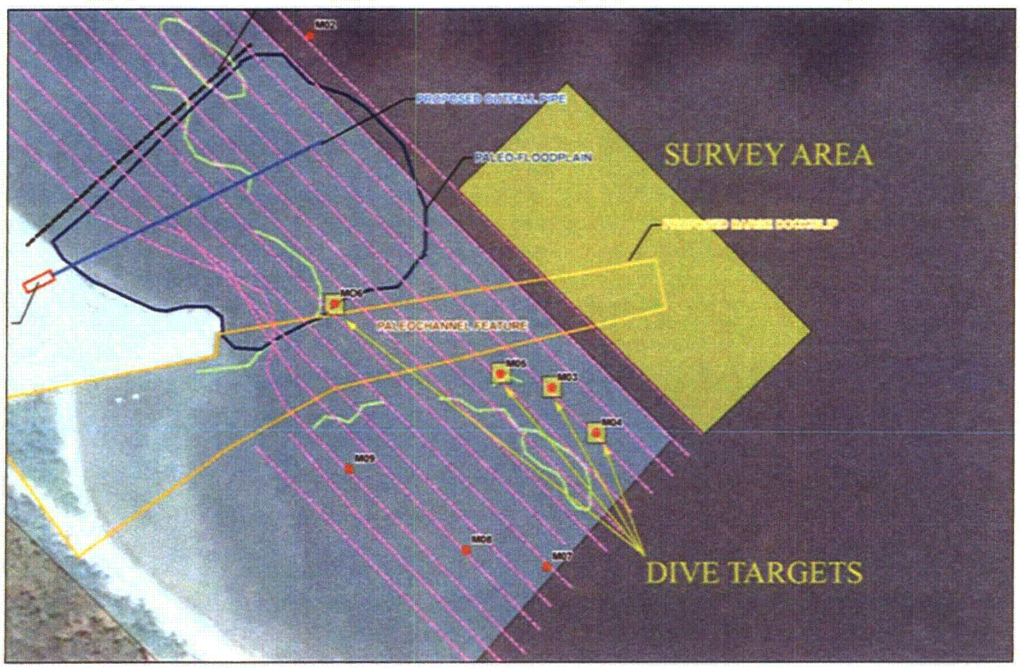
UN#12-029

Enclosure
Submerged Cultural Resources Survey
Calvert Cliffs Unit 3 (CC3)
Calvert Cliffs Nuclear Power Plant Site
Calvert County, Maryland
March 2012

PANAMERICAN CONSULTANTS, INC.

REPORT OF FINDINGS

SUBMERGED CULTURAL RESOURCES SURVEY
CALVERT CLIFFS UNIT 3 (CC3)
CALVERT CLIFFS NUCLEAR POWER PLANT SITE
CALVERT COUNTY, MARYLAND



SUBMITTED TO:

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FINAL REPORT
MARCH 2012

REPORT OF FINDINGS

SUBMERGED CULTURAL RESOURCES SURVEY
CALVERT CLIFFS UNIT 3 (CC3)
CALVERT CLIFFS NUCLEAR POWER PLANT SITE
CALVERT COUNTY, MARYLAND

Prepared for:

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Conducted Under:

GAI Project No. C081163.65

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ABSTRACT

In 2008, archaeologists with Panamerican Consultants, Inc. of Memphis, Tennessee conducted an intensive submerged cultural resources remote sensing survey for UniStar Nuclear Energy, LLC of a proposed offshore construction impact area associated with the construction of a new nuclear generation unit at the Calvert Cliffs Nuclear Power Plant located in Calvert County, Maryland. The survey recorded four potentially significant magnetic anomalies within the offshore area. Subsequent to completion of the archaeological investigation, UniStar Nuclear Energy, LLC identified modifications to the proposed offshore facilities, requiring additional archaeological investigations. Under subcontract to GAI Consultants, Inc. of Homestead, Pennsylvania, Panamerican Consultants, Inc. was tasked with conducting a comprehensive remote sensing survey of the new 91.5-x-213.5-meter (300-x-700-foot) construction/restoration area for a proposed barge dock/slip, as well as archaeological diving investigations to identify the sources of the four magnetic anomalies, M03, M04, M05, and M06, located during the 2008 survey and any potentially significant anomalies located during the current survey.

Results of the current remote sensing survey identified a total of three magnetic anomalies and no sidescan sonar targets. One of the magnetic anomalies met established criteria and was considered potentially significant for the purposes of this investigation, and was further investigated as part of the diving phase.

A 2011 re-examination of the survey data collected during the 2008 project revealed a post-processing error in the magnetic data that had resulted in a significant error being introduced into the number and positions of the recommended magnetic anomalies. Reprocessing of the 2008 data led to the elimination of one target entirely (M04) and the adjustment of the positions of the remaining three.

As a result, a total of four targets, rather than five, were investigated and assessed, including magnetic anomalies M03, M05 and M06, located during the 2008 survey and magnetic anomaly M101, located during the current survey. Target M05 was accounted for by the presence of a large rudder and propeller, M03 by the presence of a length of 0.5-meter (16-inch) diameter steel pipe, and M06, probed via hydroprobe to a depth of 2 meters (7 feet), was determined to likely consist of a large amount of isolated marine related debris. M101 was probed to a depth of 0.5 meters (2 feet), where a large impenetrable rock layer was encountered. The source of M101 is considered to be a large amount of isolated marine debris above this layer. None of the targets are considered historically significant and no further work is recommended.

ACKNOWLEDGEMENTS

Panamerican Consultants, Inc. would like to thank the following people for their assistance during this project. First and foremost, we would like to acknowledge Ms. Barbara Munford of GAI Consultants Inc. for allowing us the opportunity to conduct this investigation. Mark Hunter and the staff at the Calvert Cliffs Nuclear Power Plant deserve acknowledgement for ensuring the efficiency and safety of this project.

The crew deserves acknowledgment for their hard work, dedication, and attention to detail in conducting this project effectively and safely. Members included Andrew Lydecker, Matt Elliott, James Duff, and Michael Murray.

In-house Panamerican Consultants, Inc. personnel who must also be thanked include Kate Gilow, office manager, and Anna Hinnenkamp-Faulk, report editor.

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I. INTRODUCTION

In 2008, archaeologists with Panamerican Consultants, Inc. of Memphis, Tennessee (Panamerican) conducted an intensive submerged cultural resources remote sensing survey for UniStar Nuclear Energy, LLC (UniStar) of an offshore area associated with construction of a new nuclear generation unit (CC3) at the Calvert Cliffs Nuclear Power Plant (CCNPP) located in Calvert County, Maryland (Figure 1). Located north of both Solomons Point and the mouth of Patuxent River, the survey recorded four potentially significant magnetic anomalies within the offshore area (Faught 2009). Subsequent to completion of the archaeological investigation, UniStar identified modifications to the proposed offshore facilities, requiring additional archaeological investigations. Under subcontract to GAI Consultants, Inc. of Homestead, Pennsylvania (GAI), Panamerican was tasked with conducting a comprehensive remote sensing survey of the new 91.5-x-213.5-meter (300-x-700-foot) construction/restoration area for a proposed barge dock/slip, as well as archaeological diving investigations to identify the sources of the four magnetic anomalies—M03, M04, M05, and M06—located during the 2008 survey (Figures 2 and 3), and any potentially significant anomalies located during the current survey.

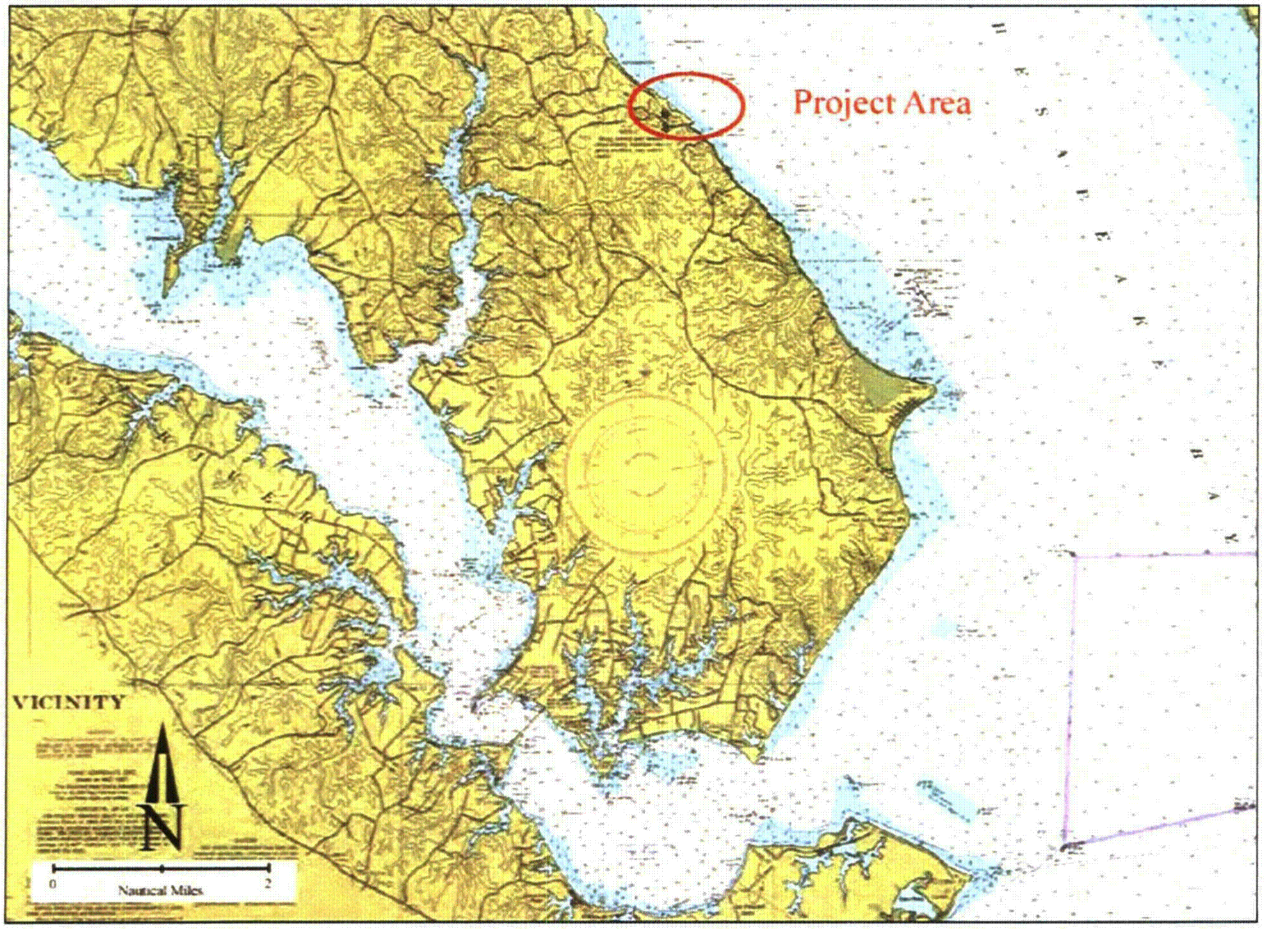

Figure 1. Project area location map (excerpt from NOAA Navigational Chart "Patuxent River and Vicinity, MD," Chart No. 12264). Data presented in Maryland State Plane, NAD83, meters.

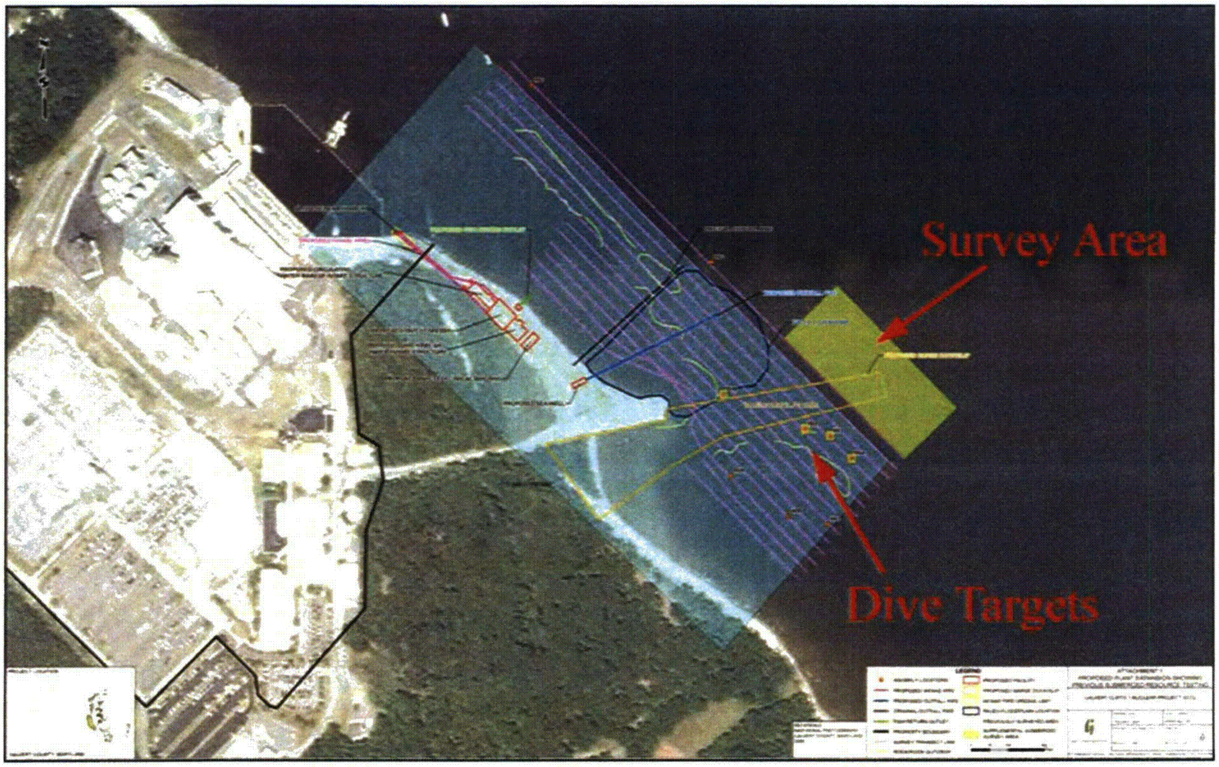

Figure 2. Calvert Cliffs Nuclear Plant with 2008 study area and dive targets, as well as the new 2011 Survey Area (yellow; base map courtesy of GAI). Data presented in Maryland State Plane, NAD83, meters.

