Guam: A Biogeographic and Maritime Cultural Landscape Exploration of a WWII Amphibious Battlefield

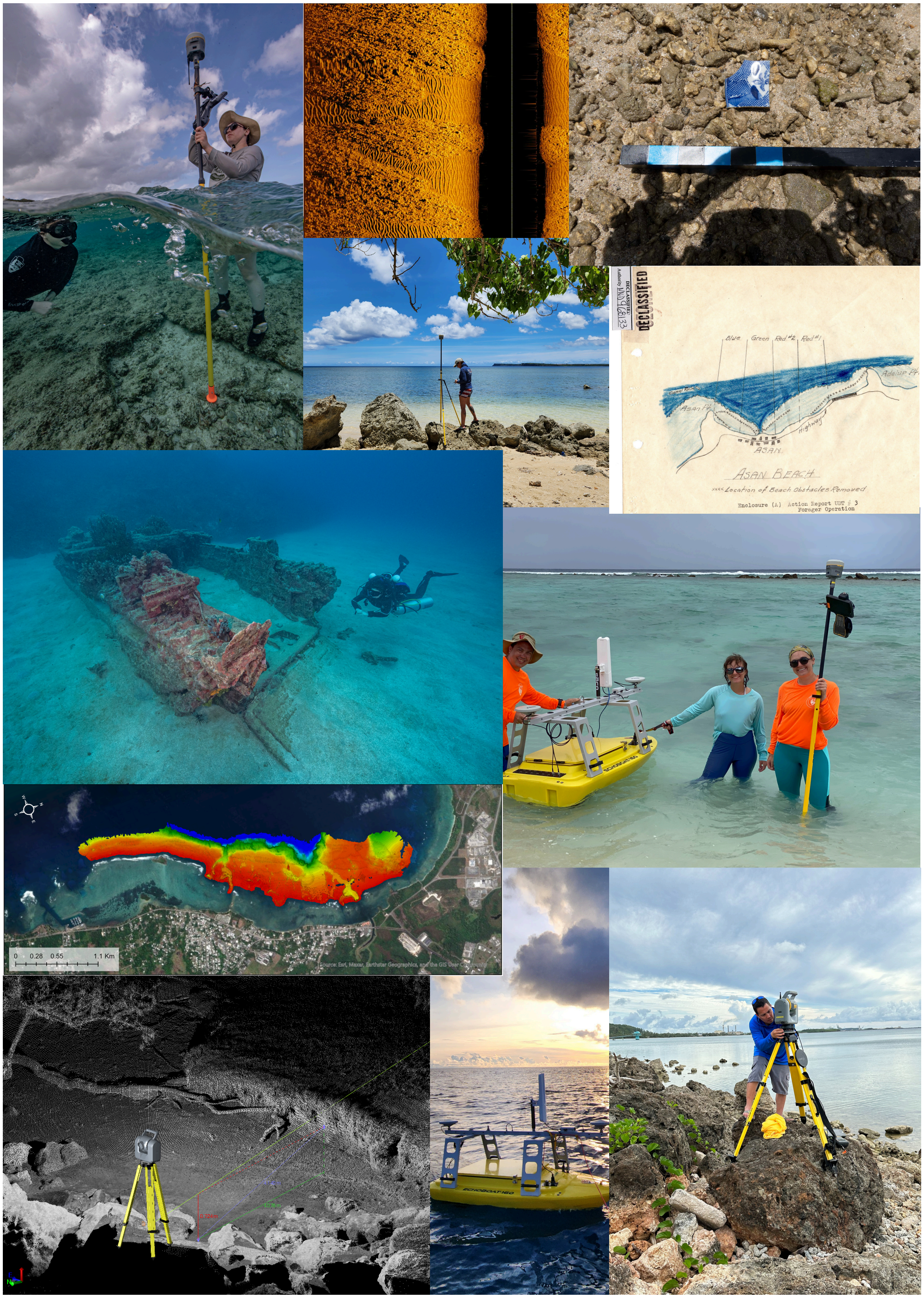
NOAA Ocean Exploration FY22 Grantee Final Report

Report prepared by:

Anne Wright Nunn (PI)[1], Monique LaFrance Bartley[2], Tahzay Jones[3], D. Blair Moore[4], Nicole LaRoche[2], Lauren Hintenlang[4], Audrey Brown [4], Jamie Kilgo[2]

[1] Submerged Resources Center, National Park Service
[2] Water Resources Division, National Park Service
[3] Science Applications and International Affairs, Fish and Wildlife Service
[4] Scientists in Parks Program, National Park Service

June 27, 2025


DECLASSIFIED
Authority NND 968133
DECLASSIFIED
Blue
Green
Red #2
Red #1
Camel Rock
Asan Pt.
Adelup Pt.
Highway
ASAN
ASAN BEACH
xxxx Location of Beach Obstacles Removed
Enclosure (A) Action Report UDT # 3
Forager Operation
0 0.28 0.55 1.1 Km

Acknowledgements

This project would not have been possible without the support of War in the Pacific National Historical Park (WAPA). Thank you to Superintendent Barbara Alberti, Tim Clark, Brooke Nevitt, Kena Lewis, Gabe Cruz, Chris Cruz, and Charles Wolford, as well as Park Interpretation, T. Stell Newman Visitor Center, and maintenance staff. Your commitment and generosity, especially with logistics, were invaluable in the completion of this project.

The project team (all of whom are listed in Table 2 of this report, and include members of the NPS Submerged Resources Center, NPS Water Resources Division, NPS Scientists in Parks program, WAPA, the NOAA Diving Program, and Task Force Dagger Foundation) played a crucial role in field data collection, analysis, and report writing. The team spent long hours in the field and in the office with unwavering dedication to the project and sense of humor and, together, we truly define what it means to be a team. Your enthusiasm and hard work are deeply appreciated. We all share in the success of this project and memories we have created.

We acknowledge the contributions of specialist assistance – Thank you to Rlene Steffy who shared her oral history knowledge and contacts; Thanks to Shawn Arnold for his expertise and assistance with the archaeological analysis of the submerged LVT at the Asan Beach unit of WAPA; Thank you to Luis Cabral for sharing his local diving knowledge and enthusiasm for the underwater world of Guam; Thank you to our oral history interviewees James Terlaje, Desiree Toledo, and Luis Cabral; Thank you to Toni Carrell for her institutional knowledge of underwater sites at WAPA; Thank you to Aleck Tan for georeferencing UXO locations from Milton et al. 2006; Thank you to our project team members from Task Force Dagger Foundation who were able to share their first hand combat knowledge on the historical battlefield; Thank you to the NOAA Ocean Exploration education staff for your guidance and assistance in developing middle school lesson plans; Thank you to our NOAA Ocean Exploration Project Manager, Phil Hartmeyer, and Christa Rabenold for your valued guidance and support throughout this project. The expertise of all of the above greatly enhanced the quality and depth of our project findings and deliverables. Any errors or omissions in this report remain the responsibility of the authors.

A special note of thanks goes to our incredible Guam-based boat team, Todd Genereux, Barnaby Acfalle, and Kody Skvaril, who provided essential support and local knowledge in expertly navigating Guam's sometimes-precarious reefs with massive amounts of cable under tow and ensuring the safe transport of personnel and equipment. A big thanks also goes to Jim Pinson for providing logistical and dive support.

We are extremely grateful to the community of Guam for their hospitality, interest, and cooperation, which greatly enriched our understanding of Assan and Hågat's historical and cultural significance beyond World War II. Finally, thank you to NOAA Ocean Exploration for making this project possible.

On a personal note, we wish to dedicate this report to loved ones who are no longer with us. From Annie: Thank you to my friend, Jim Pruitt, for allowing me to bounce initial ideas for this project off him. I wish we had gotten that fun dive in. From Monique: Thank you to my Dad, Joseph Eugene LaFrance, for being an inspiration to me, including through his 25-year career in the U.S. Navy and his love of the ocean and fishing. Also for his endless support and always being proud of me. I have and will continue to cherish this project because it provided the opportunity for my family and I to relive shared memories from when my Dad was stationed on Guam when I was growing up. This was a project my Dad and I got to "work on" together. I love you, Dad.

With immense gratitude,

Annie and Monique

Table of Contents

I. Overview

1. Grant number

Not applicable for federal PIs.

2. Principal investigators

Anne Wright Nunn	Dr. Monique LaFrance Bartley
Archaeologist	Coastal Geomorphologist
National Park Service	National Park Service
Submerged Resources Center (SRC)	Water Resources Division (WRD)
Anne_Wright@nps.gov	Monique_LaFranceBartley@nps.gov

3. Total award from NOAA Ocean Exploration:

$326,722.00

4. Project title:

Guam: A Biogeographic and Maritime Cultural Landscape Exploration of a WWII Amphibious Battlefield

5. Area of operation

Guam is a 549 sq km (212 sq mi) island in the Marianas Islands chain in the Pacific Ocean. Field operations for this project were conducted at two (of the seven) units of War in the Pacific National Historical Park (WAPA) on the western coast of Guam: the Asan Beach unit and the Agat unit (Figure 1). At both units, surveys focused on terrestrial coastal lands and submerged lands extending to the 60 m (~200 ft) isobath. The Asan Beach unit is approximately 3.1 sq km (~2.8 km x 1.1 km; 766 acres) in size and the Agat unit area is approximately 2.4 sq km (~3.4 km x 0.7 km;

3 acres). Coordinates of the two study areas are: Asan - 13.4737° N, 144.7089° E and Agat - 13.3845° N, 144.6555° E.

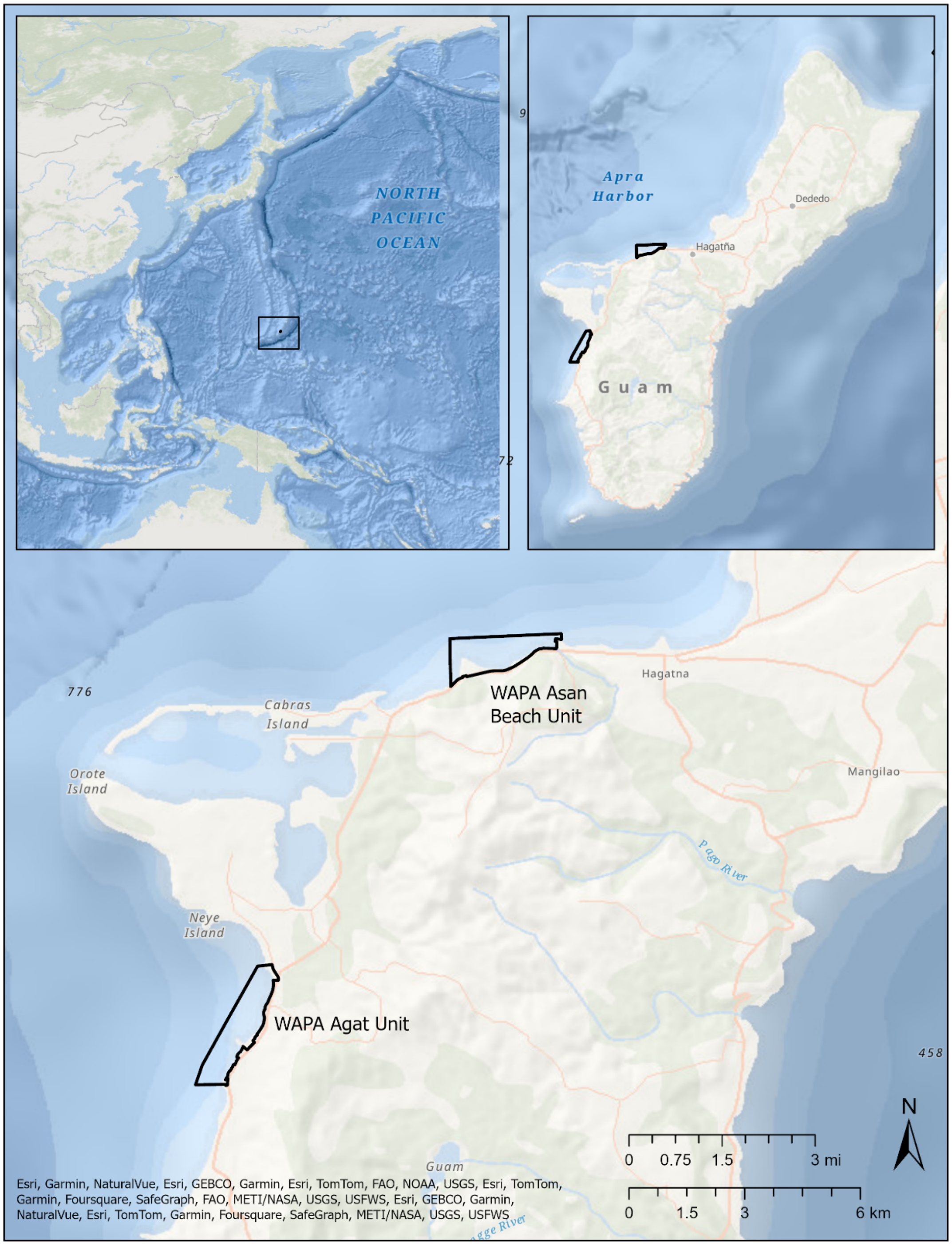


Figure 1. Location of Asan Beach and Agat study areas, both units of War in the Pacific National Historical Park (WAPA). NPS image.

6. Co-PI(s), significant participants, participating institutions, and other affiliated personnel

The project team was composed of staff, interns, and volunteers with a diverse range of expertise and experience. Team members were:

- NPS staff from the Submerged Resources Center (SRC), Water Resources Division (WRD) Ocean and Coastal Resources Program (OCRP), Alaska Region (AKR), and War in the Pacific National Historical Park (WAPA)
- NOAA staff from the NOAA Diving Program
- Interns from the NPS Scientists-in-Parks (SIP) program
- Volunteers from the NOAA Diving Program and Task Force Dagger Foundation (TFDF)

A list of all affiliated project personnel and their roles and responsibilities can be found in Table 2. All activities were coordinated with staff from War in the Pacific National Historical Park (WAPA).

The following text describes the overarching roles and responsibilities of NPS SRC, WRD, and WAPA (the primary participating institutions) as they relate to this project.

National Park Service Submerged Resources Center (NPS SRC)

For more than 40 years, NPS SRC has been a recognized leader nationally and internationally in operational and scientific diving, as well as in the location, documentation, interpretation, and preservation of underwater resources (primarily cultural). SRC embraces an interdisciplinary approach to resource management issues and works actively across disciplines to provide science-based recommendations to parks and partners in line with the preservation mandate of NPS. SRC has a well-documented history of working with NOAA to achieve common cultural resource-related goals. SRC served as the lead coordinator for all aspects of this project, and was the technical lead for the cultural resource aspects of the project. The project utilized the technical expertise of SRC staff, including scientific diving, data acquisition, processing and analysis, and science outreach and communication. SRC ensured that all data was appropriately acquired, managed, stored, and shared. SRC was also the mechanism through which financial contracts and partner agreements were run.

National Park Service Water Resources Division (WRD) Ocean and Coastal Resources Program (OCRP)

NPS WRD OCRP works with the National Park Service's 88 ocean and Great Lakes parks to advance ocean and Great Lakes stewardship through technical assistance, scientific support focused on coastal issues, coordinating policy issues nationally, and leveraging support with partners. OCRP developed COAST (Coastal and Ocean Advisory and Support Team), a Community of Practice to enhance collaboration across disciplines within and outside of NPS. COAST also works to accomplish national-level priority goals, including benthic mapping to support natural and cultural resource management. OCRP actively engages and collaborates with multiple federal agencies, including NOAA, USGS, USACE, and USFWS. For this project, OCRP served as co-lead to SRC for project coordination and implementation; and was the technical lead for the coastal impacts assessment aspects of the project. OCRP has a close relationship with NPS staff in the Alaska Region (AKR) as it relates to mapping (both submerged and coastal elevation surveys). This project utilized the technical expertise of both OCRP and AKR for data acquisition, processing and analysis, and science outreach and communication.

National Park Service War in the Pacific National Historical Park (WAPA)

WAPA was established to commemorate the bravery and sacrifice of those participating in the campaigns of the Pacific Theater of World War II, and to conserve and interpret outstanding natural, scenic, and historic values and objects of the island of Guam. WAPA staff assisted with field logistics by providing the project team with established mechanisms for communications with the Guam State Historic Preservation Office and served as a staging area and operations center during the field campaign in (January-February, May-June, July-August 2023). The park also provided guidance for science communication and outreach, and hosted Outreach Day events during both field campaigns at the WAPA Visitor's Center. WAPA staff also assisted SRC and WRP staff with field and diving operations.

7. Award period:

October 1, 2022 to September 30, 2024

II. Summary

1. Abstract

This project explored and documented the submerged remains of the World War II (WWII) 1944 Battle of Guam within War in the Pacific National Historical Park (WAPA). This battle occurred on July 21st, 1944, when American forces invaded the Japanese-held island.

While some archaeological investigations of the area had previously been completed by the National Park Service (NPS) at various times, this project was the first systematic and comprehensive survey of submerged cultural resources up to the 60m isobath in both the Asan and Agat units of the park. In addition, this project sought to document any archaeological and geomorphological evidence of demolition completed by U.S. Underwater Demolition Teams (UDTs) prior to the invasion. The team also completed LiDAR surveys of terrestrial portions of the Asan and Agat units at two points in time to document and provide insights into the lasting effects of wartime activities and storm events, better understand short-term coastal change, and inform coastal resiliency assessments.

The information, data, and deliverables produced as part of this project provide valuable historical documentation and informs park management in making critical decisions in the context of changing environmental conditions. This project also serves as a valuable long-term tool for guiding park planning efforts, facilitating positive and educational visitor use and experience, and managing park marine and terrestrial resources (cultural, historical, and natural) into the future. In addition, this project contributes to our understanding of WWII activities in the Pacific Theater and helps communicate the story of WWII in the Pacific and the long enduring legacy of the War, provide meaningful interpretive experiences to the public, and continue to honor the role that Guam played in WWII and those who lost their lives.

2. Place Names Terminology

We acknowledge that this project took place on the ancestral lands of the CHamoru people, the original stewards of Guåhan (Guam). For generations, the CHamoru people have cared for this land and passed down traditions, knowledge, and resilience. The project team recognizes the enduring stewardship of the CHamoru people on Guåhan and acknowledge their historical connection to the land and its resources. Historic colonial occupation of the island was undertaken without the consent of the CHamoru people and put the community in a precarious position in the geopolitical and military spheres during World War II. Upwards of 1,170 community members were killed, and over 14,000 people suffered numerous atrocities during the occupation (Palomo and Aguon 2024).

In this report, we refer to the official NPS place names within park units or when referencing primary historical documents. For example, primary source U.S. military reports use the terms “Asan” and “Agat.” To avoid confusion, we have remained consistent with this terminology. However, CHamoru names are used when referencing these locations prior to the park’s founding in 1978, outside of reference to primary historical documentation, or when it was more appropriate to do so.

3. Purpose of project

a. Topics and/or questions that were addressed

During WWII, Guam was a strategic military location for both the United States and Japan. Shortly after the attack on Pearl Harbor in December 1941, the Japanese invaded the American territory of Guam and quickly captured the island. Prior to the invasion, Guam was an American possession for over 40 years and served as an important refueling station for American ships traveling to the Philippines and beyond. Under the Japanese, Guam was an outpost of the Empire and integral to the Japanese plan to dominate the Pacific. The Battle of Guam began on July 21st, 1944 when American forces invaded the island and reclaimed it from the Japanese, marking a significant turning point in the war.

This project had three primary purposes, one of which was to conduct the first systematic and comprehensive study to inventory and characterize submerged cultural resources relating to the 1944 invasion of Guam up to the 200ft isobath in both the Asan Beach and Agat units of WAPA. This study used a maritime cultural landscape approach to characterize and interpret the archaeological resources found at the battle sites. This approach allows researchers to create a complete picture of the sites, drawing from not only historical documentation and the archaeological record, but the history of the natural environment and the knowledge of local people (Ford 2011). Prior to this project, the total amount of war materiel (possibly including shipwrecks, aircraft and aircraft parts, amphibious vehicles, artillery, and related debris) that remained in the archaeological record at the invasion beaches was unknown. Some archaeological investigation had been completed in these areas by NPS and others at various times. For example, the NPS Submerged Cultural Resources Unit's "Micronesia: Submerged Cultural Resources Assessment" (Carrell 1991) report noted two American LVTs (Landing Vehicle Tracked) within the survey area, one off Ga'an Point near Agat Beach, and another off Asan Beach. In addition, preliminary examination of scientific reports, discussion with local archaeologists and scuba divers, and analysis of historical data indicated that there was likely a significant amount of WWII related cultural material deposited on the seafloor near the invasion beaches.

Another primary purpose was to conduct a comprehensive documentation and analysis of the battlescape. This includes assessments of the geomorphology of the theater of war, documentation of features in the archaeological record, and applies adapted military terrain analysis approaches to better understand how the actors might have perceived the landscape. The project used a military terrain analysis approach that was adopted for archaeological purposes called KOCOA (Key terrain, Observation and fields of fire, Cover and concealment, Obstacles, and Avenues of approach/withdrawal) analysis to guide submerged battlefield documentation. This analysis can aid in furthering our understanding of what took place during the invasion and how these events might be evident in the archaeological and natural history record. Military terrain analyses have been adapted by historians and archaeologists to recreate a participant's perception of a battle space to reconcile physical, historic remains of a battle with documented historic accounts (Spennemann 2020).

The third primary purpose of this project focused on examining the resiliency of coastal and submerged features and habitats as it relates to impacts from human actions (e.g. WWII activities), as well as natural processes and climate change (e.g. storm events, sea level rise). Similar to cultural resources, at the Guam invasion beaches and offshore areas, there has been no comprehensive study that assesses the possible resulting long-lasting environmental impact on the island from WWII or the lack of natural material or features as cultural artifacts (e.g., missing reef caused by UDT blasts).

b. Describe list/project objectives

This multidisciplinary project aims to explore cultural and natural resources in relation to the WWII 1944 invasion by mapping and characterizing submerged cultural resources and investigating alterations to the coastal environment and coral reef over time in the context of WWII activities (e.g. UDT demolition) and modern data changes, e.g. from storm events and natural processes. As stated in the proposal, the project had the following goals and objectives:

Project goals

1. Conduct high-resolution remote-sensing surveys (side scan sonar, magnetometer, and bathymetric) according to NPS guidelines for archaeological survey to map the submerged portion of the study areas and provide the datasets necessary to support this study.
2. Conduct photogrammetry, ROV, and diver-based surveys to investigate submerged targets of interest indicated in the remote-sensing surveys, including those potentially containing cultural resources and those related to ground-truthing benthic environments.
3. Conduct photogrammetry surveys to document current structure for the barrier reef at the UDT blast zones, as well as at control sites outside the blast zones for comparison.
4. Complete identification of relevant submerged cultural material.
5. Assess the recovery of the barrier coral reefs and gain a better understanding of what, if any, impact pre-invasion blasting may have had on Asan and Agat beaches in terms of coastal and nearshore processes (e.g. geomorphology, shoreline shape and erosion, hydrodynamic condition) and coastal vulnerability/resiliency. Describe these wartime impacts in the context of more modern-day changes, e.g. from storms and natural processes.
6. Conduct surveys to collect coastal and intertidal elevation data using a scanning total station and RTK GPS at Asan and Agat beaches and nearby beaches for comparison.

Project objectives

1. Produce full-coverage magnetic interpolation maps, side-scan sonar mosaics, and bathymetric mosaics of the study areas.
2. Produce photogrammetrically-derived 3D models and maps of targets of interest found to yield cultural resources related to the 1944 Invasion of Guam.
3. Produce photogrammetrically-derived 3D models and maps of the surveyed portions of the barrier reef and reef flat to assess possible impacts from the UDT blasts.
4. Complete investigations and document findings for targets of interest using photogrammetry and diver-based assessments following AAUS Scientific Diving guidelines.
5. Create a comprehensive inventory and GIS database of remaining submerged WWII materiel within the study areas, along with remote sensing and photogrammetry datasets, impacted coral reef areas, and other relevant findings.

6. Develop maps characterizing geomorphology of the seafloor to better understand hydrodynamic processes influencing the study areas, which may indicate possible changes in environmental conditions and coastal resiliency caused by the UDT blasts.
7. Develop point clouds and beach profile graphs of surveyed beaches to assess if damage to the barrier reef from the UDT blasts has resulted in increased coastal vulnerability (e.g. caused erosional hotspots).

4. Approach

a. Describe the work that was performed

Archival research

Project work began with a visit by PI Wright Nunn to the National Archives at College Park, where a majority of U.S. military archival material related to World War II is housed. Historic photographs of wartime Guam, maps detailing the invasion planning, Underwater Demolition Team reports, and UDT reconnaissance maps were scanned and used for historical research and project planning. This trip proved invaluable as UDT reconnaissance maps led to the discovery and consequent documentation of craters in the reef at Asan created by UDT explosives (See Section II 6b).

Data collection overview

The first field campaign took place from January 27th – February 25th, 2023 and also from May 19th – June 17th, 2023 within the Asan Beach and Agat units of WAPA. Field operations offshore of the coral reefs during this campaign consisted of side-scan sonar, multibeam bathymetry, magnetometry, and photogrammetry surveys (Table 1). Inshore of the reefs, multibeam surveys were conducted at both park units and visual observations along transects were conducted at Asan. In addition, coastal terrestrial elevation data was collected, with point cloud coverage extent including the entirety of the visitor use areas of both park units, from the shoreline including the beach and intertidal zone, rivers, and extending to the main road including the parking lots and facilities (Table 1).

The second field campaign took place from July 16th – August 23rd, 2023. Field operations during this campaign focused on three activities. The primary activity was diver-based investigation of targets identified in the remote sensing data (collected during the first field campaign) and documenting any significant findings. During diving investigations, photographs and photogrammetry data were collected, along with visual observations. The second activity was recollecting coastal terrestrial elevation data within the beach and intertidal portions of the Asan Beach and Agat units. These surveys were a repeat of those completed during the first field campaign and were coordinated with low tide conditions to capture as much of the intertidal zone as possible. The team also worked with the local community to collect oral histories and facilitate community participation in the project during the second field campaign.

Both field campaigns were based on day operations, with instruments deployed and recovered daily. Initial data processing occurred during the field campaigns to ensure quality of data, in addition to top-side monitoring. Additional desk-based data processing and the development of data products was completed following the campaigns. No physical samples were collected during field operations; all data are digital and were collected in a non-disruptive manner.

Aluminum boats (25ft) were used to conduct remote sensing surveys and dive operations offshore of the coral reefs at Asan Beach and Agat units. Multibeam sonar, photogrammetry, and walking visual observation transect surveys conducted within the shallow waters inside of the coral reefs at both units were shore-based operations. The terrestrial coastal elevation surveys conducted at both units were ground-based.

Table 1. Summary of the type of data collected during the two field campaigns. A complete accounting of each field day and the tasks conducted are provided in the two Cruise Field Reports submitted as part of this project.

Data Type	Instrument	Collection Method
Side scan sonar	EdgeTech 4125 and Klein 3000H side scan sonar systems	Vessel-based transects with instrument towed behind vessel
Magnetometry	Geometrics G-882 Cesium Vapor magnetometer	Vessel-based transects with instrument towed behind vessel
Bathymetry	Norbit iWMBSe multibeam system	Transect-based with instrument integrated into a Seafloor Systems Inc. Echoboat-160 ASV
Photogrammetry	SeaArray system (custom built), Nikon D5 camera, Canon 5D camera	Diver swim transects with instrument operated by diver
Visual observations	Olympus Tough TG-6 underwater camera	Walking/snorkel transects with individuals taking notes and photos
Coastal elevation (LiDAR)	Trimble SX10 scanning total station	Land-based scans with instrument mounted on tripod
Coastal elevation (RTK)	Trimble R12i GNSS system	Land-based walking transects with instrument hand-held by operator
Diving anomaly investigations	XCCR rebreather, Inspiration rebreather, Megaladon rebreather, Open-circuit scuba, Aquapulse metal detector, Nikon D5 camera, Canon 5D camera	Divers deployed on a GPS location marked with a line reel and marker buoy and conducted a 15-m circle search of the area. Anomaly photos were taken with one of the cameras listed below, as well as visual observations
Oral History	Sony MP4 recorder, iPhone as back-up recording device	Oral histories were recorded with both Sony recorder and microphone and iPhone as a back-up recording method and stored as a .mp4 or .mp3. Oral histories were also transcribed into written format (pdf)

Data collection, processing, and analysis methodology

Side scan sonar

Side scan sonar uses sound waves to image the seafloor. The data is often used to locate man-made objects laying on or protruding above the seafloor, as well as natural features and habitats. A microsecond-pulsed, vertically narrow acoustic beam is transmitted from each side of the sonar multiple times per second. The beam propagates through the water and across the seafloor in a swath, reflecting incident sound energy back to the sonar sensor. The intensity and time delays of the returned sonar signal is turned into a visual image for display. The result is a bronze-scale image of the seafloor on a color scale of 0 to 255, where 0 is white and represents hard returns and 255 is black and represents soft returns or no return signal. Individual swaths of data can be combined to produce mosaics that represent coverages over wide areas.

The team towed an EdgeTech 4125 (Figure 2) and a Klein 3000H side scan sonar systems to collect acoustic imagery of the seafloor (Figure 3). The distance of the sonar above the seafloor varied, targeting 30% of the water depth. Xylem Brand HYPACK navigation software was used to design the survey area. EdgeTech Discover and Klein Marine Systems SonarPro software were used to collect and monitor the sonar data in real-time. Standard lane spacing of 15m was used and data was collected at a speed of 4-6 kts. The system was operated in conjunction with an EOS Arrow Gold GNSS RTK survey-grade GPS with satellite differential service system for navigation/positional accuracy and to correct for vessel motion (pitch, roll, and heave).

Figure 2. EdgeTech 4125 Side Scan Sonar. Image via EdgeTech.

Sonar data was processed in Chesapeake Technology SonarWiz 7 sonar processing software. Interpretation of these sonar data identified 11 exposed submerged targets within the Agat unit and five at the Asan Beach unit.

Figure 3. Sonar and magnetometer data collection underway off Asan Beach Unit. NPS Photo.

Magnetometer

The team used a Geometrics G-882 Marine Magnetometer (Figure 4) for the identification of magnetic anomalies, including those buried in the seafloor. The G-882 is ideally suited for the detection and mapping of all types of ferrous objects including anchors, cables, pipelines, munitions, and shipwrecks. The cesium- vapor technology provides a high level of sensitivity at 0.004 gammas/ÖHz and has an operating range of 20,000 to 100,000 gammas.

Figure 4. G882 Marine Magnetics magnetometer. Image via Marine Magnetics.

The magnetometer was towed together with the side scan sonar system, allowing for simultaneous co-located data collection (refer to side scan sonar section above for survey details). The target distance of the magnetometer was 10 m above the seafloor. The survey identified 187 potentially significant magnetic anomalies at Agat and 62 anomalies at Asan for a total of 249 magnetic targets of interest.

Multibeam bathymetry

Multibeam sonar data were collected using a Seafloor Systems, Inc. EchoBoat 160 autonomous surface vessel (ASV) mounted with a NORBIT iWBMSe multibeam sonar and an Applanix SurfMaster inertial navigation system (INS) (Figure 5). Survey tracks were planned in Hypack software and designed to acquire full area coverage with a target of 30% swath width overlap (i.e., 100% coverage with 20–30% overlap) in deeper waters beyond the reef crest and 5%-10% swath overlap inside of the reef crest for increased survey efficiency and coverage in these very shallow water depths. Data were collected with the ASV using both towed and autonomous methodology. Autonomous surveys were preprogrammed and run from a command station onshore inside the reef flat area (Figure 6 and 7). Offshore of the reef crest, towed ASV surveys with an onboard command station were conducted, allowing for more efficient use of the battery system within the ASV yielding greater daily overall coverage in the offshore surveys (Figure 8). Surveys were constantly monitored in real time via remote connection with the ASV through Hypack. The matrix fill method was used to assess real-time data coverage. When necessary, survey lines were modified in real time to achieve full coverage.

Figure 5. Photo showing ASV programmed to collect data on an autonomous mission within the reef flat at the Agat unit. NPS photo.

All multibeam data were collected and processed using the HySweep module in Hypack. Data processing followed standard techniques of correcting for tide and 3-d position. Data files from the INS were loaded into the Applanix POSPac MMS software and corrected using a post-processing real time extended correction (PP-RTX) method (improved GNSS position processing). Corrected positioning information was then tied back to the soundings return data in HySweep and corrected for sound velocity along with pitch, roll, and yaw corrections using MBMax64 software. Outlier soundings were removed to clean up erroneous data for the final product. Individual swaths were then combined to form bathymetric mosaics for each area representing water depths. The processed data can be rendered to 10cm pixel resolution. The final bathymetry mosaics were exported at 50 cm pixel resolution as GeoTIFF files and imported into Esri ArcGIS Pro for map creation. These high-resolution bathymetric data depict cultural resources resting on the seafloor, as well as characteristics of the natural environment, including coral structure.

Figure 6. Project team preparing to deploy the ASV. NPS photo.

Figure 7. Project team members manually drive the ASV (left) and monitoring incoming data from shore (right). NPS photos.

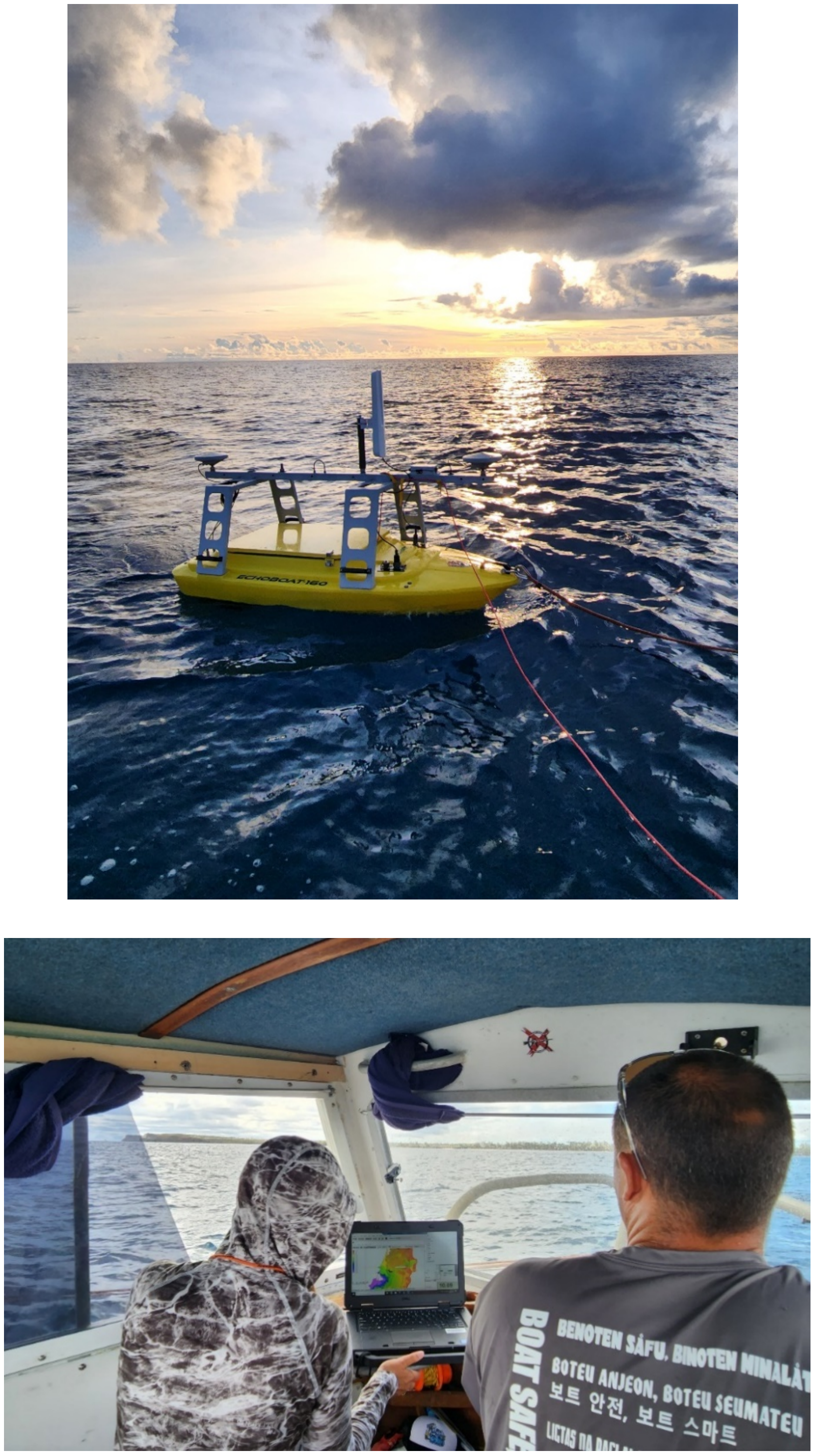


Figure 8. Multibeam survey conducted with the ASV being towed by support vessel (top). Project team monitoring incoming data (bottom). NPS photos.

Geomorphology classification

Publicly available 1 m resolution topobathymetric LiDAR data collected by NOAA (2021) was used to develop seafloor geomorphology classification maps of the Asan Beach and Agat units. This was accomplished using the Bathymetric and Reflectivity-based Estimator of Seafloor Segments (BRESS) algorithm developed by and distributed by the University of New Hampshire's HydrOffice and the Center for Coastal and Ocean Mapping (CCOM). BRESS uses bathymetric digital terrain models (DTM) as the input to classify geomorphic features of the seafloor. The intent of the software is to create classification outputs similar to those that would be created manually by a trained analyst, but with reduced data analysis time, cost, and subjectivity. An output of four classes was selected for the purposes of this project, which includes flat, ridge, slope, and valley.

Target identification

Targets representing potential cultural material were identified primarily using the side scan sonar and magnetometer data. The multibeam data was used to cross-reference some target locations. The location and water depth of targets was entered into a spreadsheet and transferred to a handheld GPS for navigation to the site during diving investigations. Additional information about each target was recorded after each diving anomaly investigation. (See Appendix C).

Photogrammetry

Photogrammetry data was collected using the NPS SeaArray system, as well as a single-DSLR camera when warranted by conditions.

SeaArray is a custom, in-house built, diver-operated three camera photogrammetry system (Figure 9). SeaArray is capable of centimeter-level accuracy over areas of hectares (Wright et al. 2020) and uses an underwater GPS system called UWIS (Underwater Information Systems) that allows the SeaArray operator to track the system's location in real-time while underwater using maps generated in ArcGIS. These maps are displayed on a waterproof tablet and ensured full coverage of the survey areas. SeaArray was used to document the portion of demolished reef at Agat that was used to land LSTs (Landing Ship Tanks) side by side in 1944 (See Section II of this report). The system was also used to document an undemolished coral reef structure at nearby Hap's Reef for comparison. SeaArray collected still digital images of the survey areas with approximately 80% overlap between each photo. These photos were processed into a 3D model and a high-resolution orthomosaic using Agisoft Metashape Professional and 3Dflow 3DF Zephyr software.

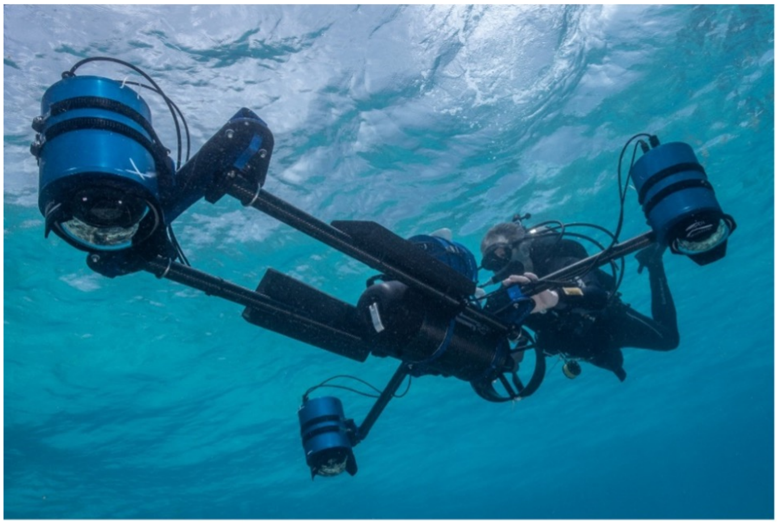


Figure 9. A diver operates SeaArray. NPS Photo.

A similar process was followed for single-camera photogrammetry data collection, which was used for smaller targets in shallow water, as SeaArray can be cumbersome in small areas or extremely shallow water, such as the location of the documented UDT crater at Asan Beach Unit. The team collected photos with an overlap rate of at least 80%, which were processed into a 3D model and high-resolution orthomosaic using Agisoft Metashape Professional. At Asan, the team disconnected the UWIS system from SeaArray and used georectified historic maps loaded onto the UWIS tablet to locate UDT craters by snorkeling to the overlaid location (Figure 10). The historic map was quite accurate, and there were clear demolition holes, or “blast craters” across the reef that aligned with the georeferenced position.

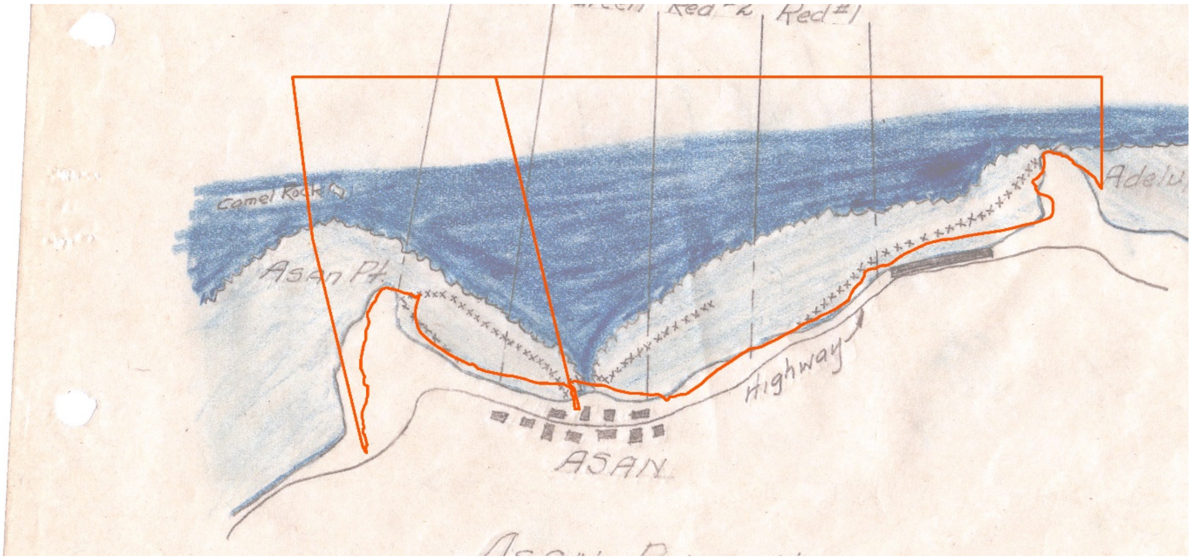


Figure 10. A georectified historic map used on the UWIS tablet for underwater navigation. NPS Map with National Archives at College Park background.

Coastal elevation surveys

A Trimble R12i (R12i) and Trimble SX10 (SX10) scanning total station interfaced with Trimble Access software (Trimble) were used to survey and collect LiDAR data at three park units: the Asan Beach unit, the Apaca Point area of the Agat unit, and the Ga'an Point area of the Agat unit (Figure 11). Survey design provided complete LiDAR coverage of the Asan Beach and Ga'an Point units in February 2023. LiDAR scans of the coastal and beach portions Asan and Ga'an Point were repeated in July 2023, along with complete LiDAR coverage of Apaca Point. Coverage extent includes the entirety of the visitor use areas of both park units, from the shoreline including the beach and intertidal zone, rivers, and extending to the main road including the parking lots and facilities.

Existing benchmarks were used as reference points to anchor the LiDAR scans. The R12i was used to establish scan and prism location points as references (control points) to establish the position and orientation of the scan stations. Use of the WAPA NTRIP base station allowed for real-time kinematic (RTK) corrections, improving the positional accuracy of the scans. The SX10 was positioned at surveyed scan station locations to collect LiDAR scans of the area. Scans were taken using the standard resolution setting resulting in points approximately 5 cm apart at 100 m (~ 5 mm at 10 m) distance. The camera in the SX10 also captured full coverage color images at all scan locations.

The resulting LiDAR scan data are point clouds – x,y,z datasets, where x and y represent coordinates (e.g. latitude and longitude or easting and northing) and z represents elevation. The scans were imported as .JXL files into Trimble Business Center (TBC) and the scans were accurately registered using the software. Scans were colorized based on the images that were taken to improve the classification determination process. The millions of points per scan were classified using the automated point cloud classification tool in TBC. This automated tool is based on a 3D deep-learning semantic segmentation model that is trained on representative datasets encompassing a broad range of geographic locations to ensure widespread applicability (Trimble 2023). This approach defines certain rules for point cloud classification into buildings, vegetation (high and medium), poles, signs, ground, noise (e.g. people, vehicles), steps, power lines, and dividers. This effort was able to accurately classify about 80% of the identified points and assign them to classification regions containing all like points. These classification regions were then manually refined to include beach, beach margin, riprap, monuments, cultural sites and artifacts, trails and sidewalks, parking lots and roads, and park infrastructure (e.g. picnic tables, benches, trash cans, bollards, etc.). Errors within each region were systematically classified and assigned to appropriate regions. Point cloud data from the February and July scans were generally classified simultaneously where appropriate to improve efficiency.

Surface models, or digital surface models (DSMs), of classified ground regions (i.e., beach, beach margin, riprap, ground, parking lots and roads, trails and sidewalks) were created using the "Create Surface" tool in TBC. This tool produces a triangulated irregular network (TIN) that approximates the surface by drawing triangles between neighboring selected points. Separate TINs were created for the February and July datasets. Both TINs were then refined by trimming unnecessary surface edges and reclassifying abnormal points. Next, using the "Create Contours" tool in TBC, smoothed contours were drawn at elevation increments of 5cm on each TIN and colored by elevation. The resulting contours for Asan and

Ga’an Point were exported as ESRI file geodatabases to ArcGIS Pro to conduct a DSM change analysis of the datasets between the two time points.

Change analysis was conducted using difference surfacing in TBC. The surface elevation from July 2023 was subtracted from the February 2023 elevation. Areas with a positive result indicate a net increase in elevation at these locations (accretion), while areas with a negative result indicate a net loss of elevation (erosion).

Figure 11. Project team members collecting LiDAR and GNSS data at the Asan Beach and Agat Ga’an Point units.

Target investigation

Diving investigations were conducted by a team of two or three divers (depending on depth range and CCR-bailout requirements) from a 25 ft aluminum boat. Prior to the dive operations, all anomaly/contact locations were loaded into a hand-held GPS. Before the start of each dive, the boat captain navigated to the precise GPS location and the team deployed a weighted line-reel with an attached buoy to mark the location. Once the dive team completed safety checks, they entered the water and descended down the marker line. Each dive team carried a camera, scale bar, north arrow, metal detector, and line reel. Once on the bottom, one diver deployed a line reel and a second diver swam out five meters (or less, depending on visibility conditions) with the end of the line. The second diver began a circle search using the underwater metal detector. Once a full circle was complete, the first diver let out additional line to the second diver, and the circle search continued either until the source of the anomaly or contact was located, or until the team had completed a circle search out to the 15 m mark.

If an artifact was located, the team photo-documented it with a digital camera. In some instances, if the artifact and/or site was significant, a dive team returned to collect photogrammetry data. If no artifact was found, the anomaly or target number was marked as “No find” and recorded in the anomaly/target spreadsheet (See Appendix C).

In total, the team completed 162 anomaly/target investigations between both survey areas. 100% of identified magnetic anomalies and side scan sonar targets were investigated in the Asan survey area. 48% of identified anomalies and side scan sonar targets were investigated in the Agat survey area. Impacts of Typhoon/Hurricane Dora caused storm conditions that prevented the completion of investigations at Agat.

Oral history

The oral history portion of this project was planned using NPS and Oral History Association best practices guidelines (Oral History Association 2023). All interviewees provided informed consent documentation to NPS and were given the opportunity to confirm and approve a transcript of their interview prior to finalization. Prior to the interview, interviewees were given a detailed project description and held a pre-interview discussion with Wright Nunn (PI) and Moore (lead for the oral history aspect of this project). Interview questions were planned but served as a discussion guide to allow for the interviewee to share themes of interest to them.

Oral histories were recorded by project team members using a Sony .mp4 Recorder and an iPhone as a back-up recording device. After the interview was complete, oral histories were digitally transcribed. Interviewees were provided a copy of the transcription for their review and approval.

Coral assessment

To better understand the relationship between the coral assemblage and the historic seascape of the park, coral cover and composition were compared to structural complexity and habitat configuration metrics. This analysis aimed to xidentify which metrics were most strongly correlated with coral cover and composition, as well as to facilitate comparisons between the Asan Beach and Agat units. The resulting bathymetry from the multibeam sonar data were imported into ArcGIS Pro, where rugosity, slope, roughness, and connectivity metrics were calculated. Coral cover and composition was derived from the Pacific Island Network Benthic Marine Monitoring Dataset (McKenna and Brown 2023), Coral Species Inventory (O'Connell et. al. 2024), and the WAPA Reef Flat surveys (Figures 12 and 13). Analysis is being conducted in R using Generalized Linear Models (GLMs). This work is ongoing, and the results will be made available in the future as an addendum to this report or as a separate report uploaded in the same NPS Data Store (IRMA) record. The resulting data will also be included in the forthcoming data package.

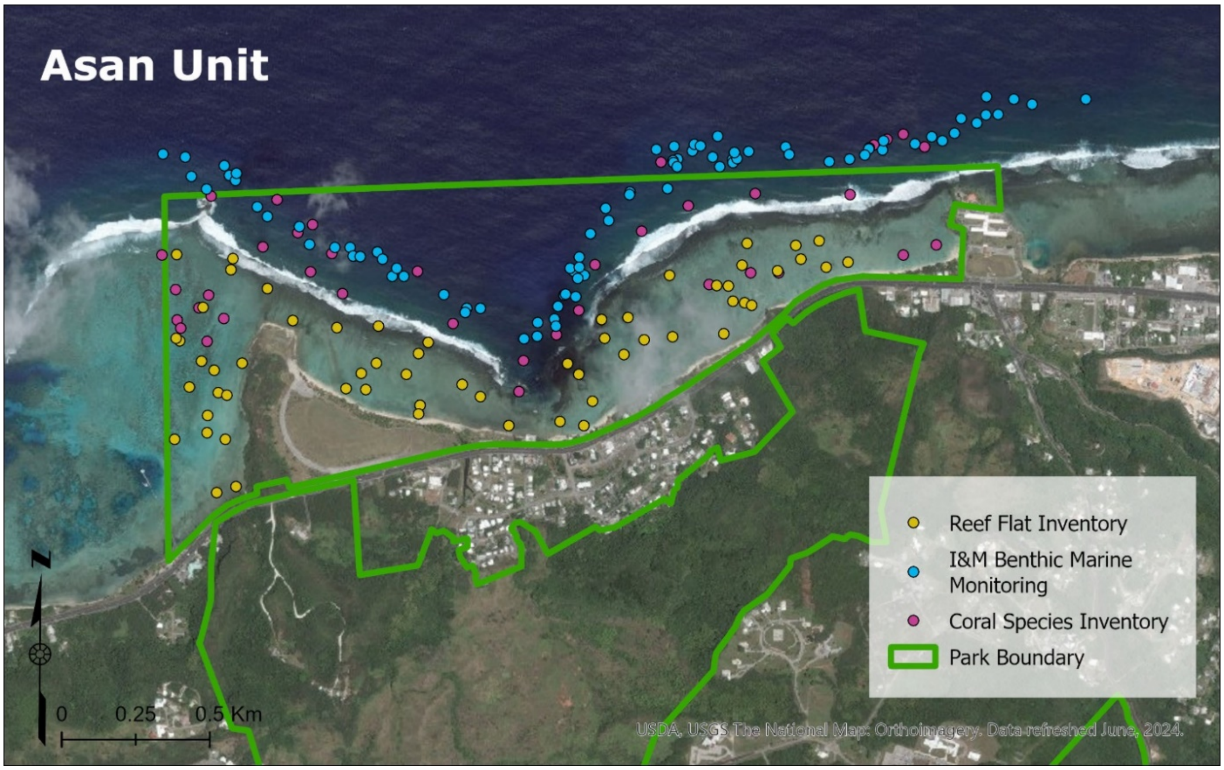


Figure 13. Available coral data from Agat Unit.

b. Describe how the project was organized and managed (e.g., roles and responsibilities of participants)

Table 2 below provides a summary of each project participant and their primary roles and responsibilities throughout the project.

Table 2. List of fieldwork participants and primary roles and responsibilities.

Participant	Affiliation	Title	Roles and Responsibilities
Anne Wright Nunn (PI)	NPS SRC	Underwater Archaeologist	Project co-lead and coordinator; co-lead for field operation logistics; lead for target investigation via technical diving and walking surveys; assisted with photogrammetry operations; assisted with oral history data collection; data manager; archaeological battlefield analysis; report author
Brett Seymour	NPS SRC	Audiovisual Production Specialist	Lead for photogrammetry operations; lead for technical diving operations; photographer
Matt Hanks	NPS SRC	Underwater Archaeologist	Lead for side scan and magnetometer surveys; data manager; participated in target investigation via technical diving and walking surveys
AJ Van Slyke	NPS SRC	Underwater Archaeologist	Assisted with side scan and magnetometry surveys
Dave Conlin	NPS SRC	Underwater Archaeologist	Assisted with side scan and magnetometry surveys; assisted with budget management
Monique LaFrance Bartley (Co-PI)	NPS WRD	Coastal Geomorph-ologist	Project co-lead and coordinator; co-lead for field operation logistics; co-lead for multibeam and coastal elevation data acquisition; multibeam data processing; data management; assisted with oral history component; report author
Tahzay Jones	NPS WRD + AKR	Coastal Ecologist	Co-lead coastal multibeam and elevation data acquisition; multibeam data processing; coastal LiDAR data processing; data management; report author
Blair Moore	NPS SIP Intern (SRC + WRD)	Underwater Archaeologist	Participated in target investigation via diving and walking surveys; led oral history data collection; developed lesson plans; report author

Liza Hasan	NPS SIP Intern (AKR)	Marine Ecologist	Assisted with coastal elevation, multibeam sonar, and snorkel surveys inside of reef crest
Olivia Helinski	NPS SIP Intern (WRD)	GIS Analyst	Assisted with coastal elevation, multibeam sonar, and snorkel surveys inside of reef crest
Julia Young	NPS SIP Intern (WRD)	GIS Analyst	Assisted with coastal elevation surveys
Marisa Agarwal	NPS SIP Intern (WAPA)	Marine Biologist	Participated in target investigation via diving surveys
Natalie Scott	NPS SIP Intern (WAPA)	Marine Biologist	Participated in target investigation via diving and surveys
Cameron Soulagnet	NPS SIP Intern (WRD)	Natural Resource Assistant	Co-led development of StoryMap; coastal LiDAR data processing
Audrey Brown	NPS SIP Intern (WRD)	Natural Resource Assistant	Co-led development of StoryMap; coastal LiDAR data processing; report author
Lauren Hintenlang	NPS SIP Intern (WRD)	Ecology Assistant	Coastal LiDAR data processing; report author
Nicole LaRoche	NPS WRD	Coastal Mapping Specialist	Multibeam bathymetry data processing; report author
Jamie Kilgo	NPS WRD	Marine Ecologist	Coral assessment
Joe Hoyt	NOAA Diving Program	NOAA Diving Program Manager; Underwater Archaeologist	Participated in target investigation via technical diving and walking surveys; NOAA technical diving supervisor; photographer
Mikey Kent	NOAA Diving Program	Training Specialist	Participated in target investigation via technical diving and walking surveys; NOAA technical diving supervisor
Jason Nunn	NOAA Diving Program Volunteer	Diving Safety Officer	Participated in target investigation via technical diving and walking surveys; NOAA technical diving supervisor
John Dailey	TFDF Volunteer	Diver	Participated in target investigation via diving and walking surveys
Worth Parker	TFDF Volunteer	Diver	Participated in target investigation via diving and walking surveys
Luis Cabral	Community Volunteer	Diver	Participated in target investigation via diving

c. Describe how data was organized, processed, and archived to meet NOAA data management requirements

Archiving, stewardship, and availability

All files (including data and other deliverables) associated with this project adhered to the Data and Information Sharing Plan (DISP) developed in the project proposal.

During the field campaigns, the original copy of data remained on the collection device and two copies of the data were saved to external hard drives, ensuring three complete copies of all data collected. Data were copied at the conclusion of each day and checked for quality the same evening. Data were organized by type and day for ease of reference. The same protocol applies to processed data and resulting deliverables; three copies organized by type exist on a combination of computers, hard drives, and cloud storage solutions. For instances where there are multiple copies of a given dataset or deliverable stored on computers and/or hard drives, these devices are in different physical locations to provide additional protection.

All geospatial data is accompanied by FGDC (Federal Geographic Data Committee) or ISO (International Organization for Standardization) metadata.

The project team will provide NOAA NCEI with all raw and processed data types they accept for archiving, stewardship, and discovery. NPS has an Inter-Agency Agreement (IAA) with NOAA NCEI that establishes a mechanism for NCEI to ingest, archive, and make accessible NPS mapping data, including for this project.

The photogrammetry 3D models created for this project have been uploaded to SRC's Construkted Reality web profile (https://construkted.com/profile/nps-submerged/?active_tab=posts).

In addition, once the project report and deliverables are finalized, they will be uploaded to the NPS Data Store (irma.nps.gov/Portal/). The project team is in the process of creating a dedicated project entry, which will also include a brief description of the project and contact information for the PI and Co-PI. The Data Store facilitates public access of the deliverables, though user-restrictions can be applied to each deliverable, as needed. This capability will allow the Data Store to house a complete record of project deliverables, while ensuring responsible access (e.g. to limit access to sensitive information), which will be determined in consultation with NOAA Ocean Exploration staff and WAPA park staff.

To facilitate awareness of the project and deliverables, links to both the NPS Data Store and Construked Reality will be posted on the public-facing websites for SRC (www.nps.gov/orgs/1635/index.htm) and OCRB (https://www.nps.gov/orgs/1439/oceans.htm), as well as on OCRB's SharePoint site (internal to DOI).

Copies of the records (in part or in full) can be provided upon request (e.g. if not available by other means described above) by contacting the project PI or Co-PI. A backup copy can also be provided to NOAA Ocean Exploration, if desired. WAPA will also be provided with a complete copy of all finalized data.

Accessibility

Per the NOAA Information and Guidance document, the project team acknowledges that "Data must be made available in at least one machine-readable format, preferably a widely used or open-standard format, and should also be accompanied by machine readable documentation (metadata), preferably based on widely used or international standards (ISO)."

All outreach materials already distributed as part of this project have been made 508 compliant, including the StoryMap and documentary video (see Section II 7b of this report). All other written materials (including this report) and maps created for this project will also adhere to Section 508 compliance requirements. Metadata will be developed for all records as appropriate.

Data and information deliverables:

Final project deliverables will be provided in basic file formats that can be accessed using freely available software or open-source viewers to ensure accessibility by all users. Deliverables will also be provided in current industry standard file formats (may be proprietary) where applicable to facilitate ease of use, e.g. by professionals.

5. Historical background and significance

See section II 2 "Place Names Terminology" for clarification between military/NPS and CHamoru place names.

a. Historical background

On December 8, 1941, four hours after the attack on Pearl Harbor (the date difference between December 7th (Pearl Harbor Day) and December 8th is due to the International Date Line), the Japanese attacked Guam. Rising tensions in the Pacific led to an evacuation order for all dependents and family of American military personnel stationed in Guam several months earlier. Just days before the attack on Pearl Harbor, diplomats from Japan and the United States met in Washington DC in an attempt to deescalate the rising tension in the Pacific, but failed to avoid war. On December 6, all classified U.S. military records on Guam were destroyed in preparation for an attack (Carano and Sanchez 1964).

For two days, beginning at 8:30am on December 8th, the Japanese bombed the island, focusing much of these efforts on U.S. military installations, including Piti Navy Yard, Apra Harbor, the patrol boat/minesweeper USS *Penguin*, the U.S. Marine barracks, the radio station at Libugon, and the Pan American Airways station. (Carano and Sanchez 1964, WAPA 1994a). The planes also strafed civilian areas, including Piti and Hagåtña. In the early morning of December 10th, the Japanese South Seas Detachment landed on the island, comprised of 5,500 Army troops and 400 Navy personnel (Figure 14). The Japanese first encountered CHamoru civilians at Apurguan, where thirteen men, women, and children were killed by the invasion force (WAPA 1994a).

Figure 14. An artist's depiction of the Japanese South Seas Detachment invading Guam by Kohei Ezaki. Image via U.S. Naval Institute Photo Archive.

Left to defend Guam were 120 members of the Guam Insular Force Guard (Figure 15), 274 U.S. Navy personnel (more than half of who were non-combatants), and 153 U.S. Marines (Palomo 1994). A large part of the Guam Insular Force Guard, along with a handful of the U.S. Navy personnel, were ordered to defend Hagåtña against the Japanese landing force at the Plaza de España with only three machine guns and a few small arms and rifles (WAPA 1994a, Quinata 2023). Before dawn, members of the Guam Insular Force Guard and U.S. Navy personnel gathered to fight. When the Japanese arrived in the village, the combined forces fought for half an hour. 21 members of the Guam Insular Force Guard and U.S. Navy and an unknown number of Japanese forces were killed. U.S. Navy Captain George McMillan ultimately surrendered to prevent the massacre of his troops (Quinata 2023).

Figure 15. The Guam Insular Force Guard. Date unknown. Photo courtesy of Guam Public Library System via Guampedia.

The Imperial Japanese Army ruled Guam from December 10, 1941 until July 21, 1944. 6000 Japanese troops occupied the island for the first few months of the war, and the island was renamed Omiya Jima (Great Shrine Island). The Japanese Navy Department of Civil Administration took charge of the day-to-day administration of the island, seizing all public buildings and churches, and some private homes (, Iwamoto 2020, Nelston et al. 2003).

As the war continued and American forces crossed the Pacific, the Imperial Japanese Army asserted that the Marianas Islands were Japan's final line of defense before the war reached Japanese shores, and must be defended at all costs. 18,500 Japanese troops were deployed to Guam, and the Imperial Japanese Army, rather than the Department of Civil Administration, was given control. The Army quickly built up military fortifications, and forced the CHamoru people into slavery. CHamoru men were forced to build airstrips and other military installations, install gun emplacements, build shoreline defenses, and other manual labor. CHamoru women and children worked in the fields to grow food, almost all of which was seized by the Army (Iwamoto 2020). The CHAmoru endured brutal beatings, intense propaganda, forced labor, rape, and executions under the Japanese Imperial Army. Massacres took place at Fena, Tinta, Faha, and Yigo. (Blaz 2023).

Just days before the American invasion, the Japanese ordered 18,000 CHamorus (nearly the entire population) to concentration camps near the island's interior, where they spent most of the Battle of Guam (Blaz 2023).

b. Underwater Demolition Teams on Guam

Introduction

Prior to World War II, the U.S. military did not have specialized units trained in the demolition of underwater obstacles, objects, and natural features (Department of the Navy 1945c). In July of 1943, the U.S. Navy established a naval combat demolition training program at the Amphibious Training Base in Fort Pierce, Florida, intended to train small units in reconnaissance and demolition focused on European operations (Department of the Navy 1945c).

The submerged landscape of many of the Pacific Islands included terrain features that U.S. forces had not previously encountered in battle, including coral reefs with breaking waves and sandbars. The U.S. Navy and Marine Corps found need for specialized units trained in underwater demolition after the disastrous amphibious landings at Tarawa, when the lack of military experience with these natural features became apparent. While pre-landing intelligence had been collected by submarine and aerial surveillance, it was not in enough detail to indicate the shallow nature of the atoll's coral reefs, or account for tidal variation. Landing crafts carrying marines were forced to lower their ramps approximately 500 yards from the beach, where the marines attempted to wade ashore, slowed by heavy gear, varying water depths and reef structure, and Japanese fire. The results were catastrophic, and after the first day at Tarawa almost one-third of the initial landing force was wounded, missing, or dead (Dubbins 2022).

After the landings at Tarawa, the U.S. Navy established a new Underwater Demolition Team (UDT) training center at Waimanalo, Hawai'i, that trained demolition crews in the conditions of Pacific Islands, specifically coral atolls. Due to the possession of a skillset similar to the role of the UDTs, the U.S. Navy filled some UDT training slots with members of the Naval Construction Battalion who had participated in coral lagoon clearance projects in other areas of the Pacific. By November 1943, there were thirty officers and 150 enlisted men in training at Waimanalo (Department of the Navy 1945c).

Each Underwater Demolition Team consisted of sixteen officers and eighty enlisted men, divided into a Headquarters Platoon of four officers and twenty enlisted men, and four Operating Platoons of three officers and fifteen enlisted men each (Department of the Navy 1945c). The Headquarters Platoon filled the administrative, medical, supply, and maintenance role for the UDT, and the Operating Platoons conducted reconnaissance, hydrographic survey, and demolition operations (Department of the Navy 1945c). At Waimanalo, UDT personnel were trained in endurance swimming and free-diving, the recognition of different types of coral formations (i.e. shelf reefs, fringing or barrier coral reefs, and coral pinnacles), knowledge of explosives and their specific use in the demolition of coral formations, and explosives loading (Department of the Navy 1945c). While UDTs were often placed in unusually hazardous environments, they did not receive the additional hazard pay given to air crews, sailors on submarines, and combat infantrymen (Hamilton 1945).

Underwater Demolition Teams 3, 4, and 6 participated in the landings at Guam (Department of the Navy 1945a, 1945b, and 1945d). UDTs 3 and 4 were formed to include members who were previously part of UDTs 1 and 2 and had combat demolition experience from the Marshall Islands Campaign (Department of the Navy 1945a and 1945d). After UDTs 3, 4, and 6 completing their training in the spring of 1944, the teams were held in reserve for the landings on Saipan but were ultimately not needed during the operation (Department of the Navy 1945a, 1945b and 1945d). The landings on Guam were the first time that UDT 3, 4, and 6 saw combat as a unit.

After the invasion of Saipan, the UDTs waited at Eniwetok (now known as Enewetak Atoll in the Marshall Islands) before proceeding to Guam. While there, UDT 4 built replicas of Japanese obstacles observed during the landings on Saipan and experimented with the most efficient ways of demolishing them (Department of the Navy 1945a). These obstacles were 6x4 foot coconut log cribs filled with coral rubble. UDT 4 found that the most efficient method for disposing of these obstacles was by placing two packs of tetrytol on the seaward side of each crib (Carberry 1944).

