three individual decks located forefront, amidships, and aft of the vessel. McDougall-Duluth freighters assembled for the United States Shipping Board maintained similar design (Dowling 1967:16).

General construction plans of *Lake Flattery*'s sister ship, *Cedar Spring*, illustrate the continued uniformity of two full-length operational decks, and the three island type decks (Figure 3.4). The bottom main deck included the main cargo holds, the engine and boiler rooms, and the forward bow accommodating the sailor's quarters. The bridge deck included the engine and boiler casings, access to cargo hatches and lifting mechanisms, and the officers' quarters including the operators, oilers, and engineers. The top boat deck housed the lifeboats, the captain's quarters, and the pilot house (McDougall-Duluth Company Shipbuilders & Engineers 1918).

Lake Flattery was a steel constructed steamer, propelled by a single bronze screw, driven by a three-cylinder triple-expansion engine and two single-ended Scotch boilers. The oil engines and boilers were designed and manufactured by McDougall-Duluth Shipbuilding Company. The engines were capable of 1500 horsepower, and could propel the vessel up to ten knots (American Bureau of Shipping 1930).

In the design of McDougall-Duluth steel vessels, it was sought to achieve three principle concepts:

> First, a ship of maximum cargo carrying capacity on moderate dimensions; secondly, a vessel which could utilize standard steel shapes in its construction, and that would require

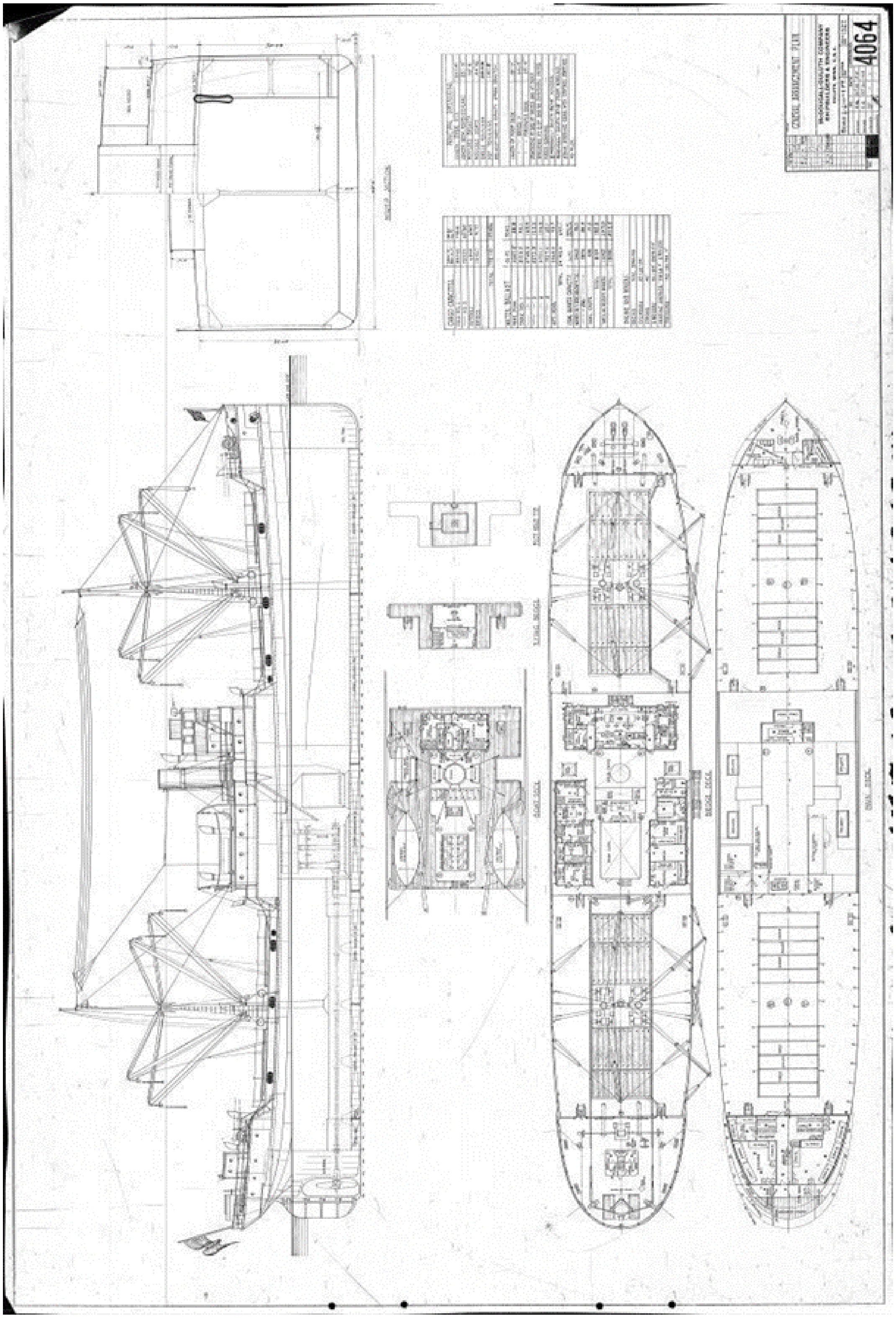

FIGURE 3.4. General arrangement plan of *Cedar Spring*, 1918 (University of Wisconsin Digital Collections, Great Lakes Maritime History Project, October 2013).

> minimum amount of shop work at the shipyard; and thirdly, so to construct the upper works, smokestacks, masts, etc. [sic], so that these could quickly be removed and placed in the hold; and the vessel, as thus stripped, be capable of clearing the bridges and overhead structures of the State Barge Canal (Scientific American 1918:568).

The dimensions of *Lake Flattery* upon completion were 251 ft. long, 43 ft. in beam and a draft of 25 ft. The Welland Canal restrictions implemented similar construction limitations amongst most vessels of the Great Lakes. In 1884, the Welland Canal, connecting Lake Erie with Lake Ontario, was enlarged to 270 ft. long, by 45 ft. wide, by 14 ft. deep. In 1901, the St. Lawrence River canals connecting Lake Ontario with tidewater were widened to the full canal dimensions seen above. Consequently, this allowed Great Lakes shipbuilders to begin building larger, standardized, ocean-going ships (Dowling 1967:1).

Lake Flattery was classified as an oil fueled, ocean-going ship, one of fifteen identical McDougall-Duluth Laker cargo type steamships fitted for oil (The American Marine Engineer 1919:20; *Marine Review* 1920:18). During World War I, the United States was the world's leading oil producer. The Emergency Fleet Corporation standardized oil-fired boilers for the war-built fleet (Gibson and Donavan 2000:114). Using oil versus coal had distinctive advantages and disadvantages. Coal could be stored in bunkers between the outer hull and the boilers. This provided smoother explosions from gunfire. Coal was also less flammable than oil, and less likely to ignite when the ship was under attack. However, oil-fueled ships could carry enough oil for longer voyages without refueling. The oil could be stored in the ships double bottom hull, also freeing up more space for cargo. Oil-fired ships required less labor to refuel the boilers. Because of the advantages and availability, the United States Navy and Merchant Marine required oil-fired propulsion for all new construction prior to World War I (Gibson and Donavan 2000:115).

Upon the conclusion of the war, on 11 November 1918, the Emergency Fleet Corporation continued for about a year, completing pending contracts, including *Lake Flattery*. There were four McDougall-Duluth vessels launched during July 1919. *Lake Flanders*, of identical construction (Figure 3.5) launched 10 July 1919, was finally delivered to the United States Shipping Board on 20 October 1919 (*Marine Review* 1920:18). *Lake Flattery* was launched 31 July, 1919 and delivered to the U.S. Shipping Board on 10 November 1919 (*American Marine Engineer* 1919:20). By 1920, incomplete contracts were cancelled, leaving unfinished hulls scattered along the coastline of the Great Lakes (Dowling 1967:89).

FIGURE 3.5. McDougall-Duluth Shipbuilding Company launching *Lake Flanders*, Nov. 1919 (University of Wisconsin Digital Collections, Great Lakes Maritime History Project, October 2013).

The United States Shipping Board retained ownership of *Lake Flattery* until 1922 (American Bureau of Shipping 1922:151). The ship was then sold to the Panama Rail Road

Company in New York City, a significant shipping line connecting its service from New York to San Francisco. The shipping line ran a route of steamships linking Nicaragua, Costa Rica, San Salvador, and Guatemala ports up to the eastern seaboard. Under the ownership of Panama Rail Road Co., *Lake Flattery* was eventually renamed *Buenaventura* and began service as a passenger and mail ship bound for South America and the West Indies. From 1923 to 1924, *Lake Flattery* transported 387 people from South American ports to Ellis Island, New York in a total of 10 trips. (American Bureau of Shipping 1930:60; *New York Times* 1938:41; *New York Times* 1940:92; Ellis Island Foundation, Inc. 2010).

On 26 October, 1940, Stockard Steamship Corporation bought *Buenaventura* for the beginning of a new Caribbean service route. Permission was granted to once again change the name of the vessel by the Department of Commerce. On 26 November, *Buenaventura* was officially renamed *Caribsea* in a renaming ceremony held before the first trip connecting Baltimore to New York and then on to San Juan and other Caribbean ports (*New York Times* 1940a:92, 1940b:51). After being purchased by the Stockard Steamship Corporation, *Caribsea* continued to transport cargo between Caribbean ports and the eastern seaboard (*Washington Post* 1941:31). This route would later be patrolled by German U-boats and the fateful waters of North Carolina would prove to be the untimely demise of *Caribsea*.

Operation Drumbeat

The Battle of the Atlantic was the longest battle of World War II, starting in September 1939, reaching its dramatic climax in the spring of 1943, and ending by May 1945. German U-boats came close to interrupting the Allies supply line until the implementation of the convoy system in 1943, which finally gave the Allies the upper hand. Earlier in the war, it was Hitler's intention to avoid incidents with American ships, his orders clearly stating that vessels should only be attacked in self-defense, but history shows this was hardly the case (Rohwer 1977:25). As American wartime tensions mounted, the German Naval Commander, Karl Doenitz, promoted the sinking of American merchant fleets. His primary concern being the amount of tonnage sunk each day at sea.

American merchant ships were targeted early on in the war. The first merchant ship casualty occurred on 8 November 1940 on *City of Rayville*, when the freighter hit a mine off the coast of Australia. *City of Flint* was captured by the German battleship *Deutschland* in October of 1939. In May of 1941, U-*69* sank the American freighter *Robin Moor,* and in October of the same year, *Lehigh* met the same fate, both in the South Atlantic waters off the west coast of Africa (Manolis 1949:8). These events marked the beginning of an extensive and successful attack on American shipping and prompted President Franklin D. Roosevelt to request the arming of American merchant ships. Unfortunately, this request did not take place in time to arm and support the older World War I merchant ships such as *Caribsea,* which bore the brunt of German U-boat attacks (Bunker 2012:4).

Immediately following the Japanese bombing of Pearl Harbor on 7 December 1941, the United States officially declared war on Japan and Germany. Shortly after, Admiral Karl Doenitz began his preparations for "Operation Drumbeat," using the offensive power of five U-boats to wreak havoc on American shipping directed off the coast of Cape Hatteras (Doenitz 1990:198). In January 1942, five Type IX German U-boats took up their positions off Cape Hatteras, the operation was planned to take effect on the 13 January (Hickham 1989:7). The standard German Type VII submarines had a radius of 8,000 mi. and an armament of 11 torpedoes. In 1942, these older submarines were replaced by the advanced Type IX, capable of traveling 13,450 mi. and carrying 22 torpedoes (Hickham 1989:25; Blair 2010:730).

To Germany's amazement, U-boat operatives found American merchant vessels sailing independently, positioned in a wide, vulnerable distribution. This reflected poorly on the Maritime Commission's intent on creating a tactical, strong, and well-organized merchant marine equipped and trained for warfare. The initial 1942 "Operation Drumbeat" attack was a resounding success. German U-boats found merchant ships caught completely off-guard, with the American coastline operating under normal peacetime conditions:

> The coast was not blacked-out, and the towns were a blaze of bright lights. The lights, both in lighthouses and on buoys, shone forth, though perhaps a little less brightly than usual. Shipping followed the normal peace-time routes and carried the normal lights (Doenitz 1990:202).

Merchant crews and captains had received very little wartime instruction up until this point, and this was apparent in their inefficiency to prevent U-boat attacks. Although America had been at war for more than five weeks, maritime coastal tactics did not reflect this.

The North Atlantic battlefront intensified as more German U-boats were built and became operational. Throughout 1942, German U-boats sank more than 1,000 Allied ships (Bunker 2012:64). As ships were sank and lost, new ships were continually needed. This ever-increasing supply and demand reflected the crucial role the Shipping Board administration played throughout the war.

The War Shipping Administration was established 7 February 1942. At that time, there were 1,340 merchant ships with a total of 11,850,000 deadweight tons (Manolis 1949:8). American merchant freighters and tankers, such as *Caribsea*, were expected to continue transporting their cargoes, while German U-boats incessantly hunted them day and night. Nicholas Manolis, Captain of *Caribsea* recalls,

> We veterans of 1942 are still marveling that we lived to celebrate V-E Day, and we marvel still more that no ship was ever tied up in port because men were afraid to take her out, even though it wasn't until August 1942 that all our freighters were armed and convoyed. Before then, the navy was too busy fighting and training recruits to spare planes and destroyers for convoy duty (Manolis 1949:8-9).

Caribsea was known as a "decent ship, a sturdy, ten-knot freighter," including an experienced crew, with several runs under their belts between New York and the West Indies. The crew was acquainted with the Caribbean route, transporting American commercial grade goods such as manganese cargo from ports in Antigua, Trinidad, and Cuba (Manolis 1949:19).

The Final Voyage

On 5 March 1942, Captain Manolis and his crew departed from the Santiago port bound for Norfolk, Virginia. *Caribsea* was responsible for the delivery of 3,600 tons of manganese ore. In the six weeks prior, 29 ships had been torpedoed and sunk along the east coast from Maine to Georgia (Gentile 1992:40). Upon *Caribsea*'s departure, neither the United States Consul nor the British authorities in the Santiago port were able to supply helpful information concerning the safest route or instructions on how to best avoid U-boat encounters (Manolis 1949:79). These circumstances forced Captain Manolis and his crew to implement their own safety precautions.

Caribsea took no chances. Captain Manolis trained his crew to, "Remember the three Don'ts—don't jump overboard, don't cut the wrong lines, don't launch the boats when the ship is full speed ahead. And do keep your life preservers on hand day and night" (Manolis 1949:79). The radio operators were instructed to stand watch all night. They monitored and recorded the position of *Caribsea* every two hours, and were given permission to send an SOS without orders from the bridge the second an explosion was seen or heard. The engine room also had orders to navigate the vessel full astern the moment an explosion was heard. Each lifeboat was equipped with a hatchet at every deployment location. Captain Manolis ordered the crew to skip lowering the boats and chop them loose instantly upon the event of a torpedoing. In addition to the survival equipment, each lifeboat and life raft was stocked with a mirror that would attract attention to survivors upon the ships sinking. In addition, blackout regulations onboard required the constant inspection of doors and portholes to ensure that light on the ship was not visible from the outside (Manolis 1949:81; Gentile 1992:40–41).

Correspondingly, the Navy gave instructions to "observe complete blackout and silence, without a single light, radio call for bearings or whistle blast, regardless of thick weather or pitch darkness" (Manolis 1949:24). Adjusted routes were given based on enemy activity, and enabled the naval control officers to give estimated positions of U-boats. In March 1942, the official directives were authorized, ordering all ships to pass Cape Hatteras in daylight hours. On 10 March, as *Caribsea* approached Cape Lookout under the eerie darkness of night, the speed was reduced to four knots in order to pass Cape Hatteras in accordance with the daylight instructions. U-boat activity had been minimal in the last 24 hours, which made the crew all the more nervous, "we couldn't know where he was or where he would strike next" (Manolis 1949:81).

While the crew of *Caribsea* continued the trek along the east coast, U-boats were lurking in the surrounding waters. By March 1942, Admiral Karl Doenitz had ordered another wave of six Type IX U-boats to patrol the waters of the Atlantic. By now, U-boats were operating from Newfoundland to Cape Hatteras. By April 1942, U-boat operations had extended to the Gulf of Mexico. U-*507* sank *Norlindo* on 30 April 1942 and the waters of the Gulf were the deadliest in the world in May 1942, sinking almost one vessel per day (Wiggins 1995). In the meantime, U-*158,* under the command of Kapitanleutnant Eriwn Rostin, was positioned approximately 15 mi.

south of Cape Lookout and headed towards the Gulf Stream in hopes of spotting merchant targets (Hickham 1989:65).

At 2300 on the night of 10 March, the wind shifted moderately to north and the temperature dropped to 40 degrees. At 2400, third mate Jim Baughm Gaskill, returned to his berth after being relieved from his watch in the wheelhouse (Duffus 2012:148). At 0100, on the morning of 11 March, *Caribsea* changed course with the expectation of seeing Cape Hatteras in the next few hours. Orders were given to Second Mate Hugh Spencer to routinely check the Cape Lookout Lighthouse bearings to prevent drifting inland. At 0145, *Caribsea* was approximately 14 mi. off Cape Lookout Lighthouse, plans were made accordingly to change course for Cape Hatteras (Manolis 1949:87).

Shortly after 0200, in the dark morning hours, Captain Manolis recalls hearing second mate Hugh Spencer ask, "Does that look like a ship to you?" As the captain peered through the window, on the starboard side of the bridge, the glass suddenly shattered in his face as the ship succumbed to a torpedo impact. Manolis later said he "hardly had time to turn around before the second torpedo struck" (*Washington Post* 1942:3, Manolis 1949:87). Only the seven crew members on deck or in the wheelhouse survived the explosions. The other 21 crew members went down with *Caribsea*.

The German Kriegstagebuch (war diary) later reported the U-*158's* first war patrol that included the sinking of *Caribsea*. On 11 March 1942, the U-boat stalked two ships simultaneously approximately 14 mi. east of the Cape Lookout Lighthouse. U-*158* initially spotted what it thought was a tanker at 2352 (0552 German Legal Time). It pursued the tanker and fired a torpedo at 0107 (0707 GLT). The torpedo missed the unknown vessel. As U-*158* maneuvered into position for a second shot at the unknown tanker, it spotted a shadow on the horizon that it believed to be a "coastal watch ship." U-*158* quickly maneuvered into position for an attack on the newly sighted target (*Caribsea*), and fired a torpedo at the vessel at 0158 (0758 GLT). After approximately a 48 second run time, the torpedo hit the target with a loud explosion, sinking the vessel with a single shot (NARA 1942).

It was later speculated that the torpedo plowed into the ships #2 hold; the supposed second torpedo or explosion could have been a consequent detonation in the boiler room. As seawater flooded the foredeck, the second mate sounded the alarm to abandon ship. There was no time to launch the lifeboats. The 3,600 tons of weighty and potentially combustible manganese ore took the vessel and 21 men down in under two minutes (*Washington Post* 1942:3; Bunker 2006:39; Manolis 1949:88). Fireman Hector Aranda, later recalled he was the last to leave the ship, "None of us had time to do anything but get out of our bunks, climb to the deck and jump into the sea. I think the six men in the engine room were either killed or trapped by the second torpedo and were unable to escape" (*Washington Post* 1942:3).

As the survivors clung to the oily wreckage surrounding them, the outline of a U-boat's conning tower appeared. The U-boat surfaced five hundred feet away and scanned the wreckage. Captain Manolis recalls thinking of the Nazi ideology, "We Nazi's [sic] will win the war because we are not afraid to kill!" (Manolis 1949:90) The U-boat continued to circle in this vicinity for hours, despite the fact that Navy planes were consistently passing by overhead (*Los Angeles Times* 1942:2). After drifting for approximately ten hours, the seven surviving crewmembers were spotted and picked up by the steamship *Norlandia* (Manolis 1949:105).

A "Just Reprisal"

Meanwhile, Kapitanleutnant Erwin Rostin and the U-*158* crew continued to sink Allied ships. By June 1942, Rostin and his men had reportedly sunk 17 merchant ships, totaling 93,342 tons. This shipping record, attained during his two patrols to the Americas, was not exceeded by any other U-boat (Blair 2010:612). Unfortunately for him, the last of Rostin's victims, his final ship encounter, *Everalda*, would prove to be the death of him.

On 29 June 1942, U-*158* encountered a Latvian steam merchant ship. In his arrogance, Rostin stopped the ship, ordered the capture of the captain, Janis Martinson, and a Spanish crew-member, seized confidential documents, and then continued to scuttle the ship (Duffus 2010:152). As Rostin reveled over his latest victory, his transmissions caught the attention of the American Navy's Bermuda-based Patrol Squadron 74. A Mariner pilot, Richard E. Schreder, received the estimated location of the U-boat and immediately turned toward the alleged position. After fifty miles, the pilot found U-*158* cruising on the surface, with men "lounging on deck," tanning themselves. He immediately attacked, dropping two demolition bombs and two Mark XVII depth charges with shallow settings. The aircrew later reported that the second depth charge hit the U-boat's bridge and wedged in the superstructure, detonating and fatally damaging U-*158* (Blair 2010:612). The entire U-boat crew of 53 men, as well as 2 prisoners, were crushed and drowned inside the damaged U-boat as it plunged 16,000 ft. to the ocean floor. This incident would later be known by the Ocracoke community as a "just reprisal" for sinking *Caribsea*, and taking one of their own (Duffus 2012:147).

The onslaught of American merchant ships continued, but by the end of April 1943, the American shipping routing and anti-submarine defense mechanisms were becoming more proficient. Unfortunately, the re-routing of shipping and the strengthening of merchant patrols was not enough to secure American merchant shipping. Slowly, the efforts of the Maritime Commission came to fruition with the construction and organization of enough ships to replace the losses, effectively educating and training outbound merchant sailors for U-boat warfare, and finally implementing the use of the convoy system. The improvement of the merchant marine configuration would be the turning point, and ultimately the downfall of the U-boat supremacy over the North Atlantic shipping routes (Blair 2010:612–613).

Historical Significance

Caribsea is representative of the "Laker" class, war-built merchant freighters. After being contracted for World War I shipping initiatives, the war ended, leaving behind a merchant fleet unsuited for the needs of peacetime. Following the war, Emergency Fleet Corporation vessels were sold to companies across the United States. For 23 years *Caribsea* steamed the North Atlantic, serving as a commercial vessel. Although *Caribsea* was in a primarily civilian industry, the vessel represents a merchant fleet built and destroyed in the throes of war.

Merchant sailors were not only expected to deliver the vital materials and goods needed for the Allied powers in the war, but also to effectively defend themselves against German U-boat warfare while remaining ill-trained and unarmed (Carse 1943:22). The men and women of the merchant marine were shot at, drowned, frozen, incinerated, and vaporized in the efforts of defending their cargoes. They suffered the highest casualty rate of all the American military services as approximately 6,000 out of 25,000 U.S. merchant sailors lost their lives (Hoehling 1990:150). Merchant sailors such as Jim Gaskill, his fellow seamen and other merchant crews assisted with the Pacific and European war fronts by transporting war goods such as ammunition, food, and supplies. For this very reason, the Axis powers targeted unarmed merchant vessels, sending thousands of merchant ships to the ocean floor along with thousands of merchant lives (Bunker 1995:4). World War II merchant shipwreck sites exhibit heroism and courage in a time of crisis and should be honored as war graves.

This conviction is shared by a group of American citizens who witnessed World War II carnage up close. Following the torpedoing and sinking of *Caribsea*, a strange phenomenon was shared by the Ocracoke community a mere 43 miles away. On 14 March 1942, Chris Gaskill was walking along the beach on the south end of Ocracoke Island when he spotted something in the surf that caught his eye. Upon further investigation, Chris discovered it was a frame holding a type of official-looking certificate. When Chris read the document, he was surprised to find the license belonging to his cousin Jim Baughm Gaskill, third mate on *Caribsea*. By the time Chris returned home, and shared his finding, the family knew of *Caribsea*'s tragic fate (Duffus 2010:148).

The next day, the Gaskill family was met with yet another eerie occurrence. An out of town guest staying at the Gaskill family owned Pamlico Inn (Figure 3.6) came across a floating piece of wreckage bumping up against one of the pilings off the inn's pier. Once the wreckage was retrieved, the name *Caribsea* was discovered etched on the side (Duffus 2010:148). This bizarre occurrence, was just another reminder of the death and destruction the U-boats were inflicting on the east coast.

It was later recognized that 187 Allied merchant sailors died at the hands of Rostin and his crew, including Ocracoke's Jim Basughm Gaskill (Duffus 2010:152). The Ocracoke people were devastated by the bloodshed surrounding their homes and the slaughter of American civilians, turning their grief into hatred against the German U-boats lurking in the waters right off their back porches. When the news of U-*158*'s sinking was finally released, the people of the Outer Banks celebrated.

FIGURE 3.6. Pamlico Inn, the location where remnants of the *Caribsea* washed up (Duffus 2012:149).

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While the loss of *Caribsea* weighed heavily upon the communities surrounding Cape Lookout, the freighter's story does not end here. After being hit and sunk by U-*158,* the vessel sank 85 ft., where it came to rest on the sandy ocean bottom. The shipwreck site not only offers a historical narrative illustrating a story of enterprise, production, and tragedy, but also serves as a popular dive spot and a significant opportunity for archaeological research and development.

Conclusion

Caribsea is symbolic of a time in America's history where merchant fleets were the epicenter of the longest, deadliest, and most crucial battle ever conducted. The Battle of the Atlantic required merchant vessels such as *Caribsea* to continue transporting their cargoes in the midst of this chaos. As a merchant freighter, the construction and life span of *Caribsea* is expectedly ordinary. The significance of this vessel, however, lies within the extraordinary tasks, heroic actions, and massive obligation instilled upon the Merchant Marine throughout World War II.

Examining the historical trajectory of *Caribsea* is the first step in assessing the types of historical and archaeological contexts of the shipwreck site. Outlining the progression of iron and steel ship construction further identifies the specific types of construction techniques and hull designs implemented during the construction of *Lake Flattery*. By reviewing the history related to *Caribsea* specifically, this reveals the various cultural and historical variables influencing the course of the ship's lifespan. The following chapter presents the combined historical and archaeological research in the form of the examination of *Caribsea*'s evaluation as a shipwreck site. This chapter is the basis on which site formation theoretical principles are built in subsequent chapters.

CHAPTER FOUR: METHODOLOGY

As discussed in Chapter Two, the understanding of an archaeological site is dependent on the thorough examination of site formation and the established circumstances leading up to and following deposition. Historical and archaeological datasets were collected in an effort to accurately illustrate the structural collapse of a World War II shipwreck. Historical resources related to the merchant freighter *Caribsea* and the archaeological investigation of the shipwreck site supplemented the development of 3D models designed to illustrate site formation. There were three major methodological steps for the development of this study:

- The collection of resources relating to the historical trajectory of *Caribsea*
- The collection of archaeological resources including remote sensing imagery and scuba diving survey concerning the current condition of *Caribsea*
- The development of 3D computer models for the illustration, interpretation, and analysis of site formation processes

This chapter offers an overview of the resources and processes used in the development of this study. The first section discusses the context and history of Battle of the Atlantic projects, followed by a section outlining the process of acquiring historical materials. This section identifies the sources and nature of primary and secondary datasets, along with a short introduction into the development of the historically accurate 3D *Caribsea* model. The next section outlines the procurement of archaeological datasets. Two types of archaeological datasets are discussed: remote sensing and non-invasive site survey. This section examines the process of acquiring, utilizing, and interpreting these datasets, and their assistance towards the 3D modeling process.

Previous Research

This research stemmed from the ongoing Battle of the Atlantic Expedition: an annual archaeological expedition to document and monitor World War II shipwrecks sunk off the coast of North Carolina. NOAA's *Monitor* National Marine Sanctuary (MNMS), in collaboration with the National Park Service, Bureau of Ocean and Energy Management, East Carolina University, and the University of North Carolina Coastal Studies Institute, has collected a wide range of archaeological data including video and photographic materials, geospatial datasets, biological survey, remote sensing imagery, and site plans. Since 2008, the annual expedition, led by MNMS archaeologist Joe Hoyt, has developed a "broad web of federal, state, and academic partnerships that pool money, resources, and man-power to accomplish its annual research goals" (Richards et al. 2011, 2012; Wagner 2010; Bright 2012:43).

This collaborative partnership was extended to graduate students with the Maritime Studies Program at East Carolina University. Numerous theses were developed from this ongoing research, resulting in the opportunity to utilize and share the collection of these data. The overall theme and collaborative aspects of this current study mirrors the academic efforts of ECU alums John Wagner (2010) and John Bright (2012), and the current study of graduate student Will Sassorossi (2015), in their studies of World War II archaeological sites off the North Carolina coast.

While the bulk of the current study was implemented under the auspices of the Maritime Studies Program at ECU, it should be noted that the archaeological site survey was undertaken as a Nautical Archaeology Society (NAS) training project through the MNMS partnership with the Battle of the Atlantic Research and Expedition Group (BAREG). BAREG is an avocational group of scuba divers that participate in archaeological endeavors under the guidance of the

NAS. Before members of the club participate in archaeological survey, they are required to undergo training in underwater archaeological objectives, policy, and methodology. The *Caribsea* survey provided both training and research, advancing the education of underwater archaeology and capturing archaeological datasets relevant to this research. Additionally, the high resolution, multibeam interactive model of *Caribsea* and the visualization *Wrecksight* software were provided by Advanced Underwater Surveys (ADUS), a commercial UK-based entity that specializes in high-resolution multibeam sonar surveying and visualization technologies.

Historical Research

The first phase of the research involved identifying, locating, and acquiring historical resources relating to the lifespan and construction of a World War II-era steel-built merchant ship. The process depended on the collection of relevant ship construction data contained within available historical resources. The resulting historical dataset could help corroborate, refute, or redefine the understanding of *Caribsea*'s site formation within a sequential series of 3D explanatory models.

Although the historical background of steel shipbuilding was imperative for the accurate visualization and interpretation of the ship, the main thrust of the project relied on finding a collection of original ship builder's plans for the chosen shipwreck-modeling candidate. Originally, five merchant shipwreck sites located a short distance off Cape Hatteras, NC were chosen as potential candidates for the creation of 3D site formation models. These shipwreck sites were selected based on depths acceptable for diving (less or equal to 200 ft.), historical significance, and the existence of historical documents and high resolution site imagery (side scan and multi-beam data in addition to high resolution photographs and video). They also represented a variety of site types encompassing intact structures, inverted structures, as well as disarticulated debris fields (Gentile 1992:24-27, 40–43; Office of National Marine Sanctuaries 2013:2–3):

1. *Caribsea* (Official ID number: 219188): 2,609-ton freighter built in 1919 in Duluth, Minnesota. Dimensions 251 ft. x 43 ft. x 25 ft. Lies in 80 ft. of water;
2. *Empire Gem* (Official ID number: 168691): 8,139-ton tanker built in 1941 in Glasgow, Scotland. Dimensions 463 ft. x 61 ft. x 33 ft. Lies in 145 ft. of water;
3. *Ashkhabad*. (No Official ID number): 5,284-ton tanker built in 1917 in Glasgow, Scotland. Dimensions 400 ft. x 52 ft. x 28 ft. Lies in 55 ft. of water;
4. *City of Atlanta* (Official ID number: 201103): 5,269-ton passenger/freighter built in 1904 in Chester. Dimensions 378 ft. x 49 ft. x 35 ft. Lies in 90 ft. of water;
5. *Dixie Arrow* (Official ID number: 221735): 8,046-ton tanker built in 1921 in Camden, New Jersey. Dimensions 485 ft. x 62 ft. x 28 ft. Lies in 80 ft. of water.

These sites were selected based on their potential range of historical and archaeological data that could culminate in the ability to create a multi-stage 3D site formation model. Multiple candidates were listed to optimize the search for construction plans: the first stage of historical research. *Caribsea* was chosen based on the largest available historical dataset and the scheduled NOAA and BAREG *Caribsea* archaeological survey.

The historical data extracted from the archival process was used to build an accurate ship model of *Caribsea*. The 3D historical model of *Caribsea* served as a starting point for all the succeeding 3D site formation models. The next section outlines in detail the materials used to recreate the historical model. This includes a discussion of the acquisition of primary and secondary sources, including ship builder's plans, photographs, official military records, and time capsule narratives. The archival phase of the study took place during the fall of 2013 and the spring of 2014 in preparation for *Caribsea* fieldwork in the summer of 2014.

Archival Research

Cartographic materials, such as charts, construction plans, or spatial guides, were obtained from a number of repositories, most exclusively from the United States National Archives and Records Administration (NARA). NARA contained the majority of records relating to World War II, and more specifically the Battle of the Atlantic. The National Archives II in College Park, Maryland, housed the cartographic and photographic records for the Maritime Administration. The primary cartographic sources identified within Record Group 32, United States Shipping Board, included McDougall-Duluth Shipbuilding Company construction plans. Although construction plans specifically related to *Caribsea* were unavailable, various sister ship construction plans and schematics of the McDougall-Duluth Laker class were found including: General Arrangement (Figure 4.1), Inboard Profile (Figure 4.2), Midship Section (Figure 4.3), Capacity (Figure 4.4), Rudder and Details (Figure 4.5), and Arrangement of Rail and Deck Fittings (Figure 4.6).

The ability to locate these plans was a crucial step, as the 3D modeling process unequivocally hinged on their acquisition. Unfortunately, the process of acquiring these records was especially slow and disappointing. Traditionally, the Merchant Marine and subsequent 20th century American merchant shipping programs, including the Emergency Fleet Corporation and the United States Shipping Board, have received very little public recognition or interest. This issue is most likely due to their civilian status and the ambiguous role the merchant marine has played throughout American history.

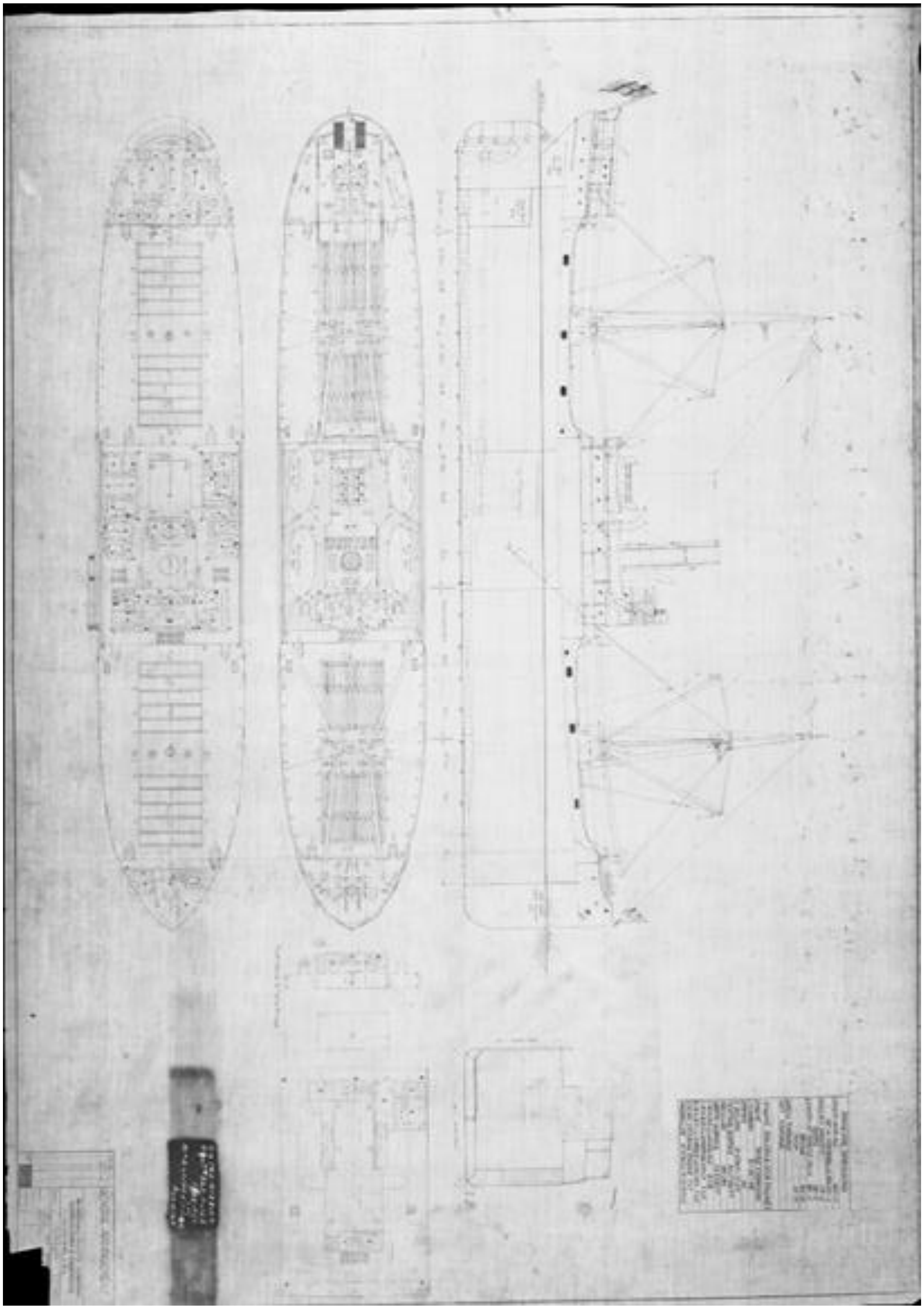


FIGURE 4.1. General Arrangement builder's plan (NARA).