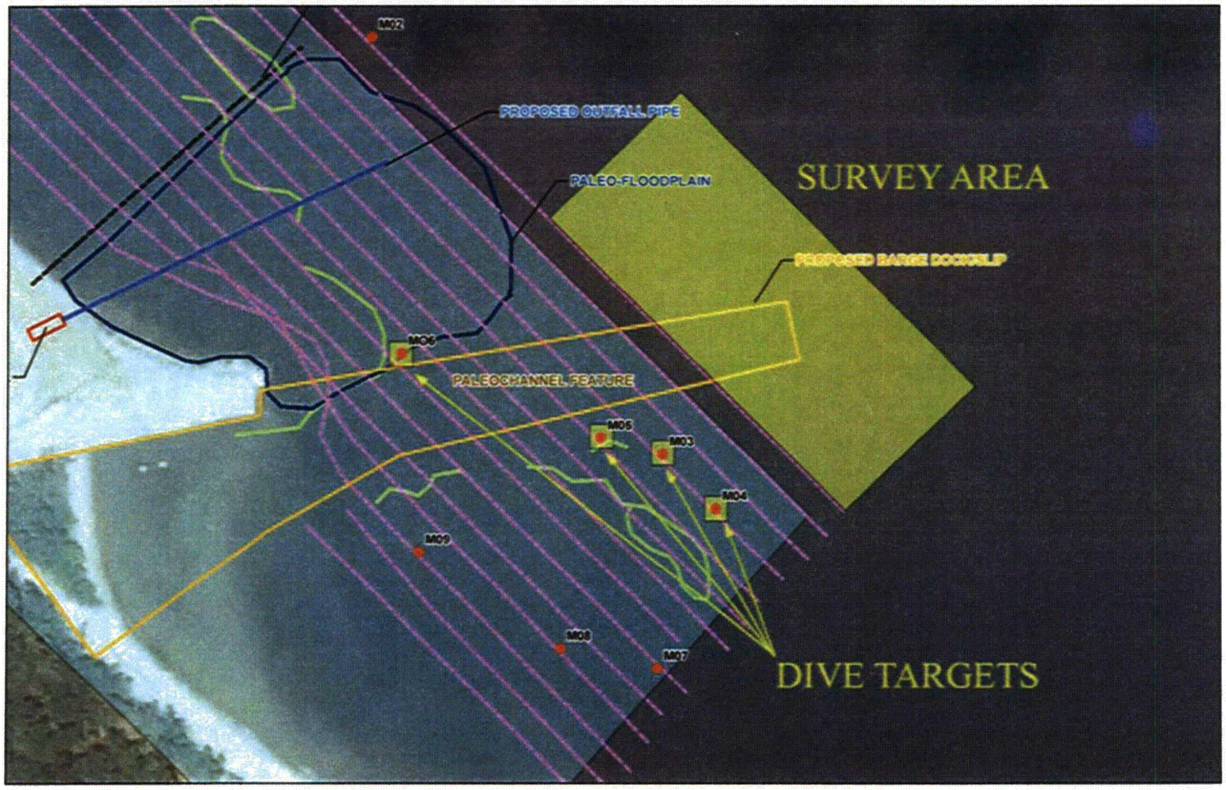

Figure 3. Close up of the new 2011 Survey Area (yellow) and four potentially significant anomalies, M03, M04, M05 and M06 (base map courtesy of GAI). Data presented in Maryland State Plane, NAD83, meters.

The current project was comprised of a magnetometer, sidescan sonar, and subbottom profiler survey of the new 91.5-x-213.5-meter (300-x-700-foot) construction/restoration area for a proposed barge dock/slip. The primary focus of this remote sensing survey was to determine the presence or absence of additional anomalies representative of potentially significant submerged cultural resources eligible for listing on the National Register of Historic Places (NRHP), which, if present, might also require diver assessment. The diving investigation was conducted to assess the identity of the four potentially significant anomalies (M03, M04, M05, and M06), as well as any newly recorded anomalies within the new survey area, and determine their significance, if any, based on NRHP criteria. The project was conducted relative to UniStar's responsibilities under various federal and state statutes and was performed in compliance with Section 106 of the National Historic Preservation Act of 1966 (NHPA), as amended (36 CFR 800, *Protection of Historic Properties*); the Abandoned Shipwreck Act of 1987 (*Abandoned Shipwreck Act Guidelines*, National Park Service, *Federal Register*, Vol. 55, No. 3, December 4, 1990, pp. 50116-50145); as well as the Maryland Historical Trust (MHT)'s Standards and Guidelines for Archaeological Investigation in Maryland (Shaffer and Cole 1994).

Results of the current remote sensing survey identified a total of three magnetic anomalies and no sidescan sonar targets. One of the magnetic anomalies met established criteria and was considered potentially significant for the purposes of this investigation, and was further investigated as part of the diving phase.

A 2011 re-examination of the survey data collected during the 2008 project revealed a post-processing error in the magnetic data that had resulted in a significant error being introduced into the number and positions of the recommended magnetic anomalies. Reprocessing of the 2008 data led to the elimination of one target entirely (M04) and the adjustment of the positions of the remaining three.

As a result, a total of four targets, rather than five, were investigated and assessed, including magnetic anomalies M03, M05 and M06, located during the 2008 survey (Figures 2 and 3) and magnetic anomaly M101, located during the current survey. Target M05 was accounted for by the presence of a large rudder and propeller, M03 by the presence of a length of 0.5-meter (16-inch) diameter steel pipe, and M06 was probed via hydroprobe to a depth of 2 meters (7 feet) determining it to likely consist of a large amount of isolated marine related debris. M101 was probed to a depth of 0.5 meters (2 feet), where a large impenetrable rock layer was encountered. The source of M101 is considered to be a large amount of isolated marine debris above this layer. None of the targets is considered historically significant and no further work is recommended.

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II. HISTORICAL BACKGROUND

Limited archival investigations were conducted for this project to understand the potential for both historic (shipwreck) resources and submerged prehistoric resources. Presented below, the background information has been divided into descriptions of the local environmental setting and cursory historic period and prehistoric period potentials.

Panamerican reviewed company reports dealing with Maryland maritime history, visited the Calvert Marine Museum in Solomons seeking information about known shipwrecks in the area or the potential for their existence, and interviewed local geoarchaeologist Darrin Lowery with regard to known locations of submerged prehistoric sites and the potentials for the same.

No shipwrecks were known for the area and it was considered low potential that they might occur along the straight, exposed shoreline. No submerged prehistoric sites were known for the area, but the potential for Paleoindian through Archaic remains was considered likely.

Environmental Setting

Most of the Maryland shoreline is broken and sinuous because sediments of the coastal plain offer little resistance to erosion and low-lying portions are easily inundated. Only the bay shore of Calvert County is marked by higher banks, or relatively straighter shorelines, and the eroding sediment hills.

Calvert Cliffs are hillocks of Miocene sediment beds shaped by erosion and sheared by calving (Figures 4 and 5). The unlithified sediments that comprise the cliffs are sequential facies of transgressive and regressive deposits including beds of clays, silts, sands, and gravels. These have been divided into three formations at the project location (Kidwell 1997): *Calvert*, the oldest, at the base; *Choptank*, in the middle; and *St. Mary's*, at the top, representing middle and late Miocene time. Sidescan sonar acoustic backscatter images resembling this "layering" were observed on the mosaiced sidescan record, indicating either slumped sediments from calving or additional, but earlier, Miocene deposits (Maryland Geological Survey 2000).

The nearest ice sheet to Chesapeake Bay was approximately 200 km north of Maryland during the last continental glaciation (approximately 25,000 BP). Sea level changes and sediment deposits around Chesapeake Bay are the indirect effects of this nearby glaciation.

Chesapeake Bay is the result of the Holocene drowning of the drainage system of the ancestral Susquehanna River (PaleoSusquehanna). The evolution of the bay includes the continued submergence of this feature. Evidence suggests that Chesapeake Bay is very young, perhaps no more than 8,000–10,000 years old, depending on when isostasy and sea level rise coincided to breach the mouth of the bay. The bay and the lands that surround it are the result of changes in sea levels associated with the fluctuations of major ice sheets during the Pleistocene.

There are rich records locally of prehistory, protohistory, colonial history, and United States history, but these are only outlined here for purposes of brevity.

Figure 4. Viewing approximately west, toward the CCNPP in the center and the barge jetty to the left.

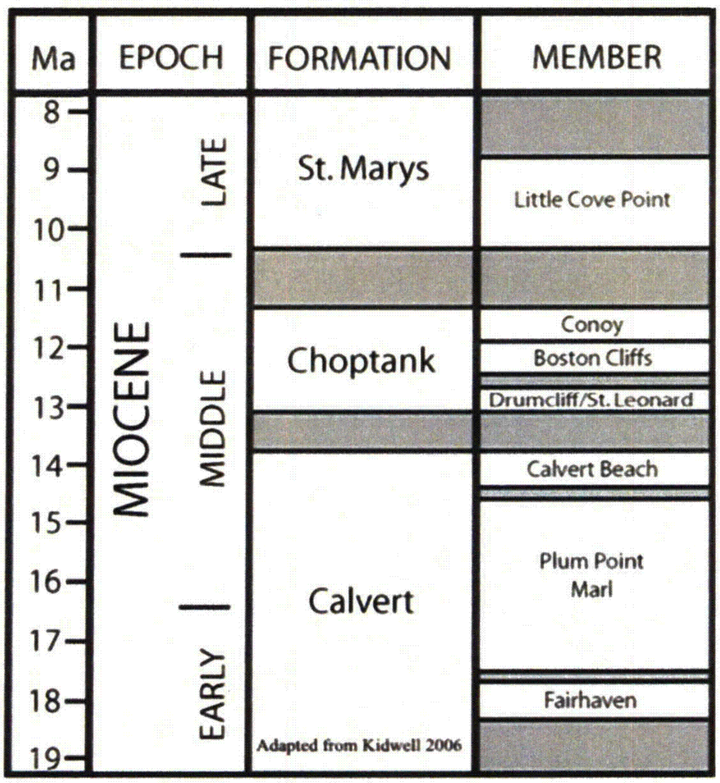

Figure 5. Members of the Miocene formations of Calvert Cliffs at the project location (adapted from Kidwell 2006).

PREHISTORIC POTENTIALS

Prehistorically, the record of Maryland includes a full sequence from the Paleoindian era through Archaic, Woodland, Protohistoric, and Colonial times for Native Americans (Snow 1980). With regard to estimating sea level changes within the Chesapeake embayment, relevant to the project area, Lowery notes, "During the early portions of the Early Archaic period ca. 11,600 BP, sea levels were approximately 65 meters (211 feet) lower and at the terminus of the Early Archaic period, sea levels were approximately 35 meters (114 feet) lower than present" (2008:31). This would have put sea levels up to the mouth of the modern embayed area and flooding would have mostly occurred after this. There is potential for Paleoindian through late Early Archaic.

Lowery again states, "around 8,000 year ago, sea levels were approximately 24 meters (78 feet) below current ... and at the terminus of the Middle Archaic period, sea levels were approximately 10 meters (32 feet) lower than present. Clearly, the Middle Archaic period was a time of rapid sea level rise and rapid ecological change. Again, virtually all of the known terrestrial Middle Archaic sites in the coastal plain are in areas that were upland settings ... 6,800 years ago" (2008:33). Sites would be predicted on paleolandscapes now submerged around this time, 6800 BP.

Since sea levels have risen over the time that people were in the area, the potential exists for submerged prehistoric sites in Chesapeake Bay and at the project location in particular (Blanton and Margolin 1994; Lowery 2003, 2008). These sites can be predicted to occur in paleolandscape situations similar to terrestrial landscape settings where sites are known to occur on land (i.e., on river terraces, near chipping stone outcrops, etc.). There is a paleochannel feature near the project impact zone whose floodplain margins meet these criteria.

Potential prehistoric components include Paleoindian, Early Archaic, and Middle Archaic remains. Woodland and later remains would only be flotsam or jetsam, which would be interesting but not significant, save for remains of canoes or fishing weirs or similar items (Blanton and Margolin 1994; Lowery 2008).

HISTORIC POTENTIALS

Since its discovery and exploration, the Chesapeake Bay area has seen the development of a rich maritime history, with several maritime museums and displays in different states around its margins. Much of this history is with regard to various kinds of sail-powered vessels; however, steam-powered vessels were introduced by 1813. Nevertheless, the exposed coastline of the Calvert Cliffs remote sensing survey project area is not as conducive to vessel abandonment and scuttling as the inlets. Thus, catastrophic encounters with the coast provide greater potential for ship remains, although none are known (John Dodds personal communication 2008). Known vessel types within Chesapeake Bay include the following (Lydecker and Krivor 2004):

- Brig/brigantine
- Barkentine
- Clipper Ship
- Canoe, Brogan and Bugeye
- Sailing work vessels
- Sloop
- Schooner, Pungy, Baltimore clipper
- Skiff
- Skipjack
- Sharpie
- Steamboats

Of the 11 types of vessels listed above, most would have been scuttled or otherwise abandoned inside more protected waters and not on the windward and waveward side of Chesapeake Bay.

DREDGING HISTORY

Part of both the 2008 and 2011 project areas encompassed the existing CCNPP Units 1 and 2 barge slip as illustrated in Figures 2 and 3 above. Detailed history of the construction and maintenance of the slip and related access channel is unavailable. However, construction for the CCNPP began in 1968 and was completed in 1977, and the barge facility was constructed during this time period as well. A recent Environmental Impact Statement regarding the proposed work on the barge slip (United States Nuclear Regulatory Commission 2011) described in detail the proposed removal of sediment from the barge channel. An area approximately 1,500 feet long by a varying distance of 100–150 feet wide would be dredged to a depth of 16 feet below mean low water, resulting in the removal of 60,000 cubic yards of material (United States Nuclear Regulatory Commission 2011:3-22). The report describes the first 1,065 feet of the 1,500-foot total length as maintenance dredging, indicating the existence of at least one previous dredging episode. Maintenance dredging will return the channel to its originally constructed depth. The additional 435 feet will be an extension beyond the original dredging limits and will result in the removal of 600 cubic yards of material.