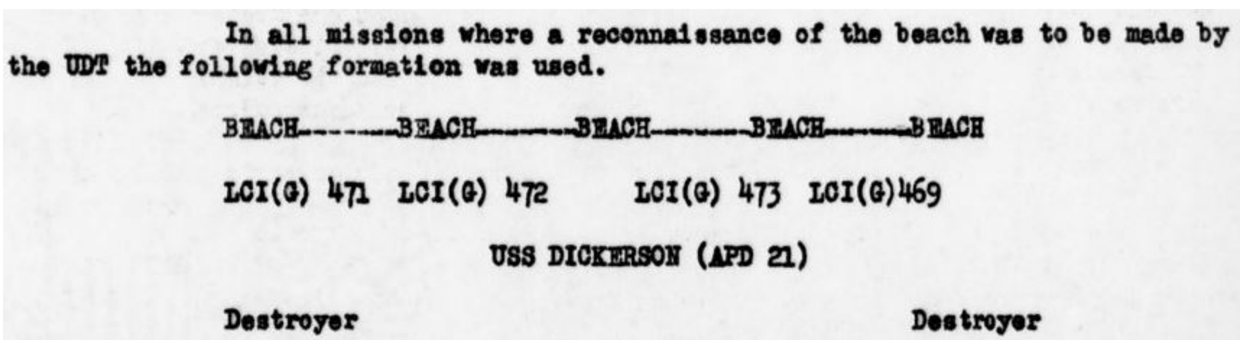
Pre-assault reconnaissance and demolition

The first phase of UDT work was categorized as pre-assault reconnaissance. Reconnaissance missions were intended to allow UDTs to collect information regarding water depth and conditions, to determine the extent of coral reefs and mark their boundaries with marker buoys, and to determine the amount, size, and nature of man-made obstacles. UDTs began the reconnaissance phase by reading all available intelligence reports, including aerial photographs and tide charts. The teams then deployed to the beaches to collect additional information, such as the information included in this passage describing the landing beach at Asan from Underwater Demolition Team 3 (1945d):

> *"…This was found to be an excellent beach for ship to shore movement. There was a reef extending 200 to 350 yards from shore all along the beach, with 18" to 24" of water at high tide and completely exposed at low tide. The surf was very light...The surface of the reef was flat,*

hard, and there were very few boulders and pot-holes. The edge of the reef, contrary to what was indicated by Aerial Reconnaissance, did not break off sharply, but had a gradual slope from 18" of water at edge of reef to about 6' of water 100 feet from edge of reef. There were numerous fissures about 100 feet from outboard edge, but these started in over 6 feet of water. The enemy had placed obstacles in an almost continuous front along the reef…These obstacles were piles of Coral rock inside a wire frame made of heavy wire net similar to 'Cyclone' fencing. They were 3 to 5 feet in diameter, 3 to 4 feet high and 5 to 8 feet apart. Some of them were incomplete, and there were indications that the enemy intended to build more. No mines were located" (Department of the Navy 1945d pg. 3).

During reconnaissance missions, UDTs were protected from Japanese fire by fire support from the following types of ships; APDs (High-Speed Transport), DDs (Destroyer), LCIs (Landing Craft, Infantry), and LCPRs (Landing Craft, Personnel, Ramped) (Department of the Navy 1945a and 1945c) (Figure 16). These ships fired at Japanese shore installations before and during UDT work on the reef, often over their heads. The LCI(G) vessel type was maneuverable enough to allow an LCI to navigate in close to the reef, and "afforded almost complete protection enabling them [UDTs] to work during the daylight hours as well as at night" (Fisher 1944 pg. 2). The fire support formation included a line of four LCI(G)s along the reef edge, with an APD and two destroyers in the rear, as illustrated by Fisher (1944), an LCI Commander, in Figure 16. An observer from the UDT was placed on each LCI to act as liaison and advisor between the ship and the UDT (Fisher 1944).


In all missions where a reconnaissance of the beach was to be made by the UDT the following formation was used.

BEACH--------BEACH--------BEACH--------BEACH--------BEACH

LCI(G) 471 LCI(G) 472 LCI(G) 473 LCI(G)469

USS DICKERSON (APD 21)

Destroyer Destroyer

Figure 16. Fire support formation during UDT work on Asan and Agat Beaches, as illustrated by Fisher (1944). Image via National Archives at College Park.

UDT 3 was the first of the teams to arrive off Guam on July 14, 1944. They began reconnaissance operations the same day at Asan Beach. Four LCPRs (Landing Craft Personnel - Ramp) were sent to four landing areas within Asan (Red 1, Red 2, Green, and Blue Beaches), illustrated in Figure 17. Each boat put two UDT swimmers in the water to inspect the reef and place marker buoys delineating the edges. Responding fire from the Japanese was very light during initial reconnaissance (Crist 1944).

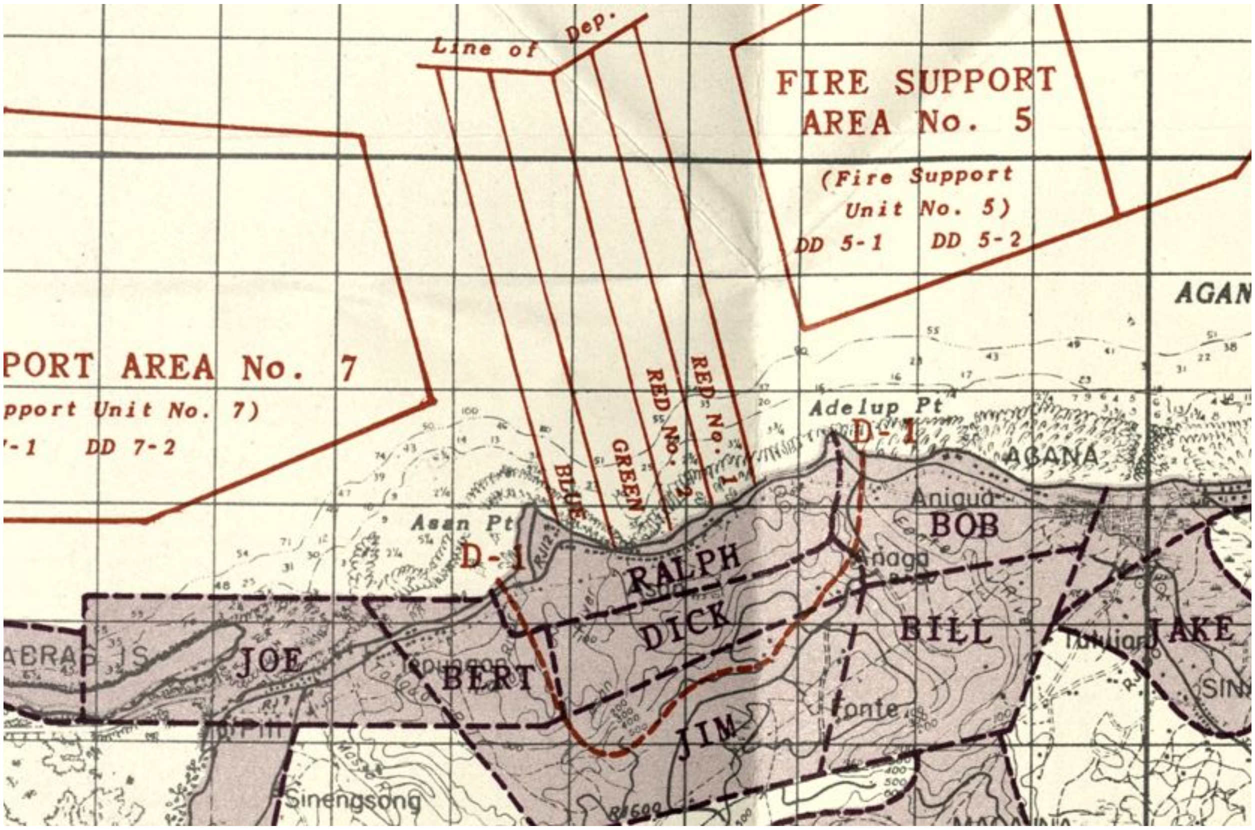


Figure 17. Task Force 53 Operations Chart indicating the division of Asan Beach into Red No. 1, Red No. 2, Green, and Blue Beaches. Image via National Archives at College Park. Declassification Authority NWMDM-D 994011.

UDT 3 also conducted diversionary reconnaissance off Agana beach on July 14th, intended to confuse the Japanese regarding which beaches the full landing force would use on W-Day. The procedure for diversionary reconnaissance was largely the same as real reconnaissance, with the exception that the teams only simulated putting swimmers in the water (Crist 1944). Diversionary reconnaissance also revealed the location of shore defenses and gun emplacements outside of the planned landing force areas, as Japanese forces often fired at UDT boats during diversionary (and real) reconnaissance operations. American forces were then able to bombard these locations once their positions were revealed.

At night on July 14th, UDT 3 returned to Asan, and worked to the water line on the beach, where considerable Japanese activity was observed, including truck movement, a cement mixer, and many small moving lights (Crist 1944).

The following day, UDT 3 conducted diversionary reconnaissance of Dadi Beach and the beach between Facpi and Bangi points. While the LCPRs carrying UDT swimmers headed into the beach at Dadi, Japanese shore batteries on Orote Point and Yona Island fired upon the U.S.S. *Dickerson* (a destroyer providing fire support to UDT 3) and supporting LCIs, revealing their positions. In addition, the LCPRs drew mortar and small arms fire (though it was reported as inaccurate) as they approached the reef to simulate dropping off swimmers. Supporting fire attacked the Japanese positions on Orote Point and Yona Island. At Facpi/Bangi points, Chief Warrant Officer R. A. Flowers was killed by machine gun fire. He was the only casualty of UDT 3 during the Guam operation (Crist 1944).

On July 16th, UDT 3 completed their final day of reconnaissance by completing diversionary missions at Tumon Bay and Agana Beach (Crist 1944).

UDTs 4 and 6 arrived off Guam on July 17th and began reconnaissance operations (Carberry 1944 and Logsdon 1944). The teams were sent to complete reconnaissance at Agat Beach after LCIs shelled the area (Carberry 1944). UDT 6 also completed additional reconnaissance at Asan (Logsdon 1944).

Regarding obstacles, reconnaissance missions found that:

> *"In general the cribs were four feet wide, six feet long and four feet high. They consisted of coconut log structure lined with wire and filled with coral. These cribs were located on the coral shelf, the nearest of which being approximately one hundred and fifty yards from the beach. The spacing was irregular with an estimated minimum distance of six feet between. The general pattern was an irregular single line parallel to and covering the entire mile of the beach. These obstacles were out of water. A 3/8" (three-eights inch) to one-half inch (1/2") wire cable was stretched between cribs, being attached at the top of cribs and sagging to within one foot off the coral floor" (Carberry 1944 pg. 1-2).*

The removal of obstacles was slated to begin on July 17th, but was delayed due to the grounding of an LCI (Landing Craft - Infantry) on the reef, and thus began at 1am on July 18th (Crist 1944). UDT 3 removed 270 obstacles over the course of the day and night from Blue, Red 2, and Green Beaches at Asan (Crist 1944). Meanwhile, UDT 4 worked on obstacle removal at Agat, though the team's report (Carberry 1944) does not specify the total number of obstacles removed. They also began expansion of a natural channel at Yellow Two Beach (indicated in Figure 18) to make it large enough to accommodate LCMs (Landing Craft – Mechanized) and conducted reconnaissance of White Beach (Carberry 1944, Department of the Navy 1945a).

On July 19th, UDT 3 removed 134 obstacles from Red 1 Beach and 130 from Blue Beach (Crist 1944). UDT 4 removed 15 remaining coral crib obstacles (likely similar to those shown in Figure 19) from Hågat Beach and continued developing the channel at Yellow Two Beach (Carberry 1944).

On July 20th, the final day of demolition before W-Day, UDT 3 removed 90 obstacles from the left side of Red 1 Beach to Adelup Point (shown in Figure 19) (Crist 1944). UDT 4 conducted clean-up work and hydrographic survey and marked several additional coral heads and obstructions found in the water for landing craft to avoid the following day.

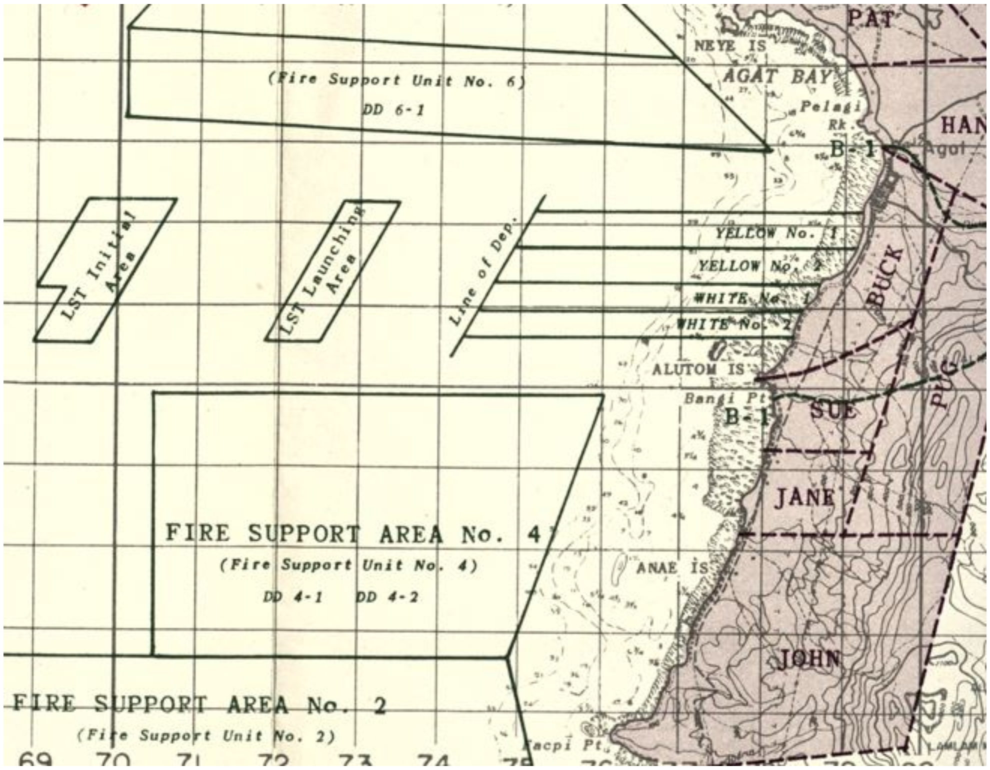


Figure 18. Task Force 53 Operations Chart indicating the division of Agat Beach into Yellow No. 1, Yellow No. 2, White No. 1, and White No.2 Beaches. Image via National Archives at College Park. Declassification Authority NWMDM-D 994011.

Figure 19. Obstacles near Adelup Point. Image via National Archives at College Park, Record Group 127 United States Marine Corps Geofiles.

The method used for demolishing obstacles with Tetrytol (Figure 20) is described by the Department of the Navy (1945d) in UDT 3's War History:

> *"Each platoon of 15 men left APD in LCPR, towing behind them two rubber boats loaded with 30 packs of Tetrytol (21#/pack). As LCPR approached reef rubber boats were cast off with 5 or 6 men in each one. These were paddled to as close to obstacles as possible. A double line of primacord was run down obstacles to be removed. One pack Tetrytol* [shown in Figure 20] *was placed on each obstacle and tied in to primacord leads. Two caps were used on each lead. When all obstacles were loaded fuse lighters were pulled, men returned to LCPR in rubber boats. As a rule 4 minute fuses were tied in together resulting in continuous explosion along entire row of obstacles. In cases of small or unfinished obstacles only ½ pack of Tetrytol was used. In all cases obstacles were completely removed. In some instances obstacles were less than 50 yards from beach and reef was completely dry, making it necessary for demolition men to run across 150 yards of exposed reef to reach objective. The average time for a platoon to remove 30 obstacles was 16 minutes from time rubber boats left LCPR until shot was fired" (Department of the Navy 1945d pg. 3).*

When removing obstacles, the UDTs applied a "more is more" approach to the number of explosives applied to an obstacle or reef structure. "…overloading is the only guarantee that a job will be well done the first time. Reloading a reef shortly after it has been blasted is almost impossible since, in most cases, several hours must elapse to permit the water to clear." (Department of the Navy 1945c pg. 19).

A UDT blast can be seen in Figure 21.

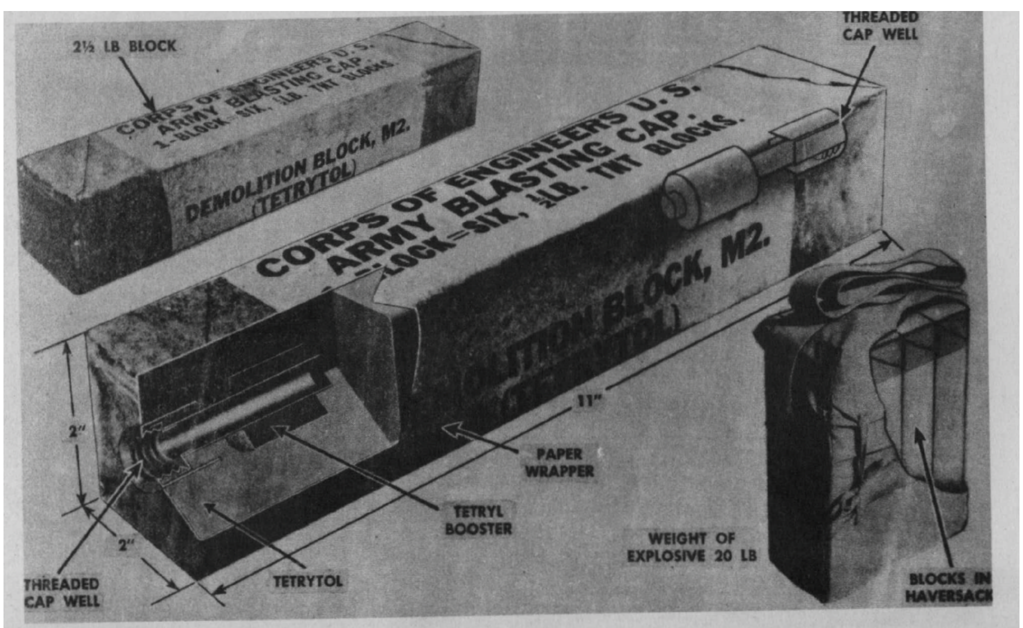


Figure 12.04b. M2 demolition block.

Figure 20. A diagram of a tetrytol pack. Image via Department of the Navy.

Figure 21. A UDT Blast in Guam. Photo courtesy of the National Museum of the U.S. Navy via National Archives at College Park, Record Group 80G: General Records of the Department of the Navy.

UDTs on W-Day

The full amphibious force landed on Guam on July 21, 1944, known as W-Day, or William Day (Department of the Navy 1945d). Under command by the Beachmaster, UDTs 3, 4, and 6 acted as pilots during the landings, guiding LCMs (Landing Craft, Mechanized), LCTs (Landing Craft, Tank), and LSTs (Landing Ship, Tank) that made up the landing force ashore (Carberry 1944, Crist 1944, and Department of the Navy 1945a). They also maintained buoys marking undemolished coral pinnacles and obstructions throughout the day (Carberry 1944).

The only casualty of UDT 4 during the Guam operation, Ensign T. D. Nixon, was killed by sniper fire on W-Day while leading landing craft ashore.

When U.S. Marines landed on the beach at Agat, they were greeted by a sign welcoming the Marines to Agat (Figure 22). The sign was placed by UDT 4 during pre-landing reconnaissance and demolition operations, with the facetious intent to inform the Marines of who landed on the beaches first (Hamilton 1945).

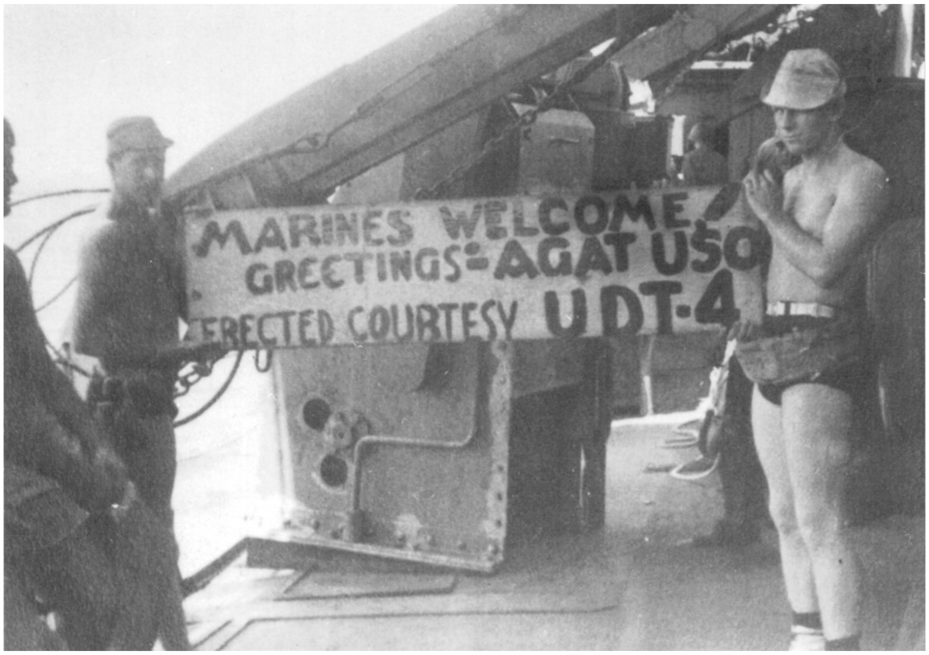


Figure 22. A sign painted by UDT 4 placed on the beach prior to the Marine landings. U.S. Navy Photo courtesy of the National Navy UDT-SEAL Museum.

Post-assault demolition

After W-Day, UDTs 3, 4, and 6 continued survey and demolition to improve the efficiency and safety of the landings and continued to pilot landing crafts ashore. With greater access to the beach after the landings, UDT 3 surveyed Asan Beach for mines. 19 plate type anti-vehicle mines were located and destroyed (Crist 1944).

UDTs also began assessing submerged infrastructure of the island in other areas than Asan and Agat, including channels. UDT 3 conducted hydrographic survey of the entrances to Tepungan and Piti Channels on July 23rd. At Piti, the Japanese had intentionally sunk sampans (a type of flat-bottomed wooden boat), barges, and other watercraft across the entrance to the channel to block access. Over the next two days, UDT 3 worked to demolish three 60-foot sampans and two barges blocking Piti Channel, which would provide additional access to Apra Harbor once cleared. Once the ocean-side entrance to the channel was cleared, UDT 3 transported 8,000 pounds of explosives by rubber boat through the channel to the harbor-side entrance, where they loaded sunken Japanese freighter *Nitiku Maru* with powder to clear the opposite opening of the channel (Department of the Navy 1945d). UDT 3's report of the Guam operations deemed the "Results very satisfactory" (Crist 1944 pg. 5). In addition to these channel-blocking vessels, UDT 3 also demolished several smaller craft inside a small boat basin at Piti (Crist 1944).

UDT 4 continued obstacle removal at Agat each on the day following W-Day, clearing a half-mile section for supplies, vehicles, and landing craft to come ashore. The team also blew a 200-foot wide channel in the reef north of Yellow One Beach in front of Hågat village that was large enough to accommodate the beaching of three LSTs at a time (Department of the Navy 1945a). This channel was located and documented by the project team and is discussed in further detail in Section II 6b of this report.

UDT 3 used 16,000 pounds of tetrytol to blast a channel through the coral at Dadi Beach, assisted by UDT 6 (Crist 1944, Department of the Navy 1945b). Though this channel location was outside the scope of this project (as it is outside the boundaries of War in the Pacific National Historical Park), the channel is still visible in aerial imagery of the barrier reef today.

The UDTs learned valuable lessons during the Guam operation that were applied to future amphibious landings. UDT 3 reported, "It is thought that one reason for low casualties among demolition personnel was the speed with which they accomplished their objective, and to insure this speed the units must be thoroughly trained and the work perfectly coordinated" (Department of the Navy 1945d pg. 9). Several UDT reports from Guam commended the fire support provided during reconnaissance and demolition operations and asserted that similar fire support should be provided for future UDT operations (Department of the Navy 1945d and Fisher 1944). W. G. Carberry (1944), Commanding Officer of UDT 4, recommended that the Navy investigate alternative small boats for UDT work to the LCVPs (Landing Craft Vehicle, Personnel, also known as a Higgins Boat) and LCPRs (Landing Craft Personnel, Ramp) used in Guam, stating that UDTs needed a small, armored boat with shallow draft, high speed capability, and better maneuverability. However, it was not until the 1960s that the Navy developed the LCSR (Landing Craft, Swimmer Reconnaissance) as a specialized boat for UDTs (Stoner 2004).

The work of UDTs in Guam was widely recognized as essential to the success of the landing by other members of the Task Force. Rear Admiral Lawrence F. Reifsnider, Commander of Amphibious Group Four, stated in a letter to the Commander of all Amphibious Forces in the Pacific theater that, "The splendid work done by the Underwater Demolition Teams at Guam is deserving of the highest commendation for both courage and efficiency" (Reifsnider 1944 pg. 1). The commander of LCI(G) 473, one of the vessels that provided fire support to the UDTs during the Guam operation, wrote in a report to Admiral Chester Nimitz that the UDTs, "…know their job, did it well, and apparently have no fear of the enemy" (Fisher 1944 pg. 7). For their participation in the Guam operation, UDT officers and enlisted men were awarded silver stars and bronze stars, respectively (Department of the Navy 1945b).

6. Findings

a. Actual accomplishments and findings (include maps, graphics, and images)

Archival research

PI Wright Nunn's visit to the National Archives at College Park was integral to historical background research for project planning. Significant findings from this trip included a hand-drawn historic map by a member of Underwater Demolition Team 3 detailing where explosives were placed on the reef and man-made obstacles (Figure 23), a map showing the invasion beaches and terrain with pre-invasion bombardment and fire support details (Figure 24), historic photos showing man-made obstacles and the invasion (samples in Figure 18, 25-29) and numerous historic documents from ships that provided this fire support and acted as a launching area for LVTs that took Marines into the beaches.

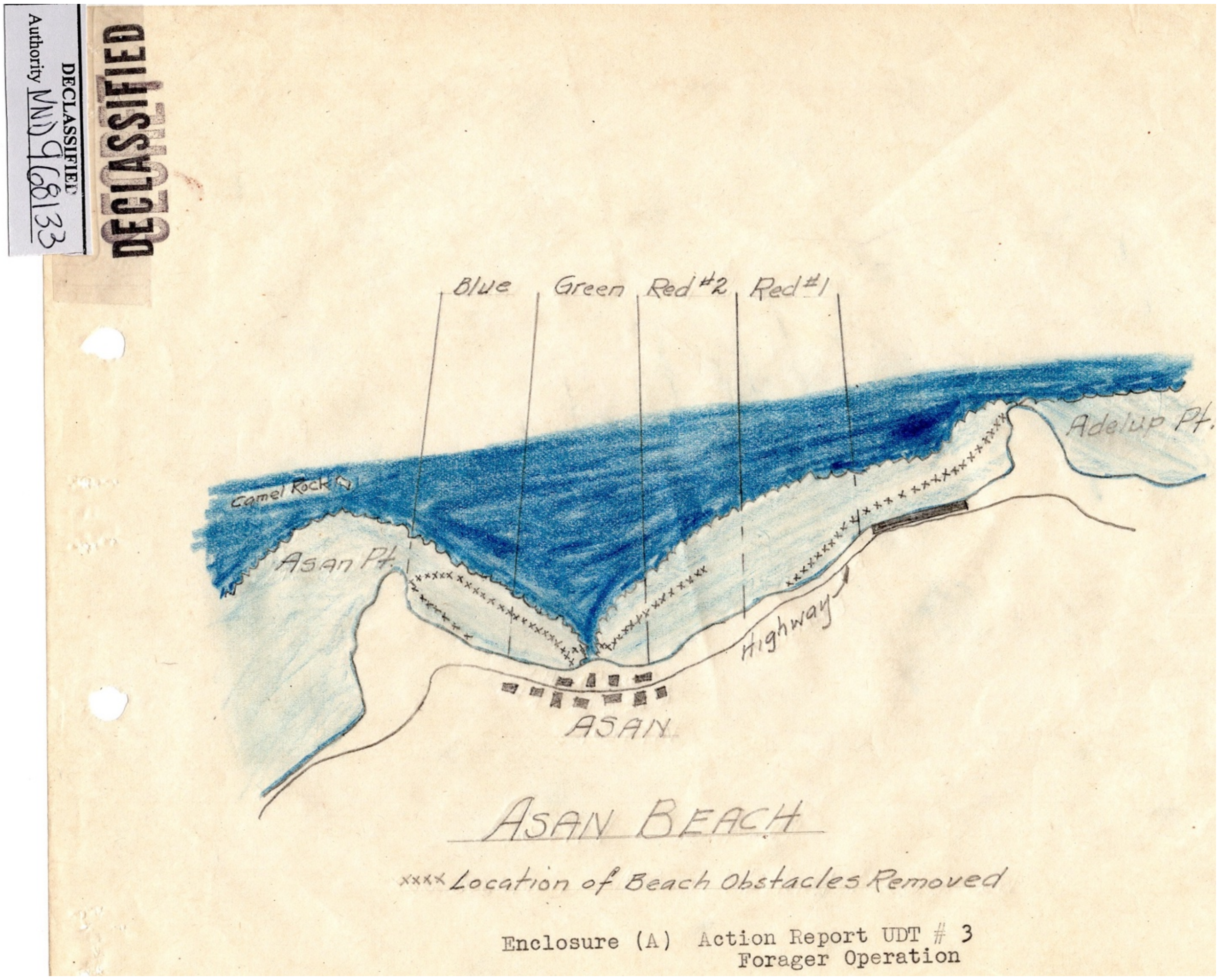


Figure 23. A historic map drawn by UDT 3 illustrating the location of removed obstacles. Image via National Archives at College Park, Record Group 38.

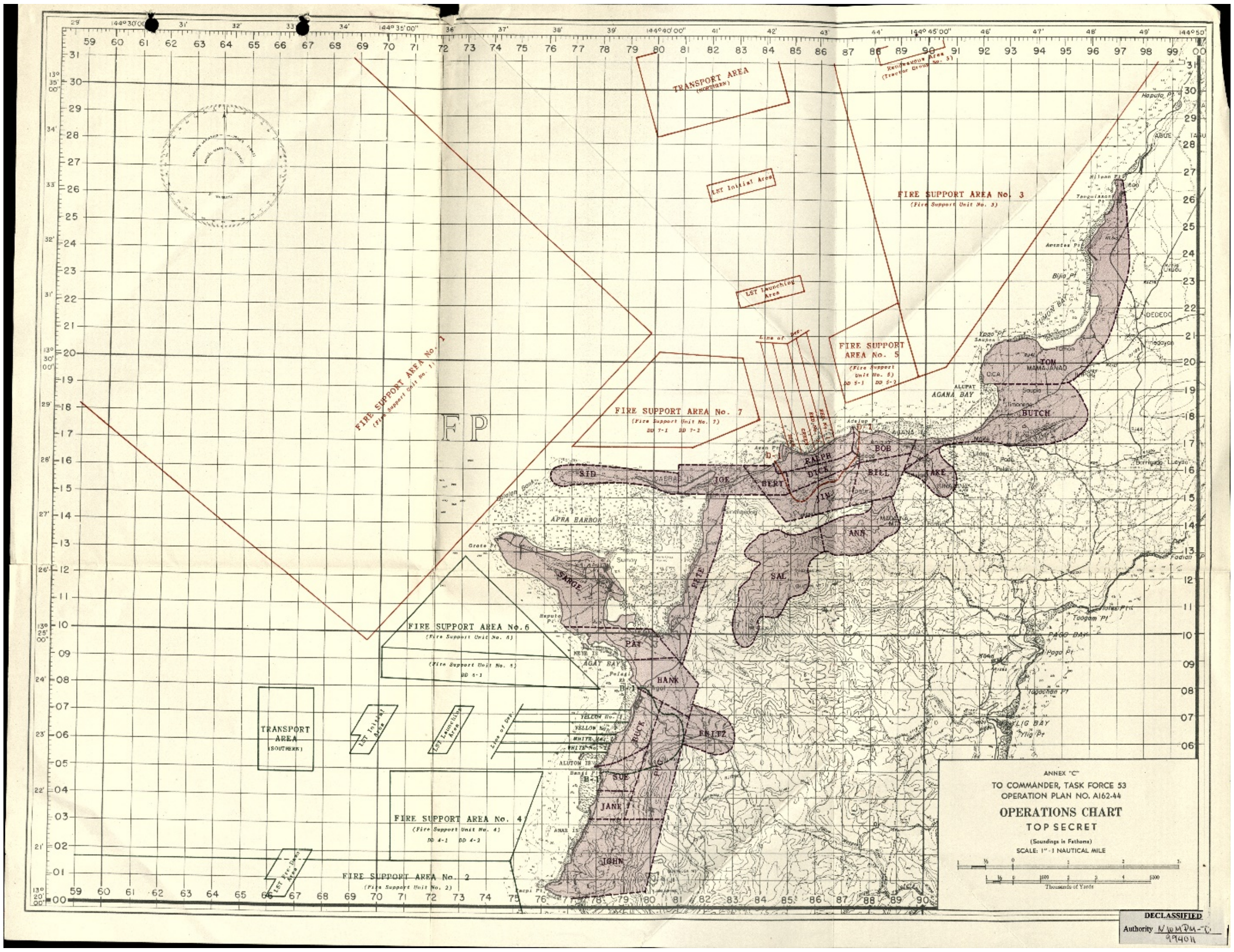


Figure 24.A historic map detailing fire support zones. Image via National Archives at College Park. Declassification Authority NWMDM-D 994011.

Figure 25. Historic photograph. "Unloading on the reef." Image via National Archives at College Park, Record Group 127GW.

Figure 26. Historic photograph. "Howitzer and gun crew in Duck heads for the beach." Image via National Archives Record Group 127GW.

Figure 27. Historic photograph. "GUAM BEACHHEAD - Invasion ships of all types crowd the beach (back-ground) at Guam, as Marines push into the rugged foothills which have been described as the worst fighting terrain yet encountered in the Pacific." Image via National Archives at College Park, Record Group 127GW.

Figure 28. Historic photograph. "Support troops come ashore." Image via National Archives at College Park, Record Group 127GW.

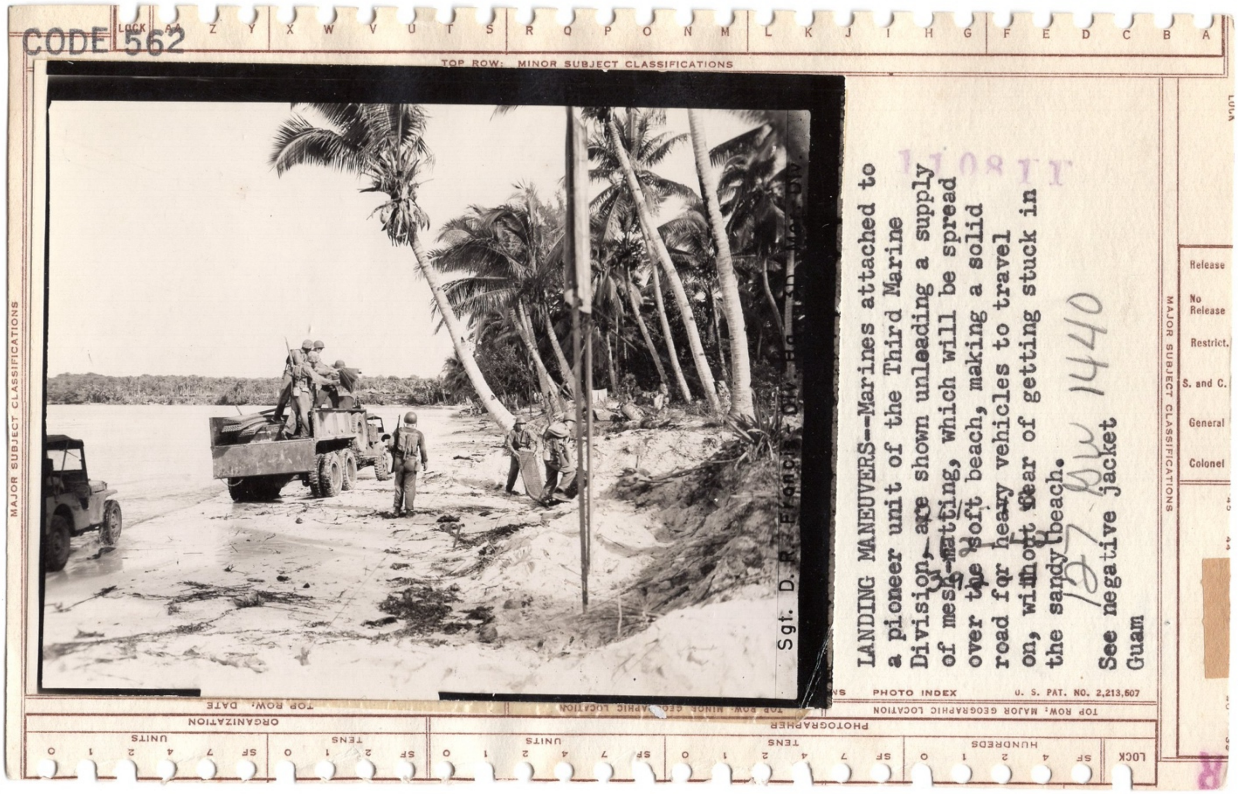


Figure 29. Historic photograph. "LANDING MANEUVERS - Marines attached to a pioneer unit of the Third Marine Division are shown unloading a supply of mesh-matting, which will be spread over the soft beach, making a solid road for heavy vehicles to travel on, without the fear of getting stuck in the sandy beach." Image via National Archives at College Park, Record Group 127GW

Remote sensing

Outside of reef crest

Multibeam bathymetry, side scan sonar, and magnetometer remote sensing surveys were conducted within the Asan Beach and Agat units of the park extending from the reef crest offshore to the 60 m isobath. Full coverage was achieved, with the exception of a few small data gaps. The resulting multibeam bathymetry data (50 cm resolution) are presented in Figures 30-32 and 34-35. Figures 30 and 31 show the mosaics for the full survey areas. Figure 32 highlights the sunken Amtrak offshore of Agat. Figure 33 presents a photograph on the sunken Amtrak taken by the project team for context. Figure 34 highlights the large blast channel in the reef at Agat. Figure 35 highlights the structure of the coral reef at Asan.

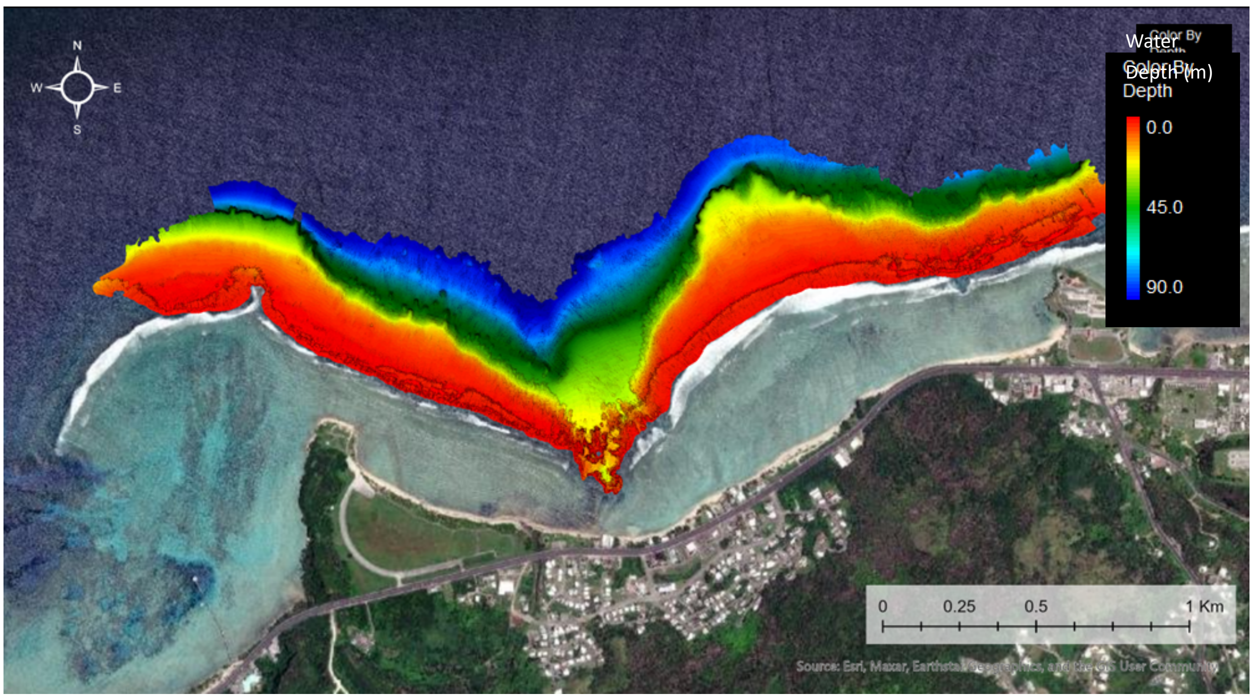


Figure 30. Bathymetric data for survey area at Asan Beach Unit extending from the reef crest out to the 60m isobath. Color scale presents water depth in meters. NPS image.

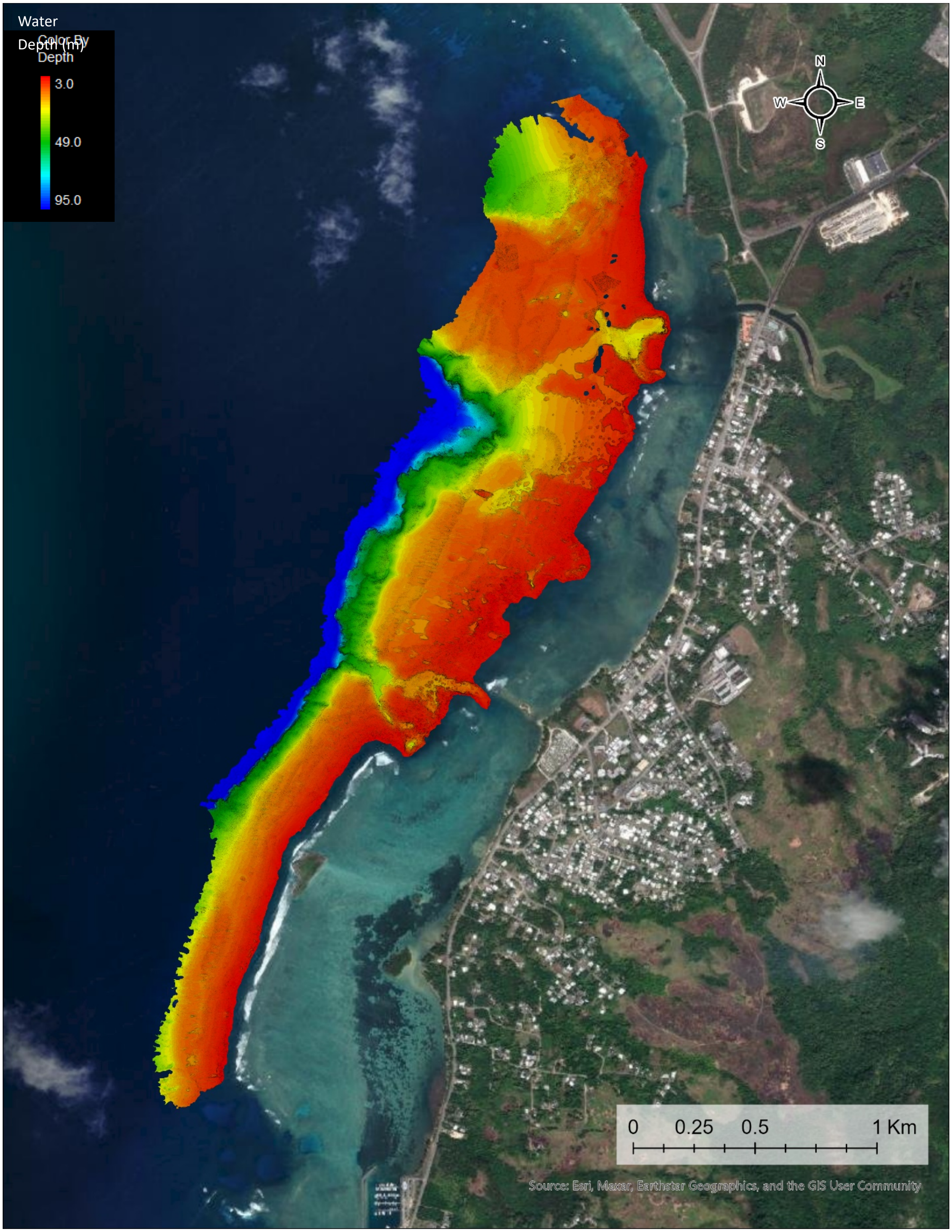


Figure 31. Bathymetric data for survey area at Agat Unit extending from the reef crest out to the 60m isobath. Color scale presents water depth in meters. NPS image.

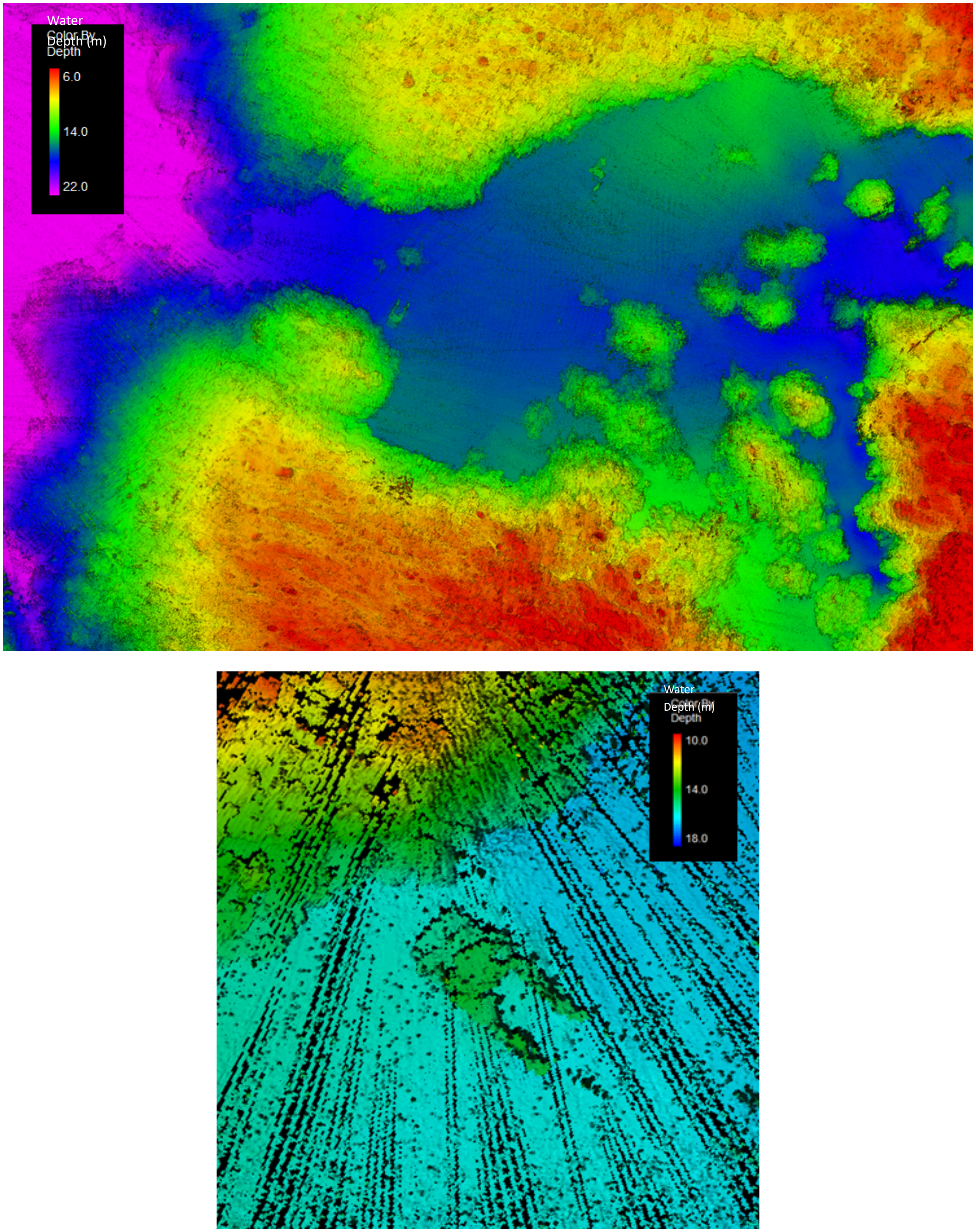


Figure 32. Bathymetric data showing the submerged Amtrak (circled in black) and surrounding seascape at Agat Unit (top) and close-up view of Amtrak (bottom). NPS images.

Figure 33. Photo of the submerged Amtrak at Agat Unit. NPS Photo.

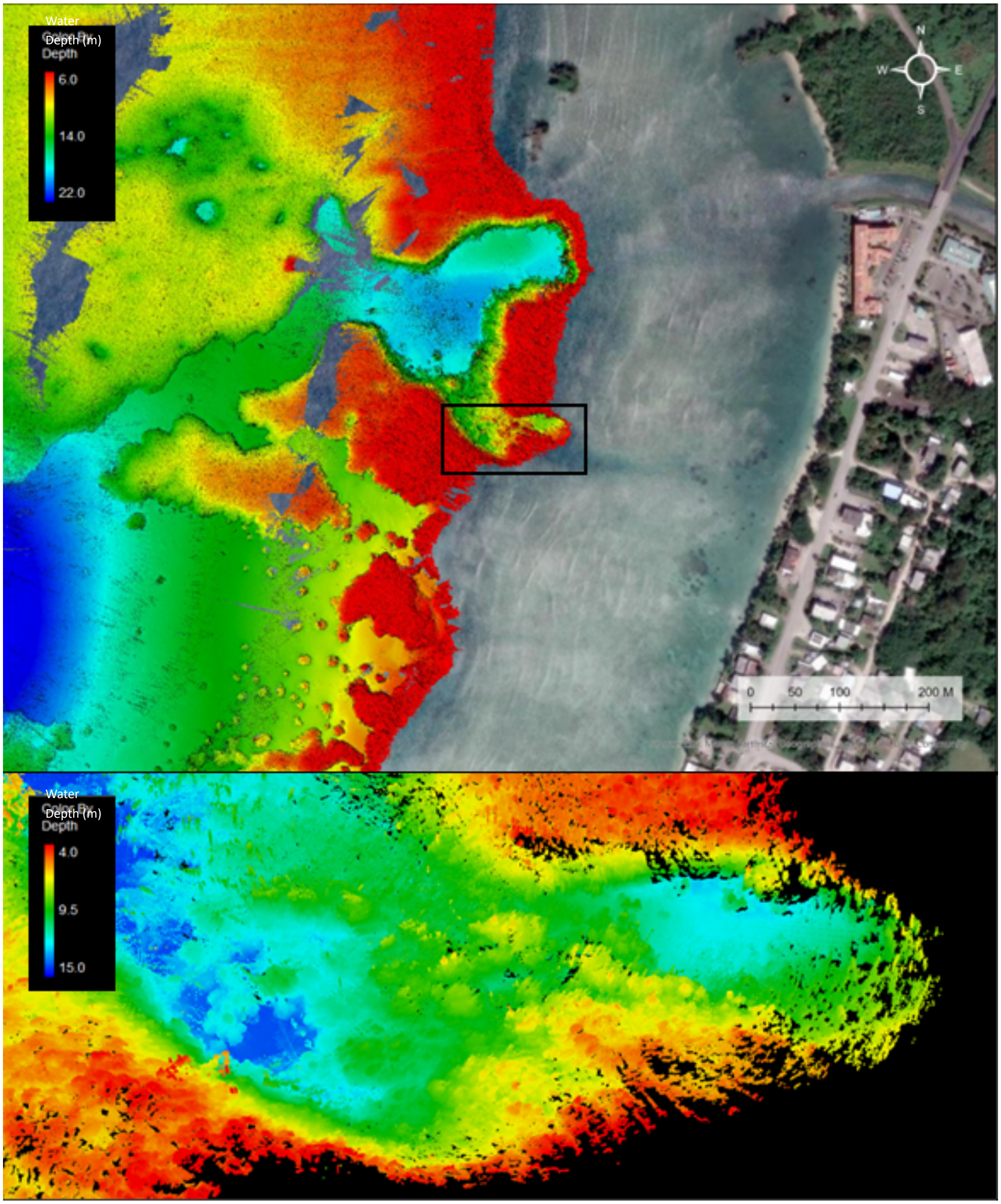


Figure 34. Bathymetry data of blast channel created in reef crest at the Agat unit. NPS image.

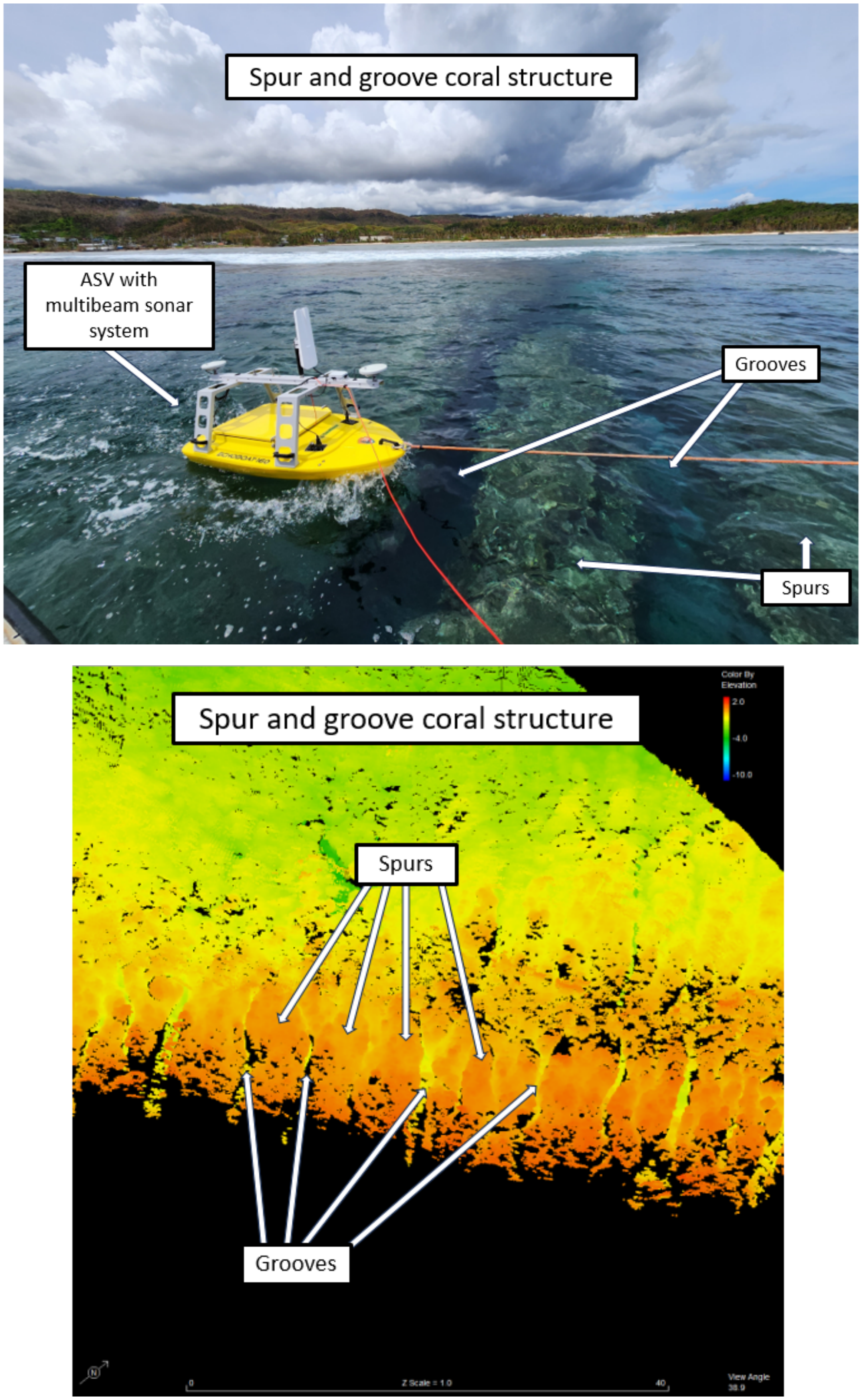


Figure 35. Photo showing ASV collecting bathymetry data offshore of Asan (top) and resulting bathymetry data (bottom) showing the spur and groove coral structure. NPS images.

The resulting side scan sonar mosaics for offshore Agat and Asan Beach are shown in Figure 36. A zoomed in view of the side scan sonar imagery collected within the Agat unit is presented in Figure 37, depicting sand waves and coral reef structure.

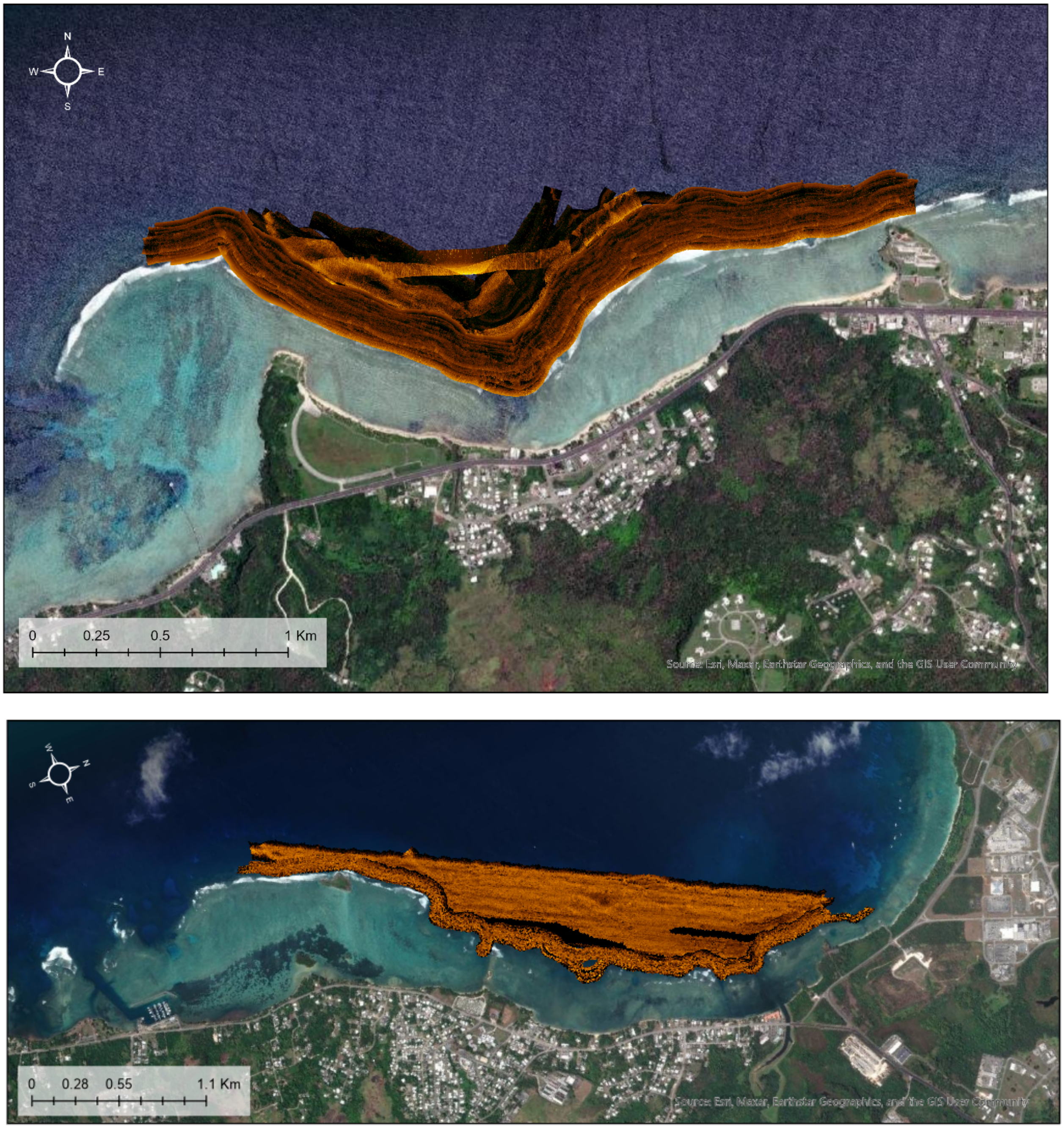


Figure 36. Side scan sonar mosaics for Asan Beach (top) and Agat (bottom) units extending from the reef crest out to the 60m isobath. Data is presented on bronze color scale from 0 (white) to 255 (black). NPS images.

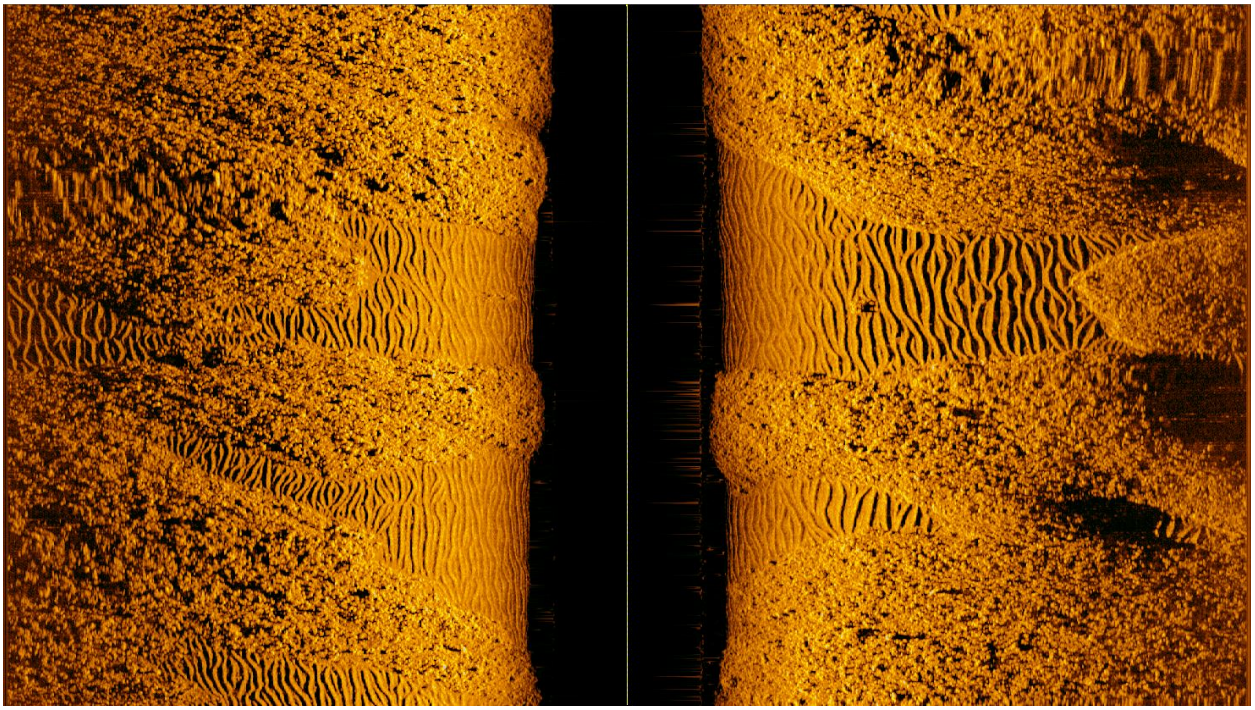


Figure 37. Zoomed in view of side scan sonar imagery collected within the Agat unit depicting sand waves and coral reef structure. Data is presented on a bronze color scale from 0 (white) to 255 (black). NPS image.

Maps showing recorded magnetic anomalies at 10-gamma gradient contours are presented in Figures 38 and 39. All anomalies shown are indicative of a ferrous, man-made object and were selected for further diver-based investigation. The amplitude, duration, number of survey lines the anomaly is detected on, and composition (i.e. monopole, dipole, or multicomponent) can be indicative of the magnetic moment, overall size, mass, and complexity of the anomaly source.

Redacted

Figure 38. Magnetometer data showing anomalies at 10-gamma gradient contours for Asan Beach unit extending from the reef crest out to the 60m isobath. NPS image.

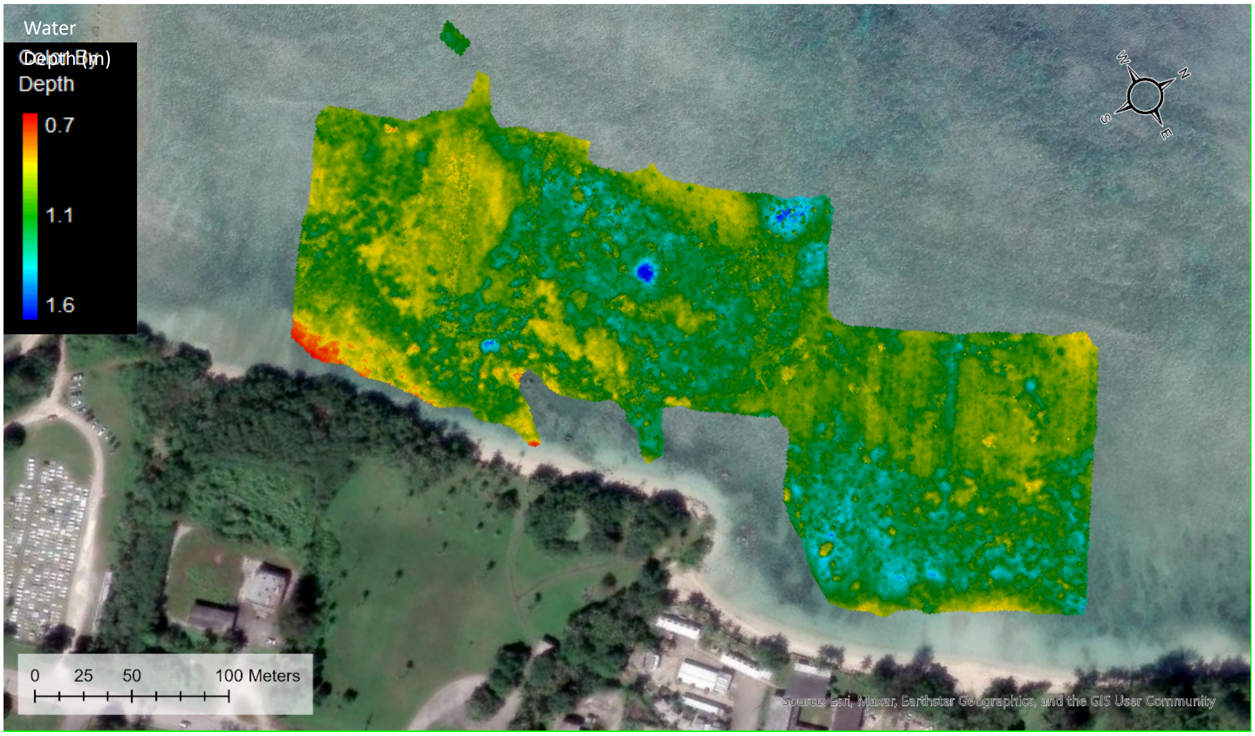
Redacted

Figure 39. Magnetometer data showing anomalies at 10-gamma gradient contours for Agat Unit extending from the reef crest out to the 60m isobath. NPS image.

Reef flat

Within the reef flats at the Asan Beach and Agat units, the project team focused on collecting full coverage data for areas of interest identified in collaboration with WAPA park staff. The remaining area was supplemented with available topobathy LiDAR (collected by NOAA in 2021). While this approach deviated from the proposal (as described in Section III 1b), project goals were still accomplished.

The areas offshore of the visitor use areas at Asan and Agat Ga'an Point were of high interest. The resulting multibeam bathymetry mosaics (50 cm resolution) are presented in Figure 40.