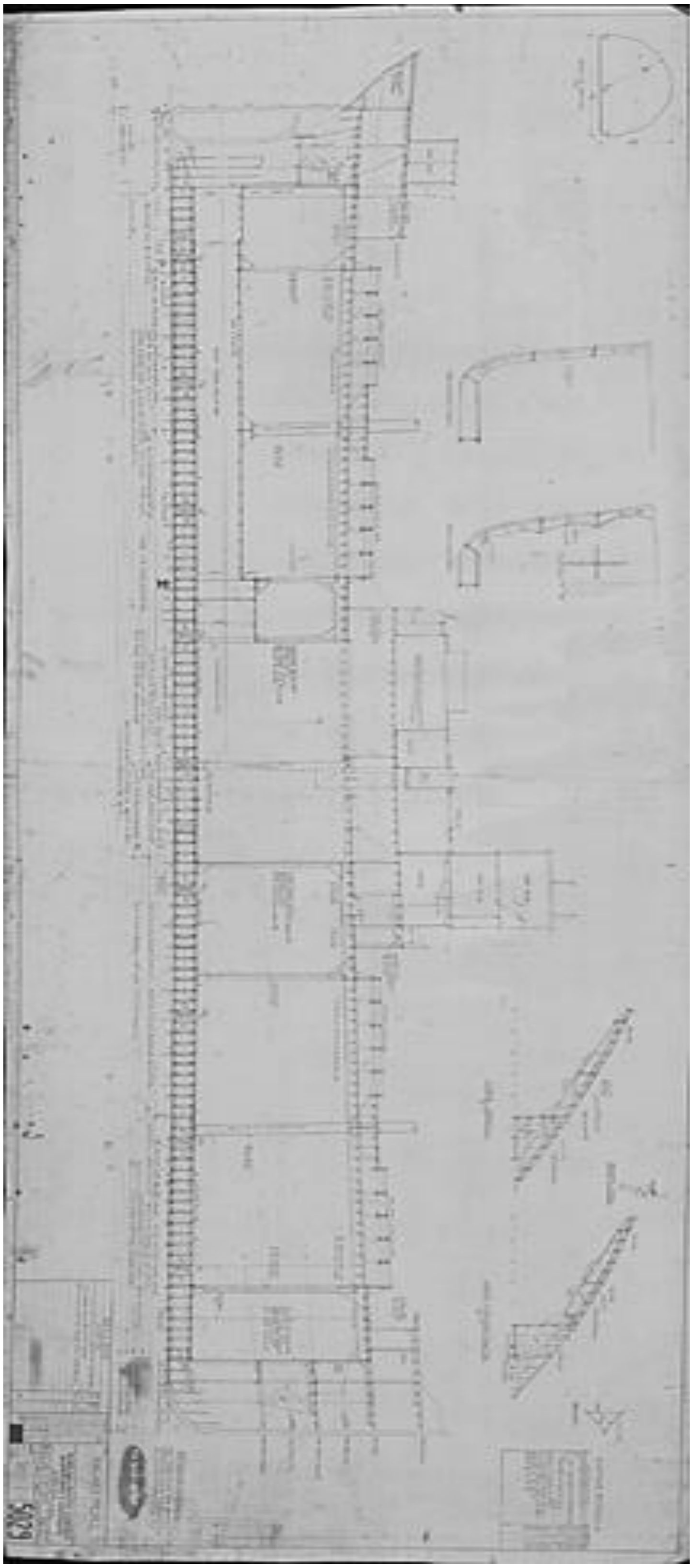


FIGURE 4.2. Inboard Profile builder's plan (NARA).

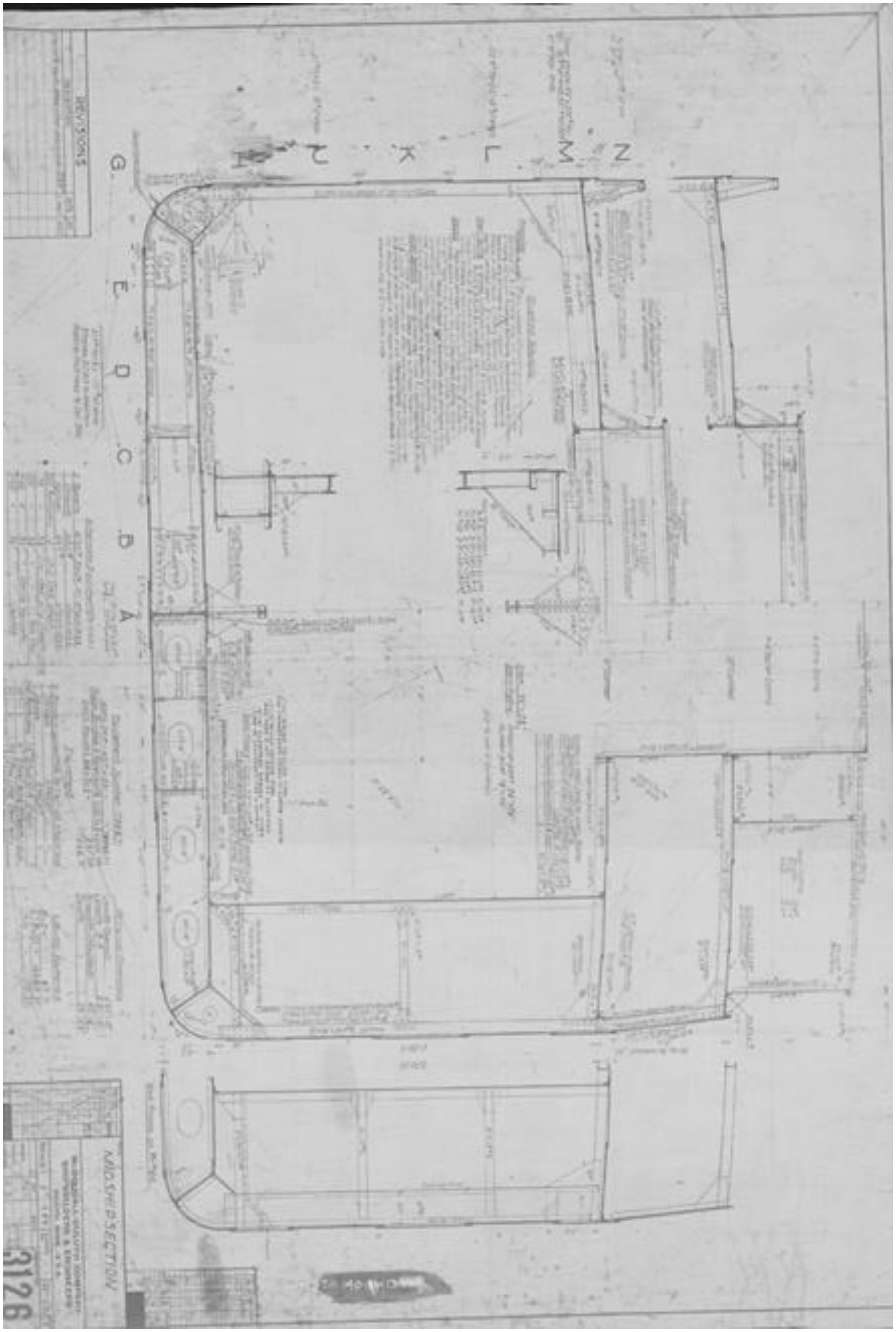


FIGURE 4.3. Midship Section builder's plan (NARA).

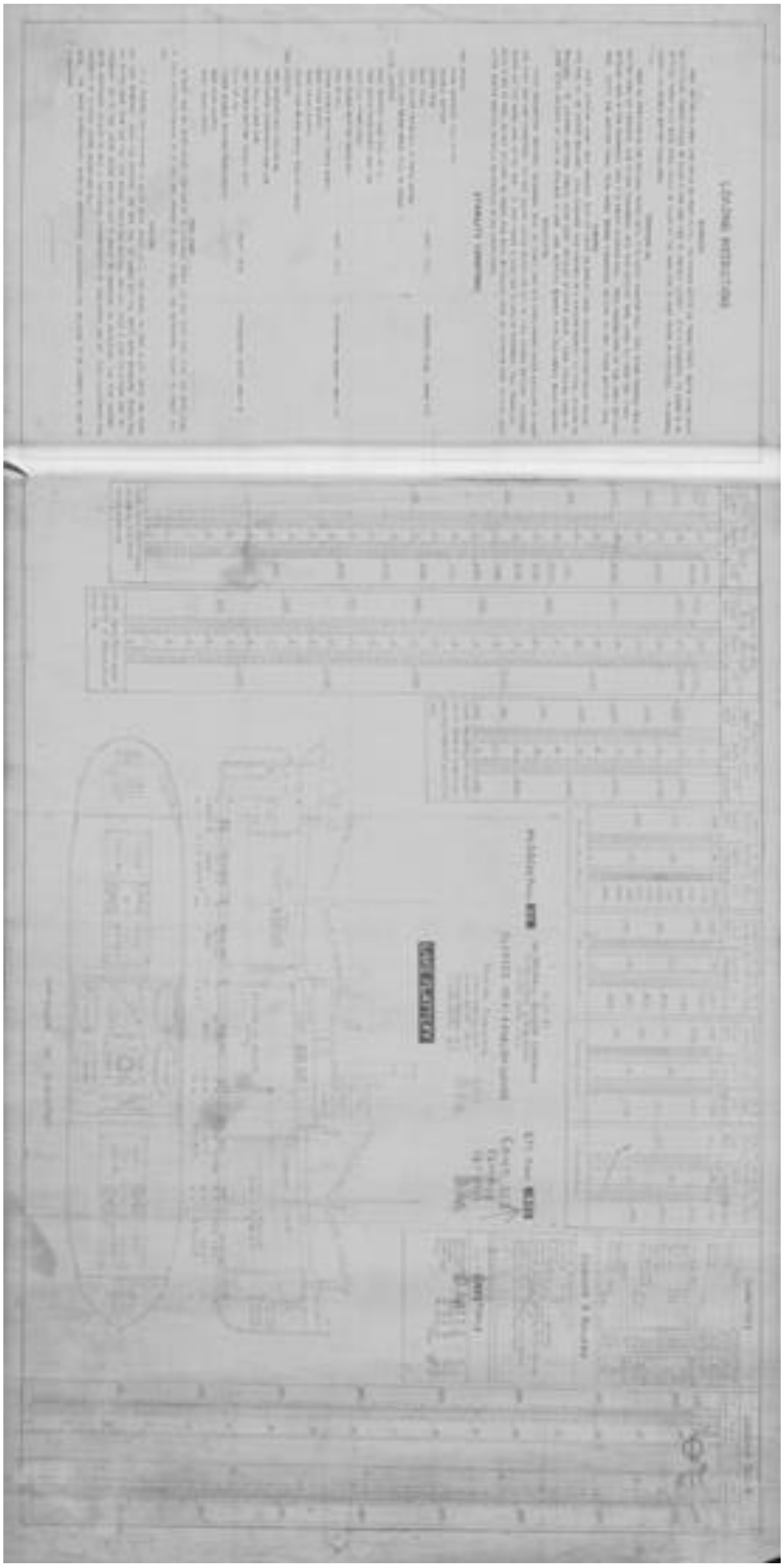


FIGURE 4.4. Capacity builder's plan (NARA).

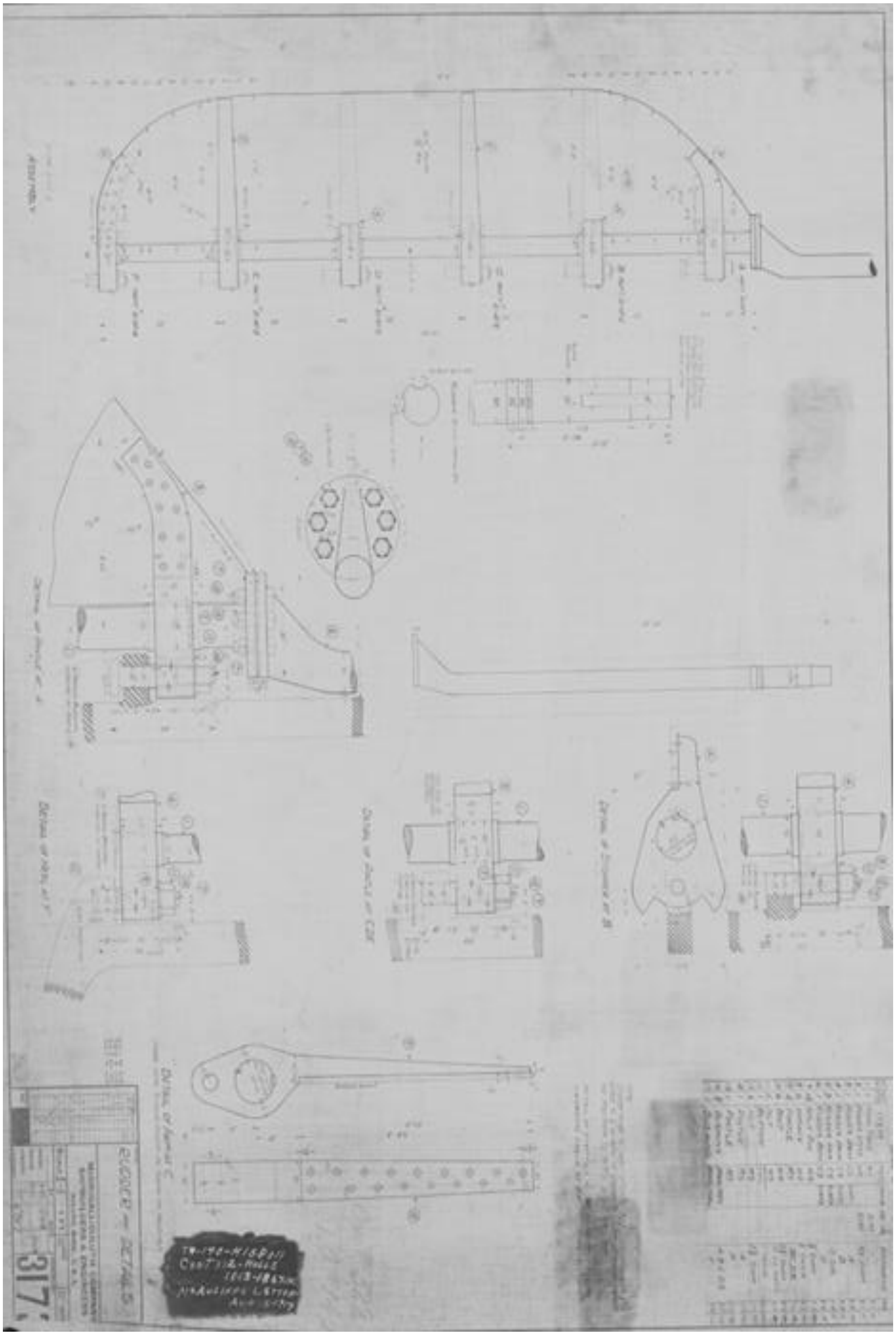


FIGURE 4.5. Rudder and details builder's plan (NARA).

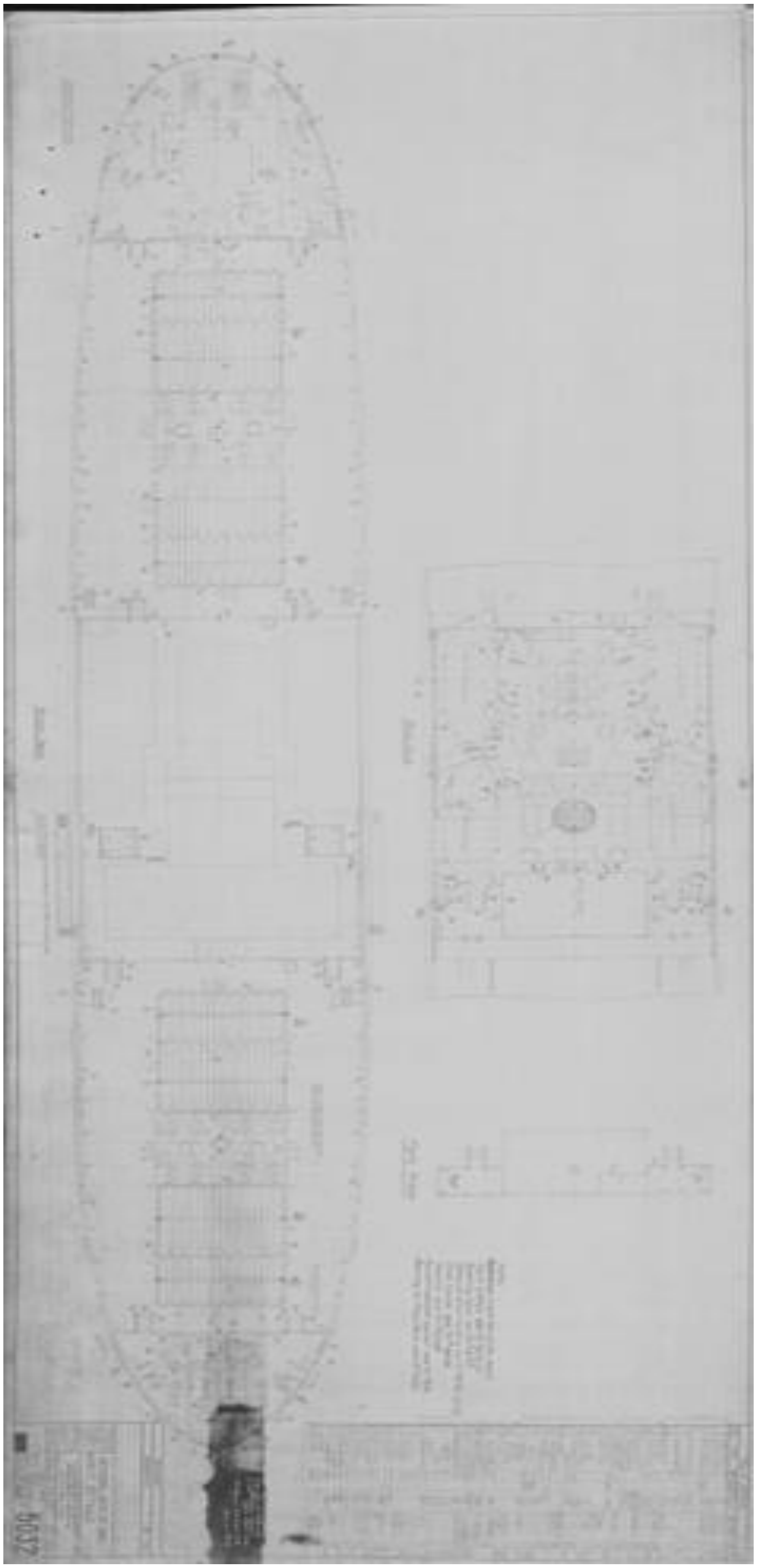
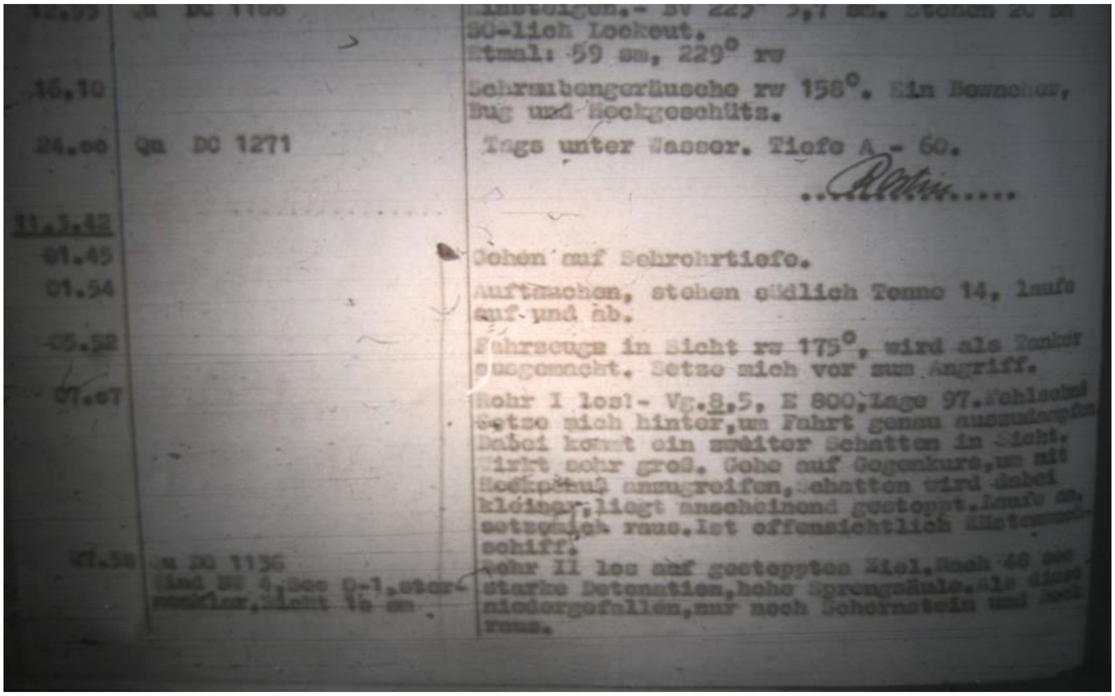


FIGURE 4.6. Arrangement of rail and deck fittings plan (NARA).

This perception is still relevant today, and was readily apparent by the cluttered and discounted collection of the 20th-century United States Shipping Board records, located within the NARA. While the NARA reference guides allegedly held a wide variety of builder's plants from the United States Shipping Board, and more specifically McDougall-Duluth Shipbuilding Co., there were very few vessels with matching builder's plans specifically associated to its design and construction. Instead, a wide variety of plans were collected from the identical *Laker*-class ships, giving a broad scope of ship construction detail and material. The only builder's plan found explicitly related to *Caribsea* (originally known as *Lake Flattery*) was the McDougall-Duluth Capacity plan (Figure 4.4).

Additionally, the National Archives II in College Park, Maryland, housed records relating to the activities and victims of the German Navy during World War II. Record Group 38, World War II War Diaries (1941-1945), provided documents depicting the torpedoing of *Caribsea*, and the outcome of survivors. These records were extracted from the Fifth Naval District Inshore Patrol and the Eastern Sea Frontier Enemy Action Diary reports detailing actions occurring 11–12 March 1942 (Figure 4.7). Lastly, record Group 242, Captured German Navy Records, provided the Kriegstabuch (KTB), the German "war dairy" of U-*158* and its logged attack on *Caribsea* on 11 March 1942. The documents were acquired and provided by the Battle of the Atlantic Research and Expedition historian, Aaron Hamilton, and were further translated by Uboatarchive.net founder and historian, Jerry Mason.

The acquisition of the KTB was especially significant because of its direct impact on the historical record. While oral testimonies within American records indicate that there were two explosions, thus supporting the conclusion that two torpedoes sank *Caribsea*, the KTB clearly states only one torpedo was fired from *U-158*.



[illegible]	[illegible]	[illegible] Einsteigen. - [illegible] 5,7 sm. Stehen 20 sm SO-lich Lookout. Etmal: 59 sm, 229° rw
16.10		Schraubengeräusche rw 158°. [illegible], Bug und Heckgeschütz.
24.00	Qu DC 1271	Tags unter Wasser. Tiefe A - 60.
11.3.42		
01.45		Gehen auf Sehrohrtiefe.
01.54		Auftauchen, stehen südlich Tonne 14, laufe auf- und ab.
05.52		Fahrzeuge in Sicht rw 175°, wird als Tanker ausgemacht. Setze mich vor zum Angriff.
07.07		Rohr I los! - Vg. 8,5, E 800, Lage 97. Fehlschuß [illegible] Setze mich hinter, um Fahrt genau auszumachen. Dabei kommt ein zweiter Schatten in Sicht. Wirkt sehr groß. Gehe auf Gegenkurs, um mit Heckschuß anzugreifen, Schatten wird dabei kleiner, liegt anscheinend gestoppt. Laufe an, setze mich raus. Ist offensichtlich Küsten[illegible]schiff.
07.58	Qu DC 1136 Wind SW 4, See 0-1, sternenklar, Sicht 16 sm	Rohr II los auf gestopptes Ziel. Nach 48 sec starke Detonation, hohe Sprengsäule. Als diese niedergefallen, nur noch Schornstein und Heck raus.

FIGURE 4.7. Original image from the KTB for 11 March 1942 (NARA).

This type of finding highlights often overlooked historical discrepancies. Additionally, this discovery further authenticated the circumstances surrounding the wrecking event.

A collection of primary sources were acquired from Jim Dan Hill Library at the University of Wisconsin. The Digital Collections held an assortment of photographs, construction plans, and reports collected from the McDougall-Duluth Shipbuilding Company. Due to the proximity the McDougall-Duluth shipyard in Duluth, Wisconsin, the Jim Dan Hill Library possessed extensive information regarding the development of the McDougall-Duluth Shipbuilding Company and shipbuilding protocol from the early 1900s until after World War I. These resources were especially useful during the modeling process, providing insight into steel ship construction and the McDougall-Duluth shipbuilding process.

The Maritime History Archives at the Mariners' Museum in Newport News offered a wide range of resources on shipbuilding, naval architecture, and World War II. Additionally, the majority of their archives are available online, allowing for easy access. The virtual Maritime

History Archives offered photographic resources of *Caribsea*. These photographs were significantly helpful in the detailed 3D reconstruction of *Caribsea* as originally built (Figures 4.8 and 4.9).

FIGURE 4.8. Photograph of *Caribsea* as *Buenventura* (Maritime History Archives).

FIGURE 4.9. Photograph of *Caribsea* in 1942 (Maritime History Archives).

A wide range of primary sources were obtained from J.Y. Joyner Library & Special Collections and the services of Interlibrary Loans. One of the more relevant and insightful sources acquired was the published memoir of Captain Nicholas Manolis: *We At Sea: The Epic of the American Mariner* (1949). This account detailed the events of *Caribsea* leading up to the sinking, and narrated the testimonies and experiences of surviving crew-members. Sources relating to iron and steel merchant ship construction were also contributory including John Gratham's *Iron as a Material for Shipbuilding* (1842), Edward Reed's *Shipbuilding in Iron and Steel* (1869), Robert Riegel's *Merchant Vessels* (1921), and H.J. Pursey's *Merchant Ship Construction* (1942). Contemporary newspaper articles, memoirs, and books written on the merchant marine also offered a time capsule glimpse into World War II that no secondary source can provide (Linley 1941; Sullivan 1941; Emmanuel 1942; Carse 1943; Douglas and Salz 1943; Scoll 1945; Standard Oil Company 1946).

Furthermore, secondary sources on the Battle of the Atlantic and background on American merchant shipping were imperative for the study. These include an assortment of topics, including iron and steel ship construction, merchant shipping, World War I, and World War II. These topics provided essential information used to contextualize the evolution of American merchant shipping and help understand the historical trajectory of *Caribsea* (Tyler 1958; Dowling 1967; Rohwer 1977; Whitehurst 1983; Balance 1989; Hickham 1989; Gentile 1992; Gardiner 1994; Felknor 1998; Bunker 2012; Duffus 2012).

3D Modeling

The primary objective of this study included developing a series of 3D models of *Caribsea* that accurately illustrates the site formation processes affecting the shipwreck site. Creating a 3D model of *Caribsea* as originally built was the culmination of the historical process.

While it is important to acknowledge the means by which the historical research was assimilated into the modeling process, a more thorough description follows in the next chapter. The following paragraphs briefly outline the steps that were taken.

Once the historic documents and construction plans were acquired, they were used to reconstruct a 3D model of *Caribsea* as originally built. This version provided the baseline condition of *Caribsea* prior to the wrecking event. The model was developed using the 3D computer aided drafting software McNeel's & Associates *Rhinoceros 4.0* (*Rhino*). *Rhino* is one of the most accessible three-dimensional modeling CAD software programs currently used, and integrates points, lines, and spatial data as a three-dimensional building tool. Data based on evidence from ship builder's plans and a contextual understanding of steel ship construction was compiled and integrated into the Rhino interface.

The 3D construction of *Caribsea* was initiated by uploading the acquired 2D builder's plans into Rhino and digitizing the virtual plans by outlining one feature at a time. The lines were then extruded into 3D objects and surfaces, slowly creating a 3D model of a ship. The virtual construction of *Caribsea* was done primarily in the same order as the physical construction of a contemporary steel vessel—following a frame-first construction style. Each structural component was organized into a "layer" allowing the user to selectively view and build individual ship components. The ability to color code specific features or shift viewing angles enhanced the experience and interpretation of the user. Following the creation of the historically accurate representation of the vessel, the archaeological data were compiled and integrated into the *Caribsea* shipwreck model (Figure 4.10).

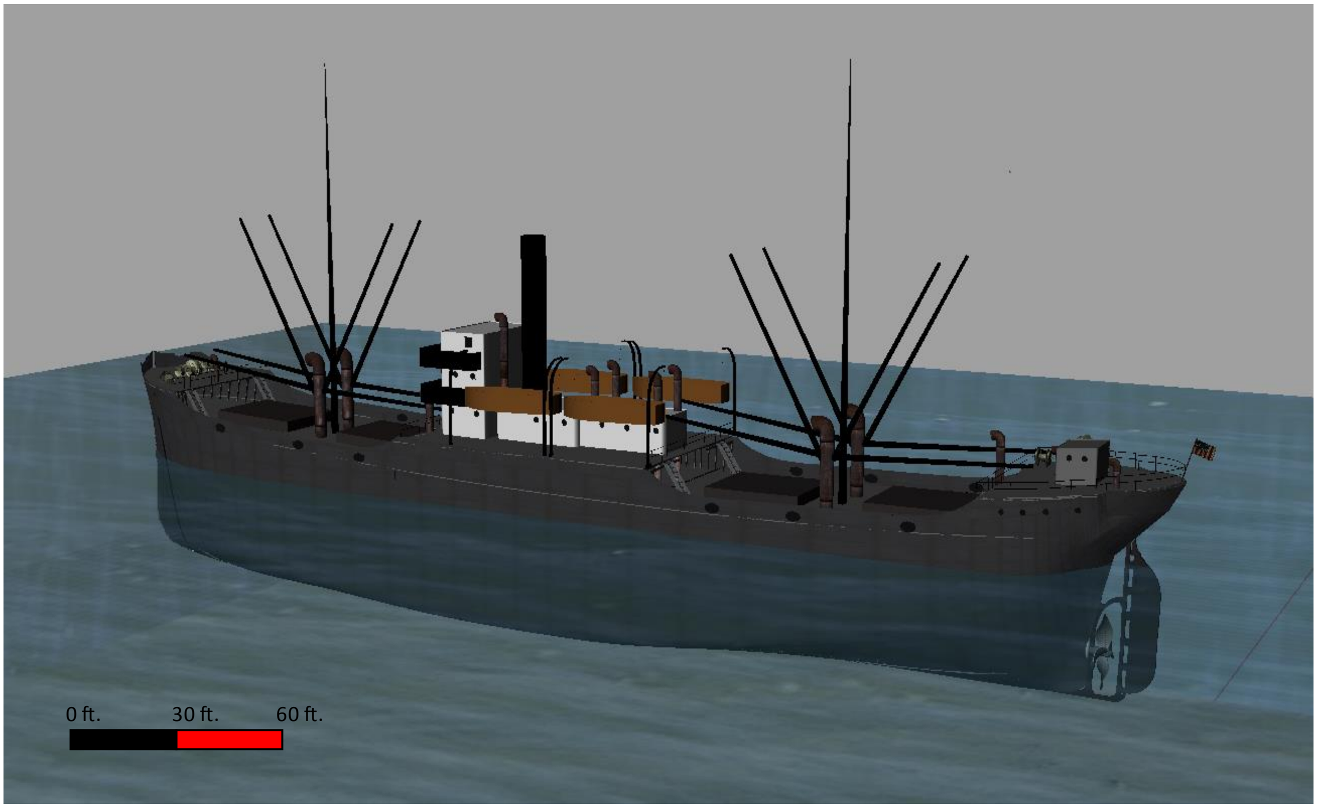


FIGURE 4.10. Example of 3D *Caribsea* model as it was originally built (Image by Kara Fox).

Archaeological Research

The second phase of the study involved acquiring enough archaeological data to recreate *Caribsea* "as shipwrecked." This process was possible through the collection of multibeam data, the development of an archaeological site plan, and the utilization and interpretation of scaled photographic materials. The resultant archaeological datasets assisted in the creation of a 3D model of *Caribsea* in its current shipwrecked condition.

Multibeam Data

In addition to archival research undertaken for this study, supplementary remote sensing surveys of *Caribsea* contributed to the accumulation of relevant data. High-resolution multibeam data were gathered during the 2011 NOAA Battle of the Atlantic Expedition by ADUS. Upon the compilation and processing of the data, the high-resolution 3D multibeam model was delivered to MNMS in April 2014 and disseminated for the development of this study. This data served as an archaeological baseline, used to verify quantifiable structural changes including artifact dispersal and degradation processes (Bates et al. 2011). Additionally, the multibeam imagery was highly useful throughout the modeling process for achieving altitude measurements of the shipwreck site.

ADUS initially grew from a partnership from academic institutions striving to create accurate visualization models of shipwrecks *in situ* from high-resolution multibeam sonar technology (Saunders 2012:320). Their primary objective has been acquiring remote sensing data on shipwrecks that pose an environmental hazard from oil spills, explosives, or nuclear material. Remote sensing surveys are also implemented on targeted sites that require very detailed investigation, including the circumstances surrounding the wrecking event or an assessment of shipwreck disintegration. By utilizing forensic archaeological methods these 3D multibeam models provide an outlet for further assessment and interpretation, uncovering "subtle clues" contained within the data (ADUS 2013).

During the 2011 Battle of the Atlantic Expedition, ADUS utilized a multibeam sonar system securing bathymetric data for every feature of *Caribsea* that provided an acoustic yield, thus allowing a detailed 3D digital landscape model to be created (Flack 2006). According to ADUS, conventional hydrographic survey techniques and basic remote sensing devices lack the positional accuracy of high frequency multibeam sonars. ADUS utilizes the Reson 8125 Seabat multibeam sonar, a system that is precisely positioned for achieving optimal detail of shipwreck sites. This is accomplished by deploying the sonar from a survey boat, which is then mounted to a deployment system (which positions the sonar head as close to the shipwreck as possible). Additionally, the location of the surveying vessel and wave movement is accounted for using sensitive positioning and motion reference systems onboard. The combination of these accurate recording systems creates a detailed 3D model of the shipwreck site and the seafloor by collecting millions of precisely positioned "spot heights" or point coordinates from the acoustic "pings" accumulated from the sonar system as the boat travels back and forth over the target. These millions of points are then further edited to filter out digital noise and movement and then imported into an animation software (Flack 2006; Dean 2010:3).

The advantages of bathymetric multibeam imagery and modeling, is that it can provide accurate measurement capabilities including the distance between any two surveyed points, calculated volumes, and quantifiable deterioration changes. These features proved to be a useful tool in the ongoing analysis of *Caribsea*, also illustrating a clear representation of the seafloor around the site, including any cultural or environmental disturbances (Dean 2010:2). While ADUS 3D multibeam models primarily serve as visual representations, the data can be further manipulated and interpreted using tools within the *Wrecksight* interface. A 3D multibeam model of *Caribsea* was produced in ADUS' *Wrecksight* software (Figure 4.11).

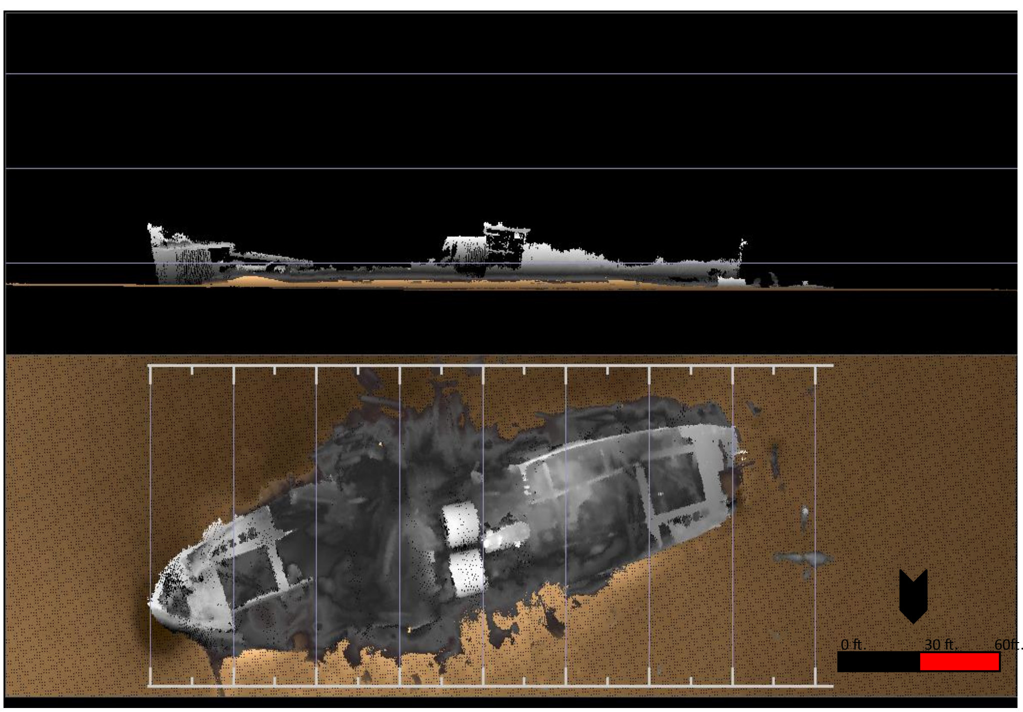


FIGURE 4.11. High resolution, multibeam model of *Caribsea* as seen in *Wrecksight* (ADUS Ltd.)