PREVIOUS INVESTIGATIONS

In 2008, archaeologists from Panamerican conducted a remote sensing survey of a proposed outflow pipe at the Calvert Cliffs Nuclear Power Plant (Faught 2009). The project area consisted of a 427-x-198-meter (1,400-x-650-foot) area centered on the proposed location of the new outflow pipe (Figure 6). The investigation consisted of a remote sensing survey utilizing magnetometer, subbottom profiler, and sidescan sonar, with a 15-meter (50-foot) survey interval, and identified nine magnetic anomalies (Table 1; Figure 7) and five sidescan sonar targets, none of which were recommended for further investigation. Analysis of the subbottom data indicated the presence of a potential paleochannel in the center of the Project Area. While this potential paleochannel was initially outside the Area of Potential Effect (APE), a realignment of the proposed location of the outfall pipe placed it within the APE (Figure 7).

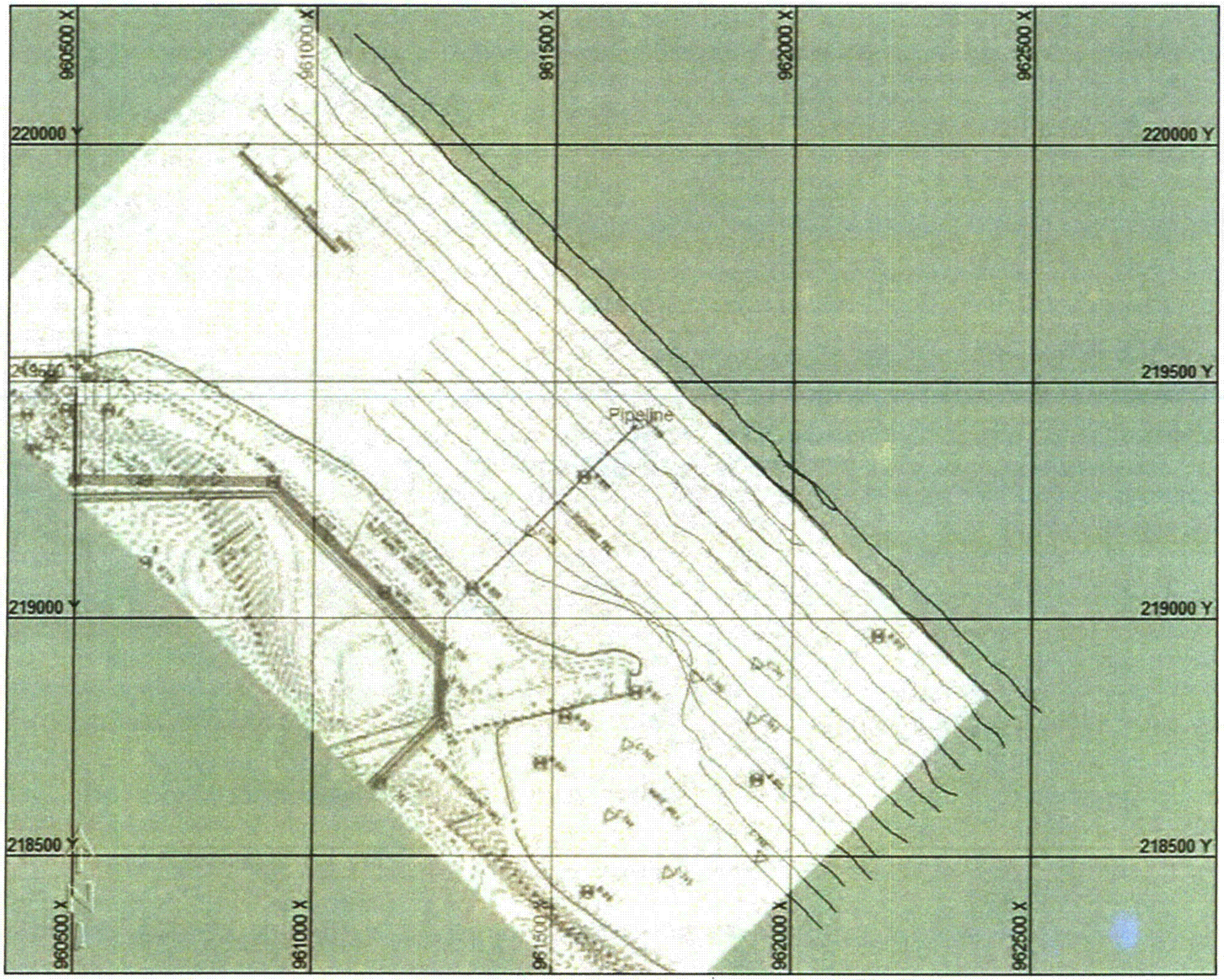

Figure 6. Proposed outflow pipe location and surveyed area (as presented in Faught 2009). Data presented in Maryland State Plane NAD27 feet.

Table 1. Magnetic anomalies located during the 2008 CCNPP survey.*†

Anomaly No.	Easting	Northing	Reading at target point	Deviation above background	Deviation below background	Duration (seconds)	Type
M01	961585.4	219742	51869.3	133	157	23	dipole
M02	962032.2	219302.7	51905.8	30	0	10	monopole
M03	962289.5	218826.3	51892.6	133	130	9	dipole
M04	962344.8	218770.1	51913.2	554	103	10	dipole
M05	962209.2	218842.9	51846.7	118	37	15	dipole
M06	961956.3	218874.2	51781.1	136	906	29	complex dipole
M07	962207.6	218549.6	52869.4	994	0	5	monopole
M08	962075.1	218551.7	51926.5	96	47	7	dipole
M09	961918.8	218630.7	51804.2	76	132	5	dipole

*As presented in Faught 2009.

†Data presented in Maryland State Plane NAD27 feet.

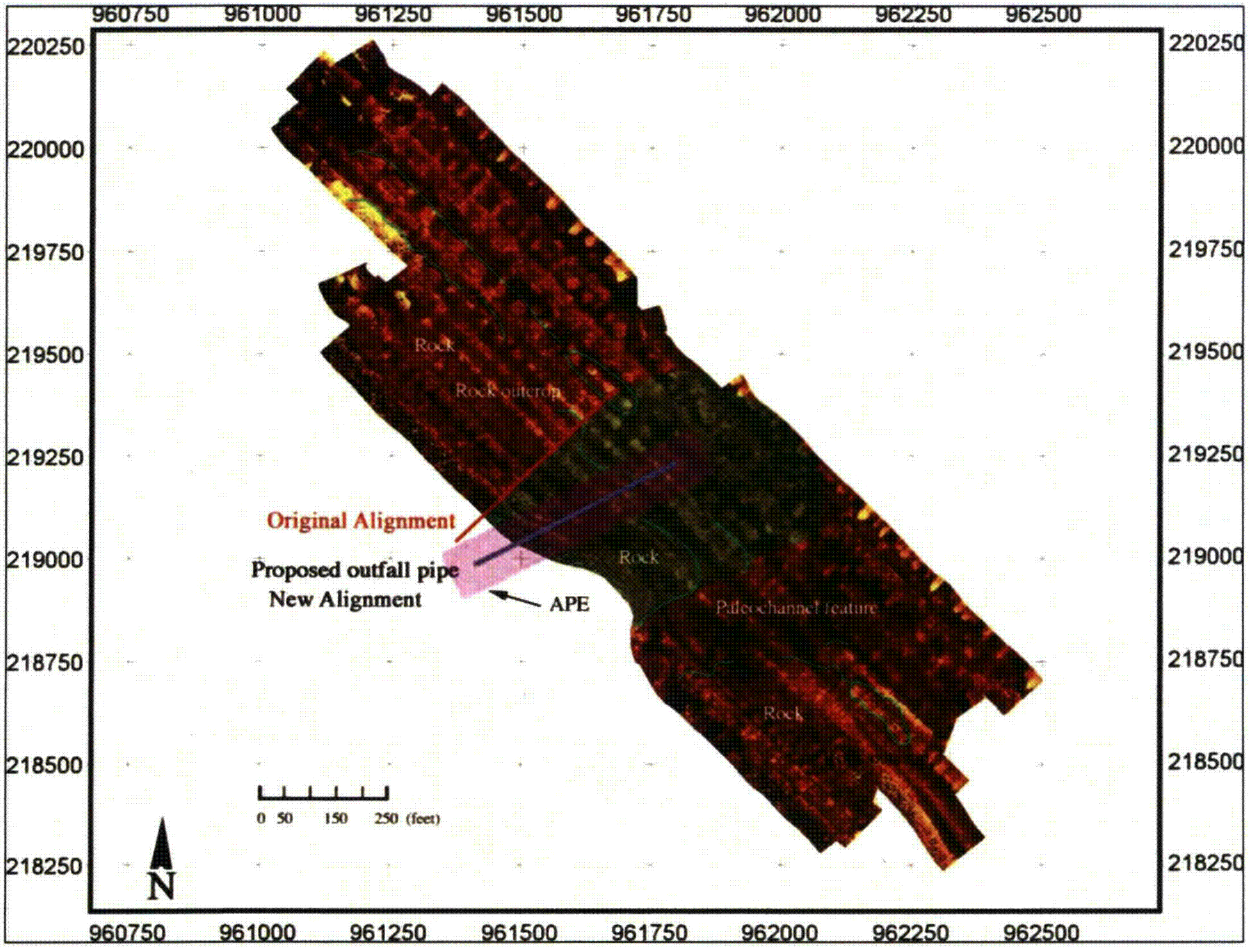

Figure 7. Location of possible paleochannel as determined during data analysis (as presented in Faught 2009). Data presented in Maryland State Plane NAD27 feet.

While initially determined to be non-significant in nature based on established criteria for magnetic analysis, including strength and duration, subsequent consultation with MHT resulted in the request that four of the magnetic anomalies—M03, M04, M05, and M06—be investigated further to determine their historical significance relative to NRHP criteria. This current report partially represents the results of this subsequent investigation as well as the survey of the additional area necessitated by the project redesign.

The data produced during the 2008 survey was reevaluated as part of the current investigation. This reevaluation was undertaken as a result of a significant discrepancy between the surveyed locations of anomalies M03, M04, M05, and M06 as presented in Faught 2009 and the locations of these anomalies as refined using the same remote sensing equipment during the current investigation. A reevaluation of both sidescan and subbottom data indicated no problems with acquisition or processing of either. However, reevaluation of the magnetic data indicated a failure to account for the correct instrument layback during the post-processing of the 2008 survey data. The proper layback, which should have been employed, but was not for the processing of the 2008 survey data, was 20 meters (65 feet). The data apparently were processed with zero layback, which introduced significant locational error into the presented magnetic contour map and the subsequent analysis of the magnetic data. This resulted in a larger number of magnetic anomalies than are actually present in the survey area, as well as inaccurate geographic locations for those that were present in the data. Figure 8 illustrates the 2008 anomalies as presented in Faught 2009 with the incorrect layback. Figure 9 illustrates the same

2008 anomalies overlaid on the corrected magnetic contour map. Figure 10 is a close up of Figure 9 showing just the four anomalies that are the subject of the current investigation.

Improper layback settings in the 2008 analysis necessitated re-plotting the anomalies detected in the data. Anomalies detected in the 2008 data, along with their locations (in Maryland State Plane NAD27 feet), are presented in Table 1 above. Table 2 presents the 2008 anomaly data as originally presented in Faught 2009, their original location data converted to Maryland State Plane NAD83 meters, and also the location data for the re-plotted anomalies in Maryland State Plane NAD83 meters. Original and layback-corrected locations are presented in Figure 11. Adjustment of the layback resulted in changes to the positions of nine anomalies. In the case of M04, layback adjustment resulted in its merging with M03 as a single anomaly (Figure 11). Going forward, reference to 2008 anomaly locations will refer to the corrected locations as presented in Table 2.

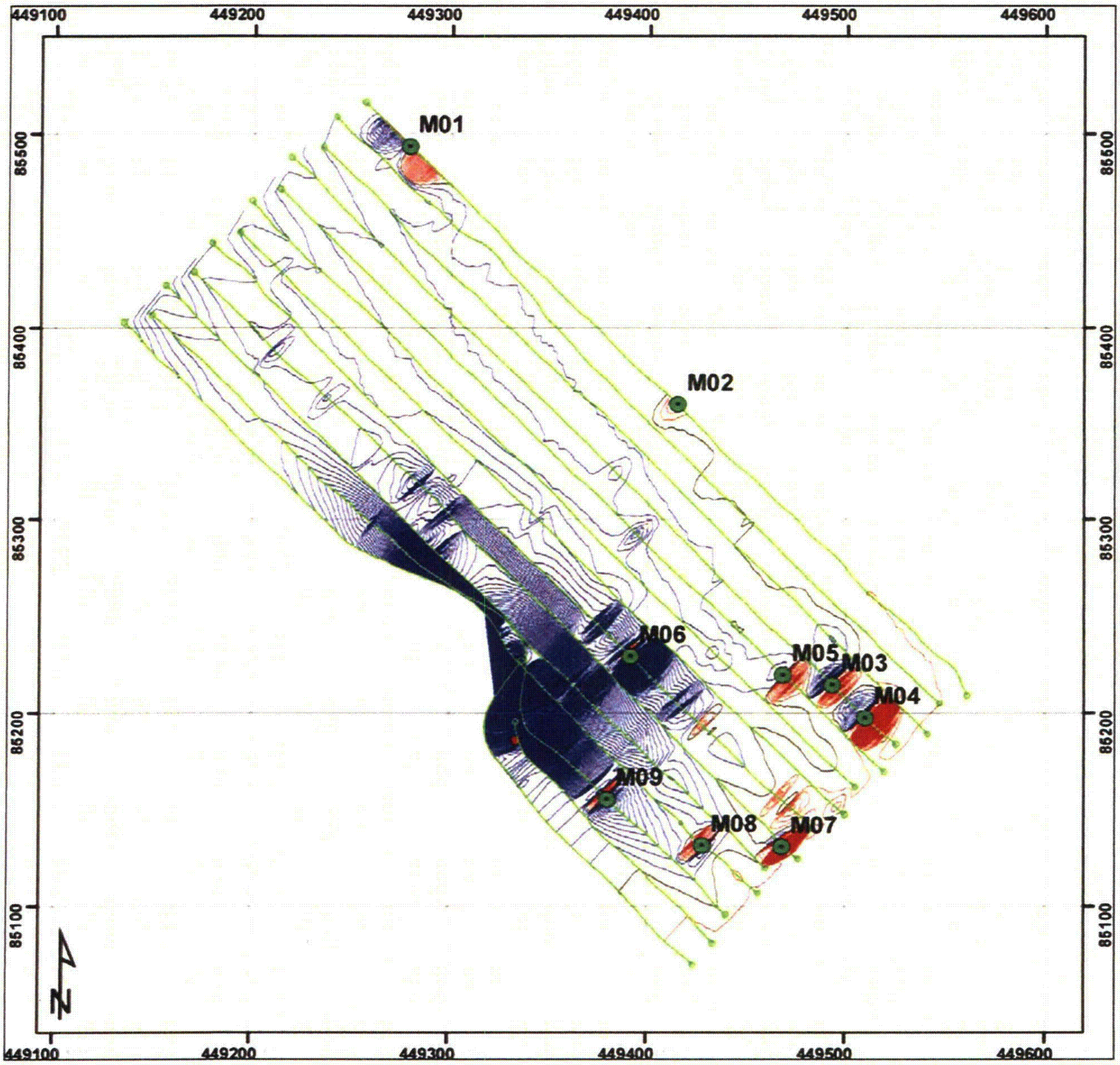

Figure 8. Contour of magnetic data from 2008 survey, processed with zero layback (as presented in Faught 2009). Data presented in Maryland State Plane NAD83 meters.