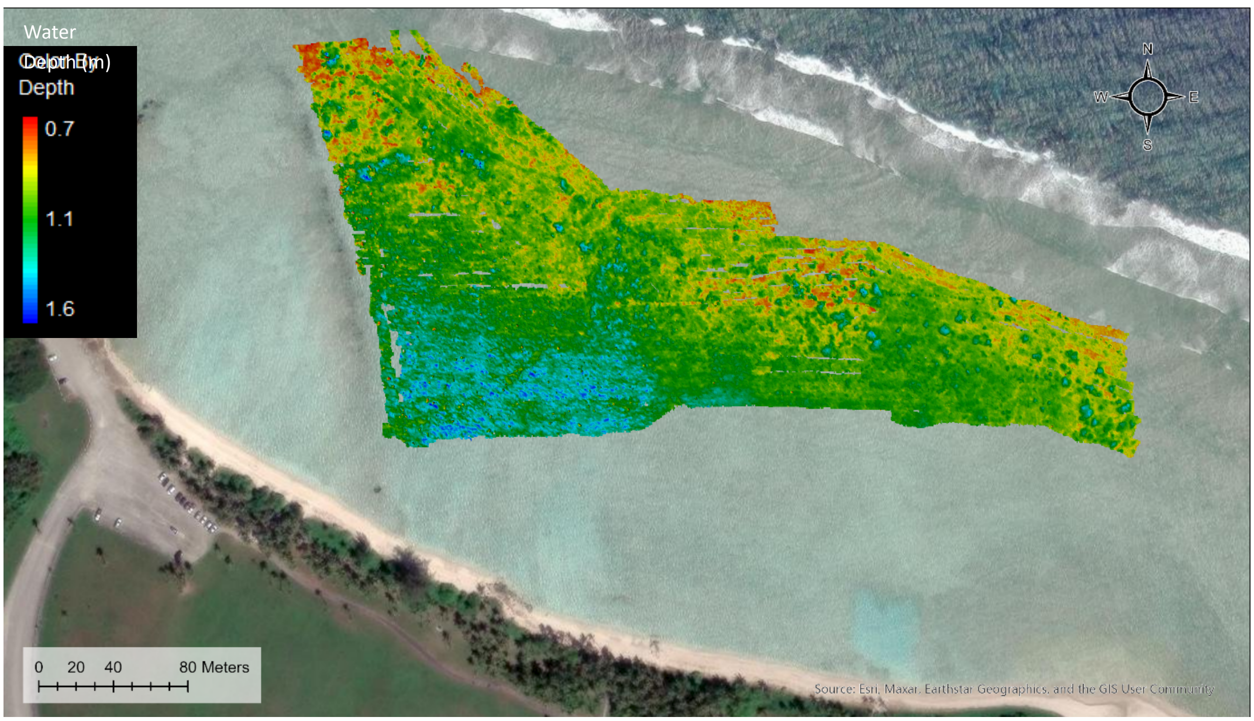


Figure 40. (top) Multibeam bathymetry data collected within the reef flats of Agat (top) Asan Beach (bottom) units. Water depth scale is presented in meters. NPS images.

Mapping the line of blast craters indicated on the historic UDT map was also a priority. The resulting bathymetry data clearly identifies the shallow water blast craters that are still present in the seascape (Figure 41). Refer to Section II 6b for additional details and discussion of the blast craters.

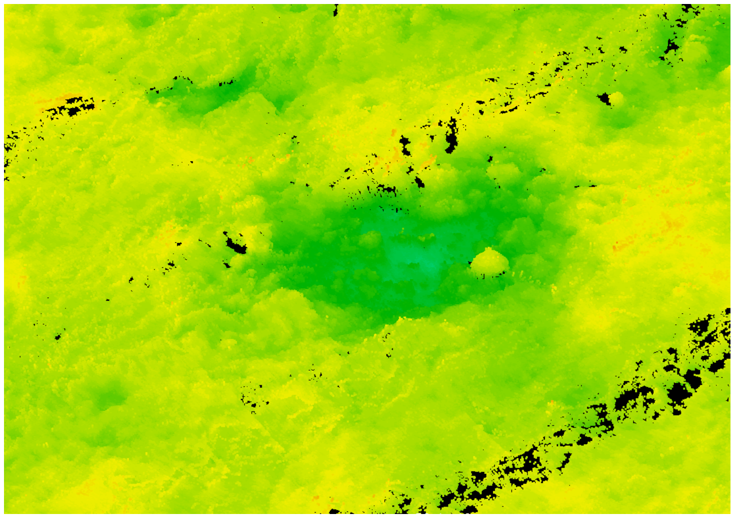


Figure 41. Bathymetry data blast crater (green) within the surrounding reef flat (yellow) at the Asan Beach unit. NPS image.

Archaeological target investigation

Diving investigations were conducted by a team of two or three divers (depending on depth range and CCR-bailout requirements) from a 25 ft aluminum boat. Prior to the start of dive operations, all anomaly/contact locations were loaded into a hand-held GPS. Before the start of each dive, the boat captain navigated to the precise GPS location and the team deployed a weighted line-reel with an attached buoy to mark the location. Once the dive team completed safety checks, they entered the water and descended down the marker line. Each dive team carried a camera, scale bar, north arrow, metal detector, and line reel. Once on the bottom, one diver deployed a line reel and a second diver swam out five meters (or less, depending on visibility conditions) with the end of the line. The second diver began a circle search using the underwater metal detector (Figure 42). Once a full circle was complete, the first diver let out additional line to the second diver, and the circle search continued either until the source of the anomaly or contact was located, or until the team had completed a circle search out to the 15 m mark.

Figure 42. Project diver Mikey Kent completes a circle search with metal detector on a deep target. NPS image.

If an artifact was located, the team photo-documented it with high-resolution imagery via digital camera. In some instances, if the artifact and/or site was significant, a team returned to collect photogrammetry data. If no artifact was found, the anomaly or target number was marked as “no find” and recorded in the anomaly/target spreadsheet (See Appendix B). Additionally, artifacts were occasionally found inside a coral head with the metal detector and were not visible. In these instances, the anomaly was marked as “embedded in coral” on the anomaly/target spreadsheet.

In total, the team completed 162 anomaly/target investigations between both survey areas. 100% of identified magnetic anomalies and selected side scan sonar targets were investigated in the Asan Beach survey area. 48% of identified anomalies and selected side scan sonar targets were investigated in the Agat survey area. Impacts of Typhoon/Hurricane Dora caused storm conditions that prevented the completion of investigations at Agat. See Section III 1b of this report for additional information.

Significant archaeological findings of interest are discussed in detail in Section II 6b “Notable findings and discussion.”

Table 3 lists all artifacts and modern anthropogenic material located during the investigation. Appendix B is a comprehensive list of targets, inclusive of “no finds.”

Table 3. Artifacts and Modern Anthropogenic Material Located.

Target Name	Description
Asan_Mag_001	Glass bottle base embedded in coral, lead weight. No mag target found.
Asan_Mag_005	Artillery Shells, See also Asan_SSS_04.2
Asan_Mag_007	Metal pole
Asan_Mag_010	Transect pin
Asan_Mag_011	Sounding/dive weight
Asan_Mag_012	Transect pin
Asan_Mag_014	Lead weight with bailing wire
Asan_Mag_015	Transect marker. All thread with set screw
Asan_Mag_018	Buried metal detector hit on coral head
Asan_Mag_020	Dive weights and pipe
Asan_Mag_029	Two tires, one with metal rim
Asan_Mag_043	UXO dump: mortar shells in crevices, 50 caliber, 20 caliber, 3 large bombs
Asan_Mag_044	UXO (15+ Mortars and artillery shells) on downslope to 300+ feet. Numerous buried metal detector hits.
Asan_Mag_045	Spent .20 caliber casing.
Asan_Mag_046	1 large artillery shells
Asan_Mag_048	1 large artillery shells
Asan_Mag_049	6 large artillery shells
Asan_Mag_050	5 large artillery shells
Asan_Mag_051	1 large artillery shell, transect bar
Asan_Mag_052	Transect pins, long piece of metal
Asan_Mag_053	4-5 8" artillery shells, 20 mm cannon, many buried metal detector hits
Asan_Mag_054	Numerous artillery shells, 6" small arms, shell casings
Asan_Mag_055	Numerous .30 and .50 caliber rounds, artillery shells and bombs
Asan_Mag_056	Box of 50 caliber, 1 large artillery shell, loose 50 caliber
Asan_Mag_059	UXO field: Approximately 5 30-06 Springfield Rifle rounds (some spent), 15-20 20 mm canon rounds, approximately 4 larger rounds (possibly 40mm canon rounds).
Asan_Mag_062	Lead Weights, no magnetic anomaly identified
Agat_Mag_001	Metal box with handle
Agat_Mag_005	Metal Pole, possibly aluminum
Agat_Mag_011	Metal Bar w/ball on the end
Agat_Mag_019	Metal ladder

Agat_Mag_022	Cinderblock anchor with rebar
Agat_Mag_068	Crumpled flat sheets of metal, corrugated metal
Agat_Mag_076	Cylindrical metal tube
Agat_Mag_081	Angle iron, partially submerged
Agat_Mag_084	Aluminum pipe
Agat_Mag_103	Metal object embedded in coral head
Agat_Mag_109	Series of transect rebar
Agat_Mag_113	Concreted square shaped piece of metal
Agat_Mag_128	Marston mat, artillery shells (6 visible)
Agat_Mag_133	Metal/tin bowl
Agat_Mag_138	Buried metal detector hit between coral heads
Agat_Mag_139	Buried metal detector hit in coral head
Agat_Mag_142	Rebar transect, 2 hits in coral rubble in a gouged area of reef
Agat_Mag_145	Known Amtrack
Agat_Mag_146	1/2 of a barrel and metal rods
Agat_Mag_148	6' - 7' channeled steel 6" wide, 2 large artillery shells
Agat_Mag_150	Large long broken cable/pipe. Followed pipe for 200+ feet with no indication that it was ending.
Agat_Mag_153	Japanese fishing boat
Agat_Mag_159	Possible dump site: Barrels, UID metal, Amtrac door, trailer, fuel tanks abundance of crates, danforth style anchor. Later identified as "American Pontoon Barge" from Carrell 1991.
Agat_Mag_162	30' piece of angle iron
Agat_Mag_165	Braided steel cable
Agat_Mag_167	15' 4" pipe, 3' historic anchor 1 arm bent
Agat_Mag_171	Concreted metal in coral head
Agat_Mag_172	Capped pipe
Agat_Mag_175	Unidentified metal object
Agat_Mag_178	1 small artillery shell
Agat_Mag_184	Concreted metal in coral head
Asan_SSS_04.2	12 small artillery shells

Coastal elevation surveys

LiDAR data were collected at the Asan Beach unit and the Agat unit at Ga'an Point and Apaca Point. Surveys conducted in February 2023 achieved full data coverage of the Asan Beach unit (40 scans) and Agat Ga'an Point unit (39 scans). Repeat surveys for the beach and intertidal portions of the Asan Beach unit (21 scans) and Agat Ga'an Point unit (13 scans) were conducted in July 2023, as well as at the full landscape of the Agat Apaca Point unit (18 scans). A total of 131 LiDAR scans were collected across the three park areas for this project. The resulting classified point cloud data of the landscapes are presented in Figure 43 (February 2023) and Figure 44 (July 2023).

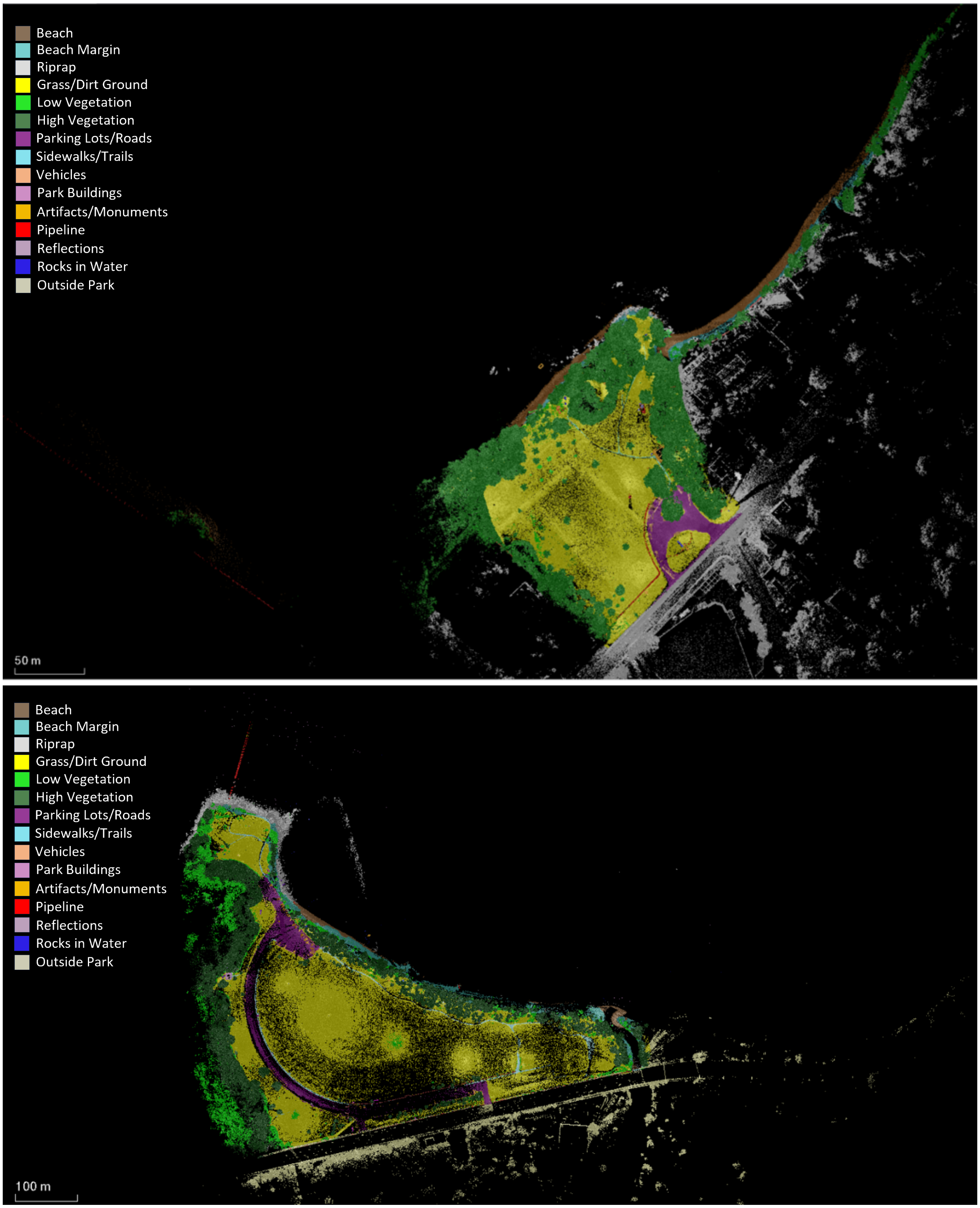
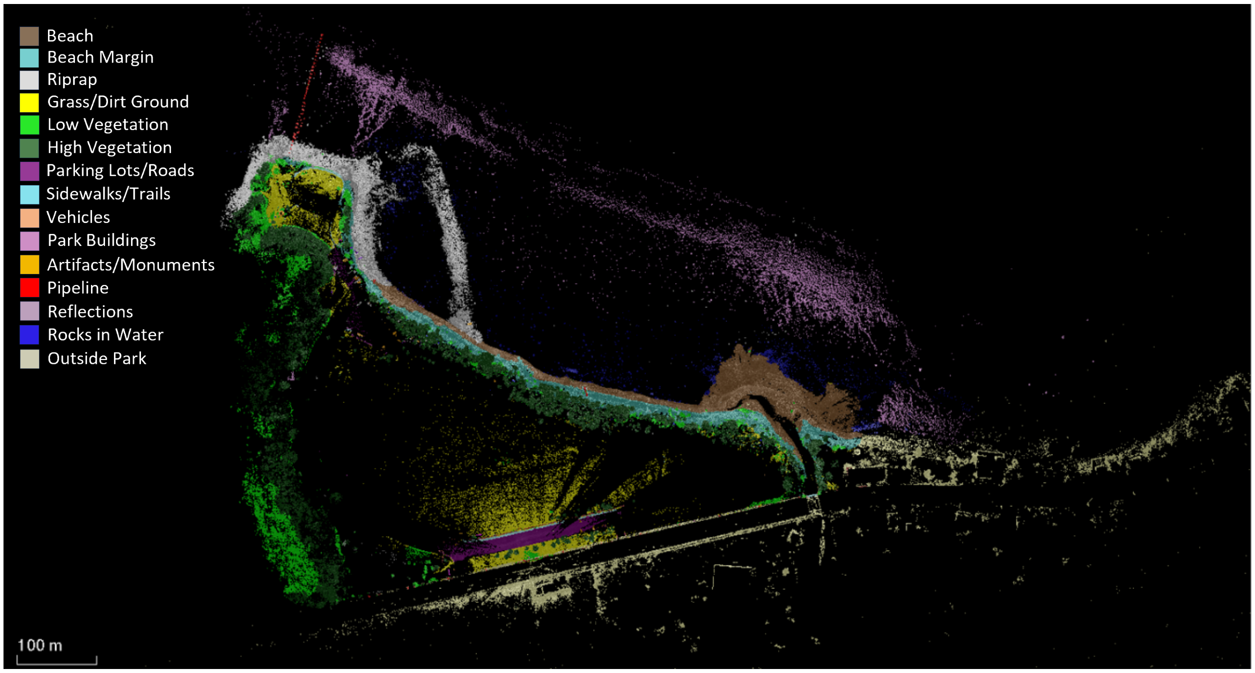
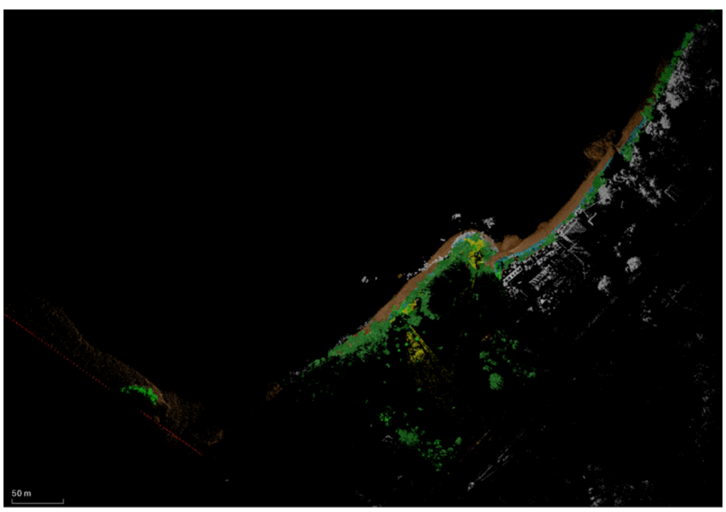


Figure 43. Classified LiDAR point cloud data collected in February 2023 of the landscape at (top) Asan Beach and (bottom) Agat Ga'an Point units. Surveys were designed to collect full coverage data of the park units. NPS images.





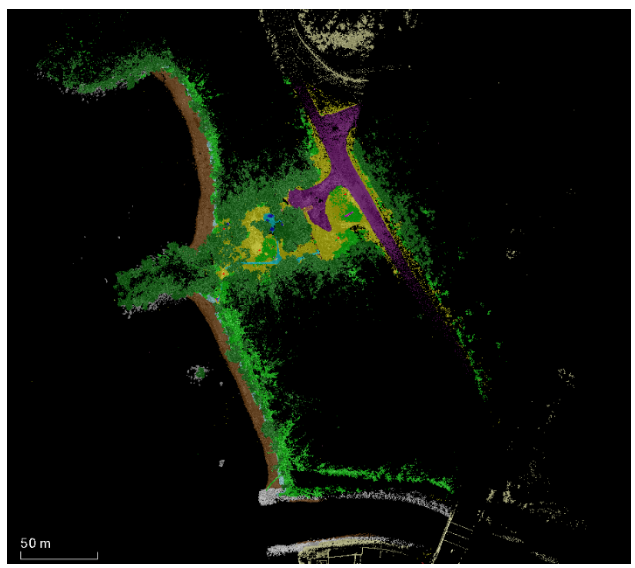


Figure 44. Classified LiDAR point cloud data collected in July 2023 at Asan Beach (top) and Agat Ga'an Point (bottom left); data collection focused on the beach and intertidal areas of the park units. Classified LiDAR data of the landscape at Agat Apaca Point unit from July 2023 focused on capturing the full landscape. NPS images.

The LiDAR data were used to document and examine features of the landscape. For example, Figure 45 shows the public access point to the beach and wayside sign, as well as the sandy beach area, the "beach margin" with dispersed vegetation debris, and vegetation.

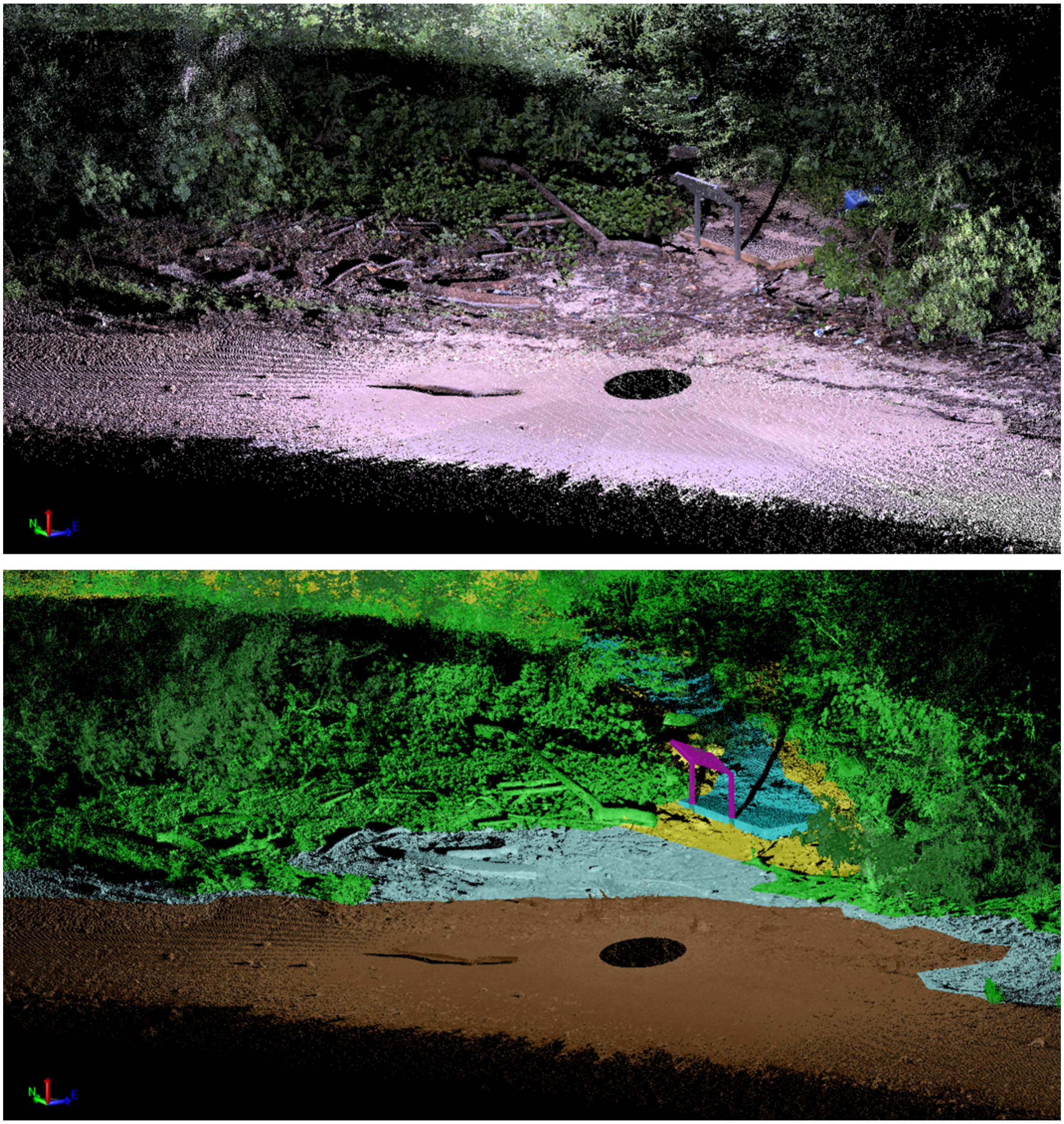


Figure 45. LiDAR data showing the point cloud colorized based on (top) photographs (true color) and (bottom) classification categories. NPS images.

In addition to the landscape, the LiDAR surveys captured cultural resources within the park units. For example, Figures 46 and 47 highlight pill boxes at the Agat Ga'an Point unit.

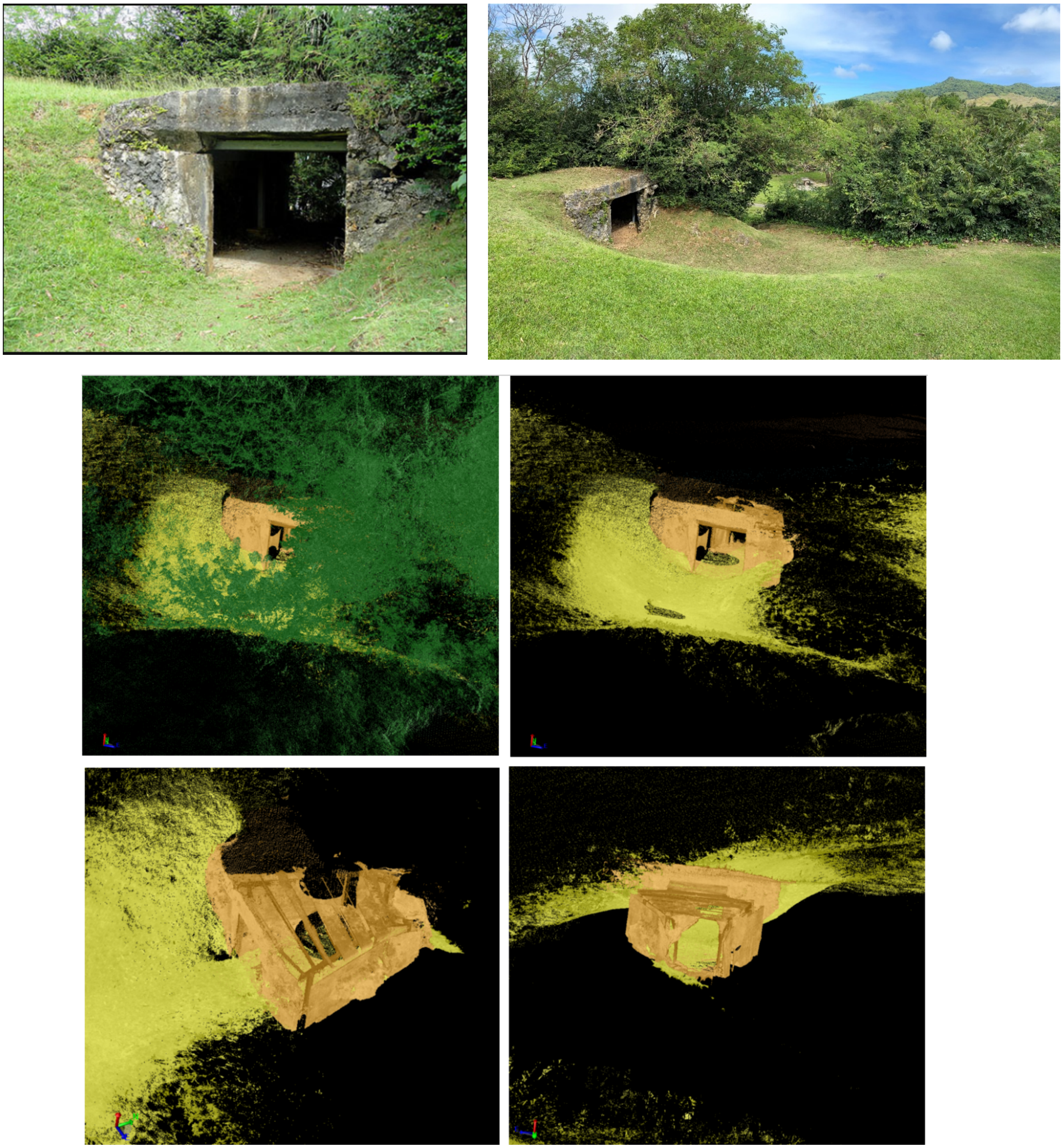
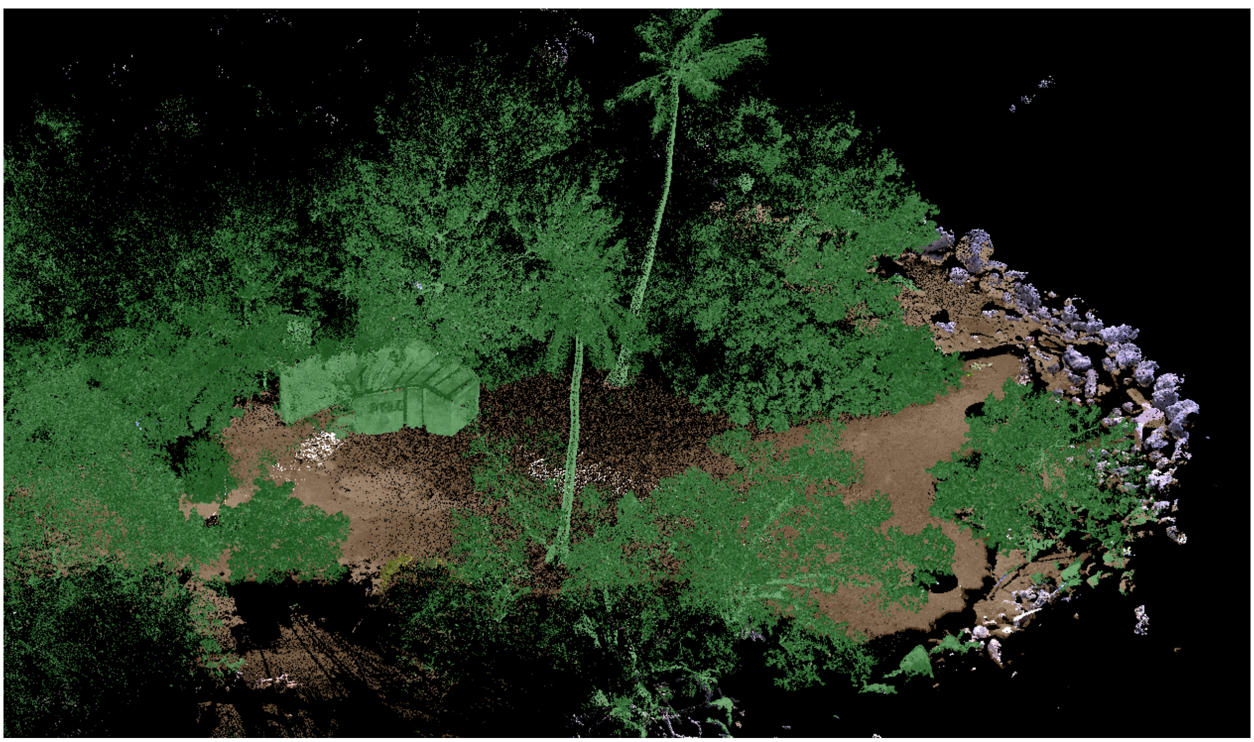


Figure 46. Photographs of the pill box, a WWII archaeological site, located on top of the hill at the Agat Ga'an Point unit (top) and LiDAR point cloud data documenting the pill box (bottom), with the pill box shown in brown, grass shown in gold, and vegetation shown in green. NPS images.



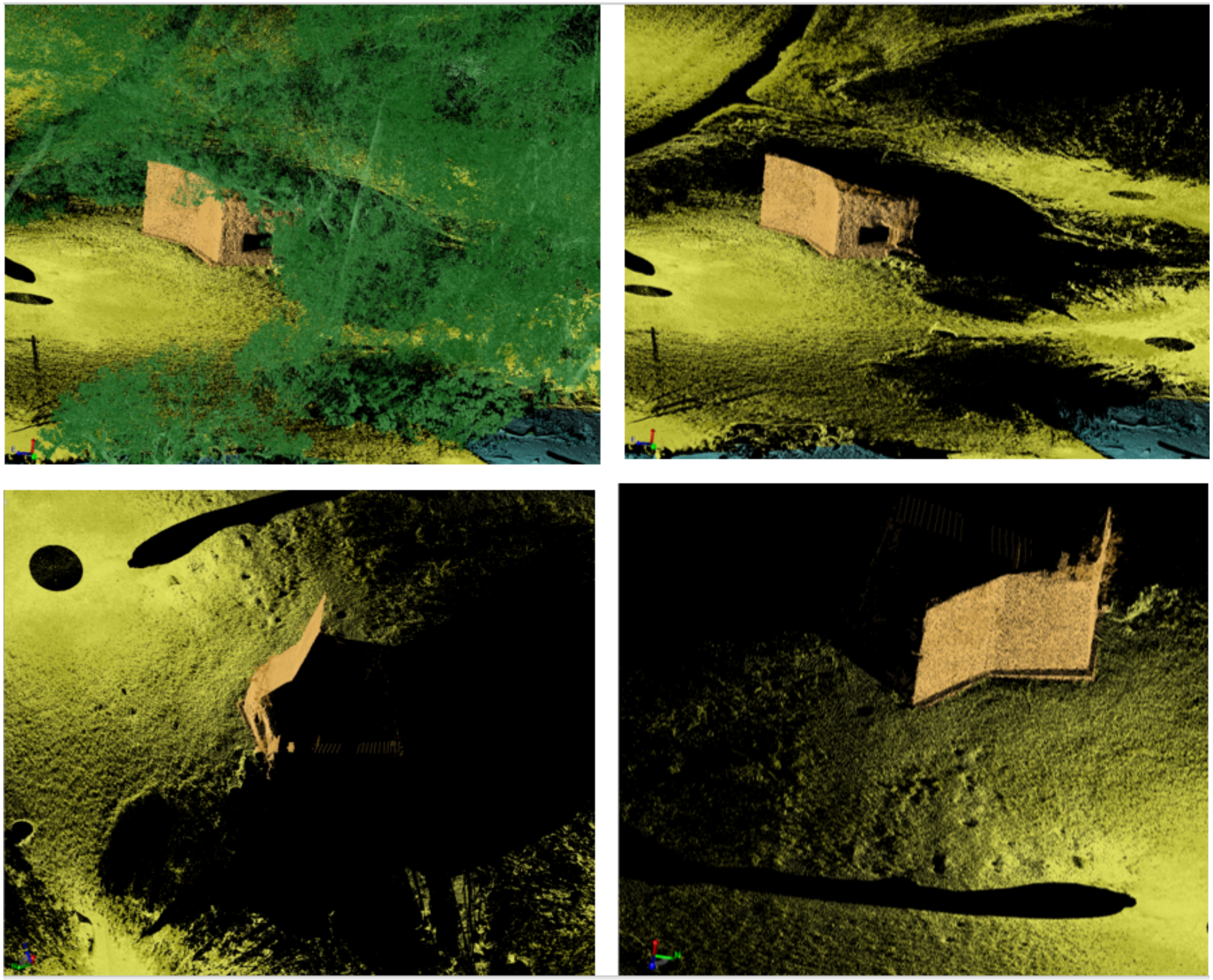
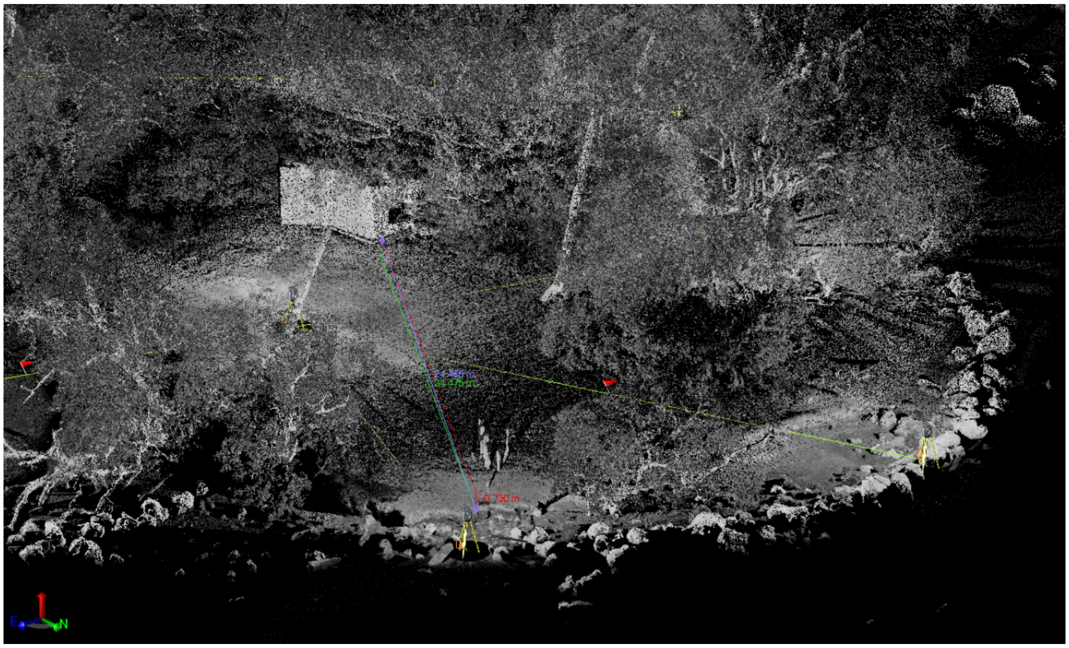


Figure 47. Photograph of the pill box, a WWII artifact, located near the shoreline at the Agat Ga'an Point unit (top). LiDAR point cloud data was captured to document the pill box shown in green within the orange box (middle). Additional views of the pill box captured in the LiDAR data shown in brown (bottom). NPS images.

The LiDAR data allows for precise measurements to be made, as demonstrated in Figure 48, making the data idea for quantitative analysis, in addition to being a qualitative visual aid.



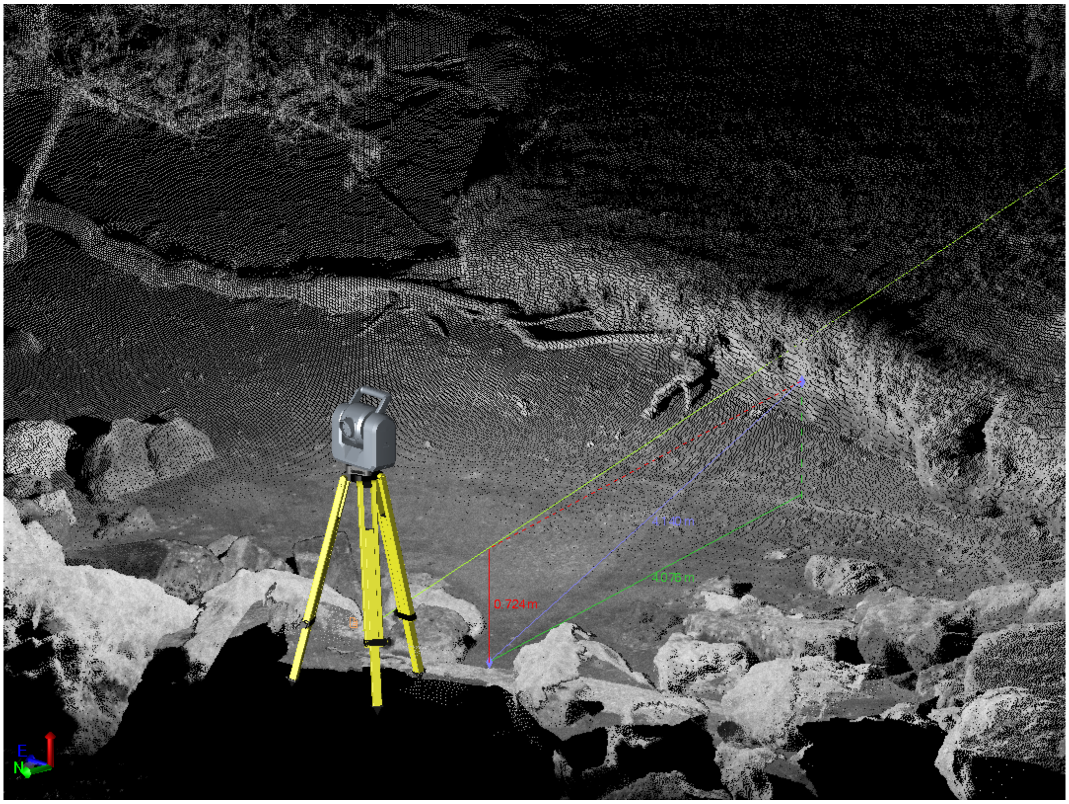


Figure 48. Examples of how LiDAR data can be used to take precise measurements. LiDAR scan showing a portion of the landscape at Agat Ga'an Point, including the rocky shoreline, beach, and one of the pill boxes, showing measured distances between features (top). Zoomed in view of the LiDAR scan measuring the width of the beach (i.e. the distance from the waterline to the erosional bank) (bottom). NPS images.

The LiDAR data was also used to create elevation contours at 5 cm increments of the park units, as shown in Figure 49.

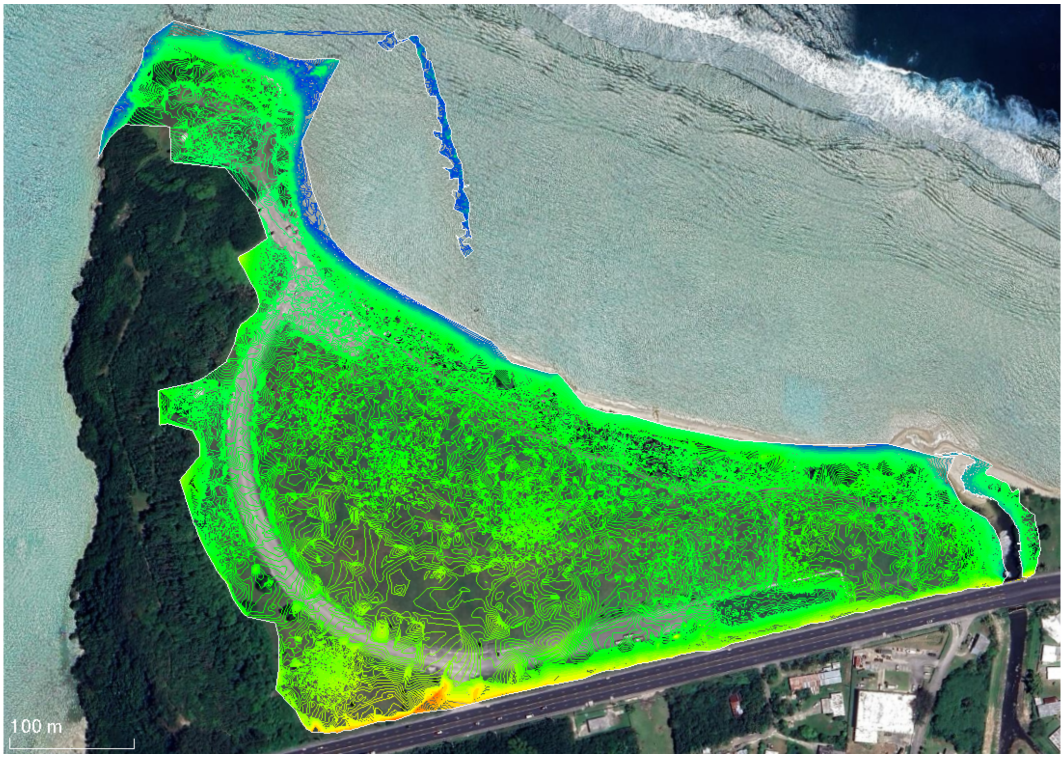


Figure 49. Planar view of Agat Ga'an Point (top), Asan Beach (middle), and Agat Apaca Point (bottom) units showing elevation contours every 5 cm (overlaid on satellite imagery taken 04/14/2023). NPS images.

Analysis of the surface elevation change between February 2023 and July 2023 showed areas of net increase in elevation (accretion) and net decrease (erosion) for Asan Beach unit (Figure 50) and Agat unit (Figure 51). Changes over the five-month period were anticipated due to the dynamic nature of these coastal areas and due to impacts of Typhoon Mawar (May 2023), which resulted in substantial erosion and transportation of sediment during the storm event and afterwards as the system reach an equilibrium. In reviewing the outputs, it was determined that the analysis realistically represented surface elevation changes over the time period, though some inconsistencies were identified. For example, the output indicates erosion occurred at Asan Point, but that is likely an artifact of the survey design as this area is characterized by large boulders and coral rubble, which can cause gaps in the LiDAR point could data and incorrectly inform the change analysis. Other inconsistencies can also be due to vegetation growth (e.g. grass) or stranded and trapped debris and the challenge of removing these points from the dataset. Therefore, while these outputs are valuable, they should be assessed and interpreted by end users familiar with the park.

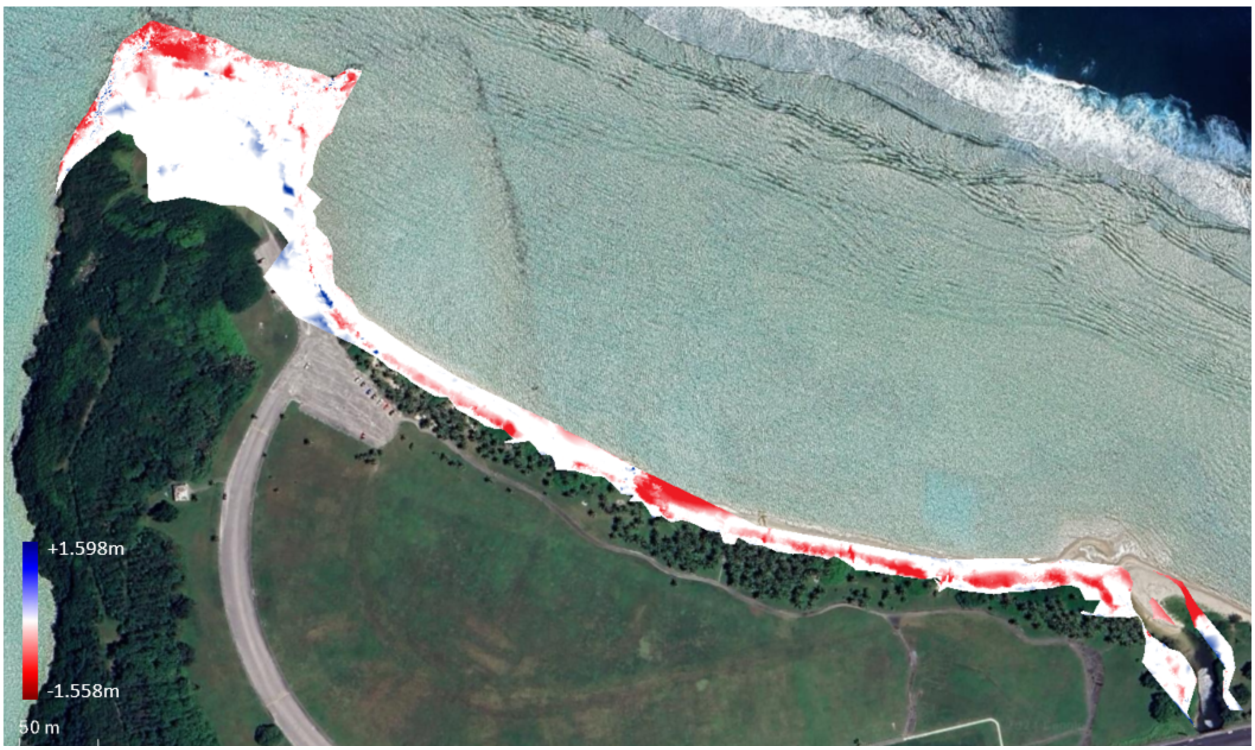


Figure 50. Surface elevation change analysis for Asan Beach unit from February 2023 to July 2023. Positive values (blue) indicate net increase in elevation (accretion) and negative values (red) indicate net decrease (erosion) over the five-month time period. Note these outputs should be interpreted by end-users familiar with the park to discern data artifacts. NPS image.

Figure 51. Surface elevation change analysis for Agat unit from February 2023 to July 2023. Positive values (blue) indicate net increase in elevation (accretion) and negative values (red) indicate net decrease (erosion) over the five-month time period. Note these outputs should be interpreted by end-users familiar with the park to discern data artifacts. NPS image.

In between the February 2023 and July 2023 surveys, Category 4 typhoon Mawar made direct landfall on Guam (May 2023). The impacts from the typhoon were still visible in July and were documented in the second set of LiDAR data. Refer to Section II 6b for additional details and discussion.

Geomorphology classification

The geomorphology classification maps of the seafloor resulting from the BRESS algorithm are shown in Figures 52-54. A four-class output was chosen, classifying “slope,” “valley,” “ridge,” and “flat.” The coral reef structure is clearly visible in the outputs (alternating yellow and purple colors), as well as the reef flat (green).

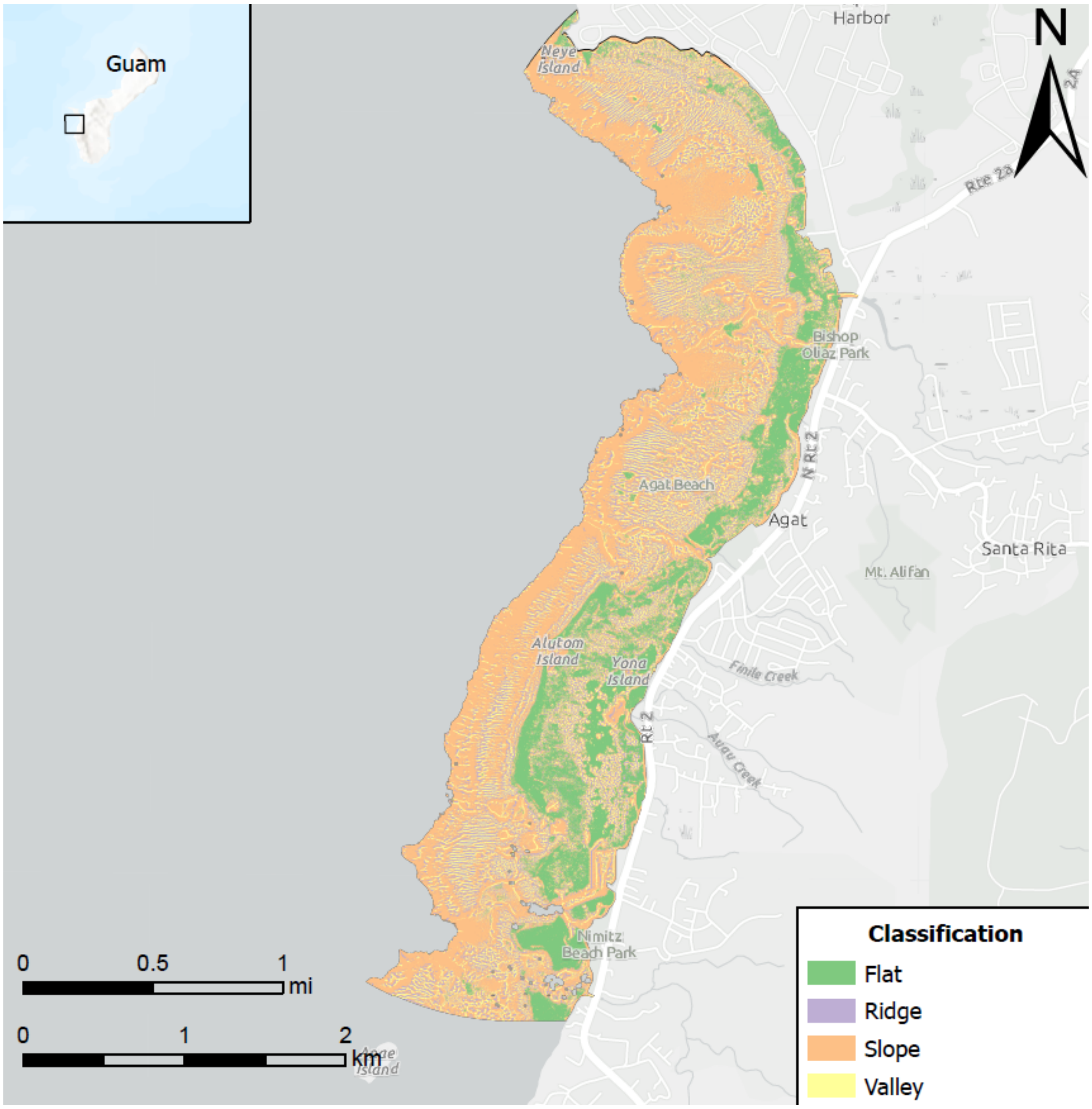


Figure 52. Seafloor geomorphology classification of the Agat unit. NPS image.

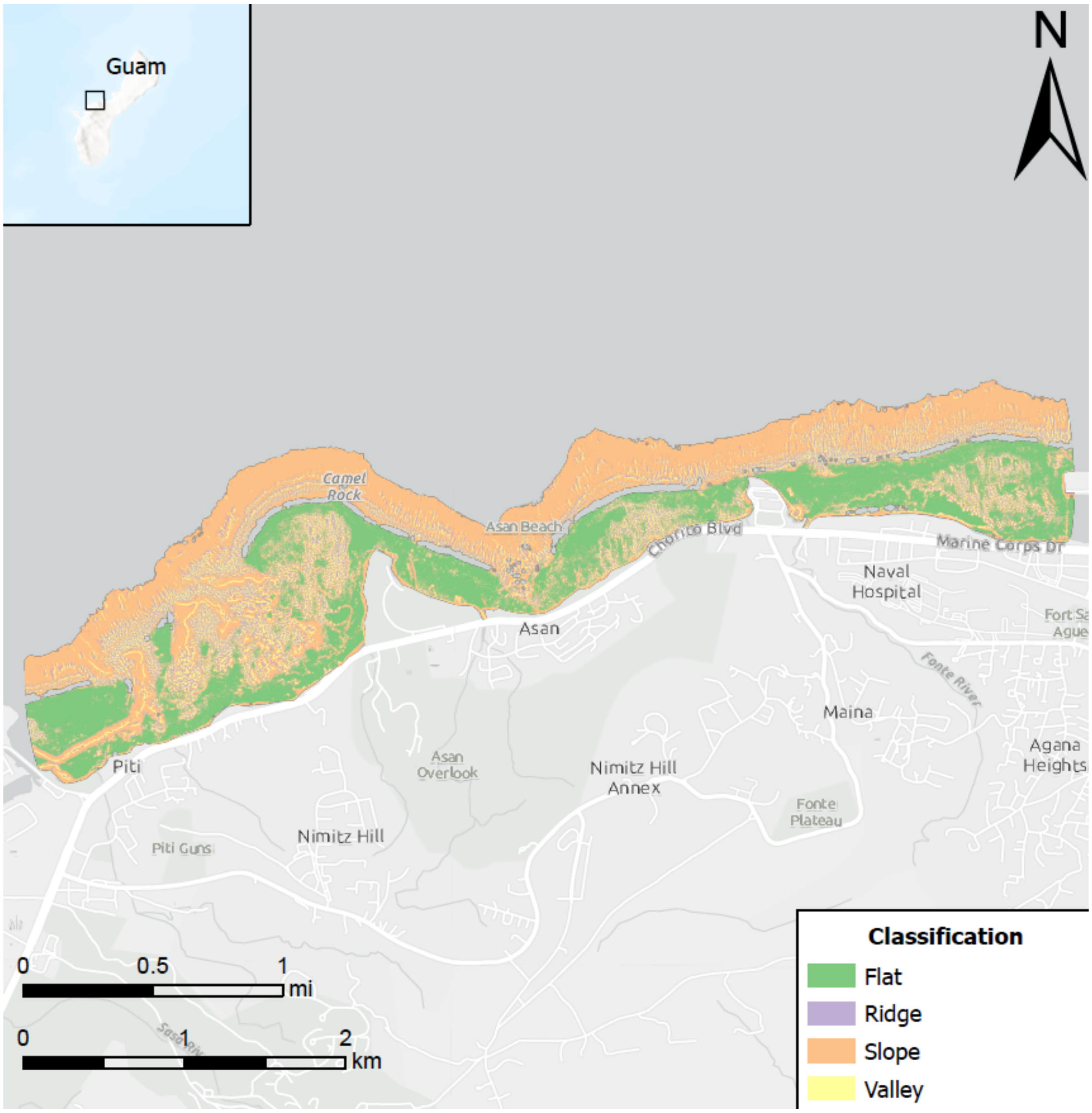
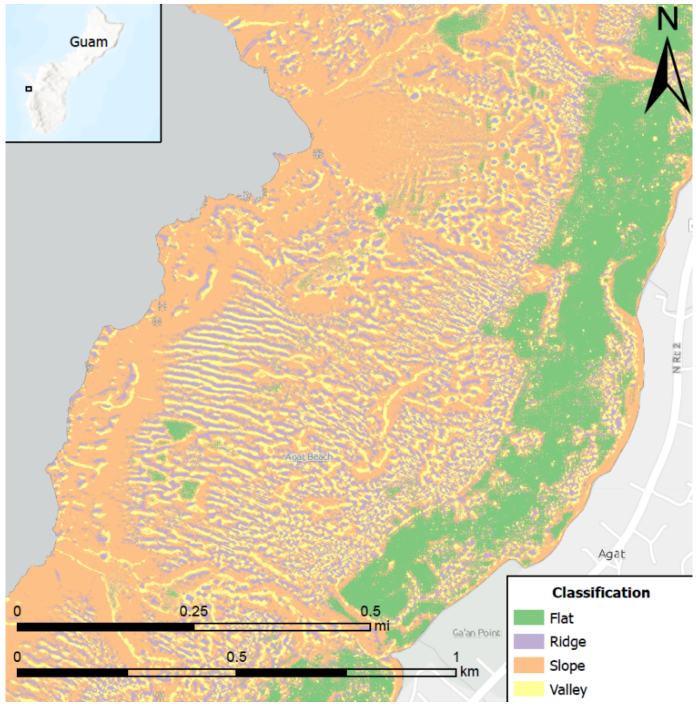


Figure 53. Seafloor geomorphology classification of the Asan Beach unit. NPS image.



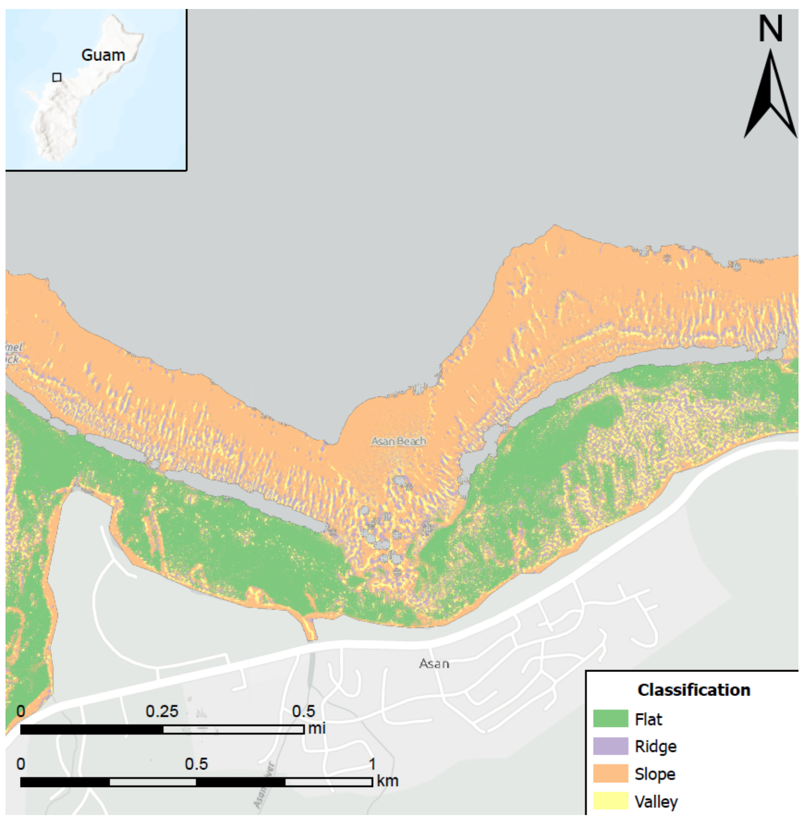


Figure 54. Zoomed-in view of the seafloor geomorphology classification at the Agat (top) and Asan Beach units (bottom). NPS images.

KOCOA analysis

Archaeologists and historians have adapted military terrain analysis approaches to better understand how actors may have perceived a battlescape and to reconcile physical, historic remains of a battle with documented historic accounts (Spennemann 2020). The archaeological application of this analysis can aid in furthering our understanding of what took place during the invasion and how these events might be evident in the archaeological and natural history record. It is also possible that this analysis can aid in determining which submerged cultural resources located at the invasion sites are directly related to the battle, and which resources are possibly a post-war dumping ground for war materials, which was a common practice in the Western Pacific after the war's end.

KOCOA is an acronym that stands for Key terrain, Observation and fields of fire, Cover and concealment, Obstacles, and Avenues of Approach/withdrawal. (McKinnon et al. 2020). These terms are feature groupings and can be useful in interpreting and understanding how a battlefield was seen and used by combatants. Underwater archaeology and maritime scholars have adapted KOCOA analysis (Brown 2012, Carrell et al. 2019, McKinnon et al. 2020) to interpret maritime and amphibious battlefields.

The National Park Service American Battlefield Protection Program Submerged Battlefield Survey Manual (McKinnon et al. 2020) defines the features as:

K – Key Terrain - Ground that must be controlled to accomplish the mission.

O – Observation and Fields of Fire - The ability to see friendly and enemy forces. FF are areas that weapons cover/can fire on efficiently.

C – Cover and Concealment - Protection from enemy fire, observation, and surveillance.

O – Obstacles - Natural or human-made landscape features that prevent, impede, or divert movement.

A – Avenues of Approach and Withdrawal - Relatively unobstructed ground route that leads to and/or away from an objective or key terrain and does not come under enemy fire.

Based on historical and archival research (Carberry 1944, Crist 1944, Department of the Navy 1945a, 1945b, 1945c, Lodge 1954, Logsdon 1944, Nelson et. Al 2003, O'Brien 1994, Thompson 1985) the team defined the following features as integral to the battlescapes at Asan (Table 4) and Agat (Table 5). The Battle of Guam spanned many other locations on the island, but as this project focused on Asan and Agat, the team included features on this list that are primarily at these two locations and consequently features that were involved in the first few days of fighting, as combatants moved past the invasion beaches. Features of the battle that are submerged or near shore were documented during fieldwork.

Table 4. Asan KOCOA Features.

Battlefield Feature	**KOCOA Feature Grouping**	**Description**
Reef flats	Key Terrain	The transport of troops via LVT across the reef flats was imperative to the success of the invasion, as Marines could not reach the beach without crossing this area.
	Obstacle	The reef flats also acted as an obstacle, as the distance traveled by LVT from the transport ships to shore was wide, and in some cases drew enemy fire. The difficult and sometimes uneven terrain of the reef also made the crossing potentially perilous.
	Observation/Fields of Fire	UDTs used the reef flats as an observation point to observe the Japanese onshore while conducting reconnaissance missions. They also drew fire while working in this area (Carberry 1944, Crist 1944, Department of the Navy 1945a-d).
	Avenue of Approach/Withdrawal	The reef flats were the only avenue of approach for LVTs to shore.
Beach	Key Terrain	As the sole landing locations, control of the beach was imperative for successful control of the battlescape.
Adelup Point	Key Terrain	Adelup Point was the easternmost flank of the Asan invasion beach (Lodge 1954).
	Cover and Concealment	Japanese defensive structures are embedded in the coral outcropping.
Asan Point	Key Terrain	Asan Point was the westernmost flank of the Asan invasion beach (Lodge 1954).
	Cover and Concealment	Japanese pillbox and gun emplacements are also embedded at Asan point, as is a tunnel. This structure represents the only remaining Japanese defense structure built by CHamoru forced labor on the island. (Thompson 1985).
Asan Beach Ridgeline	Key Terrain	Control of the high ground of the Asan Beach Ridgeline, inclusive of Chonito, Bundschu, and Fonte Ridges, was key to invasion success (Lodge 1954).
	Observation	Japanese control of the high ground made it an easy location to observe the landing forces (Lodge 1954).

	Cover and Concealment	The high ground was also used as cover by the Japanese, and was a convenient position for intense machine gun fire, such as that which held up the 1st Batallion, 3d Marines advance in their assigned zone (O'Brien 1994).
Unguarded Defiles	Avenue of Approach/Withdrawal	The 21st Marines of the 3rd Marine Division located two defiles (narrow columns) that were unguarded on either side of the regiment's assigned area (center area of Asan battlefield) and were able to climb straight to the clifftop, where they swept the area below the cliffs (O'Brien 1994).
Man-made beach defenses	Obstacle	The Japanese placed coral cribs and rock scully defenses on the beach and across the reef flats, which were largely removed by UDTs prior to W-Day (Carberry 1944, Crist 1944).
Pill boxes, cave bunkers, and tunnels	Cover and Concealment	Pill boxes were built near the beach to provide cover and concealment for the occupants. Some pillboxes and emplacements contained interior tunnels that allowed Japanese troops to travel from the shoreline to nearby ridge tops while remaining underground.
Guns/Artillery	Obstacle	U.S. Marines were under intense fire from the front and right flank at Asan Point (O'Brien 1994) and intense mortar and artillery fire from Adelup Point. Adelup Point was difficult to breach due to the cliffs, where the Japanese could roll hand grenades down the rock and onto the Marines (O'Brien 1994). In total, the Japanese had at least nineteen 200mm, eight 150mm, twenty-two 105mm and six 75mm coastal defense guns spread between both invasion beaches, as well as eighteen 75mm guns, forty 75mm pack howitzers, fourteen 105mm howitzers, 580 7.7mm machine guns and eighty-six antitank guns of various calibers. (Thompson 1985).
Tank traps	Obstacle	Tank traps were constructed of tree trunks and buried under the sand by forced CHamoru labor at Asan (Thompson 1985).

Rice paddies	Obstacle	Rice paddies near Asan Point slowed the advance of the Marines. (O'Brien 1944:32, Thompson 1985)

Documentation of Features

The following submerged or coastal features were documented as part of this project. Figure 55 is provided to illustrate the view of the landing beaches as perceived by incoming Marines, as well as the current day bathymetric context.

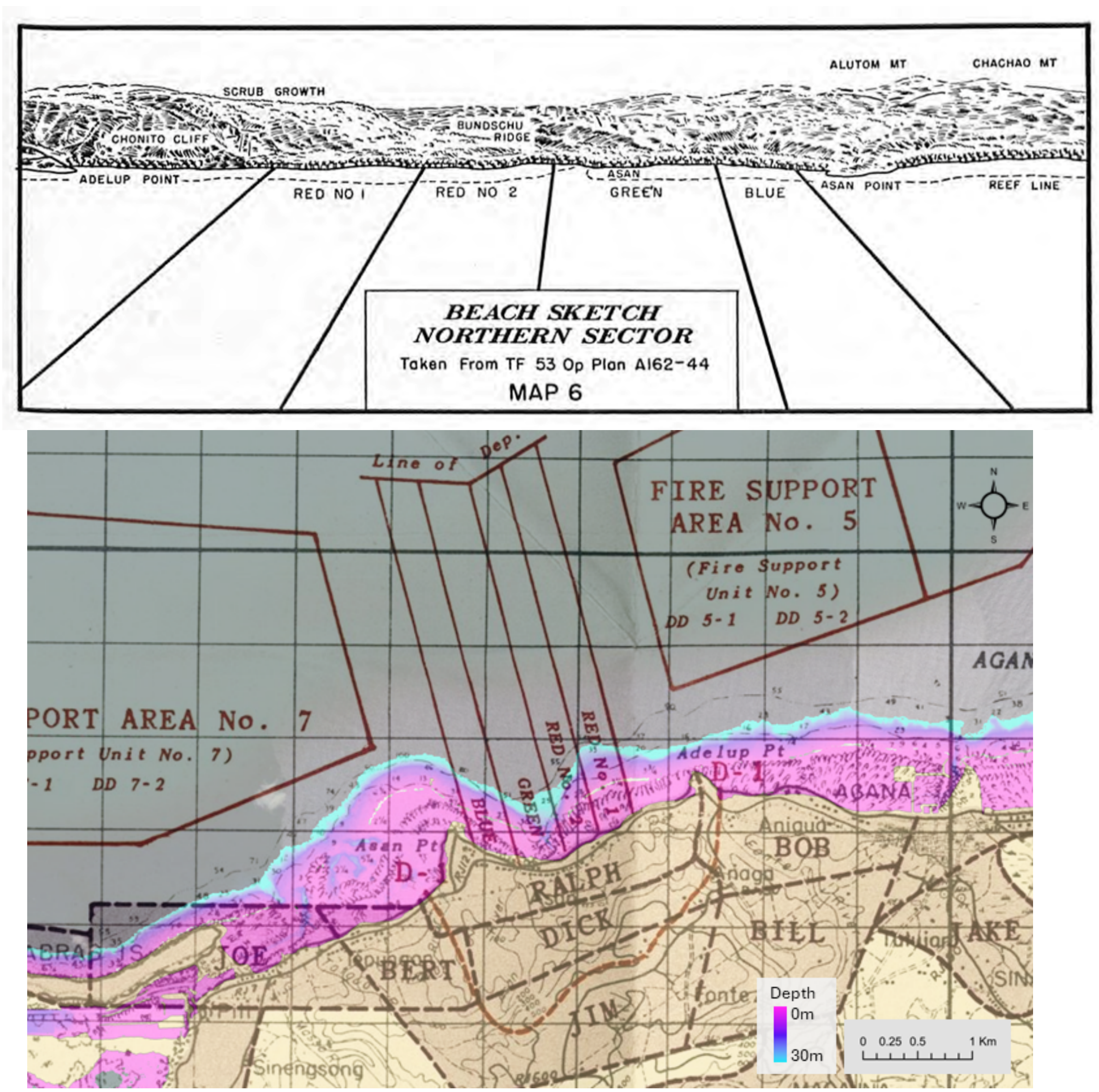


Figure 55. (top) Beach Sketch, Northern Sector, depicting landing beaches at Asan. Image via Lodge 1954. (bottom) Task Force 53 Operations Chart (as shown in Figure 17) overlaid with modern day bathymetry (collected as part of this project).