The ADUS software enabled users to fly around the virtual 3D model of *Caribsea*, zooming in and out and gaining a better understanding of the condition of the shipwreck. *Wrecksight* features enabled geospatial analysis of *Caribsea*, serving as a measurable baseline and reference. While the ADUS model served as an essential tool for this project, it lacked the detail and interpretive data desired for a detailed 3D model illustrating site formation, thus requiring additional archaeological survey and documentation.

Archaeological Documentation

Between 24 May and 1 June, 2014, NOAA's Monitor National Marine Sanctuary collaborated with BAREG to survey and map *Caribsea*. This project was conducted under the auspices of an NAS training program, and was used as both an archaeological training platform and opportunity to capture relevant data for this research. The data acquired from this project was instrumental in assessing the current condition of the shipwreck for the development of *Caribsea*'s 3D shipwreck model. The expedition was able to utilize detailed videography, scaled drawings, multibeam imagery, and scaled photographs to generate a detailed exterior survey of the shipwreck site.

The project was funded, planned, and conducted by BAREG members with archaeological guidance provided by MNMS and the Maritime Studies Program at East Carolina University. The Principal Investigator (PI) was Joe Hoyt and the Co-Principal Investigator was ECU's graduate student Kara Fox. ECU Research Vessel Captain Eric Diaddorio provided dive support throughout the project. Additionally, NOAA's MNMS provided archaeological equipment (including traditional survey instruments such as fiberglass measuring tapes, slates, mylar sheets, and straight edge scales). These tools were used to recover detailed measurements of the site and the data were later transferred to a master site plan. Photographic and videographic data were acquired using a wide range of personal instruments and was later transferred to a master hard drive (Fox and Hoyt 2014).

ECU's research vessel *Cutting Edge* served as the diving operations platform. The 30 ft. island hopper was sufficient for diving operations as it provided an adequate platform for staging various types of gear and diving operations. Water temperatures ranged from 70 to 75 degrees Fahrenheit, depending on the depth, necessitating minimal thermal protection for divers. Additionally, due to the project areas being located so far off shore, the project was susceptible to bad weather days.

Each diver provided their own personal equipment ranging from open circuit to close circuit units, including dive gear and photographic equipment. All of the data recovered during this project was available for use by BAREG, NOAA, and ECU personnel. Most divers utilized advanced diving protocol including the application of open circuit double cylinders, decompression procedures, and closed circuit rebreather units. Divers using open circuit dive gear were provided 36% nitrox, while 100% oxygen was provided for stage bottles and decompression procedures.

The dive site was located approximately 15 miles off Cape Hatteras, and 28 miles from the NOAA dock at Beaufort Inlet. Since the Cape Hatteras area is known for its high and variable currents, the location of the shipwreck site posed limitations (Figure 4.12).Visibility ranged from 20–80 ft. during the duration of the project. These factors produced a wide range of in-water efficiency from day-to day. Furthermore, the depth of the site, ranging from 80–90 ft., limited the amount of bottom time that was spent on the site each day.

FIGURE 4.12. Location of *Caribsea* (Google Maps).

Caribsea shipwreck is a gravesite to 21 merchant sailors. This presents limitations and protocol that were meticulously observed. The archaeological survey was therefore limited to exterior observations. The dive teams were advised to avoid affecting or disturbing the site. This precluded establishing permanent baselines or excavating the site (Fox and Hoyt 2014).

All dive teams included at least two divers, each equipped with either open circuit scuba equipment or close circuit rebreather units. Additionally, each team carried a slate and measuring tape for recording purposes. Before each dive, a dive plan was developed that was dependent on various dive team dynamics including air consumption rates, the type of diving unit each team was using, acquired certifications, the extent of the task, and the depth of the area. Over the nine-day project and during the seven workable diving days, the team logged 88 individual dives and over 110 hours underwater.

Under the direction of Hoyt and Fox, a temporary anchor line was installed on the site. This anchor line allowed quick and easy access to and from the site during diving operations and also avoided negatively impacting hull structure upon anchoring. Due to the dynamic environment and nature of the non-invasive survey, temporary tapes were installed (Figure 4.13). The baselines consisted of several 300 ft. fiberglass tape measures, and were strategically attached to exposed iron framing parallel to the ship's keel. These baselines were positioned on the starboard and port sides of the shipwreck site, avoiding the amidships double boiler and triple cylinder engine extending upwards 25 ft. Secondary 50' baselines were installed by individual dive teams throughout the documentation of *Caribsea*, permitting the complete and accurate documentation of inaccessible structural features.

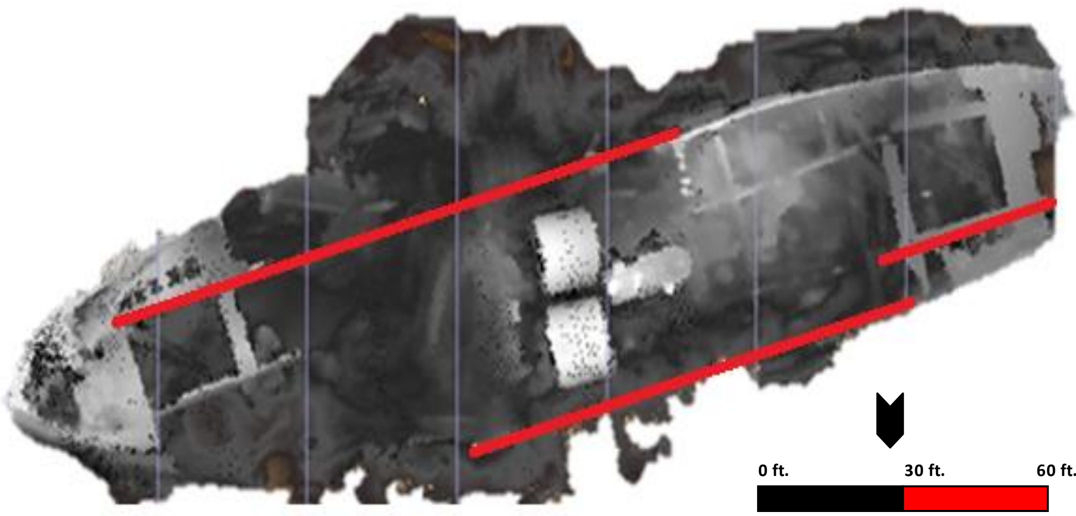


FIGURE 4.13. Locations of temporary baselines (in red) on *Caribsea* project (Image by Kara Fox).

The full documentation of *Caribsea* was accomplished by dive teams composed of two to three divers. Sections of the shipwreck site were examined and predefined using remote sensing imagery (Figure 4.14), these sections were then assigned to specific teams. Each team was given a specific task depending on their diving capabilities and archaeological skills.

Mapping included the use of fiberglass tapes, mylar paper, electrical tape, and mechanical pencils. *Caribsea* was originally built using American measurement standards of feet and inches, therefore, site measurements were also taken in feet and inches. *Caribsea* was recorded at a 1 in.: 1 ft. scale. Measurements were gathered using annotated and scaled drawings using offset or trilateration measuring methods.

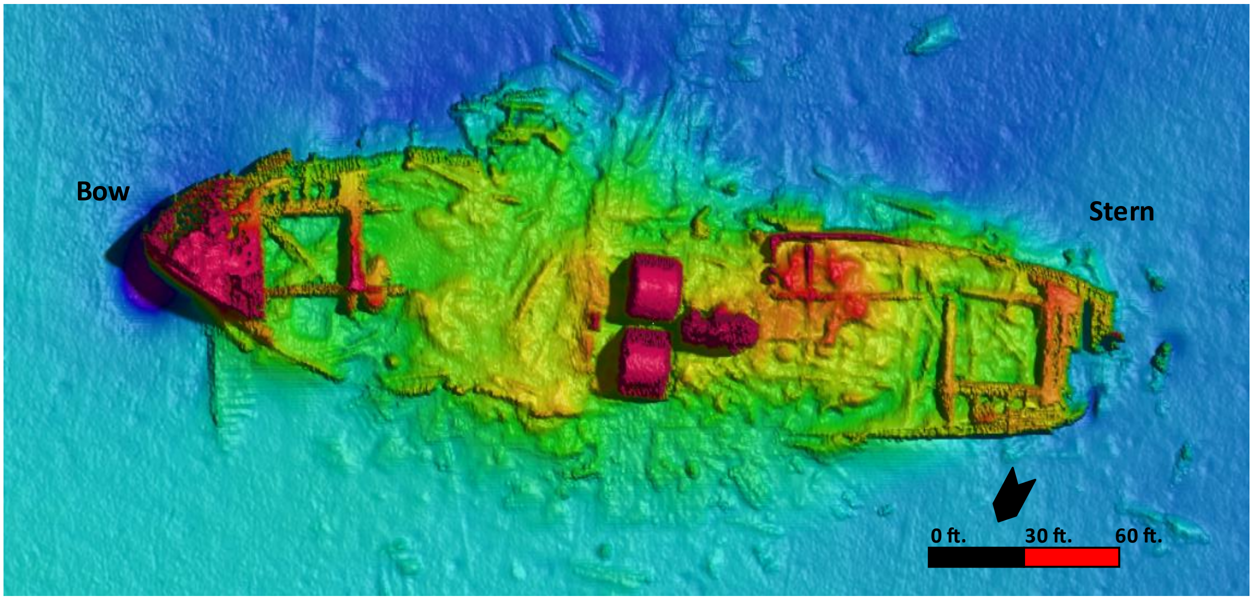


FIGURE 4.14. Example of multibeam imagery used to delineate areas of interest on *Caribsea* (NOAA 2013).

Following diving operations each day, diving personnel transferred field drawings to the *Caribsea* master site plan. Divers interpreted and extrapolated field notes and drawings, assessing missing or inconsistent data that should be reconciled. The circumstances of the project limited the extent and duration of diving operations, requiring the use of other recording techniques including photographic and video documentation. At the conclusion of the allotted fieldwork, the site plan was partially finished with several starboard and port sections that needed to be mapped. Following the conclusion of the fieldwork on 1 June 2014, Hoyt and Fox used a hybrid methodology to complete the *Caribsea* site plan.

Using a compilation of field sketches, scaled photographs, and remote sensing data, Hoyt and Fox finished the remaining sections of the site plan. Multibeam imagery and scaled photographs (taken by Hoyt during *Caribsea* fieldwork) were uploaded into Adobe Photoshop. The multibeam imagery of *Caribsea* provided a proportional framework for the missing sections of the site plan. The missing sections were identified on the remote sensing imagery and superimposed with high-resolution scaled photographs. Once the imagery was accurately aligned, shipwreck components and corresponding debris were accurately traced using a pen tool in *Adobe Photoshop* and added to the master site plan (Figure 4.15).

FIGURE 4.15. Example of the hybrid mapping technique using remote sensing imagery and scaled photographs in Adobe Photoshop (Image by Kara Fox).

Upon the completion of the site plan, stippling (a pattern simulating varying degrees of solidity or shading using small dots) was achieved to create texture amongst the various shipwreck components and emulate a more representative drawing of *Caribsea*. The culmination of *Caribsea's* field project resulted in a comprehensive site plan of the shipwreck (Figure 4.16).

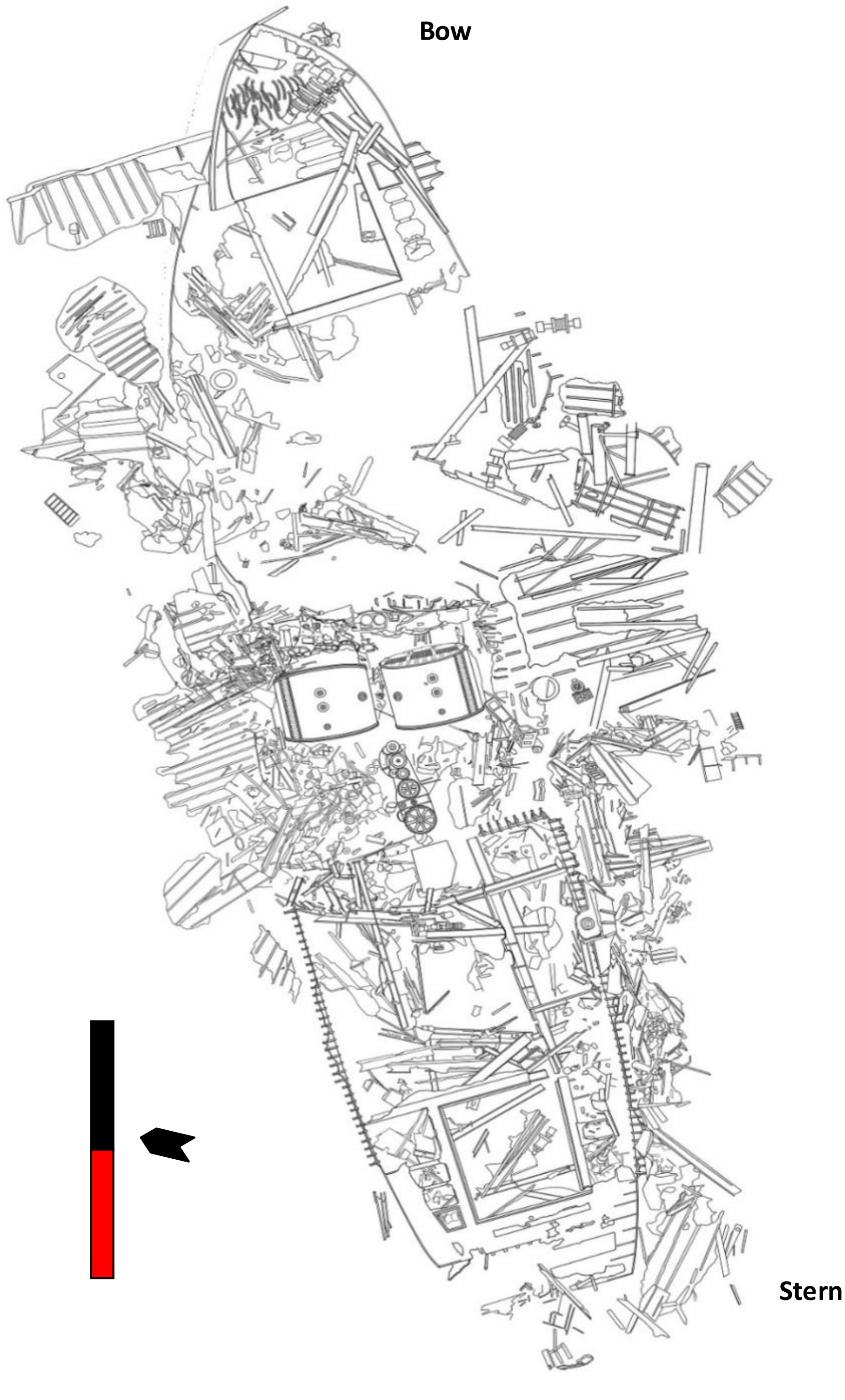


FIGURE 4.16. *Caribsea* site plan (NOAA).

Archaeological 3D Modeling

Since the development of the 3D models of *Caribsea* was an essential tool in understanding and potentially predicting site formation processes, the acquisition of the 2D site plan for the shipwreck model was a major accomplishment. While this section serves to roughly outline the next step in the methodological progression of this study, a more comprehensive examination of the archaeological 3D modeling process is discussed in the following chapter.

Once the complete site plan of *Caribsea* was obtained, the creation of the 3D shipwreck model could begin. Similar to the creation of the historical 3D model, the 2D site plan and additional dimensional material was uploaded into Rhino and used as an "archaeological-based builder's plan." The building order of the shipwreck began with importing recognizable ship features such as the bow and stern sections, including the outer hull structure and the frames. Once these features were built to scale and positioned correctly relative to the slope and curvature of the shipwreck on the ocean bottom, additional structural components and machinery pieces were added. The last component of the shipwreck site was developing the vast debris field on the interior of the shipwreck and the port and starboard sides of the site, along with corrosion or degradation that was noted within the site plan.

After the development of the 3D Current *Caribsea* Shipwreck Model (Figure 4.17) was complete, the objective of the project could begin: a site formation analysis of *Caribsea*. Using historical, cultural, and environmental variables, both the historical and current *Caribsea* models were used to develop a series of accurate 3D models representing the process of deterioration. The development and interpretation of these sequential site formation models is further discussed in Chapter Six.

FIGURE 4.17. Example of 3D *Caribsea* shipwreck model (Image by Kara Fox).

Conclusion

This chapter discussed the steps taken to collect and create a 3D dataset on *Caribsea* for the purpose of this thesis. The data collected from these processes, helped create a method for visualizing site transformation of World War II shipwrecks off the coast of North Carolina, which are detailed in Chapter Six. Ultimately, the benefit of such detailed 3D modeling greatly facilitates the interpretation and understanding of active site formation and gives historical, cultural, and environmental variables context and provenance. The following chapters further outline the utility of what has been done to illustrate, interpret, infer, and explain site formation processes regarding *Caribsea*.

CHAPTER FIVE: RESULTS—UNVEILING THE MODELS

This chapter demonstrates the results of the historical and archaeological data collection process described in the previous chapter. While one of the objectives of this study was to explore the visual potential of illustrating site formation processes using 3D capabilities, it is important to emphasize that the 3D modeling results provides more than just a visual reference. The following models are layered with historical and archaeological data, providing interpretive and analytical potential. Detailed 3D models were developed to better demonstrate the types of collapse and dispersal patterning taking place on the shipwreck site. The purpose of this chapter is to discuss in detail the 3D modeling process that took place, outlining the data acquisition, interpretation, and representation, ultimately providing a resource that allows for a more detailed and comprehensive understanding of site formation processes taking place on *Caribsea*.

The primary objective of this chapter is to more closely discuss the modeling and interpretive process. The first section of the chapter introduces the concept and utilization of 3D modeling. The following section further examines the process of developing the 3D Historical *Caribsea* Model. The last section discusses the process of developing the 3D Current *Caribsea* Model. This chapter includes the process of developing and interpreting these models, while Chapter Six discusses the method of using 3D models as an analytical tool.

3D Modeling

Archaeological 3D modeling of a ship, site, or object provides a research avenue that no other historical or archaeological resource can provide. The process of reconstruction often forces the modeler to examine the reasoning involved in building the object, focusing on the original builder's movements and rationale, and revealing techniques and processes (Steffy

1985:250). Ultimately, the modeler is exploring a virtual tactic that most historical or archaeological materials could never fulfill.

In the same way 3D reconstruction of a ship can allow a modeler to envision, infer, and study the building techniques of a shipbuilder, 3D modeling of an archaeological site also offers a unique research outlet: allowing the modeler to examine, infer, and illustrate site formation one object at a time. This process also allows the spatial and temporal trajectories of the site and elements of the site to be visually and textually captured. Thus, it becomes possible to assess the models for patterns and signs of continued or future degradation. While this qualitative research method is based on gathering in-depth knowledge of the site and the various types of environmental and cultural behaviors affecting the shipwreck, future quantitative studies could further validate the study.

3D Modeling Software

Robert McNeel & Associate's *Rhinoceros 4.0* software was chosen as the modeling platform for this project. This CAD software allows users to produce mathematically precise representations of curves and surfaces in computer graphics. While a variety of other CAD based programs (*AutoCAD*, Google *Sketchup*, and *MultiSurf*) with similar capabilities were obtainable, the convenience of *Rhino* 4.0, coupled with the user-friendly interface proved essential for the study at hand.

Typically, Rhino's versatile 3D modeling interface is used for architecture and industrial design (including automotive and watercraft design), proving the software as a good candidate f

or illustrating naval architecture and shipwreck degradation. Rhino enables users to start with a sketch, drawing, or scanned data—providing the tools to continue building and documenting the model—utilizing rendering, animation, drafting, measurement, interpretation, and analysis capabilities. The accuracy and flexibility with interface tools allows modelers to explore and create without having to spend much time learning CAD. This usability was an essential element throughout the duration of this project. While point data was used to create objects and features within the hull, the majority of the hull structure was designed using line data. Line representations were developed for each shape or feature using a variety of curvature tools, and then were ultimately re-created with surfaces to develop a 3D version of the feature.

Historical *Caribsea* Model

Recreating *Caribsea* as it was historically built was a process that began with archival research. While historical records for the modeling process were acquired, the original documentation on McDougall-Duluth *Laker*-class ship construction or more specifically *Caribsea's* ship construction was scarce. Correspondingly, the level of accuracy throughout the modeling process could have been affected due to some missing data, which ultimately lead to marginal conjecture—more specifically with the shape and curvature of *Caribsea's* hull.

As previously discussed, historical documents were procured from a variety of archives. The most essential and useful historical records included the McDougall-Duluth Shipbuilding Co. builder's plans. While the plans specifically associated with *Caribsea* were unavailable, records associated with the vessel's sister ships were accessible and used as a replacement. *Caribsea's* builder McDougall-Duluth Shipbuilding Co., produced 15 identical oil-fueled, ocean-going *Laker*-class vessels for the United States Shipping Board from November 1918 until May 1920. The records associated with these vessels were found to be of the same design and dimensions.

The historical records were digitally scanned and uploaded onto a hard drive for further interpretation. Each builder's plan was evaluated for construction notes, measurement annotations, and insight into ship building techniques. Additionally, the historical background of iron and steel ship construction and design was thoroughly examined, including the transition from traditional transverse framing systems to more longitudinal methods, the availability of increased cargo capacities, presence of new and improved steam engines, and the shift towards larger, multi-deck ships. This supplementary information provided fundamental knowledge on the trajectory of steel ship construction.

Scanned schematics were uploaded into *Rhino's* interface, providing a visual guide for the development of lines and surfaces. Once the schematics were uploaded, the accurate size and units for the modeling process was selected. This template was selected based on the measurement system indicated on the ship builder's plans. Based on this information, *Rhino* created lines and surfaces relative to feet and inches.

Building the virtual model of *Caribsea* differed slightly from the typical physical construction of steel vessels. Steel ship construction during the 20th century customarily followed a frame-first construction style (Riegel 1921; Baker 1943; Sawyer 1970; Bunker 1972). Frame-first construction methodology involved the hull shape controlled by having a rigid framework constructed first, providing control over the shape and curvature of the vessel (Figure 5.1). The hull plating would be added later, following the construction of fundamental "backbone" features including the keel, framing, and bulkheads (Figure 5.2). The outer hull plating would be one of the last features added to the vessel.

The first step in building the 3D model of *Caribsea*, however, involved building the outer hull. This process not only provided a perimeter for all additional components, but it also provided illustrative data on the shape and curvature of steel merchant ships of the era. Once the correct measurements and units were assigned for the building template, the construction of *Caribsea* began.

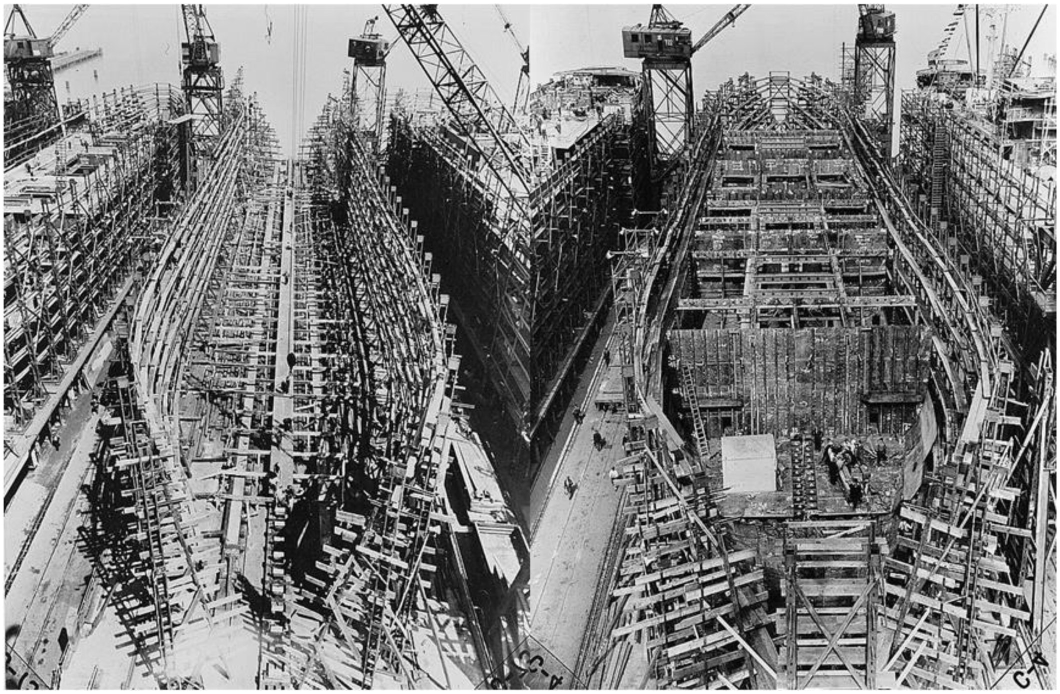


FIGURE 5.1. Example of frame-first steel ship construction of keel, frames, and bulkheads (Elphick 2006:325).

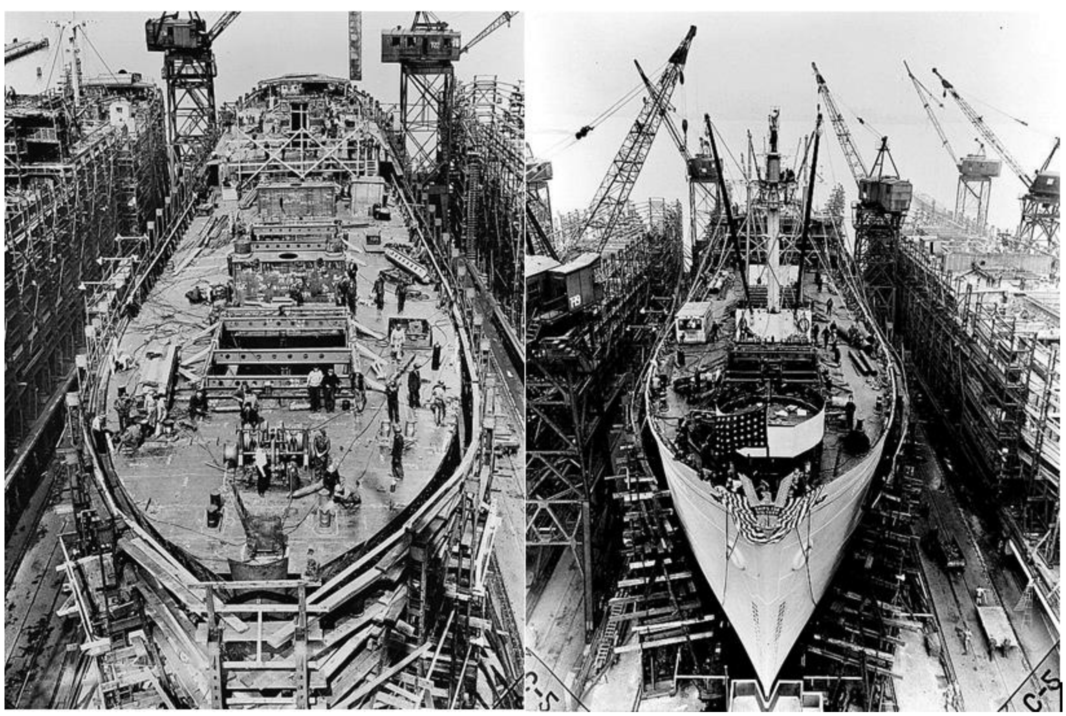


FIGURE 5.2. Example of the outer hull plating being assembled in one of the final stages of steel ship construction (Elphick 2006:326).

While building plans on the general arrangement of the decks, midship, and inner hull components had been procured, the lines drawings (sheer plans), which would have illustrated the accurate curvature of the hull, were unavailable. This proved problematic, since the general shape of the hull was the first step in the modeling process. The modeling process, however, continued using a hybridization technique which involved using the existing ship plans that included arbitrary framing sizes and locations, coupled with a "trial and error" method that involved historical-based inference and extensive knowledge on the *Laker*-type hull structure (Figure 5.3). Various line drawings were constructed and tested during the modeling process, but initially proved to be incorrect once 3D rendering was accomplished and the shape and curvature of the hull was examined and measured (Figure 5.4).

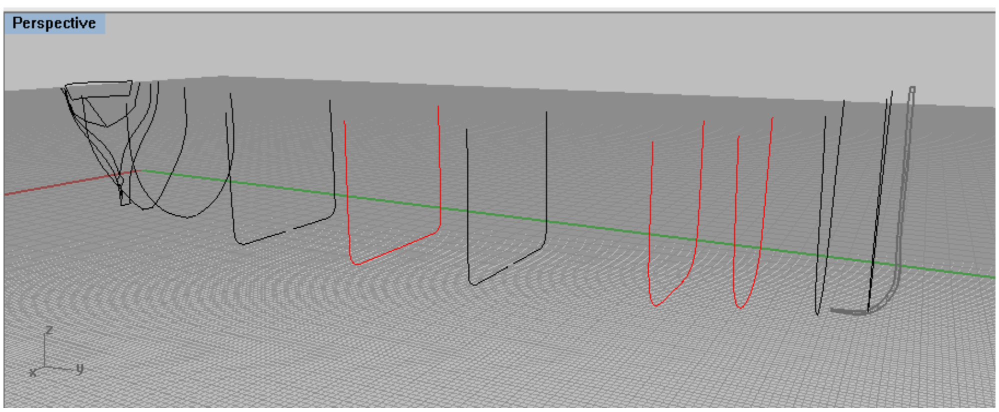


FIGURE 5.3. Example of inaccurate lines representation of *Caribsea* hull (inaccurate lines represented in red) (Image by Kara Fox).

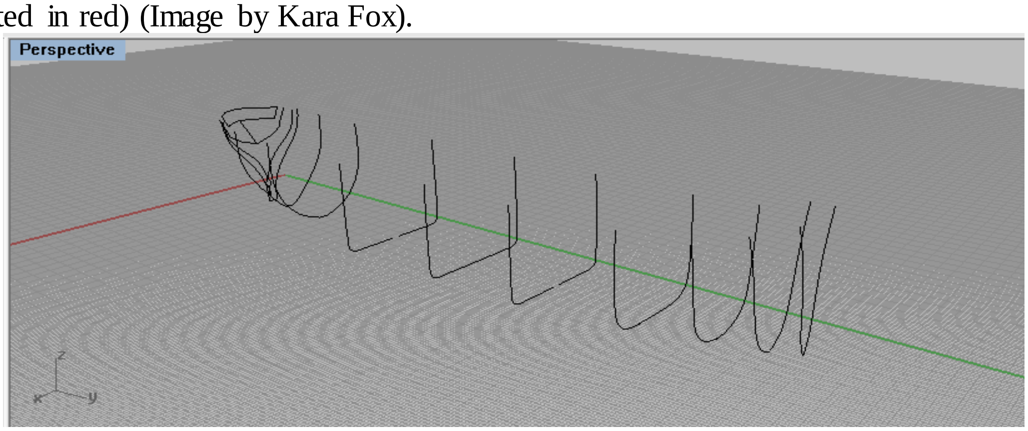


FIGURE 5.4. Example of final lines representation of *Caribsea* hull (Image by Kara Fox).

An accurate version of *Caribsea's* hull was eventually achieved and compared with historical evidence and recorded dimensions (Figure 5.5). Although the hull-first approach did provide a necessary starting point, it also highlighted a very limiting disadvantage. Because the outer hull was built first, all subsequent ship components were required to conform to the initial shape of the hull—irrespective of the accuracy or authenticity of this limitation. This factor did limit the accuracy of the design of *Caribsea* to a degree.

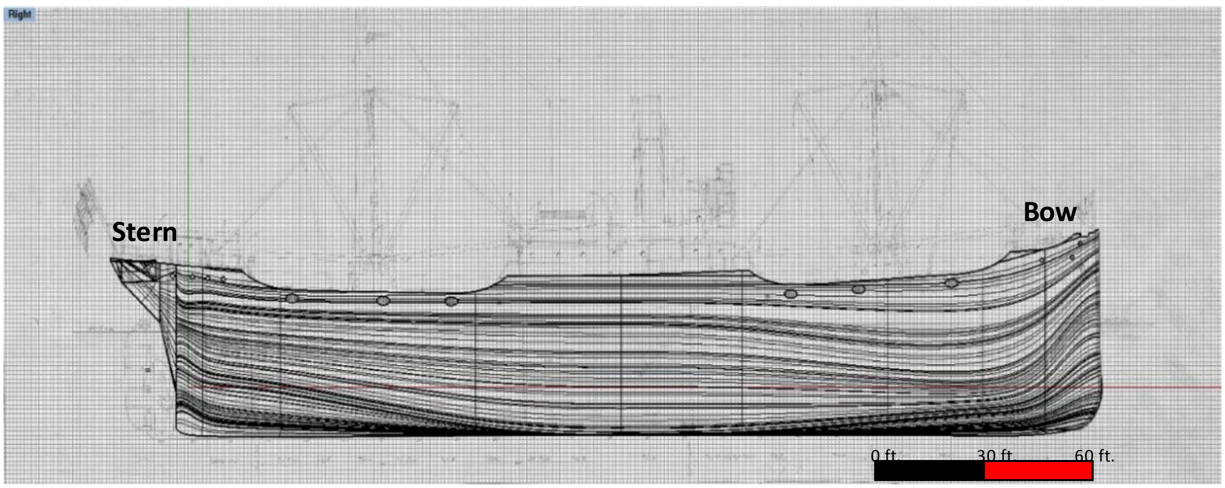


FIGURE 5.5. Example of 3D shaded rendering of *Caribsea* hull (Image by Kara Fox).

Following the construction of the hull, the "backbone" and the major structural components of the ship were assembled. Using the Midship Section builder's plan (Figure 4.3), to-scale hull components were created including the keel, floor plating, and framing. The location of these features was identified using the General Arrangement (Figure 4.1) and Inboard (Figure 4.2) builder's plans. After the completed development of the ship's framework (Figure 5.6 and Figure 5.7), additional components including decking and the superstructure could be created. These features began to give the ship a more authentic appearance, and made it possible to begin development of more auxiliary features like machinery and cargo gear.

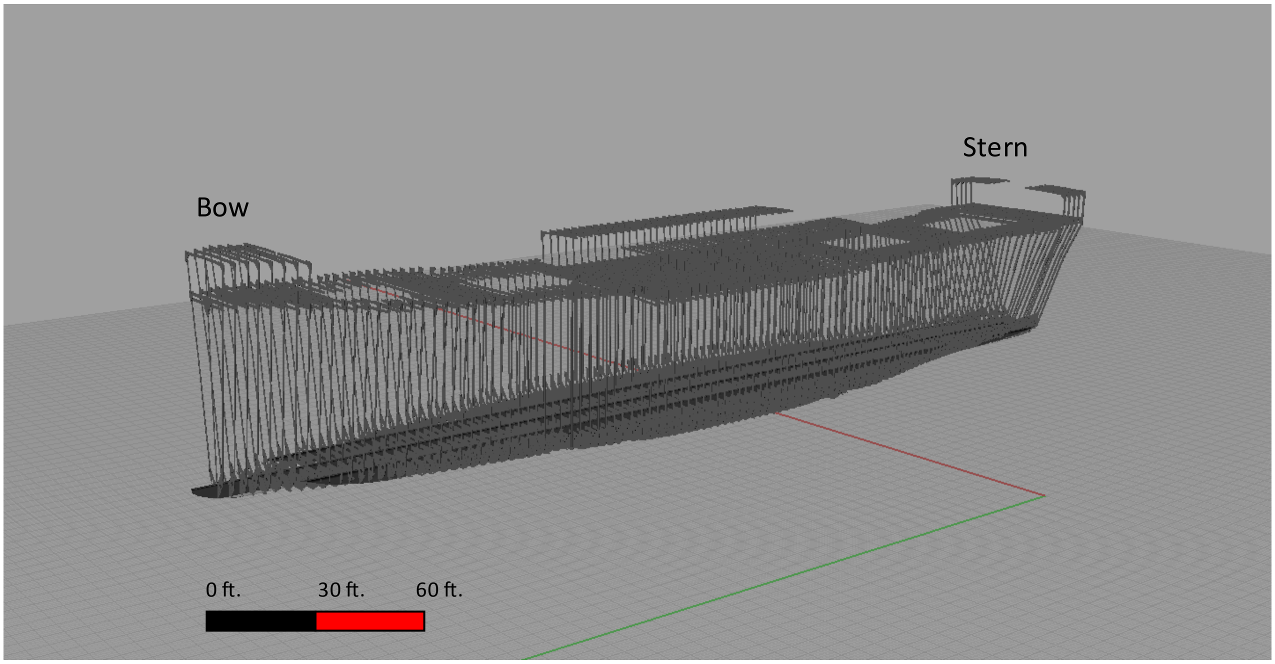


FIGURE 5.6. Example of framing and keel components of 3D *Caribsea* model (Image by Kara Fox).