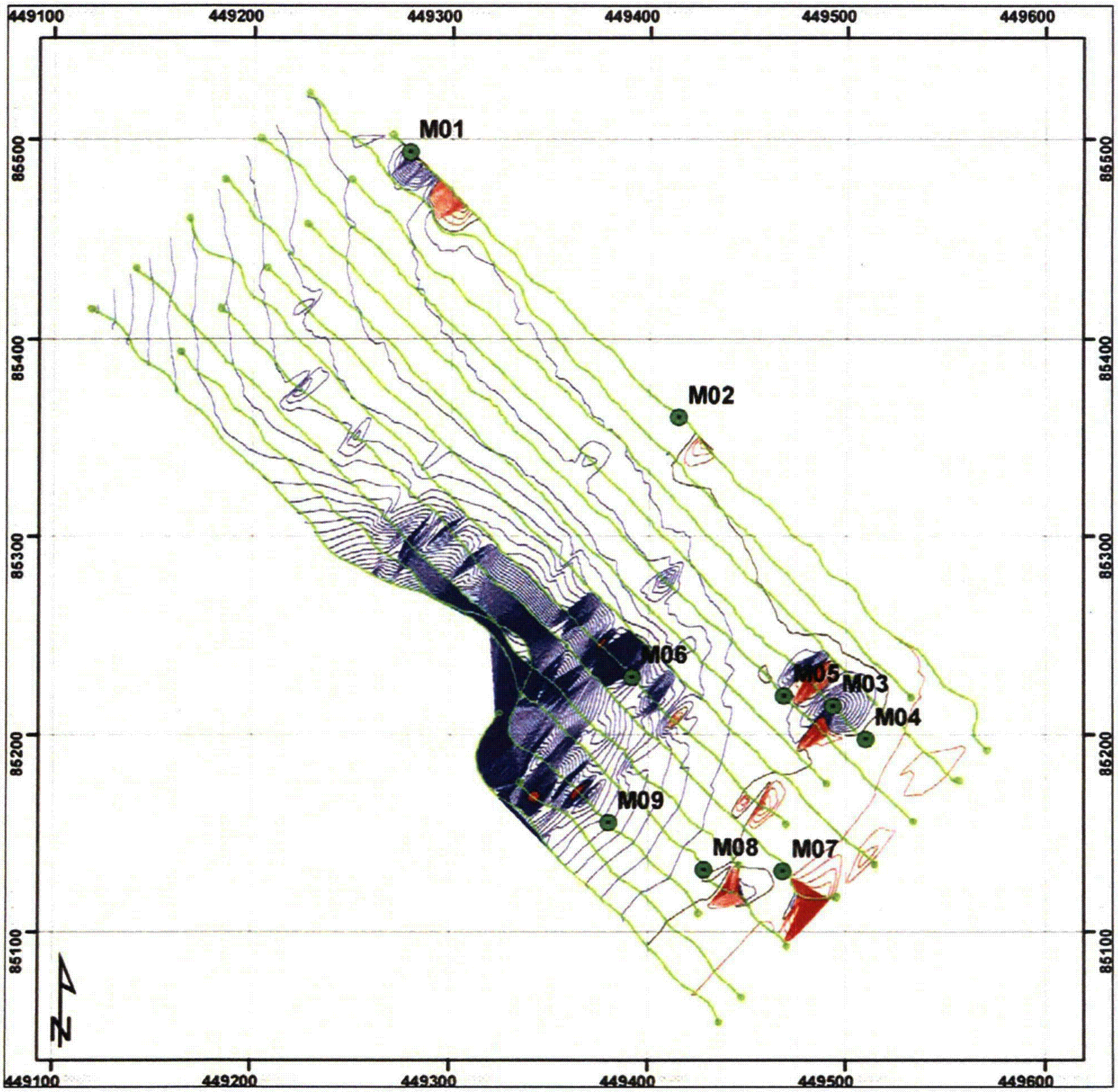

Figure 9. Contour of magnetic data from 2008 survey, processed with correct 20-meter (65-foot) layback with uncorrected anomaly locations as presented in Faught 2009. Data presented in Maryland State Plane NAD83 meters.

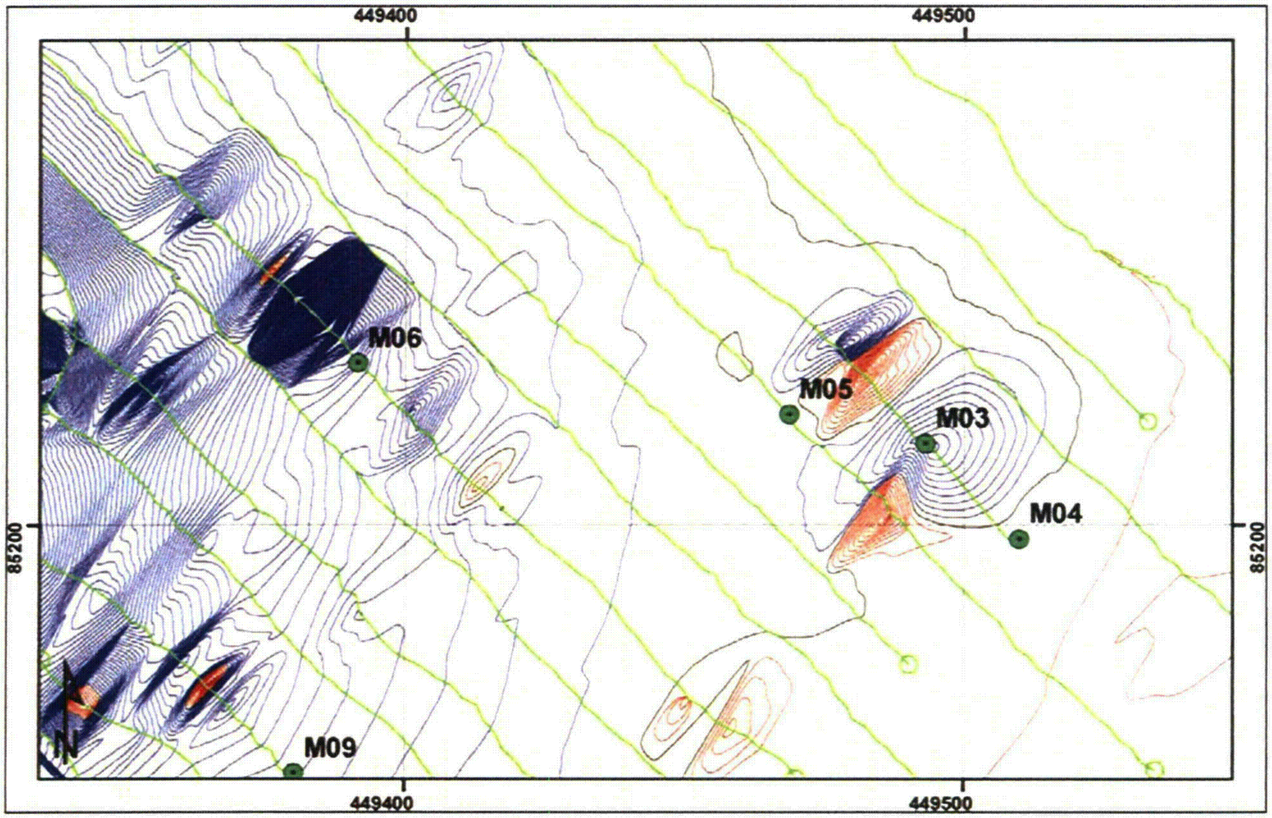

Figure 10. Contour of magnetic data from 2008 survey, processed with correct 20-meter (65-foot) layback, shown with uncorrected locations of recommended anomalies. Data presented in Maryland State Plane NAD83 meters.

Table 2. Original 2008 survey anomaly locations, reprojected 2008 anomalies, and anomaly locations replotted using correct instrument layback.

	Original location (Faught 2009) Maryland State Plane NAD27 feet		Original Location (Faught 2009) Maryland State Plane NAD83 meters		Corrected Location Maryland State Plane NAD83 meters	
Anomaly No.	Easting	Northing	Easting	Northing	Easting	Northing
M01	961585.4	219742	449278.5	85494.0	449293.2	85480.6
M02	962032.2	219302.7	449414.7	85360.1	449426.3	85347.5
M03	962289.5	218826.3	449493.0	85214.8	449490.0	85207.0
M04	962344.8	218770.1	449509.8	85197.7	--	--
M05	962209.2	218842.9	449468.6	85220.0	449479.3	85229.1
M06	961956.3	218874.2	449391.5	85229.4	449384.4	85237.3
M07	962207.6	218549.6	449468.2	85130.6	449482.7	85117.0
M08	962075.1	218551.7	449427.8	85131.2	449444.0	85119.7
M09	961918.8	218630.7	449380.2	85155.3	449364.1	85171.3

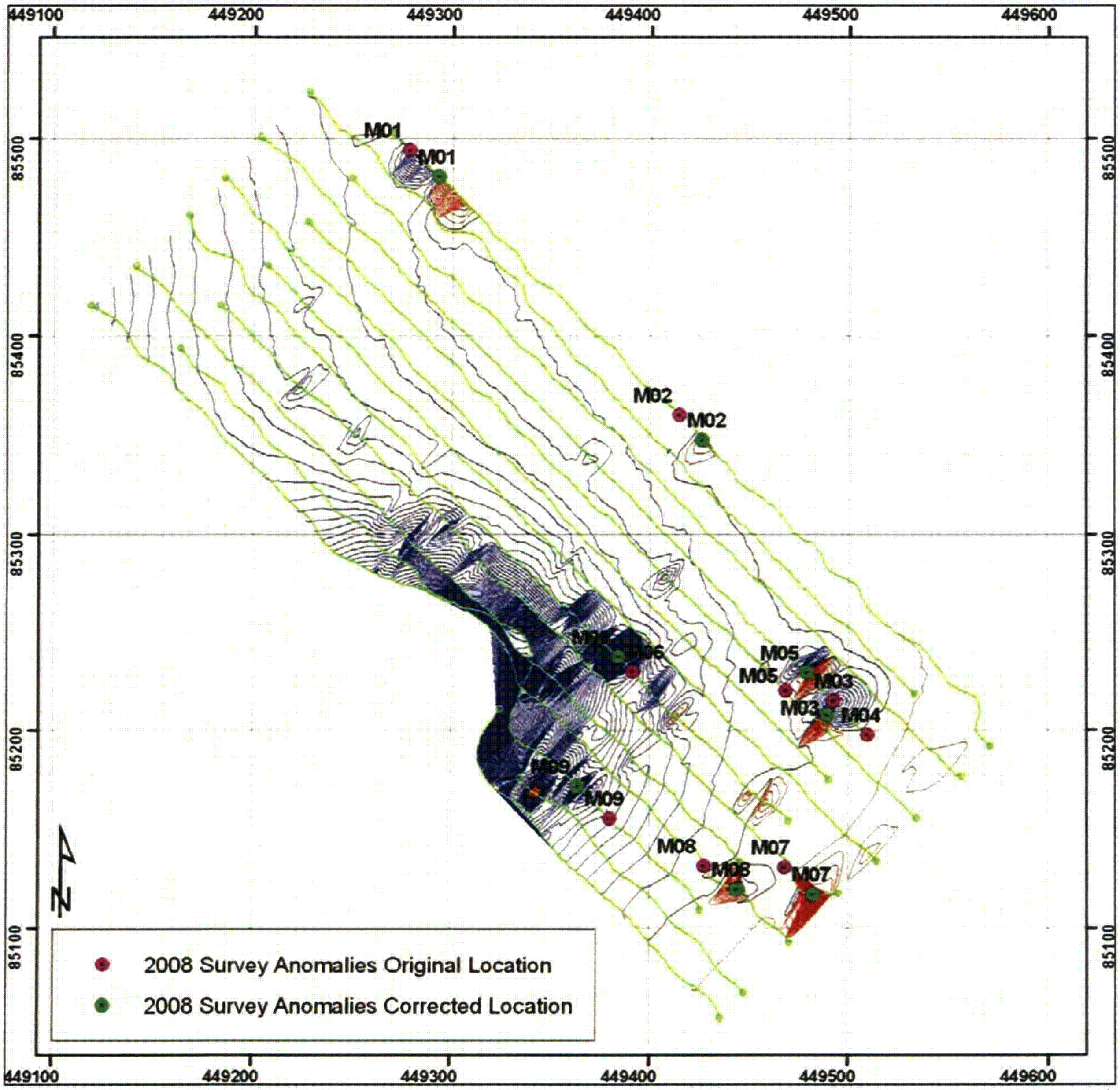

Figure 11. Original 2008 anomaly locations (Faught 2009) and corrected positions of 2008 anomalies plotted over layback-corrected magnetic contour map. Data presented in Maryland State Plane NAD83 meters.

Project Area Environment

Figure 12 conveys the environment of the project area and illustrates the working conditions of the survey area. Both the survey and diving operations were conducted at a time of relatively light winds and calm conditions. Vessel traffic was nonexistent with the exception of a scheduled tug and barge arrival.

Figure 12. Project area westward from survey vessel toward the barge dock area.