Reef Flats

The reef flats at Asan were identified as a Key Terrain feature, as control of the reef and transport of troops via LVT across the reef flats was imperative to the success of the invasion. The reef was also identified as an obstacle, observation/field of fire, and an avenue of approach and withdrawal. The classification of the reef as several KOCOA feature groupings illustrates the importance of the reef flats during the invasion, as well as the importance of removing obstacles from this area prior to mobilizing Marines.

The reef flats were documented with multibeam bathymetry using the Echoboat 160 ASV, discussed in Section II 5a of this report.

The team also completed a walking/wading survey for archaeological material on the reef flats at Asan, which is further discussed in Section II 6b of this report.

Finally, portions of the reef flats were documented using photogrammetry (UDT obstacle removal blast crater) and GNSS, further discussed below and in Section II 6b of this report.

Beach

Control of the beach was imperative for the success of the invasion. Once secure, the beach allowed for the landing of ammunition and supplies and setup of command on the island.

Asan beach was documented through coastal elevation via scanning total station and (Trimble SX10 scanning total station). The scanning total station was used to collect full coverage high density point cloud data. Data collection included the beach and extended into the intertidal and portion of the subtidal zone, allowing for coastal terrestrial to subtidal coverage. (See Section II 6a “Coastal Elevation Surveys” coastal elevation surveys of this report for images).

Asan Pillboxes

The Japanese used several pillboxes and emplacements at Asan. These pillboxes often took advantage of natural features and crevices in the rock to conceal their entrances on the cliff face. Some pillboxes and emplacements contained interior passages that allowed Japanese troops to travel from the shoreline to nearby ridge tops while remaining underground. These passages were also helpful tactically, as emplacements near the shore could be perceived as empty by U.S. Marines, allowing the Japanese to return through the passage and attack from behind. The pillboxes also employed such tools as a grenade-proof air vent, which diverted grenades thrown at the pillbox through a shoot and deposited them outside (Nelson et al. 2003).

A reinforced concrete pillbox is located in shallow water just off Asan Beach (Figure 56). It is unclear if this pillbox was originally located in its present location (though this is unlikely), or if it was moved offshore at a later date. There is no foundation site for the pillbox. The team documented it during the walking survey of Asan Beach and using LiDAR (see Section II 6a “Coastal Elevation Surveys” for additional images). There are additional pillboxes and emplacements on shore at Asan that are well-documented by WAPA.

Figure 56. Partially submerged pillbox at Asan Beach Unit (photo taken at low tide; high tide mark is visible on pillbox structure). NPS Photo.

Asan Point

Adelup and Asan Points were the eastern and westernmost points of the Asan invasion beach. Defensive structures and gun emplacements were used on both points, which acted as Cover and Concealment for the Japanese.

Asan Point was captured using LiDAR (see Section II 6a “Coastal Elevation Surveys” for additional images).

Adelup Point was not captured due to project time constraints.

Man Made Beach Defenses

At Asan, the Japanese primarily employed obstacle cribs made of coconut logs and wire filled with coral rubble (Figure 57), which were largely destroyed by UDTs prior to the landings (as described in Section II 5b of this report). While there are no remaining man made beach defenses left at Asan today, the team located and documented the historic location of many obstacles by using a hand-drawn map from UDT 3 found in the National Archives. (Location methods described in Section II 4a of this report). Blast craters indicating where the obstacles previously stood are apparent and in alignment with the georeferenced historic map indicating the location of man made beach defenses removed by UDTs.

Figure 57. Historic photograph showing coconut log obstacles at Asan. Image via RG 128, National Archives at College Park.

The presence of these craters is an interesting occurrence in which the absence of a natural resource is indicative of a cultural phenomenon. Some of the craters retain a small piece of metal that may be an obstacle remnant, but it is also possible that the craters serve as a low-lying collection point for debris. This crater is depicted below in Figure 58. Figure 59 shows the location of the obstacles (and subsequent craters) as depicted by UDT 3.

See also Section II 6b "Blast Craters" for mapped documentation.

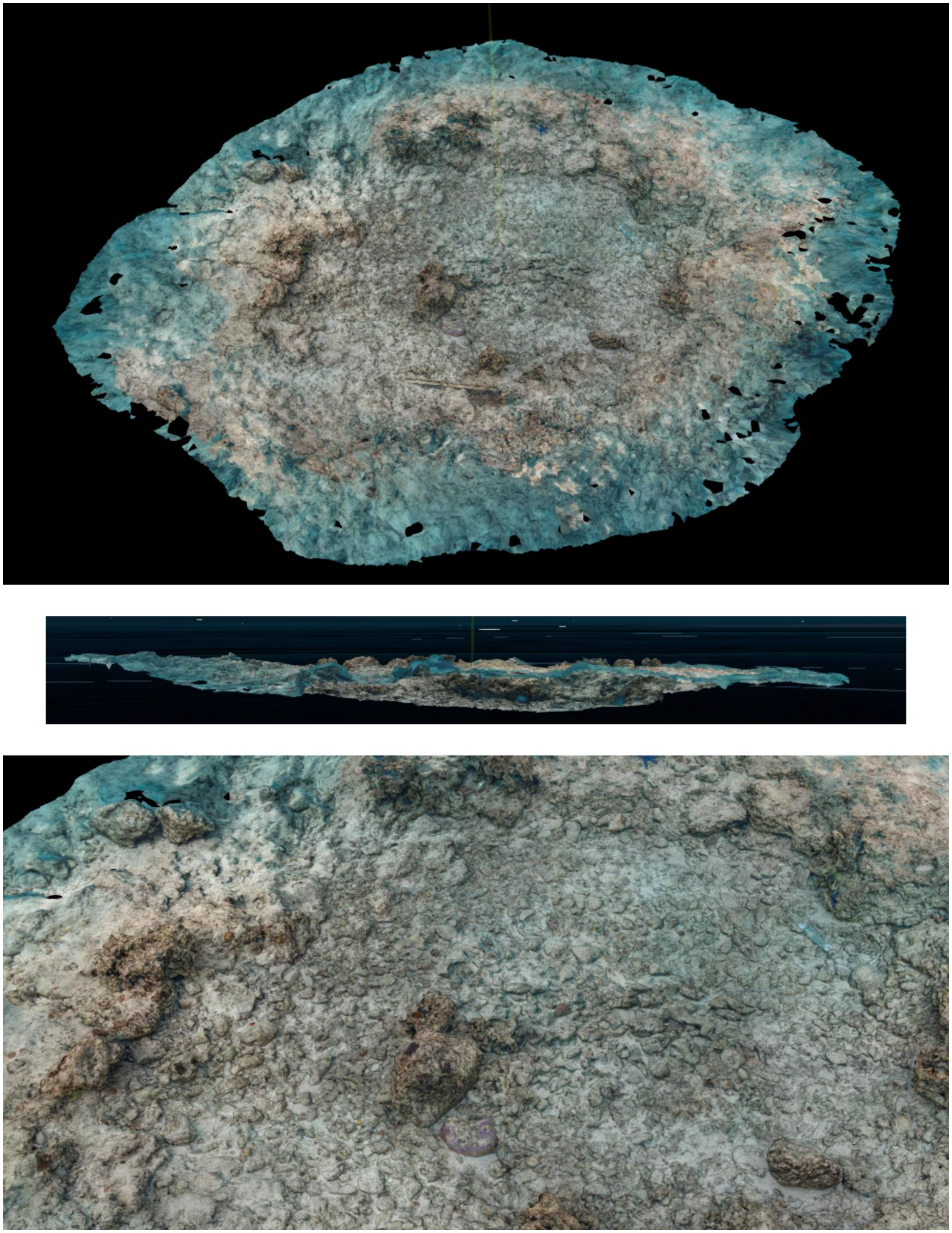


Figure 58. Orthomosaic of a shallow blast crater at Asan Beach unit. NPS Image.

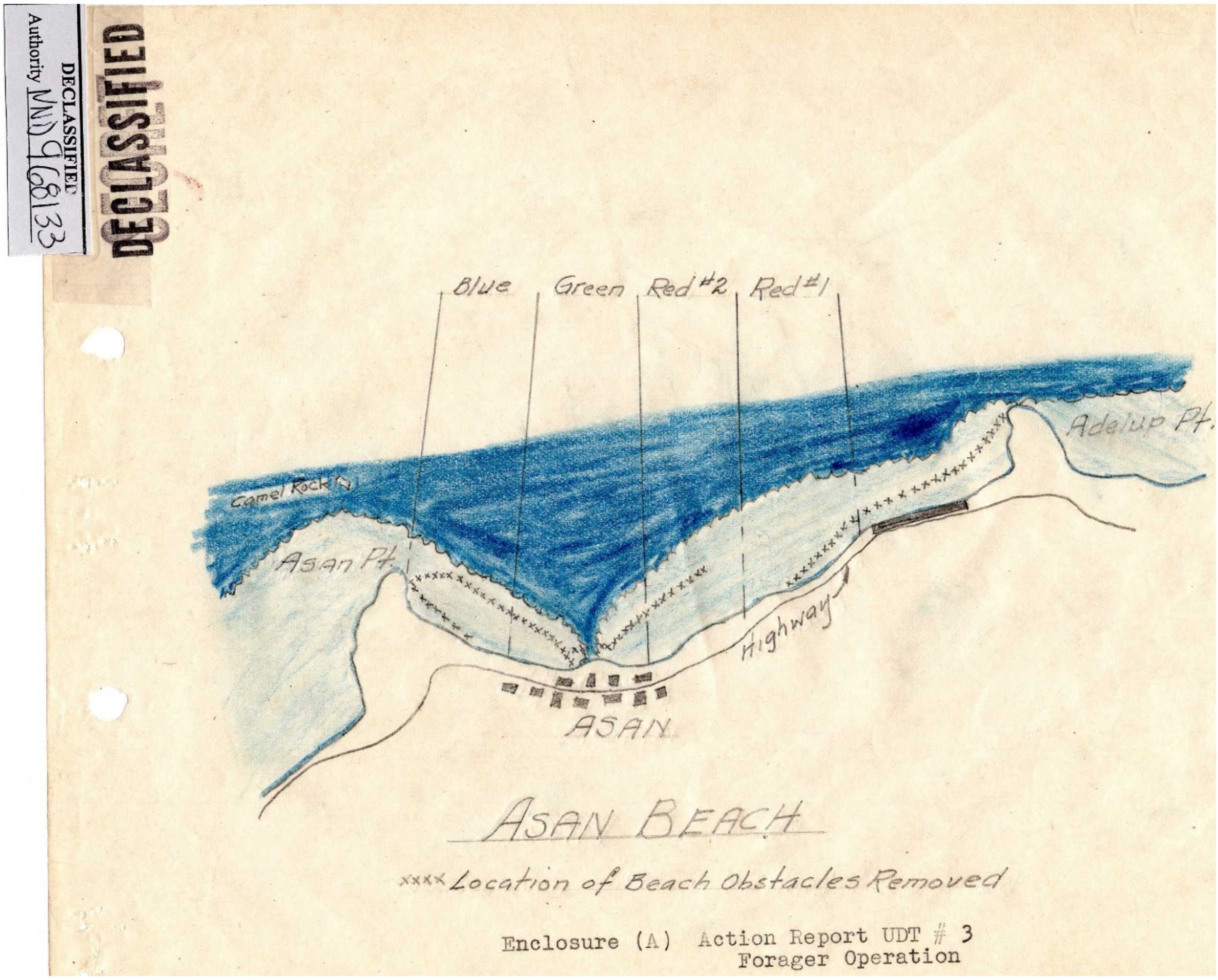


Figure 59. Historic map showing location of obstacles. The above blast crater was created as a result of the explosion at one of these "Xs." Map via National Archives at College Park, Record Group 38.

Table 5. Agat KOCOA Features.

Feature	KOCOA Feature Grouping	Description
Reef flats	Key Terrain	The transport of troops via LVT across the reef flats was imperative to the success of the invasion, as Marines could not reach the beach without crossing this area.
	Obstacle	The reef flats also acted as an obstacle, as the distance traveled by LVT from the transport ships to shore was wide, and in some cases drew enemy fire. The difficult and sometimes uneven terrain of the reef also made the crossing potentially perilous.

	Observation/Fields of Fire Avenue of Approach/Withdrawal	UDTs used the reef flats as an observation point to observe the Japanese onshore while conducting reconnaissance missions. They also drew fire while working in this area (Carberry 1944, Crist 1944). The reef flats were the only avenue of approach for LVTs to shore.
Beach	Key Terrain	As the sole landing locations, control of the beach was imperative for successful control of the battlescape. While landing on the beach, the Marines at Agat came under significantly more Japanese fire than the Marines at Asan.
Bangi Point and Hill 40	Key Terrain Cover/Concealment	Bangi Point was the southernmost point of the landing beaches at Agat. Hill 40 is located approximately 325 meters from Bangi Point. In his first hand account of the battle, O'Brien (1994:15) describes Hill 40 as a "particularly critical hill mass near Bangi Point...Hill 40's unexpectedly heated defense indicated that the Japanese recognized its importance, commanding the beaches where troops and supplies were coming ashore." Hill 40 was also the site of a major Japanese counter-attack after it had been taken by U.S. Marines, due to its recognized importance (Lodge 1954). Bangi Point also contains a Japanese pillbox made of reinforced concrete with a camouflaged roof at the water's edge, which allowed for a north and south field of fire along the beach (Lodge 1954, Nelson et al. 2003).
Apaca Point	Key Terrain Cover and Concealment	Apaca Point was the northernmost point of the landing beaches at Agat. This area contained a system of pillboxes and tunnels with a field of fire southward towards the reef and beach (Nelson et al. 2003).

Ga'an Point	Key Terrain Cover and Concealment	Ga'an Point was the central location between the White (1 and 2) and Yellow (1 and 2) landing beaches at Agat. Concrete fortifications and guns at Ga'an were also significant (Lodge 1954).
Agat Beach Ridgeline	Key Terrain Observation Cover and Concealment	Control of the high ground of the Agat Beach Ridgeline, inclusive of Mount Alifan and Maanot Ridge was key to invasion success. Control of Mount Alifan was one of the W-Day goals, but American bombardment fell sort, halting the attack (Lodge 1954, O'Brien 1994:13). Japanese control of the high ground made it an easy location to observe the landing forces, allowing for intense fire on the Marines at Agat. The high ground was also used as cover by the Japanese, and was a convenient position for intense machine gun fire, such as that which held up the 1st Batallion, 3d Marines advance in their assigned zone (O'Brien 1994).
Man-made beach defenses	Obstacle	The Japanese placed coral cribs and rock scully defenses on the beach and across the reef flats, which were largely removed by UDTs prior to W-Day (Carberry 1944, Crist 1944, Department of the Navy 1945a-d). Agat was heavily mined. Pre-landing planning instructed Amtracs to unload 1000 yards inland, but this tactic was unsuccessful due to the heavily minded beach and anti-tank ditches (O'Brien 1994).
Pillboxes, Cave Bunkers, and Tunnels	Obstacle Cover and concealment	Pillboxes contained guns, such as the 75mm gun inside a pillbox at Ga'an Point which wreaked havoc upon the landing marines (O'Brien 1994). Pill boxes were built near the beach to provide cover and concealment for the occupants. Some pillboxes and emplacements contained interior tunnels that allowed Japanese troops

		to travel from the shoreline to nearby ridge tops and other emplacements while remaining underground.
Guns/Artillery	Obstacle	U.S. Marines were under intense fire at Ga'an Point, which destroyed 24 LVTs on their way into the beach. They were also met with resistance from the Agat Beach Ridgeline (O'Brien 1994).
Tank traps	Obstacle	Tank traps similar to those at Asan were placed on the beach at Agat, interspersed with mines and other obstacles (O'Brien 1994)
Yona Island	Obstacle	Fire from Yona Island caught Marines in significant cross fire between the island and Ga'an Point (O'Brien 1994)
LVTs	Obstacle	24 LVTs were knocked out at Agat by artillery at Ga'an Point, slowing the landings and causing some Marines to have to wade ashore (O'Brien 1994).

Documentation of Features

The following submerged or coastal features were documented as part of this project. Figure 60 is provided to illustrate the view of the landing beaches as perceived by incoming Marines, as well as the current day bathymetric context.

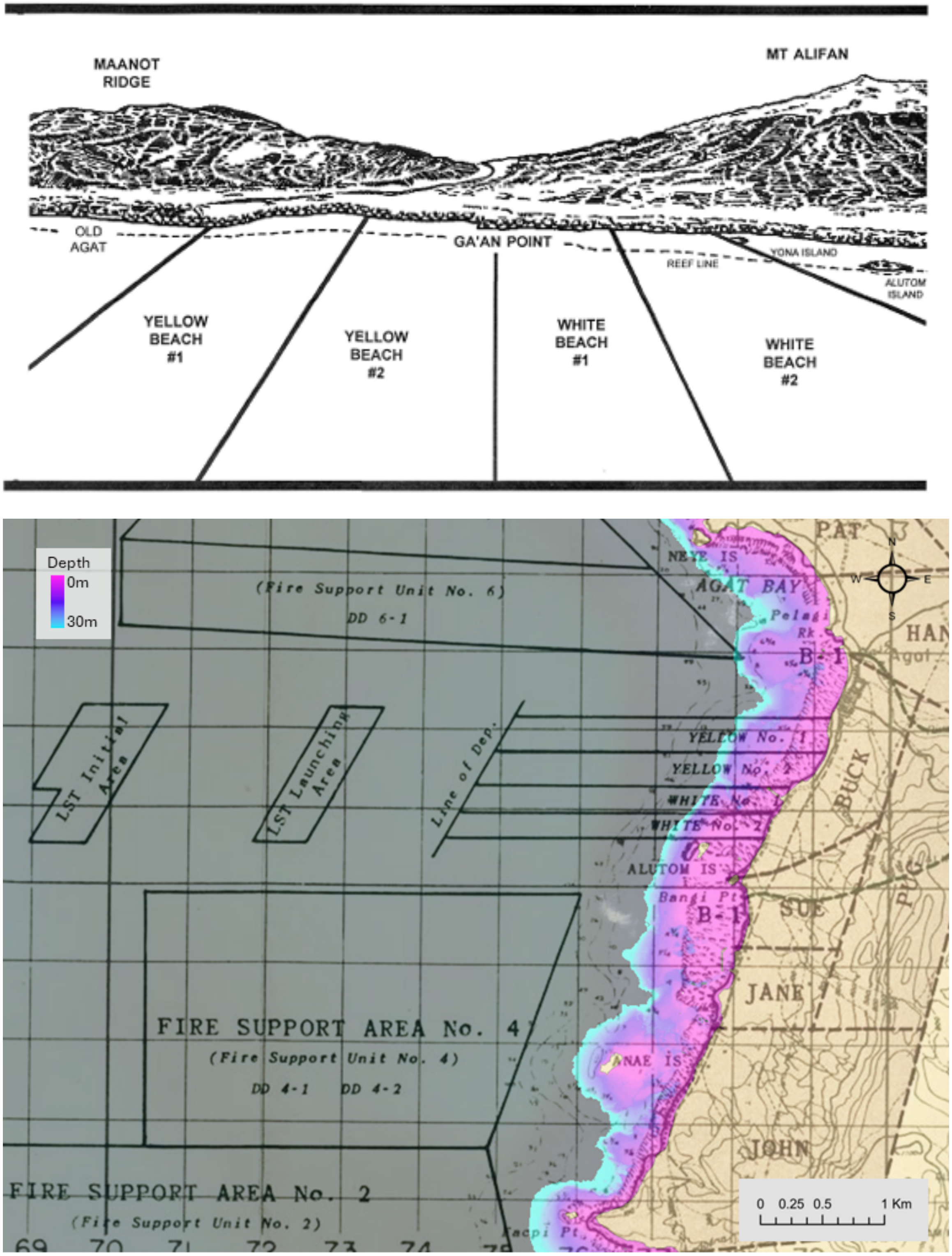


Figure 60. (top) Beach Sketch, Southern Sector, depicting landing beaches at Agat. Image via Lodge 1954. (bottom) Task Force 53 Operations Chart (as shown in Figure 18) overlaid with modern day bathymetry (collected as part of this project).

Reef flats

As at Asan, the reef flats at Agat were identified as Key Terrain feature, as control of the reef and transport of troops via LVT across the reef flats was imperative to the success of the invasion. The reef was also identified as an obstacle, observation/field of fire, and an avenue of approach and withdrawal. The classification of the reef as several KOCOA feature groupings illustrates the importance of the reef flats during the invasion, as well as the importance of removing obstacles from this area prior to mobilizing Marines.

The reef flats were documented with multibeam bathymetry using the Echoboat 160 ASV, discussed in Section II 5a of this report.

While walking survey of the reef flats at Agat were planned, Hurricane/Typhoon Dora prevented its completion. (See Section III 1b of this report).

Beach

Control of both landing beaches was imperative for the success of the invasion. Once secure, control of the beach allowed for the landing of ammunition and supplies and setup of command on the island. Japanese resistance to the landings on Agat were more intense than at Asan, in part due to the pillbox and gun emplacements at Ga'an Point directly between the divided sections of the beach, as shown in Figure 60 (O'Brien 1994:11).

Agat Beach was documented through coastal elevation via scanning total station and (Trimble SX10 scanning total station). The scanning total station was used to collect full coverage high density point cloud data. Data collection included the beach and extended into the intertidal and portion of the subtidal zone, allowing for coastal terrestrial to subtidal coverage. (See Section II 6a "Coastal Elevation Surveys" of this report for images).

Agat Pillboxes, Cave Bunkers, and Tunnels

The Japanese pillboxes at Agat played a major role in resistance to the landings. The Ga'an Point pillbox, located directly between the Yellow and White landing beaches, was particularly destructive. A 75mm gun, companion piece, and 37mm gun inside the pillbox destroyed 24 LVTs inbound to the beach. The pillbox had a four-foot thick concrete roof and was well-camouflaged. The structure was not spotted by reconnaissance interpreters, and therefore not targeted during the pre-landing bombardment. It took the entire morning and into the afternoon for Marines to overtake the Ga'an Point pillbox (O'Brien 1994).

Other pillboxes, emplacements, bunkers, and tunnels were located at Apaca and Bangi Points and Yona Island.

The structures at Ga'an Point were captured using LiDAR (see Section II 6a "Coastal Elevation Surveys" for additional images). The scanning total station was used to collect full coverage high density point cloud data.

Figure 61. Partially submerged pillbox at Agat Beach Unit. NPS Photo.

Ga'an, and Apaca Point

Due to its location in the center of the landing beaches as well as the pillboxes and gun emplacements fixed there, Ga'an Point was one of the most significant terrain features of the battle at Agat. As previously mentioned, guns at Ga'an Point eliminated 24 LVTs before U.S. Marines were able to overtake it.

Apaca Point marked the northern extent of the landing beach. Both of these points were recorded using LiDAR (see Section II 6a "Coastal Elevation Surveys" for additional images).

LVTs

The LVT-4 Amtrac located approximately 500 meters off Ga'an Point is a well-known and popular dive site, first archaeologically documented by WAPA staff and the Submerged Cultural Resources Unit (SCRU) in 1985 (Carrell 1991) as part of an underwater archaeology training session for park staff led by SCRU (Figure 62). The LVT-4 was detected with the side scan sonar and magnetometer during this project, but was not investigated as the site was known. The team visited the LVT to document it via photogrammetry (Figure 63). This model is publicly available (Agat LVT-4) and was also used in public outreach products for this project.

24 LVTs were lost on W-Day due to intense fire from the gun emplacements at Ga'an Point. However, this LVT-4 does not show apparent battle damage. It is therefore difficult to determine if it was lost during the battle or discarded after the war. Primary source historical documents found by the team at the National Archives do not mention the fate of the 24 LVTs, as this was likely not deemed relevant information to record during wartime reporting (at least within this particular report). However, this is the same vessel type that was used on W-Day, and can be considered representative of the 24 damaged LVTs.

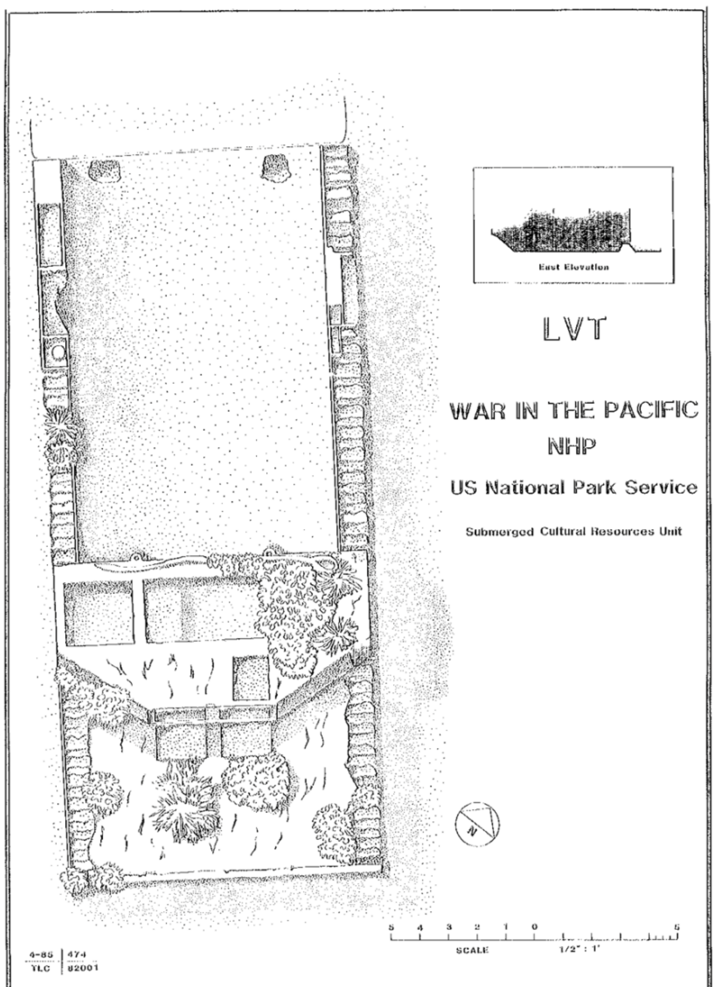


Figure 62. Archaeological drawing of the submerged LVT-4 at Agat Unit, from Carrell 1991. NPS Image.

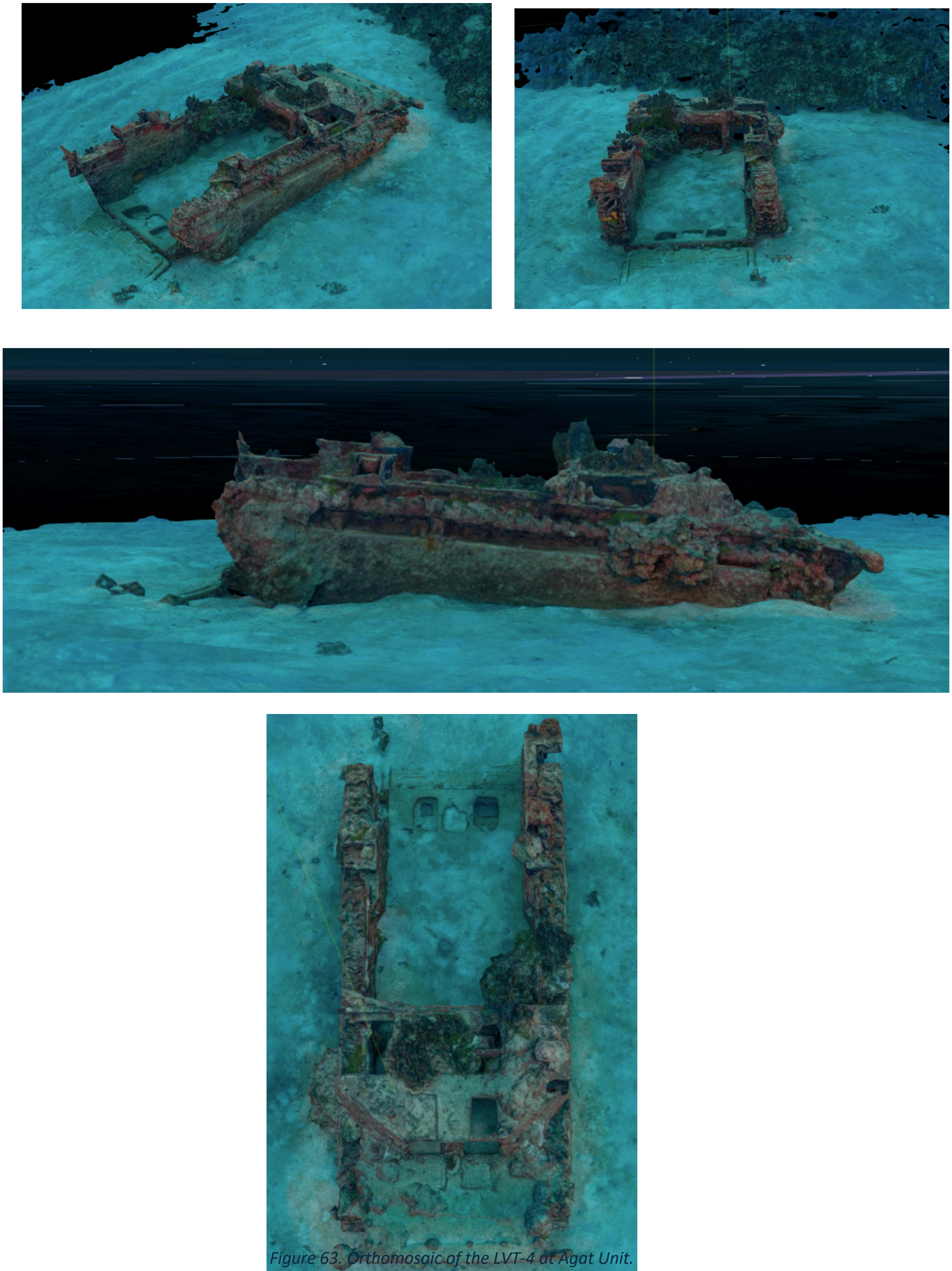


Figure 63. Orthomosaic of the LVT-4 at Agat Unit. NPS Image.

Oral history

Project Scientists-in-Parks intern Blair Moore led the oral history collection effort. As part of the internship, he worked with project leadership to define areas of interest, draft questions, and planned and led the interviews.

Prior to the second field campaign, background research was conducted on all previous known oral histories collected from the CHamoru community. WAPA previously conducted a study entitled "A Rapid Ethnographic Assessment Project for the Asan Beach Unit and Agat Unit Management Plan: War in the Pacific National Historical Park, Territory of Guam (REAP)" (Santos Steffy and Tomonari-Tuggle 2021). REAP collected eight interviews with residents of Asan and Agat. The report details oral histories with information regarding the 1930's to 2021 and included a majority of interviewees from Asan. REAP informed many of the oral history interview questions for this project and also provided the team with leads on individuals who may be interested in a follow-up interview as part of this project.

The following questions were used as guidelines during the oral history interviews, allowing for the interviewer(s) to ask additional and follow-up questions, or adapt questions based on the interviewee's interests:

- Were you or any of your family members present during World War II on Guam? Do you or your family have any significant memories or stories that you would like to share?
- Were you aware of damage caused to the reef by Underwater Demolition Teams during World War II?
- How do you and/or your family primarily use the areas in and around Asan and Agat beaches (both on land and in the water)?
- What was the land adjacent to Asan and Agat beaches used for before the war?
- Do you know any stories of what the coral reefs and beaches of Asan or Agat were like before the war?
    - How has the landscape changed?
    - In your opinion, has the extent and/or diversity of the coral reef declined?
    - Has fish abundance changed?
    - Have changes in the environment impacted the type of food collected?
    - Have fishing methods evolved to accommodate changes?
- Besides fish, what does the ocean provide for the community?
- How do you view World War II archaeological sites at Asan and Agat, underwater or on land?

Oral history collection was planned using NPS oral history guidelines and standards as set forward by the Oral History Association (OHA) (Oral History Association). Under OHA guiding principles, interview processes are transparent and engage interviewees through the entire process, including the creation of end products. All interviewees gave verbal and written consent for their stories to be used as part of this project. Interviewees were not required to participate and could decline to answer any question. Only one individual was interviewed at a time. Each interview lasted for a maximum duration of 90 minutes. All interviews were recorded and transcribed, and interviewees were given the opportunity to review the transcription to ensure the intention and the accuracy of their statements.

Three oral history interviews were collected during fieldwork. Two interviewees were also interviewed as part of REAP, and the team was able to ask follow-up questions informed by their previous interviews.

Interviews were conducted with Mr. Luis Cabral II, Mr. James Terlaje, and Ms. Desiree Toledo and are summarized below.

Luis Cabral grew up in Assan and has worked as a professional SCUBA diver for most of his adult life. Mr. Cabral shared stories of community fishing at Assan, including the practice of reef walking. Reef walking, walking along the reef flats while looking for snails or fish to harvest at low tide, is a means of subsistence fishing that he used as a child. However, in his view, reef walking is no longer a productive method due to overfishing of the area. As a child, there was a consistent seasonal fish run of *Mañåhak* (juvenile rabbit fish) that the community would fish together, but Mr. Cabral believes that overfishing and changes in the environment have made this fish run quite erratic. The community practice of *påtte*, or the practice of sharing your catch, is also no longer a prominent practice. Mr. Cabral also recalled mangrove forests near Assan that have since disappeared.

Mr. James Terlaje's interview focused on his family's use of *chenchulu*, or communal net fishing, often practiced as a weekend activity. Mr. Terlaje net fished with his parents on the reef flats and continued the practice with his own family until they became too busy to continue. The nets have weights on one side and floats on the other which allowed them to selectively spear certain fish and release others. At the end of the day, the catch would be distributed amongst family members. Mr. Terlaje kindly provided the team with photos showing his family fishing over the years, which were incorporated into outreach and education materials.

Ms. Deisree Toledo was introduced to the team through Mr. Cabral, who was her instructor for a divemaster course and dove with her in the area often. Ms. Toledo is originally from the Philippines, and our team had an interesting discussion with her about how Assan and Hågat are currently used by local divers. She described how divers at Assan usually dive from the shore (as opposed to from a boat) and therefore local knowledge of tides and entry and exit points are of paramount importance. During her regular use of the area, she is accustomed to keeping a watchful eye for UXO, and instructs other divers and tourists to leave UXO alone. PI Wright Nunn and Ms. Toledo corroborated a phenomenon at Hågat that the project team noticed while documenting the landing area created by UDT 4 at Yellow One Beach. Significant marine debris appears to collect at the base of the landing area, in comparison to the edge of the un-demolished nearby reef. Ms. Toledo did not know that this area had been demolished during World War II, and did not believe that other local divers knew this either but indicated that this is a known hot-spot for debris collection in the diver community. This indicates a probable anthropogenic impact of World War II that can still be seen underwater today.

While the team's initial intent of collecting oral histories during the planning phase of this project was to use new interviews to inform battlefield analysis and/or the interpretation of archaeological sites at Assan or Hågat, the ability to adapt questions based on the interests of the interviewees led to surprising and interesting information on the anthropogenic effect of the war on the reefs, as evidenced by the discussion of the demolished landing area at Hågat as a noticeable marine debris collection point. The team found that the interviewees who volunteered to speak with us had less interest in discussing World War II, and more interest in talking about their and their families' current and historic use of Assan and

Hågat. The exploratory nature of the oral history part of the project allowed us to adapt the interviews into insightful material for outreach and education, including the StoryMap Resilient: War in the Pacific National Historical Park, (https://www.nps.gov/maps/stories/resilient-war-in-the-pacific-national-historical-park.html), material on the NOAA Ocean Exploration website and lesson plans related to the project.

b. Notable findings and discussion

Significant archaeological findings

Several archaeological sites and individual artifacts relating to World War II were located during target investigations, as well as large amounts of non-specific metal debris (see Appendix X) that may be related to World War II. Figures 64 and 65 show maps with the location of definitive World War II sites and artifacts at Asan Beach unit and Agat unit, respectively.

Redacted

Figure 64. Map with location of definitive World War II sites and artifacts at Asan Beach unit. NPS Image.

Redacted

Figure 65. Map with location of definitive World War II sites and artifacts at Agat Beach unit. NPS Image.

Significant archaeological findings at Agat Unit

American pontoon barge

The team relocated the site designated "American Pontoon Barge" in the *Micronesia: Submerged Cultural Resources Assessment* (Carrell 1991), which had not been re-visited by archaeologists in nearly 40 years. Carrell (1991) notes the presence of "a barge with a hoist or crane assembly used for the transfer of fuel-oil drums or other supplies to amphibious vehicles. The site includes 12 55-gallon drums, a partially buried wheel cart trailer, a crane or hoist assembly with a block, batteries still in their battery boxes, large pieces of sheet metal for the barge, and a soldier's helmet" (Carrell 1991:519). The report concludes that the site is likely that of an American Pontoon Barge, used to unload cargo on the reef with cranes from supply vessels to amphibious vehicles (Carrell 1991), similar to those shown in Figure 66. (This figure illustrates the cranes only. There are no pontoon barges shown in these historic images).

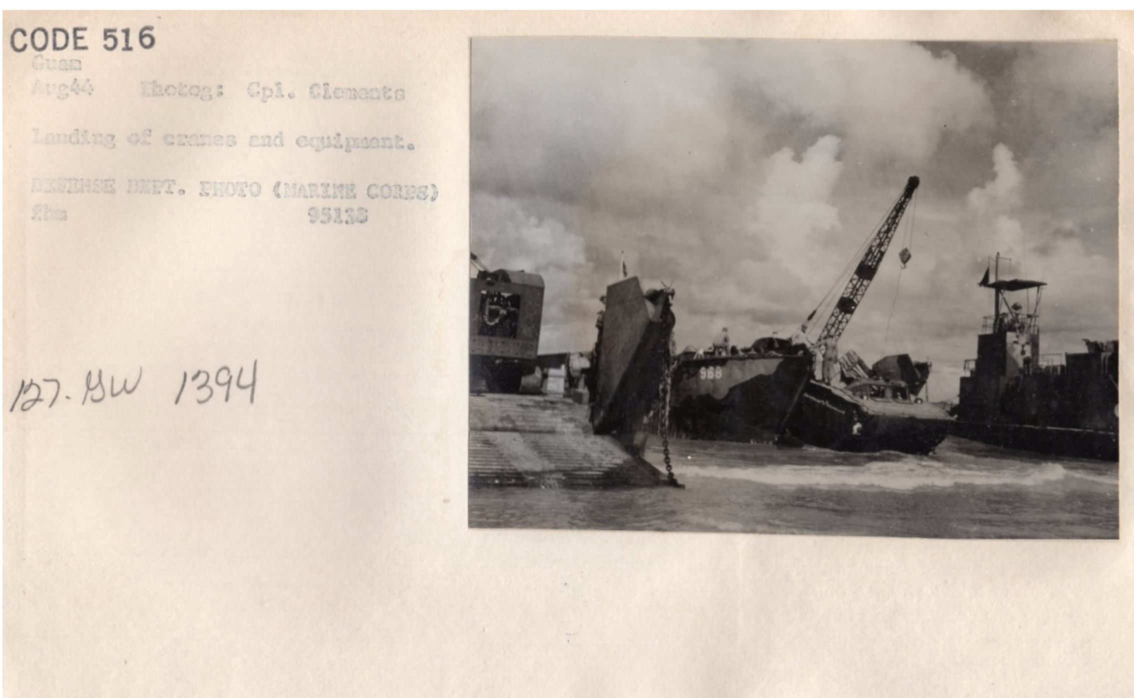


Figure 66. Cranes unload landing craft on the beach in Guam. Photo via National Archives at College Park, RG 127.

Figure 67 shows debris left behind on the beach and reef during unloading, which illustrates how materiel such as barrels and sheet metal may have been deposited on the reef.

Figure 67. Debris left behind on the beach. Photo via National Archives at College Park, RG 127.

The project team relocated this site on the final day of diving for the project. Had it been found earlier, the team would have recorded this site via photogrammetry, as it is a significant deposit of World War II materiel (see also Further Research section of this report). All artifacts mentioned by Carrell (1991), with the exception of the soldier's helmet, were identified by the team, as well as additional artifacts not mentioned, including crates of ammunition, a Danforth-style anchor, and an Amtrac door. The soldier's helmet may have been removed by divers or is now buried.

Future documentation of the site via photogrammetry will allow for a comprehensive inventory of artifacts.

Figure 68 is a historic photograph found by the team in the National Archives of Marines at Agat with a partially submerged trailer in the background. This trailer is very similar to the one found at the site. Figures 69-76 are images of the site captured by the project dive team.

Figure 68. Historic photograph showing a partially submerged trailer (left side of image) that is very similar to the type and contents of the trailer found at the "American Pontoon Barge" site. Photo via National Archives at College Park, RG 127.

Figure 69. Overturned trailer and gasoline drums found at American Pontoon Barge site. NPS Photo.

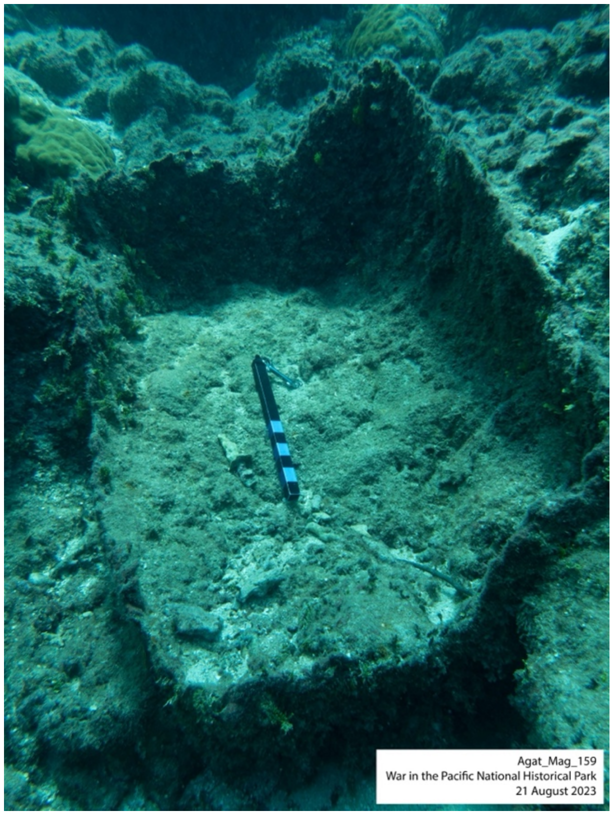


Figure 70. Gasoline drum found at American Pontoon Barge site. NPS Photo.

Figure 71. Gasoline drum found at American Pontoon Barge site. NPS Photo.

Figure 72. Overturned trailer found at American Pontoon Barge site. NPS Photo.

Figure 73. Overturned trailer found at American Pontoon Barge site. NPS Photo.

Figure 74. Buried material at American Pontoon Barge site. NPS Photo.

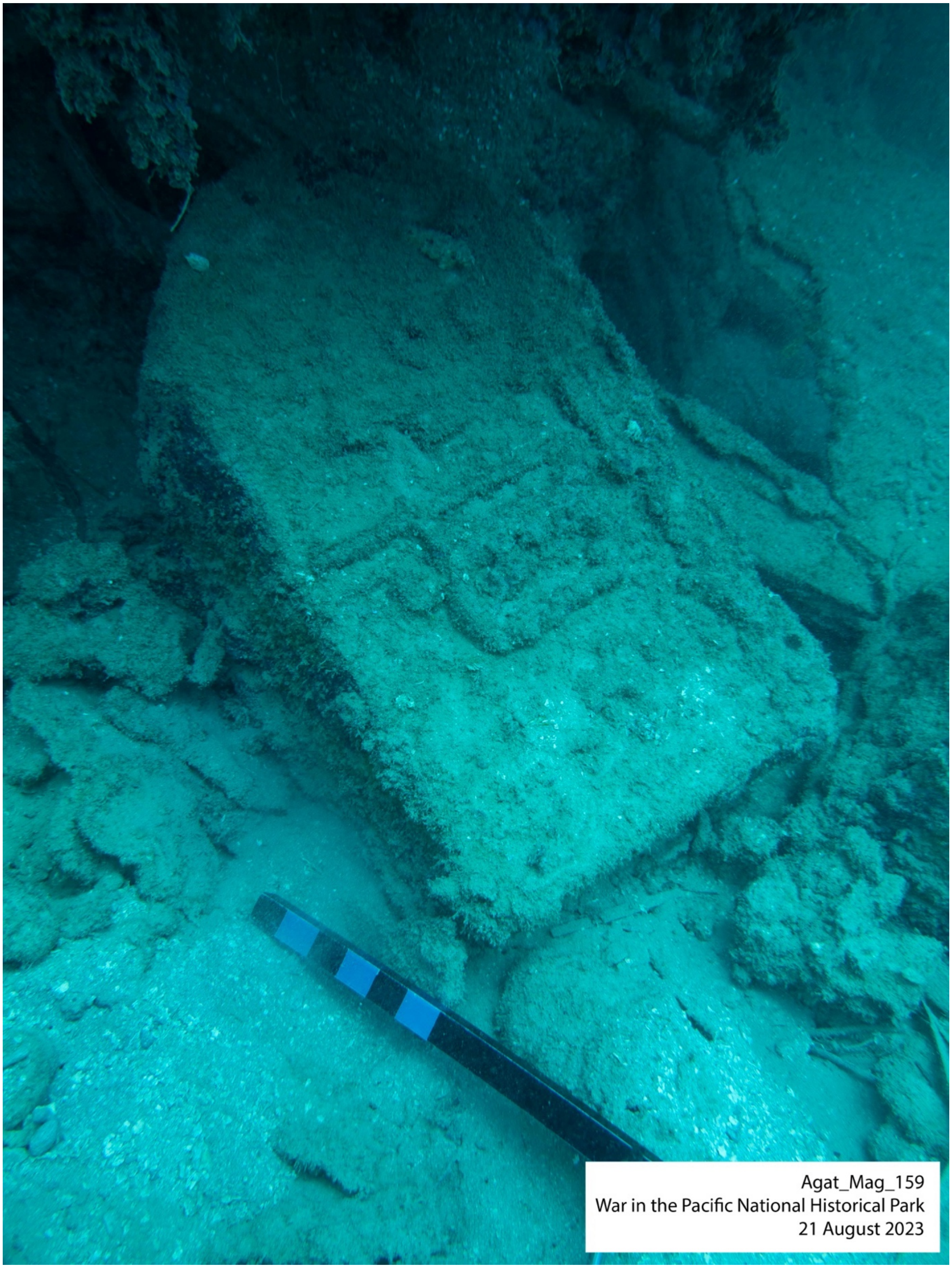


Figure 75. Large car battery found at American Pontoon Barge site. NPS Photo.

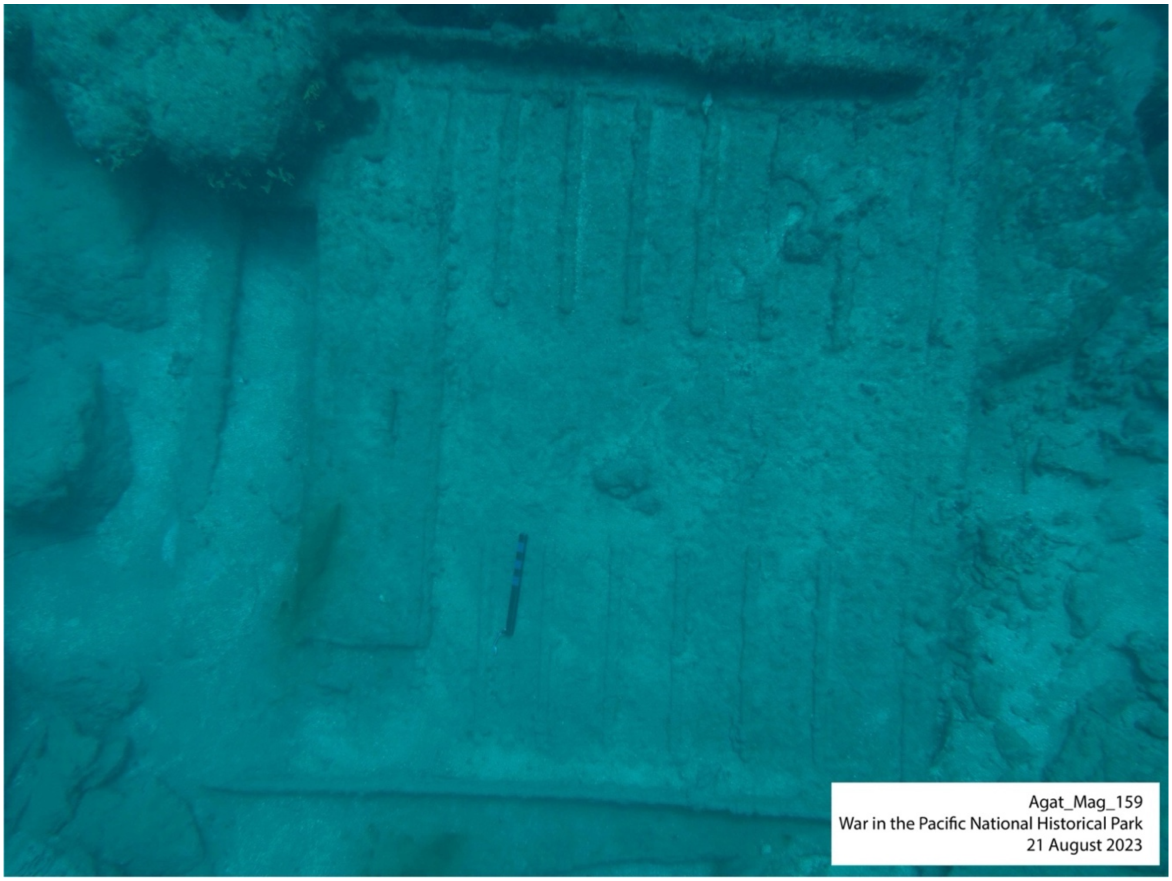


Figure 76. LVT door found at American Pontoon Barge site. NPS Photo.

Japanese fishing boat

The team located the wreck of a probable Japanese fishing vessel (Figures 77 and 78) in shallow water at Agat. While record of the boat was not found in any archaeological reports, community members who attended the outreach event in August 2023 during which the team discussed results of the project noted that they were aware of its presence off Agat Beach.

The wreck appears to be aluminum, has a squared stern and severely pointed bow, with a hull made of long, flat aluminum sheets that taper upwards at the ends. These characteristics are typical of Japanese wooden small boat design intended for fishing, though this particular craft is aluminum. Small Japanese fishing vessels used in coastal or river environments are most often flat-bottomed (Brooks 2014). Japanese influence on the maritime traditions of the island may have led to the adaptation of Japanese wooden boat shape to aluminum craft, or the boat may have originated in Japan itself and was brought to Guam.

Further research is underway on the origin of this small wreck.

Figure 77. Japanese Fishing Boat site at Agat Unit. NPS Photo.

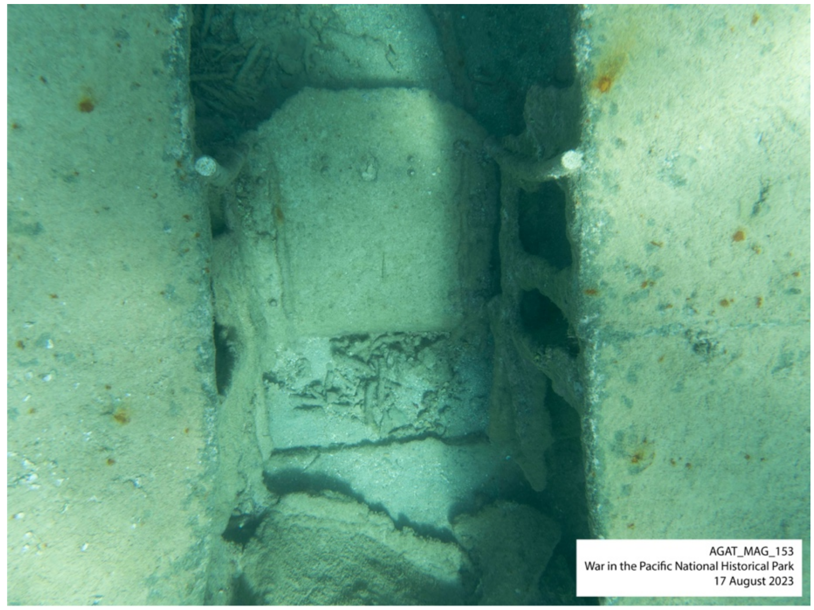


Figure 78. Japanese Fishing Boat site at Agat Unit. NPS Photo.

Marston mat

The team located five sections of pierced steel planking (PSP), also known as "Marston mats," off Agat beach (Figure 79). Marston mats were a widely-used multi-purpose building material in World War II. Initially intended for use on makeshift aircraft runways, the broad utility of the material was quickly recognized and it was employed for many uses during the war, including on amphibious battlefields in the Pacific.

Figure 79. Marston mat found offshore of Agat Unit. NPS Photo.

Based on European aircraft landing mats, the Carnegie-Illinois Steel Corporation (CI-SC) designed a preliminary steel plank for use by the United States military. The U.S. Army Air Corps required that the planks be appropriate as a temporary landing surface for use during permanent runway repairs, that they could be used on standing areas and taxi strips, and allow for the rapid building of runways (Figure 80). The planks were also required to be easy to transport, repair, camouflage, produce, install, and store for long ocean transits (Robinson 1992:197, Smith 1989).

Figure 80. Historic photo of Marston mat deployment. U.S. Army Corps of Engineers Photo.

The U.S. Army Air Corps found that CI-SC's initial plank design was too heavy and began punching holes through the material to reduce the weight. The holes also allowed for enhanced aircraft traction, runway drainage, and allowed the planks themselves to better adhere to the ground (Robinson 1992, Smith 1989). In addition, vegetation could grow through the holes, contributing to camouflage (Smith 1989).

PSP was first tested in Marston, North Carolina, where it received its name, prior to the United States entering WWII (Mola 2014). PSP quickly became a common tool of the Navy Seabees (the U.S. Naval Construction Battalions) for the movement of crucial equipment, infrastructure, personnel, and supplies on and off amphibious WWII battlefields. Figure 81 illustrates Marston mats in use as a sand stabilizer at Agat as barrels are rolled from the water to the shore. Marston mat was commonly repurposed by people living in former WWII conflict zones and can still be seen in present day. Figure 82 shows a door created from repurposed PSP.

Figure 81. Marston mat in use on the beach at Agat. Historic photo via National Park Service.

Figure 82. A door made of PSP. Image via Stories del Sud: Pierced Steel Planking: the gates of war.

Significant archaeological findings at Asan Beach Unit

Asan Landing Vehicle - Tracked

The LVT at Asan is a known site, though it is not commonly visited by recreational divers as it is located in a precarious position at the apex of Asan Cut, in poor visibility. The site is mentioned by Carrell (1991) in *Micronesia: Submerged Cultural Resources Assessment* and identified as an LVT-1. The site is in relatively poor condition and broken apart, which may indicate that this LVT was lost due to battle damage. In a Marine Corps Action Report from W-Day (Connolly 1944), there is a brief mention of an LVT-2 that was hit by a mine as it left Asan Cut after dropping Marines on the beach. “One LVT(2), returning empty from the Asan Beach after the initial landing, is known to have been blown up by a mine” (Connolly 1944:10). However, there is no mention of how significant the damage was or if the LVT consequently sank where it was hit.

Initial archaeological analysis indicates that the radioman and driver’s seat, bow section, transmission, gauges, and control panel are present on the site (Figure 83). Notably, there is little evidence of the engine, driveshaft, stern section, or ramp. The lack of engine and stern is possible indication that this LVT is an LVT-4, as large radial engines were present in the stern of LVT-2s. Conversely, the engine could be missing from the site due to post-war salvage efforts (Shawn Arnold, 2024, elec. comm).

As the site is located just under the reef wall at Asan Cut and in a difficult position to tow instrumentation, the LVT was not detected during the remote sensing survey with side scan sonar or magnetometer. But as the team was aware of its existence, we asked local divemaster and project team member Luis Cabral to show us its location and assist with its recording. Recording of this site would not have been possible without his assistance, and the team is incredibly appreciative of his local knowledge.

Though the site is mentioned in Carrell 1991, to the team’s knowledge it has not been previously archaeologically recorded. Additional detailed site documentation and analysis as part of a future study will aid in final identification.

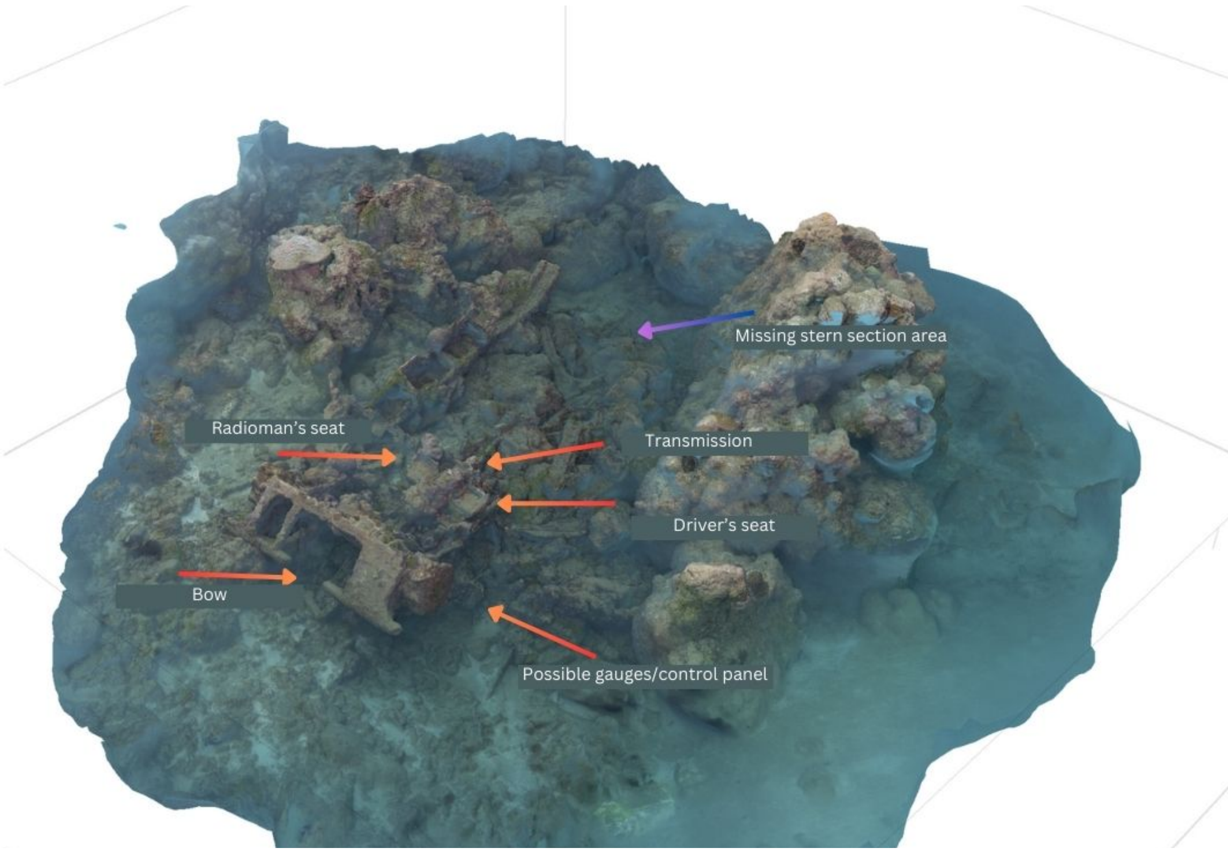


Figure 83. Orthomosaic of the Asan LVT site with labeled possible parts. Archaeological analysis credit: Shawn Arnold. NPS Image.

Amphibious tractor treads

The Amphibious Tractor Treads (Figure 84) are approximately 450 meters offshore of Asan and were first located in 1987 during a transect survey of the park (Carrell 1991:516). Carrell (1991) notes that there does not appear to be a vehicle associated with the tracks, as was confirmed by this team when it was relocated as part of the project. The tracks are embedded in a large coral head and blend in seamlessly with the surroundings.

Mr. Cabral was also integral in locating this site during the project.

Figure 84. A diver next to the amphibious tractor treads off Asan Beach Unit. NPS Image.

UXO and ammunition on the reef flats

The walking survey of Asan revealed sporadic ammunition in shallow areas, inside of the reef crest. Several bullets and bullet fragments were spread across the reef flats (Figure 85 and 86). One piece of UXO was also located farther out on the reef between Camel Rock and Asan Point, away from common beach visitation areas (Figure 87). As they were found outside of the known UXO dump near Camel Rock, these artifacts may represent artillery and ammunition used during the battle.

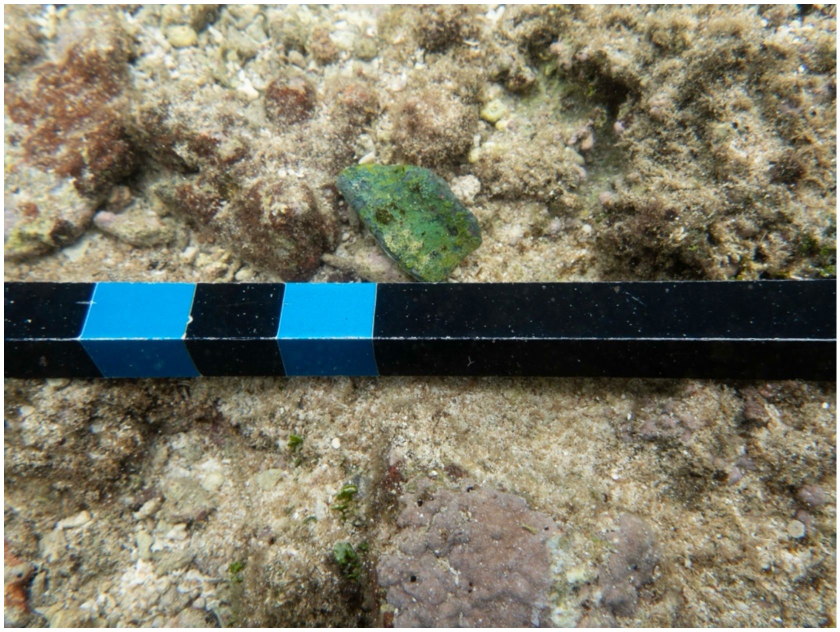


Figure 85. Bullet fragment on the reef flat at Asan. NPS Image.

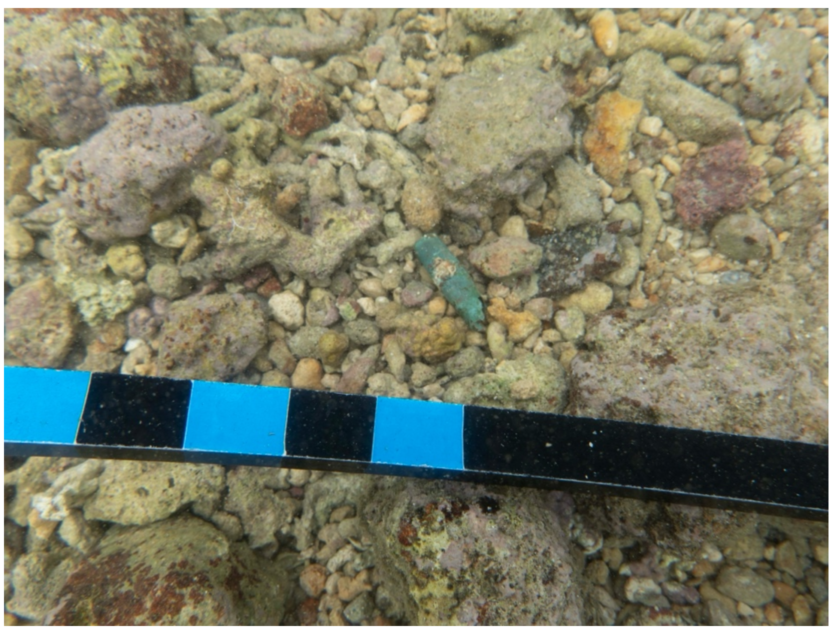


Figure 86. Bullet on the reef flat at Asan. NPS Image.

Figure 87. Shell embedded in coral rock on the reef flat at Asan. NPS Image.

Katagami pottery

These pottery sherds (Figures 88 and 89) are pieces of Japanese Katagami pottery, which was mass-produced in Japan from the 17th century to the early 20th century (Bibb 2001). Designs on this type of pottery were produced using a paper stencil and cobalt pigment (UoI 2024). Katagami style pottery had disappeared from the Japanese market by about 1920 (Ross 2012). While there is not enough archaeological context to determine if these pieces of pottery were brought to Guam by the Japanese in World War II, it does show the prevalence of Japanese influence on the island. Figure 90 shows an example of unbroken Katagami pottery.

Figure 88. Katagami pottery on the beach at Asan Beach Unit. NPS Image.

Figure 89. Katagami pottery on the beach at Asan Beach Unit. NPS Image.

Figure 90. Unbroken katagami pottery. Image via University of Idaho.

Metal Debris

Large amounts of metal debris are scattered across the reef flats at Asan. While much of this metal is labeled as "unidentified," meaning that it is scrapped in such a way that it is difficult to determine what type or types of object the scrap may have originated from, large amounts of metal debris are consistent with areas where heavy fighting occurred, and where troops and supplies came ashore during an amphibious battle. Figure 91 illustrates examples of scrap metal types found on the reef flats.

Figure 91. Unidentified metal debris. NPS Images.

UXO Beyond the Reef Crest

The team identified 17 magnetic anomalies that were unexploded ordnance (UXO), 14 of which were at Asan, and 3 of which were at Agat. Many of these anomaly sites contained multiple or many units of UXO. An estimated 64 tons of both Japanese and American UXO was dumped off Camel Rock within what was to become the Asan Beach Unit of WAPA after World War II. Asan was surveyed for UXO locations by the U.S. Navy in 1978, and again in 2006 by Natural Resources staff at WAPA (Minton et al. 2006). The 2006 survey searched in water up to 130 feet deep. This project expanded UXO survey up to 200 feet deep, and significant amounts of UXO was found at a maximum depth of 200 feet deep, with divers reporting that a scattering of UXO continued down a sloping hill farther than the eye could see to estimated depths of 400+ feet. UXO was also located in depths ranging from 160 to 170 feet in separate locations. While the team expected to find UXO during diver investigations, particularly in the Asan Beach Unit survey area, we were unsure if we would find additional UXO in depths past the maximum depths of previous survey efforts. This project allowed us to identify previously unknown UXO locations, particularly in deep water. Figure 92 details the location of UXO charted in 2006 and 2023.