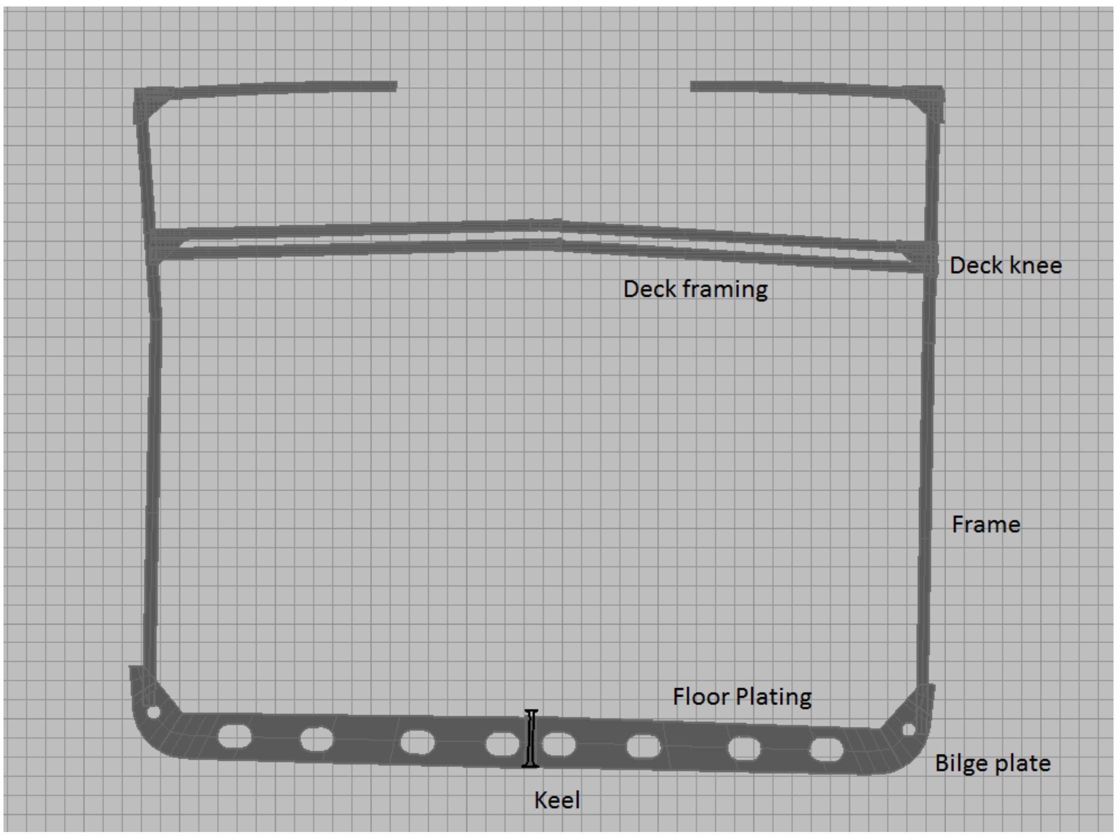


FIGURE 5.7. Midship section of *Caribsea* with labeled ship components (Image by Kara Fox).

Following the creation of the outer hull plating and the major hull components (keel and framing), additional features were developed including the decking and superstructure. The decking was easily developed because the existing deck framing reinforced the shape and location of the decks, coupled with the existing outer hull plating that provided an accurate perimeter. *Caribsea* was considered a "Three Island Type" ship, which characterized three individual partial decks located forefront, amidships, and aft of the vessel (Figure 5.8). Additionally, *Caribsea* had two full-length operational decks—a cargo deck and the main deck. The cargo deck included the main cargo holds and the engine and boiler rooms. The main deck included access to the cargo hatches, cargo lifting mechanisms, and the sailor's quarters. Once the decking was built, the superstructure of *Caribsea* could be developed. This section was created solely from to-scale representations taken from the General Arrangement builder's plan. This addition included the officer's cabin, pilot house, and flying bridge (Figure 5.9).

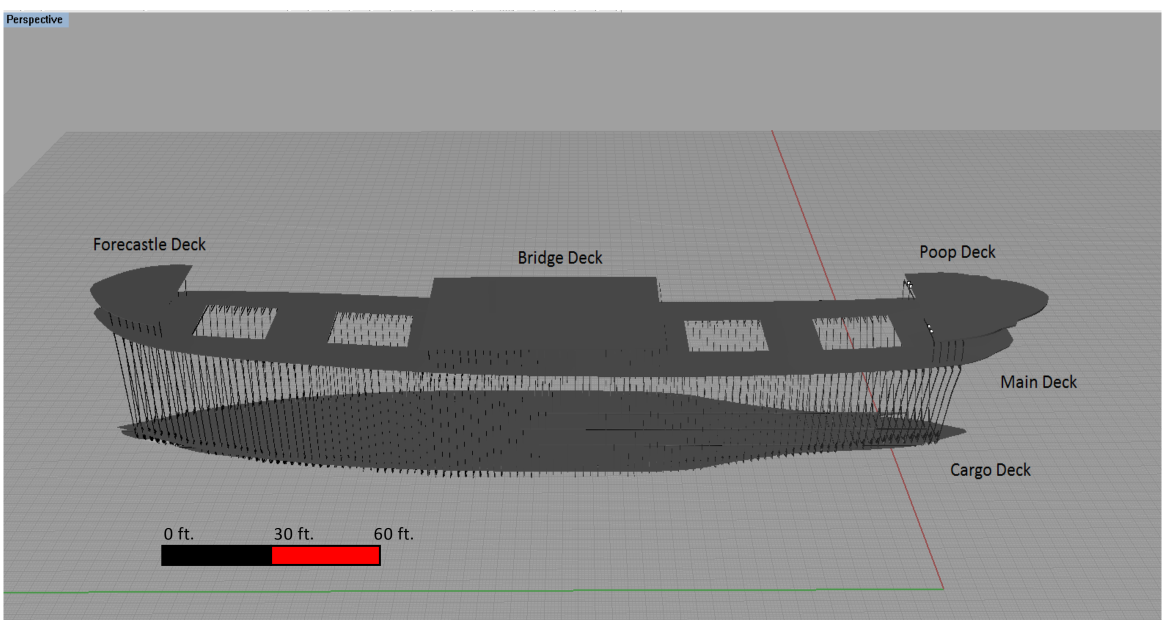


FIGURE 5.8. Image illustrating two full-length decks and three individual decks including the forecastle, bridge, and poop deck (Image by Kara Fox).

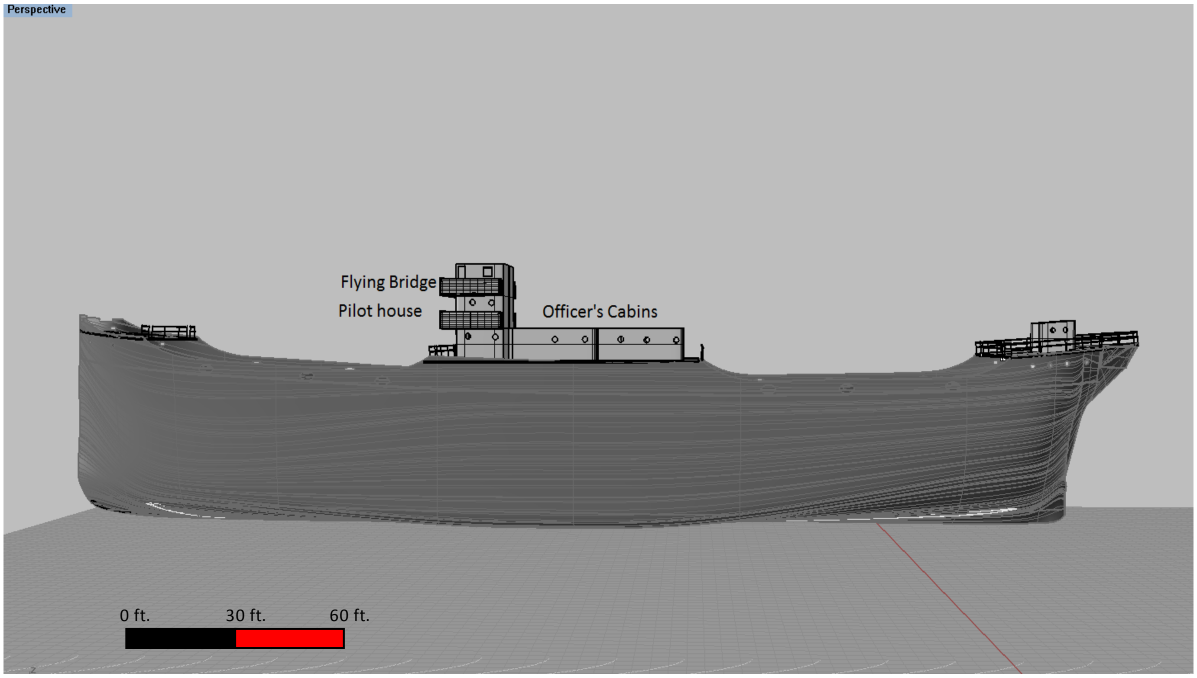


FIGURE 5.9. Image illustrating the addition of the superstructure including officer's cabins, pilot house, and flying bridge (Image by Kara Fox).

Next, the major machinery components of *Caribsea* were created. These components included a three cylinder triple expansion engine, two scotch boilers, and single bronze screw propeller and shaft (Figure 5.10). Each feature was created using a multifaceted approach—combining historical photographs, principal dimensions taken from the historical record, and to-scale representations extracted from the General Arrangement builder's plans (Figure 4.1). Historically, each component would have required a series of explicit schematics. However, this data was unavailable. In the case of *Caribsea's* rudder (Figure 5.11), the availability of explicit Rudder builder's plans provided a thorough framework for its creation. It proved to be a more complicated construction process because of the assembly detailing illustrated in the builder's plans and the inclusion of numerous components including the pintle, rudder arms, and gudgeon.

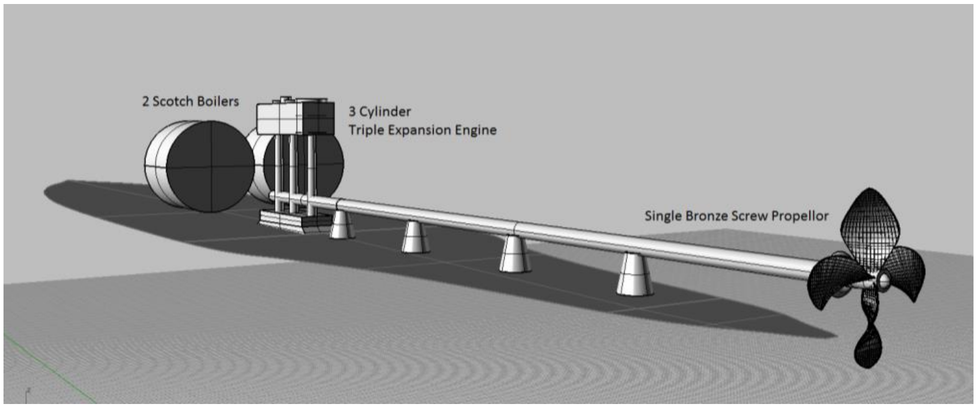


FIGURE 5.10. Image illustrating the 2 Scotch Boilers, 3 Cylinder Triple Expansion Engine, and Single Bronze Screw Propellor of *Caribsea* (Image by Kara Fox).

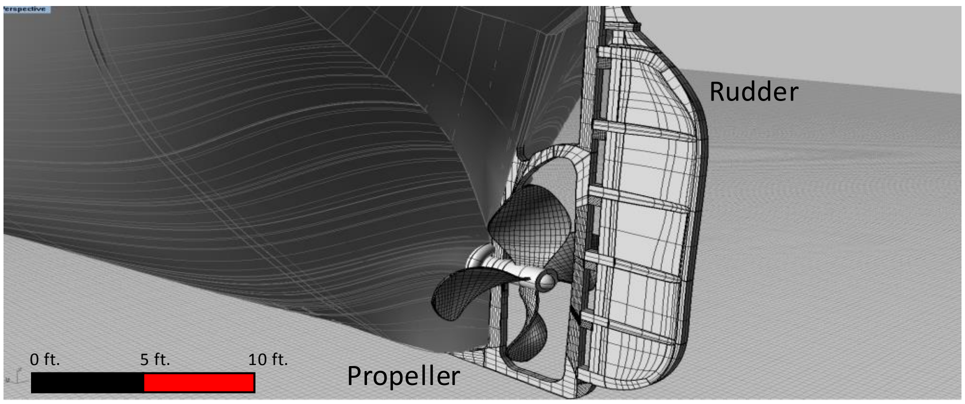


FIGURE 5.11. Image representing the finished rudder of *Caribsea* (Image by Kara Fox).

Following the creation of the rudder, modeling efforts focused on auxiliary components including the stairs, ladders, cargo gear, hatch covers, lifeboats, piping, capstans, and the windlass. The development of these features required the use of the General Arrangement plans and historical conjecture developed from archival research and background information on steel ship construction. Additionally, based on the historical records, *Caribsea* was transporting 3,600 tons of manganese ore at the time of the shipwrecking event. Because this cargo feature was corroborated within the arcaheolgoical record, the 3D representation was established in the historical model—based on artisic ability and inference. The addition of these last features also further enhanced the authentic nature of *Caribsea* (Figure 5.12 and Figure 5.13).

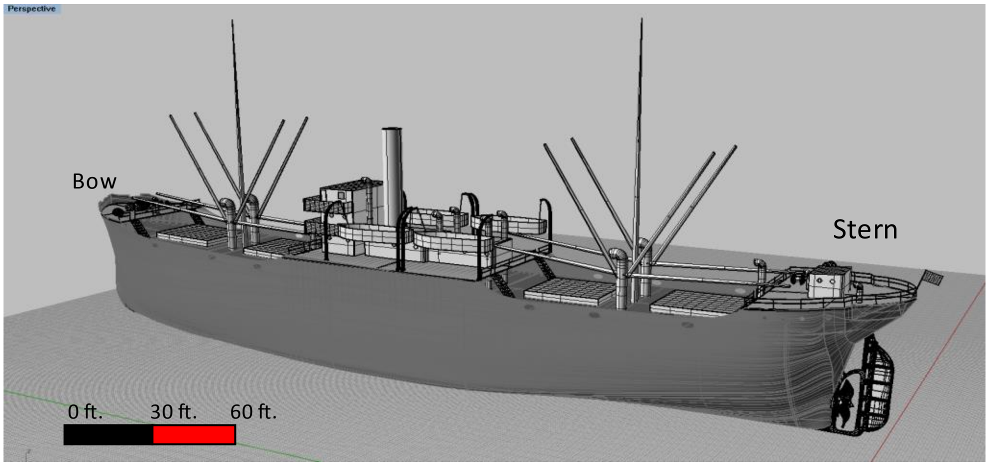


FIGURE 5.12. 3D *Caribsea* model with final auxiliary components (Image by Kara Fox).

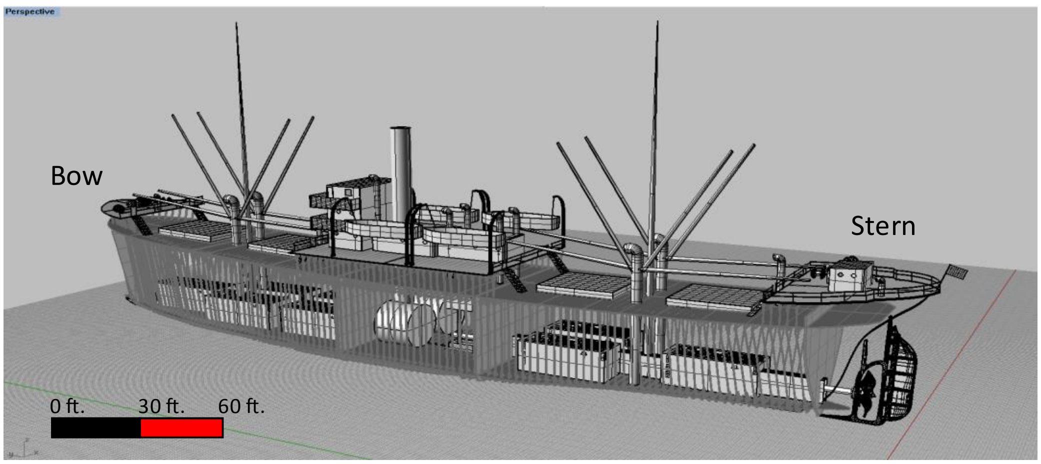


FIGURE 5.13. 3D *Caribsea* model with view of cargo hold (Image by Kara Fox).

The last phase of creating the Historical *Caribsea* Model was adding authentic surfaces to each 3D feature. This process facilitated a more realistic appearance—ultimately assisting with the overall goal of illustrating site formation and degradation. Additionally, the model was placed in a 3D ocean environment—demonstrating the possible displacement, positioning, and waterline of the vessel prior to the wrecking event (Figure 5.14).

Displacement tonnage was important to assess and illustrate because it is the weight of water that a ship displaces when it is floating (weight of the ship with its contents). The loaded displacement (weight of ship including cargo) of *Caribsea* was 4,200 gross tons. This weight would bring the vessel down to its "load draft," colloquially known as the "waterline."

Establishing the displacement and positioning of *Caribsea* at the time of its sinking was a key factor in the assessment of the shipwrecking event—as this variable would influence the location of the torpedo impacts and the progression of the sinking.

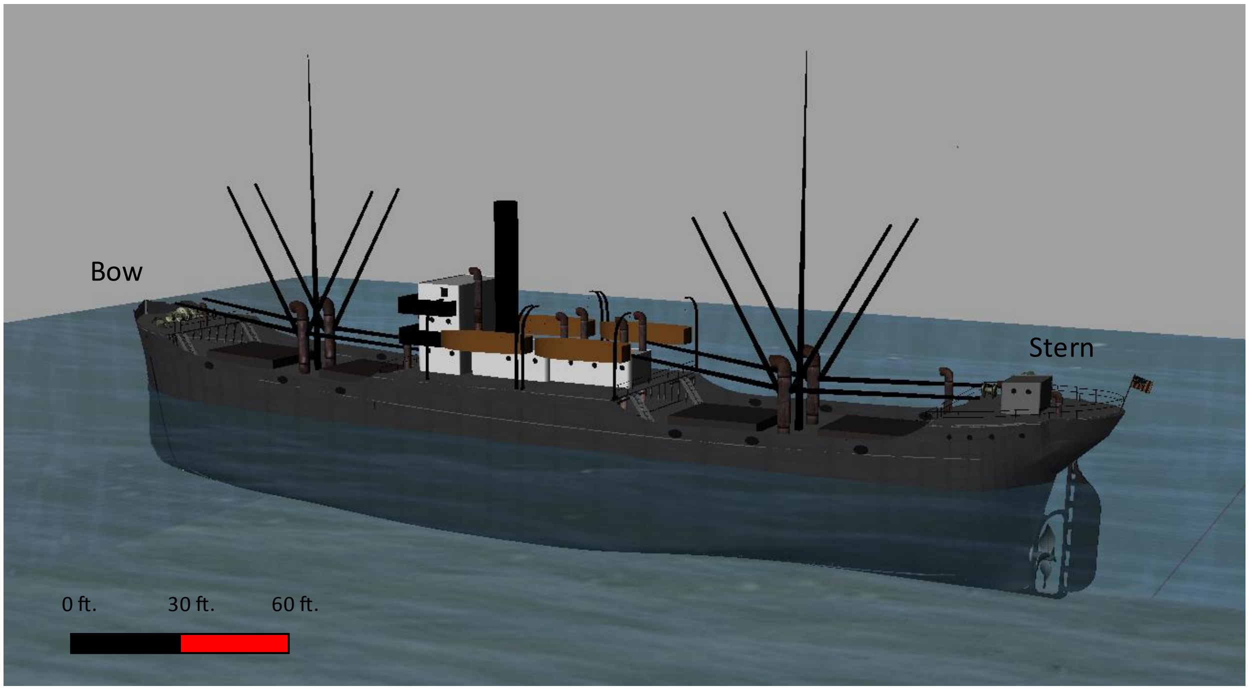


FIGURE 5.14. Image illustrating the final Historical *Caribsea* Model (Image by Kara Fox).

While historical authenticity was the objective, conjecture was unavoidable due to the minimally acquired historical documentation on *Caribsea's* construction and design. The modeling of *Caribsea* was limited to the accuracy of the acquired builder's plans and the author's ability to interpret and reconstruct the data. Physically building a vessel is a dynamic process—requiring modifications and deviations from the schematics, which often are left out of the builder's plans. This factor became progressively more apparent throughout the 3D modeling process, and was especially obvious in the inconsistencies between various to-scale builders' plans. Though, there was no historical evidence found of post-construction modifications to *Caribsea*.

Overall, the Historical *Caribsea* Model included over 50 different types of ship components and approximately 5,776 polysurfaces. The advantage of developing a 3D model of any type of vessel exists in the interpretation and detailed examination of each construction feature, especially in comparison to the archaeological record. This has a significant advantage over 2D historical data, even with the substantial time commitment.

Current *Caribsea* Shipwreck Model

Creating the historical model was necessary to capture and understand the initial condition of the vessel prior to site formation. However, the development of the Current *Caribsea* Shipwreck Model was a turning point in this project since the primary objective of this thesis involved illustrating and understanding environmental and cultural site formation processes taking place on the shipwreck site. The envisioned analysis, could only begin once the current condition of *Caribsea* was constructed and fully examined.

Recreating *Caribsea* in its current shipwreck state was a process that began following the creation of the 2D site plan and acquisition of multibeam data. While archaeological site plans serve as an excellent reference source and management component in underwater archaeology, the existing 3D geo-spatial data is largely lost in the 2D representation, negating further interpretation or manipulation of the data.

The *Caribsea* site plan was used in concordance with altitude data taken from a multibeam model of *Caribsea,* produced by ADUS, and provided by MNMS. The 3D shipwreck model was created using a hybrid of datasets: layering the site plan and ADUS data with additional orientation and degradation data taken from photographs and field notes. However, the level of accuracy throughout the shipwreck modeling process could have been affected due to a variety of factors including site plan imprecisions, modeling limitations, and interpretive inaccuracies. The 2D site plan and the ADUS multibeam model were the primary foundation for modeling the archaeological shipwreck in Rhino 4.0. These datasets made up the perimeter of the shipwreck and were used intermittently to define different features noted within the datasets. As previously mentioned, Rhino enabled the development of points, curves, and line data to provide references for surfaces and 3D objects.

Similar to the historical modeling process, the shipwreck version of *Caribsea* required plan and profile materials to create the 3D model. The acquired archaeological datasets were imported into Rhino 4.0. The 2D site plan served as the primary reference guide (Figure 5.15), while altitude data were gathered from the interactive 3D multibeam model of *Caribsea* and integrated into the model (Figure 5.16). Upon importing the 2D site plan, the same measuring template for the historical model was applied to the shipwreck model. Similarly, the model template was selected based on the measurement system indicated on the historical builder's plans and the measuring system used throughout the archaeological recording process, feet and inches.

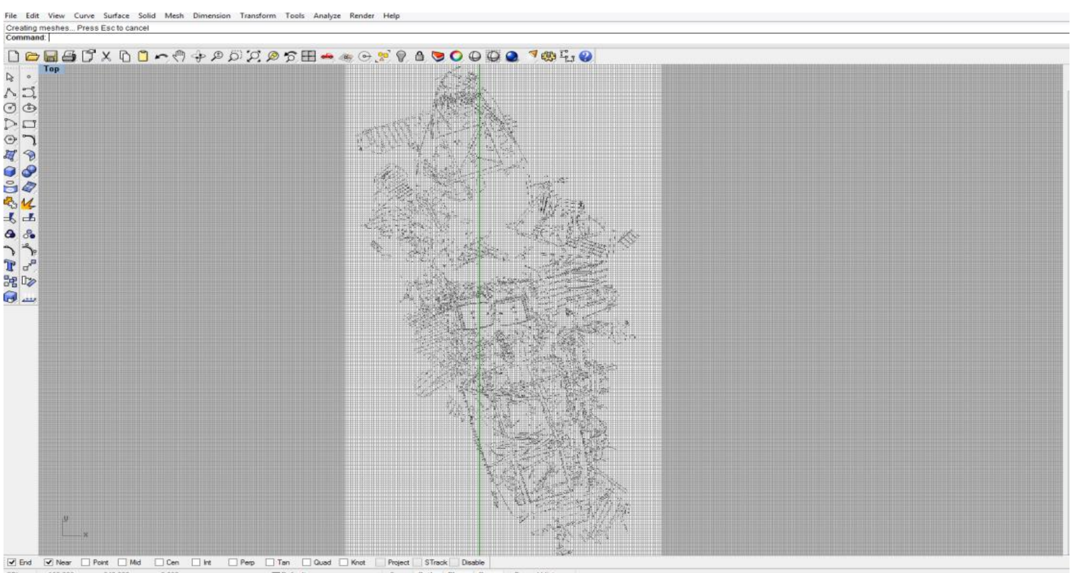


FIGURE 5.15. Site plan of *Caribsea* used as perimeter for shipwreck model (Image by Kara Fox).

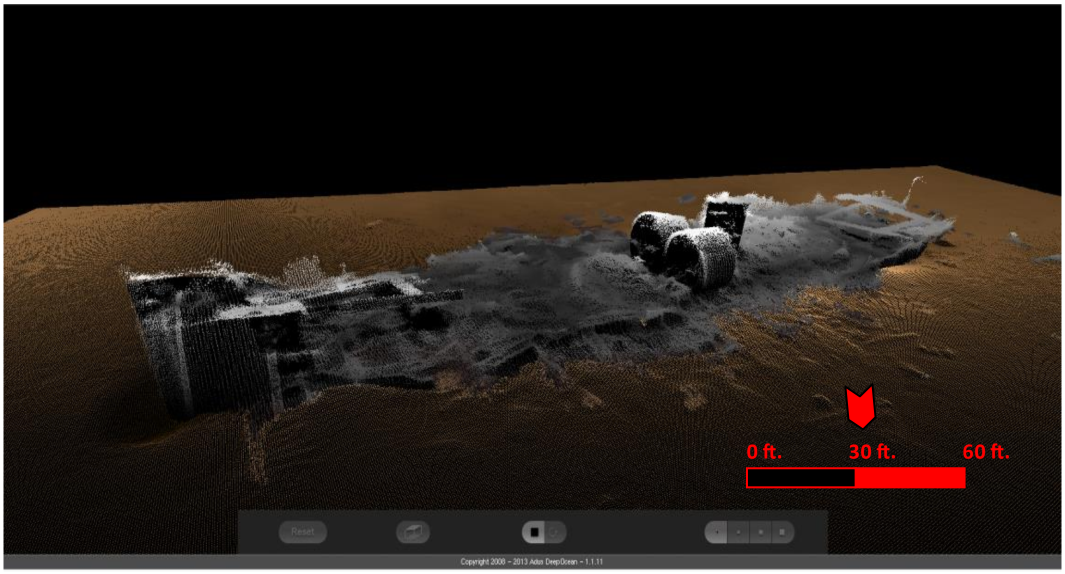


FIGURE 5.16. Example of altitude capability within ADUS *Caribsea* model (ADUS).

Once the Rhino interface was prepared, the modeling process began. Reconstruction of the shipwreck model took place in a similar manner to the construction of the historical model of *Caribsea*. The existing outer hull sections were identified, traced, and extruded into surfaces (Figure 5.17). The bow and stern hull sections comprised the only two areas of overhead relief throughout the shipwreck site—and as such, had specific curvature, slope and deterioration. Utilizing the ADUS data and measuring tools, the accurate altitude and curvature of the outer hull was achieved (Figure 5.18).

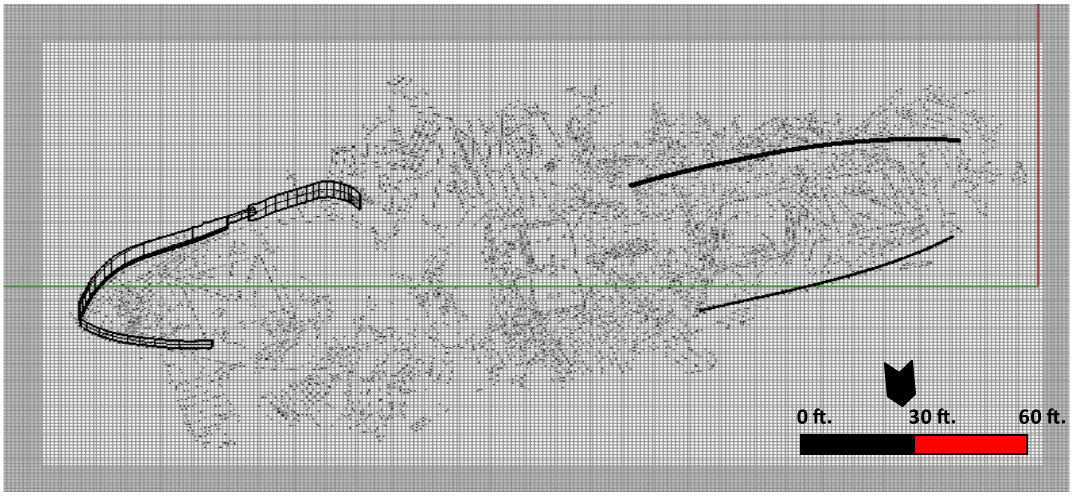


FIGURE 5.17. Plan view demonstrating the outlining of *Caribsea* site plan in *Rhino* (Image by Kara Fox).

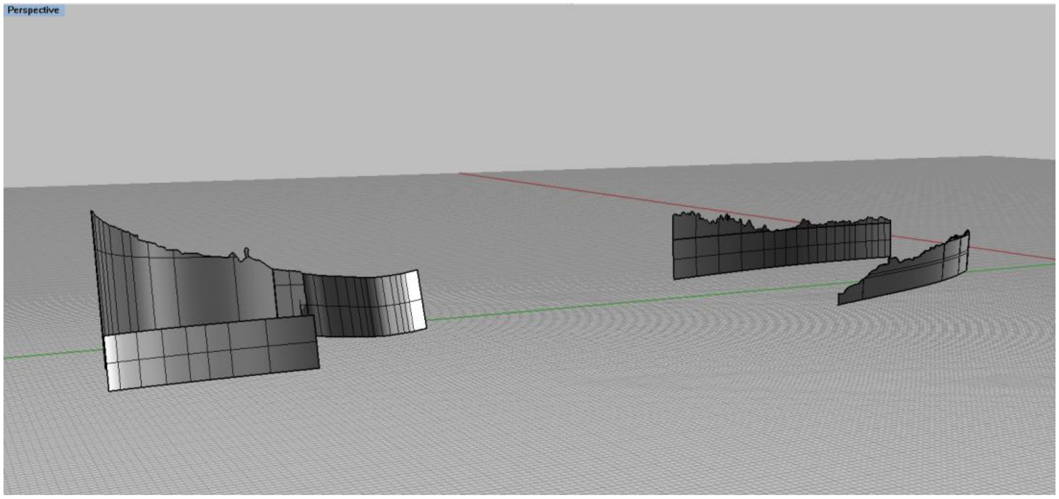


FIGURE 5.18. Perspective view demonstrating the outlining of site plan and the extrusion of the outer hull portions on shipwreck model (Image by Kara Fox).

Following the creation of the outer hull plating, additional structural components were reconstructed including frames, bow and stern decking, hatch beams, deck beams, and beam knees. Structural components were typically easy to identify on the 2D site plan, as was the condition of the various hull components (Figure 5.19). Once the outer hull structure was completed, the debris field within and surrounding the shipwreck site was reconstructed including various beams, hull plating and frames, cargo gear and masts, and other miscellaneous features (Figure 5.20).

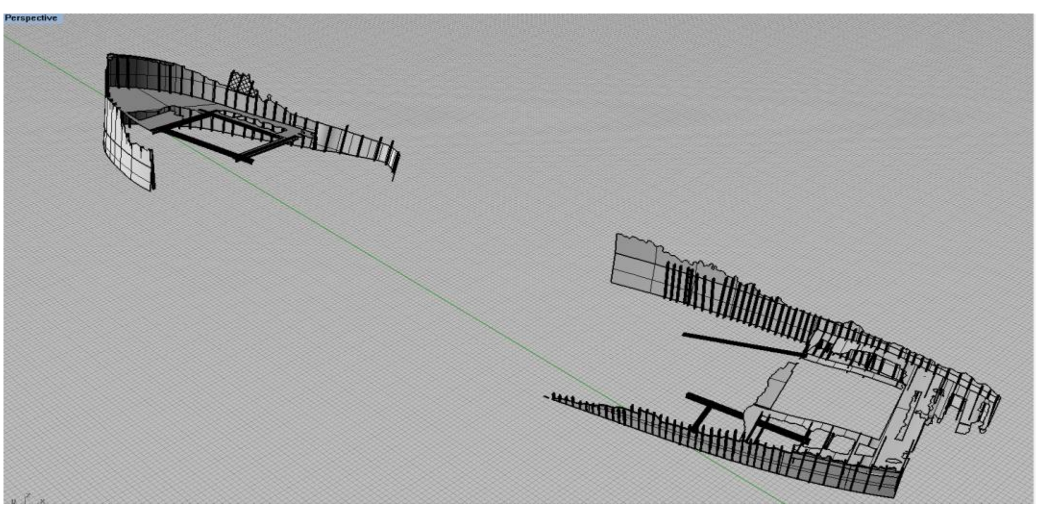


FIGURE 5.19. Example of structural components of *Caribsea* shipwreck model (Image by Kara Fox).

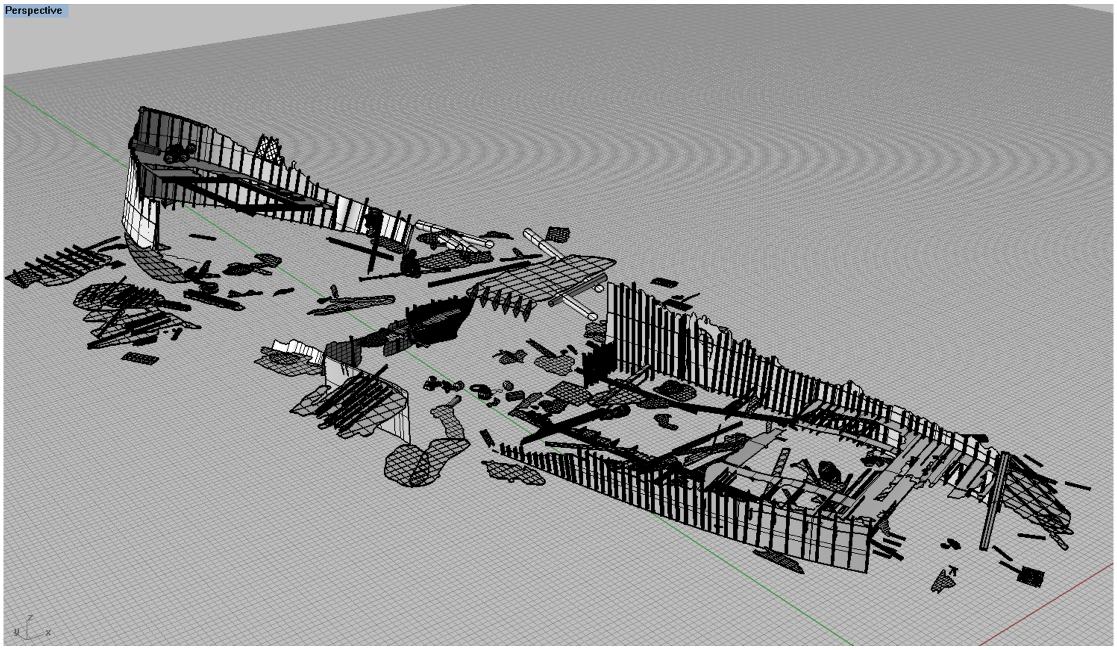


FIGURE 5.20. Example of shipwreck structure with debris field inside and surrounding the site (Image by Kara Fox).

While it was apparent that site formation processes had altered the shipwreck site significantly, components such as the triple expansion engine and two scotch boilers were surprisingly intact with slight corrosion deterioration. Once the shipwreck structure and interior and exterior debris fields were completed, the engine and boilers from the historical model were added to the current shipwreck model.

Non-structural components and debris elements were constructed and interpreted for dispersal patterning and provenience. Identifying and modeling debris items located in the midships area, specifically around the engine room, proved to be especially helpful in terms of understanding shipwreck deterioration and the disarticulation of the shipwreck site. Elements that appeared to be engine auxiliary pieces were identified on the port side of the triple expansion engine (Figure 5.21). Along with the engine components, cargo gear was identified amongst the debris (Figure 5.22). This area of the shipwreck was found to have a high concentration of artifact debris specifically related to the cargo deck. Similarly, a collection of various machinery components were located and identified throughout the shipwreck site including a large anchor windlass (see Figure 5.23) and several capstans of varying size (Figure 5.24).

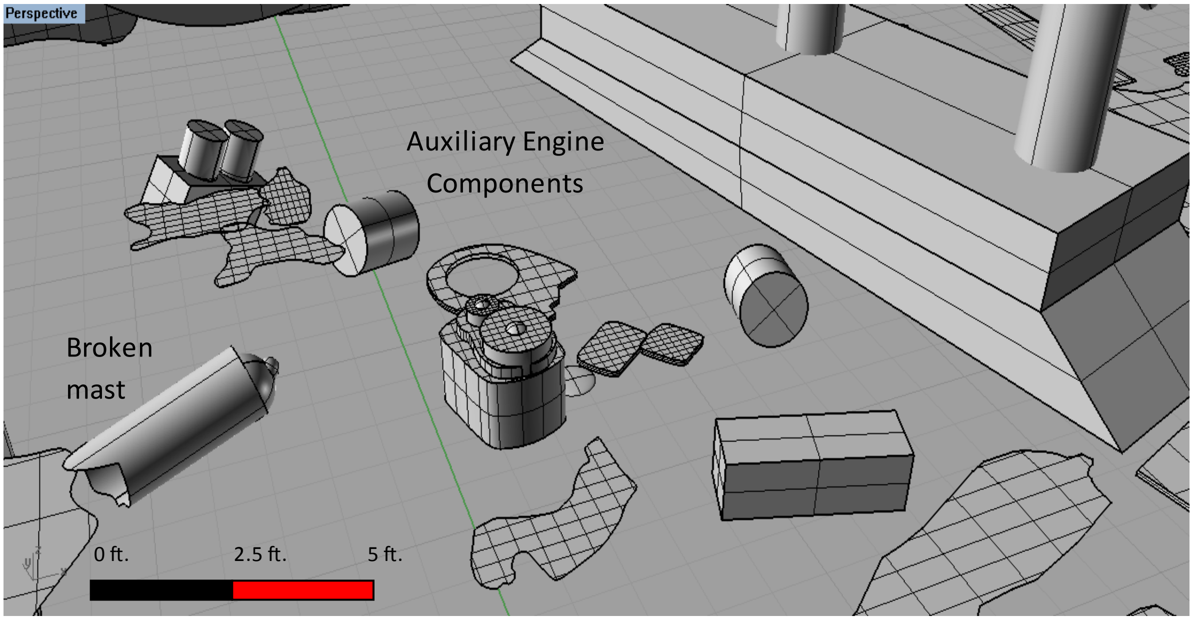


FIGURE 5.21. Engine auxiliary pieces identified and created on the port side of the engine (Image by Kara Fox).