Project Personnel

The personnel assigned to this project met training and qualification requirements outlined in the U.S. Army Corps of Engineers Safety and Health Requirements Manual (EM 385-1-1). All team members were current in their Red Cross training for first aid, cardio-pulmonary resuscitation (CPR), and oxygen administration. Andrew D.W. Lydecker served as the maritime archaeologist. Lydecker is a maritime archaeologist with a graduate degree in Anthropology (Archaeology), and has extensive experience in remote sensing surveys. Jim Duff, Matt Elliott, and Michael Murray served as archaeological divers.

Safety was of paramount concern during the remote sensing and diving phases of this project. Panamerican personnel worked closely with safety personnel at CCNPP

Remote Sensing Survey Equipment

The remote sensing survey was conducted with equipment and procedures intended to facilitate the effective and efficient search for magnetic and/or sidescan sonar anomalies and to determine their exact location. The positioning system used was a Trimble DSM12/212, Integrated

12-channel Global Positioning System (DGPS). Remote sensing instruments included a Marine Magnetics SeaSPY overhauser magnetometer, a Marine Sonic Technology sidescan sonar, and an Edgetech 424 subbottom profiler system.

DIFFERENTIAL GLOBAL POSITIONING SYSTEM

A primary consideration in the search for magnetic anomalies is positioning. Accurate positioning is essential during the running of survey tracklines and for returning to recorded locations for supplemental remote sensing operations or ground-truthing activities. These positioning functions were accomplished on this project with a Trimble Navigation DSM12/212 global-based positioning system (Figure 13).

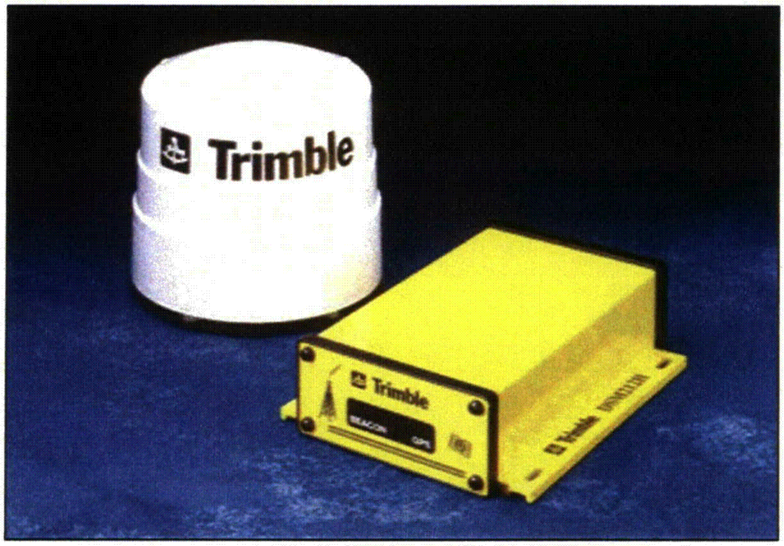

Figure 13. Trimble Navigation DSM 12/212 global-based positioning system used during the investigation.

The DSM12/212 is a GPS that attains differential capabilities by internal integration with a Dual-channel MSK Beacon receiver. This electronic device interprets transmissions both from satellites in Earth's orbit and from a shore-based station, to provide accurate coordinate positioning data for offshore surveys. This Trimble system has been specifically designed for survey positioning. The differential system corrects for the difference between received and known positions. The DGPS aboard the survey vessel constantly monitored the navigation beacon radio transmissions in order to provide a real-time correction to any variation between the satellite-derived and actual positions of the survey vessel.

For this project, the magnetometer and DGPS data were integrated with a Sony VAIO laptop computer via NMEA protocols, utilizing Hypack Max® software applications for survey control, data storage, and data analysis. Hypack Max® was developed specifically for marine survey applications by Coastal Oceanographics, Inc. The computer and associated hardware and software calculated and displayed the corrected positioning coordinates every second and stored the data along with magnetic readings at that location. The level of precision for the system is considered by the manufacturer to achieve sub-meter accuracy (Trimble Navigation Limited 1998:1-2).

Each of the remote sensing devices was measured for "layback," which is their orientation relative to the antenna (Figure 14). This information is critical in the accurate positioning of targets during the data analysis phase of the project and in repositioning for any subsequent archaeological activities. The magnetometer was run 15 meters (50 feet) off the stern, the sidescan amidships the port side, and the subbottom amidships the starboard side.

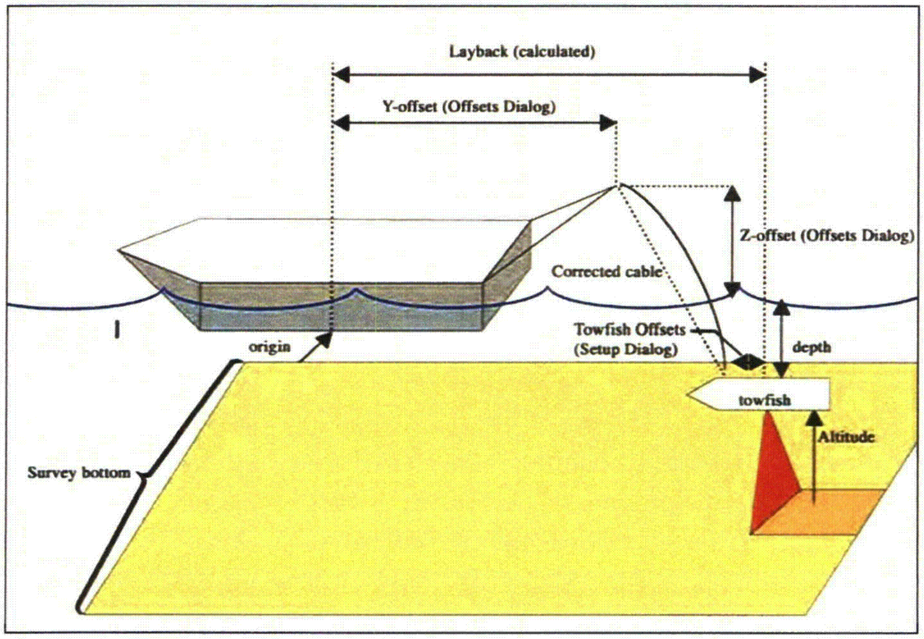

Figure 14. Equipment schematic illustrating layback (courtesy of Coastal Oceanographics, Inc.).

MAGNETOMETER

The remote sensing instrument used to search for ferrous objects on or below the ocean floor of the survey area was a Marine Magnetics SeaSPY overhauser magnetometer (Figure 15). The magnetometer is an instrument that measures the intensity of magnetic forces. The sensor measures and records both the Earth's ambient magnetic field and the presence of magnetic anomalies (deviations from the ambient background) generated by ferrous masses and various other sources. These measurements are recorded in nanoteslas, the standard unit of magnetic intensity (equal to 0.00001 gauss). The SeaSPY is capable of sub-second repeatability, but data was collected at 1-second intervals both digitally and graphically, providing a record of both the ambient field and the character and amplitude of anomalies encountered. This data was stored electronically in the navigation computer and backed up to CD-ROM.

The ability of the magnetometer to detect magnetic anomalies, the sources of which may be related to submerged cultural resources such as shipwrecks, has caused the instrument to become a principal remote sensing tool of marine archaeologists. While it is not possible to identify a specific ferrous source by its magnetic field, it is possible to predict shape, mass, and alignment characteristics of anomaly sources based on the magnetic field recorded. It should be noted that there are other sources—electrical magnetic fields surrounding power transmission lines, underground pipelines, navigation buoys, metal bridges and structures—that may significantly affect magnetometer readings. Interpretation of magnetic data can provide an indication of the likelihood of the presence or absence of submerged cultural resources. Specifically, the ferrous components of submerged historic vessels tend to produce magnetic signatures that differ from those characteristics of isolated pieces of debris.

While it is impossible to specifically identify the source of any anomaly solely from the characteristics of its magnetic signature, this information, in conjunction with other data (historic accounts, use patterns of the area, diver inspection), other remote sensing technologies, and prior knowledge of similar targets, can lead to an accurate estimation. For this project, the height of the magnetometer above the seafloor was within 3 meters (10 feet) of the bottom, and line spacing was 15 meters (50 feet), thus ensuring total horizontal coverage.

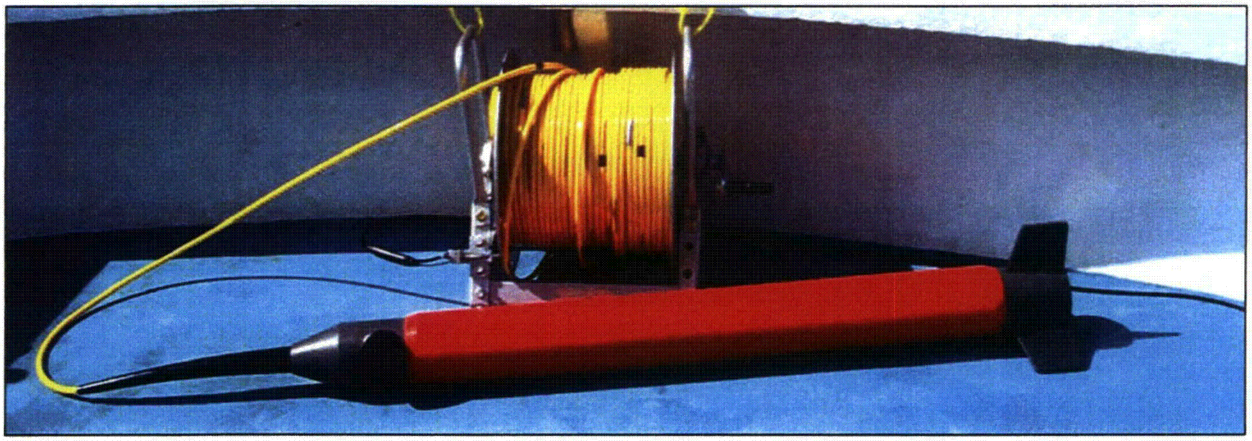

Figure 15. Marine Magnetics SeaSPY overhauser magnetometer used during the survey.

SIDESCAN SONAR

The remote sensing instrument used to search for physical features on or above the ocean floor was a Marine Sonic Technology (MST) Sea Scan sidescan sonar system (Figure 16). The sidescan sonar is an instrument that, through the transmission of dual fan-shaped pulses of sound and reception of reflected sound pulses, produces an acoustic image of the bottom. Under ideal circumstances, the sidescan sonar is capable of providing a near-photographic representation of the bottom on either side of the trackline of a survey vessel. This range was set at 40 meters during the Calvert Cliffs survey.

The MST Sea Scan sidescan sonar unit utilized on this project was operated with an integrated single frequency 600 kHz towfish. The Sea Scan PC software has an internal capability for removal of the water column from the instrument's video printout, as well as correction for slant range distortion. This sidescan sonar was utilized with the navigation system to provide manual marking of positioning fix points on the digital printout. Sidescan sonar data are useful in searching for the physical features indicative of submerged cultural resources. Specifically, the record is examined for features showing characteristics such as height above bottom, linearity, and structural form. Additionally, potential acoustic targets are checked for any locational match with the data derived from the magnetometer and the subbottom profiler.

The MST Sea Scan PC software sidescan sonar was linked to a towfish that employed a 600 kHz power setting and a variable side range of up to 100 meters-per-channel (meters/channel; 200 meters of coverage per line) on each of the run sidescan lines. The 40 meters/channel setting was chosen to provide detail and enough overlapping coverage with the 15-meter (50-foot) line spacing to insure full coverage of the survey area. The power setting was selected in order to provide maximum possible detail on the record generated; 600 kHz was the preferred frequency. The 40 meters/channel selection made it possible to collect acoustic data over an 80-meter wide area on each line that the sidescan sonar was employed, ensuring multiple overlap and multiple views of any targets.

The sidescan sonar record included 71 files of data, which were mosaiced on the project grid using Hypack Hyscan® software. These images were combined with other data in ArcMap 9.2®.

Figure 16. Marine Sonic Technology (MST) Sea Scan sidescan sonar system.

SUBBOTTOM PROFILER

The survey crew deployed an Edgetech 424 multiple frequency towfish with topside processor (Figure 17). This system included a Model 3100-G Topside Processor with laptop computer and DISCOVER Subbottom software.

Subbottom profilers generate low frequency acoustic waves capable of penetrating the seabed and then reflecting off boundaries or objects within the subsurface. These returns are received by hydrophone or hydrophone array operated in close proximity to the source. The data are then processed and reproduced as a cross section scaled in two-way travel time (the time taken for the pulse to travel from the source to the reflector and back to the receiver). This travel time can then be interpolated to depth in the sediment column by reference to the travel time of the sound (averaging 1,500 meters-per-second). These seismic cross sections can be studied visually and the shapes and extent of reflectors used to identify bottom and subbottom profile characteristics.

There are several types of subbottom profilers: sparkers, pingers, boomers, and CHIRP systems. Sparkers operate at the lowest frequencies and afford deep penetration but low resolution. Boomers operate from 0.5–5 kHz and can penetrate to between 30–100 meters with resolution of 0.3–1.0 meter. Pingers operate from 3.5–7 kHz and penetrate seabeds from a few meters to more than 50 meters depending on sediment consolidation, with resolution to about 0.3 meter. CHIRP systems operate around a central frequency that is swept electronically across a range of frequencies between 3–40 kHz and resolution can be on the order of 0.1 meter in suitable near-seabed sediments. The Edgetech system used for the Calvert Cliffs survey was operated at a range of 4–16 kHz for best penetration of sand.

Unconformities and other strata contacts can be determined by seismic remote sensing since these surfaces make acoustic impedance contrasts when printed (or projected). In general, high and low amplitude reflectors (light and dark returns) indicate the presence of stratigraphic beds while parabolic returns indicate point source objects of sufficient size to be sensed by the wavelength and frequency of the power source. Erosional or non-depositional contacts can be identified by discontinuities in extent, slope angle, and shape of the reflector returns. This latter fact is important when identifying drowned channel systems and other relict and buried fluvial system features (e.g., estuarine, tidal, lowland, upland areas around drainage features).