Redacted

Figure 92. Map of UXO within Asan Beach unit. Green dots indicate UXO located by the Milton et al. 2006 survey, and purple dots indicate the location of UXO identified in 2023 as part of this project. NPS image with georectified 2006 data by Aleck Tan.

It is likely that some of the UXO located in 2023 are the same artifacts that were located in 2006. The slight difference in location may indicate that UXO is moving around the seafloor due to natural events such as storms and wave action. The sloping nature of the reef near the UXO dump may also cause significant movement of UXO. If a storm or other event is powerful enough to move these artifacts, they may roll farther down the reef and into deeper water, as seen during project dives beyond 200 feet. Figures 93 illustrates typical examples of UXO found on the reef.

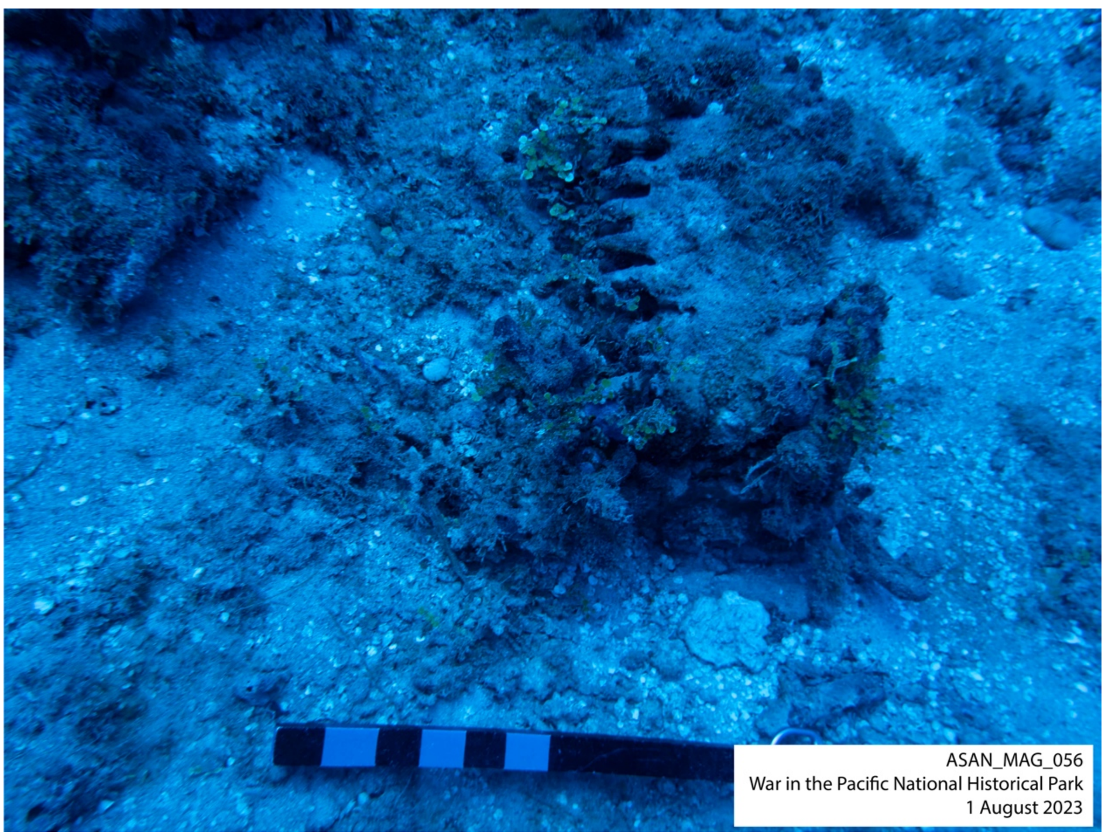


Figure 93. Submerged UXO off Camel Rock at Asan Beach Unit. NPS images.

Coastscape and seascape

Coastal elevation and bathymetry data allow scientists to document how the coastal and submerged environments, respectively, are changing over time. At WAPA, such data is particularly important because past human activities, such as those related to WWII, and natural events, such as typhoons and other storms, have contributed to the current shape and structure of the coast. Understanding changes the park has experienced, is now experiencing, and may anticipate in the future will help the park to identify the most effective management strategies for preserving its cultural and natural resources both on land and offshore, and can be used to enhance park interpretation and outreach efforts.

Underwater Demolition Team pre-invasion blast craters

The Japanese attempted to deter U.S. troops from reaching shore by placing obstacles in the water prior to the American invasion. An after-action report from UDT Team 3 describes the obstacles offshore of Asan Beach as being "in an almost continuous front along the reef…these obstacles were piles of coral rock inside a heavy wire frame made of heavy wire net" (Department of the Navy 1945d:4). Offshore of Agat Beach, the obstacles were described as having been placed "all along the reef, built of coral rock, enclosed in light wooden frame" (UDT Report 1944) (e.g., Figure 94). This report also describes the method used to clear obstacles on the beach via tetrytol explosives. In all, the UDT team used upwards of 10,600 pounds of tetrytol explosives to clear the invasion landing beaches of Japanese obstacles and patches of the barrier reef.

Figure 94. Historical photo of rock scully obstacles placed by the Japanese. Image via National Archives at College Park, Record Group 80-G.

Before fieldwork began, the team conducted archival research to determine blasting locations. A hand-drawn historic map from a member of UDT team #3 was found at the National Archives and indicated the location of obstacles within the reef flat at Asan Beach that were destroyed prior to the invasion

(Figure 95). This map was georectified and, once in the field, the team located a clear line of craters formed by tetrytol blasting across the reef flat in the vicinity of the indicated positions on the historic map.

These blast craters were documented in a variety of ways, including with photogrammetry, multibeam bathymetry, and photographs (Figures 96-98). Additionally, the location of each crater was recorded using high precision GNSS equipment (Figure 99).

The project team considers the presence of these blast craters in the reef flat nearly 80 years after the events of WWII to be an unexpected discovery. Some of the craters were found to contain fragments of embedded metal, which could be remnants of the obstacles that were destroyed by the UDTs. The craters exist in a very shallow water and high-energy environment; because of this, the team had expected that the craters would have been filled in (e.g. with sand and coral fragments) through natural coastal processes. The presence of the blast craters serves as confirmation of long-lasting WWII-related impacts to Guam's seascape. The historic diameter and depth of the blast craters is unknown. While it is possible that the initial craters were more expansive and have filled in over time, the relatively comparable diameter and depth among the existing craters offers evidence to suggest otherwise. Ecologically, the craters appear to have limited impact on reef flat habitat quality or associated species. As illustrated in Figures 96 and 98, the blast craters and the surrounding environment exhibit similar physical and biological characteristics, primarily coral rubble and sandy sediment interspersed with live coral, aquatic vegetation and macroalgae, and associated marine life.

The blast craters are also considered to be cultural features due the removal of natural material caused by UDT blasts. Additionally, these craters now have significance to the modern-day local community. For example, community members use the shallow depressions for fishing practices. One community member that the project team spoke with was moved to learn the origin of the depressions and connection to his own history.

The discovery of the blast craters is a uniquely valuable outcome of this project; it can communicate the events and impacts of WWII in a way that can meaningfully resonate with people and garner appreciation and awareness across disciplines (e.g. cultural, social, environmental).

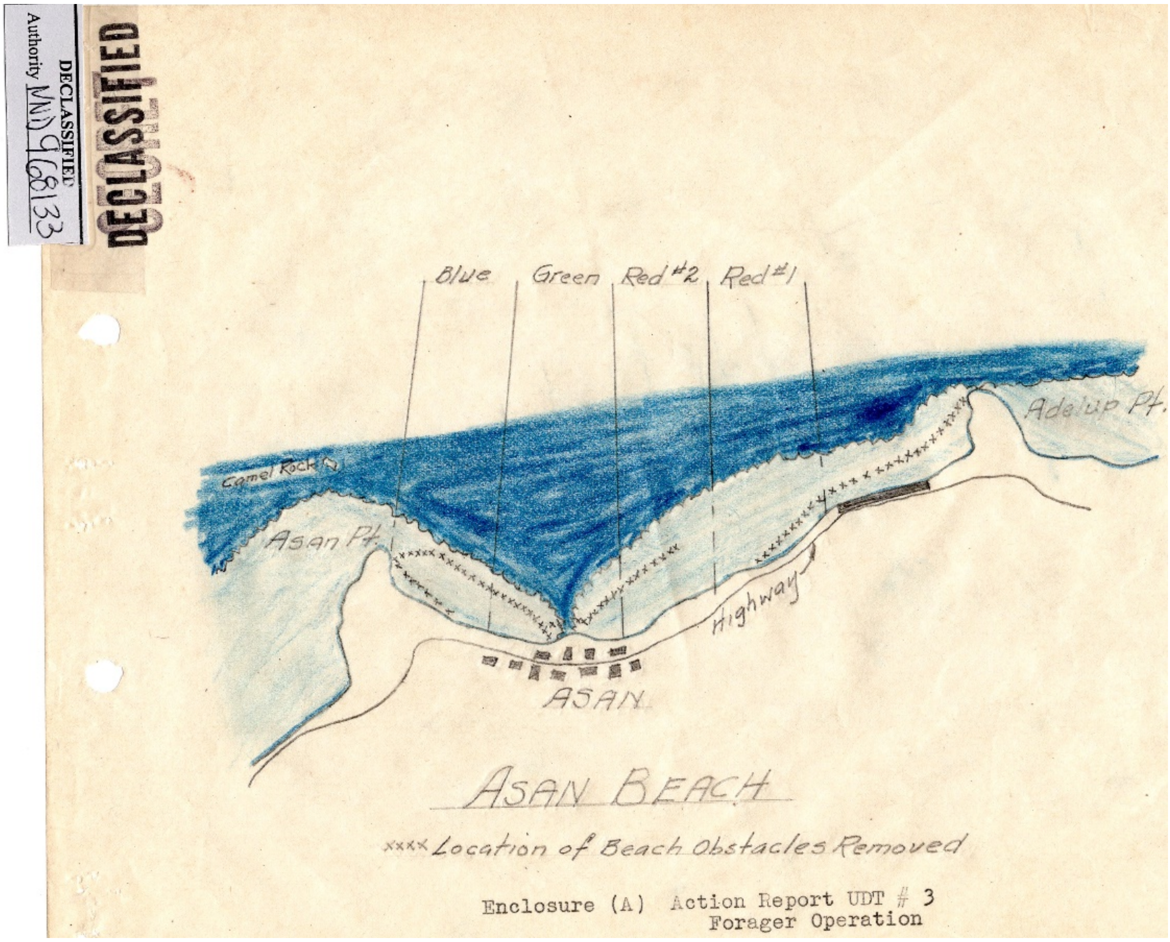


Figure 95. Hand-drawn historic map found in the records of Underwater Demolition Team #3 that indicate the locations of obstacles placed by the Japanese that were removed by UDT#3 at Asan Beach. The small Xs in the light blue area indicate an obstacle. Credit: Action Report UDT #3 Forager Operation, Record Group 38: Records of the Naval Office of the Chief of Naval Operations, World War II Action and Operational Reports, Records of the Navy, National Archives at College Park.

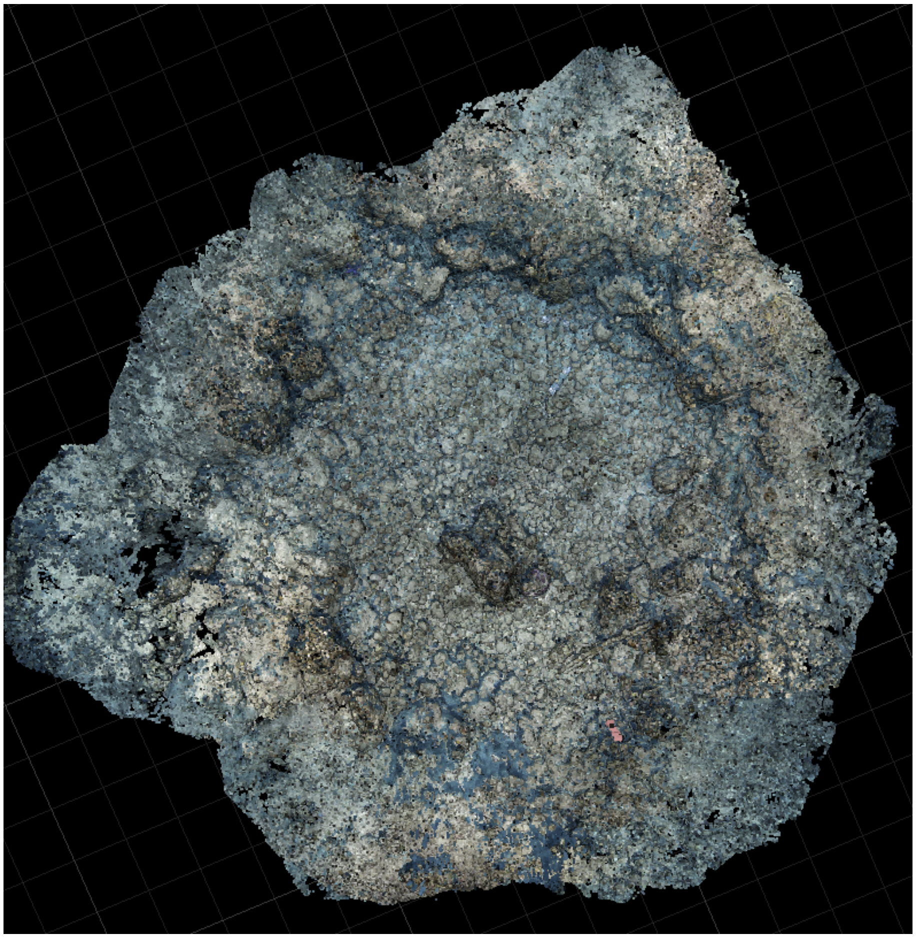


Figure 96.. Top-down view of a photogrammetric model of a UDT-blast crater off Asan Beach unit. NPS image.

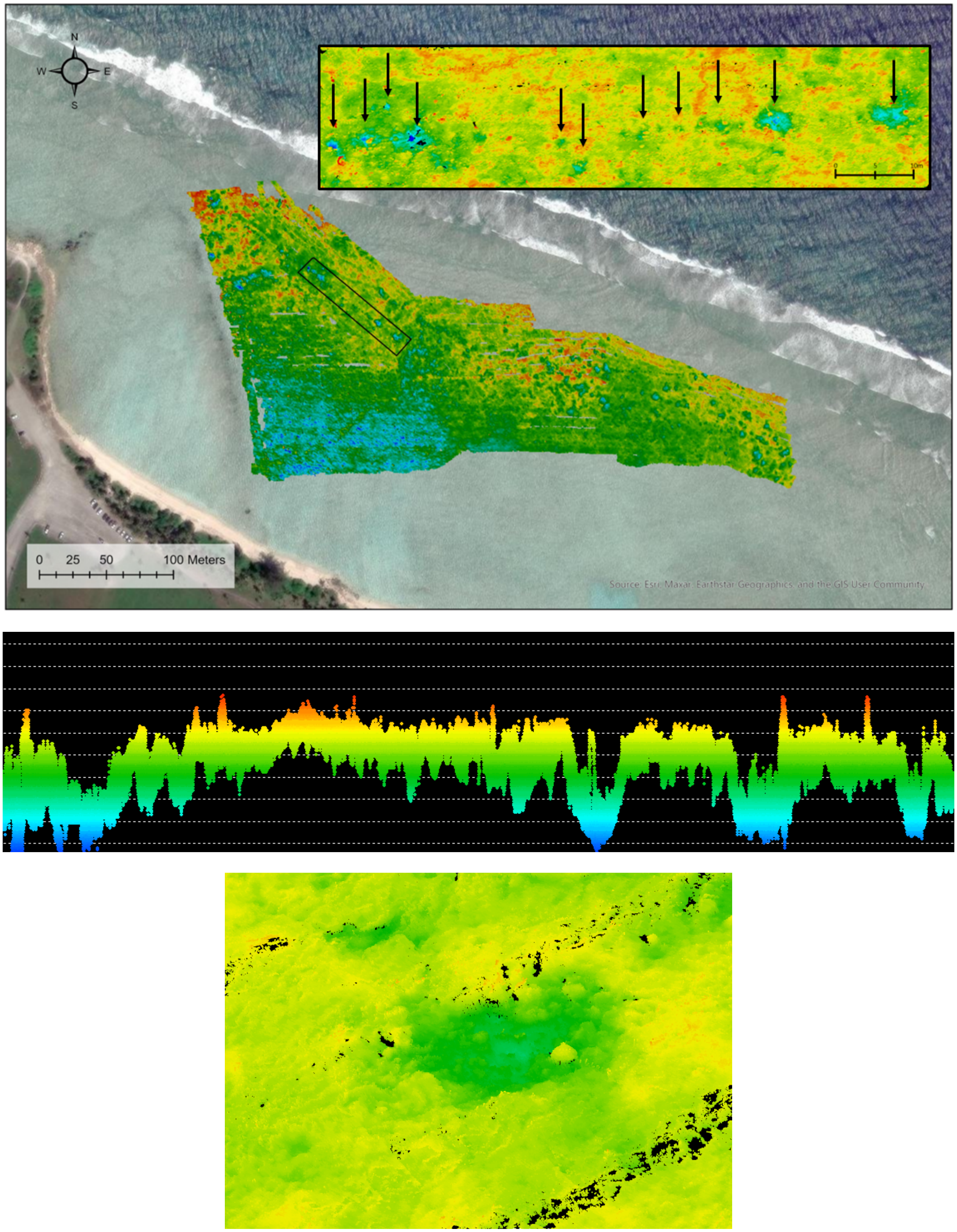


Figure 97. Bathymetry data documenting the blast craters within the reef flat at Asan Beach unit. Bathymetry mosaic shows the line of blast craters within the reef flat (top); profile view of the bathymetry data showing four distinct blast craters with a depth of approximately 0.5m (middle); zoomed in view of blast crater (bottom). NPS images.

Figure 98. Photograph of blast crater depression visible at low tide at Asan Beach unit. NPS photo.

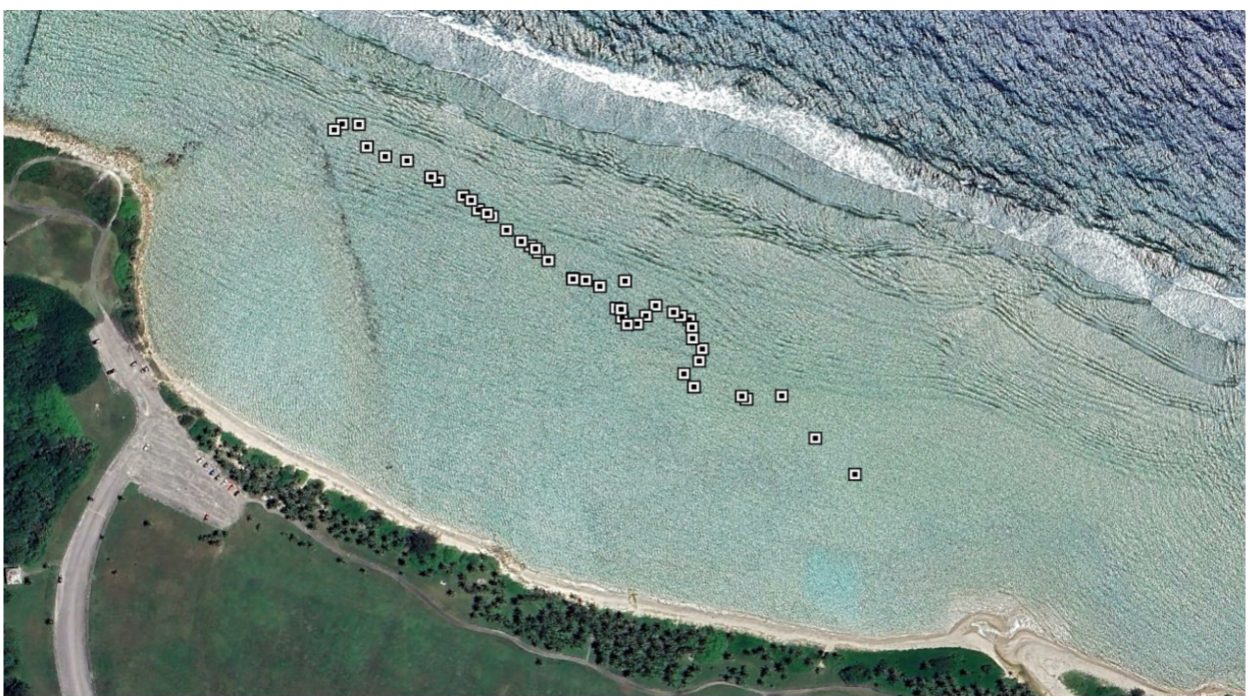


Figure 99. Project team members documenting location of blast craters at Asan using GNSS equipment (top) and resulting mapped locations of blast craters (bottom). NPS images.

Coastal landscape and sea level rise

LiDAR data can be used to both visually and quantitatively to document areas and features of interest because of the high precision associated with the millions of georeferenced x,y,z locations in the point cloud collected in the surveys. When those points are colorized and classified, they yield important information regarding objects and distances which can be measured. Such documentation is important to support park management of cultural and natural resources. For example, LiDAR data from this project captured the location and elevation of monuments at the park (Figure 100), which can be used to assess vulnerability of these resources to sea level rise and storm impacts.

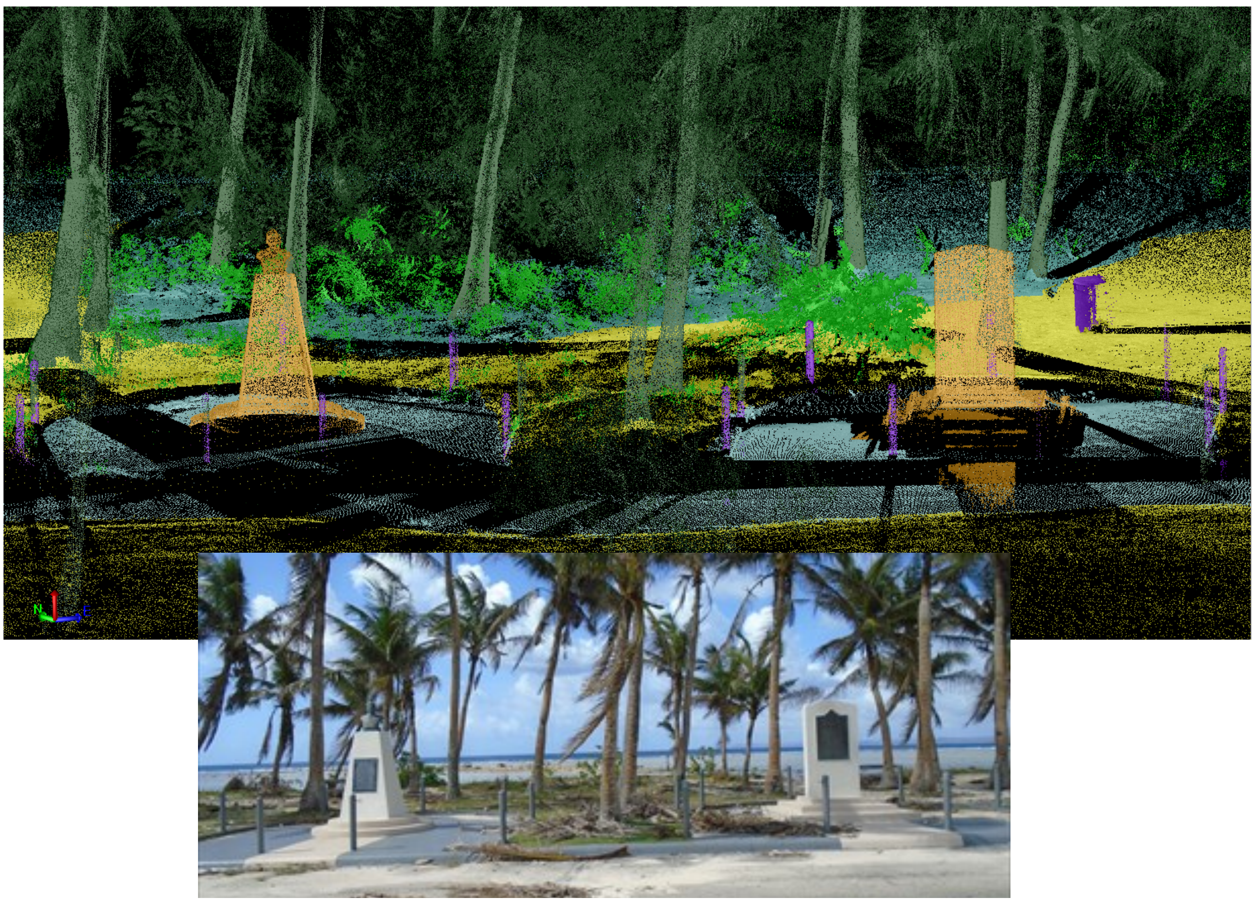


Figure 100. 3D view of Apolinario Mabini historical markers in Asan Beach Unit. LiDAR image captured using February 2023 point cloud data. Photo credit: https://www.waymarking.com/waymarks/WMNY82_Apolinario_Mabini_Asan_Beach_Guam. NPS images.

The documentation of features is critical in understanding changes and impacts to resources over time in quantifiable ways. Focused assessments of large-scale terrain features can be compared to future sea level rise projections to understand the full extent of realistic anticipated impacts. Sea level rise projections provided by the Interagency Task Force on Sea Level Change and resulting publication (Sweet et al. 2022) were overlaid on LiDAR data collected at Asan Beach (Figure 101), Agat Ga'an Point (Figure 102), and Agat Apaca Point units (Figure 103) to understand the potential impacts to overall unit management, as well as impacts to cultural and natural resources, as the examples in the figures illustrate.

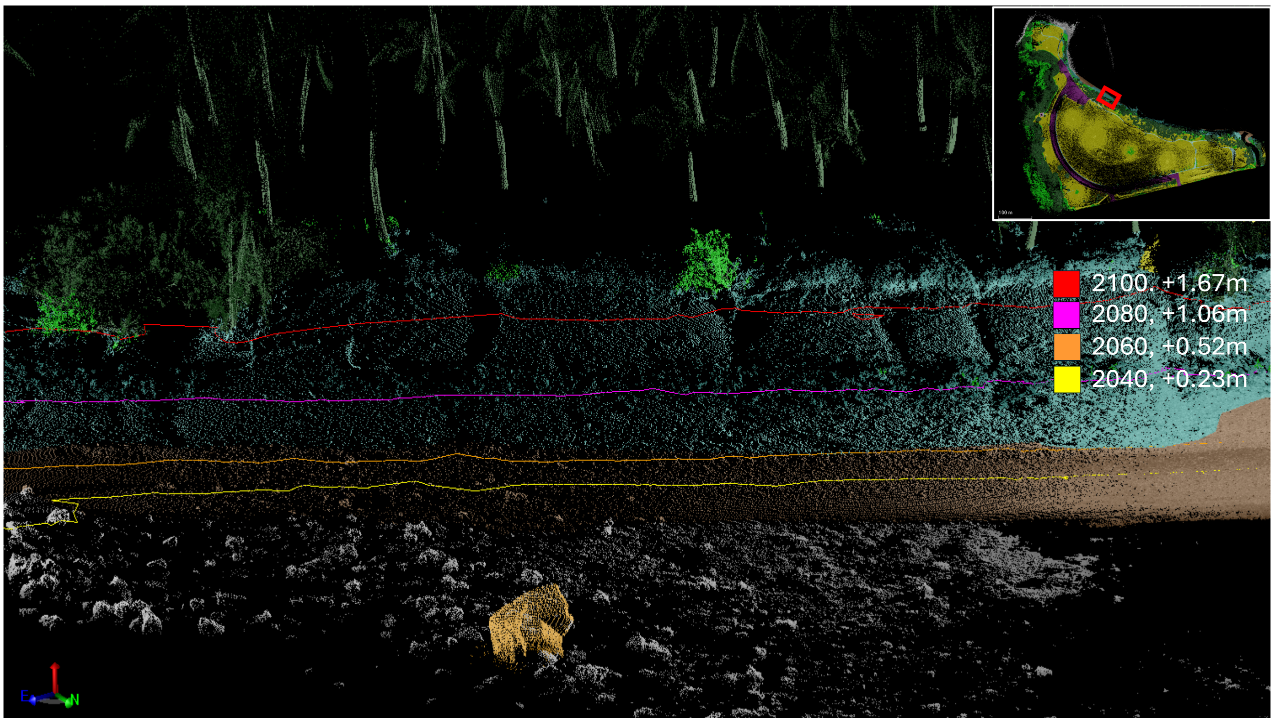


Figure 101. Close up view of erosional features at the Asan Beach unit. Lines indicate the projected sea level rise on current terrain (as determined for LiDAR data collected as part of this project) for the years 2040 (yellow), 2060 (orange), 2080 (magenta) and 2100 (red). Projections of sea level rise from Sweet et al., 2022. NPS image.

Figure 102. Sea Level rise projections at Ga'an Point in the Agat Beach unit. Lines indicate the projected sea level rise on current terrain (as determined for LiDAR data collected as part of this project) for the years 2040 (yellow), 2060 (orange), 2080 (magenta) and 2100 (red). Projections of sea level rise from Sweet et al., 2022. NPS image.

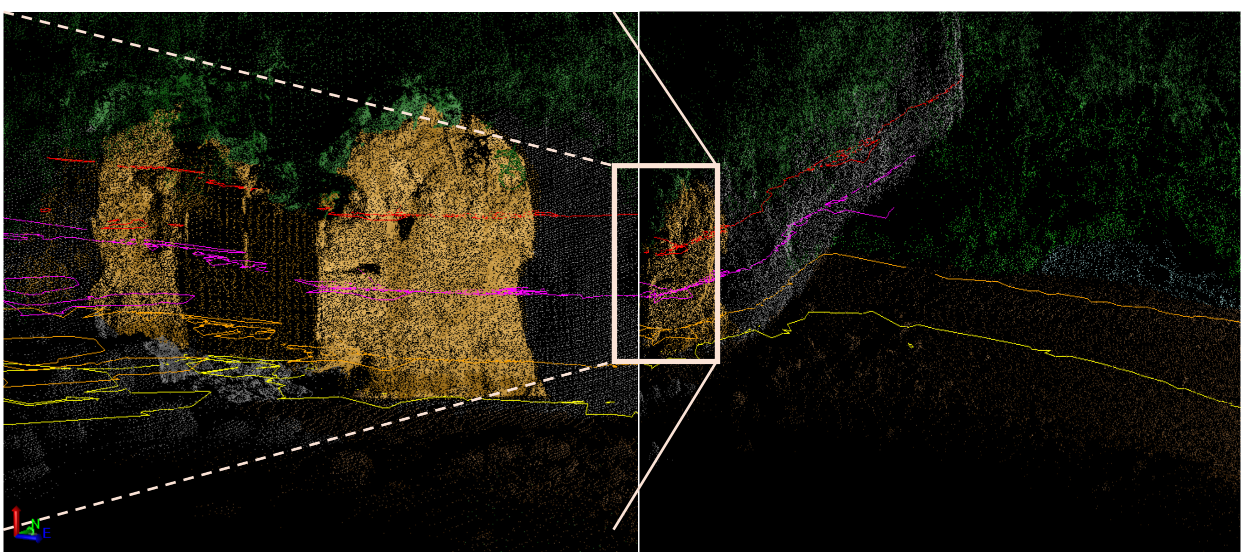


Figure 103. Sea level rise projections on an ocean-facing pillbox at Apaca Point in the Agat unit. Lines indicate the projected sea level rise on current terrain (as determined for LiDAR data collected as part of this project) for the years 2040 (yellow), 2060 (orange), 2080 (magenta) and 2100 (red). Projections of sea level rise from Sweet et al., 2022. NPS image.

In addition, surface contours were created to understand the overall surface topology and coastal beach geomorphology in support of enhancing management capacity, planning and decision making processes of the coastal units. For example, highly detailed contour maps of the coastal units were developed and can be used to aid in understanding potential flooding extent from storm surge, sea level rise, and/or precipitation (see “Coastal Elevation Surveys” in Section II 5a). The maps can also aid the identification of potential point sources of pollution through sheet-flow run-off into the marine environment.

In comparison, these datasets can also be used to identify resources and areas of the park that are more static and experiencing slower changes, which can help prioritize management actions.

Storm impacts

Guam is located in a part of the Pacific Ocean known as “Typhoon Alley” and has experienced dozens of hurricane-strength storms (typhoons in the Pacific) throughout recent recorded history (Figure 104). Typhoons, along with more minor storm events, contribute to the reshaping coastal and riverine systems, which are naturally dynamic and complex. The impact that these storms can have on natural environments is highly variable, ranging from damaged coral to defoliated trees and even complete restructuring of coastlines and river mouths.

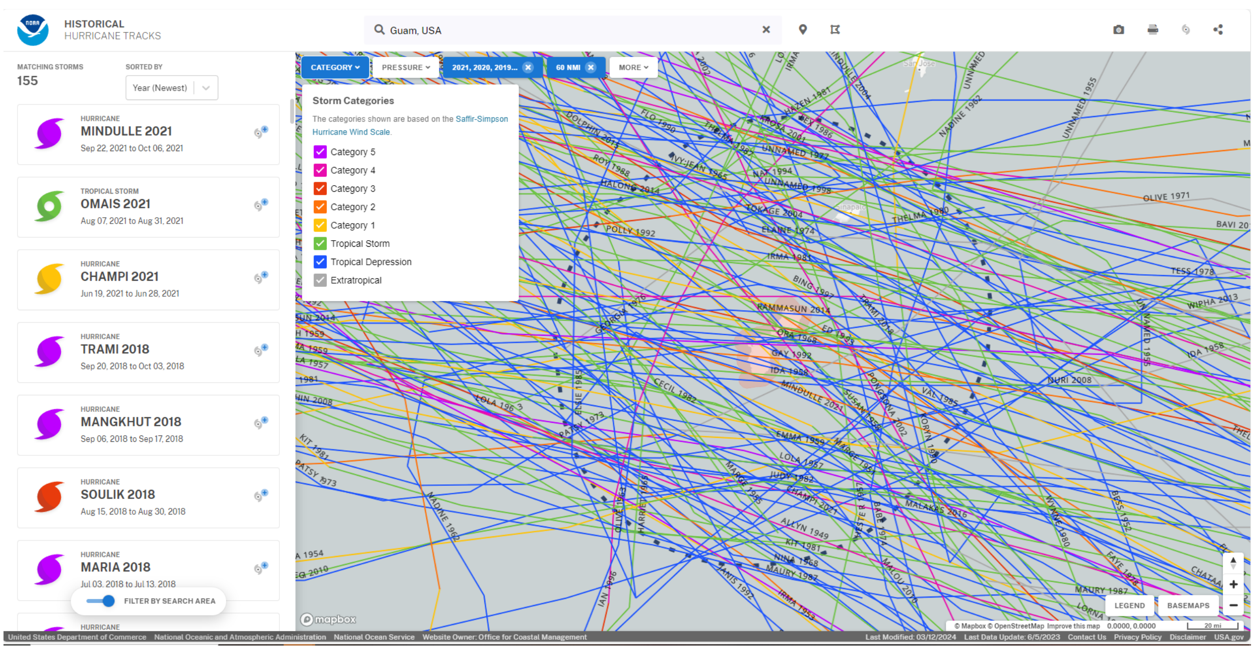


Figure 104. Screenshot showing historical storm tracks over Guam. Image via Historical Hurricane Tracks.

During WWII, coral reef blasting and major deforestation through pre-invasion bombardment altered Guam's natural landscape, reducing the coastal resiliency of the island. Removal of vegetation and coral reduced the island's protection from storms and likely increased erosion from later storm events.

In this project, analyses were conducted on the coastal beach areas of the park units. Key features were targeted to enhance overall understanding of coastal dynamics. Efforts included documentation of highly erosional areas (Figure 105), in addition to cultural sites and coastal geomorphology.

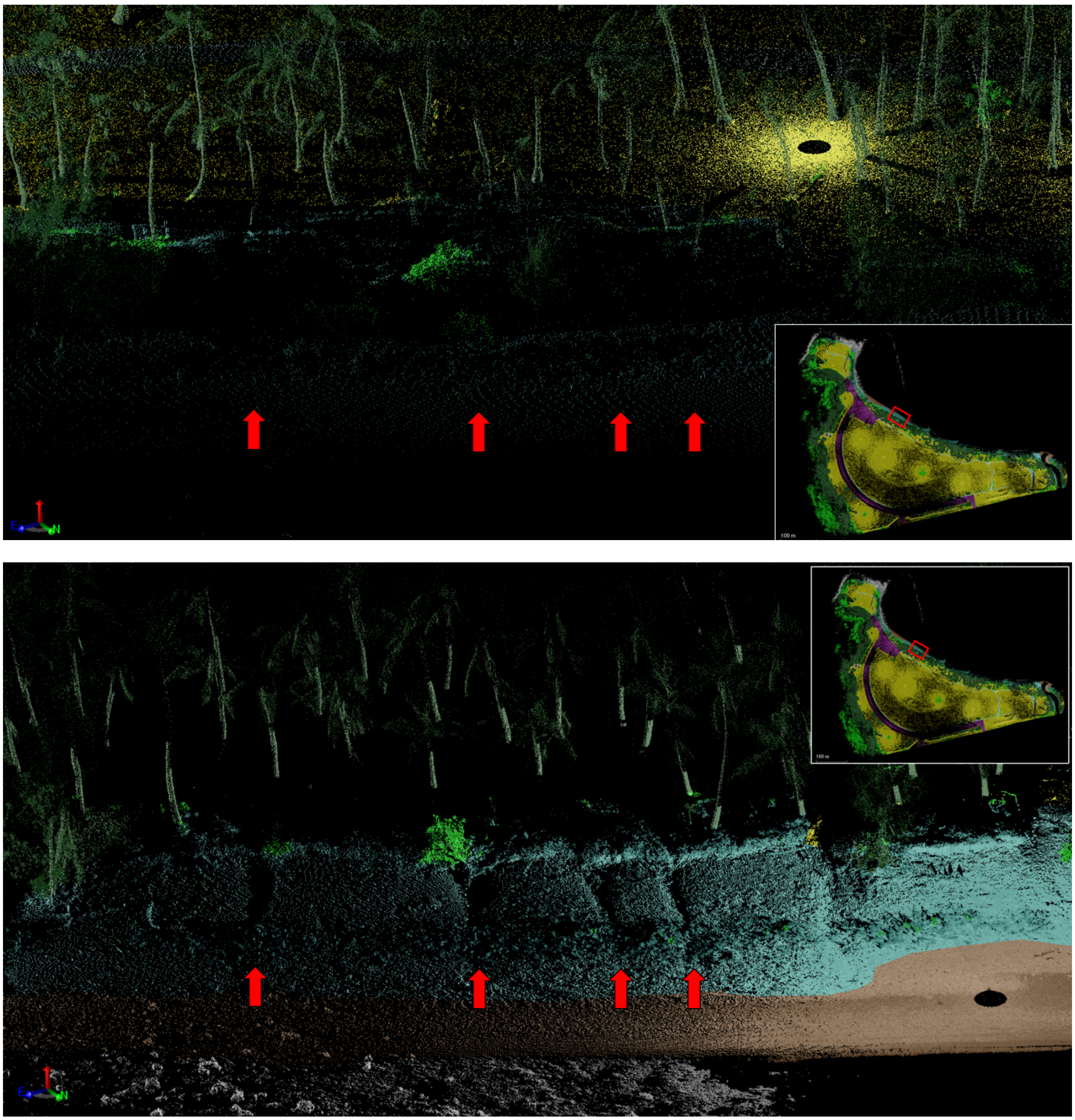


Figure 105. 3D view of the upper beach shoreface at the Asan Beach unit in (top) February 2023 and (bottom) July 2023, with the latter showing clear erosional cuts after Typhoon Mawar (May 2023). NPS images.

Using the terrestrial LiDAR scans, the project team was able to carefully examine and assess the potential impacts from storms through both visual assessment and analytical methods. Side by side point clouds were compared for feature and areas of interest, such as the eroding shoreface shoreward of the gun emplacements at Agat Ga'an Point (Figures 106). The point clouds were then used to develop surface models of the coastal areas for comparison following the passing of category 4 Typhoon Mawar, which made landfall over the island in May 2023. Differencing of the surfaces pre- and post-typhoon indicated areas where substantial erosion and accretion occurred. Photographs were also taken to provide context and supplemental information (Figure 107). This project also provided an opportunity to observe the depositional environment at the outflows of the rivers in the park units following substantial storm-induced rain inundation periods (Figures 108 and 109). Documentation of these changes are particularly important for the park because highly depositional environments restructure the shoreline and are known to have negative impacts on coral growth and settlement.

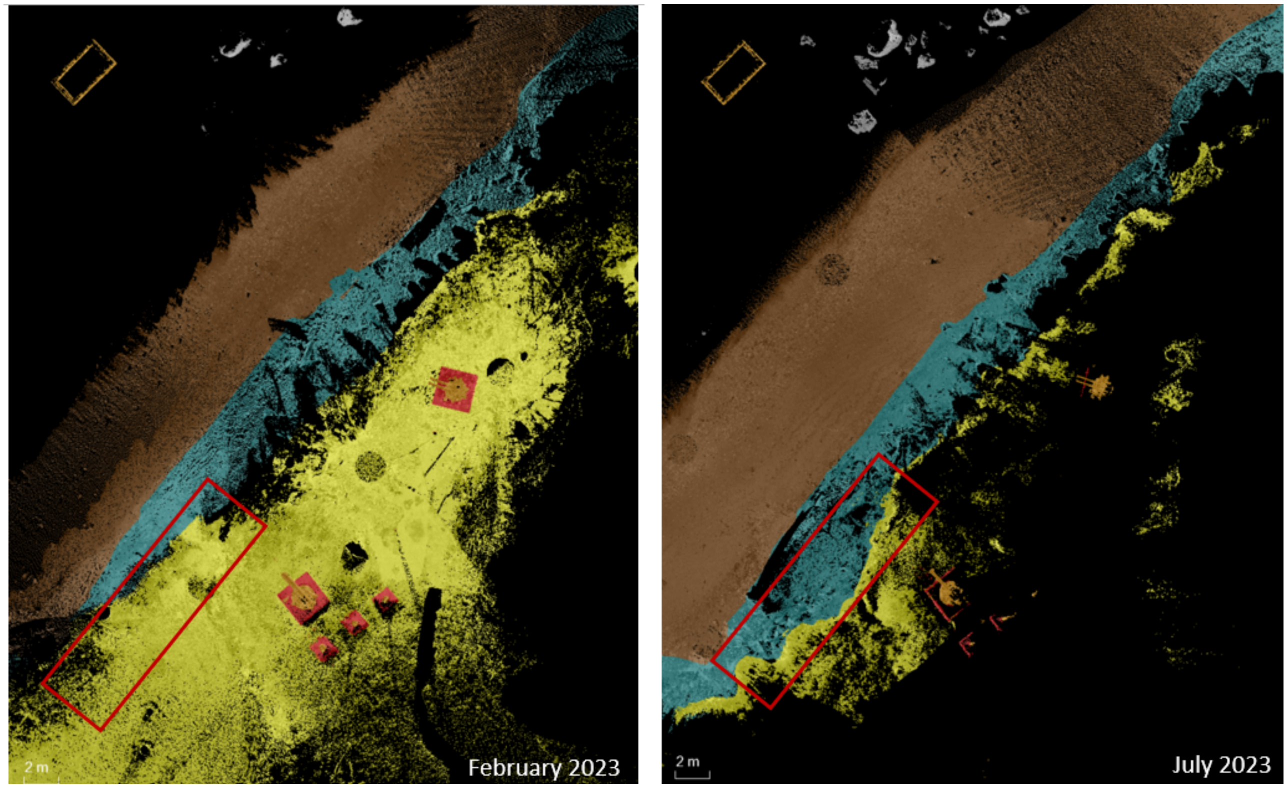


Figure 70. Planar view of post-Typhoon Mawar (May 2023) erosion at Ga'an point in the Agat unit as depicted in LiDAR data collected in February 2023 (top left) and July 2023 (top right). Red rectangles indicate area of erosion in close proximity to gun emplacements at the park (classified in the LiDAR data as red squares and brown guns). Surface differencing of the February and July 2023 scans at the same location (bottom) show a quantitative demonstration of erosion of the area. NPS images.

Figure 107. Photograph showing substantial erosion of the Agat unit shoreline (and accumulation of debris) in the vicinity of the gun emplacements in the days after Typhoon Mawar (May 2023). NPS photo.

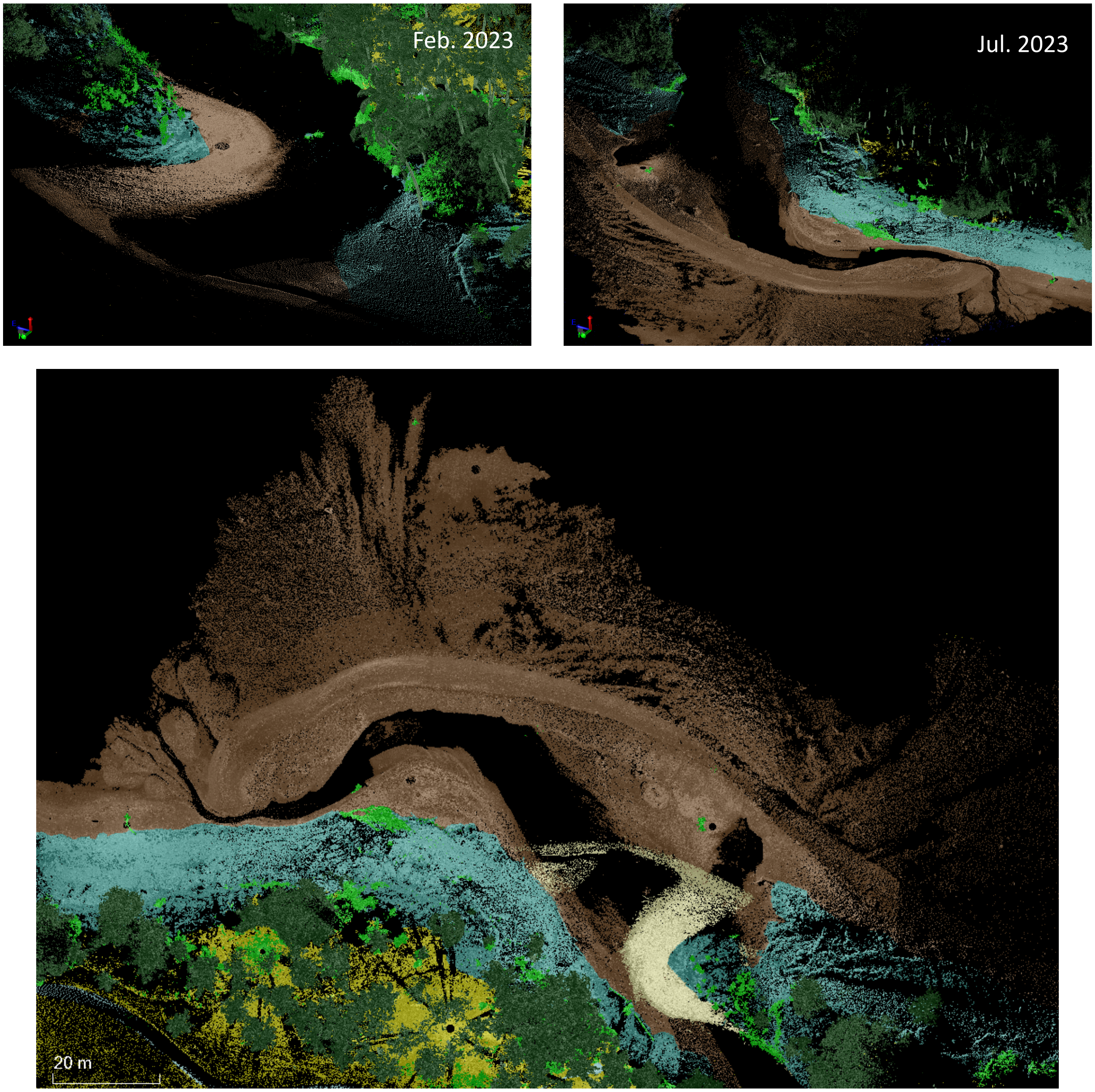


Figure 108. Planar views of LiDAR data collected at the Asan River outflow in the Asan Beach unit of War pre-typhoon Mawar (February 2023; top left) and post-typhoon (July 2023; top right), demonstrating the substantial depositional environment of post Typhoon Mawar at the Asan River mouth. Bottom image shows the location of Asan River mouth pre-Mawar (light tan) and post-Mawar (dark brown). Typhoon Mawar made landfall in May 2023. NPS images.

Figure 109. Photograph of Trimble SX10 collecting LiDAR data of new sediment deposition at the river mouth. Typhoon Mawar made landfall in May 2023; LiDAR data was collected in February 2023 and July 2023. NPS photo.

c. Inventory of activities

In total, 3.86 sq km (1.49 sq mi) were mapped with remote sensing as part of this project. The mapped coverage for the deep water survey area extending from the coral reef crest to the 60 m isobath was 2.38 sq km (0.92 sq mi) for the Agat unit and 1.38 sq km (0.53 sq mi) for the Asan Beach unit. The data collected for these areas were side scan sonar, multibeam bathymetry, and magnetometry. Within the shallow water reef flats, multibeam data was collected over 0.05 sq mi (0.02 sq mi) each at the Asan Beach and Agat units.

The team completed 162 dives, with 2-3 divers on each dive, focused on investigating submerged targets of interest identified in the remote sensing data.

See Section II 4 “Approach” for a detailed overview of activities.

d. Inventory of samples collected

No physical samples were collected for this project; all data are digital and were collected in a non-disruptive manner.

e. Final data inventory

The sections below identify all raw data, processed data, geospatial data, and maps created as part of this project and associated file types. Data management for all project files (including data and data products) follow the plan outlined in the Data and Information Sharing Plan (DISP) created for this project. Details of how project files are being organized, archived, and backed up are presented in Section II 4c. NOAA Ocean Exploration will have access to all data generated as part of this project. Access can be granted to most project files via links (as described in Section II 4c), though raw data files may need to be sent via external hard drive (upon request).

Raw data

Note: Data collection methods are detailed in Section II 4a.

- Side scan sonar data were collected using an EdgeTech 4125 sonar system in .JSF file format and a Klein 3000H in .SDF and .XTF file formats.
- Magnetometry data were collected using a Geometrics G-882 Cesium Vapor magnetometer in .RAW and .HSX file formats.
- Bathymetry data were collected using Norbit iWMBSe multibeam system (integrated into a Seafloor Systems Inc. Echoboat-160 ASV) in .RAW, .HSX, and .7K file formats within a single file structure. Accompanying navigation files used for data correction were also recorded in .000 file format.
- Photogrammetry data were collected using SRC's custom-built system called SeaArray for deeper water sites and a single DSLR camera was used for the shallower water sites in .RAW file format and converted to .JPG for processing.
- Visual observations were documented using a Sony mirrorless camera in an underwater housing in .RAW file format and converted into .JPG. Accompanying written field notes were translated to an Excel spreadsheet (.XLSX format).
- Coastal LiDAR data were collected using a Trimble SX10 scanning total station and TSC-7 data collector in .RWCX and .JPG file format within the Trimble Access .JOB/.JXL file structure.
- Coastal GNSS RTK data were collected using Trimble R12i receives and TSC-7 data collector in .T04 file format.
- Photographs documenting diver-based target investigations were collected by underwater cameras in .RAW file format.
- Oral histories were recorded using a Sony MP4 recorder in .MP4 file format. The recordings were then transcribed into written .PDF format.

Processed data outputs

Note: Data processing methods are detailed in Section II 4a.

- Side scan sonar mosaics were exported in GeoTIFF file format
- Interpolated magnetic anomalies maps were exported in GeoTIFF file format
- Bathymetry mosaics were exported in GeoTIFF format
- Bathymetry point data (lat, long, depth) were exported in .XYZ file format

- Photogrammetry models were exported in .OBJ with .WLD georeferencing files and uploaded to SRC's Construkted Reality site for access.
- LiDAR point cloud data (lat, long, depth) were exported from Trimble TBC in .LAS and .XYZ file formats
- LiDAR data were exported from ESRI ArcPro .APRX or .PPKX format
- RTK GNSS data (lat, long, elevation) were exported in .TXT or .XYZ file format
- Geomorphology classification outputs were exported as (feature class (.SHP)) file formats
- Information regarding targets of interest (lat, long, water depth, target description/notes) was recorded in an Excel spreadsheet (.XLSX format)
- Imagery – still photographs (e.g. .JPG) and video (e.g., .MOV, .MP4)

Geospatial datasets:

- All processed data outputs noted above are also GIS accessible within a geodatabase (.gdb). These outputs were kept in GeoTIFF or DEM format, converted to shape file or feature class format, or hyperlinked within an attribute table, as appropriate.
- Additional products include final study areas, remote sensing survey track lines, ground-truth locations in feature class format (.shp)
- All datasets are spatially referenced to UTM Zone 55N (NAD83 MA11) and NAVD88
- All data are accompanied by FGDC (Federal Geographic Data Committee) or ISO (International Organization for Standardization) metadata files

Maps and figures:

- All images, such as maps, figures, and photos, illustrating datasets (e.g. for report, presentations, etc.) are in .pdf or .jpg file format
- All presentations are in PowerPoint (.pptx) or .pdf format
- Interactive digital maps – ESRI ArcGIS StoryMap

7. Communication

The project team worked with NOAA to jointly develop a Web and Communications Plan. The team also worked with the NPS Natural Resource Office of Communication to communicate the project to higher level offices and individuals within NPS and to obtain permission to participate in media enquiries and contribute to social media content intended for the public. All official NOAA Ocean Exploration web content and media coverage were posted to the NPS SRC Facebook page. The sections below highlight the various communication materials that were developed over the duration of the project.

a. List of resulting publications, presentations, websites, etc.

Presentations at professional conferences

The project team hosted sessions and gave presentations at two conferences related to this project. In November 2023, members of the project team attended the Coastal and Estuarine Research Federation (CERF) Conference in Portland, Oregon. The session and presentations were:

- Session: *Shallow Water Mapping in Coastal Environments: Research, Methods, and Management* (co-convened by Co-PI Monique LaFrance Bartley)
    - Presentation: *Mapping War in the Pacific National Historical Park (Guam) 80 Years After World War II* (Tahzay Jones)

In January 2024, members of the project team presented at the Society for Historical Archaeology (SHA) Conference in Oakland, California. The sessions and presentations were:

- Session: *From Whalers to World War II: Guam Underwater Archaeology and other WWII Maritime Projects* (Chaired by Anne Wright Nunn)
    - Presentation: *National Park Service Battlefield Survey of War in the Pacific National Historical Park, Guam: A Biogeographic and Maritime Cultural Landscape Exploration* (Anne Wright Nunn)
    - Presentation: *Artillery and Anomalies: Marine Remote-sensing off Guam's WWII Invasion Beaches* (Matthew Hanks)
- Session: *Exploration-Forward Archaeology Through Community-Driven Research* (chaired by NOAA Ocean Exploration staff)
    - Presentation: *Investigating Changes to the Coastal Environment and Coral Reef Habitat in Relation to WWII: War in the Pacific National Historical Park, Guam* (Monique LaFrance Bartley)

In addition, in April 2024, Co-PI LaFrance Bartley was invited to present on behalf of the project team at the NPS Water Resources Division Annual Meeting. This presentation was an extended version of the presentation given at SHA.

Web content

- Resilient: War in the Pacific National Historical Park – ESRI StoryMap
- The Battle for Guam: 80 Years Later – project overview video produced by NPS (11 minutes)
- War in the Pacific National Historical Park Underwater Resources webpage
- NOAA Ocean Exploration project page and Expedition Features
    - Expedition Summaries
    - Expedition Overview (Jan 2023)
    - Exploring Guam's World War II Amphibious Battlefield (Feb 2023)
    - Documenting Underwater World War II Blast Artifacts (April 2023)
    - Technical Divers Enable Greater Access to Our Past (Aug 2023)
    - Project Findings Once "Paved" the Way for Invasion (Aug 2023)
    - Measuring Elevation to Understand Coastal Change (Sept 2023)
    - Using Oral History to Understand Impacts of World War II Reef Destruction on Guam Today (Oct 2023)
- Underwater photogrammetry models (developed by NPS Submerged Resources Center project team members)
    - Blast crater on Asan Beach Unit Reef Flat (https://construkted.com/asset/a4u95ft8mzb/)
    - LVT offshore of Asan Beach Unit (https://construkted.com/asset/asuyyo7dbh4/)

- LVT offshore of Agat Unit (https://construkted.com/asset/axddx28i5o1/)
- LVT landing area crater offshore of Agat Unit (https://construkted.com/asset/aoulyjec3p1/)
- Hap's Reef (https://construkted.com/asset/a5v1x3ytpng/)

Resulting publications

An article for publication in a peer-reviewed archaeology journal is in preparation. In addition, articles will be submitted to NPS Park Science Magazine and the NPS Geospatial Newsletter. Manuscripts and other publications will be open-access whenever possible.

NOAA Ocean Exploration will be provided with drafts for review prior to publication for awareness and to have the opportunity to make programmatic comments. Also, as stated in this project's Data Information and Sharing Plan, all documents and pre-publication manuscripts drafted as a result of this project will be submitted to the NOAA Central Library's Institutional Repository (and be section 508 compliant).

b. Outreach, education, and engagement

Presentations at WAPA Visitor Center

The project team hosted two outreach days at the park's T. Stell Newman Visitor Center. The events were attended by local community members, military personnel, and park staff and volunteers. The first event was on February 11th, 2023, during which the team gave three presentations, entitled:

- *Underwater Archaeology of an Amphibious Battlefield: the American Invasion of Guam in 1944* (presented by Anne Wright Nunn)
- *Exploring What Lies Beneath: Mapping the Seafloor of our National Parks* (presented by Monique LaFrance Bartley)
- *Beneath Pearl Harbor: An Archaeologist's Perspective* (presented by Dave Conlin at the request of WAPA Superintendent)

The second event was on August 19th, 2023, during which the team gave two presentations, entitled:

- *Underwater Battlefield Archaeology: the American Invasion of Guam in 1944* (presented by Anne Wright Nunn)
- *Artillery and Anomalies: Diver Investigations off Asan and Agat Beaches* (presented by Matthew Hanks) (Figure 110).

In addition, at the request of the Park Superintendent, project team members gave a presentation on July 26th, 2023 to WAPA park staff and FWS Wildlife Refuge staff highlighting this project (data collection efforts, preliminary findings, next steps, and management context) and the team's post-Typhoon Mawar data collection efforts that took place while the team was on Guam in May 2023. This presentation was entitled *Coastal and Underwater Mapping at War in the Pacific National Historical Park, Guam* (presented by Tahzay Jones and Monique LaFrance Bartley)

Figure 110. The public attending presentation by the project team at the T. Stell Newman WAPA visitor center. NPS photo.

Engagement

The team sought the active inclusion of students, veterans, and local community members to enhance the project and provide meaningful experiences. In total, the project team engaged nine student and early career interns, three local community member volunteers, and two veteran volunteers representing the Task Force Dagger Foundation (TFDF). Refer to Table 2 for listing of each participant's role.

The NPS Scientists in Parks (SIP) internship program is a paid science-based work experience program that is a partnership with NPS and several non-governmental partner organizations, including Stewards Individual Placements Program, Conservation Legacy, Ecological Society of America, The Geological Society of America, and the National Park Foundation. The SIP program aims to provide participants with meaningful career-building experiences that inspires and develops the next generation of park stewards and fosters a life-long connection to the National Park System. Through this program, the project directly employed underwater archaeology graduate student Blair Moore, who also used project content for his Masters of Professional Science thesis at the University of Miami. An additional eight SIP interns working with WRD, the Alaska Region, and WAPA participated in various aspects of the project, including field work and data analysis.

Two veteran volunteers participated through a partnership with Task Force Dagger Foundation (TFDF). TFDF is an organization that provides rehabilitative support and assistance to wounded, ill, or injured U.S. Special Operations Command members and their families. This project provided opportunities for

TFDF members to engage with their own submerged military heritage while participating in diving activities to investigate targets of interest. Figure 111 shows the two TFDF volunteers diving on the UXO dump site at Asan.

Figure 111. John Dailey and Worth Parker of Task Force Dagger Foundation dive on the site of the dump site at Asan.

The team also sought community member participation in diving operations, where possible. Local dive instructor, WAPA volunteer, and CHamoru community member, Luis Cabral, joined the dive team and assisted with anomaly investigations. In addition, he showed the project team known World War II artifacts at Asan. He was integral to the documentation of the Asan Amtrac site as well as the "tracks" site, both of which were not detected by the team's remote sensing equipment.

K-12 lesson plans

As part of his internship, NPS Scientists-in-Parks intern, Blair Moore, created three middle school-level lesson plans using data and content from this project.

The NPS team worked alongside NOAA Ocean Exploration education specialists to develop the lesson plans, who indicated that they were updating their educational content to include the "Sensemaking" teaching methodology developed by NOAA Ocean Exploration and the National Science Teaching Association (NSTA). Sensemaking theorizes that students learn more from being hands-on and uses interactive exercises to educate students on scientific principles.

The first lesson plan, entitled "*Investigation: What is Underwater Archaeology*?," is designed to introduce students to the STEM and social science-based disciplines used by underwater archaeologists. Using handouts specifically designed for this lesson, the students are provided with the basics of underwater archaeology, and answers the question "*Why are there archaeological sites underwater and how did they get there?*" The students use this information to participate in an in-class exercise where they watch a selection of videos developed by NPS and NOAA. Throughout the videos, the students are asked questions designed to have them think critically about the submerged sites they are viewing. Four products were developed to support this lesson plan, including an implementation guide for educators, handouts and worksheets for students.

The second lesson plan, entitled "*Investigation: Underwater Archaeology Site Documentation Techniques,*" builds from the information provided in the first lesson. This lesson focuses on math-based knowledge that underwater archaeologists use to create maps of submerged sites. It follows a similar format to the previous lesson, in which students are exposed to background content using specifically generated handouts. For the class exercise, students map a mock-shipwreck created by the instructor using household items. To allow for differences in class size and structure, two versions of this exercise were developed. This lesson plan includes educator's guides, student worksheets and handouts.

The third lesson plan, entitled "*Investigation: Submerged Battlefield Archaeology in Guam,*" uses this project as the case study to educate students about the social science skills of an underwater archaeologist by introducing them to anthropology, history and historic research. The students are provided with information on the geo-political context of wartime Guam. Students are also introduced to the underwater archaeology subfield of submerged battlefield archaeology. For the class exercise, students conduct a field survey of a mock-site using the same methodology the project team used to survey the reef flats of the Asan Beach Unit. While conducting the survey, students locate and document images of real artifacts that were found during this project. Once they have documented the artifacts, the students must identify them through a matching exercise. Students are shown images of what the artifacts may have looked like prior to deposition on the seafloor and are then asked to match these images with their documented artifacts. Two versions of this exercise were also created to accommodate a broader range of class types and structure. This lesson plan includes educator's guides, student worksheets and handouts, as well as a CHamoru key terms list (included in Appendix E).

Each lesson plan was reviewed and accepted by NPS and NOAA Ocean Exploration. The plans are currently awaiting their final graphic design and formatting from NOAA Ocean Exploration before publication on both NPS and NOAA Ocean Exploration websites.

Media coverage

PIs Anne Wright Nunn and Monique LaFrance Bartley conducted several interviews during and after fieldwork, which resulted in the following media publications:

- News article by reporter Mark Price entitled "Search underway for key WWII battlefield hidden on Pacific seafloor off Guam, team says." Published in the *Miami Herald*, the *Sacramento Bee*, the *Charlotte Herald,* and other newspapers owned by the McClatchy Group. The project team tracked that this article was shared across over 40 news outlets.
- Interview by reporter Kyle Evans on the podcast *Pacific Beat* entitled, "Project investigates environmental impact of WWII relics on Guam" https://www.abc.net.au/pacific/programs/pacificbeat/national-parks-service-uncover-forgotten-wwi-artifacts-on-guami/102061250
- Article in the online military and history magazine *Task & Purpose* by reporter Nicholas Slayton. Scientists are exploring the underwater aftermath of World War II at Guam (taskandpurpose.com)
- Article in the online magazine *The Past* entitled "Survey explores underwater battlefield in western Pacific"
- News article by reporter Mark Price entitled "Graveyard of WWII battle holds an 'immense amount' of unexploded bombs, team learns" Published in the *Sacramento Bee* and other newspapers owned by the McClatchy Group.
- News article by reporter Mark Price entitled "Mysterious steel sheets found in Pacific Ocean played role in World War II, study says" Published in the *Miami Herald* and other newspapers owned by the McClatchy Group.
- Article by Russell Worth Parker – former U.S. Marine and volunteer diver from Task Force Dagger Foundation – entitled "Diving with Ghosts" Published in Salvation South

III. Evaluation

1. Adjustments

a. Explain any major changes or adjustments from previously submitted reports

There are no major changes or adjustments from previously submitted reports.

b. Explain adjustments between proposed and accomplished work

Adjustments to equipment used for data collection

The project proposal indicated an ROV would be used to investigate targets of interest identified in the remote sensing data (in addition to divers), but this was determined to be unnecessary. The use of the ROV was meant to allow for increased survey efficiency and increase the safety margin for deeper dives. However, only a few deep-water targets were identified and the project team had a sufficient number of divers to conduct the investigations. The project team also recognized that the additional costs for shipping the ROV and potentially the need to rent a second boat to conduct the surveys compared to the small amount of time the ROV may have saved was not considered cost-effective overall.
Similarly, the project proposal stated "a Biosonics MX Aquatic Habitat single beam echosounder will take the place of the multibeam sonar and provide single-beam bathymetry data in shallow water areas"

inside of the reef. The project team determined the echosounder was not necessary because the multibeam sonar could operate in waters as shallow as 0.5m and provide a wider swath (i.e. more coverage) that the single-beam echosounder.

Weather

The team encountered several periods of adverse weather due to the effects of Typhoon Mawar and Typhoon/Hurricane Dora. Both were significant storm events that disrupted survey activities the project team had planned, as described below. In these situations, the project team discussed alternative paths forward, targeting priority tasks/areas to ensure the overall project objectives would still be accomplished.

Typhoon Mawar

Typhoon Mawar made landfall on Guam May 24th, 2023 as a category 4 storm and was the strongest storm event since Typhoon Pongsona in 2002. The project team experienced Typhoon Mawar at the onset of the May-June 2023 field effort focused on multibeam mapping surveys. No storm alerts were posted when project team member LaFrance Bartley checked the weather at the airport in Boston on her way to Guam on May 19th, 2023. However, 17 hours later when she landed at Narita airport in Japan, the typhoon system had formed and was anticipated to make direct landfall on Guam in a matter of days. This unprecedented event resulted in the complete loss of the first week of fieldwork and interruptions during the following week. The team also lost survey time due to flash flood warnings and torrential downpours as the remnants of the typhoon passed through the area in the days following the storm making landfall.

To adjust for this situation, the team focused on completing multibeam mapping for the areas offshore of the reefs because deeper water depths allowed for greater survey efficiency and coverage and for priority areas inside of the reefs identified in consultation with park staff. Of greatest interest inside of the reefs was the vicinity of the visitor use areas at Asan and Agat Ga'an Point. Mapping the line of blast craters located by referencing a historic map was also a priority for the team.