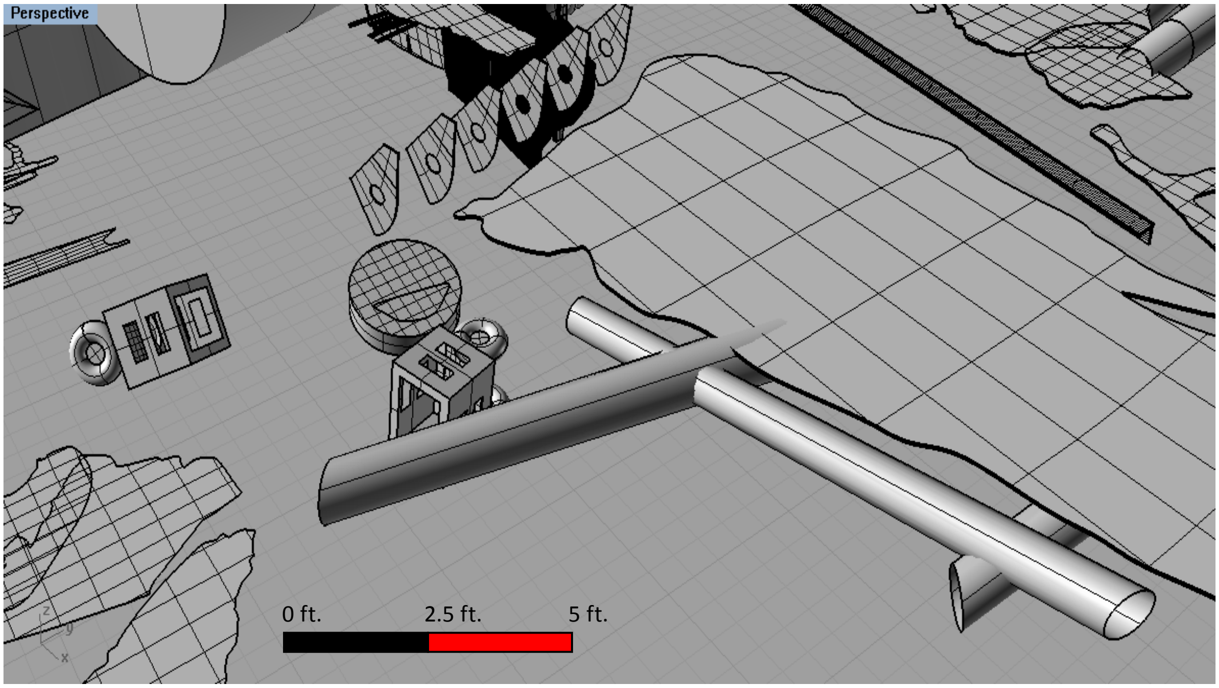


FIGURE 5.22. Cargo gear that was identified and created amongst the debris field on the starboard side (Image by Kara Fox).

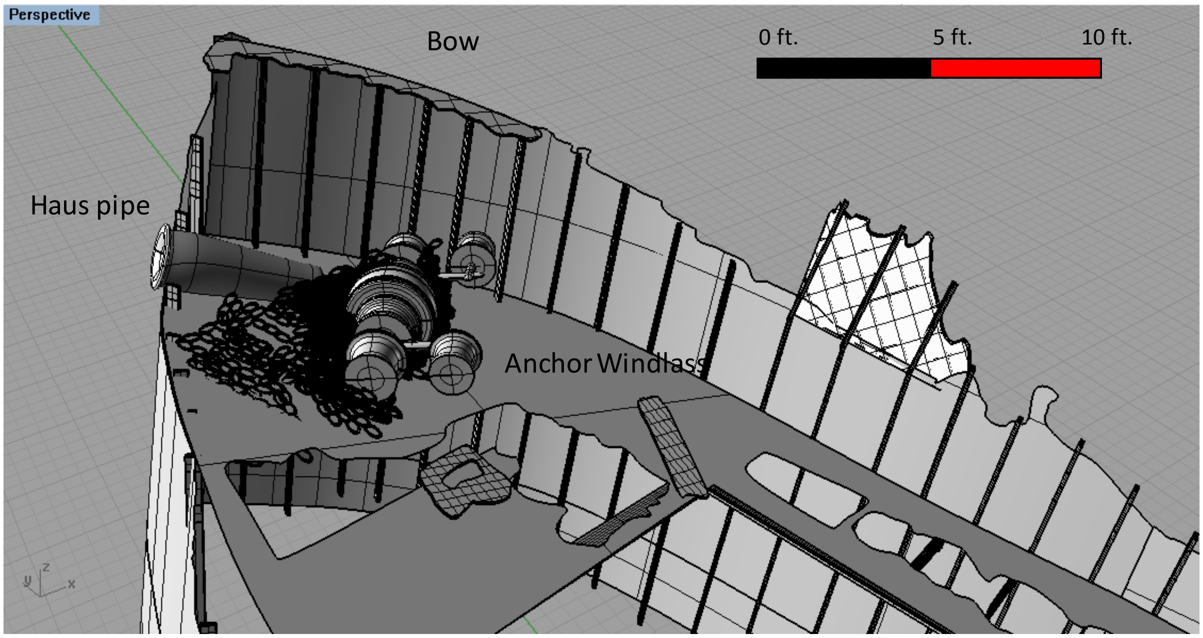


FIGURE 5.23. Large anchor windlass found on the bow section (Image by Kara Fox).

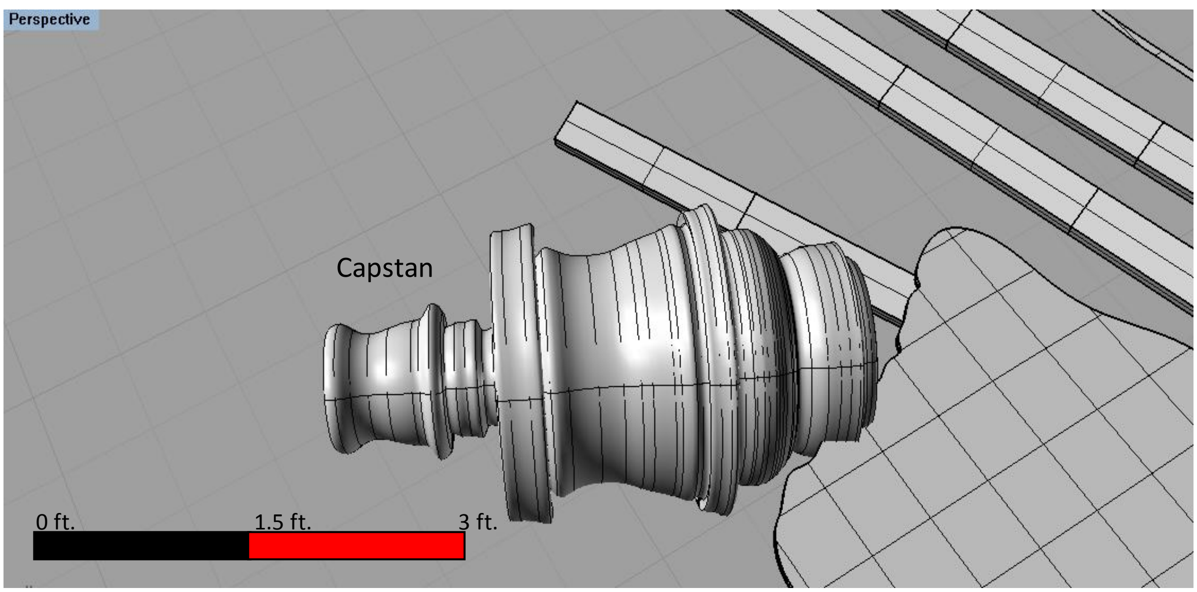


FIGURE 5.24. Example of a type of capstan found throughout the shipwreck site of *Caribsea* (Image by Kara Fox).

Upon completion of the shipwreck model, surfaces were added to authenticate the model and create the accurate shipwreck setting (Figure 5.25). Like the historical model, the shipwreck model was placed in an ocean environment with a water column and sand scour. This feature gave the model perspective, and illustrated the positioning of the shipwreck relative to the ocean bottom. Overall, the Historical *Caribsea* Model included over 30 individual shipwreck components and approximately 750 polysurfaces. Additionally, a scuba diver was added to the model for scale purposes. The scuba diver is 6 feet long.

FIGURE 5.25. Example of 3D Current *Caribsea* Shipwreck Model (Image by Kara Fox).

Conclusion

The purpose of this chapter was to illustrate the capabilities of 3D modeling platforms utilizing the acquired historical and archaeological datasets. Additionally, the manipulation, observation, and interpretation of the 3D models facilitates intimate site knowledge—further informing the historical record, and enriching the understanding of the shipwreck as it sits on the seabed. The ultimate objective of this study requires these datasets to be transformed into a series of regressive site formation modes, adequately demonstrating the effects of shipwreck transformation through 3D capabilities.

The next chapter demonstrates the potential for 3D modeling techniques beyond a methodology that is purely illustrative. By outlining the 3D development and interpretation of the historical and archaeological data as related to *Caribsea*, the processes attributing to the deterioration of the shipwreck site are better understood.

CHAPTER SIX: ANALYSIS—BRIDGING THE PAST TO THE FUTURE

The goal of this study was to explore the potential application of 3D modeling capabilities related to the documentation and interpretation of shipwreck transformation. This was accomplished by acquiring a collection of historical and archaeological materials, which were assimilated, organized, and integrated into a 3D modeling platform (*Rhino* 4.0). The unison of the historical and archaeological resources resulted in a series of 3D computer models of *Caribsea* before, during, and after the wrecking event.

The modeling efforts presented in Chapter Five unveils the historical and archaeological modeling process of *Caribsea*. The utilization of historical documents, archaeological materials, and an understanding of the types of site formation processes which impacted (and continue to impact) *Caribsea* in its systemic and archaeological contexts are all determining factors in the creation of these models, and the development of a predictive model. Because of limited time, funding, and personnel--this study is not a "complete picture" of site formation. The aforementioned limitations prevented the measuring and assessment of the many quantifiable variables including corrosion, sedimentation, and biological growth. Nevertheless, it is possible to make reasonable inferences about site transformation because of site formation theories and models (see Chapter Two). Additionally, this study offers an in-depth analysis of structural collapse and site disarticulation through 3D modeling visualization capabilities.

The purpose of this chapter was to analyze and interpret the 3D models beyond an illustrative capacity—using knowledge of the shipwreck site and the understanding of site formation theory to create a sequential series of illustrative models which displays the degradation and structural collapse of a shipwreck site. To review, the process can be broken down into six steps: 1) acquisition of historical documentation; 2) development of historical 3D model; 3) acquisition of archaeological documentation; 4) development of archaeological 3D model; 4) interpretation of historical and archaeological 3D models; 5) analysis of site formation processes and development of explanatory site formation 3D models; 6) development of predictive site formation 3D model.

The following sections discuss site formation theory as it relates to the 3D models of *Caribsea*. These sections include the analysis of systemic versus archaeological contexts and the discussion of pre and post-depositional processes affecting the shipwreck site, additionally, discussing the predictive capabilities of the 3D modeling process. This chapter will conclude by examining the original thesis questions in light of the actual 3D modeling *Caribsea* results.

Historical *Caribsea* Model

As mentioned in Chapter Two, site formation theory begins with the ship itself. The factors leading to the origination and construction of the ship are highly influential in the lifespan of the vessel—both in a systemic context and later in an archaeological context. The transformation of an archaeological site involves an array of pre-depositional and post-depositional processes—influencing the creation and the alteration of the shipwreck site.

In regards to this study, the Historical *Caribsea* Model was developed with the intention of having a baseline understanding of the archaeological assemblage that would be assessed. Once *Caribsea* became embedded within the archaeological record, these pre-depositional processes continue to have an impact on the ship's transformation, and were evaluated alongside the post-depositional processes interacting with the archaeological record.

Pre-Depositional Factors

The following pre-depositional site transformation processes are examples of Michael Schiffer's C-transforms discussed in Chapter Two. Schiffer noted that these C-transforms are processes influencing any type of material or structure located on a site prior to its deposition. These processes can include human effects, circumstances, or behaviors that influence or modify a material before its transition into the archaeological record (Schiffer 1987:28-35). Similarly, Muckelroy's pre-depositional site formation definition can be regarded as the pre-wreck nature of a shipwreck site. These defining characteristics were identified through archival research, and were further acknowledged throughout the historical lifespan of *Caribsea* in Chapter Three.

The pre-depositional nature of *Caribsea* was found to be war-built, *Laker*-type, and merchant-oriented. To clarify, this meant the medium-sized freighter was originally designed and built by a Great Lakes shipbuilding company with a construction template and design intended for the Great Lakes region. The freighter was contracted under the duress of war—and built quickly and efficiently for transportation of moderately sized cargoes, including mail, mineral ores, and even passengers. By establishing the circumstances leading up to the shipwrecking event, it gives archaeologists the ability to decipher what was originally part of the systemic assemblage of the ship, versus what has been altered in the archaeological context of the shipwreck site. Muckelroy (1978), O'Shea (2002), and Gibbs (2006), focused on this type of analysis due to the potential for a more accurate understanding of the archaeological assemblage. The connection between *Caribsea's* historical 'pre-wreck' factors and the current condition of the assemblage observed in the archaeological record was considered and used to account for sequential collapse and disarticulation of the shipwreck site.

Caribsea was built quickly and efficiently by McDougall & Duluth Shipbuilding Company, out of Duluth Minnesota, originally for the war efforts during World War I (although *Caribsea* was not completed until a year after the war ended). By the time *Caribsea* was built and launched in November 1919, steel ship construction had become an established and reliable shipbuilding technique. Steel construction materials and upgraded engine machinery, coupled with advanced shipbuilding techniques such as the new Isherwood system of longitudinal style framing resulted in a more structurally stable and seaworthy vessel (Figure 6.1). The site-specific shipbuilding techniques and materials were considered later in the assessment of the shipwrecking event and the development of the 3D models.

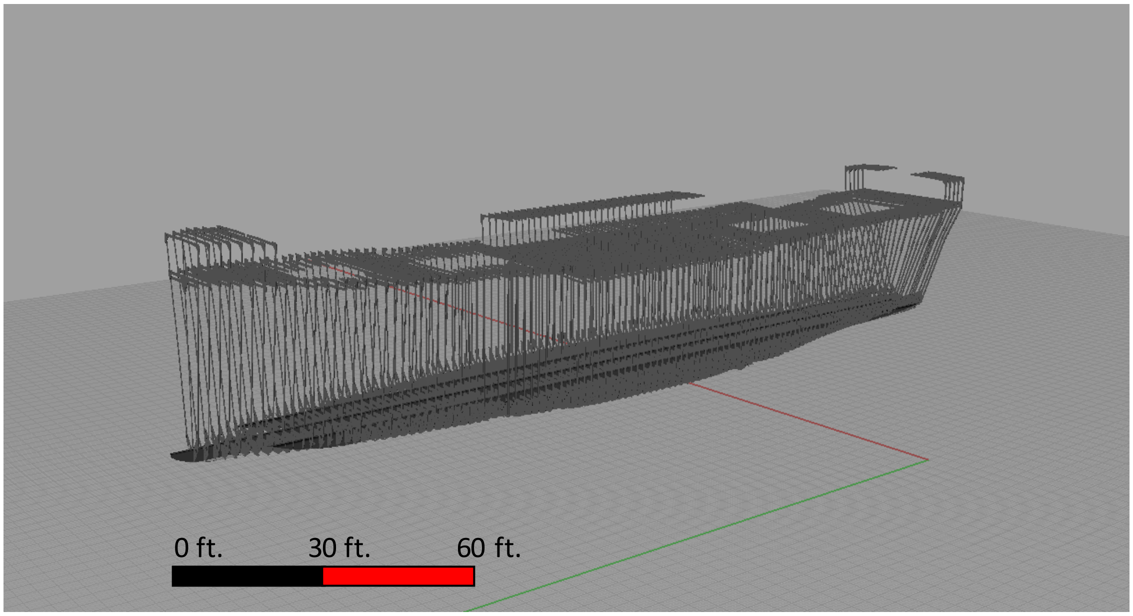


FIGURE 6.1. Image illustrating Isherwood system of framing of *Caribsea* (Image by Kara Fox).

Following *Caribsea's* war-instigated construction, the cargo ship was later used in the Battle of the Atlantic during World War II. This historical setting had an obvious implication on the final deposition of the shipwreck site. Starting in September 1939, and ending by May 1945, German U-boats actively sought to disrupt the Allies supply line by sinking as many American merchant ships as possible. Unfortunately ships like *Caribsea*, eventually became the primary target for German naval offensive operations. In March 1942, *Caribsea* left from Santiago, Cuba bound for Norfolk, Virginia. The unarmed ship (Figure 6.2), was traveling alone with a cargo of 3,600 tons of manganese ore in the most hunted waters of the North Atlantic—later known widely as Torpedo Alley.

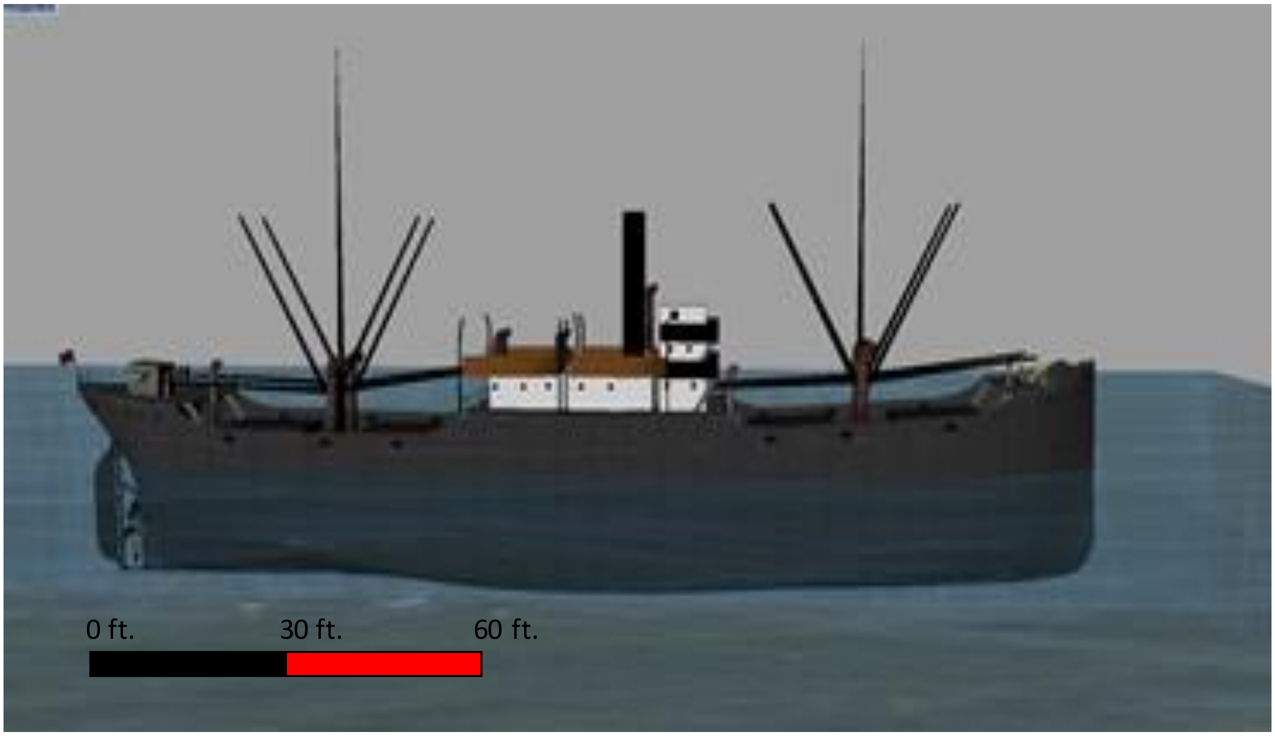


FIGURE 6.2. 3D historical model of *Caribsea* (Image by Kara Fox).

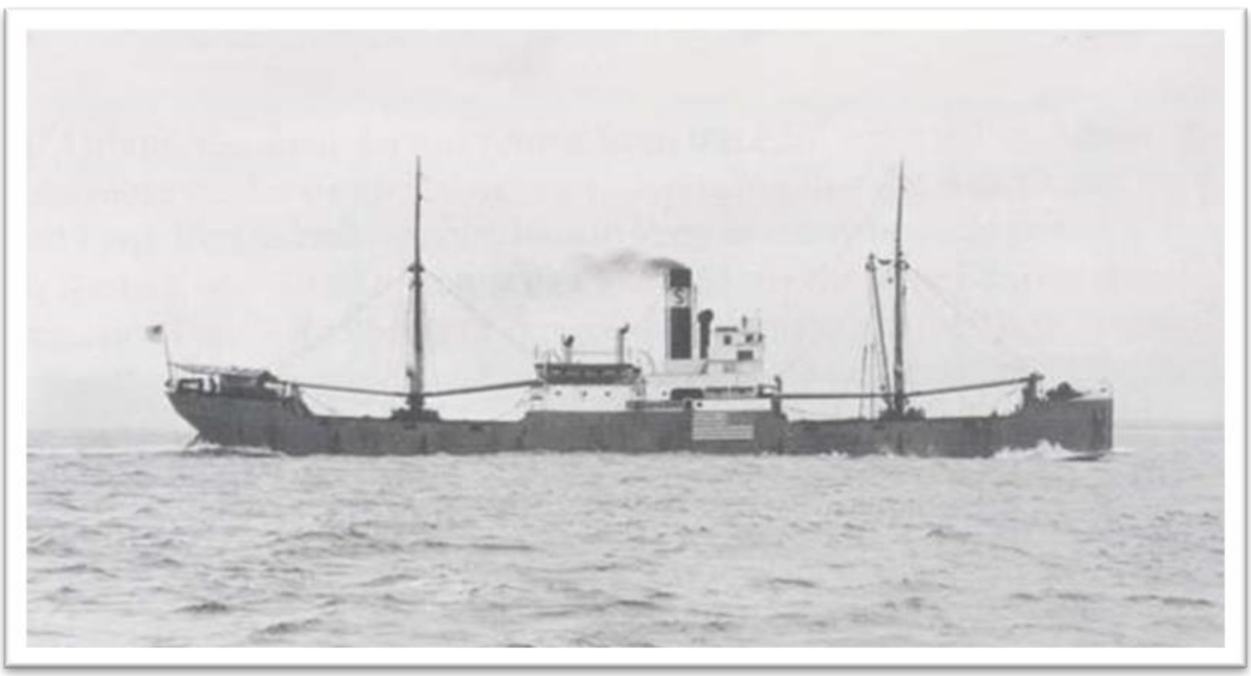


FIGURE 6.3. Historical photograph of unarmed merchant freighter, *Caribsea* (University of Wisconsin Digital Collections, Great Lakes Maritime History Project, October 2013).

Torpedoed *Caribsea* Model

The next model that was developed was the Torpedoed *Caribsea* Model. It was important to consider the processes, circumstances, and factors affecting a ship as it passes from a systemic context into a state of archaeological context. Various pre-depositional influences were identified as factors contributing to the torpedoing of *Caribsea* through the combined efforts of theoretical, historical, and archaeological assessment. The following variables were found to directly affect the systemic trajectory of *Caribsea* before it became an archaeological site.

Pre-Depositional Factors

According to Schiffer (1987), C-transforms tend to originate in pre-depositional site formation processes. While these cultural processes often refer to human effects or behaviors (as discussed in the previous Historical *Caribsea* Model section), factors representing human agency or decision making should also be taken into consideration. Similarly, Souza (1998) and Gibbs (2006) discussed the potential for shipwreck assemblages to often indicate the vessel's reaction or behavior prior to the shipwrecking event itself. Historical and archaeological associations representing circumstances taken by individuals (i.e. Captain Manolis) in order to minimize risk or exploit an advantage were considered during this assessment because they constitute the organization of the material record prior to the vessel's shipwrecking event.

Extremely shallow depths, due to the continental shelf, characterize the majority of the waters along the eastern seaboard. This geographical feature was a serious drawback to U-boat offenses during World War II. To avoid being trapped in these shallow waters, U-boats were advised to only attack at night, leaving time to retreat back to deeper waters upon sunrise (Blair 2000:439). The waters surrounding the Outer Banks of North Carolina, however, are characterized by a "bottlenecking" manifestation. In this area, the continental shelf is less than thirty miles wide-forcing ships (like the *Caribsea*) into a highly congested area, but also offering easy access to deep water (Figure 6.3). Based on the confines of this area, the geographical circumstances were found to be uniquely influential in the trajectory of U-*158*, and the ultimate demise of *Caribsea*.

FIGURE 6.4. Image illustrating the highly congested area off of the Outer Banks known as the "bottleneck" manifestation (Source: Google Earth).

Another factor that could have contributed to the torpedoing of *Caribsea* was the vessel's limited maneuverability in passing Cape Hatteras. As *Caribsea* approached Cape Lookout on 10 March 1942 in the darkness of night, Captain Manolis reduced the ship's speed to four knots in order to pass Cape Hatteras in accordance with the safety of daylight and the accompaniment of aircraft patrol (Manolis 1949:87). While this tactic afforded safety regarding the trek around Cape Hatteras, the slow speed generated a new set of problems—limiting the ships ability to maneuver. This provided an easy target for lurking U-boats, such as U-*158*.

The German war diary dictates that on the night of 10 March, 1942, U-*158* had the opportunity to follow two ships. Upon spotting an unknown tanker at approximately 2352 EST, U-*158* pursued the ship, fired one torpedo, and missed its target. As U-*158* maneuvered into position for second shot at the unknown tanker, it spotted another shadow on the horizon. For reasons that were not specified, the newly sighted ship seemed like a more viable target, and upon maneuvering into position, one torpedo was fired, hitting and sinking the ship in a matter of minutes. The luckless fate of this ship would later be identified as *Caribsea*. It could be deduced that the slow speed of the ship, coupled with the U-boat's indicated assumption that the ship was a "coastal watch ship," sealed the fate for *Caribsea* (NARA 1942).

It is possible mere minutes might have spared *Caribsea* from the fate of sinking that early morning. Upon investigating the historical record for additional documentation on the torpedoing of the ship, there is one major historical discrepancy. Several published accounts (Ballance 1989:1963; Gentile 1992:40; Blair 2010:612; Duffus 2012:152) cite two torpedoes hitting *Caribsea*. Furthermore, crewmembers were published speculating the impact and detonation of two torpedoes, as Captain Manolis later recalled how he "hardly had time to turn around before the second torpedo struck (Manolis 1949:107)." But, the German war diary dismisses these claims by clearly recording the firing of one torpedo from Tube II at 0758 GLT. Upon a 48 second run time, this one recorded torpedo hit *Caribsea* with a loud detonation, sinking the ship with a single torpedo (NARA 1942). The claim of a second explosion that is so commonly found in the historical record could have been a consequent detonation from one of the two Scotch boilers, or from one of the several auxiliary boilers found on *Caribsea*.

An additional theory for the second explosion brings into question the combustibility of the 3,600 tons of manganese ore that *Caribsea* was carrying upon its torpedoing. While the validity of this claim is largely unresolved, some irregular patterning was noted in the assemblage of the ore located throughout the shipwreck site. During the survey and 3D modeling process for the Current *Caribsea* Model (to be discussed), the dispersal of the manganese ore in the bow area differed from the dispersion of the ore in the stern area of the shipwreck site (Figure 6.4 and Figure 6.5). However, at that stage in the shipwrecking event this observation could be attributed to both cultural and non-cultural transformation processes. Examples of C-transforms include military and diver salvage, while examples of N-transforms include environmental processes such as physical, chemical, and biological decay (Schiffer 1987:21).

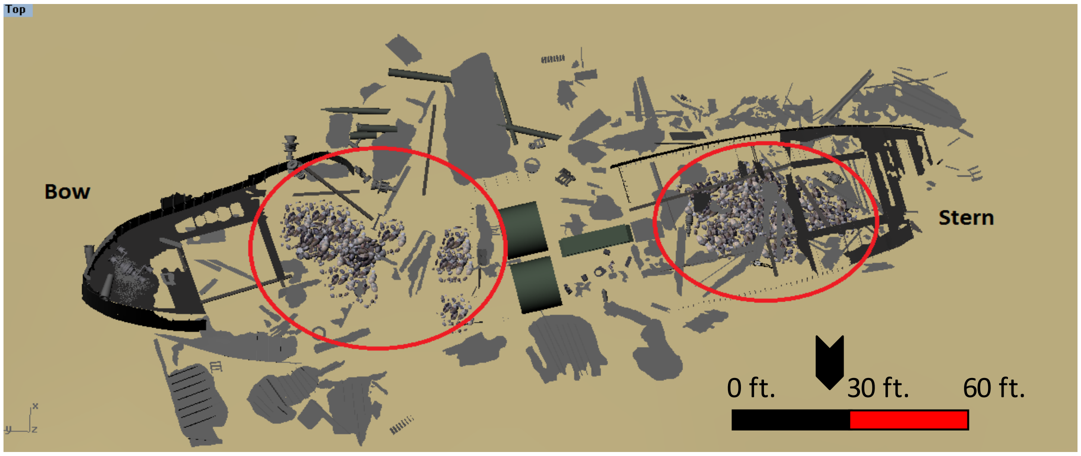


FIGURE 6.5. 3D shipwreck model of *Caribsea* illustrating manganese cargo dispersal within red circles (Image by Kara Fox).

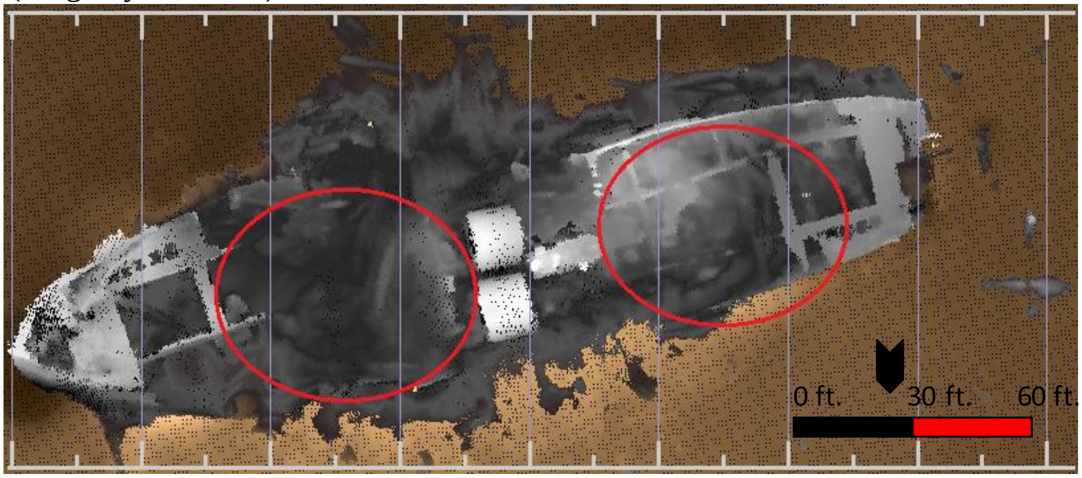


FIGURE 6.6 .Multibeam image of *Caribsea* illustrating the location of the manganese dispersal within red circles (Source: NOAA).

While the exact location of the torpedo impact is inconclusive, the historical record indicates that the torpedo plowed into *Caribsea's* second cargo hold on the starboard side. This theory was contingent upon the memoirs of Captain Manolis, who later recalled his second mate Hugh Spencer noticing a ship-like shadow on the starboard side of the bridge, before the glass of the wheel house shattered in their faces, and the ship succumbed to a torpedo impact (Manolis 1949:87). The *Caribsea* was loaded with a full cargo of manganese ore; this would have fully loaded the cargo deck's carrying capacity, resulting in a large portion of the vessel's hull being submerged (Figure 6.6 and 6.7). This factor, as opposed to a ship with lighter displacement, likely provided a greater target for U-boats.

Upon the assessment of the Current *Caribsea* Shipwreck Model (to be discussed), it became apparent that the hull structure in the starboard bow portion of the shipwreck site was indicative of the torpedo impact that was referenced within the historical record. The first indication of a torpedo impact was noted during the 3D modeling process in a small section of lower hull framing and hull plating on the starboard side of the bow (Figure 6.8 and 6.9).

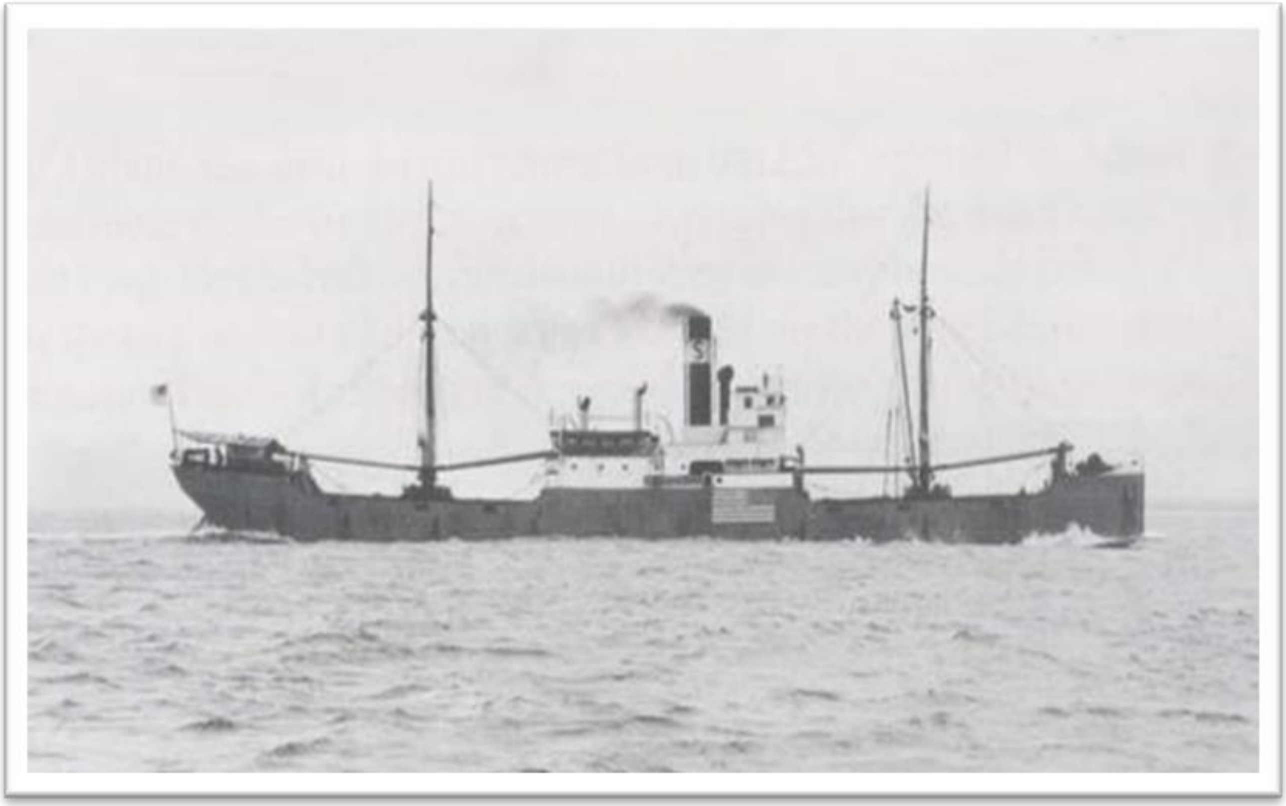


FIGURE 6.7. Photograph of *Caribsea* prior to World War II (University of Wisconsin Digital Collections, Great Lakes Maritime History Project, October 2013).