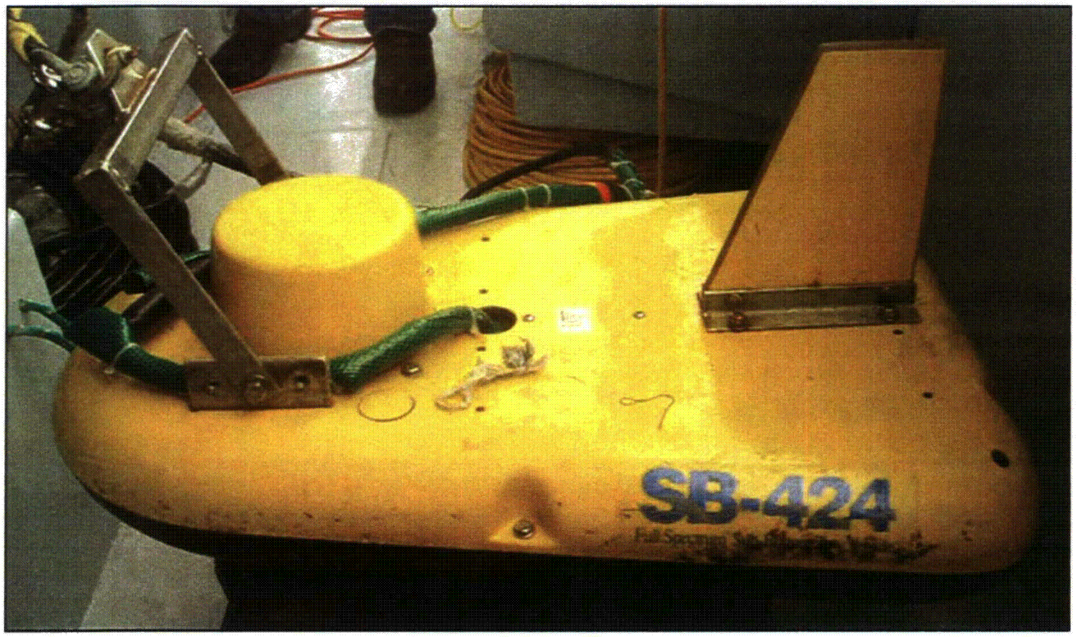

Figure 17. The EdgeTech subbottom 424 towfish employed in the survey.

There are five types of spurious signals that may cause confusion in the two dimensional records: direct arrivals from the sound source, water surface reflection, side echoes, reflection multiples; and point source reflections. Judicious analysis is required to identify them.

Sand is notoriously difficult to penetrate with frequencies equal to 4 kHz or higher. Much of the Calvert Cliffs sediment beds appear to be sand or pebbly sand, and sedimentary rocks probably composed of sand. There was no need to penetrate these beds because of their age.

SURVEY VESSEL

The vessel used for the survey was Panamerican's 7.5-meter (25-foot) *Parker* (Figure 18). The vessel meets all U.S. Coast Guard requirements for safety equipment. There is abundant covered deck space for the electronic gear, generator, and towfish. Mr. Duff drove the vessel during the remote sensing operations.

Figure 18. Panamerican's 7.5-meter (25-foot) *Parker* employed for the investigation.

Figure 19. Survey instruments employed during the investigation include (from left to right) the subbottom profiler, the sidescan sonar and the magnetometer. Honda generator employed to power the instruments is in the background adjacent to the transom.

SURVEY PROCEDURES

Coordinates for the proposed survey area were entered into the navigation program Hypack® and pre-plotted tracklines were produced (Figure 20). Nine pre-plotted tracklines with a 15-meter (50-foot) interval were programmed to adequately obtain total horizontal coverage for the additional area.

The magnetometer, sidescan sonar, and DGPS were mobilized and tested; finding them operational, the running of pre-plotted tracklines began. The helmsman viewed a video monitor linked to the DGPS and navigational computer to aid in directing the course of the vessel relative to the individual survey tracklines. The monitor displayed the real-time position of the path of the survey vessel along the trackline.

As the survey vessel maneuvered down each trackline, the navigation system determined vessel position along the actual line of travel every second. One computer recorded positioning and magnetometer data every second while a separate computer recorded all sidescan sonar returns during the survey. Vessel speed was maintained between 3 and 5 miles-per-hour, acquiring magnetic readings every second. The positioning points along the line traveled were recorded on the computer hard drive and the magnetic data were stored digitally.

Each trackline was run until completed. Any navigation errors, problems with the remote sensing instruments or with the positioning system during the running of a line resulted in the termination of that run. Significant off-line errors in navigation resulted in the immediate repetition of that line. Problems with remote sensing instruments were resolved before repeating the run of an aborted line. Upon completion of the magnetometer survey, the raw positioning and magnetometer data were edited within Hypack®. The edited file was input into the system's contouring program to produce magnetic contour maps. The maps, field notes, and magnetometer digital strip charts were then analyzed to create a list of magnetic anomalies that were indicative of potentially significant cultural resources. Afterwards, the sidescan sonar data was reviewed for any evidence of submerged cultural resources.

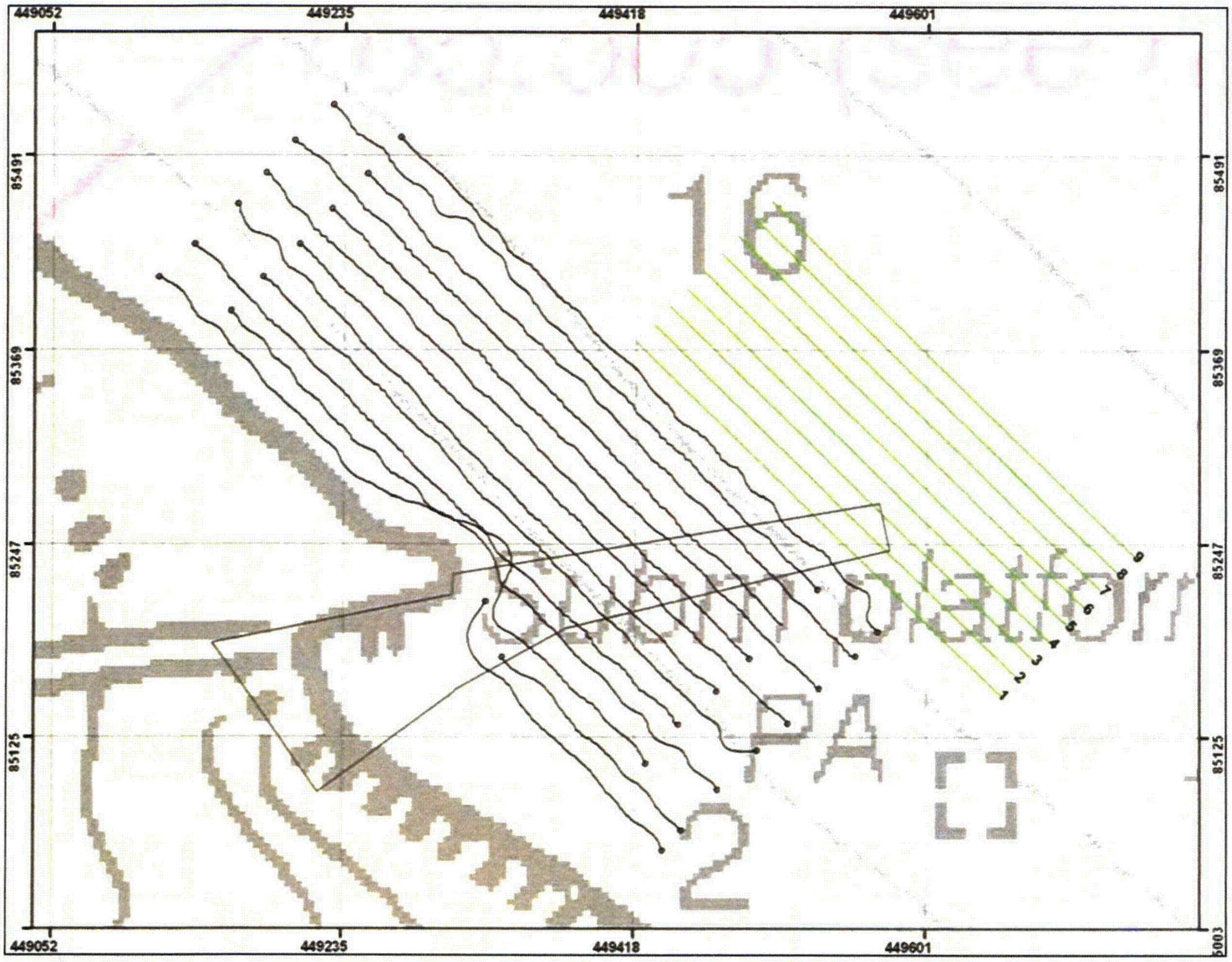

Figure 20. Nine pre-plot tracklines with 15-meter (50-foot) offsets were programmed for the additional Calvert Cliffs remote sensing survey area. Black lines indicate the previously surveyed area and the grey polygon indicates the maximum dredge area. As indicated on the map, gridlines are spaced at 152.5 meters (500 feet). Data presented in Maryland State Plane, NAD83, meters.

It should be stated that before contour map production, a review of each survey trackline is conducted in Hypack®. Magnetic anomalies present on each survey trackline are labeled at this time, and locational information (Easting, Northing) and nanotesla deviations are taken from the electronic strip chart data and tabulated, the data table appearing in the report. Once all survey tracklines have been analyzed and all anomalies along each line have been labeled and tabulated, the contour map is produced.

The locations of targets found during the 2008 survey were resurveyed as part of the current project in order to relocate them and to further refine their locations.

Refinement Survey Procedures

Prior to diving investigations, geophysical remote sensing refinement surveys were conducted at each of the three 2008 targets. Spaced at approximately 7.5-meter (25-foot) intervals and centered on the target coordinates, survey lines were conducted to effectively cover the area surrounding each target (Figure 21). The magnetometer, subbottom, and DGPS were mobilized, tested, and found operational, and the trackline running began. The helmsman viewed the video monitor linked to the DGPS and navigational computer to aid in directing the course of the vessel along survey tracklines over and parallel to each target. The speed of the survey vessel was maintained at approximately 3–4 knots for the uniform acquisition of data. As the survey vessel maneuvered down each trackline, the navigation system monitored the position of the survey vessel relative to the tracklines every second, each of which was recorded by the computer. Event marks delineated the start and end of each trackline. The positioning points along the traveled line were recorded on the computer hard drive and the magnetic and subbottom data was also stored digitally.

Once the refinement survey was completed, a refinement magnetic contour map was produced. Based on proven principles of magnetism, the source material for a dipole anomaly is located directly between the positive and negative fields (Figure 21). Buoys were placed at this refined source material location between the positive and negative contours for each anomaly as illustrated in Figure 22.

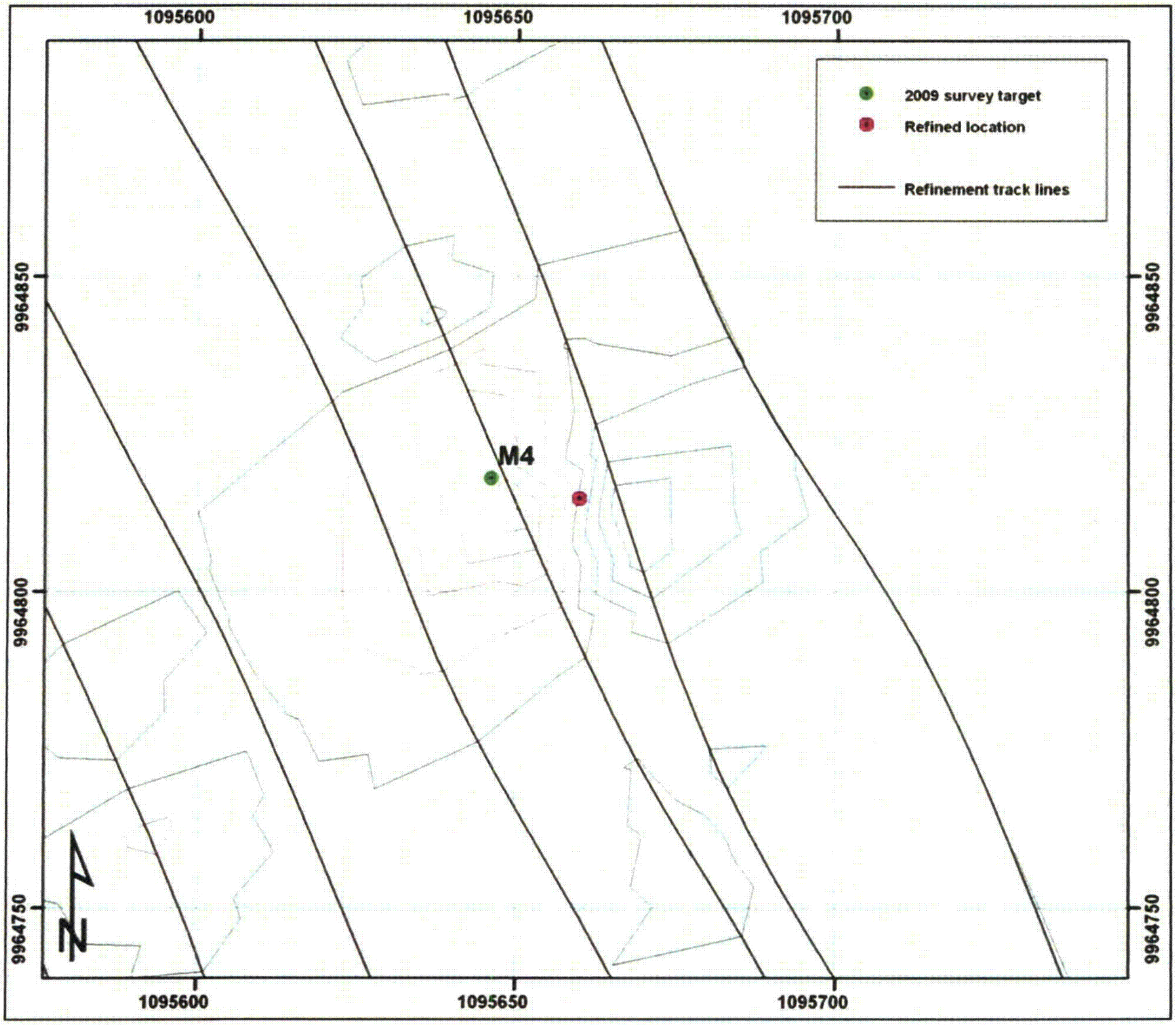

Figure 21. Example of refinement survey transects as employed during the refinement of 2008 survey targets. Transects at Calvert Cliffs were oriented in a N-S direction.