The many days of rainfall during the May-June campaign had the potential to hinder mapping efforts because the surveys are facilitated through a laptop. While the laptop is ruggedized, it cannot withstand hours of being in the rain. To overcome this challenge, the team bought a tent, which provided shelter and provided the mobility needed to set up at different locations along the coast to support field operations inshore of the reefs (Figure 112). While not as efficient, this approach allowed the project team to continue to make progress. The team also extended their trip by one week (funded by NPS) to provide the team opportunity to collect additional data and "make up" for some of the lost time.

Figure 112. The project team conducting multibeam mapping operations in the rain from inside a tent. NPS photo.

As a side note, the project team had the unique opportunity to collect post-Mawar data in the days immediately following the storm to support the park and sister Federal agencies at their request. While these efforts support outside projects, the team is proud to have been able to contribute such valuable ephemeral data that would have been lost otherwise. For example, the USGS asked the team to document the inland extent of the storm surge inundation at the park units and nearby areas to help refine and validate their flood models. FWS asked the team to collect similar data for the Guam National Wildlife Refuge at Ritidian to provide a baseline understanding of post-typhoon conditions. The team also provided these data to the National Weather Service at their request to assist with their post-storm reporting efforts. The summary of all data collected while the team was on Guam from May 20th – June 16th are outlined in Appendix C. It is important to note that this project remained the team's first priority. All additional datasets were collected when operating the ASV multibeam system was not possible (e.g. low tide, high surf conditions, no power available to charge equipment).

Typhoon/Hurricane Dora

Typhoon/Hurricane Dora (August 2023) a record-breaking storm that most heavily affected Hawaii, Wake Island, and Johnston Island during the July-August 2023 field campaign. While the storm did not come directly over Guam, it created adverse conditions across the Western Pacific and made conditions at both Asan and Agat unworkable on several days, and drastically changed conditions at Agat for several weeks. The storm caused the prevailing wind condition to change, creating storm surge that could be felt up to 100 feet deep. The surge also caused extremely low visibility conditions (less than two feet in some circumstances). As a consequence, two full weather days were required. Once the rain ceased, the team was able to change gears and begin shallow water snorkel/walking survey at Asan, slated for the end of the project. Consequently, the team was able to use five working days originally intended for diving for beach survey at Asan. However, this impacted the completion of diving investigations at Agat, for which 48% of the survey way completed. (Note 100% of diving investigations were completed at Asan.)

The storm caused zero-visibility conditions in the shallow water survey area at Agat for the remaining duration of the project (Figure 113). Consequently, the team was unable to complete walking/snorkel surveys at Agat, as the lack of visibility would have made visual surveys nearly impossible as well as potentially dangerous due to hidden debris.

Figure 113. Photographs showing reduced water visibility inhibiting target investigation operations.

Bathymetry surveys inside of reef

The project proposal stated that bathymetry data would be collected for the full extent of Asan Beach and Agat park units. This is true for the areas extending from the reef crest offshore to the 60 m isobath. However, the project team was not able to achieve full coverage extent of the park units extending from the reef crest inshore to the shoreline. Instead, the team focused on areas of interest identified in collaboration with WAPA park staff and supplemented the remaining area with available topobathy LiDAR (collected by NOAA in 2021). Of greatest interest were the areas offshore of the visitor use areas at Asan and Agat Ga'an Point. Mapping the line of blast craters was also a priority for the team. While the entirety of the waters inside the reefs were not able to be mapped, it is worth noting that the ASV still offered the benefit of being able to survey in very shallow waters inside of the reefs that are otherwise inaccessible by boat and that the multibeam system still provided greater coverage and higher resolution data than a singlebeam system would have.

The limited coverage extent was due to several reasons, including weather delays (as described above), the areas inside of the reefs were shallower than anticipated, technical challenges, and shipping delays (add described below).

The shallow water depths required tighter line spacing (3m) and substantially more time was required than originally planned for this component of the project. For context, the survey grid inside the reef at Asan shown in Figure 40 required three days to map, which is the same amount of time it took to map the entirety of the offshore area of Asan shown in Figure 30. Furthermore, the project team had planned to leverage high tide to optimize survey efficiency, but also planned to map regardless of tidal state. However, surveying was not possible at low tide, which limited the timeframe for data collection. The team did their best to maximize their survey window by surveying during the incoming tide, high tide, and outgoing tide and by surveying early in the morning and into the evenings, when necessary. Additionally, the water was too shallow to map in some areas, even at high tide (Figure 114).

Figure 114. Photographs taken from the Governor's Mansion looking west to the eastern portion of the Asan park unit. The photos serve to demonstrate the area is too shallow to be mapped with the ASV. The breaking water line is the reef crest and people are visible walking just inside of the reef.

Technical challenges were encountered during the January-February 2023 field effort and attributed to a software upgrade performed by the manufacturer. The ASV equipped with the multibeam sonar system had been pro-actively sent to the manufacturer prior to being shipped to Guam for this project to ensure the system was running optimally. Unfortunately, the system was not functioning properly when it was shipped to Guam (unbeknownst to the project team or the manufacturer) and so unanticipated time during the project was spent trouble-shooting issues that were cascading from one larger software issue. Complicating the technical issue was the delayed shipment of batteries needed to power the ASV and multibeam system also posed a challenge during the January-February 2023 field effort. The batteries were estimated to arrive five days after shipment and the WRD team sent the shipment six weeks in advance of the project start date, anticipating that would be ample leeway. However, the shipment ended up taking eight weeks, and, as a result, the batteries arrived 10 days into field operations. Combined with technical issues that arose with the system which could not have been known until the system was powered (described above), multibeam data collection was hindered during the January-February portion of the field campaign. The issue was resolved at the end of the field campaign in February before the team left Guam and surveys resumed during the May-June field campaign.

LIDAR survey coverage extent within park units

As described in above, the project team experienced delays with the multibeam sonar during the January-February 2023 field campaign. To compensate for this, when the multibeam system was not operational, the team pivoted their focus and collected additional coastal elevation data in support of the project. The project proposal stated the team would collect elevation data for the beach and intertidal portion of the Asan Beach and Agat park units. Instead, the team actually completed surveys for the entire visitor use areas of both park units. Over 40 scans were collected within each unit, with coverage extending from the shoreline, including the beach and intertidal zone, to the main road (park unit inland boundary), including the parking lots and facilities. The riverbanks and river mouths from the main road to the ocean were also scanned, with emphasis on documenting the erosion that is occurring.

These surveys were repeated (as planned) for the beach and intertidal portions of the park units during the July-August 2023 field campaign. These datasets allow for a short-term change analysis to be conducted, which proved to be valuable given the impacts of Typhoon Mawar (May 2023).

LIDAR surveys of nearby beaches

A project goal stated in the proposal was to “Conduct surveys to collect coastal and intertidal elevation data using a scanning total station and RTK GPS at Asan and Agat beaches and nearby beaches for comparison.” The project team did complete some surveys are nearby beaches, including at the Mayor’s Complex in Agat, the opposite river bank at Asan Beach, and further north at Ritidian. Surveys of other nearby beaches was hindered by overhanging vegetation or because coastal characteristics were substantially different than that of the park units (e.g. developed shorelines that are maintained and managed by local government). These differences limited the value of collecting data for the purpose of comparing differences in the context of WWII. Instead, the project team focused on expanding survey coverage within the park units (as described above).

Oral history

Fewer oral history interviews were collected than the team had originally hoped for prior to the start of the project, though a specific number was not scheduled. Despite efforts to seek out interested parties through contacts at WAPA and with local community members, the team interviewed fewer people than originally anticipated. While the team learned very interesting and important information about how Assan and Hågat beaches are currently used by the community, few interviewees shared stories or information relating to World War II. The exploratory nature of the oral history part of the project allowed us to adapt the interviews into material for outreach and education.

a. Original planned expenditures

Table 6 summarizes original planned expenditures for the project, as submitted with the proposal. The full budget justification submitted with the proposal is attached to this report as Appendix D.

Table 6. Summary budget table submitted with the project proposal.

SUMMARY BUDGET TABLE

Category	Year 1	Year 2	Total Costs
Personnel	0	0	**0**
Fringe Benefits	0	0	**0**
Travel	56,880	115,092	**171,972**
Equipment	0	0	**0**
Supplies	15,000	11,000	**26,000**
Contractual	0	0	**0**
Other	49,375	79,375	**128,750**
Indirect Costs	0	0	**0**
TOTAL	121255	205467	**326,722**

b. Actual expenditures

Actual expenditures prior to April 1, 2023 (first fieldwork campaign) are outlined below.

Travel
The following is a breakdown of actual expenditures for travel.

Airfare:
1 trip X 10 people @ airfare range between $2,017.90 - $2,710.34
*1 additional trip X 1 person @ airfare $2,224.02 = $2,224.02
*Note: This expense is the result of a team member returning to Denver to pick up and hand-carry equipment that was lost by the shipping company. See Section II(2c) for further explanation.

Per diem:
25 days per diem @ $124/day x 4 people = $12,400
22 days per diem @ $124/day x 3 people = $8,184
21 days per diem @ $124/day x 1 person = $2,604
12 days per diem @ $124/day X 1 person = $1,488
11 days per diem @ $124/day x 1 person = $1,364

Lodging:
18 nights lodging @ $159/night x 1 person = $2,862
21 nights lodging @ $159/night x 1 person = $3,339
21 nights lodging @ $159/night x 2 people = $6,678
21 nights lodging @ $130 night x 3 people = $8,970
19 nights lodging @ $159 night x 1 person = $3,021
11 nights lodging @ $159 night x 1 person = $1,749
9 nights lodging @ $159 night x 1 person = $1,431

Vehicle rental:
2 rental vans @ $97.50/day each for 22 days = $2,145

Other:
**Other = $6,700.62
**Note: This expenditure is comprised of lodging taxes, Concur (NPS travel booking system) fees, airline baggage charges, travel to and from the airport (taxi, uber, shuttle, etc.), rental vehicle fuel expenses, and associated charges for a research trip to the National Archives by PI Anne Wright Nunn (see Section 2(c) for explanation).

Total = $87,582.26

Supplies
The following is a breakdown of actual expenditures for supplies.

Miscellaneous supplies = $2,387.53
Diving consumables = $289
1 100-meter magnetometer cable @ $6000/cable = $6,000

Total = $8,678.53

Other costs
The following is a breakdown of actual expenditures for “other” costs.

Subaward - 2 Vessel Charters = $20,720
***Shipping costs = $25,683.14
***Note: $4,416.25 in shipping costs are currently being disputed. See below for additional explanation.

Total = $46,403.14

<u>Actual expenditures April 1, 2023 – October 31, 2023 (second fieldwork campaign) are outlined below.</u>

Travel
The following is a breakdown of actual expenditures for travel.

Airfare:
1 trip (May/June) x 2 people @ airfare of $2,740.54 and $3,278.72 = $6,019.26
1 trip (July/August) X 10 people @ airfare range between $2,158.64 - $2,866.94 = $26,502.74*
* Note: This expense and additional travel expenses does not include the airfare expense of team member B. Moore, as his travel costs were covered by the NPS SIP Program through subaward of this grant.

Per diem:
24 days per diem (May/June) @ $124/day x 2 people = $5,952
29 days per diem (July/August) @ $124/day x 2 people = $7,192
19 days per diem (July/August) @ $124/day x 3 people = $7,068
10 days per diem (July/August) @ $124/day x 1 person = $1,240
18 days per diem (July/August) @ $124/day X 2 person = $4,464
17 days per diem (July/August) @ $124/day x 1 person = $2,108
15 days per diem (July/August) @ $124/day x 1 person = $1,860

Lodging:
22 days lodging (May/June) @ $159 night x 2 people = $6,996
27 nights lodging (July/August) @ $159/night x 2 person = $8,586
9 nights lodging (July/August) @ $159/night x 2 person = $2,862
15 nights lodging (July/August) @ $159/night x 1 people = $2,385
13 nights lodging (July/August) @ $159 night x 3 people = $2,067
16 nights lodging (July/August) @ $159 night x 2 person = $5,088
*Lodging nights are inconsistent with per diem total days as some team members shared housing expenses when rooms in rental house became available.

Vehicle rental:
1 rental truck (May/June) @ $100/day for 24 days = $2,400
1 rental van (July/August) @ $55/day for 26 days = $1,430
1 rental van (July/August) @ $55/day for 23 days = $1,265
1 rental truck (July/August) @ $100/day for 15 days = $1,500

Other:
**Other = $3,441.24
**Note: This expenditure is comprised of lodging taxes, Concur (NPS travel booking system) fees, airline baggage charges, travel to and from the airport (taxi, uber, shuttle, etc.), and rental vehicle fuel expenses.

Total = $100,711.24

Supplies
The following is a breakdown of actual expenditures for supplies.

Miscellaneous supplies = $4,901.61
Diving consumables = $3,793.95
Supplies purchased after fieldwork and before expiration of fiscal year = $24,614.76

Total = $33,310.32

Other costs
The following is a breakdown of actual expenditures for "other" costs.

Subaward Vessel Charter (1) May/June = $2,000
Subaward Vessel Charters (2) July/August = $17,000
Subaward SIP intern = $24,100 (Cost of internship $17,100 + internship travel funds $7000)
***Shipping costs = $6,938.75

Total = $50,038.75

c. Final budget expenditures table

Table 7. Final budget expenditures for this project.

BUDGET EXPENDITURES REPORT				
PLANNED EXPENDITURES VERSUS ACTUAL EXPENDITURES FOR REPORTING PERIOD				
NOAA Grant No.:	**NA22OAR01101XX**			
Institution Name:	**National Park Service Submerged Resources Center**			
Lead PI Name:	**Anne Wright Nunn**			
Award Period:	**10/1/2022 - 9/30/2024**			
Reporting Period:	**10/1/2022 - 9/30/2024**			
Total Award Amount:	**$326,722**			
	Total*	**Actual Expenditures**	**Actual Expenditures**	
	Funds Available	**10/1/2022-4/1/2023**	**4/1/2023-10/1/2023**	**Balance Remaining**
Salaries & Wages	$ -		$ -	$ -
Staff Benefits	$ -		$ -	$ -
Travel	$ 171,972.00	$ 87,582.26	$100,711	$ -
Services	$ -		$ -	$ -
Supplies	$ 26,000.00	$ 8,676.53	$33,310.32	$ -
Equipment	$ -		$ -	$ -
Other	$ 128,750.00	$ 46,403.14	$50,038.75	$ -
Indirect Cost	$ -		$ -	$ -
			$ -	
Total	$ 326,722.00	$142,661.93	$184,060.07	$ -

d. Discrepancies between planned and actual expenditures

The following describes discrepancies between planned and actual expenditures for the first fieldwork campaign.

Discrepancies in travel expenditures

Travel expenditures were higher in cost than initially estimated in the proposal for the reasons described below.

Airline costs increased over the one year period between when the project was initially proposed and initiated. The average cost of a flight from the continental U.S. to/from Guam increased from about $1,800 per flight to about $2,400 per flight. In addition, the federal per diem rate for Guam increased on February 1st, 2023 from $96 per day to $124 per day per person, which, as a federal agency, the NPS is obligated to pay to travelers.

Also, after initial fieldwork operations and careful consideration of our fieldwork objectives during planning, the team realized that additional days in the field were needed to complete the scheduled work. Additional days of per diem and lodging expenditures were consequently added.

Furthermore, travel costs from PI Anne Wright Nunn's trip to the National Archives were added to the travel expenditures. This trip was made in lieu of hiring an independent researcher as was originally planned (as indicated in the "other" expenditures section).

Discrepancies in supplies expenditures

The team spent less on supplies than originally estimated in the proposal, particularly within the sub-category of diving consumables. Since the proposed dives at Asan Beach turned out to be unnecessary due to the shallowness of the area inside the reef, fewer dives were completed during this first fieldwork campaign than planned. Instead, the project team was able to snorkel the area.

Discrepancies in "other" expenditures

Shipping

Shipping costs associated with the first field campaign were higher than the team anticipated, due to an increase in rates between the proposal being accepted for funding and the project start date. In addition, a pallet of gear was temporarily misplaced by the shipping company, which caused a significant delay. Upon being found, project objectives required that the gear was expedited to Guam.

Archival Research

We also planned to spend $2,000 to contract an independent researcher to locate documents related to the 1944 invasion of Guam and records of the US UDTs. However, we were unable to find a researcher with the appropriate expertise within the necessary time frame. PI Anne Wright Nunn has a background in archival research and successfully conducted the research herself. The total cost for her trip from Denver to the National Archives in College Park, Maryland was $2,621.48, which included all travel and per diem costs. This amount is listed in the actual expenditures under travel rather than in the "other" category.

Vessel Charters

The team estimated $28,000 on vessel charters in the proposal. The cost for these charters was less than originally intended ($20,720) as the charter company kindly did not charge us for days the vessels were not needed, e.g. during the time team was still waiting for equipment to arrive or for time spent trouble-shooting gear.

The following describes discrepancies between planned and actual expenditures for the second fieldwork campaign:

Discrepancies in travel expenditures

Travel expenditures were $11,445.02 less than scheduled for the reasons outlined below.

Some costs were higher than indicated in the proposal, but the team was able to adjust other expenditures to stay on budget. Airline costs increased over the one-year period between when the project was initially proposed and initiated. The average cost of a flight from the continental U.S. to/from

Guam increased from about $1,800 per flight to about $2,400 per flight. In addition, the federal per diem rate for Guam increased on February 1st, 2023 from $96 per day to $124 per day per person, which, as a federal agency, the NPS is obligated to pay to travelers.

For the July-August field campaign, the team implemented several cost saving measures for travel expenditures. The number of divers needed to complete the diver-based summer fieldwork objectives (as determined based on the results of the February fieldwork campaign) was less than originally proposed. We reduced the planned team of 16-participants to 12, which allowed us to re-coup some travel expenditures spent during the February fieldwork campaign and accommodate the expenses associated with the two-person follow-up multibeam mapping campaign in May. The team number was reduced further, to 11 people, when a volunteer from Task Force Dagger Foundation was unfortunately unable to participate due to a personal injury several weeks before the start of fieldwork. We also reduced travel costs by incorporating local team members (WAPA staff and volunteers) as dive team members.

Discrepancies in supplies expenditures

We budgeted $11,000 for supplies and spent $8,695.56 before and during fieldwork efforts. The team spent less on supplies than originally estimated in the proposal, particularly within the sub-category of diving consumables, which included air, nitrox, and mixed-gas cylinder fills for both open circuit and closed circuit rebreather operations. Weather days resulted in a reduction of cost, as cylinder fills were not needed on these days. The team also often opted for the use of rebreathers for some shallow-water dives, which meant the team needed less cylinder fills overall. In addition, some rebreather parts and consumables that the team had planned to purchase with project funds were paid for from a different funding source, and the rebreathers did not need to be refurbished twice in one year. This also resulted in a cost savings.

Once fieldwork was complete in August 2023, remaining funds in the amount of $24,614.76 were due to expire at the end of the federal fiscal year on September 30, 2023. The team worked with NOAA Ocean Exploration staff via our designated contact (Phil Hartmeyer) to seek approval to spend out the remaining funds on project-related replacement supplies, as this amount would put us over our allotted 10% discretion. These supplies included digital storage space for 3D models, a replacement diver propulsion vehicle for SeaArray, a rebreather computer replacement, and a replacement AquaPulse metal detector that was damaged during the project. These supplies totaled $24,740.94. The $126.18 difference between remaining funds and replacement supplies was paid out of a separate NPS account. In this way, all project funds were used for project-related expenses and no funds expired at the end of the fiscal year.

Discrepancies in "other" expenditures

Shipping

Shipping costs were less than anticipated. We budgeted $9,000 for shipping and spent $6,938.75. The team was able to check some bags and pelican cases on flights at a less expensive rate than shipping which resulted in a cost savings. Also, the cost of shipping the ASV out of Guam was split between this project and Cape Cod National Seashore, where the ASV was used for its next project.

NPS Scientist in Parks (SIP) Intern

We budgeted $20,750 for the NPS Scientists in Parks internship program in the project proposal because we planned to have two 12-week interns. When the fieldwork component of the project became a single fiscal year endeavor due to the federal funding schedule, we decided on one 20-week internship after discussing with NOAA Ocean Exploration personnel. The cost of the 20-week internship was $17,100, subawarded to Conservation Legacy. In addition, we added $7,000 in funds to the internship to cover the cost of the intern's travel, per diem, and lodging on Guam.

Vessel Charters

The team estimated $60,000 on vessel charters in the proposal for the second fieldwork session. The cost for these charters was significantly less than originally intended ($19,000) as the charter company did not charge us for weather days, or for time spent trouble-shooting gear. Additionally, based on the number of anomalies/targets identified during the remote-sensing survey in February, the team was able to cut the estimated number of boats needed for diving investigations down from three to two, which resulted in a significant cost savings. During the May-June field effort, $1,400 (of $3,400 total) for the vessel charter was funded from an outside project which required the same data (resulting in a $2,000 vessel charter charge to the project and a cost savings of $1,400).

e. Equipment inventory

The only piece of equipment purchased specifically for this project was a 100-meter magnetometer cable for $6,000. The cable was used during the project and is now housed with NPS at SRC.

Once fieldwork was complete in August 2023, remaining funds in the amount of $24,614.76 were due to expire on September 30, 2023. The team worked with NOAA OER staff via our designated contact (Phil Hartmeyer) to seek approval to spend out the remaining funds on project-related replacement supplies (not considered equipment), as this amount would put us over our allotted 10% discretion. These supplies included digital storage space for 3D models, a replacement diver propulsion vehicle for SeaArray, a rebreather computer replacement, and a replacement AquaPulse metal detector that was damaged during the project. These supplies totaled $24,740.94. The $126.18 difference between remaining funds and replacement supplies was paid out of a separate NPS account. In this way, all project funds were used for project-related expenses and no funds expired at the end of the fiscal year.

2. Conclusions and next steps

a. Planned or expected outcomes

Publications and presentations

An article for publication in a peer-reviewed archaeology journal is in preparation. This article will focus on the identification of cultural resources related to World War II (including in the context of the natural environment and change over time) and battlefield analysis and will discuss future potential management of these resources. The project team also plans to submit an article to NPS Park Science Magazine highlighting this project and significant results, with particular emphasis on how the project supports the park's mission and management needs. In addition, an article will be submitted to the NPS geospatial newsletter focused on the use of LiDAR data to assess coastal change and serve as a case study for other parks interested in using the Trimble SX12 scanning total stations available to NPS staff. Manuscripts and other publications will be open-access whenever possible.

NOAA Ocean Exploration will be provided with drafts for review prior to publication for awareness and to have the opportunity to make programmatic comments. Also, as stated in this project's Data Information and Sharing Plan, all documents and pre-publication manuscripts drafted as a result of this project will be submitted to the NOAA Central Library's Institutional Repository (and be section 508 compliant).

The project team will also continue to identify additional opportunities to increase awareness of this project, including at professional conferences and developing web content as relevant. We expect that NPS, NOAA, USGS, and others will utilize resulting information and datasets to inform future research, develop additional interpretive materials, and guide park management decisions.

b. Description of how project deliverables and outcomes contribute to societal and/or ecosystem well-being

The mission for which the park was established (1978) is to "commemorate the bravery and sacrifice of those participating in the Pacific Theater of World War II and to conserve and interpret outstanding natural, scenic, and historic values and objects on the island of Guam for the benefit and enjoyment of present and future generations." This project supports the park's mission by strengthening the connection between history and current day, including describing how the repercussions of WWII activities have been integrated into, and continue to influence, the environment and people of Guam.

The landscape and seascape of Guam have been transformed due to both natural and human activities (including WWII). This project has provided the opportunity to better understand how Guam has changed over time and may change into the future. Our ability to confidently interpret how WWII activities have directly shifted the function of the physical environment over the last 80 years is complicated by the influence of other factors, including storms and climate change. However, this project's data and findings provide value and have practical applications for park resource management, education and outreach, and visitor use (refer to Section II 6b "notable findings and discussion" for examples).

Understanding past, present, and anticipated future landscape and seascape changes will help the park identify the most effective management strategies for preserving, interpreting, and communicating its cultural and natural resources. For example, data from this project has already been incorporated into the park's recently completed Unit Management Plan and associated Flood Plain Statement of Findings focused on identifying and mitigating risk to human health and safety and resources in floodplain areas. These planning efforts, as well as data from this project, align with the Resist-Accept-Direct (RAD) Framework, which encourages consideration of the range of climate change adaptation approaches to facilitate appropriate and reasonable park planning and resource decision-making in the face of changing conditions.

The discovery of the blast craters that still exist among the reef flat within the Asan Beach unit was a important outcome of this project. These craters are now an integral part of the seascape and continue to serve as a reminder of the attacks that took place eight decades ago, tying together in a clear and visceral way the connections between history, culture, and the environment. This finding helps communicate the events of WWII and associated impacts in a way that can meaningfully resonate with people and connect them to their shared history.

Similarly, the sunken Amtraks offshore of Asan Beach and Agat units provide opportunities for public outreach and engagement, as well as archaeological and scientific advancement. The Amtrak at Agat is a well-known site and commonly visited by divers; while the Amtrak offshore of Asan Beach is less well known and in poorer state of preservation. This project fully documented the sites using photogrammetry to create 3D models. This documentation serves as valuable baseline dataset for comparing future change.

This project is also significant in that it provides an updated archaeological survey documenting UXO and other WWII artifacts that still remain on the seafloor. The previous systematic submerged archaeological survey of the park is detailed in *Micronesia: Submerged Cultural Resources Assessment* (Carrell 1991). The team was able to update the archaeological data for many submerged sites, such as the American Pontoon Barge, that had not been visited by archaeologists in almost 40 years, and added new sites to the park record, including a Marston Mat site and a Japanese Fishing Boat site. In another previous survey, UXO were documented to the 130 ft isobath (Milton et al. 2006). This project extended the known boundary of the UXO dump at Asan off of Camel Rock. Project divers confirmed that the UXO dump extends well past 200 ft depth, down the reef slope and out of sight to at least 300 ft deep. This project offers updated reference surveys that can be used to track shifts in location and condition of *in situ* WWII artifacts. This information can aid managers in making informed decisions as these WWII remains continue to age and move on the seafloor. For example, as submerged UXO deteriorates, corrosion may cause harmful chemicals to leach into the water and impact marine life.

c. Brief description of needs and/or plans for additional work, if any

Diver-based investigations

As time and funding allows, NPS will prioritize completing diver investigations of anomalies at Agat Unit identified in the remote sensing data that the team was unable to complete due to the effects of

Hurricane/Typhoon Dora. There may be additional archaeological sites and material at these uninvestigated sites that could enhance the findings of this project and further tell the story of the 1944 Battle of Guam at War in the Pacific National Historical Park.

Monitoring activities

The team is also interested in conducting monitoring activities across the park to assess change over time, especially in the context of changing environmental conditions, such as anticipated increased frequency and intensity of storm events. For example, monitoring should be undertaken for the shifting location and condition of submerged UXO near Camel Rock at the Asan Beach Unit. Conducting archaeological study on the rate of deterioration and monitoring the condition of the Amtracs in both park units is also a primary interest. Additional LiDAR surveys can inform changes across the coastal landscape, including rates and extent of erosion, which would especially benefit park planning and protection efforts. And, continued documentation of the blast craters can inform any impacts of these features on the natural environment and associated species, as well as highlight their significance as a cultural feature.

Continued research on Agat Channel

There are two man-made channels in the reef at Agat Unit. Historical sources (Carberry 1944, Crist 1944, Logsdon 1944) dictate that the size of the channel blasted in the reef for the purpose of landing LSTs was 200 feet across and directly offshore of (Old) Hågat Village (Hågat Village was completely destroyed during the pre-landing bombardment and its location was moved further south for rebuilding, at the site of present-day Hågat). The southernmost channel depicted here (Figure 115) is almost exactly 200 feet across at its widest point. It is evident that the northern channel that aligns with the mouth of the Namo River is also man-made (and was made significantly more evident by processing and collecting of multibeam data during this project), but is significantly larger at 405 feet across than the channel described in reports from UDTs 3, 4, and 6, of their post-W-Day demolition activities. The southern channel is also filled with broken coral rubble and possibly-war related metal debris and UXO, whereas the northern channel has a smoother, sandy bottom. During fieldwork, there was only scheduled time to document one channel, and as there was no mention of the larger, northern channel in the historical documentation, the team chose to document the southern channel which best aligned with the historic description.

The team plans to continue further historical research to determine if the northern channel is also related to World War II demolition activities, or if the channel described in historic reports was larger in actuality.

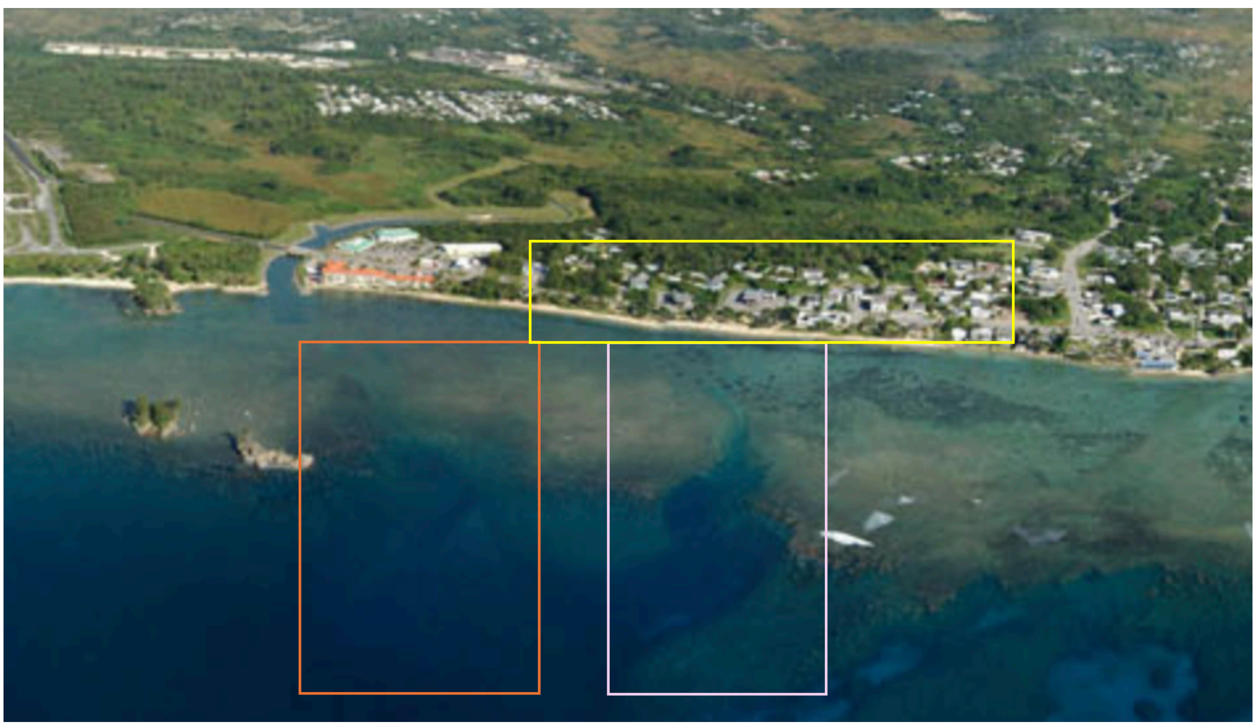


Figure 115. (Top) This image shows a geo-referenced orthomosaic of the documented channel. (Bottom) The red rectangle shows the location of the northern channel that is also man-made but was not documented during this project. The pink rectangle shows the location of the documented channel, and the yellow rectangle shows the location of old Hågat Village. Background image via Guam Aerial Imagery Project.

Signature of Principal Investigator: *Anne E. W. Nunn*

Date: 14 March 2025

Appendix A. References

References

Blaz, Vicente

2023 *CHamorus Forced into War Effort*. Guampedia <https://www.guampedia.com/chamorus-forced-into-war-effort/>. Accessed March 9, 2023.

Bibb, Leland

2001 Japanese Stencilwares of the Meiji and Taisho Eras. Asian American Comparative Collection Newsletter, Supplement Vol. 18, No. 1.

Brooks, Douglas

2014 Japanese Wooden Boatbuilding: History and Traditions. Education About Asia: Volume 19:2 Maritime Asia. <https://www.asianstudies.org/publications/eaa/archives/japanese-wooden-boatbuilding-history-and-traditions/>. Accessed 19 August 2023.

Brown, Craig J.

2012 *The Battle of Chelsea Creek, May 27-28, 1775 : Kocoa Military Terrain Analysis Applied to Heavily Urbanized and Coastal Marine Environments in Boston, Chelsea, and Revere, Massachusetts*. Master's thesis. University of Massachusetts at Boston.

Carano, Paul and Pedro C. Sanchez

1964 *A Complete History of Guam*. Charles E. Tuttle Company, Rutland, Vermont.

Carrell, Toni L. (editor)

1991 *Micronesia Submerged Cultural Resources Assessment*. National Park Service Submerged Cultural Resources Unit, Santa Fe, New Mexico.

Carrell, Toni L., Madeline J. Roth, and Jennifer F. McKinnon

2020 Submerged Battlefield Survey Manual. American Battlefield Protection Program, U.S. National Park Service, Washington, DC <https://www.researchgate.net/publication/343750458_SUBMERGED_BATTLEFIELD_SURVEY_MANUAL>. Accessed January 8, 2023.

Carberry, W. G.

1944 *Report of Underwater Demolition Team 4 – Its Activities During the Guam Operation and Recommendations for Future Demolition Operations*. Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Connolly, Richard L., Rear Admiral

1944 *Report of Amphibious Operations for the Capture of Guam.* Office of the Commander, Group Three, Amphibious Forces, United States Pacific Fleet. Record Group 127: United States Marine Corps Geofiles. National Archives at College Park, Maryland.

Crist, T.C.
1944 *Action Report Underwater Demolition Team #3 Forager Operation*. Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Dubbins, Andrew
2022 *Into Enemy Waters: A World War II Story of the Demolition Divers Who Became the Navy Seals.* Diversion Books, New York.

Department of the Navy
1945a *History of Underwater Demolition Team Four.* Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Department of the Navy
1945b *History of Underwater Demolition Team Six.* Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Department of the Navy
1945c *Naval Combat Demolition in the Central Pacific.* Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Department of the Navy
1945d *UDT-3 – War History*. Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Fisher, Charles E.
1944 *COM LCI(G) DIVISION 74 – Rep of pre-invasion activities off Guam Island, Marianas, 7/14 – 20/44.* Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Ford, Ben (editor)
2011 *The Archaeology of Maritime Landscapes.* Springer Books, New York, NY.

Geier, Clarence R., Douglas D. Scott, and Lawrence E. Babits (editors)
2014 *METT-T KOCOA, and the Principles of War: A Template Guiding a Better Understanding of Battlefield Behavior and Detritus, Appendix.* In *From These Honored Dead: Historical Archaeology of the American Civil War*, University Press of Florida, Gainesville <https://doi.org/10.5744/florida/9780813049441.005.0001>. Accessed October 13, 2024.

Lodge, O.R., Major
1954 *The Recapture of Guam*. U.S. Marine Corps Historical Branch, G-3 Division Headquarters, U.S. Marine Corps.

Logsdon, DeEarle M.
1944 *Marianas Operation – Report of Underwater Demolition Team No.6.* Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

McKenna, S. and E. Brown
2023 Pacific Island Network Benthic Marine and Marine Fish Monitoring Dataset 2006-2022. National Park Service. Fort Collins, CO. < https://doi.org/10.57830/2300415>. Accessed 3 September 2024.

McKinnon, Jennifer, Madeline Roth, and Toni L. Carrell
2020 Submerged Battlefield Survey Manual, Ships of Exploration and Discovery Research, Inc. <https://irma.nps.gov/DataStore/Reference/Profile/2278077>. Accessed 25 October 2022.

Minton, Dwayne, Allison Palmer, Jenny Drake, and Anna Pakenham
2006 Survey of the submerged ordnance at Camel Rock and War in the Pacific NHP, Guam. Natural Resources Division, War in the Pacific National Historical Park. Asan, Guam. <http://uxoinfo.com/uxofiles/enclosures/Asan_Beach_Survey.pdf>. Accessed 4 October 2022.

Mola, Roger
2014 These Portable Runways Helped Win the War in the Pacific. *Smithsonian Air & Space Magazine.* <https://www.smithsonianmag.com/air-space-magazine/these-portable-runways-helped-win-war-pacific-180951234/>. Accessed October 21 2023.

National Park Service
2024a *Assan/Asan Beach*. War in the Pacific National Historical Park <https://www.nps.gov/places/assan-beach.htm>. Accessed October 9, 2024.

National Park Service
2024b *Asan Beach Unit*. War in the Pacific National Historical Park <https://www.nps.gov/wapa/planyourvisit/asan-beach-unit.htm>. Accessed March 9, 2025.

National Park Service
2024c *Imperial Japanese Occupation of Guam (1941–1944).* War in the Pacific National Historical Park. <https://www.nps.gov/wapa/learn/historyculture/imperial-japanese-occupation.htm>. Accessed October 16, 2024.

National Park Service
2024d Piti Guns. War in the Pacific National Historical Park <https://www.nps.gov/places/piti-guns.htm>. Accessed October 9, 2024.

National Park Service
2024e Agat Beach Unit – Apaca and Ga'an Point. War in the Pacific National Historical Park. <https://www.nps.gov/wapa/planyourvisit/gaan-point.htm.> Accessed October 10, 2024.

Nelson, Peggy, Lisa Duwall, and Laila Tamimi
2003 *Asan and Agat Invasion Beaches: Cultural Landscape Inventory, War in the Pacific National Historical Park*. Cultural Landscapes Inventory Report No. 975116. National Park Service, Pacific West Regional Office. Electronic document, <https://irma.nps.gov/DataStore/Reference/Profile/2185575>, accessed August 3, 2023.

O'Brien, Cyril J.
1994 *Liberation: Marines in the Recapture of Guam*. History and Museums Division, Headquarters, U.S. Marine Corps.

O'Connell, K., D. Burdick, M. Vaccarino, C. Lock, G. Zimmerman, and Y. Bhagat
2024 Coral species inventory at War in the Pacific National Historical Park: Final report. Natural Resource Report. National Park Service. Fort Collins, CO. < https://doi.org/10.36967/2302040>. Accessed 3 September 2024.

Oral History Association
2023 *Best Practices*. Oral History Association <https://oralhistory.org/best-practices/>. Accessed June 17, 2023.

Palomo, Tony and Katherine Aguon
2023 *WWII: From Occupation to Liberation*. Guampedia <https://www.guampedia.com/wwii-from-occupation-to-liberation/>. Accessed March 9, 2023.

Reifsnider, L.F.
1944 Letter to Commander Amphibious Forces, Pacific Fleet from L.F. Reifsnider, Commander Amphibious Group Four, Pacific Fleet. Department of the Navy, Office of the Chief of Naval Operations, Intelligence Division, Office of Naval Records and Library. Record Group 38: Records of the Office of the Chief of Naval Operations. World War II Diaries, Other Operational Records and Histories. National Archives at College Park, Maryland.

Robinson, Michael C.

1992 Landing Mat Development at WES. In *Builders and Fighters: U.S. Army Engineers in World War II,* Barry Fowle, editor, pp 195-206. U.S. Army Corps of Engineers.

Ross, Douglas E.

2012 *Late-Nineteenth and Early-Twentieth-Century Japanese Domestic Wares from British Columbia.* In *Ceramics in America,* Chipstone Foundation. *<https://chipstone.org/article.php/515/Ceramics-in-America-2012/Late-Nineteenth--and-Early-Twentieth-Century-Japanese-Domestic-Wares-from-British-Columbia>.* Accessed 3 June 2024.

Santos Steffy, R., and M. Tomonari-Tuggle

2021 A Rapid Ethnographic Assessment Project for the Asan Beach Unit and Agat Unit Management Plan, War in the Pacific National Historical Park, Territory of Guam. International Archaeology, LLC. <https://irma.nps.gov/DataStore/Reference/Profile/2302732>. Accessed April 22, 2023.

Sweet, W.V., B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak

2022 Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD, 111 pp. <https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nostechrpt01-global-regional-SLR-scenarios-US.pdf>. Accessed 11 March 2025.

Smith, Richard K.

1989 Marston Mat. *Air & Space Forces Magazine. <https://www.airandspaceforces.com/article/0489marston/>.* Accessed October 21, 2023.

Spennemann, Dirk H. R.

2020 Using KOCOA Military Terrain Analysis for the Assessment of Twentieth Century Battlefield Landscapes. *Heritage* 3(3): 695–709. <https://www.mdpi.com/2571-9408/3/3/42>. Accessed October 11, 2024.

Stoner, Robert H.

2004 Naval Special Warfare: Small Combatant Craft Development – World War 2 Through Vietnam. Accessed via warboats.org. <https://www.warboats.org/stonermst.htm#:~:text=The%20boat%20was%20soon%20replaced,the%20bow%20of%20the%20boat.>. Accessed 23 February 2024.

Thompson, E. N.

1985 *War in the Pacific National Historical Park: Historic Resource Study*. National Park Service. Electronic document, <https://irma.nps.gov/DataStore/Reference/Profile/650943>, accessed August 4, 2023.

University of Idaho

2024 Katagami. Accessed via Historical Japanese Ceramic Comparative Collection Online. < <https://www.lib.uidaho.edu/digital/hjccc/glossary/katagami-paper-stencil.html#:~:text=Katagami%20(%E5%9E%8B%E7%B4%99),-Literally%20%22molding%20paper&text=Developed%20in%20the%20Edo%20era,(Ross%202009%3A156)>. Accessed 3 June 204.

Wright, Anne E., David L. Conlin, and Steven M. Shope
2020 *Assessing the Accuracy of Underwater Photogrammetry for Archaeology: A Comparison of Structure from Motion Photogrammetry and Real Time Kinematic Survey at the East Key Construction Wreck.* Journal of Marine Science and Engineering 8(11):849-869. <https://doi.org/10.3390/jmse8110849>.

Appendix B. Magnetic Anomaly and Side Scan Sonar Contact Investigation Results

1. Asan Magnetic Anomalies (GPS points and water depths have been redacted).

Anomaly Name	Bottom Type	Description	Investigator	Date Investigated
Asan_Mag_001	Coral Flats	Glass bottle base embedded in coral, fishing weight. (No magnetic target identified).	AN, BM, LC	8/3/2023
Asan_Mag_002	Coral Reef	No Find	MK, JH	8/6/2023
Asan_Mag_003	Coral Reef Slope/Sand Channel	No find	JN, JH, MK	7/31/2023
Asan_Mag_004	Coral Reef	No Find	Mk, JH	8/6/2023
Asan_Mag_005	Coral Reef	UXO Artillery Shells, See also Asan_SSS_04.2	JN, MK	8/6/2023
Asan_Mag_006	Coral Reef	No find	JN, MH	8/3/2023
Asan_Mag_007	Coral Reef Slope	Metal pole	AN, BS	7/31/2023
Asan_Mag_008	Coral Flats	No Find	MK, JH	8/6/2023
Asan_Mag_009	Coral Reef Slope/Sand Flats	No Find	AN, BM	8/2/2023
Asan_Mag_010	Coral Reef	Transect pin	JN, JH	8/5/2023
Asan_Mag_011	Coral Reef	Sounding/dive weight	BM, MH	7/31/2023
Asan_Mag_012	Coral Reef	Transect pin	JN, MK	7/31/2023
Asan_Mag_013	Coral Reef	No Find	MH, JD	8/9/2023
Asan_Mag_014	Coral Reef	Lead weight with bailing wire	MH, JD	8/9/2023
Asan_Mag_015	Coral Reef	Transect pin	JN, AN	8/2/2023
Asan_Mag_016	Coral Reef	No Find	MK, JN	8/5/2023
Asan_Mag_017	Coral Reef	No Find	AN, MA	8/8/2023
Asan_Mag_018	Coral Reef	Buried metal detector hit in coral head	MA, NS	8/9/2023
Asan_Mag_019	Coral Reef	No find	MA, NS	8/9/2023
Asan_Mag_020	Coral Reef	Dive weights with 4 6" metal pipes cut in half lengthwise	MA, NS	8/9/2023

Asan_Mag_021	Coral Reef	No Find	WP, AN	8/9/2023
Asan_Mag_022	Coral Reef	No Find	WP, AN	8/9/2023
Asan_Mag_023	Coral Reef	No Find	JN, MK	8/6/2023
Asan_Mag_024	Coral Reef	No Find	BS, MH	8/2/2023
Asan_Mag_025	Coral Reef	No Find	JH, MK	8/2/2023
Asan_Mag_026	Coral Reef	No Find	BM, WP	8/15/2023
Asan_Mag_027	Coral Reef	No Find	JD, AN	8/15/2023
Asan_Mag_028	Coral Reef	No Find	WP, MH	8/15/2023
Asan_Mag_029	Sand Flats	Two tires, one with metal rim.	JH, MK	7/31/2023
Asan_Mag_030	Sand Flats	No Find	JH, MK	7/30/2023
Asan_Mag_031	Coral Reef	No Find	AN, JD	8/15/2023
Asan_Mag_032	Coral Reef	No Find	MH, BM	8/15/2023
Asan_Mag_033	Reef Wall with Sand at Bottom	No Find	BM, MH	7/31/2023
Asan_Mag_034	Reef Wall with Sand at Bottom	No Find	JH, MK	7/31/2023
Asan_Mag_035	Coral Reef	No Find	MK, JN, JH	7/30/2023
Asan_Mag_036	Coral Reef	No Find	MK, JN	8/6/2023
Asan_Mag_037	Coral Reef	No Find	JN, JH	8/6/2023
Asan_Mag_038	Coral Reef	No Find	JH, MK	7/31/2023
Asan_Mag_039	Sand Flats	No Find	MH, JN	7/31/2023
Asan_Mag_040	Coral Reef Slope	No Find	JH, JN	8/9/2023
Asan_Mag_041	Coral Reef	No Find	BM, MH	7/31/2023
Asan_Mag_042	Coral Reef Slope	No Find	JH, JN	8/9/2023
Asan_Mag_043	Coral Flats	UXO dump: mortar shells in crevices, .50 caliber rounds, .20 caliber rounds, 3 large artillery shells	AN, BS	7/31/2023
Asan_Mag_044	Sand Flats with Coral Rubble	UXO dump on downslope: 15 Mortar/Artillery Shells visible, some metal detector hits buried in coral heads	BS, JN	8/1/2023
Asan_Mag_045	Coral Flats	One spent .20 cal casing. Very active area of the reef.	AN, BM, LC	8/3/2023

		Likely indicative of more in the area		
Asan_Mag_046	Coral Flats	1 Mortar Shell	JN, MK	8/9/2023
Asan_Mag_047	Coral Flats	1 Artillery shell, no brass	JN, MK	8/9/2023
Asan_Mag_048	Coral Flat	No Find	JN, MK	8/9/2023
Asan_Mag_049	Coral Flats	6-8 Artillery Shells	JN, MK	8/9/2023
Asan_Mag_050	Coral Flats	4 Mortar shells, 1 large Artillery shell	BM, AN	8/1/2023
Asan_Mag_051	Coral Flats	Transect pin, 1 Artillery shell	JH, MK	7/31/2023
Asan_Mag_052	Coral Flats	Transect pins, long piece of metal	JN, BM	8/1/2023
Asan_Mag_053	Coral Reef Slope/Sand Flats	4-5 8" artillery shells, 20 mm cannon, large number of buried metal detector hits	MH, BS	8/2/2023
Asan_Mag_054	Coral Flats	1 Large Artillery shell, 6" small arms ammunition, shell casings	JN, MH	8/3/2023
Asan_Mag_055	Coral Flats	.30 and .50 caliber rounds, numerous large artillery shells	JN, JH	8/6/2023
Asan_Mag_056	Coral Reef	Box of .50 caliber, 1 large mortar shell, loose .50 cal	AN, MH	8/1/2023
Asan_Mag_057	Coral Reef	No find	AN, BS	7/30/2023
Asan_Mag_058	Coral Reef Slope/Sand Channel	No find	AN, BS	7/30/2023
Asan_Mag_059	Coral Reef	UXO dump: 5 30-06 Springfield Rifle rounds (some spent), 15 20mm canon rounds, approximately 4 larger rounds (possibly 40mm canon rounds). Could have kept following debris field but stopped.	MH, JN	8/3/2023
Asan_Mag_060	Sand Flats	No Find	MK, JH, JN	8/2/2023
Asan_Mag_061	Coral Reef	No Find	JN, JH	8/6/2023
Asan_Mag_062	Coral Reef	Dive weights	JH, MK	8/3/2023

2. Asan Side Scan Sonar Targets (GPS points and water depths have been redacted).

Name	**Bottom Type**	**Description**	**Investigator**	**Date Investigated**
Asan_SSS_05	Coral Slope to Sand Flat	No Find - target appears to be large coral head	JH, MK	8/3/2023
Asan_SSS_04.2	Sand Flat	12 + shell casings, possibly 14 mm	JN, MH	8/3/2023
Asan_SSS_02	Coral Reef	No Find - target appears to be large coral head	JH, MK	8/3/2023

3. Agat Magnetic Anomalies (GPS points and water depths have been redacted).

FID	**Bottom Type**	**Description**	**Investigator**	**Date Investigated**
Agat_Mag_001	Coral Reef	Metal box with handle	MH, WP	8/5/2023
Agat_Mag_002	Coral Reef	No Find	AN, JD	8/5/2023
Agat_Mag_003	Coral Reef	No Find	AN, JD	8/5/2023
Agat_Mag_004	Coral Reef	No Find	MH, WP	8/5/2023
Agat_Mag_005	Coral Reef	Metal pole	MH, JD	8/6/2023
Agat_Mag_006	Coral Reef	No Find	MH, JD	8/6/2023
Agat_Mag_007	Coral Reef	No Find	MH, JD	8/6/2023
Agat_Mag_008	Coral Reef	No Find	AN, WP	8/6/2023
Agat_Mag_009	Coral Reef	No Find	AN, WP	8/6/2023
Agat_Mag_010	Coral Reef	No Find	AN, WP	8/6/2023
Agat_Mag_011	Coral Reef	Metal bar with ball on the end	MH, JD	8/6/2023
Agat_Mag_012	Coral Reef	No Find	AN, MH	8/5/2023
Agat_Mag_013	Coral Reef	No Find	AN, MH, JD, WP	8/5/2023
Agat_Mag_014	Coral Reef	No Find	MH, JD	8/6/2023
Agat_Mag_015	Coral Reef	No Find	WP, AN	8/6/2023
Agat_Mag_016	Coral Reef	No Find	WP, AN	8/6/2023
Agat_Mag_017	Coral Reef	No Find	AN, MH, JD, WP	8/5/2023
Agat_Mag_018	Coral Reef	No Find	BM, MA	8/21/2023
Agat_Mag_019	Coral Reef	Metal ladder	MH, NS	8/21/2023
Agat_Mag_020	Coral Reef	No Find	MH, NS	8/21/2023
Agat_Mag_021	Coral Reef	No Find	MH, NS	8/21/2023

Agat_Mag_022	Coral Reef	Cinderblock anchor with rebar	BM, MA	8/21/2023
Agat_Mag_023	Coral Reef	No Find	AN, MH	8/5/2023
Agat_Mag_024	Coral Reef	No Find	BM, MA	8/21/2023
Agat_Mag_025	Coral Reef	No Find	BM, MA	8/21/2023
Agat_Mag_026		NOT INVESTIGATED		
Agat_Mag_027		NOT INVESTIGATED		
Agat_Mag_028		NOT INVESTIGATED		
Agat_Mag_029		NOT INVESTIGATED		
Agat_Mag_030		NOT INVESTIGATED		
Agat_Mag_031		NOT INVESTIGATED		
Agat_Mag_032		NOT INVESTIGATED		
Agat_Mag_033		NOT INVESTIGATED		
Agat_Mag_034		NOT INVESTIGATED		
Agat_Mag_035		NOT INVESTIGATED		
Agat_Mag_036		NOT INVESTIGATED		
Agat_Mag_037		NOT INVESTIGATED		
Agat_Mag_038		NOT INVESTIGATED		
Agat_Mag_039		NOT INVESTIGATED		
Agat_Mag_040		NOT INVESTIGATED		
Agat_Mag_041		NOT INVESTIGATED		
Agat_Mag_042		NOT INVESTIGATED		
Agat_Mag_043		NOT INVESTIGATED		
Agat_Mag_044		NOT INVESTIGATED		
Agat_Mag_045		NOT INVESTIGATED		
Agat_Mag_046		NOT INVESTIGATED		
Agat_Mag_047		NOT INVESTIGATED		
Agat_Mag_048	Coral Reef/Sand Flats	No Find	JN, JH	8/7/2023
Agat_Mag_049		NOT INVESTIGATED		
Agat_Mag_050		NOT INVESTIGATED		
Agat_Mag_051		NOT INVESTIGATED		
Agat_Mag_052		NOT INVESTIGATED		
Agat_Mag_053		NOT INVESTIGATED		
Agat_Mag_054		NOT INVESTIGATED		
Agat_Mag_055		NOT INVESTIGATED		
Agat_Mag_056		NOT INVESTIGATED		
Agat_Mag_057		NOT INVESTIGATED		
Agat_Mag_058		NOT INVESTIGATED		
Agat_Mag_059		NOT INVESTIGATED		

Agat_Mag_060		NOT INVESTIGATED		
Agat_Mag_061		NOT INVESTIGATED		
Agat_Mag_062		NOT INVESTIGATED		
Agat_Mag_063		NOT INVESTIGATED		
Agat_Mag_064		NOT INVESTIGATED		
Agat_Mag_065		NOT INVESTIGATED		
Agat_Mag_066		NOT INVESTIGATED		
Agat_Mag_067		NOT INVESTIGATED		
Agat_Mag_068	Coral Reef	Crumpled flat sheets of metal, corrugated metal pieces	AN, WP	8/17/2023
Agat_Mag_069	Coral Reef	No Find	AN, WP	8/17/2023
Agat_Mag_070		NOT INVESTIGATED		
Agat_Mag_071		NOT INVESTIGATED		
Agat_Mag_072		NOT INVESTIGATED		
Agat_Mag_073		NOT INVESTIGATED		
Agat_Mag_074		NOT INVESTIGATED		
Agat_Mag_075	Coral Reef	No Find	BM, MA	8/17/2023
Agat_Mag_076	Sand Flats	Cylindrical metal tube	JN, JH	8/7/2023
Agat_Mag_077		NOT INVESTIGATED		
Agat_Mag_078	Sand Flats	No Find	JN, MK	8/7/2023
Agat_Mag_079	Sand Flats	No Find	JN, MK	8/7/2023
Agat_Mag_080	Sand Flats	No Find	AW, BS	8/7/2023
Agat_Mag_081	Sand Flats	Angle iron, partially buried	JN, MK	8/7/2023
Agat_Mag_082		NOT INVESTIGATED		
Agat_Mag_083	Sand Flats	No Find	MH, NS	8/21/2023
Agat_Mag_084	Sand Flats	Pipe	MH, NS	8/21/2023
Agat_Mag_085	Sand Flats	No Find	MA, MH	8/7/2023
Agat_Mag_086	Sand Flats	No Find	MA, MH	8/7/2023
Agat_Mag_087	Coral Reef	No Find	JD, WP	8/7/2023
Agat_Mag_088	Coral Reef/Sand Flats	No Find	JD, WP	8/7/2023
Agat_Mag_089	Coral Reef/Sand Flats	No Find	AN, NS	8/7/2023
Agat_Mag_090	Coral Reef/Sand Flats	No Find	AN, NS	8/7/2023
Agat_Mag_091		NOT INVESTIGATED		
Agat_Mag_092		NOT INVESTIGATED		

Agat_Mag_093		NOT INVESTIGATED		
Agat_Mag_094		NOT INVESTIGATED		
Agat_Mag_095		NOT INVESTIGATED		
Agat_Mag_096		NOT INVESTIGATED		
Agat_Mag_097		NOT INVESTIGATED		
Agat_Mag_098		NOT INVESTIGATED		
Agat_Mag_099		NOT INVESTIGATED		
Agat_Mag_100		NOT INVESTIGATED		
Agat_Mag_101		NOT INVESTIGATED		
Agat_Mag_102		NOT INVESTIGATED		
Agat_Mag_103	Sand Flats	Metal detector hit in coral head	JN, JH	8/7/2023
Agat_Mag_104	Coral Rubble	No Find	JH, MK	8/8/2023
Agat_Mag_105	Coral Reef	No Find	MH, AS	8/18/2023
Agat_Mag_106	Coral Reef	No Find	MH, AS	8/18/2023
Agat_Mag_107	Coral Reef	No Find	MH, BM	8/20/2023
Agat_Mag_108	Coral Reef	Hap's Reef Buoy	AN, MH	8/20/2023
Agat_Mag_109	Coral Reef	Series of transect pins	MH, AN	8/20/2023
Agat_Mag_110	Coral Reef/Sand Flats	No Find	AN, BM	8/20/2023
Agat_Mag_111	Sand Channel	No Find	MH, BM	8/20/2023
Agat_Mag_112		NOT INVESTIGATED		
Agat_Mag_113	Coral Reef	Concreted square shaped piece of metal	MA, BM	8/17/2023
Agat_Mag_114		NOT INVESTIGATED		
Agat_Mag_115		NOT INVESTIGATED		
Agat_Mag_116		NOT INVESTIGATED		
Agat_Mag_117		NOT INVESTIGATED		
Agat_Mag_118	Coral Sand Channel	No Find	BM, MA	8/17/2023
Agat_Mag_119	Coral Reef	No find	MH, MA	8/18/2023
Agat_Mag_120	Coral	No Find	AN, BM	8/18/2023
Agat_Mag_121		NOT INVESTIGATED		
Agat_Mag_122	Coral	No Find	MH, MA	8/18/2023
Agat_Mag_123	Coral	No Find	BM, NS	8/18/2023
Agat_Mag_124	Coral	No Find	BM, NS	8/18/2023
Agat_Mag_125	Coral	No Find	BM, NS	8/18/2023
Agat_Mag_126		NOT INVESTIGATED		
Agat_Mag_127		NOT INVESTIGATED		

Agat_Mag_128	Coral Reef	Marston mat pieces, 6 artillery shells	JN, JH	8/8/2023
Agat_Mag_129	Reef	No Find	MK, JN	8/8/2023
Agat_Mag_130		NOT INVESTIGATED		
Agat_Mag_131		NOT INVESTIGATED		
Agat_Mag_132		NOT INVESTIGATED		
Agat_Mag_133	Coral	Metal bowl	BM, MA	8/17/2023
Agat_Mag_134		NOT INVESTIGATED		
Agat_Mag_135		NOT INVESTIGATED		
Agat_Mag_136	Coral	No Find	AN, BM	8/18/2023
Agat_Mag_137	Coral Gulley	No Find	MH, JD	8/17/2023
Agat_Mag_138	Coral	Buried metal detector hit between coral heads	AN, WP	8/17/2023
Agat_Mag_139	Coral	Buried metal detector hit in coral head	AN, WP	8/17/2023
Agat_Mag_140	Coral	No Find	MH, NS	8/21/2023
Agat_Mag_141	Coral	No Find	MH, AS	8/18/2023
Agat_Mag_142	Coral	Rebar transect, 2 metal detector hits in coral rubble in a gouged area of reef	AN, BM	8/18/2023
Agat_Mag_143		NOT INVESTIGATED		
Agat_Mag_144		NOT INVESTIGATED		
Agat_Mag_145	Sand and Coral Reef	Agat Amtrac (known site)	BM, MA	8/17/2023
Agat_Mag_146	Low profile reef	Barrel piece and metal rods	MK, JN	8/8/2023
Agat_Mag_147	Patch Reef	No Find	MK, JN	8/8/2023
Agat_Mag_148	Coral Reef	6', 6" wide channelled steel piece, 2 large artillery shells	MH, JD	8/17/2023
Agat_Mag_149		NOT INVESTIGATED		
Agat_Mag_150	Coral	Large long broken cable/pipe. Divers followed pipe for 200+ feet with no indication that it was ending.	MK, JH	8/7/2023
Agat_Mag_151		NOT INVESTIGATED		
Agat_Mag_152		NOT INVESTIGATED		

Agat_Mag_153	Coral Reef	Pipe fragment, "Boat" 40' from drop line, 4' corrugated circle	MH, JD	8/17/2023
Agat_Mag_154		NOT INVESTIGATED		
Agat_Mag_155		NOT INVESTIGATED		
Agat_Mag_156		NOT INVESTIGATED		
Agat_Mag_157		NOT INVESTIGATED		
Agat_Mag_158		NOT INVESTIGATED		
Agat_Mag_159	Coral Reef	Barrels, UID metal, Amtrac door, trailer with tires, fuel tanks, abundance of crates, danforth style anchor, possible crate of UXO	BM, MA	8/18/2023
Agat_Mag_160	Coral			
Agat_Mag_161	Coral			
Agat_Mag_162	Coral Reef	30' piece of angle iron	MH, JD	8/17/2023
Agat_Mag_163	Coral	No Find	MK, JH	8/7/2023
Agat_Mag_164		NOT INVESTIGATED		
Agat_Mag_165	Coral Reef	Braided steel cable	AN, WP	8/17/2023
Agat_Mag_166		NOT INVESTIGATED		
Agat_Mag_167	Coral Flat	15' 4" pipe, 3' historic anchor with a bent arm	MH, JD	8/17/2023
Agat_Mag_168		NOT INVESTIGATED		
Agat_Mag_169		NOT INVESTIGATED		
Agat_Mag_170	Coral Flat	No Find	BM, NS	8/16/2023
Agat_Mag_171	Coral Flat	UID metal concreted to coral head	AN, WP	8/16/2023
Agat_Mag_172	Coral Flat	Capped pipe	AN, WP	8/16/2023
Agat_Mag_173	Coral Flat	No Find	BM, NS	8/16/2023
Agat_Mag_174		NOT INVESTIGATED		
Agat_Mag_175	Coral Flat	UID metal object	MH, JD	8/16/2023
Agat_Mag_176	Coral Flat	No Find	MH, JD	8/16/2023
Agat_Mag_177	Coral Flat	No Find	AN, WP	8/16/2023
Agat_Mag_178	Coral Flat	Concreted small artillery shell	AN, WP	8/16/2023
Agat_Mag_179	Coral Flat	No Find	BM, NS	8/16/2023
Agat_Mag_180	Reef	No Find	BM, NS	8/16/2023
Agat_Mag_181	Coral Flat	No Find	MH, JD	8/16/2023
Agat_Mag_182	Coral Flat	No Find	MH, JD	8/16/2023
Agat_Mag_183	Rocky Coral	No Find	AN, MA	8/18/2023

Agat_Mag_184	Low Reef	UID metal concreted to coral head	AN, MA	8/18/2023
Agat_Mag_185	Coral	No Find	AN, MA	8/18/2023

4. Agat Side Scan Sonar Contacts (GPS Points and water depths have been redacted).

Name	Description
Agat_SSS_01	NOT INVESTIGATED
Agat_SSS_01.1	NOT INVESTIGATED
Agat_SSS_02	NOT INVESTIGATED
Agat_SSS_03	NOT INVESTIGATED
Agat_SSS_04	NOT INVESTIGATED
Agat_SSS_04.1	NOT INVESTIGATED
Agat_SSS_05	NOT INVESTIGATED
Agat_SSS_06	NOT INVESTIGATED
Agat_SSS_09	NOT INVESTIGATED

Appendix C. Summary of post-Typhoon Mawar data collection

The following text summarizes data collected by project team members Monique LaFrance Bartley and Tahzay Jones during the May-June 2023 field campaign. The team's primary focus was multibeam data collection for this project. Though, when that was not possible (e.g. low tide, high surf conditions, no power available to charge equipment), post-typhoon Mawar data was collected for the park and other Federal agencies at their request. This was a unique opportunity for the team to support sister agencies and capture valuable ephemeral data that would have been lost otherwise.

NPS – WAPA and NOAA Ocean Exploration Project

- Multibeam sonar surveys using ASV:
    - Completed full coverage multibeam surveys for the entirety of Asan and Agat park units from the reef crest to just outside of the park boundaries.
    - Conducted reef flat multibeam surveys within Asan and Agat focused on the park unit adjacent reef flat areas immediately offshore of the terrestrial units.
- Mapping coastal features using GNSS equipment (Trimble R12 and TSC7):
    - Mapped the shoreward erosional beach faces, effectively the shoreward vegetation line. At Asan, data was collected from Asan Point to Asan River. At Agat, data was collected for the entire Ga'an Point unit. We also have these datasets from our field efforts in February.
    - Mapped the top and bottom of bank along the river at Asan. We also have this dataset from our field efforts in February.
    - Took photographs and short narrated videos to provide context to these datasets and describe our decision-making process.
- Documenting marine debris and coral damage via snorkel surveys
    - At Asan, conducted snorkel surveys and collected documentation photos offshore of the reef crest in 6 – 15 feet of water from the Asan Cut to Camel Rock.
    - At Agat, conducted snorkel surveys and collected documentation photos from Ga'an Point out to the reef crest, then along the outside of the reef crest from just outside the Hotel near the Namo River to the pipeline and back to shore.
- Documenting coastal post-typhoon change
    - Took hundreds of photographs and short videos to document coastal post-typhoon changes. At Asan, we documented from Asan Point to Asan River. At Agat, we documented both the Ga'an and Apaca units.
    - Took photographs of the two pill boxes along the Piti side of Asan accessible from the ridge trail.

USGS – Flood modeling refinement and validation

- Mapping coastal features using GNSS equipment (Trimble R12 and TSC7)
    - Mapped the inland extent of the wrack line for the primary portions of Asan and Agat Ga'an units to document the extent of inundation from the storm surge.
    - Mapped the inland vegetation line at Agat Ga'an unit to demonstrate how the presence of vegetation influenced the storm surge extent and pattern.

- Surveyed in the northern portion of Asan adjacent to the Governor's Mansion to reoccupy beach profile transects USGS collected in January. We also mapped the top and bottom of the erosional bank.
- Mapped the inland extent of the wrack line along the Alupang Beach Park portion of Marine Corps Drive (on the landward side of the road). This location was chosen because there was clear evidence of the storm surge crossing the road and being "stopped" by the cliff wall and other vertical structures (concrete walls, buildings).
- Took photographs and short narrated videos to provide context to these datasets and describe our decision-making process

FWS- Ritidian baseline data

- Mapping coastal features using GNSS equipment (Trimble R12 and TSC7):
  - Public side - mapped the vegetation line from start of public access all the way to the end of the refuge. We realized that the veg line was also largely representative of the storm surge inundation line, so there was no need to collect both datasets individually.
  - Closed side – began collecting the vegetation line, and then noticed the landscape transitioned to a bluff face, so we mapped the top of the bluff and bottom - so you have the height of that erosional face, which varies quite a lot. The bluff was also functionally the storm surge inundation line, so again, there was no need to collect a separate dataset.
  - Public and closed side - collected a handful of beach profiles across the entire refuge. These are transects that are perpendicular to the shore - they begin in the water (about calf-height) and extend across the beach to the veg line.
  - Took photographs to provide context to these datasets and describe our decision-making process

National Weather Service (NWS) – Post-typhoon reporting

- Provided NWS with the GNSS datasets outlined above to support their post-storm reporting. They were particularly interested in the data we collected at the eastern portion of Asan and along Marine Corps Drive, as well as Ritidian.

Appendix D. Budget justification submitted with project proposal

Section J: Budget Justification and Budget Table:

YEAR 1

Personnel

Personnel costs were not requested for this project. All participants are federal employees or volunteers.

Fringe Benefits

Fringe benefits were not requested for this project. All participants are federal employees or volunteers.

Travel

In Year 1, ten team members will travel to Guam for 14 days of fieldwork. A flight from Denver, CO near the Submerged Resources Center office to Guam was priced at $1800 per person via Concur (the NPS travel booking system). DoD lodging and per diem rates were used to calculate the price of lodging and per diem for the project team for 14 days (16 days for per diem due to additional travel days). Two eight-passenger vans were priced at $45 each per day via Expedia quote.