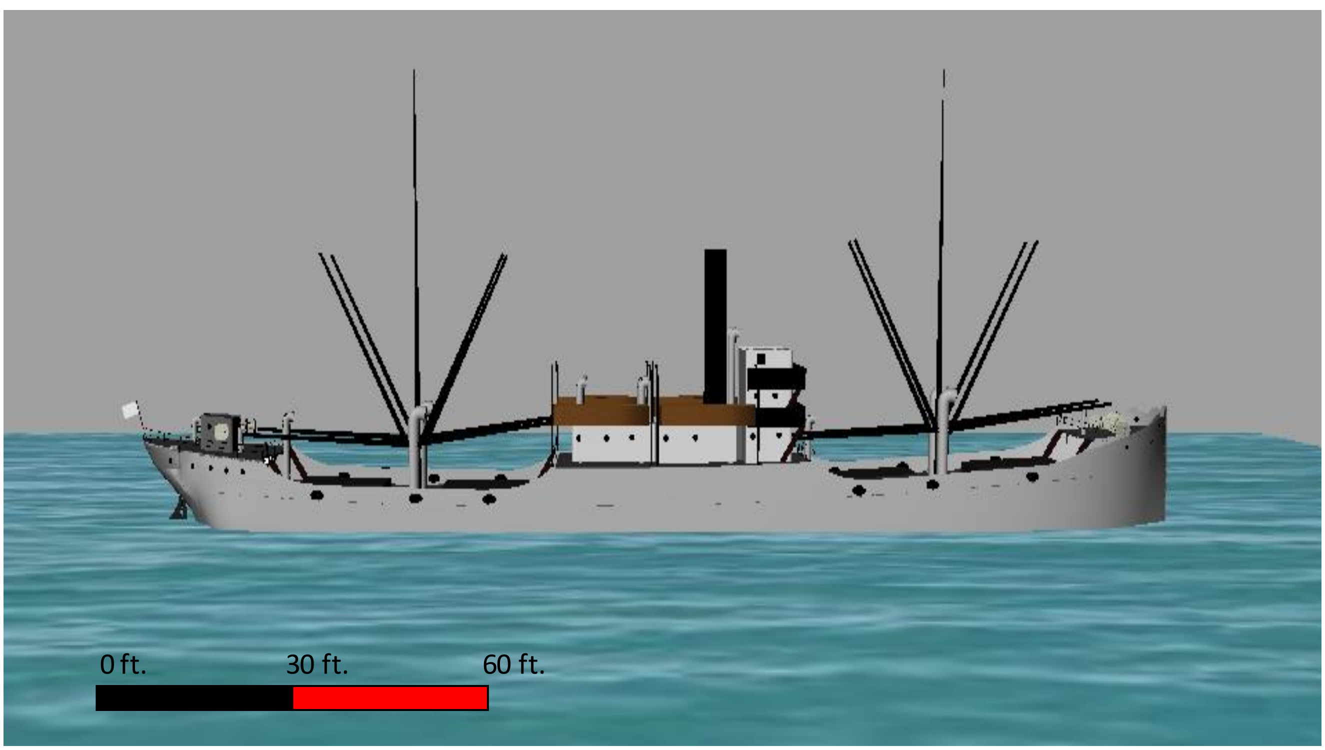


FIGURE 6.8. 3D historical model of *Caribsea* prior to its sinking (Image by Kara Fox).

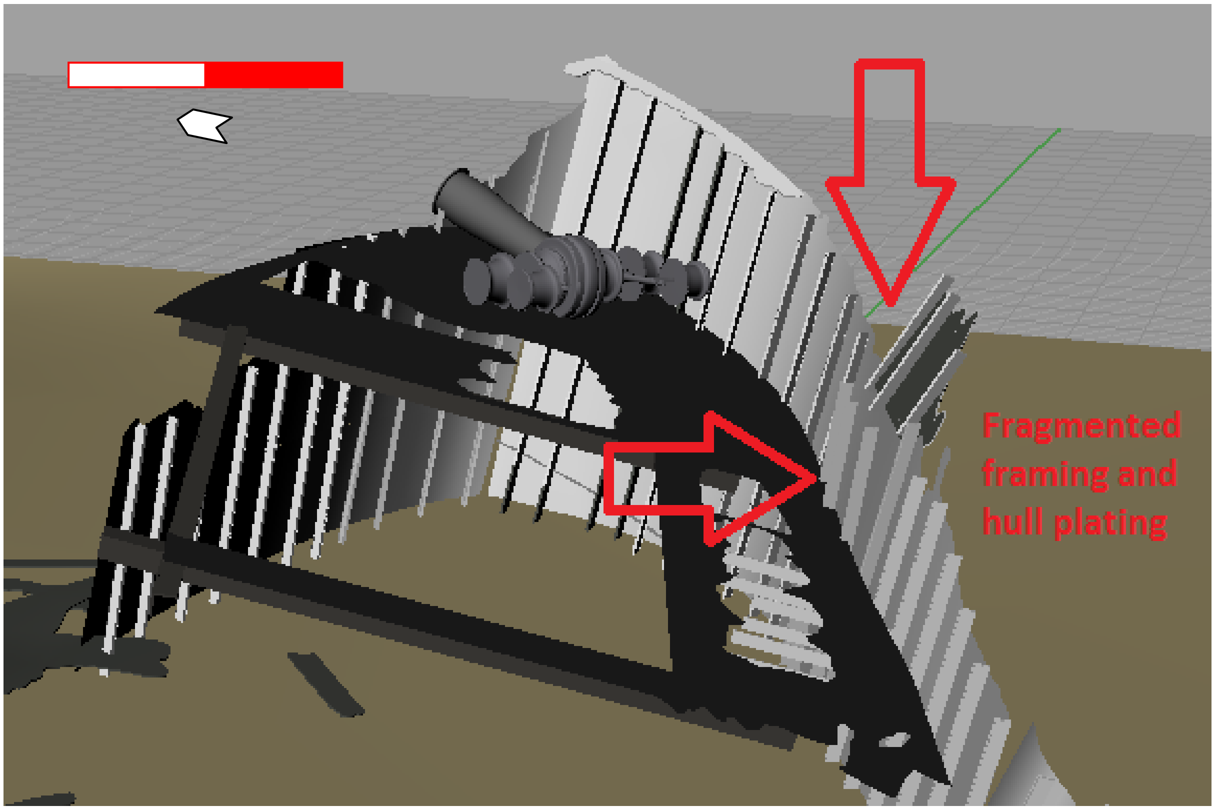


FIGURE 6.9. Image of Current *Caribsea* Shipwreck Model illustrating the fragmentation of starboard hull framing and plating (Image by Kara Fox).

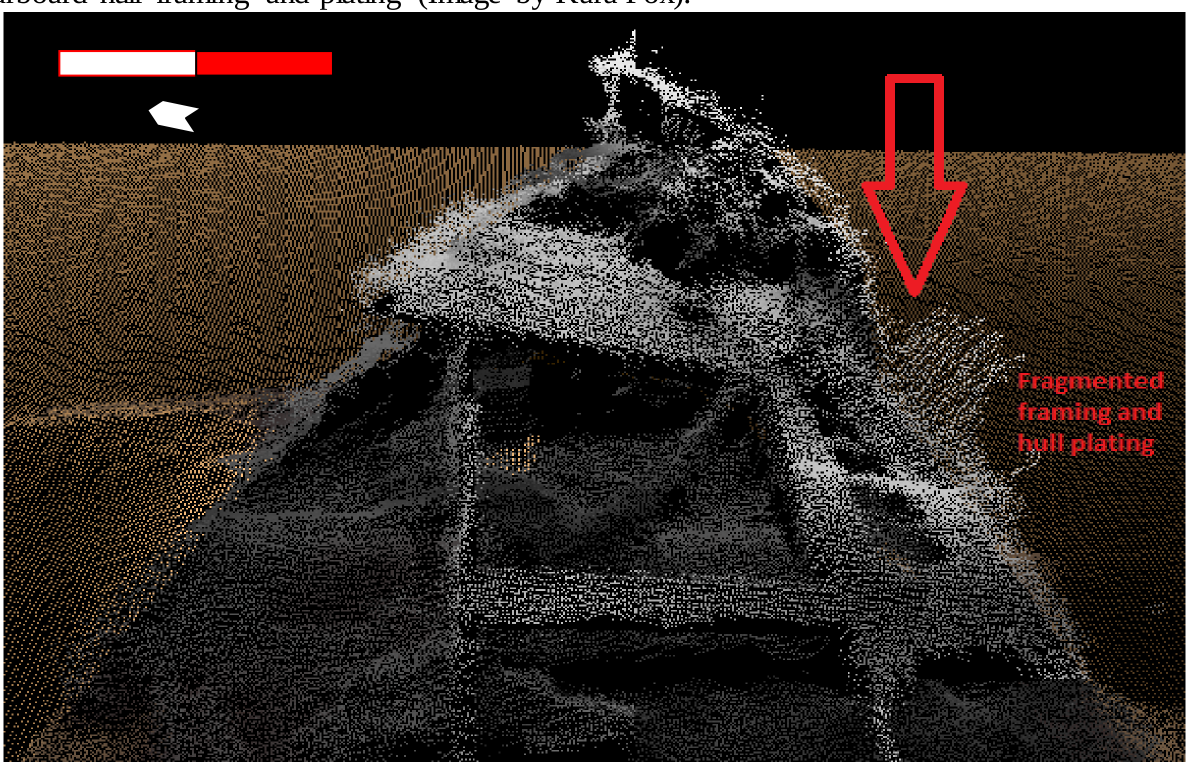


FIGURE 6.10. Multibeam of *Caribsea* illustrating the fragmentation of starboard hull framing and plating (NOAA).

The hull plating and framing in this section had a distinctive fragmentation that was indicative of a detonation comparable to a torpedo impact, versus a more inert post-depositional process such as corrosion or hydrodynamic activity. The second indication was the noticeable tilt of the bow portion of the shipwreck site (Figure 6.10 and 6.11). Assuming *Caribsea* was hit on the starboard side of the bow, the area of impact (in this case the starboard bow cargo hold) would have filled the quickest with water, resulting in the vessel sinking bow first, and plunging into the sandy ocean bottom below.

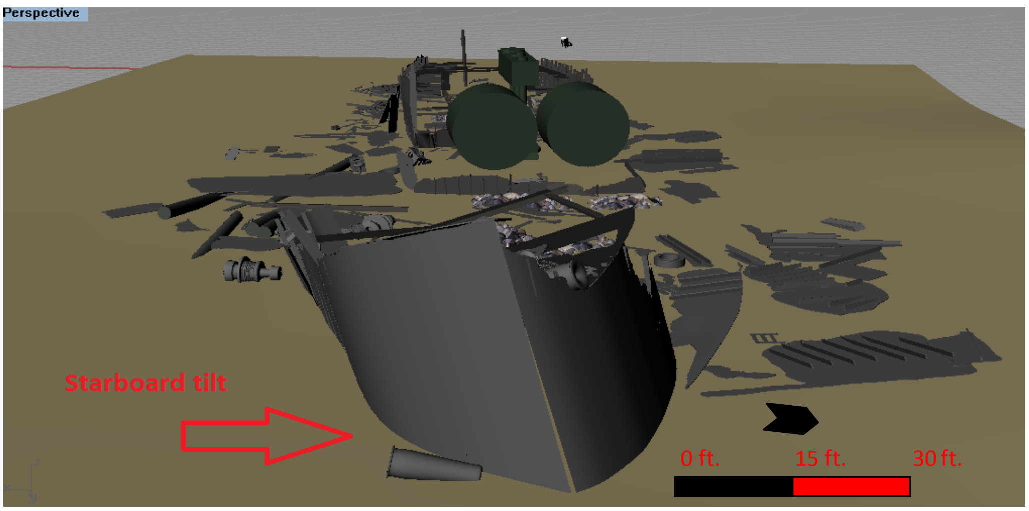


FIGURE 6.11. 3D model of *Caribsea* illustrating the apparent tilt of the hull (Image by Kara Fox).

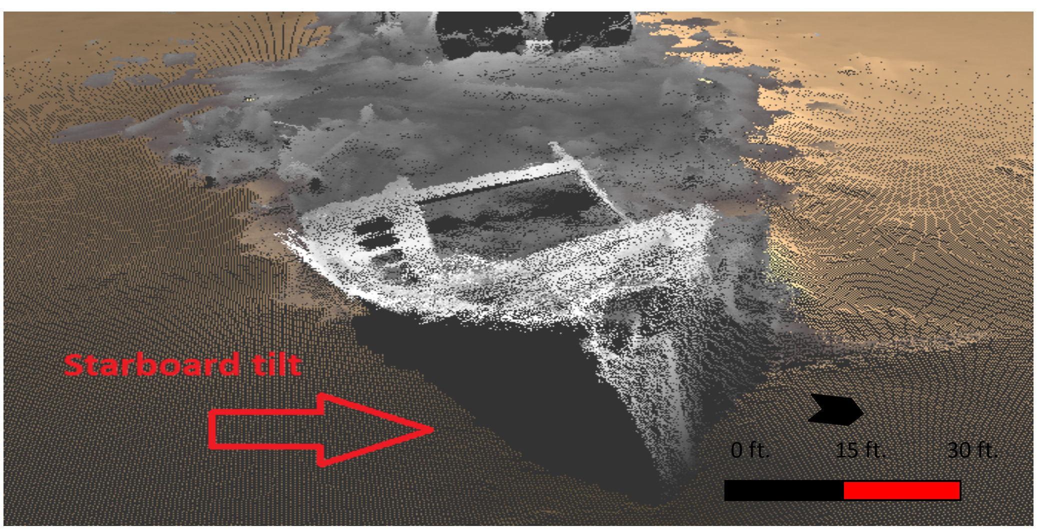


FIGURE 6.12. Multibeam image illustrating the apparent tilt of *Caribsea's* hull structure (NOAA).

The progression of delineating the pre-depositional processes from the post-depositional processes was influential in developing a series of sequential shipwrecking models for *Caribsea*. According to the historical and archaeological datasets available, the 3D modeling indicated *Caribsea* succumbed to a torpedo impact in the starboard bow cargo hold (Figure 6.12). This event would have resulted in the vessel listing quickly to its starboard side, sinking bow first (Figure 6.13). After approximately two minutes, *Caribsea* was recorded as being completely submerged and sitting upright on the sea bottom in approximately 90' of water. According to the historical dimensions of the ship, and the depth of the water column, the masts and cargo gear of *Caribsea* were most likely intact and sticking up out of the water. This issue would have immediately posed a navigational hazard to ongoing shipping traffic (Figure 6.14).

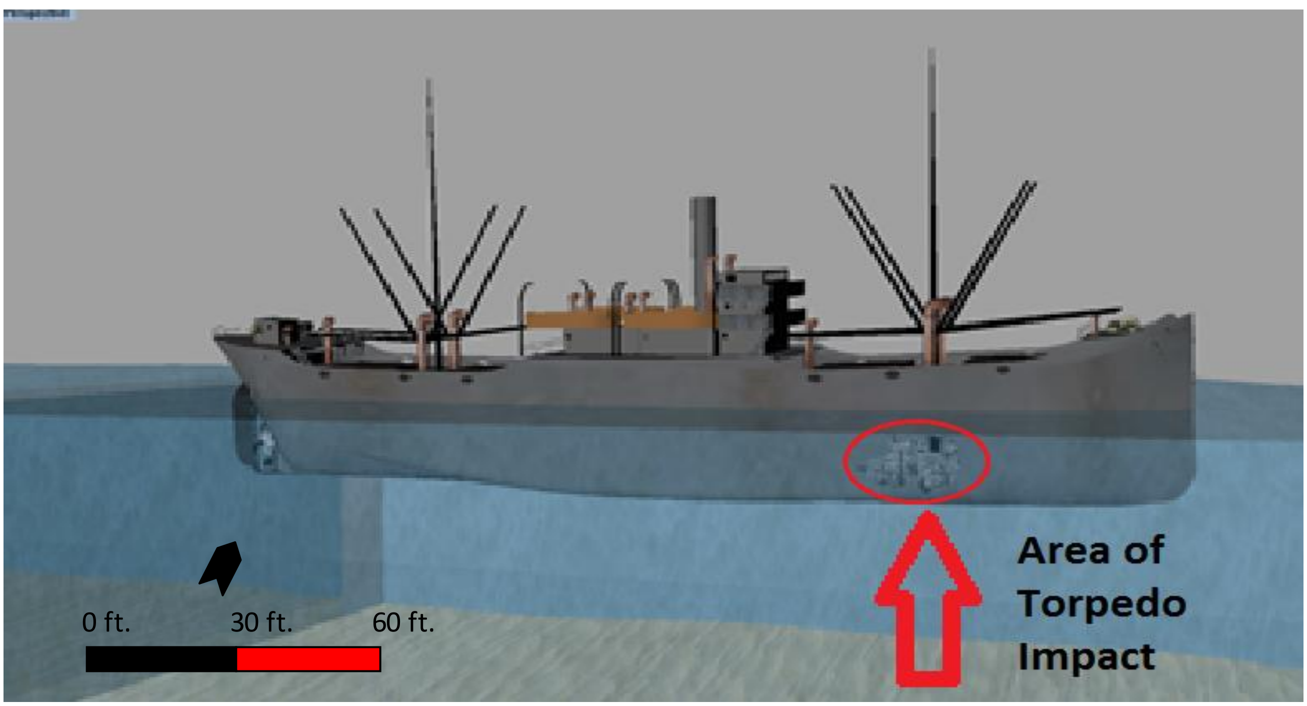


FIGURE 6.13. Image of Torpedoed *Caribsea* Model illustrating the potential location of the torpedo impact (Image by Kara Fox).

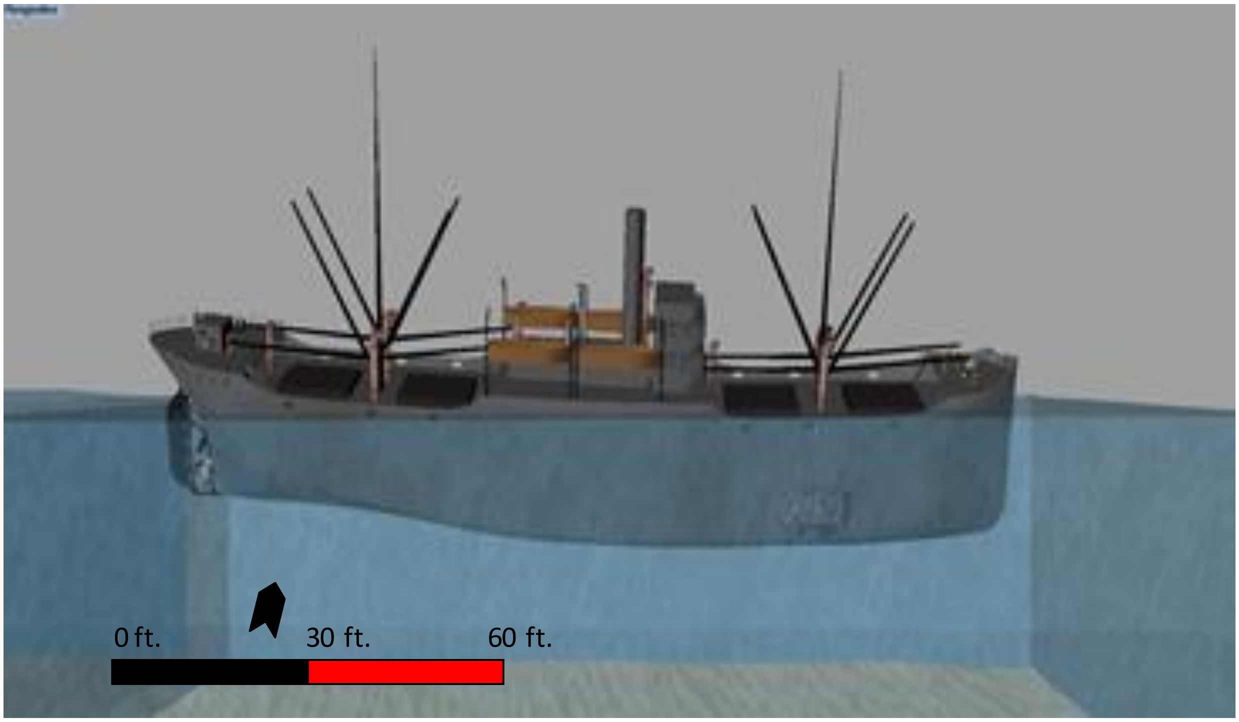


FIGURE 6.14. Hypothesized image of Sinking *Caribsea* Model illustrating the severe listing of the ship as it sank (Image by Kara Fox).

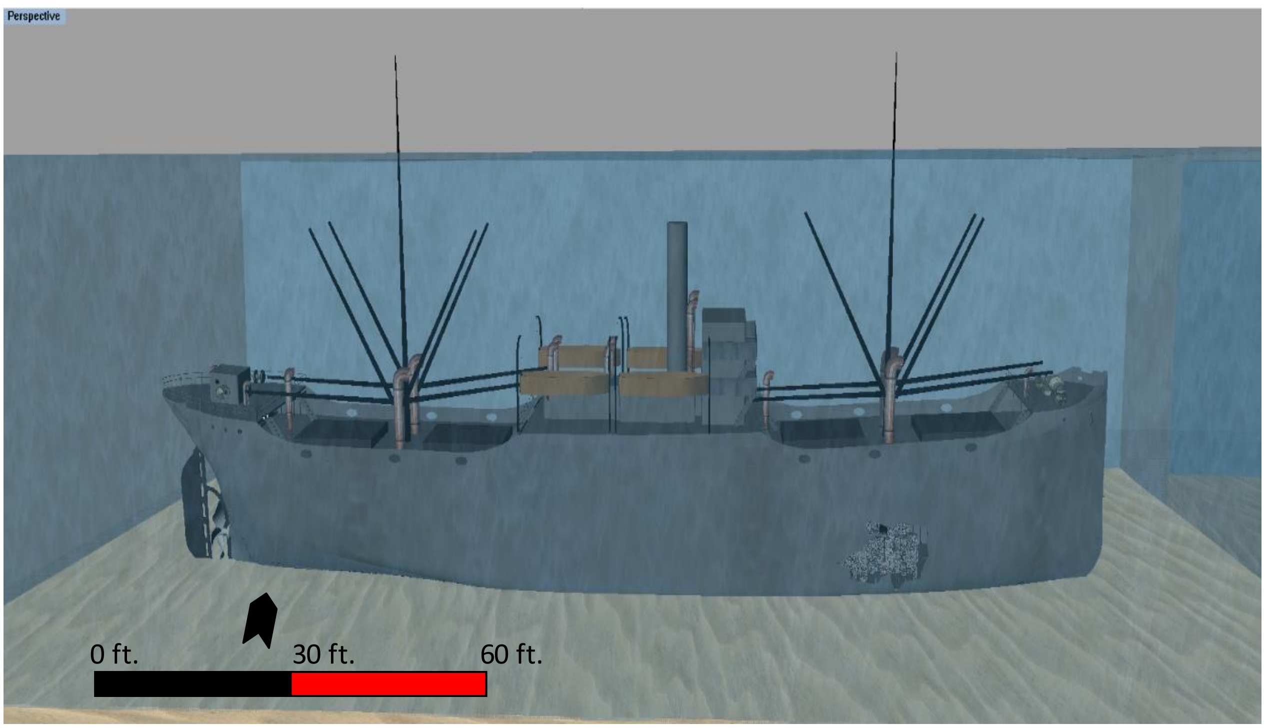


FIGURE 6.15. Hypothesized image of Submerged *Caribsea* Model illustrating the positioning and condition of *Caribsea* upon sinking (Image by Kara Fox).

Caribsea's structural damage is consistent with the historical accounts of the U-boat attack. A study focusing on the deepwater debris scatter of seven shipwrecks lost during the mid-twentieth century articulated the relationship between the shipwrecking event, water depth, ship size, and the extent of the debris scatter (Church et al. 2007:221). Because of the relatively forceful nature of *Caribsea's* shipwrecking event, it is likely that as the damaged hull plunged to the ocean floor resulting in some scattered debris and effected hull structure spilling out simultaneously. However, the shallow depth of the shipwrecking location (90 ft.) coupled with the progression of the shipwrecking event (model discussed above illustrating an upright position and contiguity) and the current disarticulated condition of the shipwreck (model discussed later)—prevented the debris scatter extent to be fully theorized and assessed.

Post-Salvage *Caribsea* Model

Once *Caribsea* was deposited onto the ocean bottom, it passed from a use or systemic context into an archaeological context. As previously stated in Chapter Two, upon the deposition onto the ocean bottom, *Caribsea* would have immediately started to undergo transformation due to environmental (chemical, physical, and biological) or cultural processes (such as commercial salvage, military salvage, and impacts from recreational diving). It was imperative for this study to continue to differentiate the pre-depositional processes from the post-depositional processes. This distinction provides context for each identified process—greatly increasing the understanding of the archaeological site. Post-depositional processes are considered mechanisms that facilitate the change or movement of a shipwreck once in its archaeological context. Over a period of time, pre-depositional and post-depositional process will interact with one another to transform a shipwreck site. The following pre and post-depositional processes were observed, identified, and assessed on *Caribsea*.

Pre-Depositional Processes

When assessing a shipwreck site, it is important to remember the pre-depositional factors that were influential in the systemic context, and how they continue to interact with post-depositional factors in the archaeological context. While this task is limited due to the ever-present and evolving constraints taking place on a shipwreck site---many of these variables can be and should be identified and accounted for. Ultimately, this identification amplifies the evidence regarding the historical and archaeological record.

The pre-depositional factors that were identified in the Post-Salvage *Caribsea* Model were the aforementioned 'pre-wreck' aspects of the shipwreck including the type and class of the ship and the techniques and materials used in the construction of the vessel. Pre-wreck cultural factors such as the nature of a ship's design and construction directly influences subsequent post-depositional factors such as the manifestation and the extent of military salvage activities. Additionally, the location of the shipwrecking event—involving the proximity to Cape Hatteras was considered significant during the 3D modeling of the Post-Salvage *Caribsea* Model.

Post-Depositional Processes

Following the sinking of *Caribsea*, the historical record provides very little information on the condition of the shipwreck site. Thus, the majority of the post-depositional analysis was dependent on 3D model interpretation, inferences based on comprehensive understanding of pre-depositional factors influencing the deterioration of *Caribsea*, and the evaluation of the Submerged *Caribsea* Model (Figure 6.15) as compared to the Current *Caribsea* Model (Figure 6.16). In this comparison, it was noted that while the current shipwreck site is contiguous and largely intact, at some point in time it was subject to severe processes and activities.

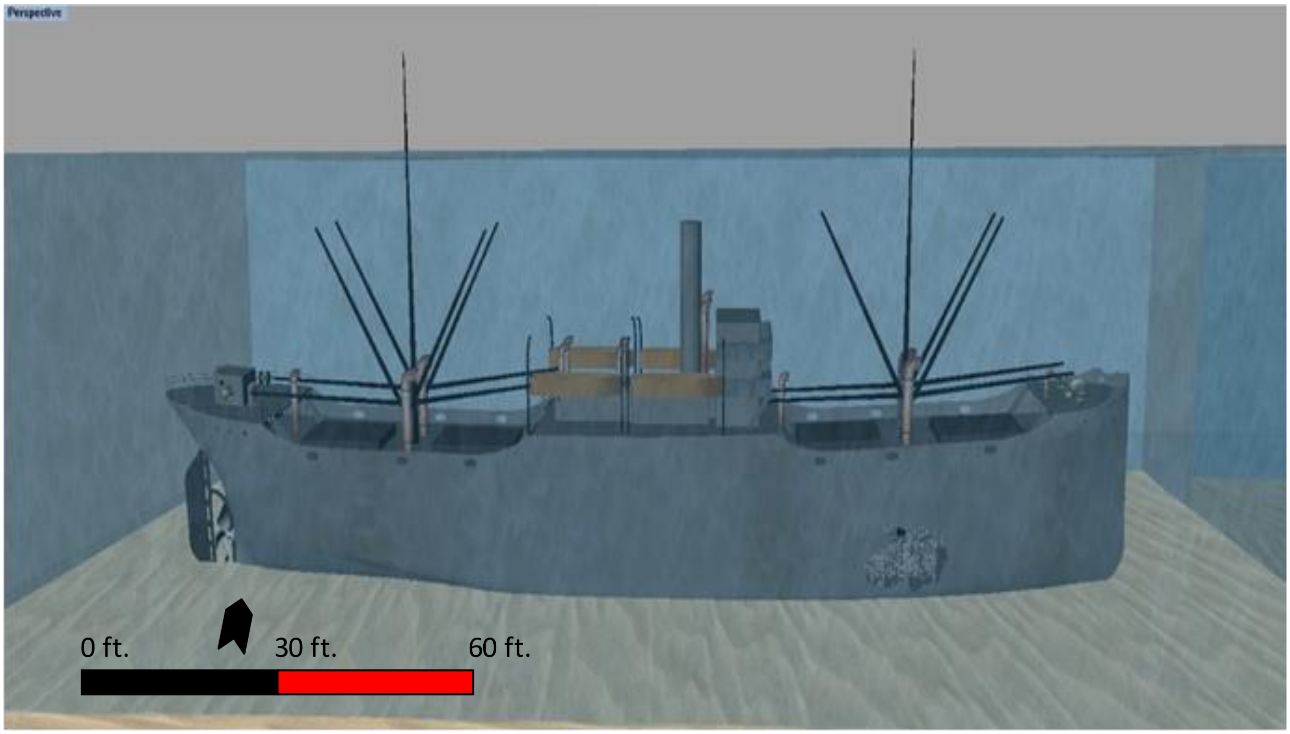


FIGURE 6.16. Image of Submerged *Caribsea* Model illustrating the condition of the shipwreck site prior to extreme site transformation (Image by Kara Fox).

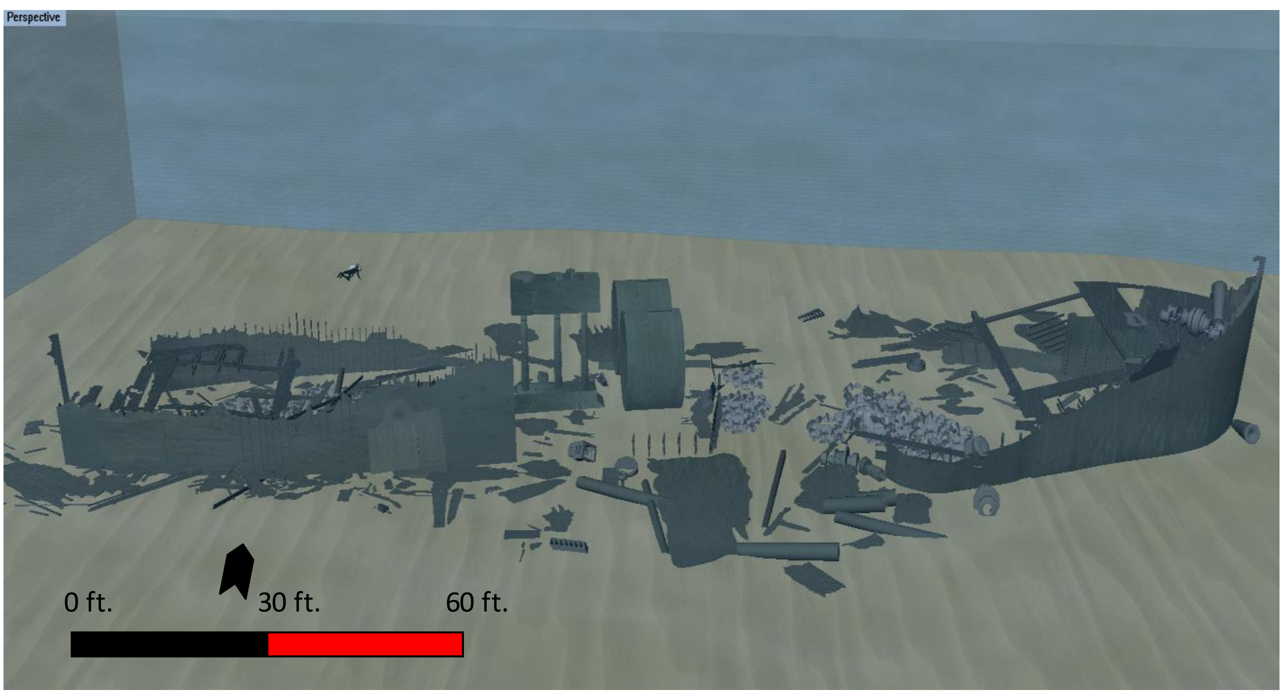


FIGURE 6.17. Image of Current *Caribsea* Model illustrating the current condition of the shipwreck site following site transformations (Image by Kara Fox).

The discrepancy between Figure 6.15 and Figure 6.16 indicates a series of extreme site transformations taking place on the shipwreck site in the years following its deposition. As discussed in Chapter Two, forces of storms and hurricanes can often have a dramatic impact on a shipwreck site. Hurricane activity has been known to alter, move, or damage a shipwreck site including structural collapse, lateral displacement, rolling, and vertical displacement (Gearhart et al. 2011). Although the observed impact of hurricane activity on *Caribsea* was unavailable, the historical weather records show at least one unnamed hurricane system passing within a 15 mile radius of *Caribsea* in June of 1945 (NOAA 2015). *Caribsea's* close proximity to this particular hurricane system, coupled with the shallow water depth (90 ft.) supports the probability of site transformation and disarticulation. However this hypothesis could not be substantiated within the archaeological record.

Upon further research, it was found that following World War II, shipwrecks with close proximity to shore were often found to be hazards for navigation—especially when sunk within a shipping lane. Many shipwrecks in this area were then systematically depth charged and wire dragged by the Navy Salvage Service to an excess of 40 ft. of clearance (Gentile 1992:40-41). While no historical document was found to corroborate this broad claim (as related to *Caribsea)*, the broken and disarticulated condition of *Caribsea* (as illustrated in Figure 6.16) indicates the use of explosives.

Several observations supporting the probability of explosives were noted during the 3D modeling process. The first observation was the absent superstructure of *Caribsea*. While sections of lower hull plating and framing from the main deck are present, existing in some areas upwards of 10 ft. (Figure 6.17 and Figure 6.18), the majority of the upper structure is missing.

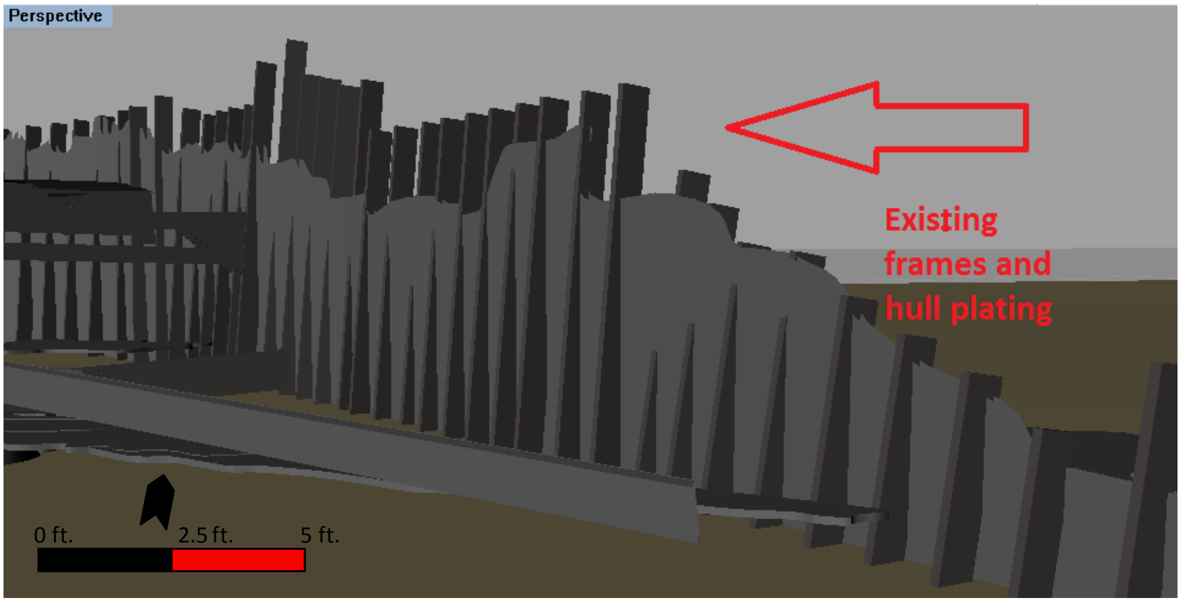


FIGURE 6.18. Image illustrating existing frames and hull plating on starboard side of shipwreck (Image by Kara Fox).

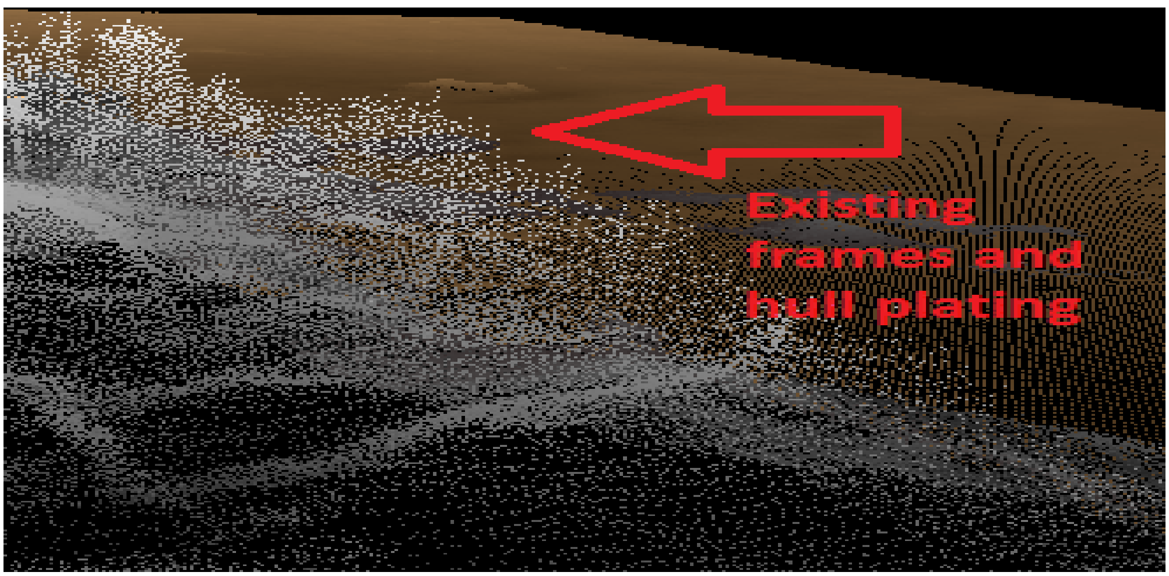


FIGURE 6.19. Multibeam image illustrating existing frames and hull plating on starboard side of shipwreck site (Source: NOAA).