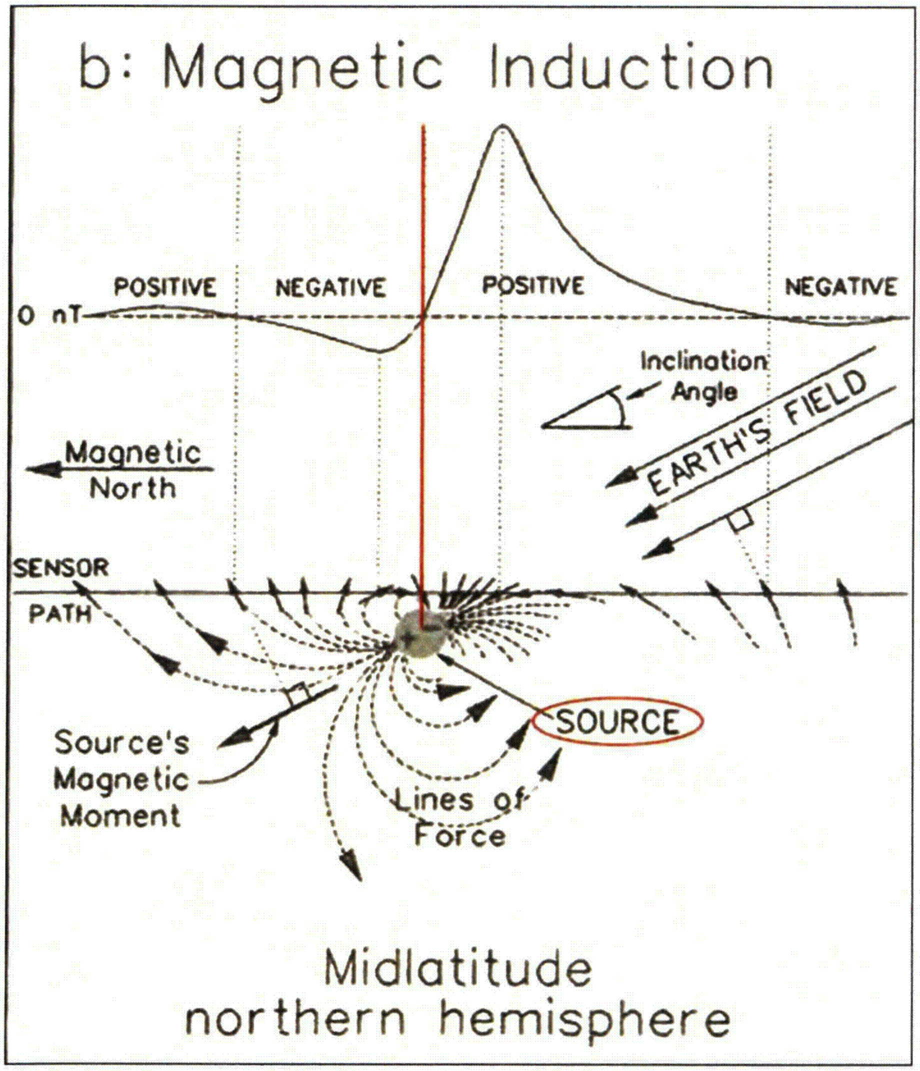

Figure 22. Location of source material between positive and negative magnetic readings of a dipole (as presented in Gearhart 2011:94).

DATA PROCESSING AND ANALYSIS

Once collected, survey data was processed and analyzed using an array of software packages designed to display, edit, manipulate, map, and compare proximities of raster, vector, and tabular data. These packages include Hypack® Hyscan for mosaicing sidescan sonar and subbottom profiler data, mapping target extents and generating target reports, figure details, and GIS layers; and Hypack® Single Beam Editor, Hypack® TIN Modeler, and Hypack® Export for tabulating anomaly characteristics and contouring magnetic data, and generating GIS data layers. ESRI ArcMap and ArcView are used to display the data on background charts, to conduct a "proximity analysis" for each of the three types of targets, and to create maps and figures.

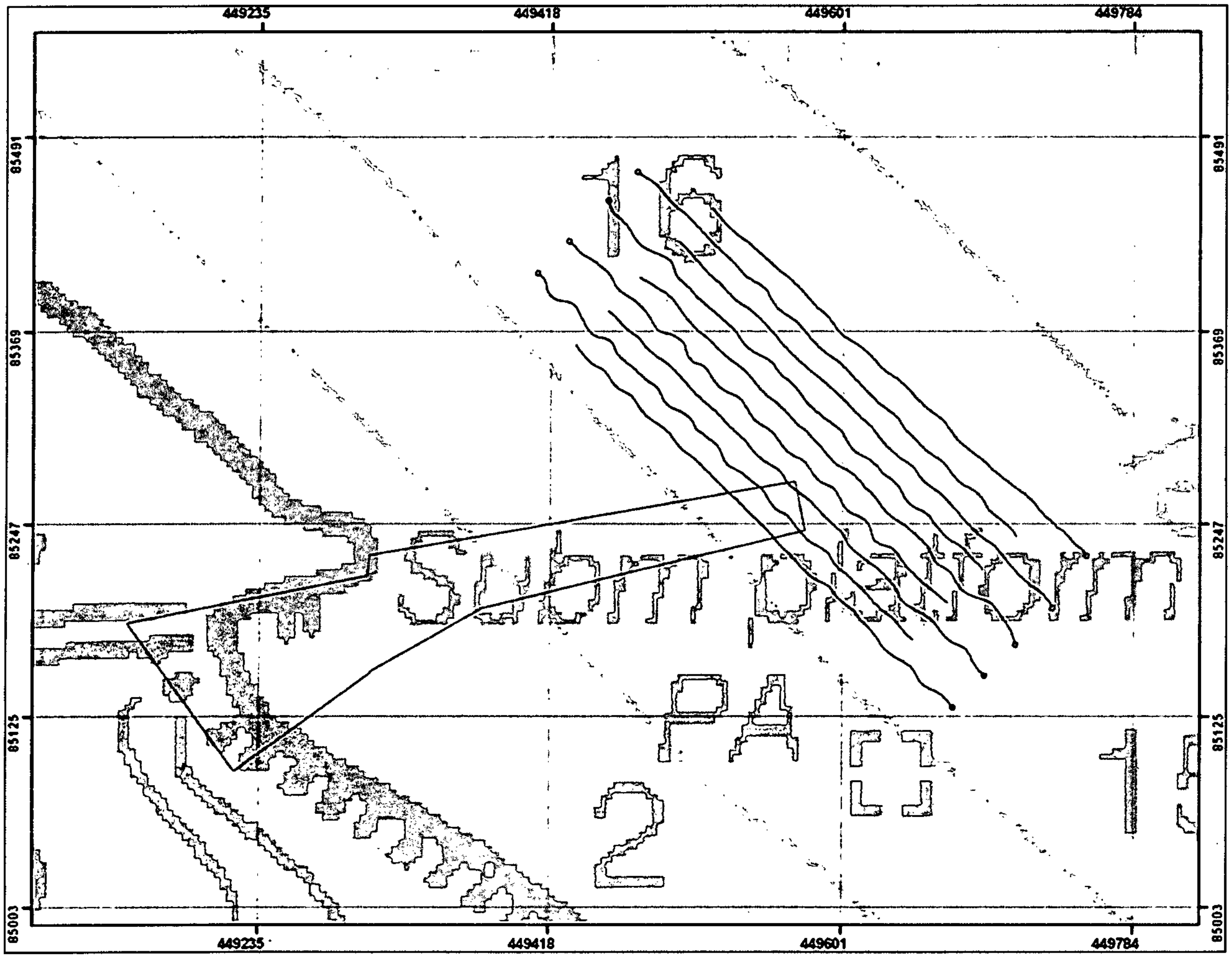

Figure 23. Post-plot survey lines. As indicated on the map, gridlines are spaced at 152.5 meters (500 feet). Data presented in Maryland State Plane, NAD83, meters.

Upon completion of the remote sensing survey, the data were reviewed. This task essentially entailed the archaeologist analyzing the previously acquired and processed data. Sidescan and subbottom features and magnetic anomalies were tabulated and prioritized as to possible significance by employing signal characteristics (e.g., spatial extent, structural features, etc.). Magnetic data was presented in a magnetic contour map(s) with trackline format. Specific sidescan targets are also located on the map and are illustrated and discussed individually. The magnetic anomalies and/or sidescan targets shown on the map(s) are sequentially numbered and tabulated as to location (Northing and Easting), as well as magnetic deviation. The contoured/labeled targets are then compared with strip chart records and attendant sidescan data. Each magnetic anomaly or sidescan target, described with the proper terminology and locational and positional information, is included. If any of the remote sensing targets correlated with any documentary evidence, it was noted.

The evaluation of the potential cultural significance of targets was then conducted, which was dependent on a variety of factors including the detected characteristics of the individual targets (e.g., magnetic anomaly strength and duration, and sidescan image configuration), association with other sidescan or magnetic targets on the same or adjacent lines, relationships to observable target sources such as channel buoys or pipeline crossings, and correlation to the historic record. Magnetic anomalies were evaluated and prioritized based on amplitude or deflection intensity in concert with duration or spatial extent. Targets such as isolated sections of pipe can normally be immediately discarded as nonsignificant. Targets that were likely to represent potential historical shipwrecks or other potentially historic submerged resources were identified, and recommendations were made for subsequent avoidance or assessment by archaeological divers.

MAGNETIC DATA COLLECTION, PROCESSING, AND ANALYSIS

Data from the magnetometer is collected using Hypack Max® and stored as *.RAW files by line, time, and day. Raw data files are opened, and layback parameters are set. Contour maps are produced of the magnetic data with the TIN Modeler. The DXF file is saved and exported into the combined GIS database. The contour maps allow a graphic illustration of anomaly locations, spatial extent, and association with other anomalies. Magnetic data is reviewed by the Hypack® Single Beam Editor (Figure 24), and the location, strength, duration, and type of anomaly is transcribed to a spreadsheet along with comments.

Interpretation of data collected by the magnetometer is perhaps the most problematic to analyze. Magnetic anomalies are evaluated and prioritized based on magnetic amplitude or deflection of nanotesla intensity in concert with duration or spatial extent; they are also correlated with sidescan targets. The problems of differentiating between modern debris and shipwrecks based on remote sensing data have been discussed by a number of authors. This difficulty is particularly true in the case of magnetic data, therefore it has received the most attention in the current body of literature dealing with the subject. Pearson and Saltus state, "even though a considerable body of magnetic signature data for shipwrecks is now available, it is impossible to positively associate any specific signature with a shipwreck or any other feature" (1990:32). There is no doubt that the only positive way to verify a magnetic source object is through physical examination. With that said, however, the size and complexity of a magnetic signature does provide a usable key for distinguishing between modern debris and shipwreck remains (see Garrison et al. 1989; Irion et al. 1995; Pearson et al. 1993). Specifically, the magnetic signatures of most shipwrecks tend to be large in area and tend to display multiple magnetic peaks of differing amplitude.

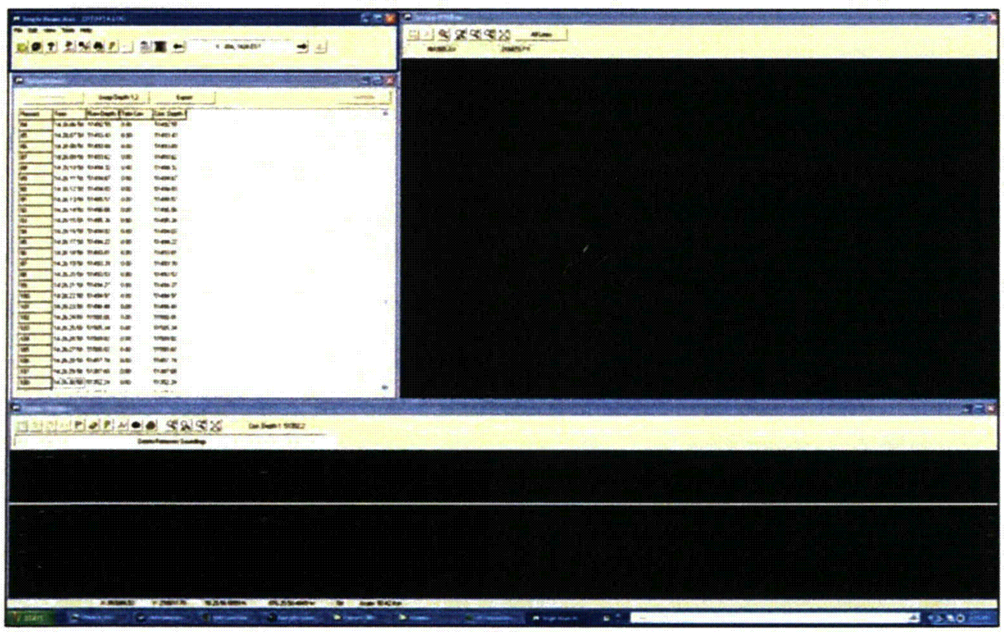

Figure 24. Hypack® Single Beam Editor magnetic data display of a survey line. Using these windows, one can analyze anomaly position, strength, duration, and type. The peaks of these variations are the locations of anomaly coordinates (cross in circle); their width is the duration. This anomaly is a dipole with a magnetic deviation of 156 nanoteslas. It comprises the large central anomaly of M101.

The state of technology of iron-hulled or steam vessels may also be considered a factor in their potential for being detected by modern remote sensing techniques. The magnetometer detects ferrous objects that create deviations in the Earth's natural magnetic field. The greater the weight of iron in the remains of a shipwreck, the greater the likelihood the remains will be observed, at least theoretically. The mass of metal on iron-hulled or steam vessels is made up of the hull and/or boilers, pipes, valves, steam engines, hogging trusses and straps, deck gear, auxiliary engines, pumps, hoists, winches, and other pieces of equipment. As the state of steam technology advanced, boilers and engines got larger, and/or more were used for larger vessels. Larger locomotion systems contained more iron and therefore are more likely to have a detectable magnetic signature.