1 trip x 10 people @ $1800 airfare =	$18,000
16 days per diem x $96/day x 10 people =	$15,360
14 nights lodging x $159/night x 10 people =	$22,260
2 rental vans @ $45/day each for 14 days =	$1,260
Total	**$56,880**

Supplies

General project supplies are estimated to total $5,000 for the first year of the project. These supplies include such items as archaeological measuring tapes and slates, batteries, SD memory cards for underwater cameras, external hard-drives for data, etc. Similarly, it is estimated that consumables related to scuba diving will cost approximately $4,000 and includes such items as air, nitrox, and oxygen fills, sofnolime for closed-circuit rebreathers, and incidentals. In order to reach the planned maximum remote sensing depth of 200 feet, the project team must purchase a 100m magnetometer cable. This cable has been quoted by the manufacturer at $6000.

Miscellaneous supplies	$5,000
Diving consumables	$4,000
1 100-meter magnetometer cable @ $6000/cable	$6,000
Total	**$15,000**

Other

Subaward $40,375

Prior to the first year of fieldwork, the project team plans to contract an archival researcher to research, collect, and scan historical reports, maps, and documents at the National Archives relating to the 1944 Invasion of Guam. While it is known that these documents exist, most of them are not publicly available online and require a visit to the National Archives at College Park, Maryland to retrieve. It is more cost effective to hire an independent researcher to conduct this work than it is to send a project team member. The project team estimates that it will take an independent researcher approximately 40 hours of work to complete the task, and has been quoted at $50 an hour. The project team will rent two survey vessels for 14 days of field work, at a cost of $1000 per day per vessel, which includes the use of fuel and a professional captain. This project will host a Scientists-in-Parks (SIP) intern, the cost of which is provided directly from the SIP program. The SIP will assist the project team with research and outreach activities.

Subaward – Archival Research =	$2,000
Subaward - 2 Vessel Charters @ $1,000/day for 14 days	28,000
Subaward - SIP Intern =	10,375

Shipping $9,000

A large amount of remote sensing equipment will need to be shipped from Colorado to Guam (SeaArray (6 cases), Magnetometer (3 cases), Side Scan Sonar (3 cases), Multibeam (3 cases) dive gear (10 cases)). The National Park Service has a negotiated shipping rate with FedEx which will allow the project team to ship all equipment to Guam at a substantially reduced rate than is available to the general public. The project team created a quote with FedEx to estimate shipping costs.

25 Pelican cases shipped both ways @ $180/case =	$9,000
Total	**$49,375**
TOTAL YEAR 1	**$121,255**

YEAR 2

Personnel

Personnel costs were not requested for this project. All participants are federal employees or volunteers.

Fringe Benefits

Fringe benefits were not requested for this project. All participants are federal employees or volunteers.

Travel

In Year 2, 16 team members will travel to Guam for 18 days. A flight from Denver, CO near the Submerged Resources Center office to Guam was priced at $1800 per person via Concur (the NPS travel booking system). DoD lodging and per diem rates were used to calculate the price of lodging and per diem for the project team for 18 days (20 days for per diem due to additional travel days). Two eight-passenger vans were priced at $45 each per day via Expedia quote.

1 trip x 16 people @ $1800 airfare =	$28,800
20 days per diem x $96/day x 16 people =	$33,792
18 nights lodging x $159/night x 16 people =	$50,880
2 rental vans @ $45/day each for 18 days =	$1,620
Total	**$115,092**

Supplies

General project supply costs are reduced in Year 2, as many of the supplies from Year 1 will be reused. Supply items that will be purchased with Year 2 supply money include archaeological measuring tapes and slates, batteries, SD memory cards for underwater cameras, external hard drives for data, etc. Diving consumables costs will increase in Year 2, as Year 2 fieldwork will include significantly more diving than Year 1 and with more divers. Diving consumable costs include such items as air, nitrox, and oxygen fills, sofnolime for closed-circuit rebreathers, and incidentals.

Miscellaneous supplies	$3,000
Diving consumables	$8,000
Total	**$11,000**

Other

Subaward

The project team will rent two survey vessels for 20 days of field work, at a cost of $1000 per day per vessel, which includes the use of fuel and a professional captain. This project will host a Scientists-in-Parks (SIP) intern, the cost of which is provided directly from the SIP program. The SIP will assist the project team with research and outreach activities. A large amount of remote sensing equipment will need to be shipped from Colorado to Guam (SeaArray (6 cases), Magnetometer (3 cases), Side Scan Sonar (3 cases), Multibeam (3 cases) dive gear (10 cases)). The National Park Service has a negotiated shipping rate with FedEx which will allow the project team to ship all equipment to Guam at a substantially reduced rate than is available to the general public. The project team created a quote with FedEx to estimate shipping costs.

Subaward – 3 Vessel Charters @$1,000 day for 20 days =	$60,000
Subaward – SIP Intern =	$10,375
Total	**$70,375**

25 Pelican cases shipped both ways @ $180/case = $9,000

Total **$79,375**

TOTAL YEAR 2 **$205,467**

SUMMARY BUDGET TABLE

Category	Year 1	Year 2	Total Costs
Personnel	0	0	**0**
Fringe Benefits	0	0	**0**
Travel	56,880	115,092	**171,972**
Equipment	0	0	**0**
Supplies	15,000	11,000	**26,000**
Contractual	0	0	**0**
Other	49,375	79,375	**128,750**
Indirect Costs	0	0	**0**
TOTAL	121255	205467	**326,722**

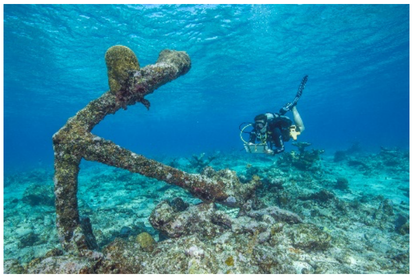
Appendix E. Lesson Plans

Investigation: What is Underwater Archaeology?

Overview

TOPIC: Underwater Archaeology

FOCUS: Students ask how underwater archaeologists study cultural heritage sites that are submerged in rivers, lakes, and the ocean. Using video, students analyze two different shipwrecks. Students will attempt to interpret various aspects of these shipwrecks. Students will participate in a hands-on experience to map and document their own site using the same methods as underwater archaeologists.



GRADE LEVEL: 6^{th} – 8^{th}

TIME NEEDED: Two 45 – 50 minute class periods (Part 1 and Part 2)

PHENOMENON (DRIVING QUESTION): How do underwater archaeologists' study cultural heritage sites that are submerged in rivers, lakes, and the ocean?

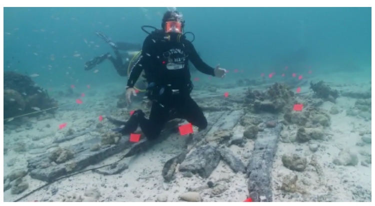
OBJECTIVES/ LEARNING OUTCOMES:

Students will:

- View introductory video highlighting various aspects of the scientific field.
- Interpret an 18^{th} century shipwreck and determine how it came to be at the bottom of the Atlantic Ocean off the coast of Florida. Assess the components of the ship they are looking at.
- Examine and discuss a WWII era submarine and its uses over the years.
- Conduct a site survey and use ratios and scales to create a detailed map of the section of the site each student pair surveyed.

Overview cont.

MATERIALS:



Part 1:

- Underwater Archaeology Fundamentals Handout
- Site Interpretation Class Discussion Slides 1 – 5
- Site Interpretation Class Discussion Worksheet

Part 2:

- Site Documentation Techniques Handout
- Site Documentation Worksheet
- Site Documentation Worksheet – Answer Key
- Site Documentation Exercise Educator's Guide Slides 1 – 19
- Site Documentation Data Sheet

Videos:

- A Needle In A Haystack: June - July 2019 (03:42) NOAA Ocean Exploration
    - Also, in Site Interpretation Class Discussion Slides
- HMS Fowey, Biscayne National Park (11:45) NPS Submerged Resources Center
    - Also, in Site Interpretation Class Discussion Slides
- The Wreck of *Humaitá* (ex-USS *Muskallunge*): June 26, 2021 (05:20) NOAA Ocean Exploration
    - Also, in Site Interpretation Class Discussion Slides
- Digital Preservation (01:53) NPS Submerged Resources Center
    - Also, in Site Documentation Techniques Handout

EQUIPMENT:

Part 1 & Part 2:

- Computer and projector for class viewing of videos.
- Whiteboard and dry erase marker or online platform to record class discussion points.

Part 2:

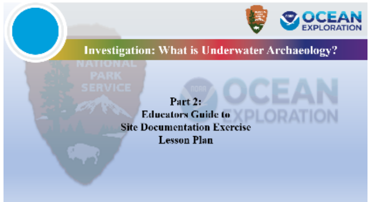
- Educator Materials
    - Blue Painters tape
    - 60+ household items
        - i.e., books, plates, cups, pots
    - 1 tape measure
- Student Materials
    - 16 tape measures
    - 16 rulers
    - 16 drawing compasses
    - Graph paper

SET-UP INSTRUCTIONS:

Part 1:

- Have students read Underwater Archaeology Fundamentals Handout as homework before the scheduled class.
- Cue up the Site Interpretation Class Discussion Slides

Overview cont.



Part 2:

- Have students read Site Documentation Techniques Handout as homework before the scheduled class.
- Before class, follow instructions in Site Documentation Exercise Educator's Guide Slides 1 – 19
- Make sure there is enough of the equipment for each pair of students to have a set.

Educator Guide

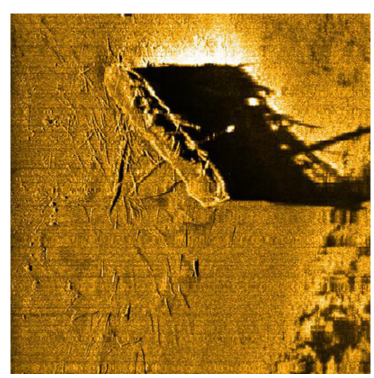
Background:

Underwater archaeologists are story tellers. It is their job to locate and interpret the material remains of submerged sites. Interpreting and telling the story of the individuals who created and lived at these sites comes with great responsibility.

Underwater archaeology was not a recognized field of scientific study until the 1960's. Jaques-Yves Cousteau and Emile Gagnan's invention in the 1940's of the Self-Contained Underwater Breathing Apparatus or SCUBA provided an efficient and low infrastructure means for archaeologists to safely dive on submerged sites. The first successful systematic underwater survey of a site was conducted in 1960 by photojournalist Peter Throckmorton and archaeology doctoral student George Bass at Cape Gelidonva, Turkey on a 13th century shipwreck.

The world's rivers, lakes and oceans have routinely been the most efficient means for societies to source food, and to transport people and goods. Whether caused by conflict, natural events or human error, invariably tragedies occur, and ships sink. However, shipwrecks are not the only type of submerged site that underwater archaeologists' study. Communities have emerged on the shores of these same rivers, lakes and oceans, and over time events such as rivers changing course, or sea level rise force communities to abandon their settlements. These abandoned settlements may be slowly covered by sand and silt. Due to the submerged environment and difficulty with access, these sites can be found mostly undisturbed, creating what is commonly referred to as the "time capsule" effect. Very often these material remains are the only physical remains of this specific time frame and community.

Underwater archaeology is a complex, multi-disciplinary field of scientific study. To locate a site, underwater archaeologists must understand the scientific principles behind the ways that sonar and magnetometry work. To access sites, they need to comprehend the physics that allow people to safely SCUBA dive. To interpret a site, they need to be highly adept at social sciences to comprehend human elements of the site. To document a site accurately, underwater archaeologists need to be able to utilize complex geometry and mapping skills and be able to navigate complex computer software that can render 3D models of the site.



Educator Guide cont.

PART 1: SITE INTERPRETATION CLASS DISCUSION

Distribute Site Interpretation Class Discussion Worksheet. You can elect to have the students answer the questions out loud or have them write the answers down. The point of this exercise is not for them to get the right answer, but to have them think like an archaeologist who has just discovered a site and must understand what they are seeing. The same questions are also listed below.

Start Site Interpretation Class Discussion Slides

Slide 2: Play "A Needle in the Haystack: June – July 2019"

After the video ask the following questions:

1) From material remains alone, what do you think you could learn about the people that lived on board a ship?
2) Treasure was mentioned in the video. Do you agree with the statement that "the treasure of knowledge and understanding is more important than that of intrinsic value", it's more important to learn about people and the past than it is to get rich? Why?

Slide 3: Image of HMS Alarm

This image gives students an idea of what the ship they are about to view looked like before it was wrecked.

Slide 4: Play "HMS Fowey" video on Mute.

At the time markers listed below pause the video and ask the students the following questions. These questions are also listed on the worksheet.

Pause at 02:30

3) What portion of the ship do you think is being shown here?

A) The Deck B) The Keel (Bottom)

C) The Side D) The Bow (Front)

Why?____

Pause at 03:16

4) What do you think he is showing that is hidden within the sandy looking concretions?

A) Cannon Balls B) Glass Bottles

C) Animal Bones D) All the above

Pause at 03:46

5) What was the square whole used for?

A) Window B) Point cannons out of.

C) Use oars to row the sailboat. D) To deploy the anchor.

Pause at 05:26

6) Why do you think the cannon ended up pointed under the ship like that when it sank?

Pause at 06:26

7) Why are the divers documenting the site? What do you think they will do with the information they gathered?

Educator Guide cont.

Pause at 07:57

8) Often times coral or other biological growth will grow on objects that are left in the sea for long periods of time. What parts and materials of this colonial era war ship do you think allowed this small coral reef to grow?

At the end of the video

9) Now that you have seen the whole video, how do you think this ship came to be at the bottom of the ocean?
10) What happened to the rest of the ship?

Replay the video with the sound on without pausing it.

Have the students discuss the following questions either in groups or as a whole class. The goal here is for the students to critically discuss what they saw and learned about this site and underwater archaeology in general.

11) Were any of the questions answered correctly without the sound during the first viewing?
    a. If so, how did they come to that answer?
12) Do you think the mound of coral created by the shot locker full of cannon balls should be excavated?
    a. Why?
    b. What could we learn from excavation?
    c. Is there another way to learn the same thing without destroying the coral?

Slide 5: Play "The Wreck of *Humaitá* (ex-USS *Muskallunge*): June 26, 2021"

As a class, the students discuss the following questions. Only question 13 has a correct answer, the others are just meant for discussion.

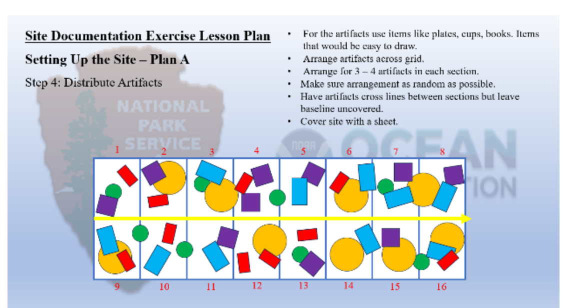
13) As you can see, ships can have many lives/purposes. How many lives/purposes do you think this ship had?
    a. Correct answer 3: US Navy Submarine, Brazilian Navy Submarine, and a coral reef.
14) What could we learn from each life this submarine had?
15) As you can see, the ecosystem and the remains of the shipwreck have become linked to each other. Is it more important to protect the ecosystem or study our past?
    a. In what situation could you see studying our past as more important than protecting nature?

At the end of class distribute the Site Documentation Techniques Handout and Site Documentation Worksheet so that the students can read and complete them before Part 2.

PART 2: SITE DOCUMENTATION TECHNIQUES EXCERCISE

The day before class use Site Documentation Exercise Educator's Guide Slides to prepare the "site".

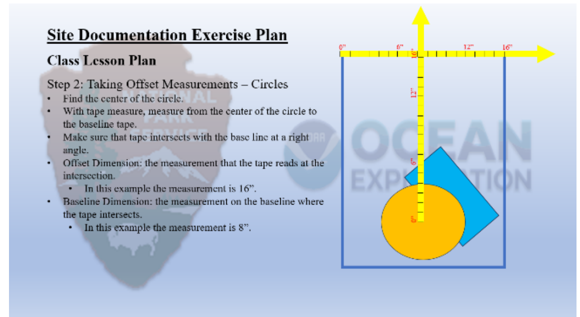
- Slides 2 – 3: Tell you about materials and which site plan to choose.
- Slides 4 – 7: Plan A set-up instructions.
- Slides 8 – 11: Plan B set-up instructions.
- Materials needed to set up site plan:
    - Blue Painters tape
    - 60+ household items
        - i.e., books, plates, cups, pots
    - Tape measure



Educator Guide cont.

The day of class use Site Documentation Exercise Educator's Guide Slides

- Slides 12 – 16: Explains how to take measurements from the site.
- Slide 17: Explains how to record the data.
- Slide 18: Explains how to use the data to make a map of the site.
- Slide 19: Putting it all together.
- Each buddy team will need:
    - Site Documentation Data Sheet
    - 1 tape measure
    - 1 ruler
    - 1 drawing compass
    - Graph paper



Investigation: What is Underwater Archaeology?

Underwater Archaeology Fundamentals Handout

What is underwater archaeology?

Underwater archaeology is the scientific study of the material remains, or artifacts, of past human activity that is submerged underwater. This includes but is not limited to submerged sites found in oceans, lakes and rivers. People are creators, they have always made items from materials like wood, stone and metals. Therefore, it is these artifacts that are left for archaeologists to study and learn about past societies.

Can we learn more from submerged sites than terrestrial sites?

Submerged material remains may be in better condition than artifacts found on land of the same age. This is important because it creates what is sometimes referred to as the "Time Capsule" effect. Submerged sites are harder to access and therefore are less likely to be impacted by humans, through such processes as ground disturbance and looting. These artifacts have a tendency to not be as degraded as their terrestrial cousins; therefore there can be more viable material for archaeologists to interpret. This is mostly due to the anoxic environment that some submerged artifacts are in. Anoxic refers to the lack of oxygen present in an environment. Whether metal or wood, oxygen reacts to these materials at a biological and chemical level that causes them to degrade. The dynamic nature of submerged environments can cover sites with sand and silt, even further limiting an artifact's exposure.

Figure 1:1960 Divers Prepare to Dive. Institute of Nautical Archaeology

How old is underwater archaeology as a scientific field?

It was not until the 1940's when Jaques-Yves Cousteau and Emile Gagnan developed the first, Self-Contained Underwater Breathing Apparatus (SCUBA) that people were provided with a reliable means to be underwater for extended periods of time. It was this invention that allowed submerged sites to be studied in earnest. In 1960 photojournalist Peter Throckmorton and archaeology doctoral student George Bass set out specifically to use the same scientific based field techniques that terrestrial archaeologists use and apply them to a submerged site. In Cape Gelidonya, Turkey, they were successfully able to excavate a late 13th century shipwreck using the same methodology as terrestrial archaeologists. This

Underwater Archaeology Fundamentals Handout cont.

proved to the scientific community that underwater archaeology was a viable field of study. Since then, underwater archaeology has been a distinct subset of the archaeology field.

What are underwater archaeologists looking for?

Shipwrecks are what most people picture when they think of underwater archaeology, but they are by no means the only types of sites that are studied. Paleo-landscapes, battlefields, airplanes, remains from the space industry, and shipping containers are all other possible sources of sites that underwater archaeologists study.

Figure 2: A National Park Service diver swims around the upside-down wings of a World War II era F4U Corsair lost at Midway Atoll. NPS photo by Dave Conlin.

Long before the world was paved over by asphalt roads and interstates, the sea was the most efficient means to transport goods around the world. To this day, the ocean still remains the primary mechanism that nations use to conduct trade with one another. Along with studying how ships were constructed, archaeologists can learn a lot about a civilization by studying the remains of the cargo that a ship carried. What did that country or group of people produce? What items did they value? What type of food did they eat? What kind of life did people live on board the ship? These are a small example of some of the questions that the remains of shipwrecks can answer.

Humans have always settled next to sources of water because of the inherent benefits water brings to life. Whether it be along rivers, lakes or ocean shores, communities have traditionally settled in these places. Over time though, the location of rivers banks move due to natural erosional and sedimentation processes, dams are built creating lakes where there previously were none, other lakes dry up, and arctic ice melts causing sea levels to rise. These events can cover up past human settlements with water and/or sediment. Finding and studying these sites can tell us so much about how people used to live.

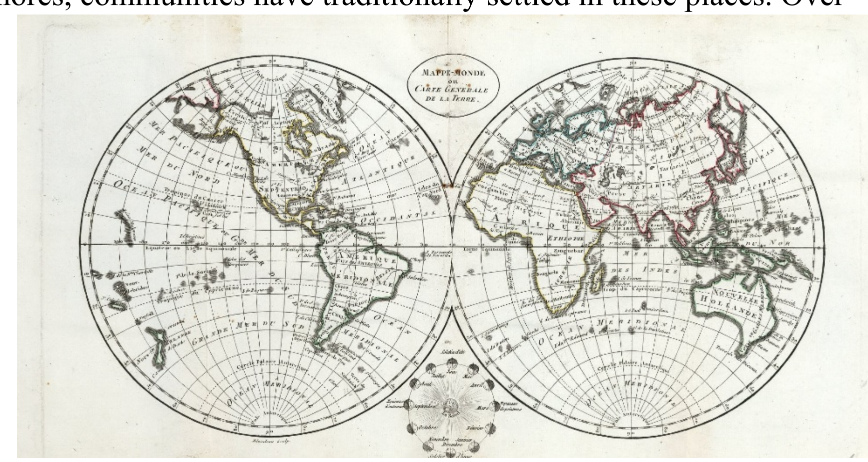


Figure 3: 1809 World Map by Blondeau. Courtesy of David Rumsey Map Collection.

There are known archaeological sites in the US with signs of human occupation that date back to over 15,000 years ago. These types of sites are referred to as Paleo-landscapes. By studying these sites, archaeologists can learn things like how areas were settled, how communities migrated, and how they gathered food.

Often in war, amphibious assaults (or the movement of a military force from water to land, just like an amphibian animal can move from water to land) are a way that one military army can invade another's territory. War invariably leaves its mark on the landscape one way or another. Archaeologists can learn more about what actually happened in these battles. They can study the long-term impacts the battle had on the local community and ecosystem. This can be seen through World War II bomb holes left in the coral of the Pacific Ocean,

Underwater Archaeology Fundamentals Handout cont.

destroyed military vehicles left where they broke down, or shot down aircraft. These are just a few examples of areas of study that archaeologists pursue in submerged battlefield archaeology.

Shipping containers and the remains from the space industry are two areas that might become bigger areas of interest to archaeologists in the future. As the space industry expands more and more, discarded rockets and satellites find themselves at the bottom of the sea. Shipping containers are a common means in which the modern world transports its goods. Inevitably, containers fall off ships. As time passes, these will be sealed time capsules for future archaeologists to study and learn about present day human habits.

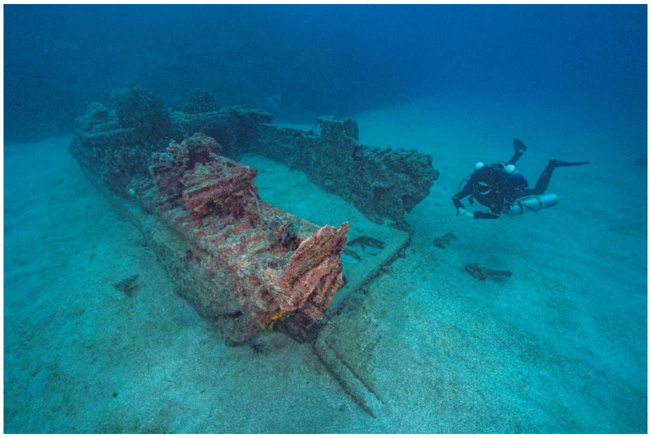


Figure 4: WWII Amtrac (amphibious tractor) located in Asan, Guam. NPS photo by Brett Seymour.

How are submerged sites found?

One of the tried-and-true methods of locating an archaeological site is through local knowledge. Often members of the local community know what is under the water in their area. In an underwater context, local people often know about sites because they use these spots to fish or dive and snorkel them for their own recreational purposes.

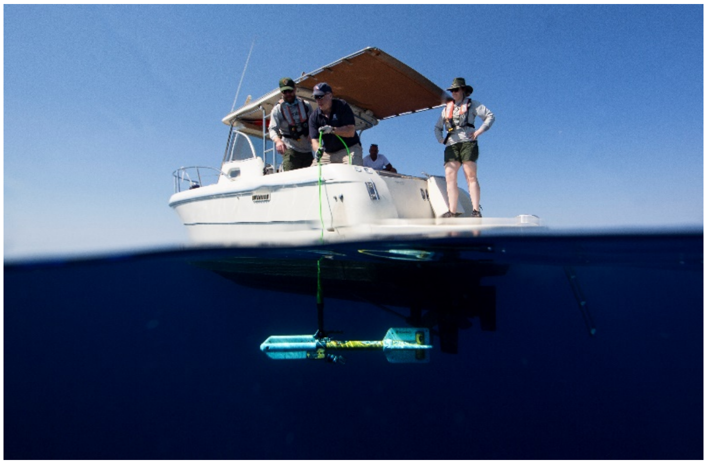


Figure 5: NPS Archaeologists deploying magnetometer sensor. NPS photo by Idee Montijo.

Side scan sonar is a form of remote sensing that archaeologists use to search for targets on the sea floor. A target is the term archaeologists use to refer to an area that deviates from the local ecosystem and therefore deserves to be examined further. Sonar is the process of emitting soundwaves and measuring the time it takes for the soundwaves to return once they have reflected off of a solid object. Items on the seafloor that are at different depths will give different returns and this data can be used to produce an image of the seafloor. For example, if there is a ship laying in a patch of sand, the different elements of the ship will be at different heights than the sand, so the soundwaves will reflect off these surfaces at different times. These differences are then measured by sonar software to create an image. To accurately survey an area using side scan sonar, archaeologists will deploy a sensor, or "fish", that emits these soundwaves off the back of a boat. Then the boat will tow the "fish" back and forth over an area in a pattern similar to mowing the lawn. The benefit of side scan sonar is that it does not matter what material an artifact or archaeological site is made from. If it is not buried under the ocean floor, there is a high likelihood that the side scan sonar will detect it.

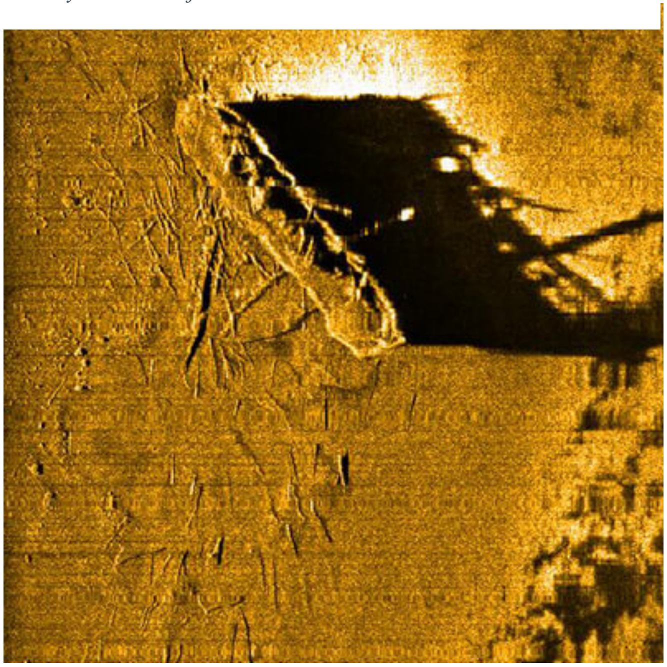


Figure 6: Image of side scan sonar target of Audubon in Thunder Bay National Marine Sanctuary.

Underwater Archaeology Fundamentals Handout cont.

Magnetometry is another form of remote sensing. It is deployed in a similar fashion to side scan sonar in that a sensor is deployed off the back of a boat and towed over a site. A magnetometer is used to detect magnetic anomalies and is essentially a large metal detector. Ferrous or iron-based materials, like steel, have magnetic properties that differ from the surrounding magnetic property of the earth. Unlike with sonar, an image that resembles the target is not produced. Magnetometer data produces a reading that details the size of the polarity of the object. The distance the sensor is from the item and the size of the item determine the size of the anomaly that the sensor reads. These sensors are capable of detecting items that are buried under the surface, but they can only detect ferrous-based items. If archaeologists are looking for a wooden sailboat, it will not detect the wooden hull, but it can detect its iron anchor.

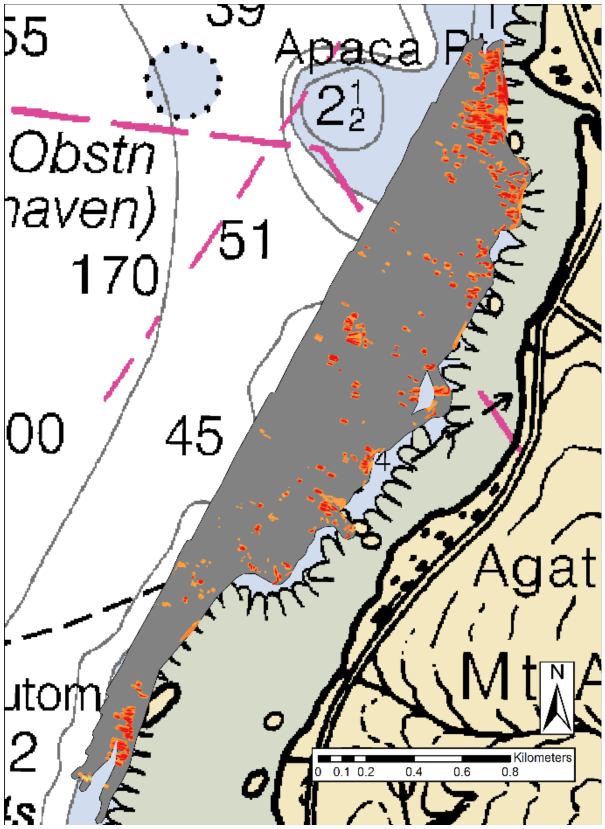


Figure 7: Image of magnetometry anomaly data gathered during survey of Agat Beach in War in the Pacific National Historical Park, Guam. Image provided by Submerged Resources Center, NPS.

How are submerged sites preserved?

Figure 7: 17th- century Swedish ship Vasa. Sunk in 1628 during its maiden voyage. Vasa was raised from the sea in 1961 and officially put on display in Stockholm in 1990. Photo courtesy of Brandon McCarthy.

Excavating a site and bringing its artifacts on land and conserving them to be studied or placed in a museum is one approach to underwater archaeological site preservation. The benefit of excavation and conservation is that it allows the general public to be able to view artifacts and allows a wider group of scientists to be able to study the artifacts. However, the conservation process of submerged artifacts is costly and time intensive. Once artifacts are exposed to air, they almost immediately begin to degrade. This happens for various reasons, but the commonality between all materials beginning to degrade is exposure to oxygen in the atmosphere. This invariably starts biological and chemical reactions with the artifacts' material that will cause them to degrade. To prevent this, artifacts need to be treated with chemicals. The treatment is different for each type of material. The process that preserves iron is not the same as the

Underwater Archaeology Fundamentals Handout cont.

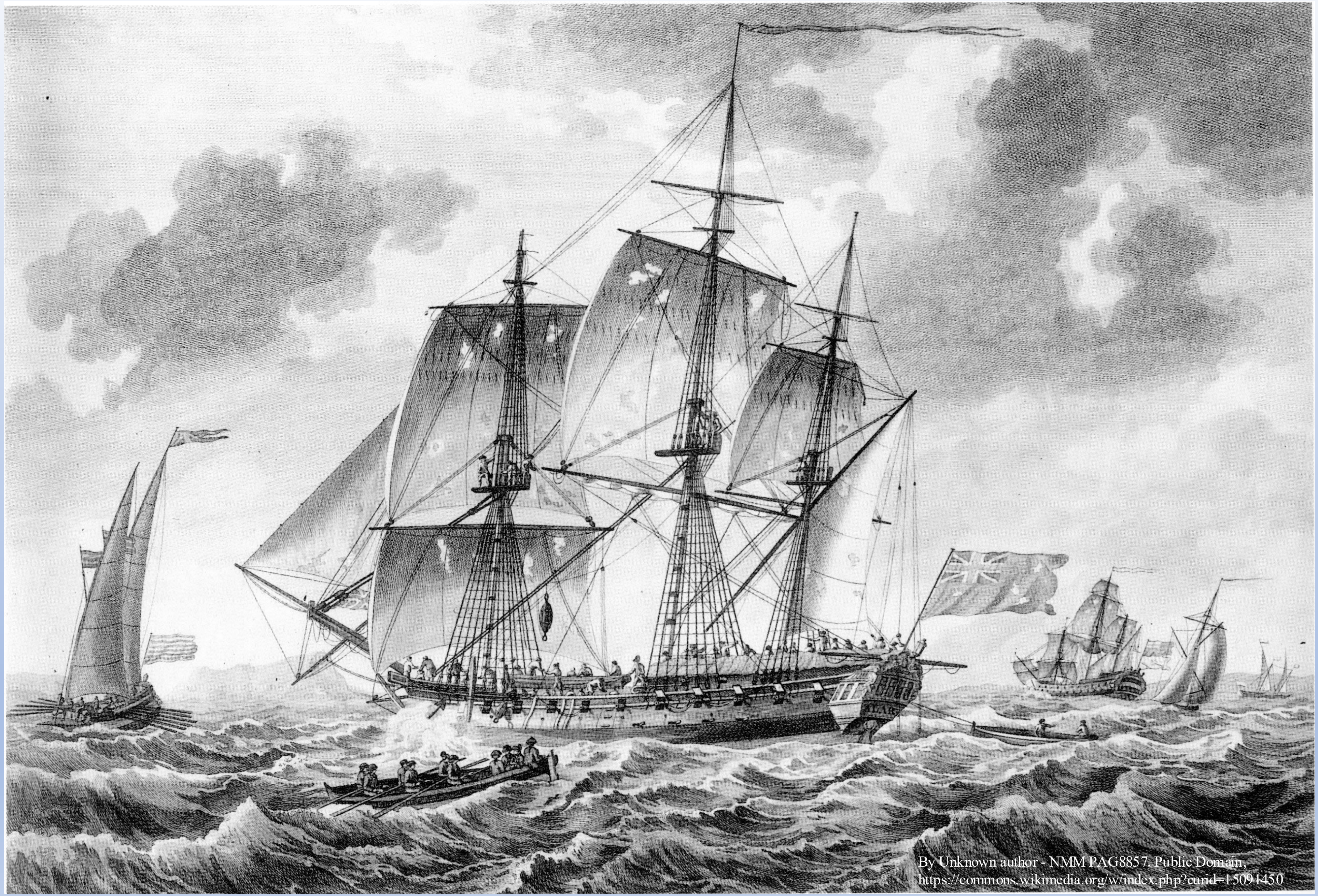
process to preserve a piece of wood. Conservation becomes complicated when an item is made of multiple materials, like a firearm that has metal and wooden parts. There are cases where large ships like *HMS Mary Rose* and *Vasa* were excavated and preserved in entirety, but it is more common to conserve only smaller artifacts or a selection of important or diagnostic artifacts.

The most common type of preservation is called *in situ* preservation. *In situ* is the Latin phrase for “in position,” and means that all pieces of an archaeological site are left in their original place. When a site is discovered, archaeologists may map and document the site in its entirety. Sometimes this entails excavating only parts of the site. Once all the data that is required from small-scale excavation is obtained, then any areas that have been excavated are reburied. Depending on the site and the area that it is in, archaeologists might decide to bury the whole site (including parts that were exposed when the site was found) to help protect it from events like major storms or from people looting the site. When feasible, archaeologists will make regular trips to these sites to redocument them and measure any changes to the site. Regular monitoring sometimes leads to new discoveries, because the dynamic force of the ocean can expose areas that had not been studied before. The downside to this process is that it makes the sites only accessible to those with the means and rights to access them. Advances in technology like photogrammetric 3D models and virtual reality are making it so that more people will be able to view archaeological sites in a manner that still allows the site to be preserved.

Figure 8: NPS archaeologist documenting in situ a WWII Japanese "Jake" seaplane located in Saipan. NPS photo by Brett Seymour.

Investigation: What is Underwater Archaeology?

Part 1:
Site Interpretation
Class Discussion
Videos



By Unknown author - NMM PAG8857, Public Domain,
https://commons.wikimedia.org/w/index.php?curid=15091450

- This is HMS Alarm, a contemporary of HMS Fowey.

- It is not the same ship, but it is of similar size and design of the one you are about to view before it wrecked in 1748 off the coast of Florida.

Investigation: What is Underwater Archaeology?

Site Interpretation Class Discussion Worksheet

Slide 2: A Needle In A Haystack: June - July 2019

After watching this video in a group or as a class, answer the following questions:

1) From material remains alone, what do you think you could learn about the people that lived on board a ship?
2) Treasure was mentioned in the video. Do you agree with the statement "the treasure of knowledge and understanding is more important than that of intrinsic value"? Why?

Slide 4: HMS Fowey Video

For questions 1 – 7 answer them like you are an archaeologist who is examining this site for the first time. Hypothesize about what you are seeing. What are these items? How did they get there? The goal is to use your imagination to think critically about how this ship wrecked and how its remains ended up where they are. Remember Slide 3 and the image of what this ship resembled when it was in service.

3) What portion of the ship do you think is being shown here?

   A) The Deck　　B) The Keel (Bottom)

   C) The Side　　D) The Bow (Front)

   Why?____

4) What do you think the diver is showing that is hidden within the sandy looking concretions?

   A) Cannon Balls　　B) Glass Bottles

   C) Animal Bones　　D) All the above

5) What was the square hole used for?

   A) Window　　B) Point cannons out of.

   C) Use oars to row the sailboat.　　D) To deploy the anchor.

6) Why do you think the cannon ended up pointed under the ship when it sank?

____

____

____

7) Why are the divers documenting the site? What do you think they will do with the information they gathered?

8) Often times coral or other biological growth will grow on objects that are left in the sea for long periods of time. What parts and materials of this colonial era war ship do you think allowed this small coral reef to grow?

9) Now that you have seen the whole video, how do you think this ship came to be at the bottom of the ocean?

10) What happened to the rest of the ship?

Discuss the following questions with your group or the whole class:

11) Were any of the questions answered correctly without the sound during the first viewing?
    a. If so, how did they come to that answer?
12) Do you think the mound of coral created by the shot locker full of cannon balls should be excavated?
    a. Why?
    b. What could we learn from excavation?
    c. Is there another way to learn the same thing without destroying the coral?

Slide 5: The Wreck of *Humaitá* (ex-USS *Muskallunge*): June 26, 2021

Discuss the following questions with the whole class:

13) As you can see, ships can have many lives/purposes. How many lives/purposes do you think this ship had?
14) What could we learn from each life this submarine had?
15) As you can see, the ecosystem and the remains of the shipwreck have become linked to each other. Is it more important to protect the ecosystem or study our past?
    a. In what situation could you see studying our past as more important than protecting nature?

Investigation: What is Underwater Archaeology?

Site Documentation Techniques Handout

Introduction

Site documentation is the process in which archaeologists create maps or models of archaeological sites. These maps and models are the primary methods that archaeologists use to document changes that a site will undergo. In ideal situations archaeological sites will be surveyed on a regular basis. The maps from these site documentation surveys are then compared to previous maps. These comparisons show archaeologists how the site has changed over those time intervals from daily events like tidal changes or visitors, to unusual events like hurricanes. This can help archaeologists determine if any preservation methods should be utilized on the site. There are many methods in which underwater archaeologists document sites and various factors an archaeologist considers when choosing the correct method. These factors include but are not limited to the terrain of the site, the composition of the submerged site, and the materials available to the archaeologist. Two traditional methods that are used are baseline offsets and trilateration. These are analog methods in which archaeologists use tape measures to measure the site to create a hand drawn map. Photogrammetry is a digital method of site documentation and is a more recent evolution in site documentation methodology. This method uses digital cameras and computer software to render 3D models of the submerged site. Accurate measurements of the site can be taken using computer software that measures the 3D model.

Baseline Offset

Gathering the Data at the Site

The "baseline offset" method is a basic but accurate method of gathering measurements of a submerged site. This method works well with smaller, flat sites that do not have a lot of terrain relief, meaning that they do not come very high off the seafloor or have large coral structures. To accomplish this, the minimum requirements are two divers, two long tape measures, a slate (an archaeologist's term for an underwater clipboard), and some pencils. To collect "baseline offset" measurements, a tape measure must be laid either next to the site or down the center of it. This tape measure is known as the baseline. Using another tape measure, divers lay a tape measure from the baseline out to the point that is being referenced (for example, an artifact). This is the offset measurement. In order to make this an accurate measurement, the offset tape must be run at a right angle from the baseline tape. One diver will hold the "0" end of the offset tape on the baseline while the other diver runs the tape out to the desired point. Two measurements are recorded for each point being referenced: one where the offset tape intersects the baseline tape and one for the length that the offset tape is run out to the point being referenced. It is integral for the accuracy of this method that the baseline never moves. It should be fixed in place and if necessary, left in place for as long as it takes to complete the mapping project. The more measurements you take of the site, the more accurate your resulting map will be. However, one of this method's shortcomings is that the longer the offset tape needs to be, the less likely that it can be accurately maintained perpendicular to the baseline. Maintaining the right angle is critical for the accuracy of the measurements. This is why large sites with lots of relief are not ideal for this method.

Site Documentation Techniques Handout Cont.

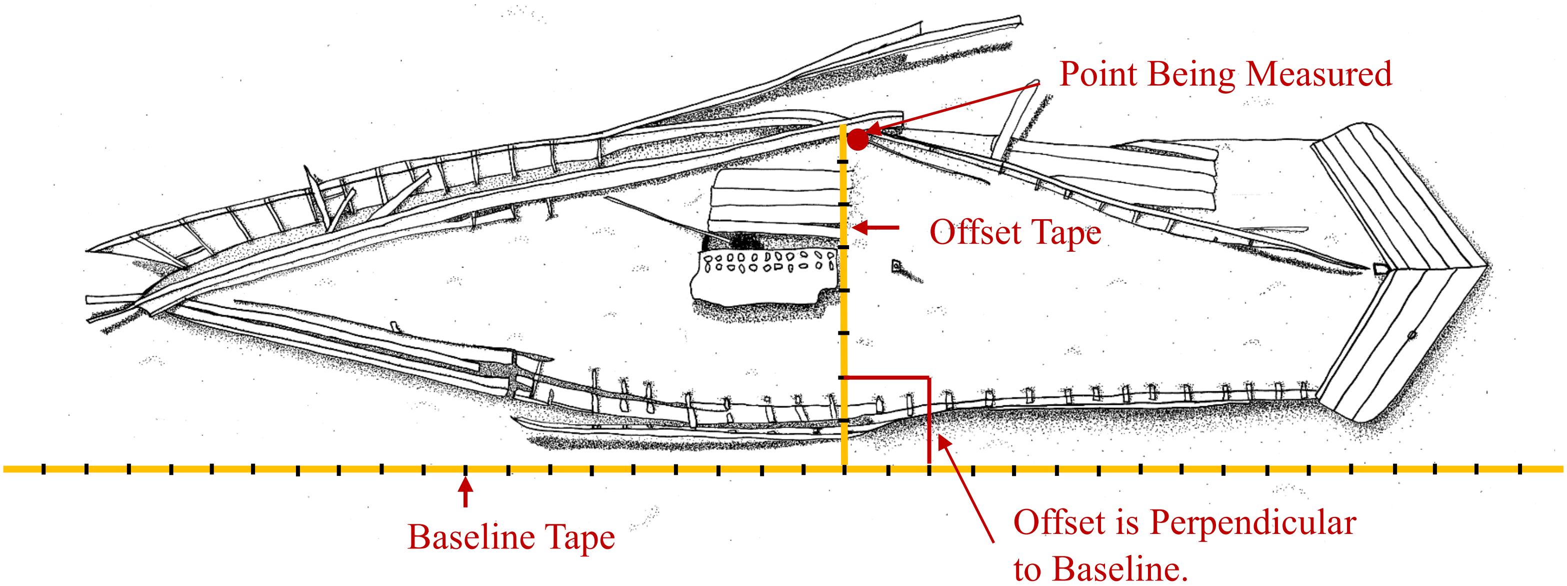


Figure 1: Baseline Offset Diagram

Creating a Map with the Data

To make a map using the "baseline offset" method is relatively straightforward. All one needs is paper, and at least 2 rulers long enough to cover the desired overall length of the map. A drafting triangle can also be a useful tool. The first step is to determine the best scale to use to fit all the details of the submerged site as best as possible on the sheet of paper. Then, all the recorded data measurements need to be converted using that scale. Once all the data is converted to the proper scale, the baseline can be drawn onto the map. On the baseline, note the 0 end and the final length. It can also be useful to mark off regular measurements across the baseline. For example, if the overall site was 100' long it might be useful to mark every 10' on the baseline. When the baseline is established, points can be added to the map. To do this, a ruler is placed on the desired point perpendicular to the baseline, and a mark is placed on paper where the corresponding measurement is along the ruler. The drafting triangle is useful here to ensure the ruler is perpendicular to the baseline and kept at a right angle. Repeat this process for all the reference points. Once all measurements are marked, the points can be connected with lines to create an outline of the submerged site or artifact.

Site Documentation Techniques Handout Cont.

Trilateration

Gathering the Data at the Site

Trilateration uses a similar methodology to "baseline offset" but is more complex and more accurate. To measure a site using trilateration, a minimum of 2 divers are required, along with at least 2 long tape measures, a slate, and pencils. Trilateration has the same limitations as baseline offset when it comes to sites with a significant amount of relief on them. The baseline is set on the site in the same manner as baseline offset. Once the line is secured, determine a set interval of measurements to use as the starting point on the baseline. For example, if the site is 150' long then intervals of either 10' or 15' could be used. It is ideal to label these markers to make the recording of data easier. To measure a point on the site, one diver holds the "0" end of the tape at the interval on the baseline. The other diver runs the tape out to the point and records that measurement. Then the diver on the baseline moves to the next closest marker on the baseline and the other diver adjusts the tape measure accordingly and records that measurement. For every measurement taken, it is imperative that the marker on the baseline and the length of the tape to the point are both recorded. Unlike with baseline offset, for every reference point, two measurements are taken. The more measurements that can be taken to reference a point, the more accurate it is.

- Step 1 – Taking 1st Trilat Measurement

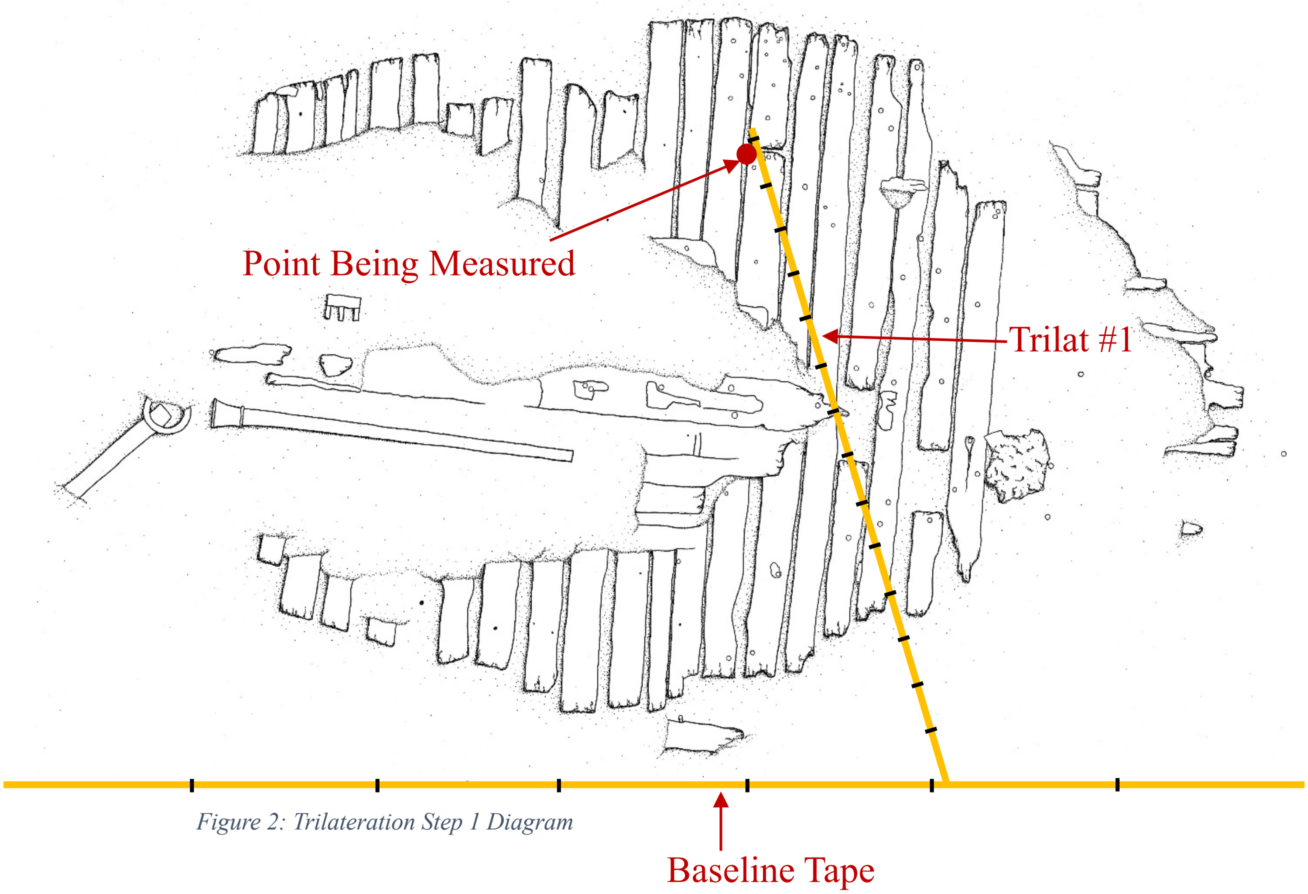


Figure 2: Trilateration Step 1 Diagram

Site Documentation Techniques Handout Cont.

- Step 2 – Taking 2nd Trilat Measurement

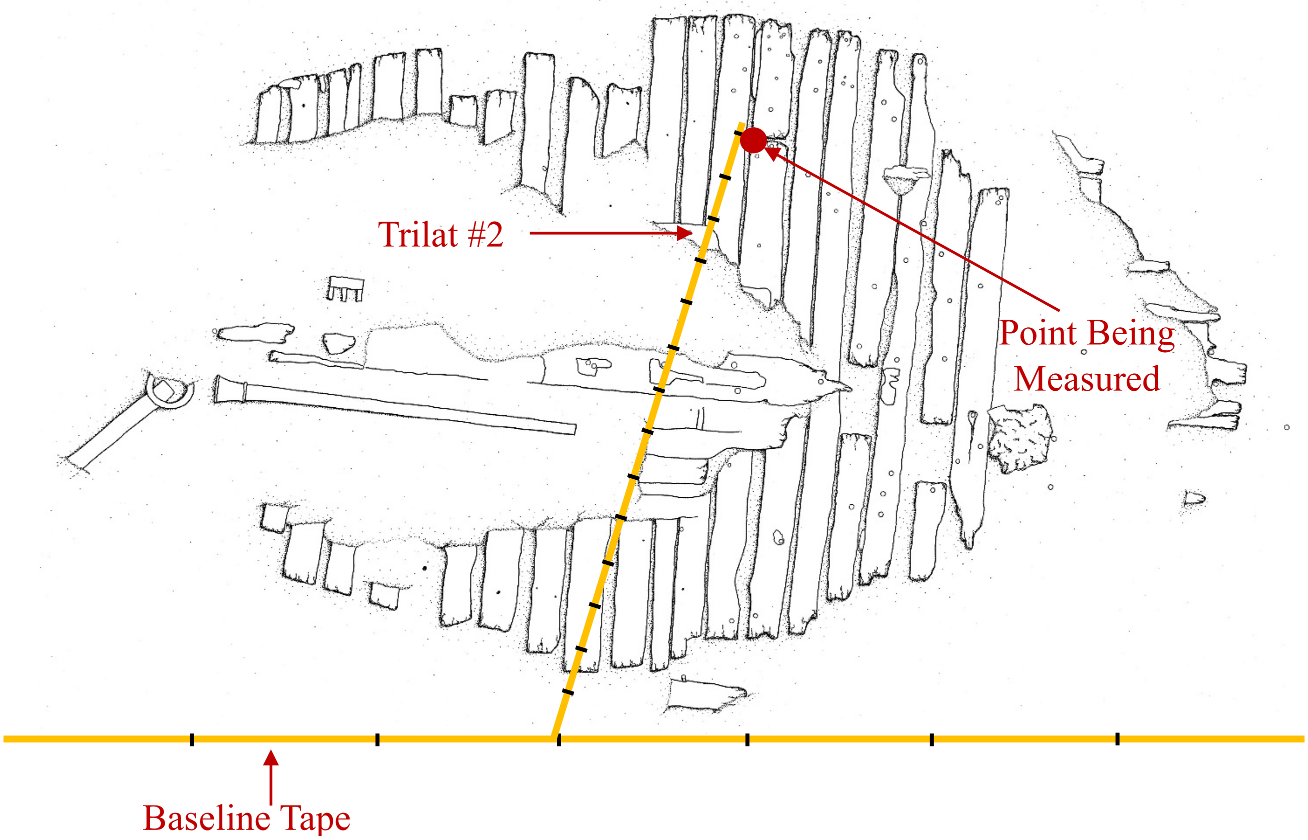


Figure 3: Trilateration Step 2 Diagram

Creating a Map with the Data

To create a map using the data gathered by trilateration, the drawer will need paper, a long ruler, and a drawing compass. Once an appropriate scale is determined and all the data is converted to that scale using the same method as described for "baseline offset", draw the baseline. On the baseline, all the markers should be denoted. The drawing compass is the main tool used to transfer the points on to the map. Set the compass to the appropriate scaled down length of the measurement from the first marker. A drawing compass has a metal point on one end and pencil point on the other. Place the metal point of the compass on the corresponding marker spot on the baseline and swing an arc with the pencil end in the general area the point should be in. Then adjust the compass to the length of the second marker measurement. Place the metal point of the compass on the second marker and swing the pencil end of the compass out making an arc that intersects with the first arc. This intersection is the reference desired point. This process is repeated for all the reference points and then connects these points to create the map.

Site Documentation Techniques Handout Cont.

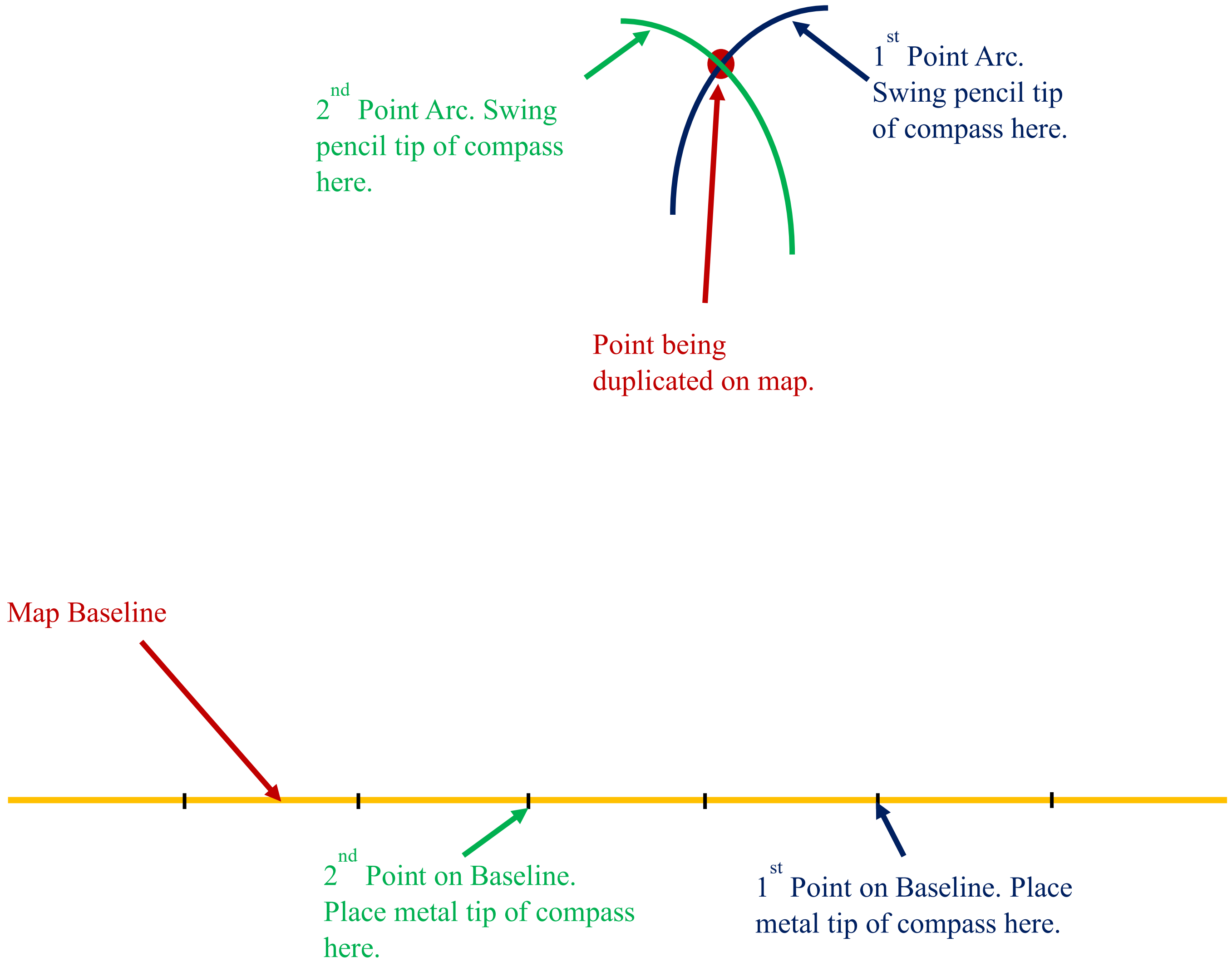


Figure 4: How to use a drawing compass to create a point on a site map.

Site Documentation Techniques Handout Cont.

Scaling/Ratios

When it comes to mapping a site, understanding the use of ratios to scale down or in some cases scale up dimensions is a valuable skill. Ratio refers to the mathematical formula used, and scale refers to the relationship between the measurements taken at the site and the measurements used in the drawing. When documenting a site, archaeologists scale the measurements down to fit on the desired size of paper. If a small artifact is documented, then one can scale it up so that every little detail can be captured in the drawing.

Ratios

- The ratio of 4:1 translates into every 4 units of measurement becomes 1 unit of measurement. I.e., if you measure 4' on the site then that translates to 1' on the drawing.
- 5:1
  - 25'/(5/1) = 5'
- 10:2
  - 100'/(10/2) = 20'
- 1:6
  - 20"/(1/6) = 120"
- An artifact that you are surveying has the longest dimension 30", the largest you can make it in the drawing is 10", what ratio would you want to use?
  - 30/10 = 3 = 3:1 = 30/(3/1) = 10

Scales

The scale of a map can be represented as a ratio if the same unit of measurement is being used from both the site and the map. Scales though are not limited to that. There are times where the site being measured is much larger than the paper it is being drawn on to, in these cases it might be needed to scale from feet to inches, or meter to centimeters.

- ¼" =1' for every 1' of measurement on the site represents ¼" on the map
  - ¼" = 1'; What would 16' convert to using this scale?
    - $\frac{1/4''}{x} = \frac{1}{16'}$
    - $\frac{1}{4}(16) = x$
    - $4'' = x$
- 1" =1'; 10" =10'
  - This is a 1:1 ratio where all that is changed is the unit of measurement.
- The shipwreck that your mapping is 150' long, but you must scale the drawing so that it is only 10" long. What scale do you use?
  - $\frac{150}{10} = \frac{1}{x}$
  - $15 = x$
  - $15' = 1''$

Site Documentation Techniques Handout Cont.

Examples of Site Maps

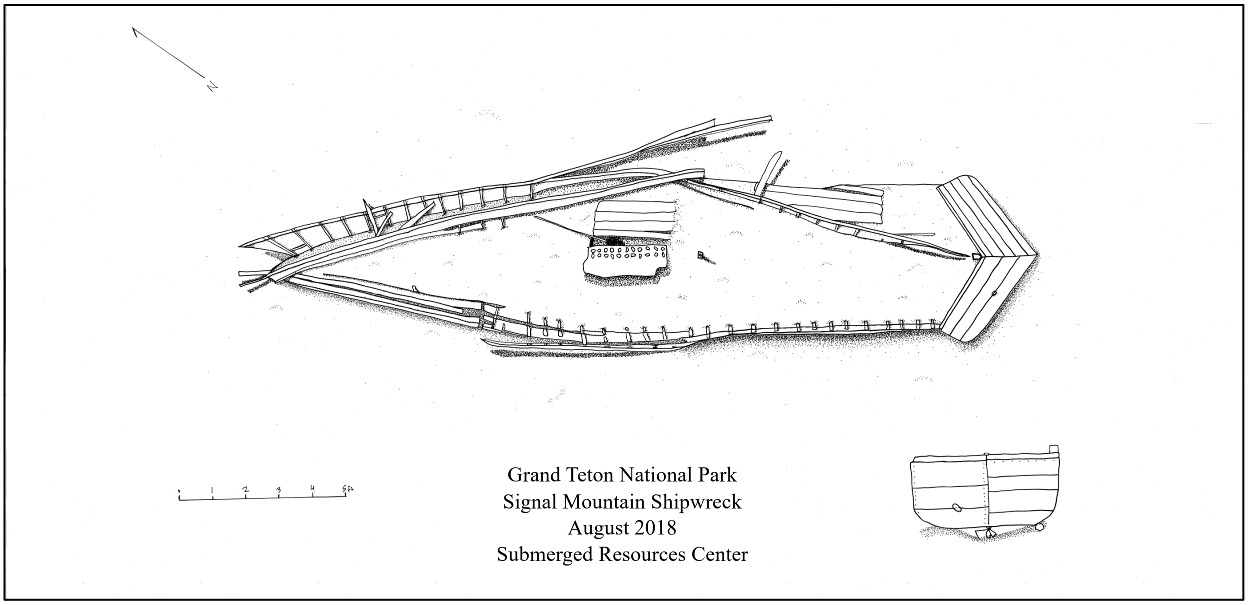


Figure 5: Hand Drawn Map of Signal Mountain Shipwreck

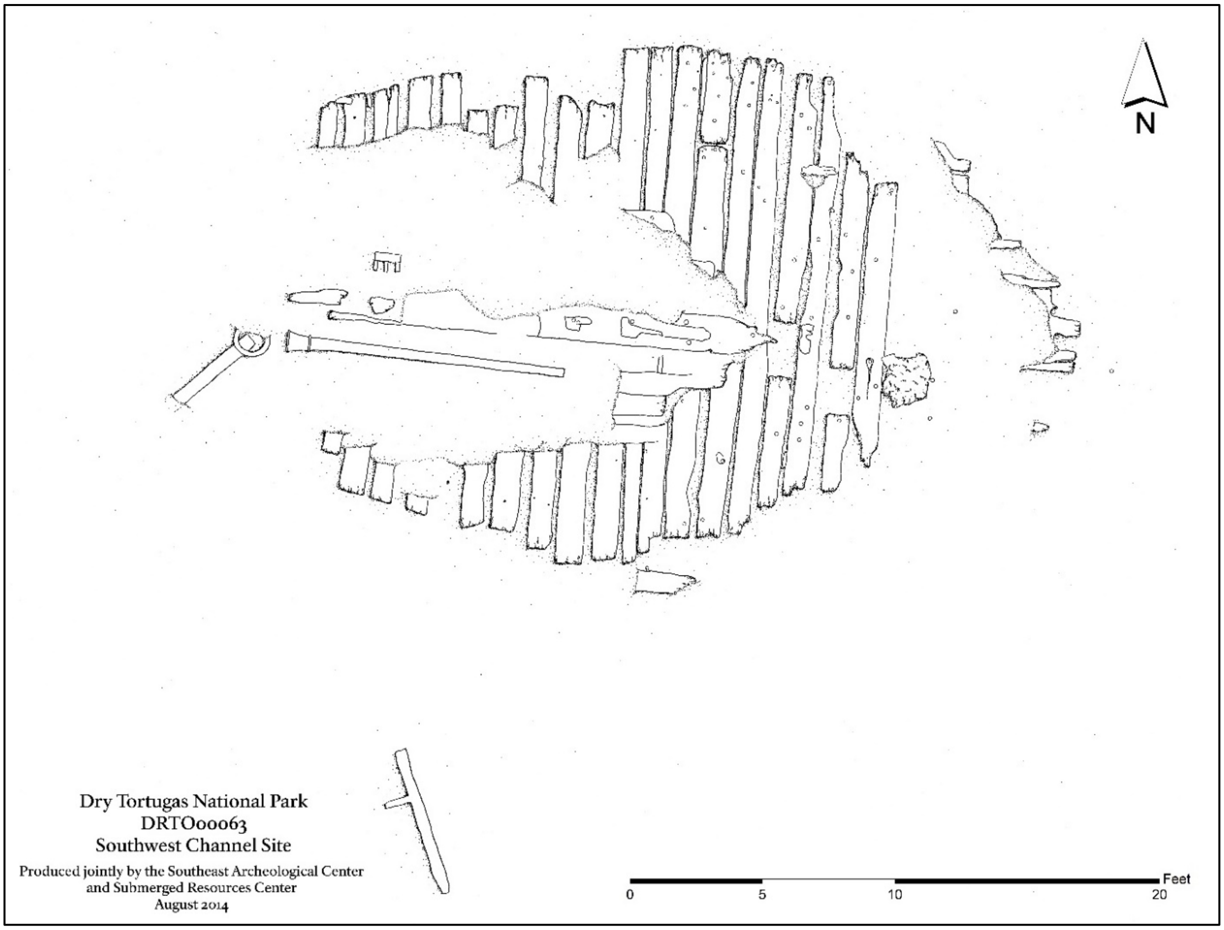


Figure 6: Hand Drawn Map of Southwest Channel Site

Site Documentation Techniques Handout Cont.