Furthermore, the shipwreck site exhibits an extensive debris field located within the shipwreck and also surrounding the shipwreck on both port and starboard sides (Figure 6.19). Based on a series of large-scale studies (Church et al. 2007; Murphy & Russell 2008:123; Gearhart et al. 2011; NOAA 2013) focusing on the various types of environmental processes affecting the collapse and deterioration of shipwrecks, the type of dispersal and artifact disarticulation most prominently found on *Caribsea* was not symptomatic of environmental processes. While recognizable features such as frames, hull plating, piping, capstans, and cargo gear masts were identified and appeared to be undergoing deterioration due to corrosion and biological growth. Many artifacts (Figure 6.20) identified within the debris field, however, appeared to be broken apart by abnormal force instead of slow deterioration.

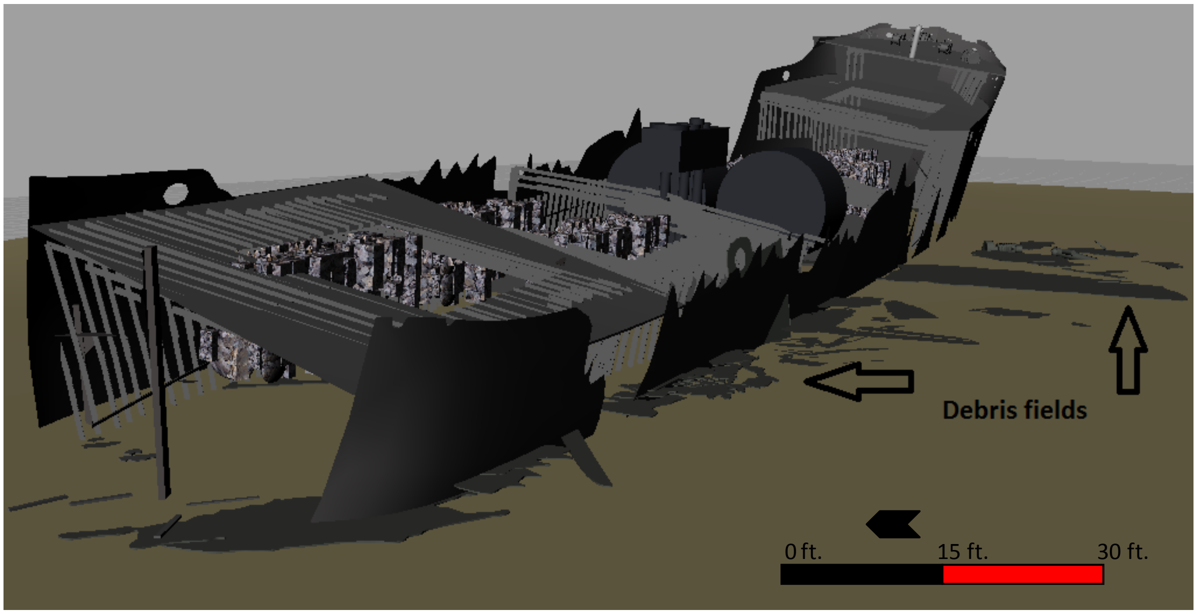


FIGURE 6.20. Image illustrating the debris fields in Post-Salvage *Caribsea* Model (Image by Kara Fox).

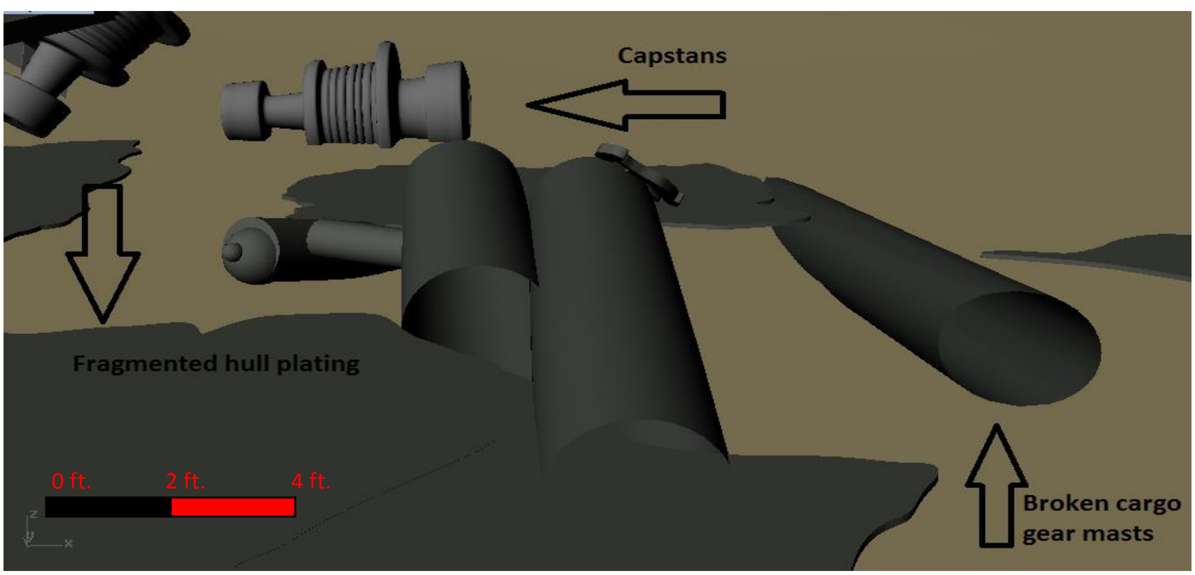


FIGURE 6.21. Image illustrating detailed view of objects in debris field from Post-Salvage *Caribsea* Model (Image by Kara Fox).

Based on the aforementioned pre-depositional and post-depositional observations, an explanatory Post-Salvage *Caribsea* Model was developed (see Figure 6.21). This model was developed based on the disassembly of the Submerged *Caribsea* Model interpretations taken from the archaeological record (Figure 6.15) and inference centered on an understanding of various site formation models and theories (Muckelroy 1976, 1978; Schiffer 1987; Steward 1999; Ward et al. 1999; O'Shea 2002; Gibbs 2006; Martin 2012). Based on the evidence found in the remaining structural components of the Current *Caribsea* Shipwreck Model, the superstructure and the majority of the main deck structure were removed from the Submerged *Caribsea* Model piece by piece until the remaining structure exhibited similarities to the Current *Caribsea* Model. While the exact locations of discharged explosives remains unclear, the amidships and stern sections of the shipwreck exhibited the most structural damage—this circumstance was indicated in the Post-Salvage Model (Figures 6.22 to Figure 6.27).

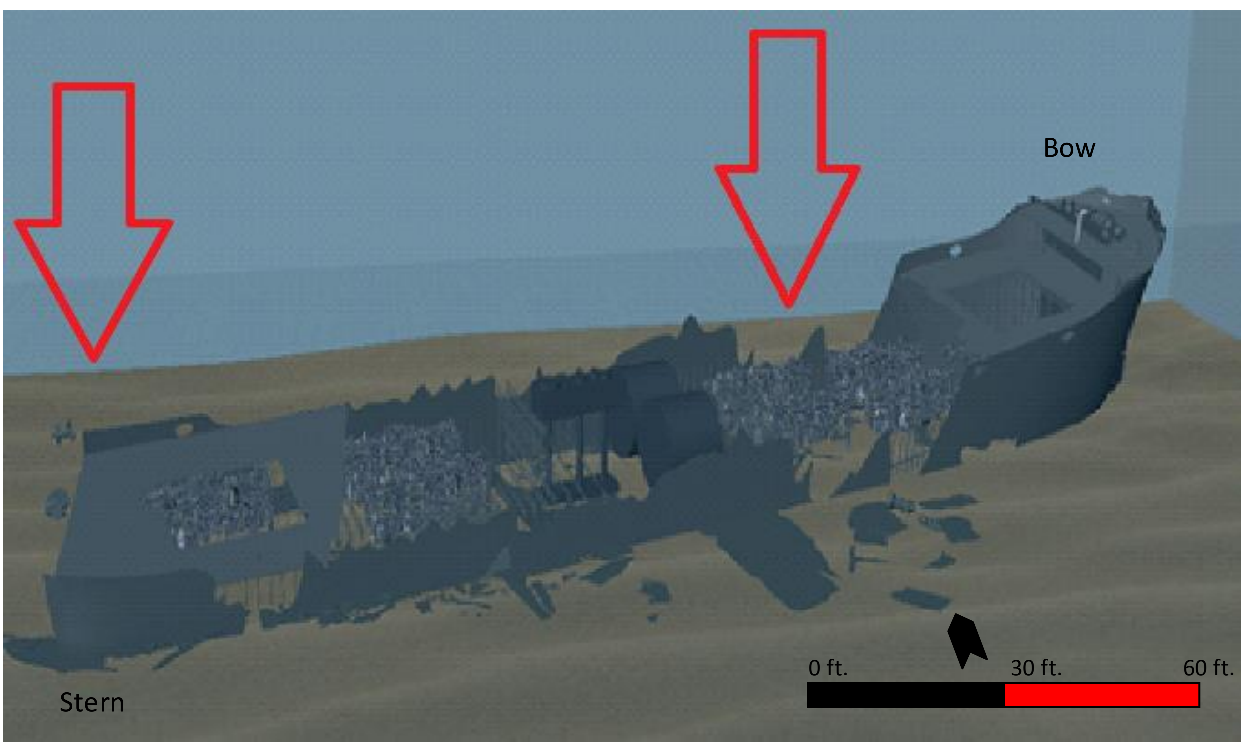


FIGURE 6.22. Image of Post-Salvage *Caribsea* Model illustrating the severe disarticulation caused by hypothesized Navy Salvage Service depth charges (location of damage highlighted by red arrows) (Image by Kara Fox).

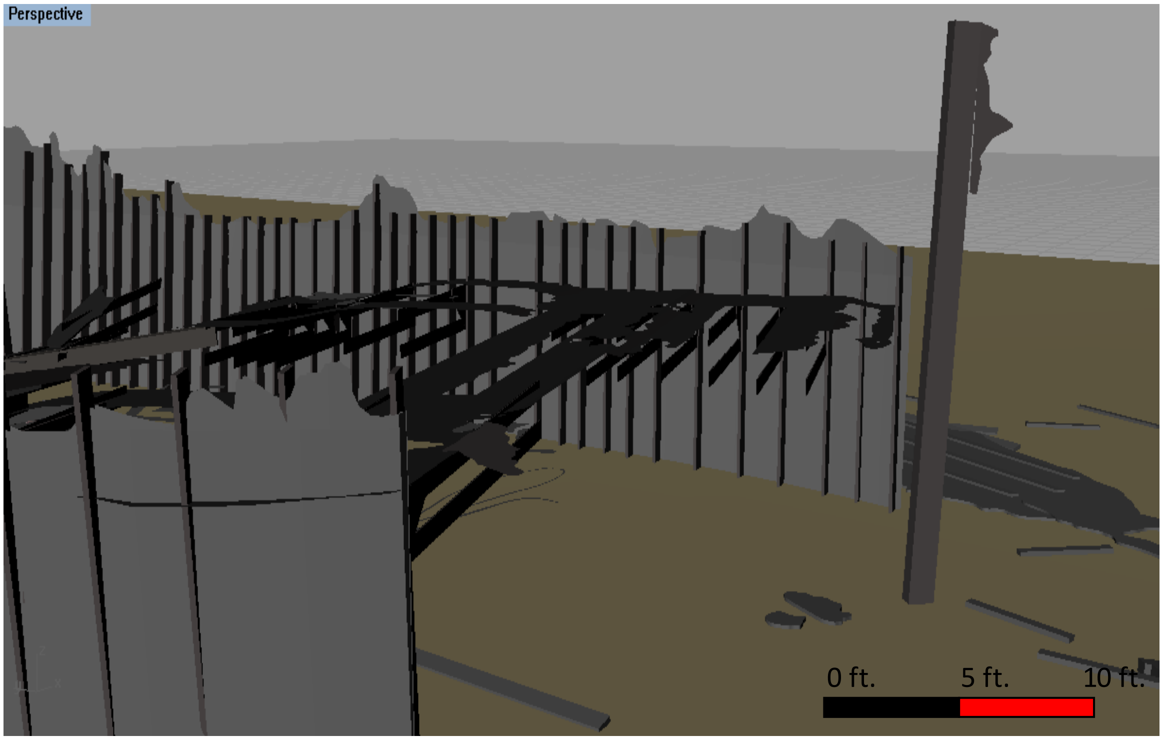


FIGURE 6.23. Image of 3D *Caribsea* Shipwreck Model illustrating the missing stern section of the shipwreck (Image by Kara Fox).

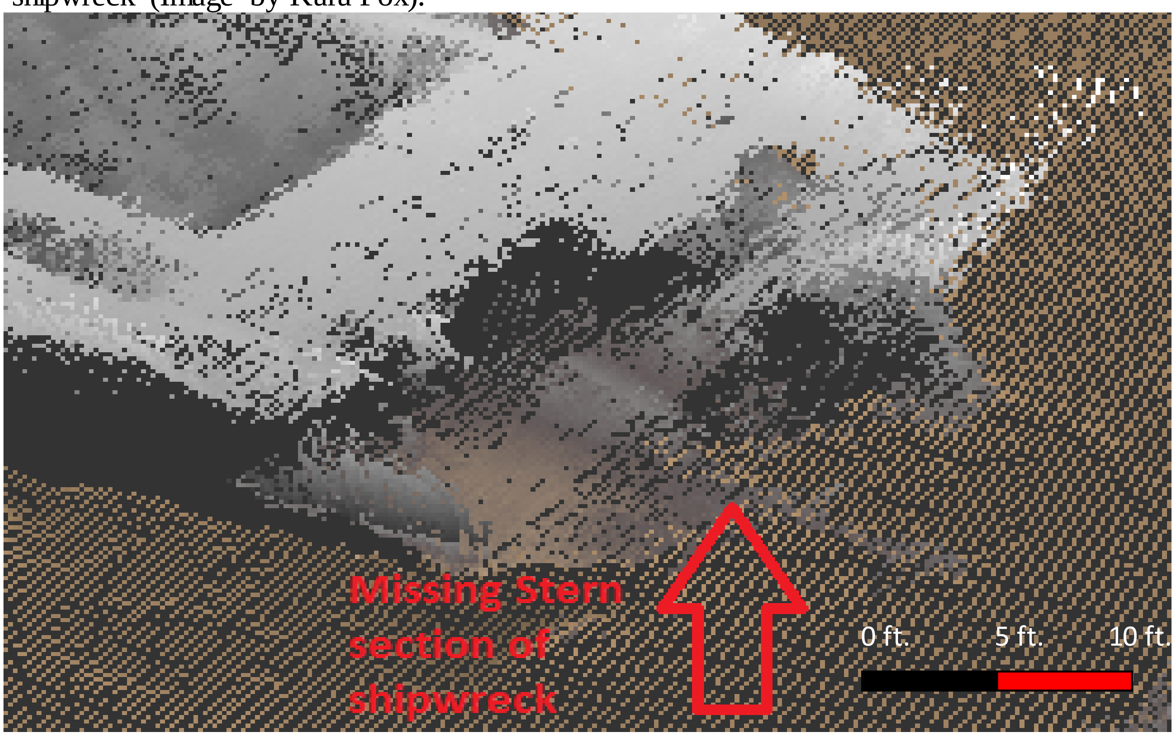


FIGURE 6.24 Multibeam imagery illustrating the missing stern section of the shipwreck site (Source: NOAA).

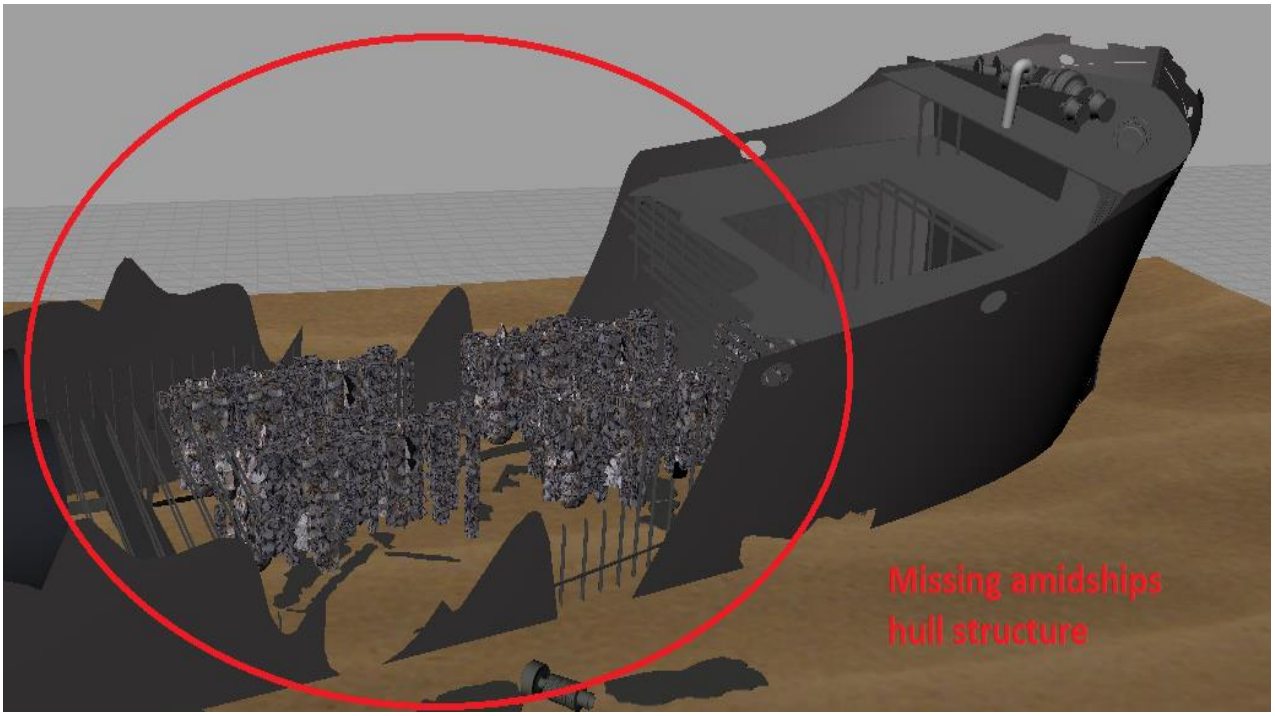


FIGURE 6.25. Image illustrating the missing hull structure on Post-Salvage *Caribsea* Model (Image by Kara Fox).

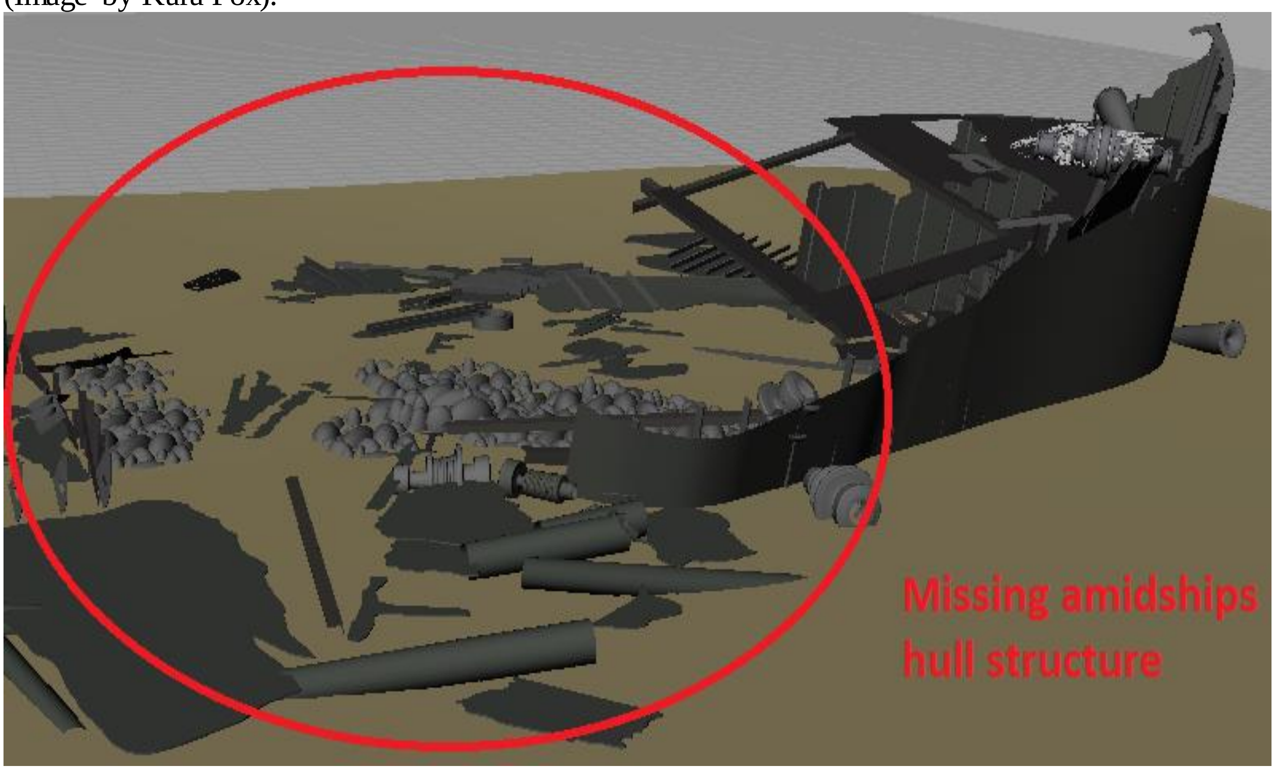


FIGURE 6.26. Image illustrating missing hull structure on Current *Caribsea* Shipwreck Model (Image by Kara Fox).

FIGURE 6.27. Image illustrating missing stern structure on Post-Salvage *Caribsea* Shipwreck Model (Image by Kara Fox).

FIGURE 6.28. Image illustrating missing stern structure on Current *Caribsea* Shipwreck Model (Image by Kara Fox).

Current *Caribsea* Model

As with the previous Post-Salvage *Caribsea* Model, the Current *Caribsea* Model's assessment included both pre-depositional and post-depositional processes. Because of the amount and quality of data that were acquired during the *Caribsea* Expedition in the summer of 2014, a more detailed site formation assessment was achieved. The following variables were observed, identified, and assessed in the 3D shipwreck model of *Caribsea*.

Pre-Depositional Factors

The pre-depositional factors influencing the transformation of *Caribsea* were an integral part of assessing the collapse of the current shipwreck site. Being able to refer back to the Historical *Caribsea* Model and the cultural variables that contributed to the construction and trajectory of the vessel were instrumental in the identification and interpretation of the current shipwreck site because of their influence on both the interpretation of the shipwreck assemblage and the rate of transformation throughout the shipwreck site. Archaeological site formation theory is often focused on recognizing the post-depositional processes and accounting for their quantified effects on the archaeological record. Generally speaking, the pre-depositional facet of site formation often goes discounted. Gould (2000:9) noted the importance of identifying the sociocultural variables of a shipwrecking event in relation to the case study of several 19th and 20th century vessels. Similarly, Lenihan and Murphy (1998:237) made references to pre-depositional processes, arguing that the culturally derived archaeological signatures associated with a shipwrecking event contain patterns of site formation that are underrepresented and overlooked.

Muckelroy discussed the potential patterning found in regards to the break-up of a shipwreck site and the relationship between pre-depositional and post-depositional variables. His site formation musings included:

> A ship floating or sailing on the surface of the sea is a complex machine containing a large number of constituent parts arranged in a specific order to ensure seaworthiness, ease of handling, and other desirable qualities. From the moment of impact, however, that high degree of organisation [*sic*] begins to break down, until the remains are assimilated into the sea-bed in some degree of disorder, often very extensive. This constitutes the first stage in the rearrangement of the elements of a vessel which interests the researcher, and is covered by the title 'process of wrecking.' (Muckelroy 1978:169).

This type of theoretical framework instigated the inclusion of pre-depositional variables in each of the 3D *Caribsea* models. The break-up of a shipwreck site on the ocean bottom comes in stages—often depending on many pre-depositional factors including ship design, materials, crew, historical context, cargo, ect. By recognizing these types of variables, the ability to clearly identify and assess the post-depositional factors became possible.

Post-Depositional Factors

Post-depositional factors acting on the Current *Caribsea* Model included cultural, physical, biological, and chemical processes. These processes often can include but are not limited to human use, sedimentation, tides, currents, weather patterns, encrustation, boring, biological decay, and corrosion. Through the 3D modeling process, it became evident that many of these types of factors were (and are) playing an active role in the deterioration of *Caribsea*. A proficient knowledge base of *Caribsea*, combined with an informed understanding of pre and post-depositional site formation processes assisted in achieving an in-depth understanding of the structural collapse of *Caribsea*.

Past site formation studies have made claims that physical processes including sedimentation, tides, currents, wave action, and storms are typically the most prominent site formation process on a shipwreck site (Muckelroy 1978; Robinson 1981; Schiffer 1987; Ward et al.1999; Wheeler 2002; Quinn 2006). Based on these studies, the effects of sedimentation were accounted for in the 3D model and the assessment of C*aribsea's* current condition.

The Gulf Stream is a warm ocean current moving from the Caribbean all the way to Europe. It skirts along the coastline until it reaches Cape Hatteras, where it converges with the colder Labrador Current which runs along the east coast from Greenland. The collision of various properties and ecosystems results in an underwater island of shifting sands known as Diamond Shoals. Additionally, this high degree of variability has a noticeable effect on shifting sands throughout the water column, creating deep scours deposits that shift continually.

This type of activity is believed to cause periods of episodic scour and deposition at shipwreck sites in environments such as the Cape Hatteras area (Ward et al. 1999; Wheeler 2002; Quinn 2006). In light of this, sedimentation and sand scouring effects were detected on the site during the 3D modeling process of *Caribsea*. However, sedimentation variability was noted on the port and starboard sides of the shipwreck site. The port side of the shipwreck (see Figure 6.28 and Figure 6.29) indicated more sedimentation build-up (see Figure 6.28 and 6.29), while the starboard side indicated less sedimentation build-up (see Figure 6.30 and 6.31).

While the specific causes for this variability (wave direction, currents, angle of shipwreck to currents, ect.) were not captured in the confines of this study, the implication of these variables was observed throughout the archaeological data collection and modeling process. It has been noted by Quinn (2006) that both waves and currents play important roles in sediment variation. Furthermore, many shipwreck sites occur in environments where the sediment dynamic is characterized by a combination of tidal currents and wave processes—increasing the complexity of the scouring processes and affecting the deterioration of the shipwreck site.

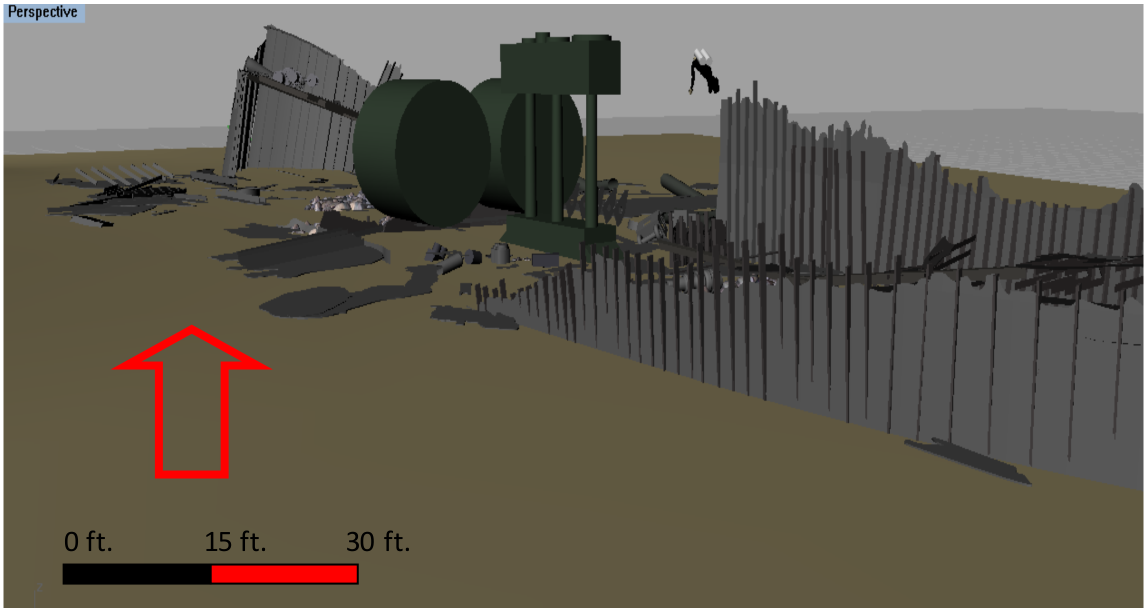


FIGURE 6.29. Port side of shipwreck exhibiting more sand scouring and sediment buildup (Image by Kara Fox).

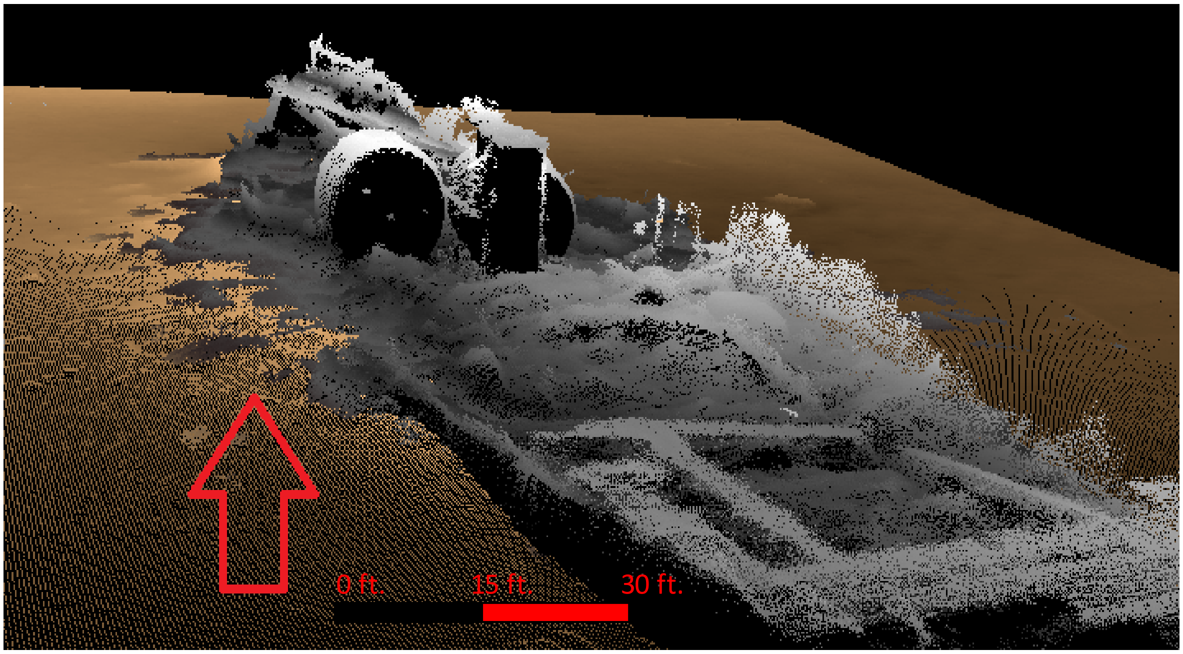


FIGURE 6.30. Multibeam image illustrating port side of shipwreck site exhibiting more sand scouring and sediment buildup (NOAA).

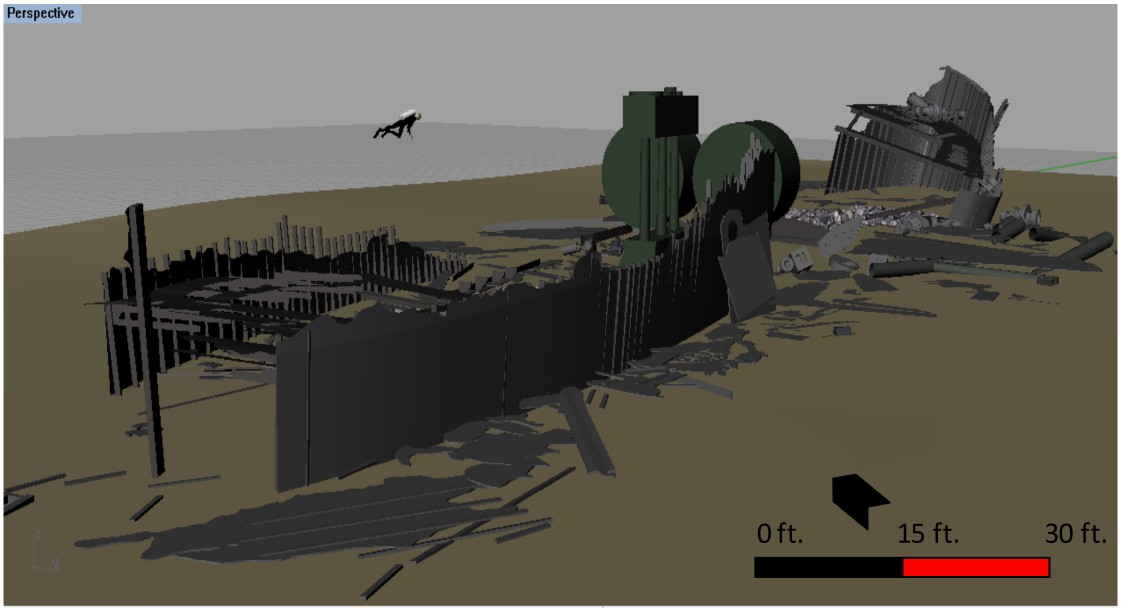


FIGURE 6.31. Starboard side of the shipwreck site exhibiting exposed a debris field due to minimalized sedimentation (Image by Kara Fox).

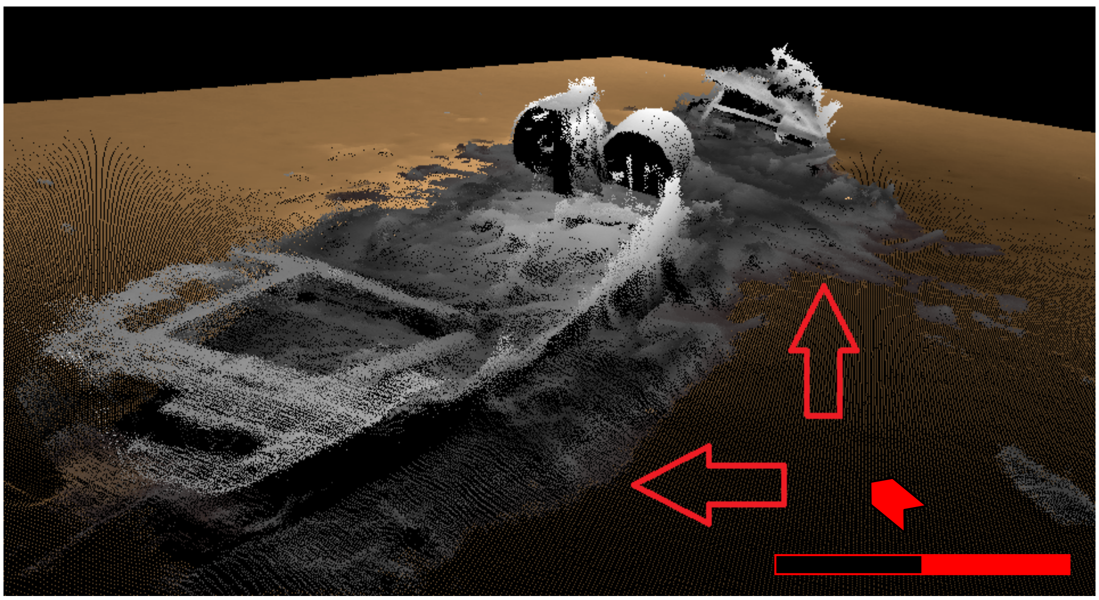


FIGURE 6.32. Multibeam imagery illustrating starboard side of shipwreck site exhibiting a more exposed debris field due to minimalized sedimentation (NOAA).

Post-depositional biological processes most likely affecting *Caribsea* included the direct impact of marine organisms (habitation, boring, encrustation, or biological decay) on a shipwreck site. Biological activity that is associated with shipwrecks actively influence the food chain regarding the development of reef systems and fish activity (Ward et al. 1999:566;

Wheeler 2002:1150-1151). Theoretically, as the growth of benthic organisms around *Caribsea* has grown, so has the occurrence of marine life (spadefish, baitfish, amberjacks, stingray, cobia, Spanish mackerel, sand tiger sharks, and loggerhead turtles). In the case of *Caribsea*, this process would directly encourage human use in the form of scuba diving and commercial fishing.

While biological processes are a known variable of site transformation on *Caribsea*, this particular facet of site formation was not measured during this study. Furthermore, the effects of biological forces are often difficult to measure and illustrate without an intrusive sampling of the shipwreck site and a more baseline understanding of the original typology and assemblage of site materials. In light of this incapacity, biological processes were not accounted for in the 3D modeling process. However, it is important to note that this type of deterioration has a known presence on this type of shipwreck site—and could be a focal point in future studies.

Lastly, chemical processes were also recognized as being a major contributor to the continual deterioration of *Caribsea*. Chemical deterioration includes the direct reaction of ferrous shipwreck materials to the marine environment (seawater). Noted in Chapter Three, a variety of environmental attributes contribute to the nature and rate of corrosion including depth, current, encrustation, and underwater topography. While the quantitative variables that would affect the rate of corrosion (pH, temperature, salinity, and dissolved oxygen mass found in water) and indicate accurate predictive capabilities were not acquired, the presence and nature of corrosion were acknowledged and illustrated in the 3D modeling process.