In a study of magnetic anomalies located in the northern Gulf of Mexico, Garrison et al. (1989) indicate that a shipwreck signature will cover an area between 10,000–50,000 meters squared. Applicable to the Gulf Coast and based on large vessel types, the study's findings are not entirely relevant to wooden sailing vessels in the pre-steam era. However, criteria from the Garrison et al. (1989) study and others developed to identify the signatures of larger vessel types are applicable. Using the Garrison et al. (1989) study, as well as years of "practical experience," in an effort to assess potential significance of remote sensing targets, Pearson et al. (1991) developed general characteristics of magnetometer signatures most likely to represent shipwrecks. The report states, "the amplitude of magnetic anomalies associated with shipwrecks vary [*sic*] considerably, but, in general, the signature of large watercraft, or portions of watercraft, range from moderate to high intensity (>50 nanoteslas) when the sensor is at distances of [6 meters] 20 feet or so" (Pearson et al. 1991:70). Using a table of magnetic data from various sources as a base, the report goes on to assert, "data suggest that at a distance of [6 meters] 20 feet or less watercraft of moderate size are likely to produce a magnetic anomaly (this would be a complex signature, i.e., a cluster of dipoles and/or monopoles) greater than [24 or 27.5 meters] 80 or 90 feet across the smallest dimension..." (Pearson et al. 1991:70).

While establishing baseline amounts of amplitude and duration reflective of the magnetic characteristics for a shipwreck site, Pearson et al. recognize, "that a considerable amount of variability does occur" (1991:70). Generated in an effort to test the 50-nanotesla/24.5-meter (80-foot) criteria and determine the amount of variability, Table 3 lists numerous shipwrecks as well as single- and multiple-source objects located by magnetic survey and verified by divers. All shipwrecks meet and surpass the 50-nanotesla/24.5-meter (80-foot) criteria, while all single-source object readings, with the exception of the pipeline, fall below the criteria. However, the signature of the pipeline should show up as a linear feature on a magnetic contour map and not be confused with a single-source object. While the shipwrecks and single-source objects adhere to the 50-nanotesla/24.5-meter (80-foot) criteria, the multiple-source objects do not. If all targets listed on the table had to be prioritized as to potential significance based on the 50-nanotesla/ 24.5-meter (80-foot) criteria, the two multiple-source object targets would have to be classified as potentially significant.

Table 3. Magnetic data from shipwrecks and nonsignificant sources.*‡

Vessel (object)	Type & Size	Magnetic deviation	Duration (meters)	Reference
Shipwrecks				
Tug	wooden tug with machinery	-30257	53.5	Tuttle and Mitchell 1998
Mexico	288-ton wooden bark	1260	138	Tuttle and Mitchell 1998
J.D. Hinde	39-meter (129-foot) wooden sternwheeler	573	33.5	Gearhart and Hoyt 1990
Utina	81-meter (267-foot), 238-ton wooden freighter	690	46	James and Pearson 1991; Pearson and Simmons 1995

Vessel (object)	Type & Size	Magnetic deviation	Duration (meters)	Reference
King Phillip	55.5-meter (182-foot), 1,194-ton clipper	300	61	Gearhart 1991
Reporter	43-meter (141-foot), 350-ton schooner	165	49	Gearhart 1991
Mary Somers	967-ton iron-hulled sidewheeler	5000	122	Pearson et al. 1993
Gen. C.B. Comstock	53-meter (177-foot) wooden hopper dredge	200	61	James et al. 1991
Mary	71-meter (234-foot) iron sidewheeler	1180	61	Hoyt 1990
Columbus	42-meter (138-foot), 416-ton wooden-hulled Chesapeake sidewheeler	366	91.5+	Morrison et al. 1992
El Nuevo Constante	38.5-meter (126-foot) wooden collier	65	76	Pearson et al. 1991
James Stockton	17-meter (55-foot) wooden schooner	80	40	Pearson et al. 1991
Homer	45-meter (148-foot) wooden sidewheeler	810	61	Pearson and Saltus 1990
Modern shrimp boat	8-x-1.5-meter (27-x-5-foot) segment	350	27.5	Pearson et al. 1991
Confederate obstructions	various wooden vessels w/ machinery removed, filled w/ construction rubble	110	long duration	Irion and Bond 1984
Single-Source Objects				
pipeline	0.5-meter (18-inch) diameter	1570	61	Duff 1996
anchor	2-meter (6-foot) shaft	30	82	Pearson et al. 1991
iron anvil	150 pounds	598	8	Pearson et al. 1991
engine block	modern gasoline	357	18	Rogers et al. 1990
steel drum	55-gallon	191	10.5	Rogers et al. 1990
pipe	2.5-meter (8-foot) long, 7.5-centimeter (3-inch) diameter	121	12	Rogers et al. 1990
railroad rail segment	1-meter (4-foot) section	216	12	Rogers et al. 1990
Multiple-Source Objects				
anchor/wire rope	2.5-meter (8-foot) modern stockless/large coil	910	42.5	Rogers et al. 1990
cable and chain	1.5-meter (5-foot)	30	15	Pearson et al. 1991
scattered ferrous metal	4-meter (14-foot)	100	33.5	Pearson et al. 1991

*Data presented in Maryland State Plane, NAD83, meters.

‡After Pearson et al. 1991

Although data indicate the validity of employing the 50-nanotesla/24-meter (80-foot) criteria when assessing magnetic anomalies, other factors must be taken into account. Pearson and Hudson (1990) have argued that the past and recent use of a body of water must be an important consideration in the interpretation of remote sensing data, and in many cases it is the most important criterion. Unless the remote sensing data, historical record, or specific environment (e.g., harbor entrance channel) provide compelling and overriding evidence to the contrary, it is believed that the history of use should be a primary consideration in interpretation. What constitutes "compelling evidence" is to some extent left to the discretion of the researcher; however, in settings where modern commercial traffic and historic use are intensive, the presence of a large quantity of modern debris must be anticipated. In harbor, bay, or riverine situations with heavy traffic, this debris will be scattered along the channel right-of-way, although it may be concentrated at areas where traffic would slow or halt; it will appear on remote sensing surveys as small, discrete objects.

SIDESCAN SONAR DATA COLLECTION, PROCESSING, AND ANALYSIS

Post-processing of sidescan sonar is accomplished using Hypack Hyscan, a product that enables the user to view the sidescan data in digitizer waterfall format, pick targets, and enter target parameters including length, width, height, material, and other characterizations into a database of contacts (Figure 25). In addition, Hyscan "mosaics" the sidescan data by associating each pixel (equivalent to about 10 centimeters) of the sidescan image with its geographic location determined from the DGPS position (layback rectified) and distance from the DGPS position (Figure 26). The results are exported from Hyscan as geo-referenced *TIFFs for importing to the GIS database of the project.

By contrast, analysis of sidescan sonar data is less problematic than magnetometer analysis. The primary factors considered in analyzing sidescan data included linearity, height off bottom, size, associated magnetics, and environmental context. Since historic resources in the form of shipwrecks usually contain large amounts of ferrous compounds, sidescan targets with associated magnetic anomalies are of top importance. Targets with no associated magnetics usually turn out to be items such as rocks, trees, and other non-historic debris of no interest to the archaeologist. In addition, since historic shipwrecks tend to be larger, smaller targets tend to be of less importance during data evaluation. In addition, the area in which the target is located can have a strong bearing on whether or not the target is selected for further work. If a target is found in an area with other known wreck sites, or an area determined to have high probability for the location of historic resources, it may be given more consideration than it would have otherwise. However, every situation and every target located is different, and all sidescan targets are evaluated on a case-by-case basis.

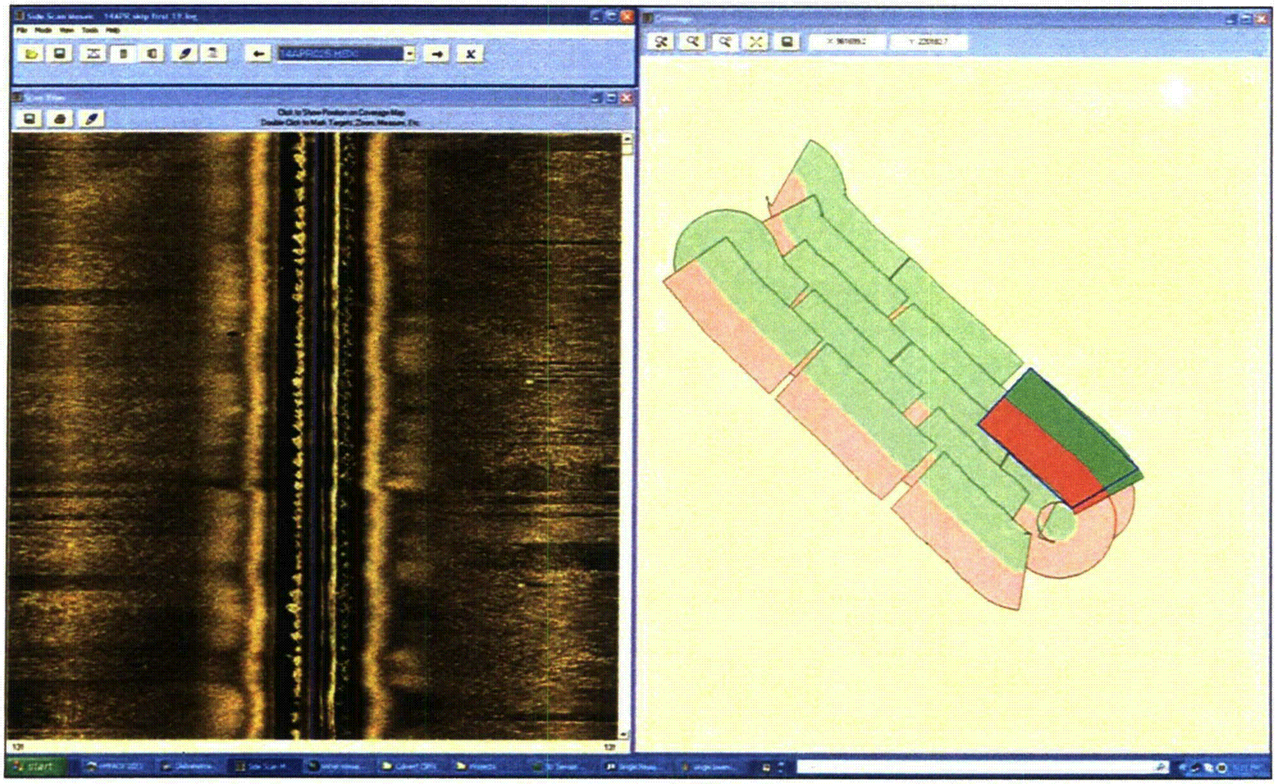

Figure 25. Hypack® Hyscan display of the survey area. Using these windows, one can analyze all aspects of the sonar data, pick targets, and export a mosaic.

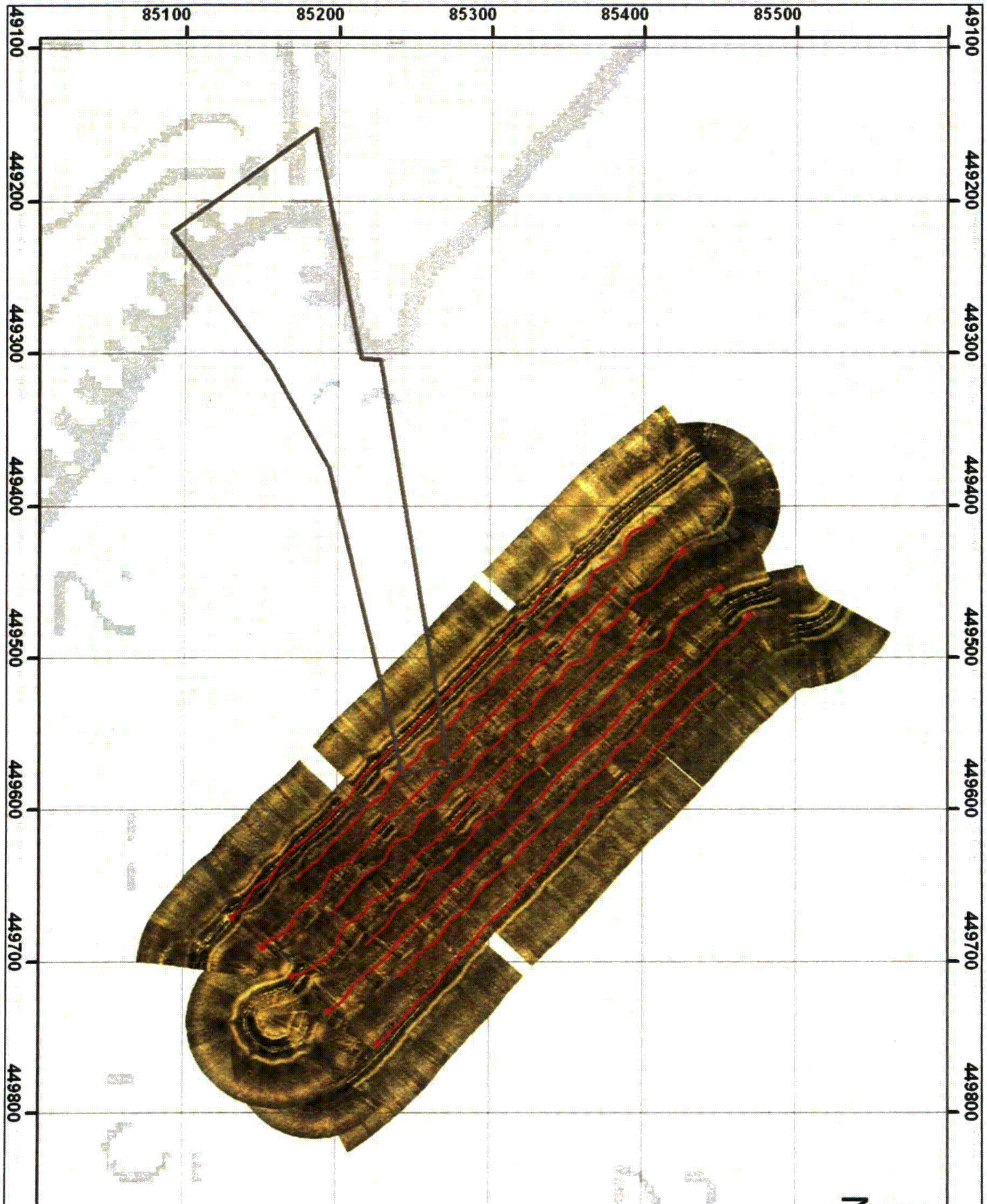

Figure 26. ArcMap 9.2 with mosaic of survey area created in Hyscan. Data presented in Maryland State Plane, NAD83, meters.