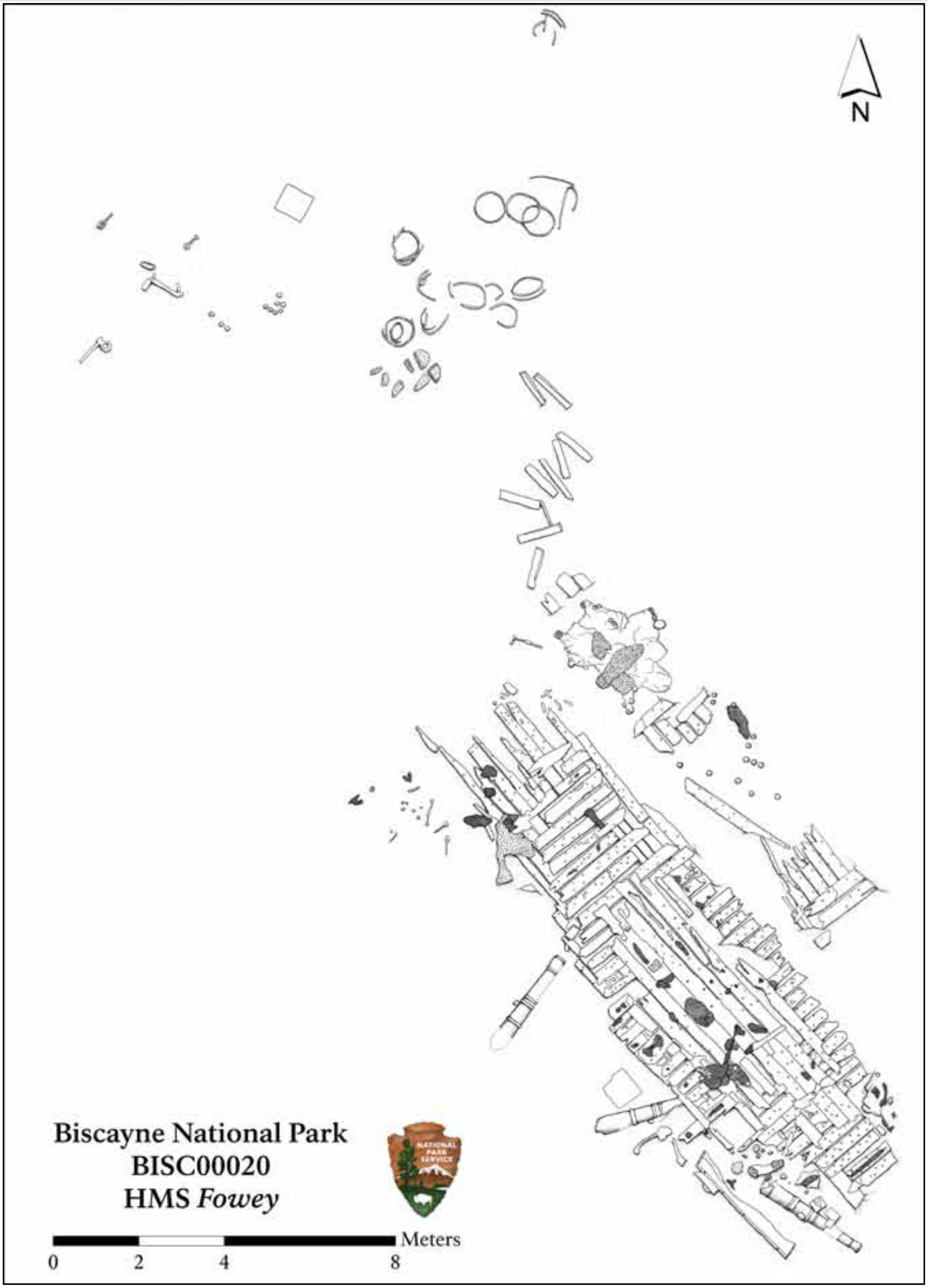


Figure 7: Hand Drawn Map of HMS Fowey Site

Site Documentation Techniques Handout Cont.

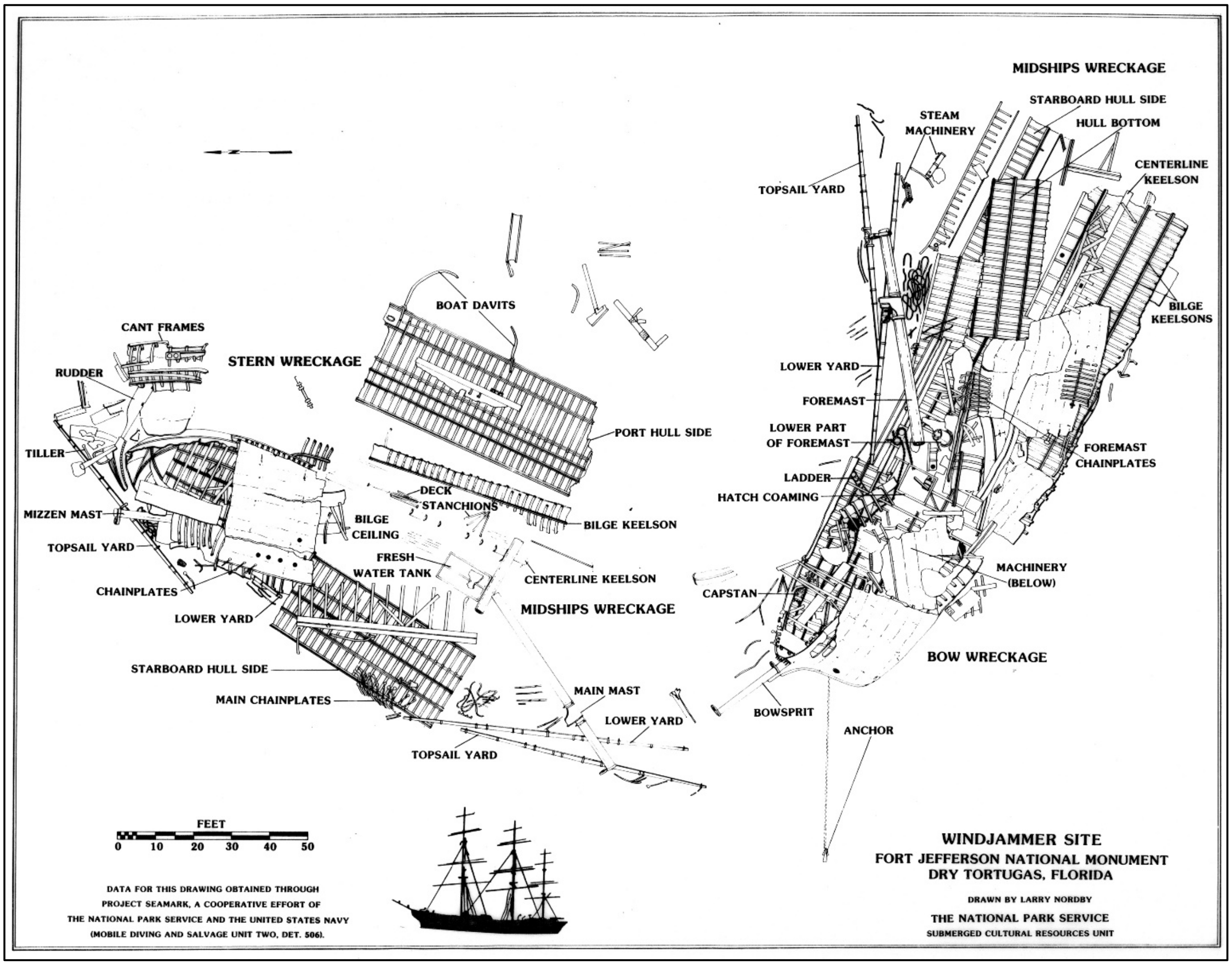


Figure 8: Hand Drawn Map of Windjammer Site

Site Documentation Techniques Handout Cont.

Photogrammetry

Gathering the Data at the Site

Photogrammetry is the most accurate and versatile site mapping technique but requires the most expensive equipment. At a minimum, a digital camera in a waterproof housing is required. Photogrammetry can be used on all types of sites and the presence of terrain relief does not become the limitation as it does with other methods. If the site is small, a diver can use one camera but if the site is large, then multiple cameras can be linked to each other and attached to a diver propulsion vehicle (DPV). The process requires a diver to take repetitive pictures over the site. Ideally, each successive picture should overlap the previous picture by 80%. This process follows a similar pattern to that of mowing the lawn. A diver swims a straight line over the site while taking photos and then turns around and repeats the process taking photos adjacent to the lane of photos they just took. These photos should also overlap the previous lane by 80%. When documenting larger sites with multiple cameras on a DPV, the cameras are linked to a computer-generated trigger that is set so that each camera takes a picture at the same time. For sites that are not flat and have lots of relief, this process will need to be repeated with the cameras facing to the side to capture the full relief of the site. Depending on the size of the site, this process can take tens of thousands of photos or more.


NPS Photo by Brett Seymour

Figure 9: Diver Using DPV mounted 3 camera system called the Sea Array

Creating an Image with the Data

These photos are downloaded on a computer and with the use of specialized software are stitched together to create one large 3D image. The end result is an image that the viewer can zoom in and out of and manipulate in 3D. Specialized software also allows for accurate measurements of the site to be taken.

- Watch Digital Preservation Video

Site Documentation Techniques Handout Cont.

Examples of Photogrammetry

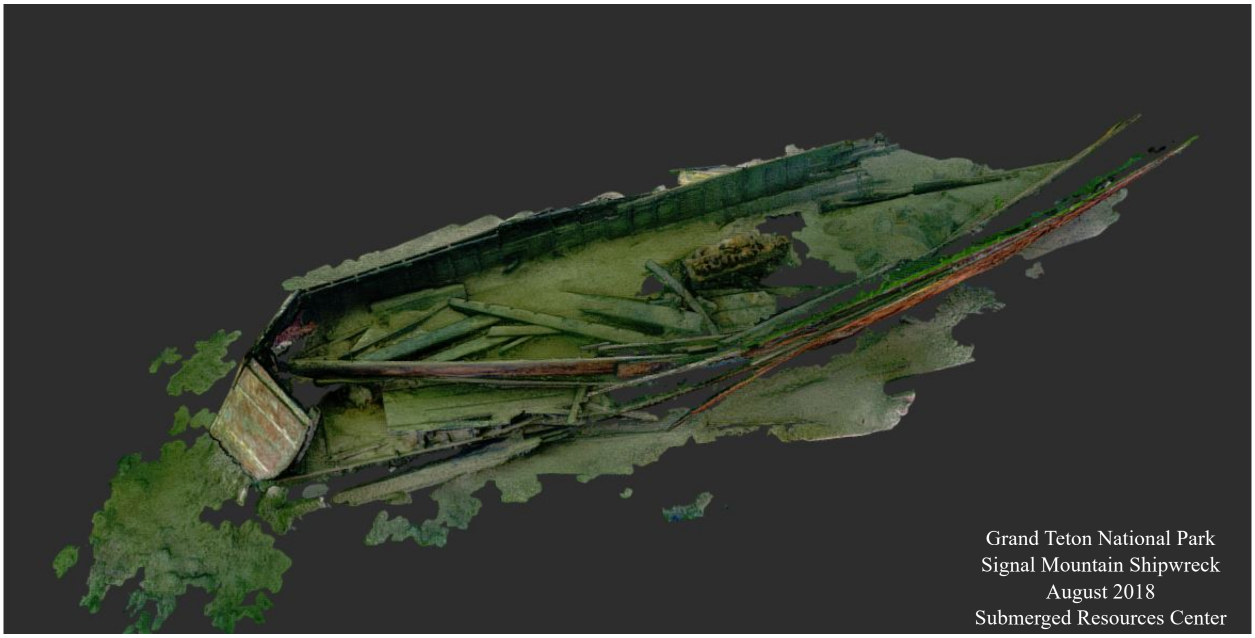


Figure 10: Screenshot of Signal Mountain Shipwreck 3D Model

Explore the 3D model of the Signal Mountain Shipwreck

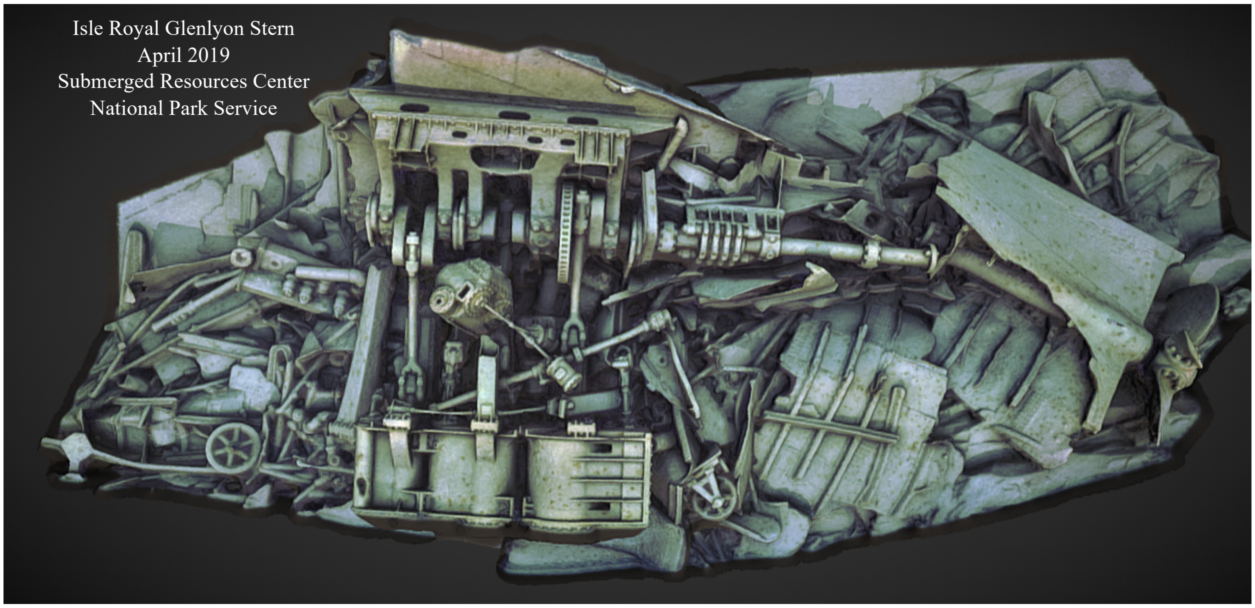


Figure 11: Screenshot of Isle Royal Glenlyon Stern 3D Model

Explore the 3D model of the Isle Royal Glenlyon Stern

Site Documentation Techniques Handout Cont.

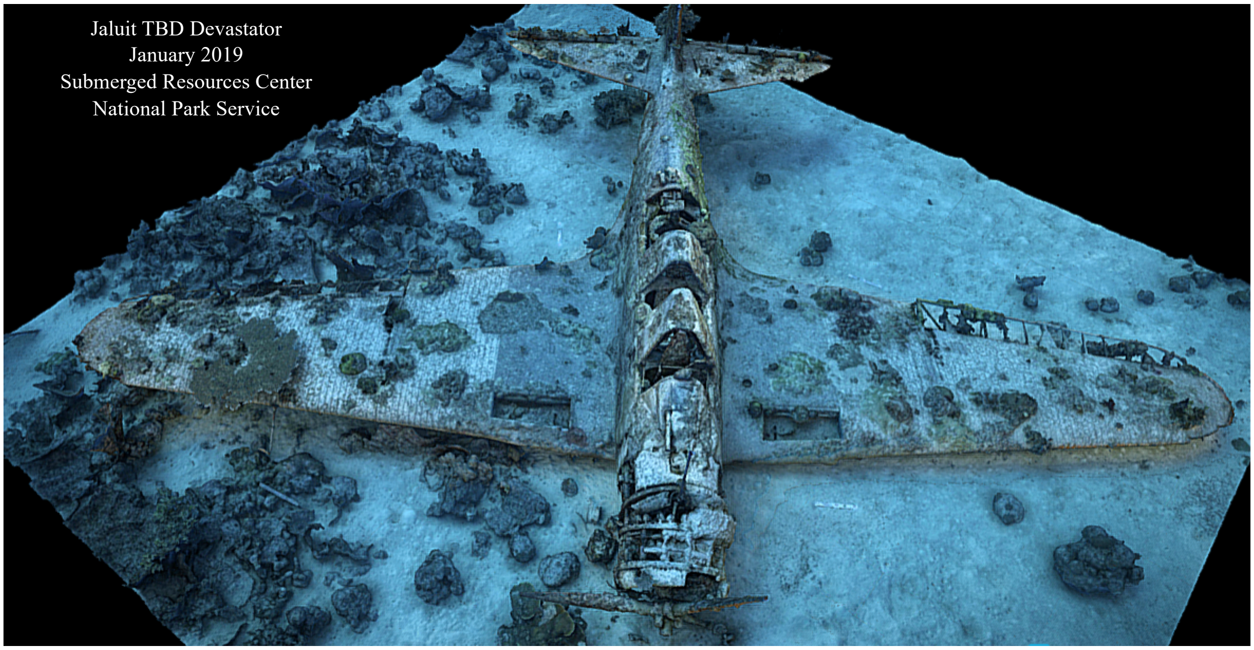


Figure 12: Screenshot of Jaluit TBD Devastator 3D Model

Explore the 3D model of the Jaluit TBD Devastator

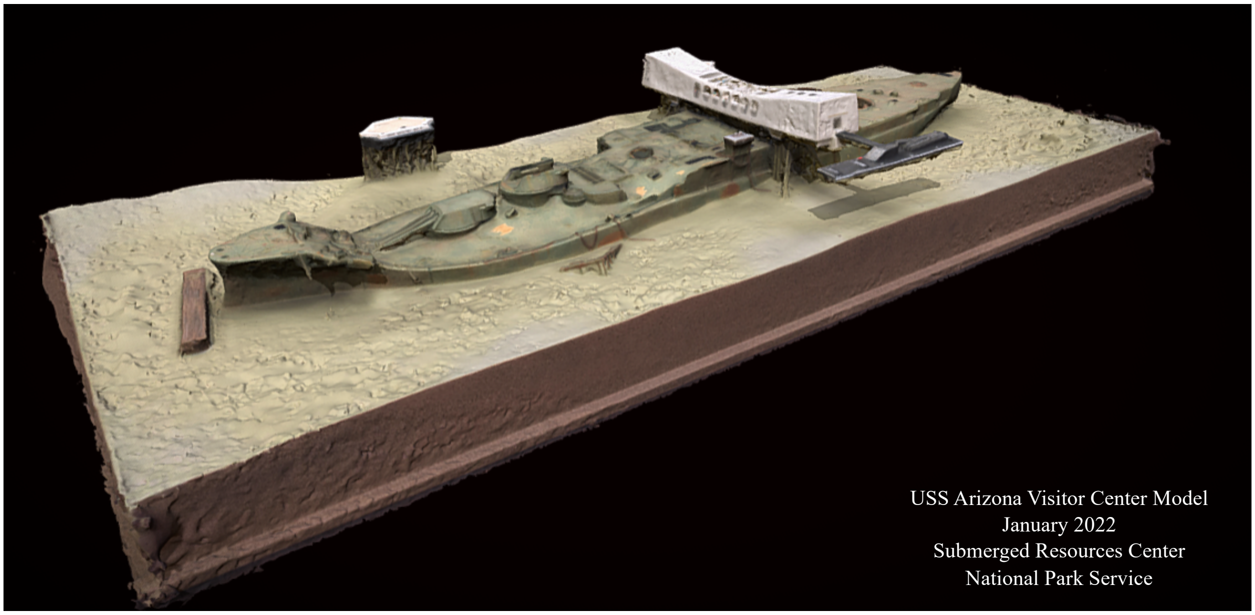


Figure 13: Screenshot of USS Arizona Visitor Center 3D Model

Explore the 3D model of the USS Arizona Visitor Center Model

Investigation: What is Underwater Archaeology?

Site Documentation Techniques Worksheet

Do all the conversations for the ratios and scales.

1) Scale up using this ratio 3:1; 15” = ____________________

2) Scale down using this ratio 15:1; 120’ = ____________________

3) Scale down using this scale ½” = 5’; 500’ = ____________________

4) Scale up using this scale ¼” = 2”; 1 - ½” = ____________________

5) You just finished surveying a shipwreck that measured 250’ in length now you need to map it. You have to scale it down to 50” for the site map. What scale are you going to use? ____________________

6) You have discovered an intricate piece of pottery and to document it properly in the drawing you need to enlarge it. The longest portion of the actual piece measures 1 – 1/2” and you want to enlarge it to 9”, what ratio would you use? ____________________

Investigation: What is Underwater Archaeology?

Site Documentation Techniques Worksheet Answer Key

Do all the conversations for the ratios and scales.

1) Scale up using this ratio 3:1;   15” = **45”**

2) Scale down using this ratio 15:1;   120’ = **8’**

3) Scale down using this scale ½” = 5’;   500’ = **25”**

4) Scale up using this scale ¼” = 2”;   1 - ½” = **12”**

5) You just finished surveying a shipwreck that measured 250’ in length now you need to map it. You have to scale it down to 50” for the site map. What scale are you going to use?   **1” = 5’**

6) You have discovered an intricate piece of pottery and to document it properly in the drawing you need to enlarge it. The longest portion of the actual piece measures 1 – 1/2” and you want to enlarge it to 9”, what ratio would you use? **6:1**

Investigation: What is Underwater Archaeology?

Part 2:
Educators Guide to
Site Documentation Exercise
Lesson Plan

Site Documentation Exercise Lesson Plan

Materials

Teachers
- Site Mapping Exercise Lesson Plan.
- Tape measure greater than 10’ long.
  - May need extras if using Plan B.
- 1-1/2” – 2” wide Blue Painters Tape.
- 60 + Artifacts
  - These should be items such as plates, cups, books or other items of a simple geometric shape.

Students (1 Each per Buddy Team)
- Site Mapping Data Sheet
- Scratch Paper
- Graph Paper
- Pencil
- Tape Measure
- Ruler
- Drawing Compass

Site Documentation Exercise Lesson Plan

Choosing a Site Plan

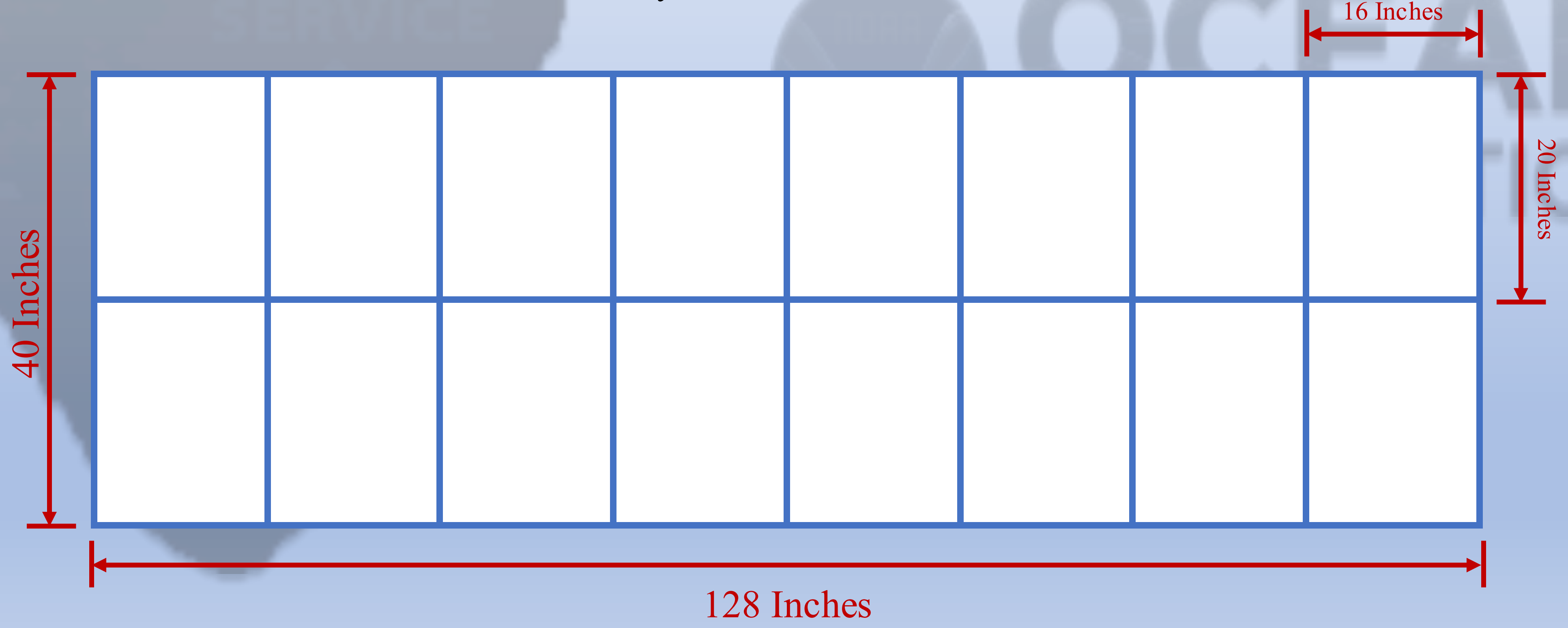
- Depending on classroom size 2 plans have been provided to create the mapping site.
    - Plan A – 1 large site
        - 128” x 40” is the overall space required for the site.
            - Designed to accommodate up to 16 Buddy Teams.
        - Provides the most accurate experience but requires the most space.
    - Plan B – Multiple smaller sites
        - Modular design
        - The overall goal is to have a 20-inch by 16-inch rectangle for each Buddy Team to use.
        - Ideally set up so that at least 2 of these squares next to each other.
            - You may have to use tabletops or spread out to different sides of the floor, but you want the pairs of students to be able to use a desk surface for drawing so do not cover all of them.
        - This plan requires there to be an extra tape measure for each site to be used as the baseline tape.
        - The end result is that you should have a square for each Buddy Team.

Site Documentation Exercise Lesson Plan

Setting Up the Site – Plan A

Step 1: Creating the Grid

- Using painters tape layout 16 sections measuring 20” x 16”
- End result should look like diagram below.
- For the entire exercise, inches will be the only unit of measurement used.

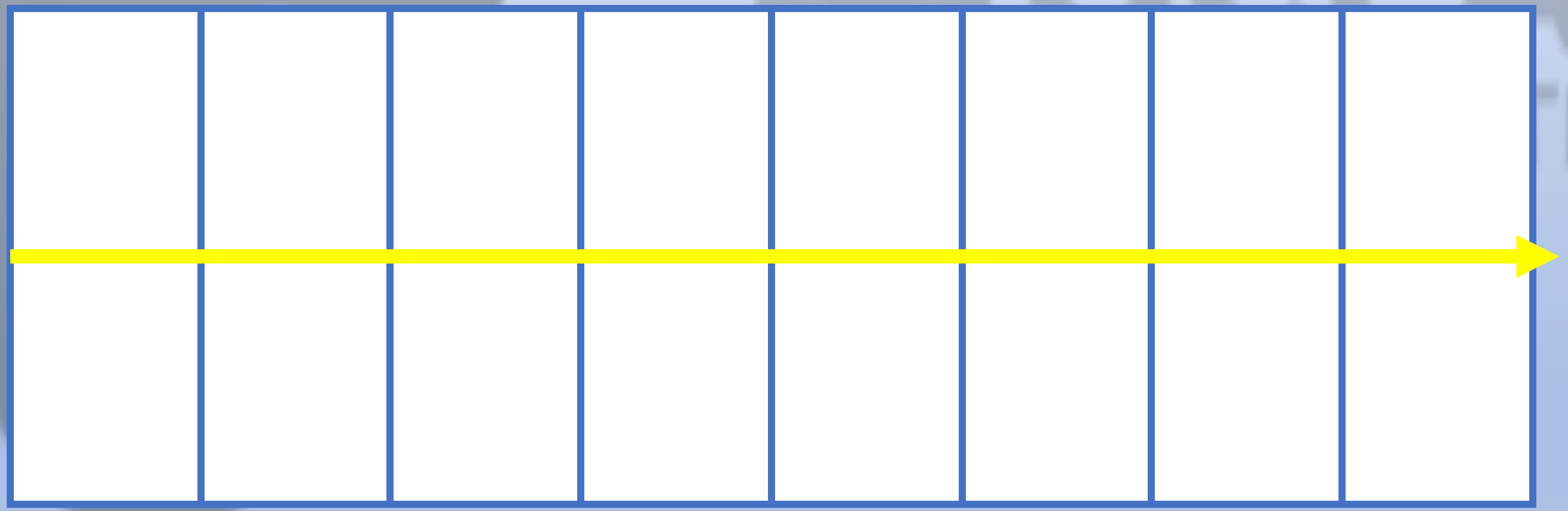


Site Documentation Exercise Lesson Plan

Setting Up the Site – Plan A

Step 2: Laying out the Baseline Tape

- Lay tape measure out down the middle of the grid.
- This will know be known as the baseline tape.
- This will be left in place for the entire exercise.
- May need to use painters tape to keep baseline tape in place.

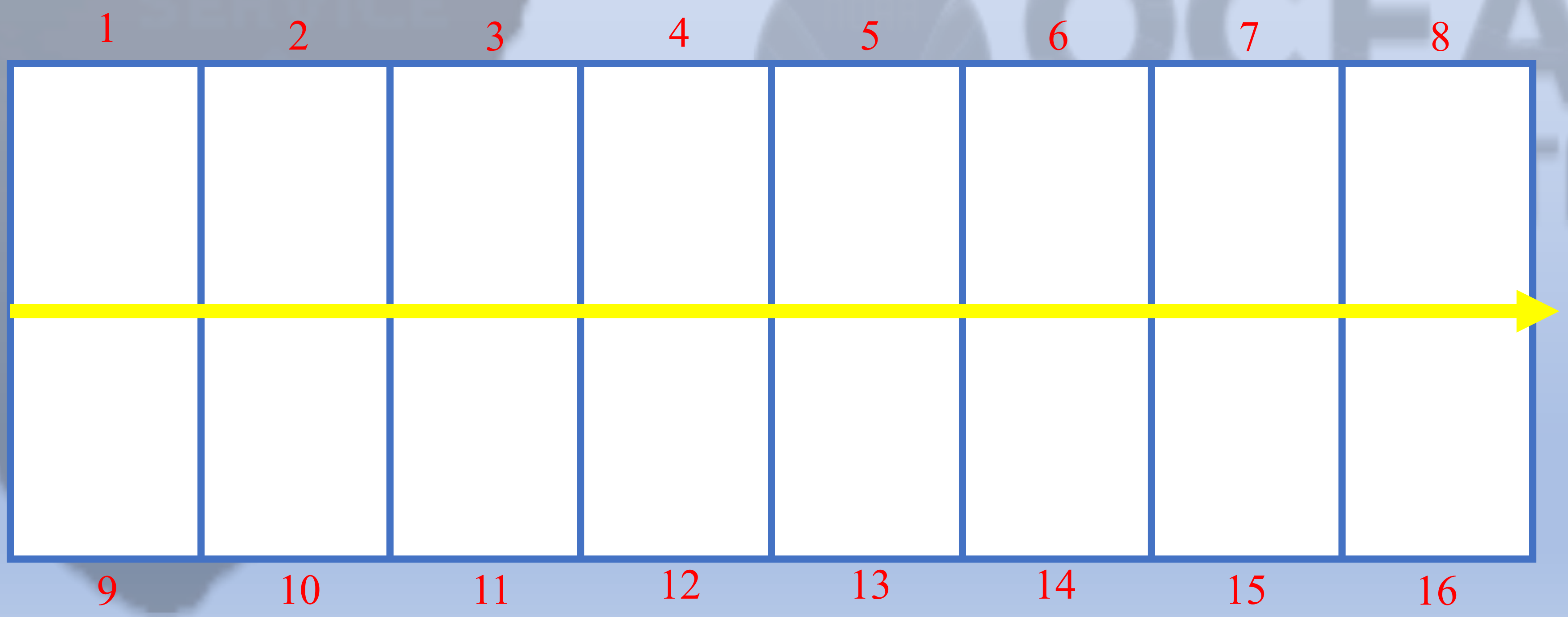


Site Documentation Exercise Lesson Plan

Setting Up the Site – Plan A

Step 3: Number Sections

- On the outside of the grid number the sections 1 – 16.

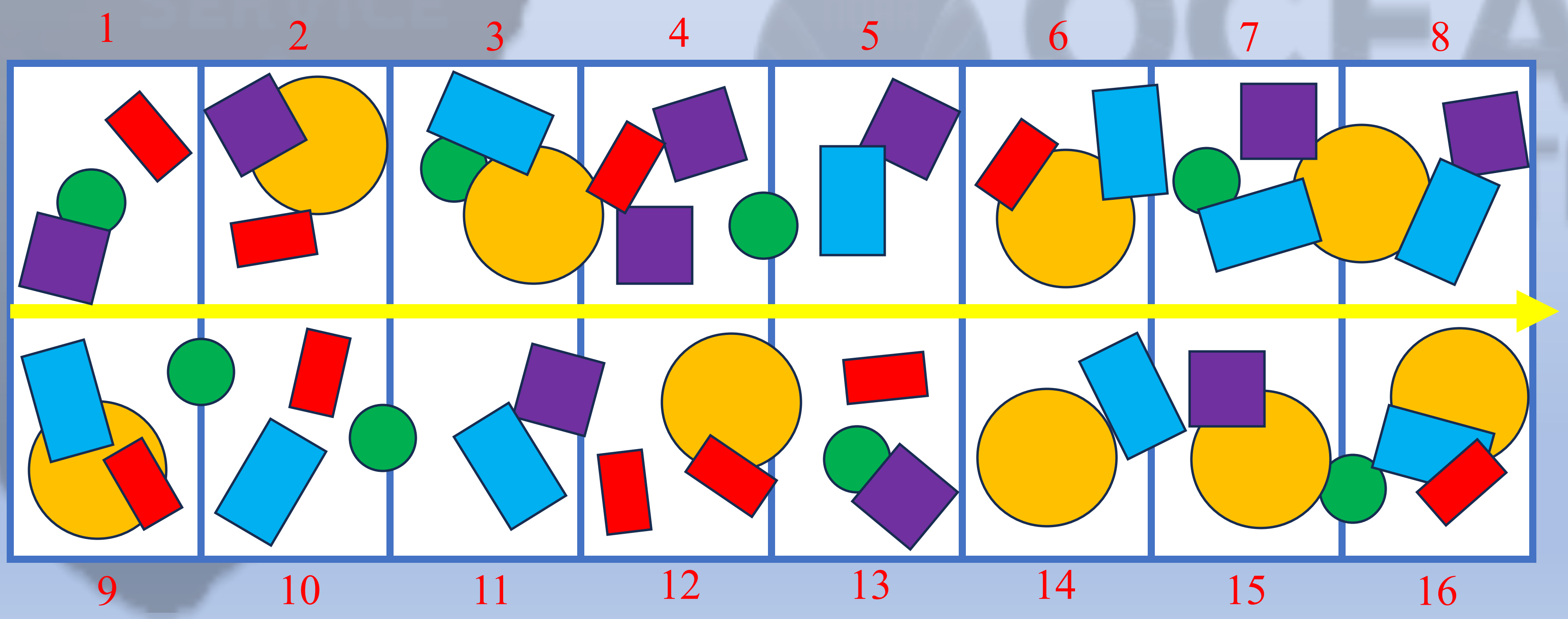


Site Documentation Exercise Lesson Plan

Setting Up the Site – Plan A

Step 4: Distribute Artifacts

- For the artifacts use items like plates, cups, books. Items that would be easy to draw.
- Arrange artifacts across grid.
- Arrange for 3 – 4 artifacts in each section.
- Make sure arrangement as random as possible.
- Have artifacts cross lines between sections but leave baseline uncovered.
- Cover site with a sheet.

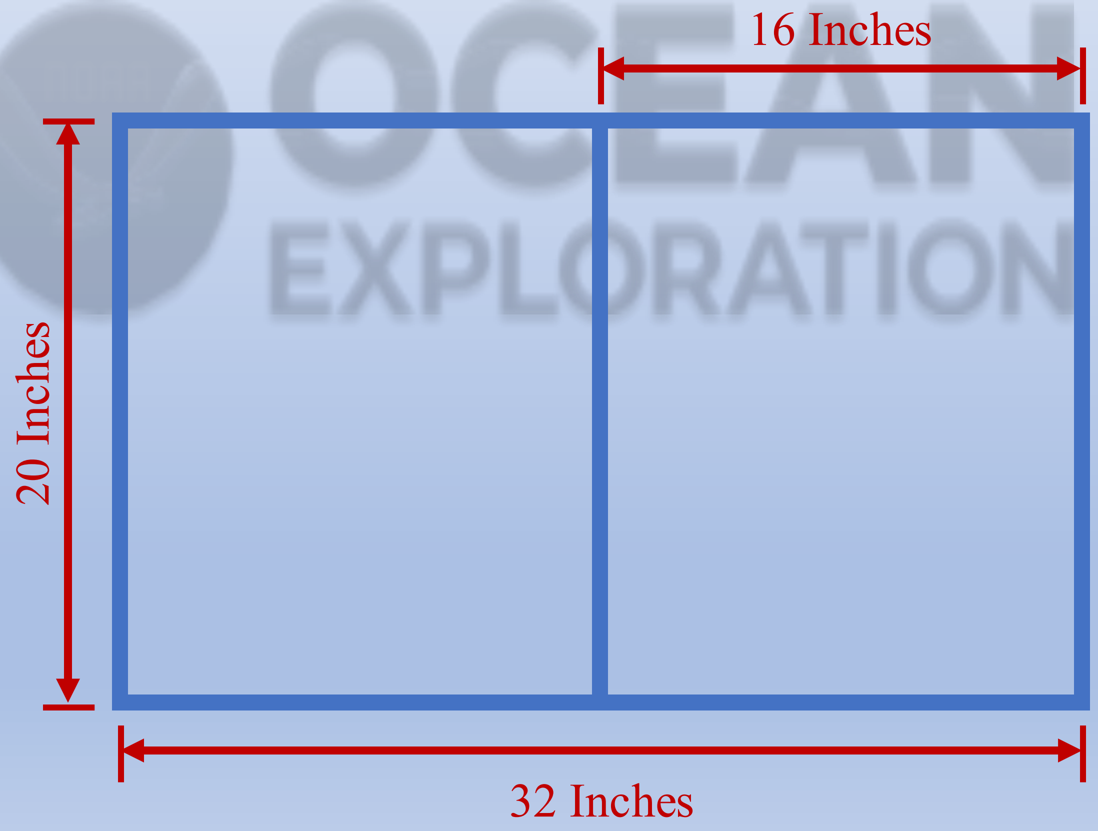


Site Documentation Exercise Lesson Plan

Setting Up the Site – Plan B

Step 1: Creating the Grid

- Using painters tape layout sections measuring 20” x 16”
- End result should look like diagram below.
- Can add sections on if space permits.



Site Documentation Exercise Lesson Plan

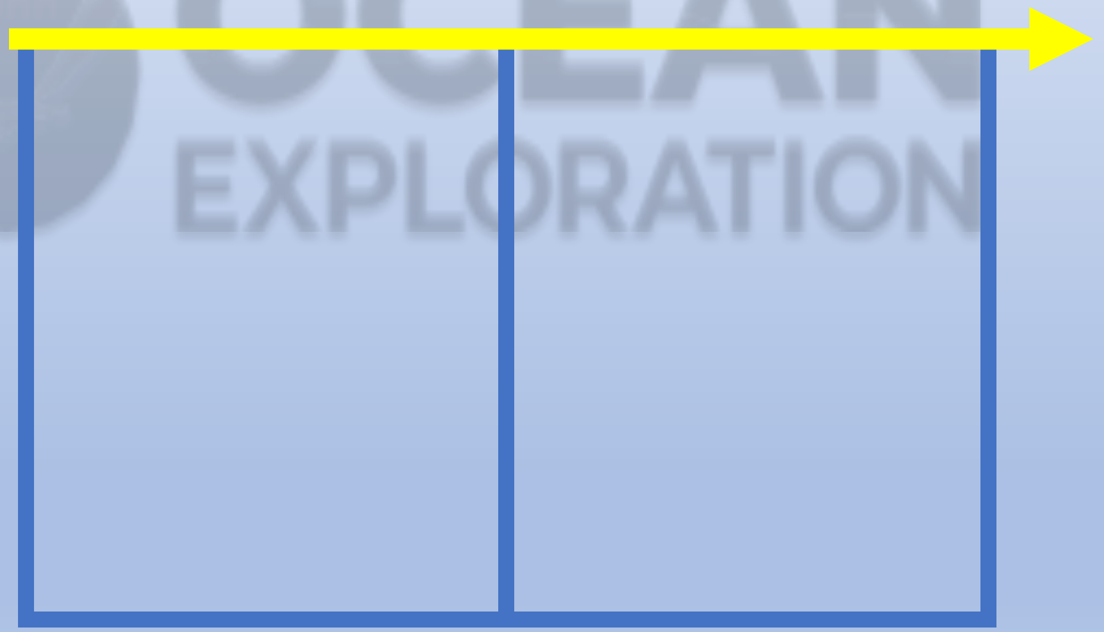
Setting Up the Site – Plan B

Step 2: Laying out the Baseline Tape

- Lay tape measure out down the middle of the grid.
- This will know be known as the baseline tape.
- This will be left in place for the entire exercise.
- May need to use painters' tape to keep baseline tape in place.

Alternative Baseline Options

- If site is only 2 sections, yardsticks can be used.
- Using a felt tipped pen, can also layout measurement markings onto top edge of grid.
  - Recommended to have at least ¼" increments for accuracy.



Site Documentation Exercise Lesson Plan

Setting Up the Site – Plan B

Step 3: Number Sections

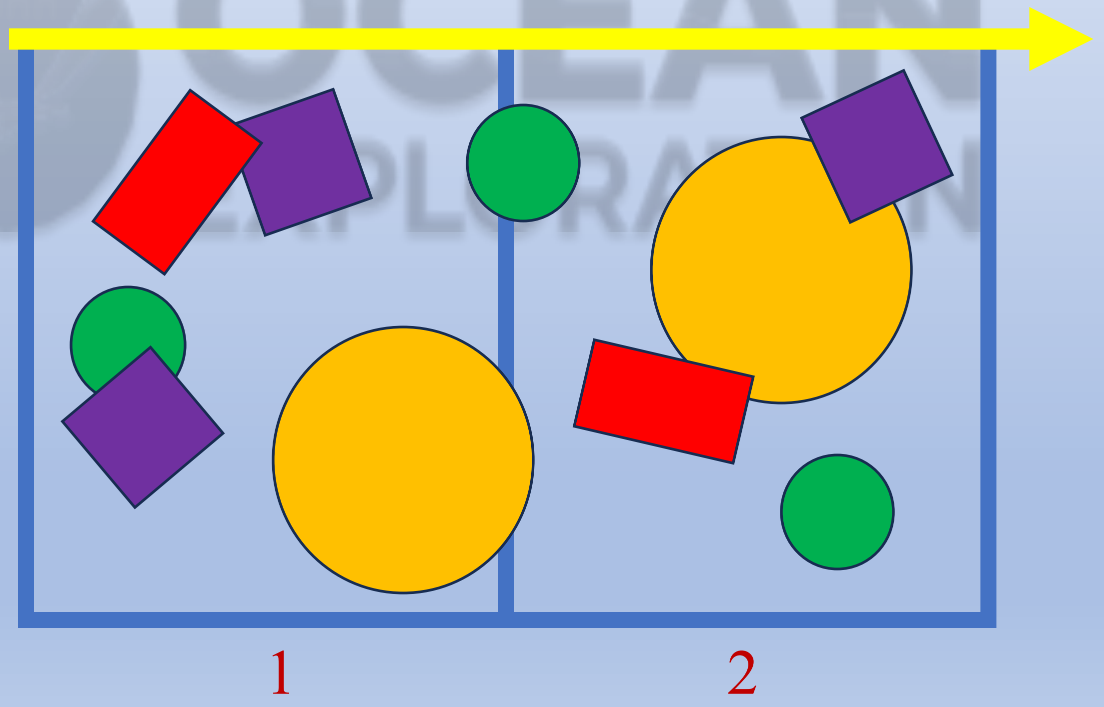
- Outside of the grid number the sections accordingly.

Site Documentation Exercise Lesson Plan

Setting Up the Site – Plan B

Step 4: Distribute Artifacts

- For the artifacts use items like plates, cups, books. Items that would be easy to draw.
- Arrange artifacts across grid.
- Arrange for 3 – 4 artifacts in each section.
- Make sure arrangement as random as possible.
- Have artifacts cross lines between sections but leave baseline uncovered.
- Cover site with a sheet.

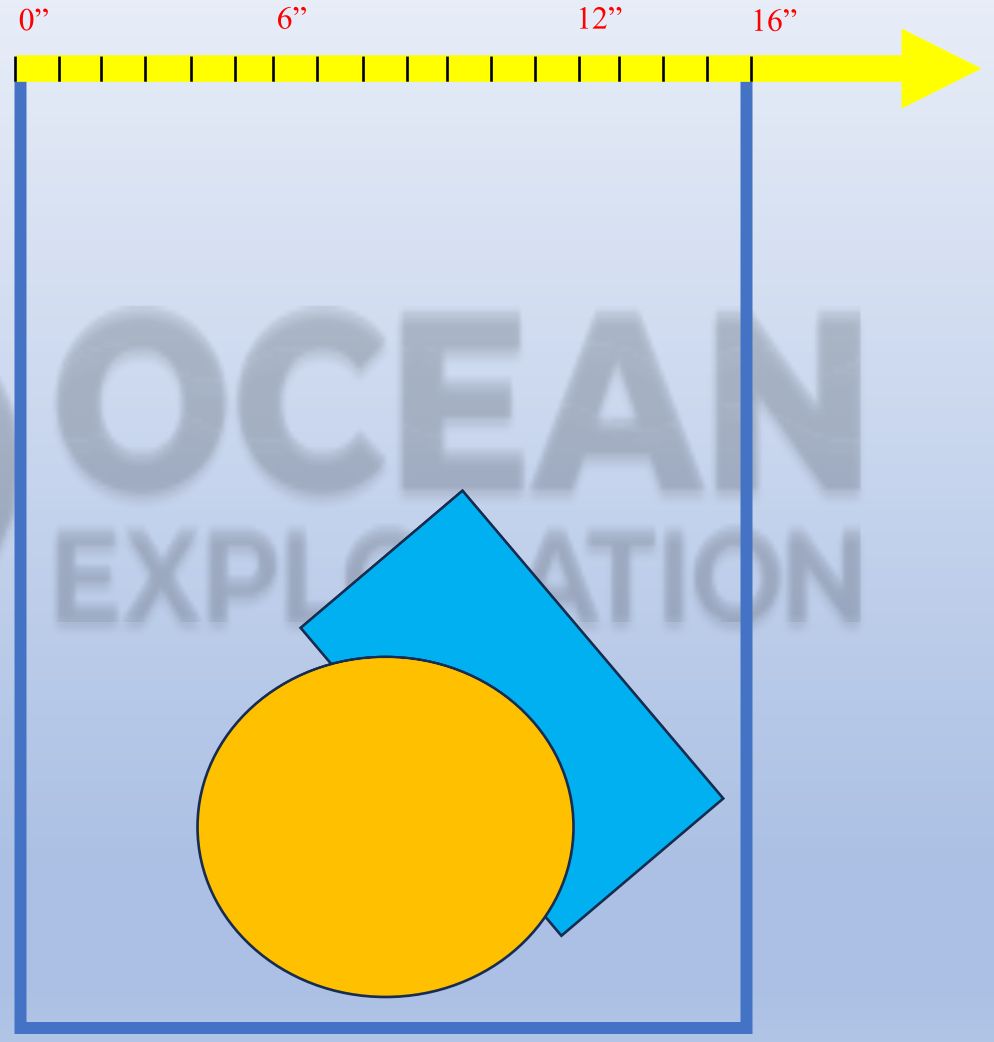


Site Documentation Exercise Plan

Class Lesson Plan

Step 1

- Break the class up into Buddy Teams of 2 students.
- Dispense materials to students.
- Identify 1 student to be the data gatherer and 1 student to be the data recorder.
    - Data gatherer gets the tape measure and ruler.
        - Measures items and calls out measurements to data recorder.
    - Data recorder gets data sheet, scrap paper, and pencils.
        - Records measurements in data sheet
        - Creates rough sketch of site, labeling artifact numbers, and points where offset measurements are taken from.
- Use the next steps to demonstrate how to take the necessary data.

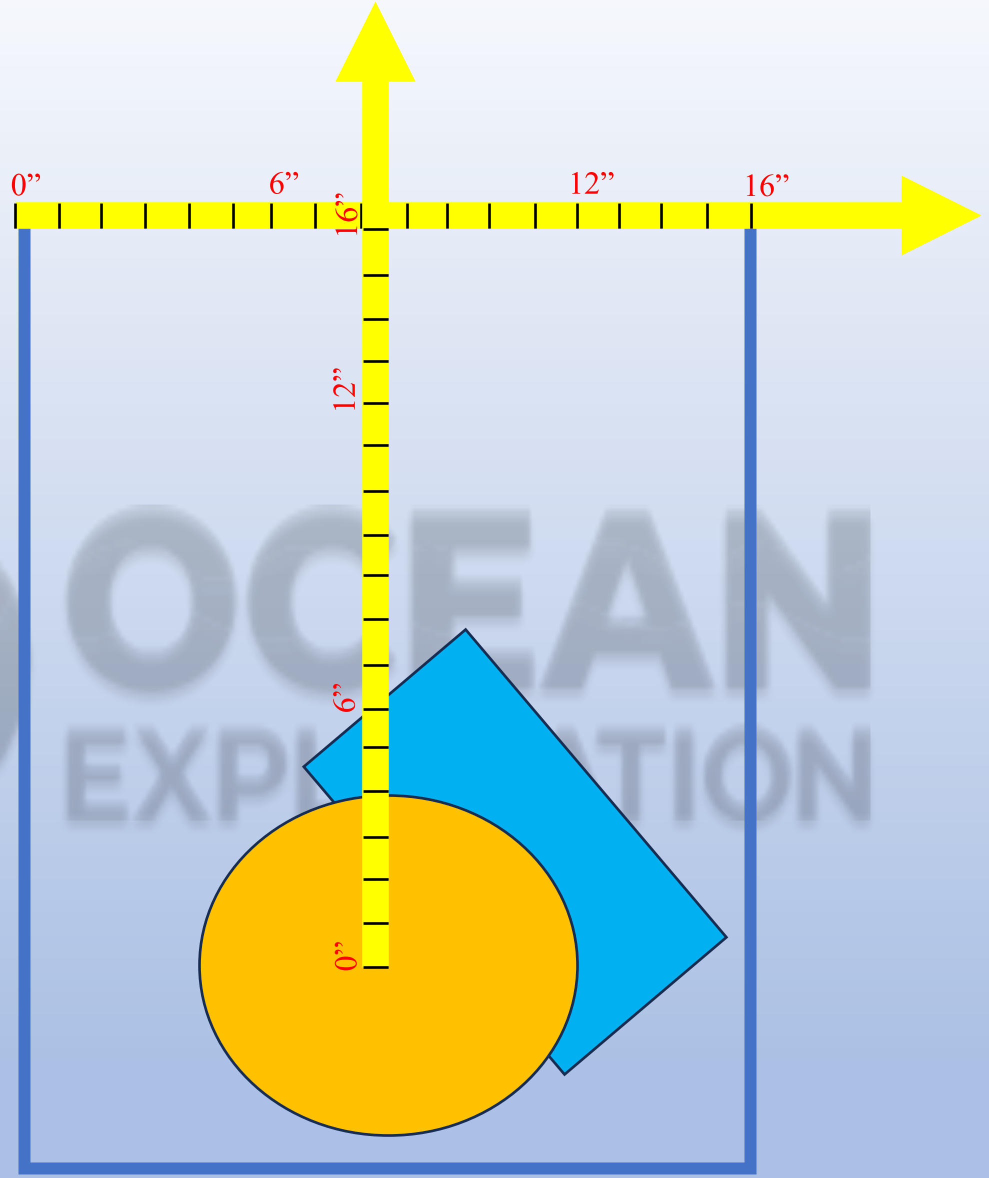


Site Documentation Exercise Plan

Class Lesson Plan

Step 2: Taking Offset Measurements – Circles

- Find the center of the circle.
- With tape measure, measure from the center of the circle to the baseline tape.
- Make sure that tape intersects with the base line at a right angle.
- Offset Dimension: the measurement that the tape reads at the intersection.
  - In this example the measurement is 16”.
- Baseline Dimension: the measurement on the baseline where the tape intersects.
  - In this example the measurement is 8”.

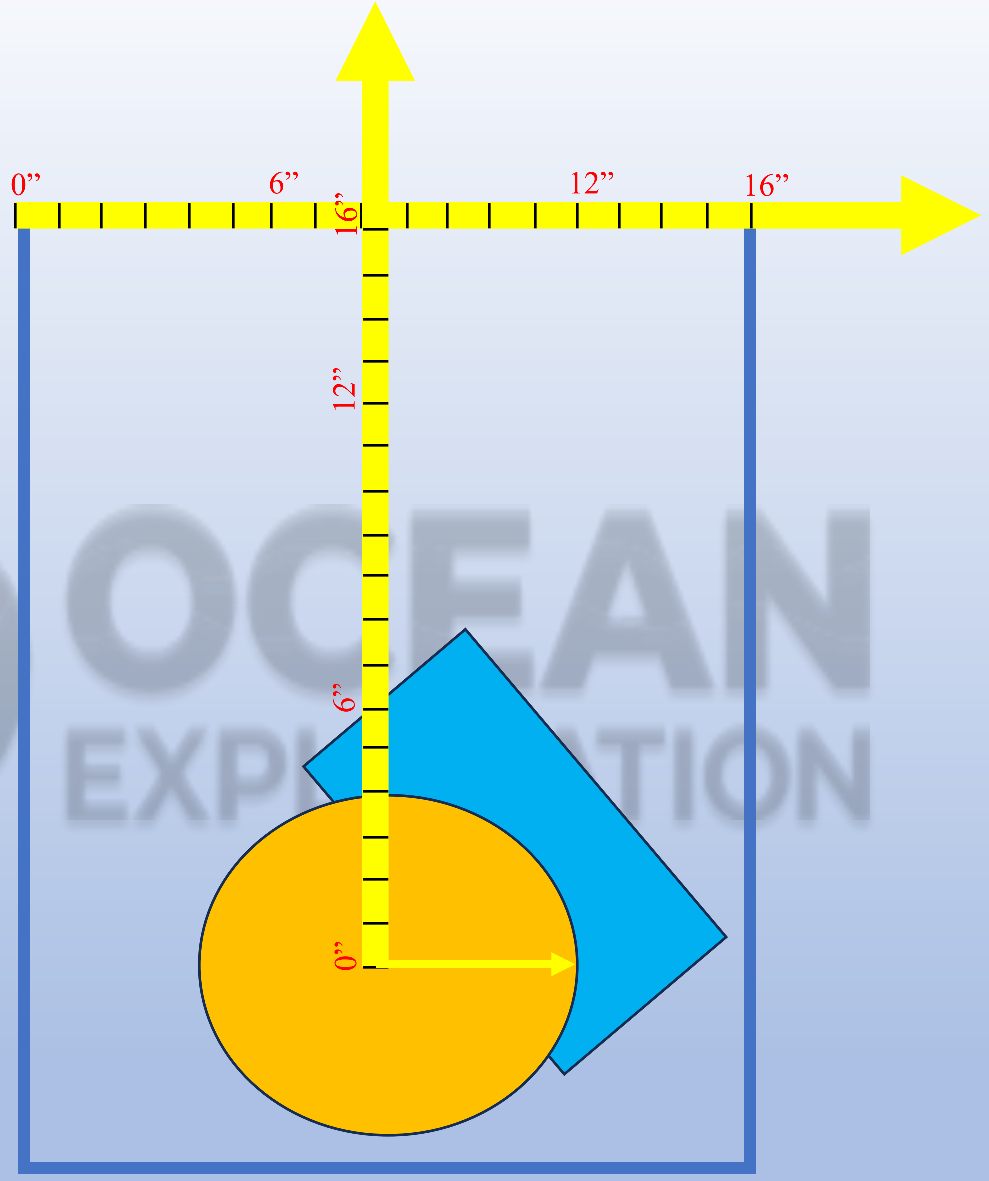


Site Documentation Exercise Plan

Class Lesson Plan

Step 3: Taking Dimensions – Circles

- Using ruler measure from the center of the circle to the edge of the circle.
- Make sure that you measure from the same spot you took the offset dimension from.
- This will get you the radius of the circle.

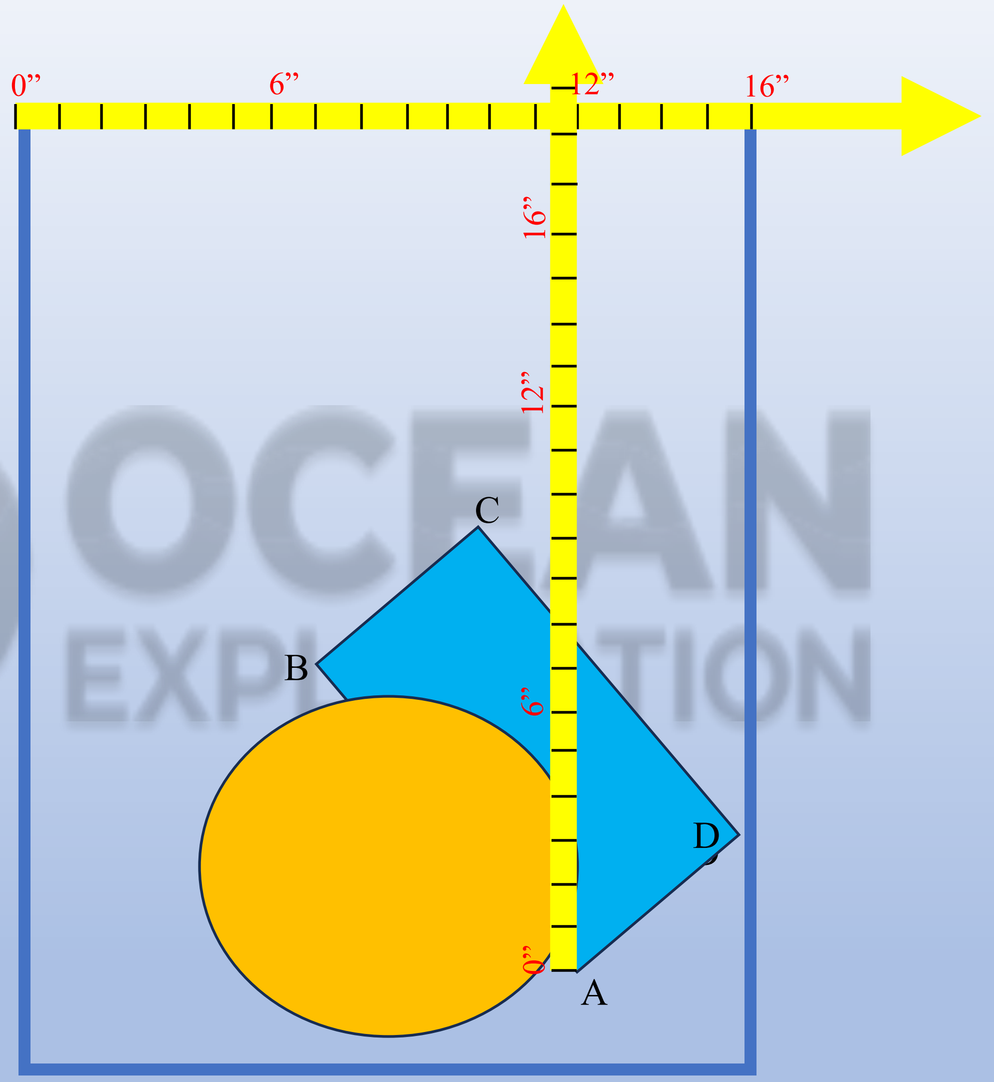


Site Documentation Exercise Plan

Class Lesson Plan

Step 4: Taking Offset Measurements – Rectangles

- Data recorder should label corners on sketch.
- Run the tape measure up from corner "A" to the baseline.
  - Offset Dimension: the measurement that the tape reads at the intersection.
    - In this example the measurement is 18".
  - Baseline Dimension: the measurement on the baseline where the tape intersects.
    - In this example the measurement is 12".
- Repeat this same procedure for all 4 corners.

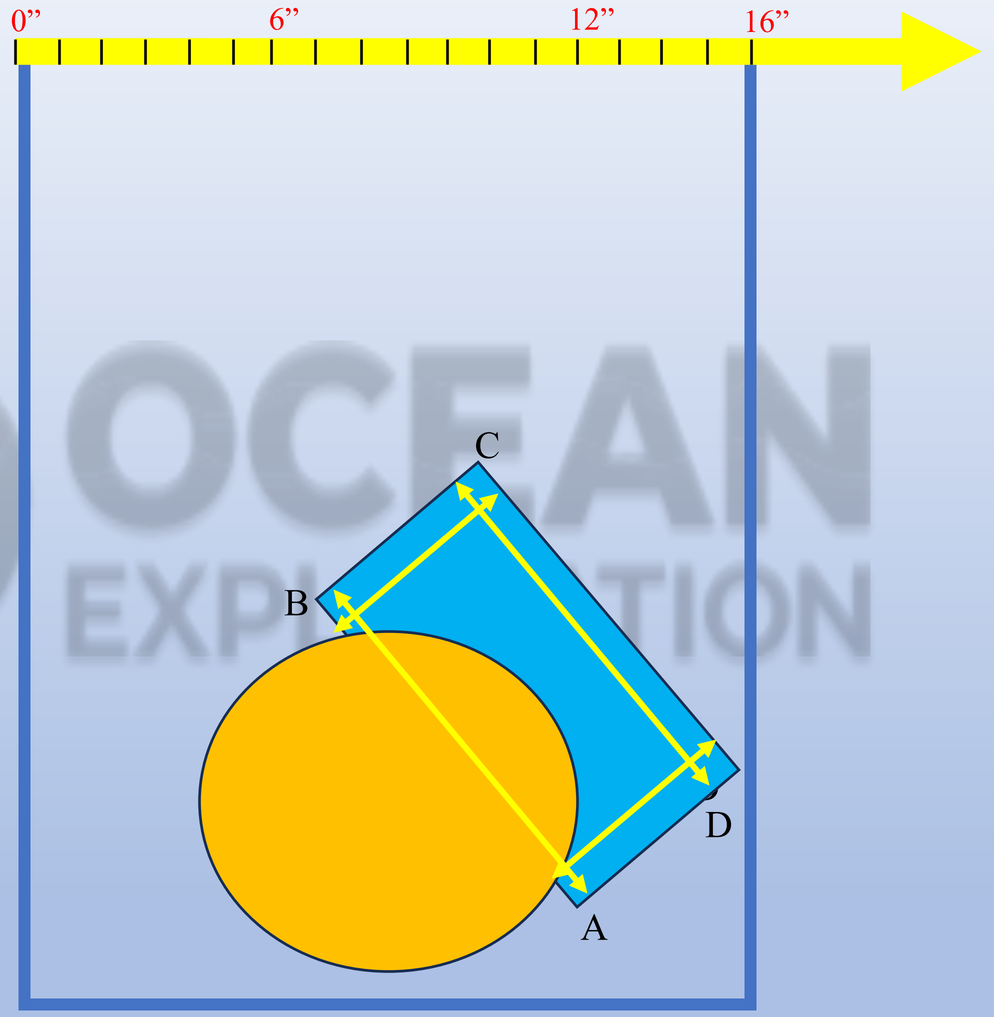


Site Documentation Exercise Plan

Class Lesson Plan

Step 5: Taking Dimensions – Rectangles

- As a means to corroborate the offset measurements overall dimension measurements should also be taken.
- Data gatherer should measure all 4 sides to get their overall length.
    - Do not assume that any 2 sides will have the same dimension.
- Data recorder should note which dimension belongs to what side.
    - i.e. A – B, B – C, C – D, D – A



Site Documentation Exercise Plan

Class Lesson Plan

Step 6: Recording the Data

- Remove the covering on the site.
- Assign sections to each Buddy Team.
- Filling out Site Mapping Data Sheet
  - Record Site Number
  - Record Baseline Range
    - The specific range of measurements in the Baseline the team's section lies in.
  - For every artifact fill out each section of data sheet.
- Creating the rough sketch.
  - Goal of sketch is record where measurements were taken from.
- Artifacts should not be moved by team members.
- Once teams have filled out Site Mapping Data Sheet and rough sketch they can go back to their desk and begin their maps.
  - Students cannot return to site once they leave.

What is Underwater Archaeology?

Site Documentation Data Sheet

OCEAN EXPLORATION

Names:

Date: **Class:**

Site Number: **Baseline Range:**

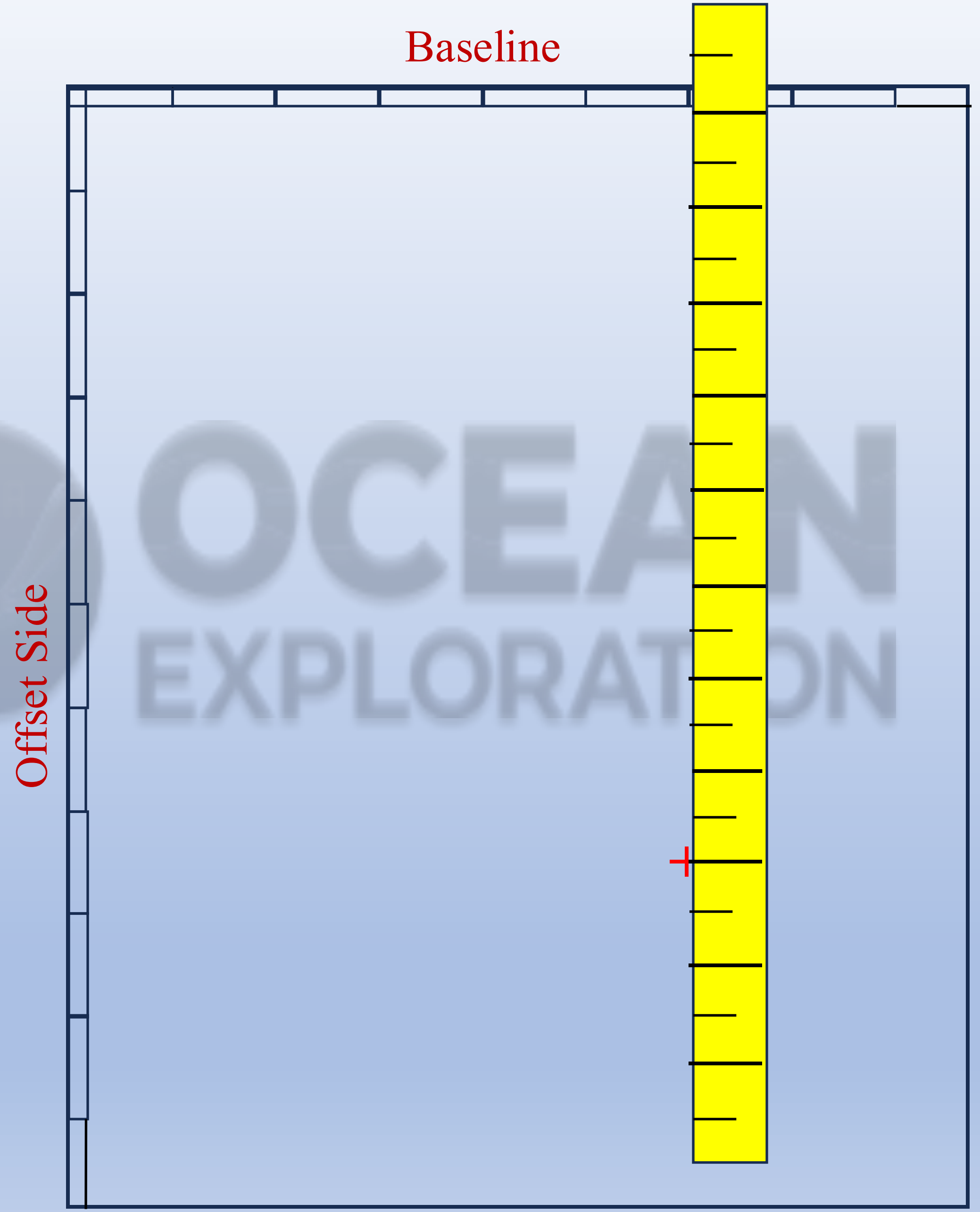
Artifact #	Baseline Dimension	Offset Dimension	Artifact Dimensions	Artifact Description

Site Documentation Exercise Plan

Class Lesson Plan

Step 7: Creating the Map

- The scale for this is 2:1
  - Every 2” on the site will become 1” on the graph paper.
- On graph paper layout the baseline range of measurements at the top of the sheet.
- To transfer measurements:
  - Align ruler at desired baseline dimension.
  - Make sure ruler follows grid lines of graph paper.
  - Place a mark on paper at the offset dimension.
  - If artifact is rectangle repeat this process for each corner.
    - Connect the four corners.
    - Double check this with the overall dimensions taken.
  - If artifact is circle set drawing compass to scaled down radius measurement and draw circle.



Site Documentation Exercise Plan

Class Lesson Plan

Step 8: Putting it all together

- Once each Buddy Team is done with their map section have the class get back together and layout each map section in order so that the site is recreated.
- Have students notice what lined up and what didn't.
- Talking points:
  - What worked?
  - What didn't work?
    - Why did some things not work?
  - What conclusions can one draw from the artifacts found on the site?

What is Underwater Archaeology?

Site Documentation Data Sheet

Names:

Date: ______________________ **Class:** ______________________

Site Number: ______________________ **Baseline Range:** ______________________

Artifact #	Baseline Dimension	Offset Dimension	Artifact Dimensions	Artifact Description