Similar to biological processes, whereas corrosion was a known contributor to the transformation of *Caribsea*, the process was not quantifiably captured during the confines of this study. The effects of corrosion, however, were observed in the remaining hull structure, deck plating, and debris fields of the shipwreck site. The remaining hull structure and decking components of the shipwreck site appeared to exhibit active signs of corrosion which appeared in the form of various sized holes and structural decay (see Figure 6.32 and Figure 6.33). Additionally, more substantial features (anchor windlass, hatch beams, and frames) have added additional weight to specific areas of the shipwreck that has maintained deck plating. This factor, combined with the oxidizing chemical environment has resulted in continued disintegration of steel components. Based off current corrosion studies, this condition could eventually result in complete collapse, especially in the case of the bow section (Figure 6.34 and 6.35) (Muckelroy 1977:51; North 1982:76-78; Wheeler 2002:1151; McCarthy 2002:90-91).

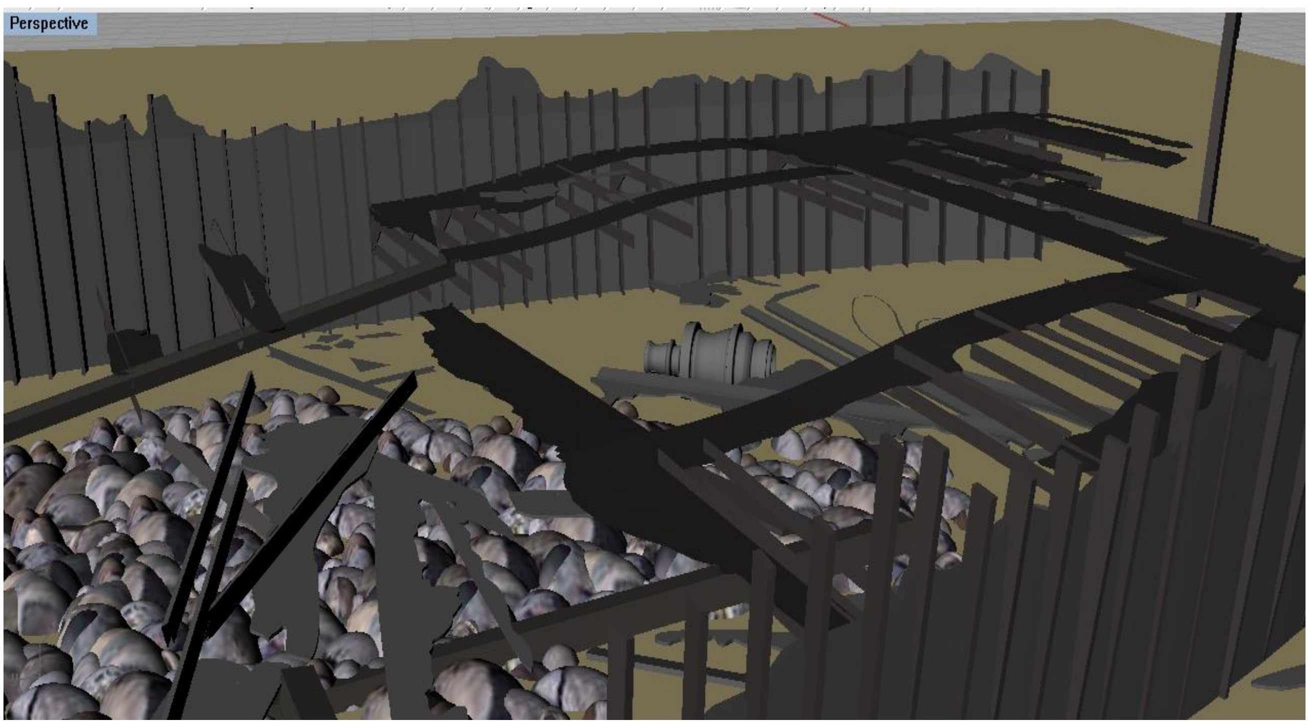


FIGURE 6.33. Image illustrating existing upper decking in stern section (Image by Kara Fox).

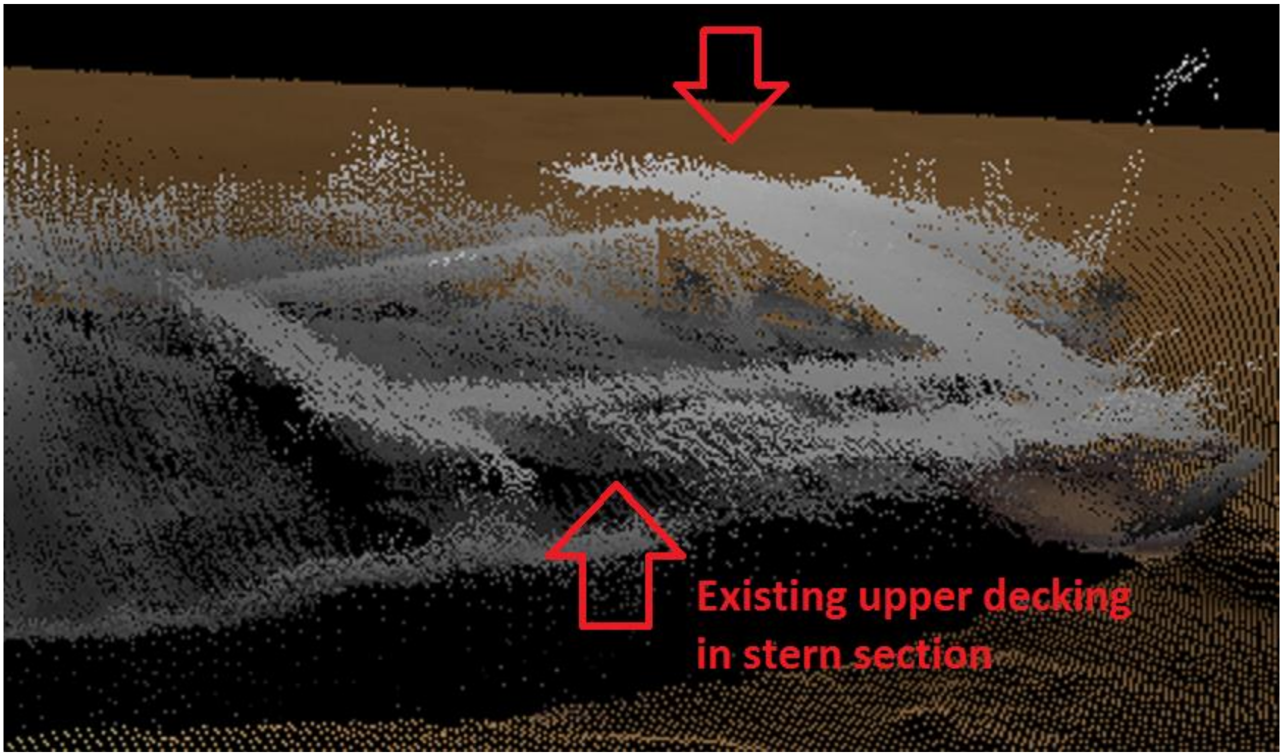


FIGURE 6.34. Multibeam imagery illustrating existing upper decking in stern section (Source: NOAA).

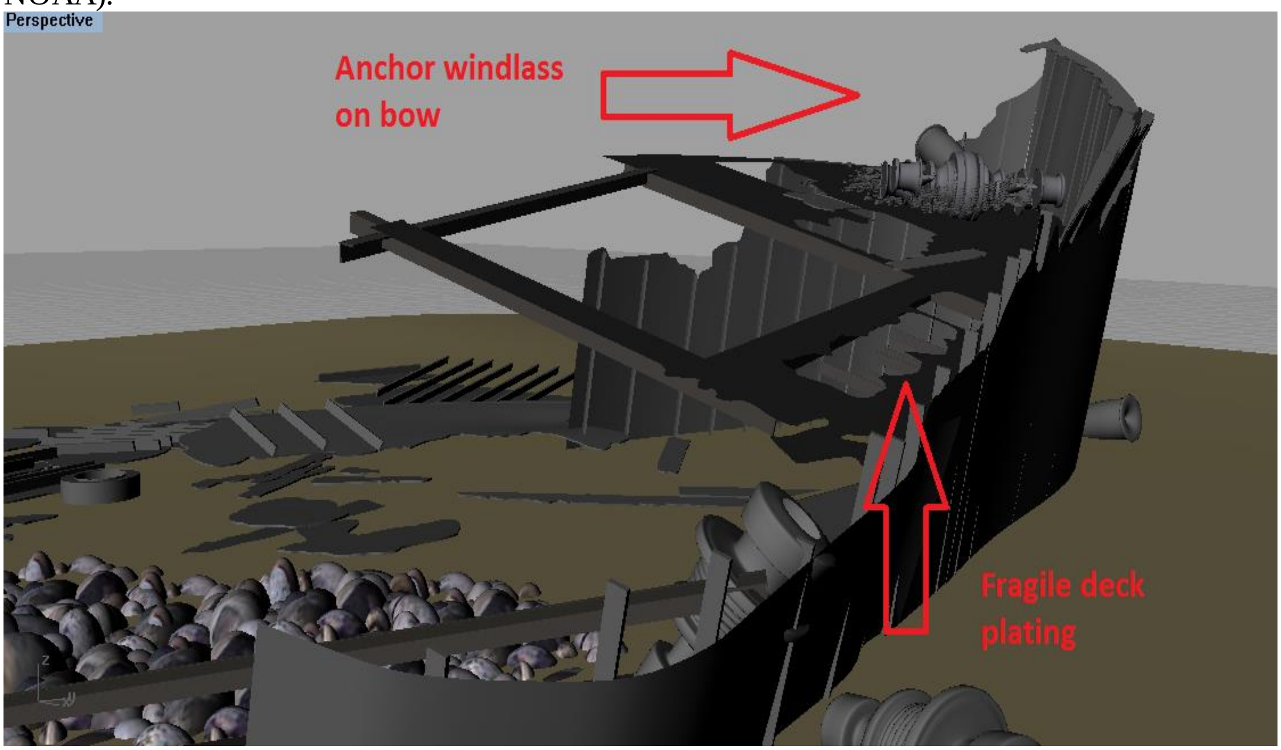


FIGURE 6.35. Image illustrating existing upper decking in bow section (Image by Kara Fox).

FIGURE 6.36. Multibeam image illustrating existing upper decking in bow stern (Source: NOAA).

Lastly, the scuba diving survey and 3D modeling process of *Caribsea* resulted in the observation of human-induced damage due to scuba diving and fishing activities. Substantial and easily accessible features on the wreck (protruding frames; stem post; triple expansion engine), often provide anchoring locations for diving and fishing charters. The indication of this impact was recording during the *Caribsea* Expedition, and was further substantiated as a known practice in the area. Anchoring onto a shipwreck dislodges or disrupts protective concretions covering iron and steel components, causing the shipwreck to deteriorate at a faster rate. While it was difficult to, a) decipher this type of deterioration using remote sensing imagery or a site plan, or b) illustrate this deterioration for future assessment or management—the 3D models facilitated the deterioration to be documented and assessed for future evaluation. By providing an updated virtual dataset of the existing *Caribsea* assemblage, future surveys and assessments can be used to monitor the condition of the shipwreck site.

Predictive *Caribsea* Model

While the primary objective of this study was to accurately illustrate and assess site formation processes utilizing 3D capabilities, an accompanying facet of this research aimed to explore the predictive potential of comparative models. The predictive potential of this study exists by using a time-series of past models in order to infer future site transformations. By demonstrating intimate site knowledge, the ability to rule out some processes and infer the effects of other processes for the potential of predictive site modeling becomes plausible. Once the specific types of environmental and cultural processes affecting the status of *Caribsea* were identified, and the pre and post-depositional effects were assessed, a foundation for future transformations was established. The resultant 3D dataset and assessment provides a predictive aspect for the future site transformation on the shipwreck site.

Predicted Processes

Based on the pre-depositional circumstances including the type of vessel and the shipwrecking location, coupled with the post-depositional effects of cultural and environmental factors it was found that *Caribsea*, although seemingly stable—continues to undergo structural transformation. The absolute rate of transformation is inconclusive due to the qualitative nature of this study; however the assessment of site formation infers the absolute continuation of collapse and disarticulation due to various site formation variables.

As mentioned before, and subsequently illustrated through 3D modeling capabilities, the majority of the shipwreck site (extensive debris fields on port and starboard side, three cylinder triple expansion engine, two Scotch boilers, port and starboard structural hull components, machinery) exhibited signs of collapse, disarticulation, and deterioration. Furthermore, the areas of the shipwreck that have maintained remnants of its original structural integrity, including the remaining forward and aft decks, were found to exhibit unstable and corroded conditions—seen before in Figure 6.30 through Figure 6.33.

Due to the popularity of *Caribsea* for scuba diving and fishing charters, the direct impact of these cultural activities is predicted to be a perpetual source of transformation on the shipwreck site. In particular, further deterioration is expected on large structural elements throughout the site because of anchoring methods that are trademarked to the region (i.e. continually tying into a portion of the triple expansion engine). Additionally, easily accessible artifacts and items of potential significance or monetary value (i.e. machinery components, anchors, cargo features) are currently still accessible on the site and remain susceptible to salvage.

Corrosion is another process that is projected to have continued effects on *Caribsea*. Because of the qualitative nature of this project, the chemical processes affecting *Caribsea* were not measured. However, the corrosive environment was accounted for as a result of observed corrosion properties (ample concretion, crumbling hull structure, pitted and discolored ferrous material, cracked and holed deck plating), theoretical models of shipwreck transformation, and site formation case studies (Muckelroy 1977:51; Wheeler 2002 1151-1152; North 1982:76-78; McCarthy 2002:90-91).

The observed state of the hull structure and deck framing, coupled with the known forces affecting the environment (cultural, physical, biological, and chemical processes) generates a shipwreck susceptible to continued transformation. Based on the current status of the shipwreck, especially in regards to the fragility of the remaining structure with existing decking components (bow and stern sections), it is predicted the shipwreck will likely continue to undergo additional collapse and disarticulation over time, specifically but not limited to corrosion processes. The heavy anchor windlass located in the bow section will likely collapse the forward decking structure. It is ultimately projected that the area as seen in Figure 6.34, will eventually succumb to complete collapse and disarticulation. Therefore, based on the continuance of the weight of the anchor windlass, coupled with the observed corrosive environment—the predictive model is shown with a collapsed bow section (see Figure 6.36 and Figure 6.37).

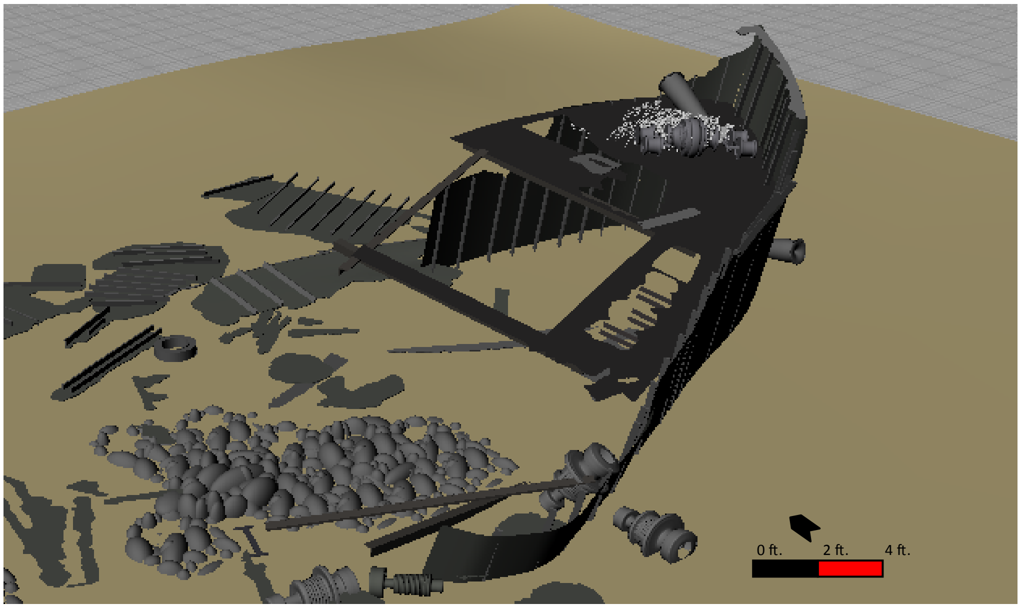


FIGURE 6.37. Image illustrating the existing bow section on Current *Caribsea* Shipwreck Model (Image by Kara Fox).

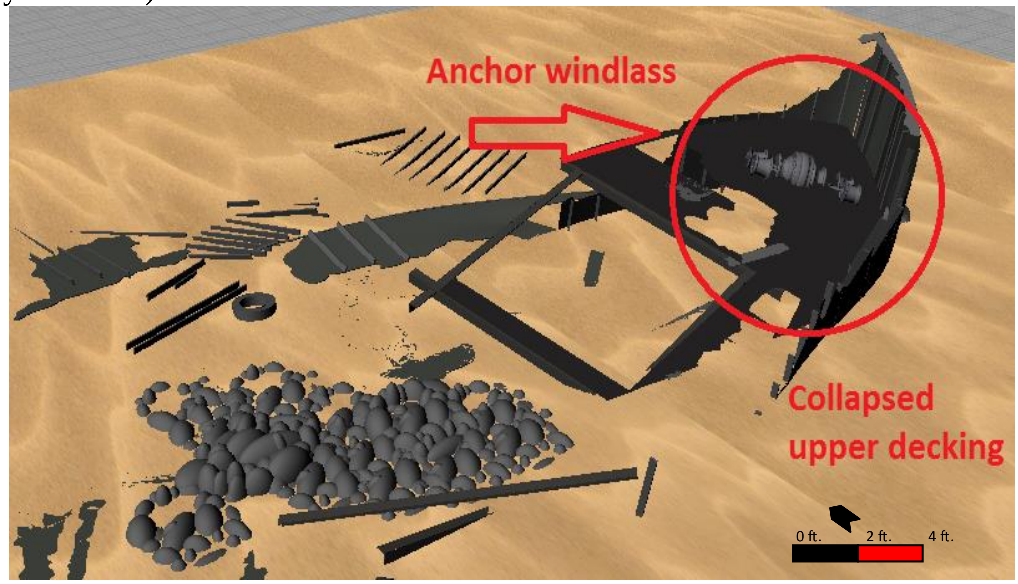


FIGURE 6.38. Image illustrating future collapse of bow area on Predictive *Caribsea* Model (Image by Kara Fox).

Currently, *Caribsea* sustains a rich marine ecosystem (seen in Figure 6.38, 6.39 and 6.40). The biological system includes various types of micro and macro organisms, algae, coral, fish, and marine life. Based on the current state of the artificial reef system, which is stimulated by the condition of the shipwreck structure and the fluctuating relationship with the surrounding environment, this biological system is forecasted to continue to grow—both providing protection to the shipwreck site, while simultaneously causing physical and chemical deterioration (Ward et al. 1999:566; Wheeler 2002:1150-1151).

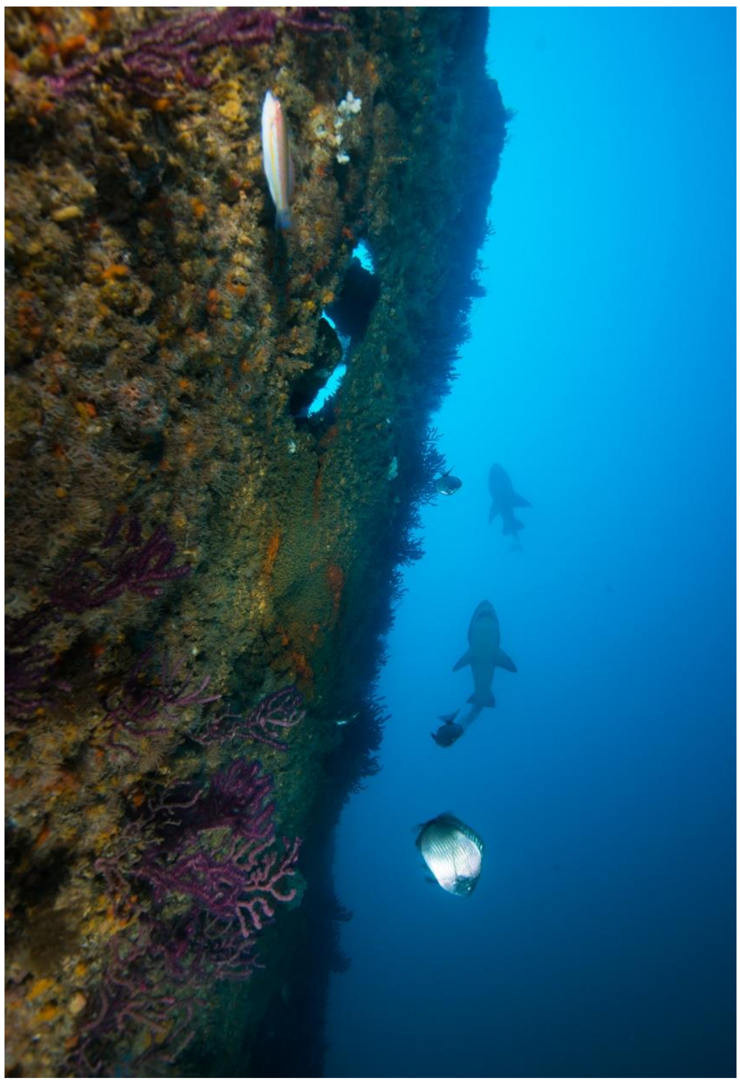


FIGURE 6.39. Image illustrating diverse biological environment on *Caribsea* shipwreck (Source: NOAA).

FIGURE 6.40. Image illustrating diverse biological environment (sand tiger shark) on *Caribsea* shipwreck (Source: NOAA).

Lastly, sedimentation and scour is a factor that is projected to have a continued effect on *Caribsea*. Based on the interpretive aptitudes specific to this study, the future exposure of the shipwreck site was accounted for based on the current status of the shipwreck and the known sedimentation patterning and sand burial activity that is characteristic to areas prone to seabed movement similar to the North Carolina area (Muckelroy 1978:176; Souza 1998:38-39; Quinn 2006:1420; Wheeler 2002:1150). Moreover,

These studies supported the observation that sediment disturbance is primarily a result of water movement, i.e. tidal currents, weather patterns, and wave action. While the degree of impact is typically based on quantifiable measurements, the knowledge of the process also serves as a diagnostic tool and suggests the re-sorting and burial of artifacts or structure.

Since hydrodynamic activity (seabed movement and weather patterns) and sedimentation is forecasted to be a continued presence on the shipwreck site—seabed movement was noted as having an active influence on the assemblage and burial of the shipwreck site from year to year. Therefore, this observation was included within the layered 3D *Caribsea* model sequence. Thus an estimated projection based on qualitative interpretations of *Caribsea's* transformation due to continual sedimentation, sand scouring, reburial, and exposure was captured (seen in Figure 6.41 and Figure 6.42).

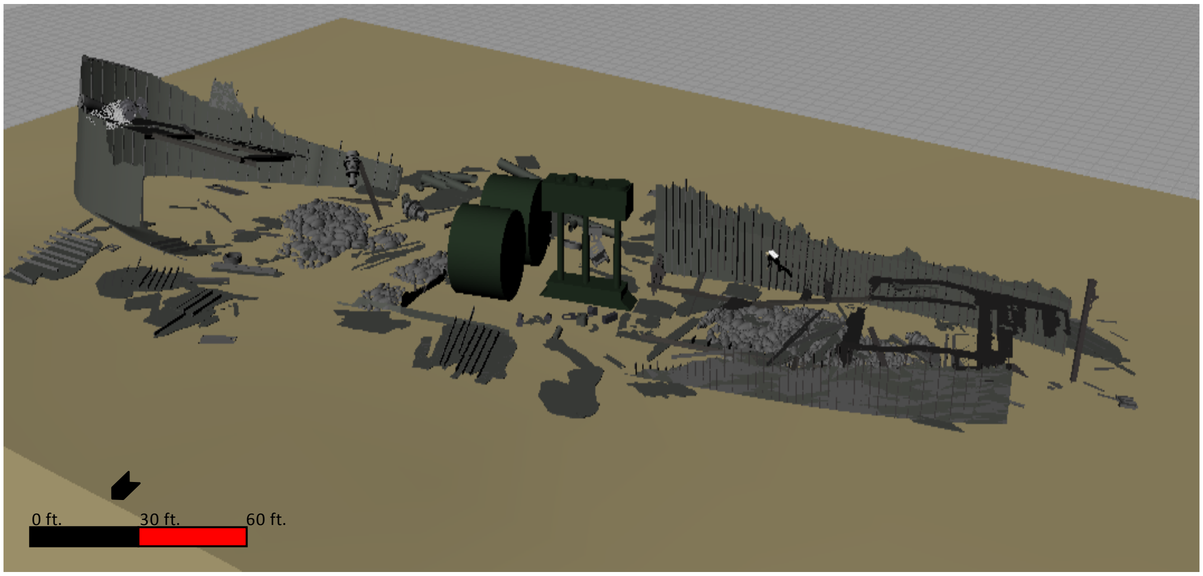


FIGURE 6.41. Image illustrating the existing sedimentation on port side of the Current *Caribsea* Shipwreck Model (Image by Kara Fox).

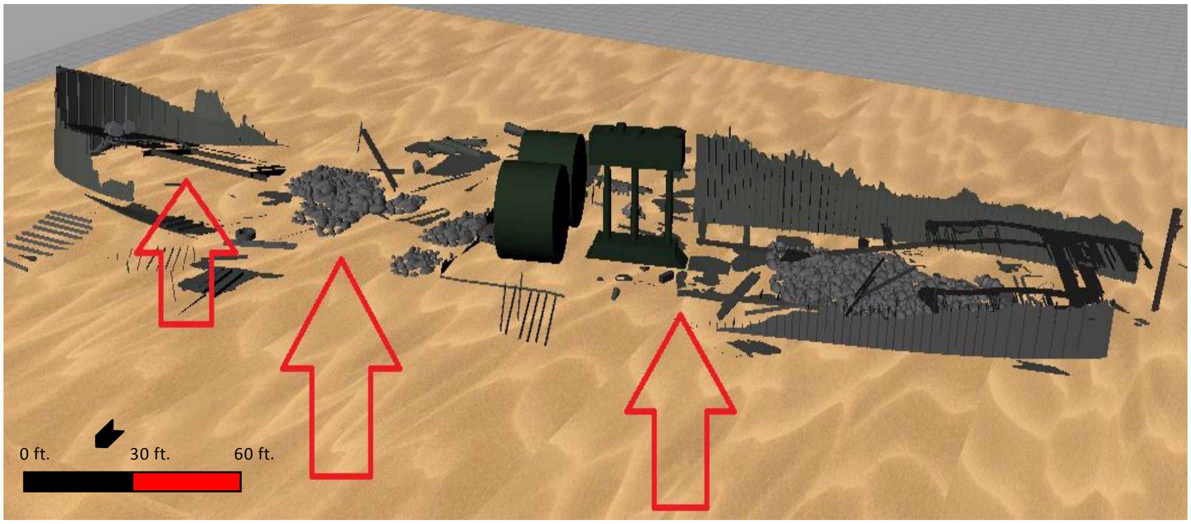


FIGURE 6.42. Image illustrating future sedimentation on port side of the Predictive *Caribsea* Shipwreck Model (Image by Kara Fox).

Ultimately, it was the goal of this study to visually illustrate and assess the overall transformation of *Caribsea* before, during, and after the shipwrecking event. The illustrative and predictive capabilities of this study stemmed from the ability to accurately deduce shipwreck transformation based on intimate site knowledge, a thorough understanding of site formation theory, and the potential effects these variables can have on a specific shipwreck site. As discussed throughout the duration of this study, there were many variables that have and will continue to contribute to the transformation and structural collapse of shipwrecks like *Caribsea*. The following model sequence is based on a multifaceted method of collecting and utilizing historical, archaeological, and theoretical data. The model series, as seen in Figure 6.43, is based on the current known datasets of *Caribsea*—barring intervention, preservation, or management.

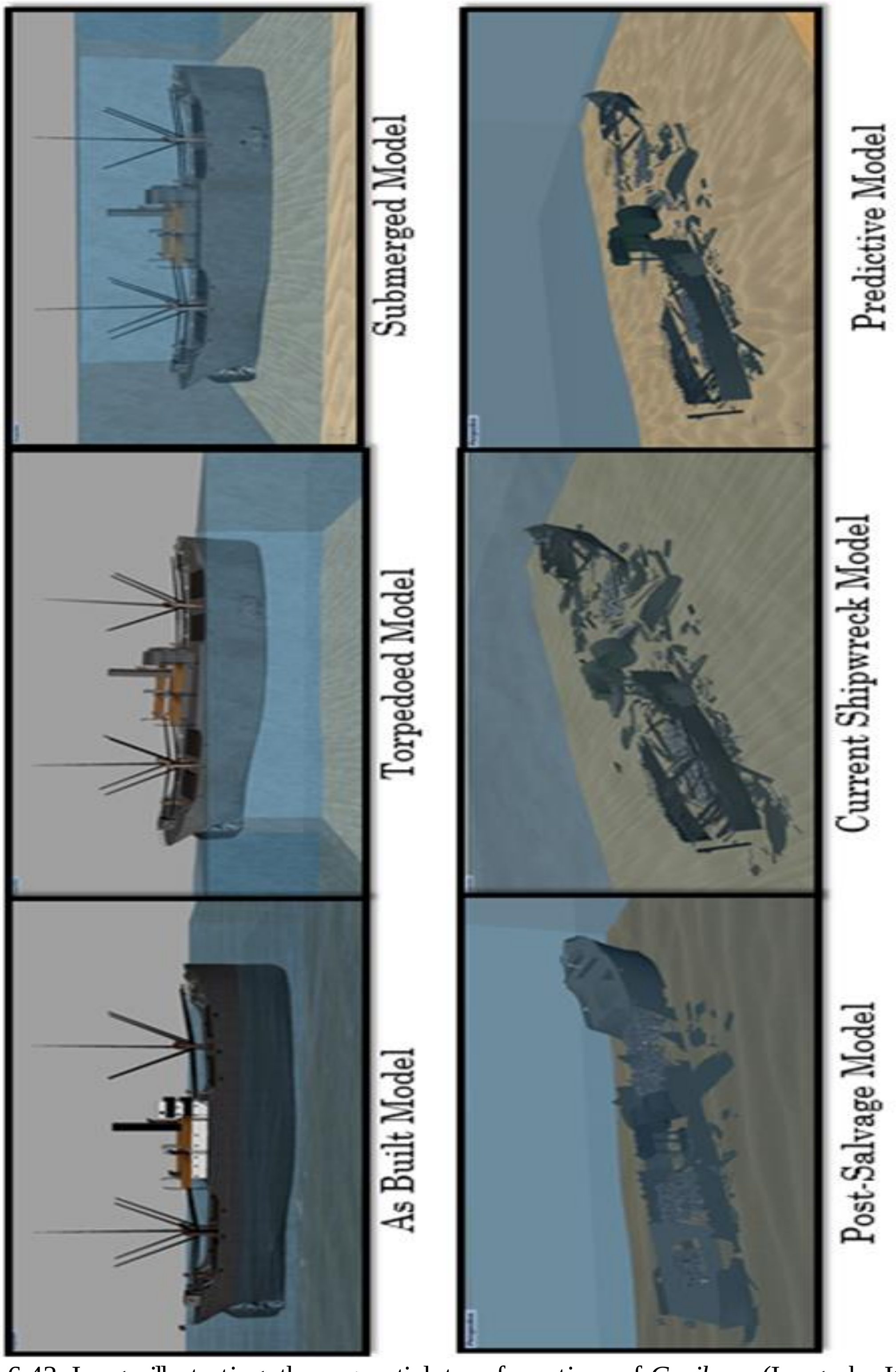


FIGURE 6.43. Image illustrating the sequential transformation of *Caribsea* (Image by Kara Fox).

Conclusion

This chapter represents the culmination of this thesis, further building upon the results of the 3D modeling process outlined in Chapter Five, illustrating and assessing the various stages of deterioration on a shipwreck site. Using comprehensive knowledge of the shipwreck site and the site formation theory—3D models were developed creating a sequential series of illustrative models displaying sequential transformation of the shipwreck site. By incorporating theoretical site formation considerations into the 3D modeling process, an interpretive and analytical progression was expanded into an archaeological discussion. In the context of virtual archaeology, this study was the first of its kind to organize a qualitative analysis involving the collection of historical, archaeological, and site formation datasets in the pursuit of capturing, illustrating, and understanding the transformation processes affecting a World War II shipwreck site.

As discussed previously, the goal of this study was to move beyond an illustrative concept—providing a visual and analytical archaeological tool. Thus, it was the purpose of this chapter to culminate the basis for this type of study, demonstrating the resultant breakdown for *Caribsea*, and the potential for 3D platforms to provide an effective and necessary framework for the organization, illustration, and manipulation of large amounts of historical and archaeological data. Additionally, the development of this study is hoped to instigate future site formation studies through the continual research of site formation processes through 3D capabilities.

CHAPTER SEVEN: CONCLUSION

This study utilized a multifaceted approach to developing a series of 3D models illustrating the sequential transformation of a shipwreck site. The use of a 3D CAD platform combined with site formation theories from Muckelroy (1978) and Schiffer (1987) were influential in the development and exploration of four research questions. Next, the collection of historical and archaeological datasets was essential in the process of examining and interpreting the sequential transformation of *Caribsea*. These datasets were assimilated and then integrated into a 3D platform, allowing for the illustration and analysis of site formation processes. Fundamentally, the 3D models not only yielded an impressive visual reference for *Caribsea's* site transformation, they also served as an analytical tool: shedding light on intimate site knowledge and site formation processes that typical archaeological resources might lack.

As a result, the modeling process allowed for the temporal and spatial trajectory of the shipwreck site to be illustrated and examined. In order to make more accurate assessments about the archaeological site, the types of site formation processes that have impacted the site were categorized into pre-depositional processes (factors contributing to the creation of the shipwreck site), and post-depositional processes (factors contributing to the alteration of the shipwreck site). As discussed in Chapter Four, the establishment of these circumstances increased the understanding of the shipwreck site, and ultimately the ability to predict future structural collapse on the site.

As noted in Chapter Two, environmental and cultural parameters such as corrosion and human-caused damage patterns determine the occurrence and rate of formation processes. For example, a shipwreck site located at a deeper depth would be less prone to human induced damage, thus decreasing the chance (but not ruling out the possibility) of the removal of artifacts due to salvage or cultural factors. Similarly, by drawing upon the potential types of site formation processes affecting a shipwreck site due to the patterns observed in its illustrated deterioration, archaeologists can appreciate the use of highly detailed, but accessible 3D technologies.

Chapter Three outlined the historical trajectory of *Caribsea*. Acquiring historical datasets, and piecing together the lifespan of the vessel highlighted the potential factors, circumstances, behaviors, and occurrences of pre-depositional variables that could be ruled out or assigned during the research and 3D modeling process. This data was organized, reviewed, and assessed in light of the archaeological data that was later acquired.

The applicability of the historical data, coupled with the archaeological data towards the development of site formation models was revealed in Chapter Four. While there was enough data to attain a final understanding and analysis of *Caribsea's* site transformation, there were many gaps in the historical and archaeological datasets that would have proven helpful if they had been available. Ideally, a full set of the ship builder's plans of *Caribsea*, along with more photographic evidence, would have allowed for a more intimate understanding of the specific vessel's construction. Additionally, a detailed site plan of *Caribsea's* profile view would have provided a more methodical and detailed modeling process. However, the obtainable datasets proved to be effective for the objective of the study.

Chapters Five and Six presented the results and analysis of the site formation study. The historical and archaeological datasets were further explained in light of the 3D models. Using *Rhino* 4.0, each phase of *Caribsea's* shipwrecking event (including prior, during, and following), were successfully illustrated. The models were used as an analytical tool to gain a better understanding of site formation processes and the ultimate transformation of *Caribsea*.

This specific project focused on the acquisition and utilization of specific datasets including archival records, archaeological imagery, and site formation theory. The subsequent interpretation and assessment provided a model that not only served as an impressive visual reference, but was ultimately layered with site specific information on shipwreck transformation. The definitive contribution of this study rests in the analytical capacity of the utilized datasets—providing insight into the deterioration of a ferrous World War II shipwreck off the coast of North Carolina.

Though the study achieved its objective: developing a series of 3D sequential site formation models, the limited means of the study and the qualitative scope of the research have the potential to be expanded to a much more comprehensive site formation assessment. The addition of measurable environmental processes including corrosion, sedimentation, hydrodynamics, and biological growth would provide a tangible predictive component to the modeling process. Additionally, a focused statistical investigation on human-induced damage (recreational scuba diving and fishing patterns) would be instrumental for future site formation and cultural resource management studies. While the current study was able to provide an explanatory model for future *Caribsea* transformations, the limited analysis failed to provide substantial data for actual predictive calculations. Thus the culminating models provide an explanatory prototype supported with qualitative interpretations, versus a predictive model substantiated with quantifiable measurements.

The 3D modeling of *Caribsea* provided an effective method for assessing the structural transformation of a shipwreck site. The available historical and archaeological datasets, coupled with the qualitative interpretation of site formation theories allowed for the illustration of the various site formation processes acting on the shipwreck site, showing the structural collapse and disarticulation of the World War II merchant freighter, *Caribsea*. Ultimately, the study of *Caribsea* could set the stage for future site formation case studies—further improving the understanding of shipwreck change and deterioration.

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