FIELD INVESTIGATION METHODS

This research investigation compiled information concerning underwater archeological cultural resources in the alignments of three proposed highway bridges. It was organized to accomplish three main tasks, which were the following. 1) Establishing the historical context of the project areas. 2) Determining the presence, distribution and potential significance of submerged cultural resources. 3) Evaluation of the potentially significant underwater archeological sites found to be present.

The work accomplished consisted of literature and background research, a remote sensing reconnaissance survey, site evaluation, data analysis, and preparation of a technical report. This section describes the equipment and methods utilized to accomplish the remote sensing survey and site evaluation field work.

Remote Sensing Survey

A survey was conducted for the purpose of searching the project area to determine whether any cultural materials having the potential to be considered historically significant were present. Because the project areas are underwater all or much of the time, a direct surface inspection with subsurface test excavations such as would be conducted in a terrestrial project area was neither efficient nor feasible. As a consequence, as is standard procedure in underwater archeology, a remote sensing survey was conducted using electronic sensing instruments to compile data relating to the presence and distribution of cultural materials. A survey employing sensing instruments that do not make direct contact with the terrain being investigated is termed a remote sensing survey.

During this work, two underwater remote sensing instrument systems were employed. They were the marine proton magnetometer and the bathymetric recording sonar. In the following discussion the magnetometer is described first followed by the sonar.

The proton magnetometer ("mag") is an electronic measuring and data collection instrument for determining the strength of the Earth's magnetic field. In more than a quarter century of use in underwater archeology, it has proven to be the most efficient remote sensing instrument for locating buried shipwrecks and other cultural deposits dating to the historic period. It is very useful for compiling data that enables the underwater distribution of ferrous artifacts to be mapped.

The mag takes readings that measure the amplitude of the magnetic field at its sensor head. Measurements are made in units of magnetic force called "nanoteslas" (nT). The term "gammas" is synonymous and is usually used in place of nanoteslas in applied magnetometry.

The presence of cultural materials containing iron (a magnetic material)

causes the magnetometer to produce data readings that are unusual (anomalous) in comparison with the norm associated with the surrounding ambient magnetic field. Submerged cultural deposits such as shipwrecks are thereby discovered by means of detecting the disturbances they create in the Earth's magnetic field.

In a magnetically pristine ("clean") area, the amplitude of the ambient magnetic field is fairly uniform. In the absence of distortions caused by iron artifacts, the observed field values change gradually and are almost always of very small amplitude. These gradual changes can be observed as the sensor's location is moved from one location to another. The strength of the magnetic field also changes as the Earth rotates through its 24-hour (diurnal) cycle because the relationship of a location on the Earth to the Sun slowly shifts.

Localized distortions in the Earth's natural magnetic field are called "magnetic anomalies." These may be caused by a variety of factors including geological features and electrical fields from power lines. Importantly for archeological purposes, anomalies occur in the vicinity of cultural materials, especially those containing iron which is a magnetic metal. As a consequence, anomalies can reveal the presence of archeological sites by means of their associated distortions in the Earth's magnetic field.

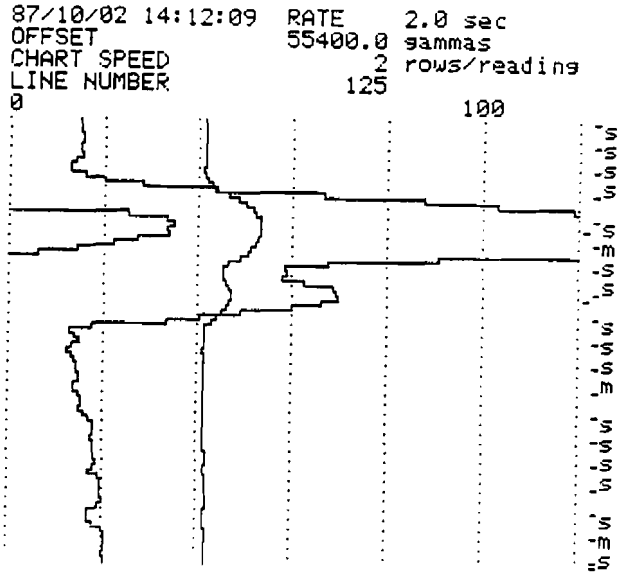
An artifact that contains iron causes a distortion in the magnetic field that is proportional to the magnetic mass that it contains. The presence of an anomaly is revealed when the magnetometer data output displays a significant deviation from the normal ambient background magnetic field.

Since nearly all sunken vessels contain some amount of iron or steel in the form of hull fastenings, equipment, fittings, or cargo, they create magnetic anomalies detectable with the proton magnetometer. In addition, anomalies are created by isolated objects containing iron. Material such as steel drums, wire cable, steel pipe, automobile tires, and other miscellaneous debris can be detected from their associated magnetic anomalies. Anomalies associated with individual objects can usually be distinguished from those caused by sunken vessels. Characteristics of anomalies that permit preliminary assessments to be made of a target's approximate size, possible identity, and potential significance include amplitude, configuration, dimensions, and clustering.

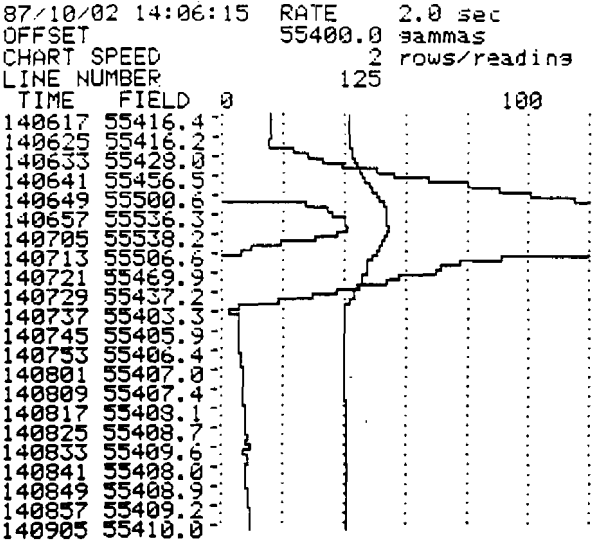
Figures 40 and 41 illustrate representative magnetic anomalies from strip chart data records produced by the Barringer M-234 proton magnetometer. The "signature" of an anomaly as shown on a magnetometer's data output will vary depending on several factors. These include the anomaly's amplitude and configuration, the distance relationship and orientation of the mag head relative to the anomaly, the cyclic rate of the magnetometer, the sensor's speed over the terrain, as well as several other reasons. In addition, the strength (amplitude) of an anomaly is proportional to magnetic mass. An object containing a large amount of iron causes an anomaly that is stronger and larger than an object containing only a small mass of iron when measured from the same distance.

FIGURE 40

Magnetic Anomaly Signature Examples (Barringer M-234 Mag Strip Chart)



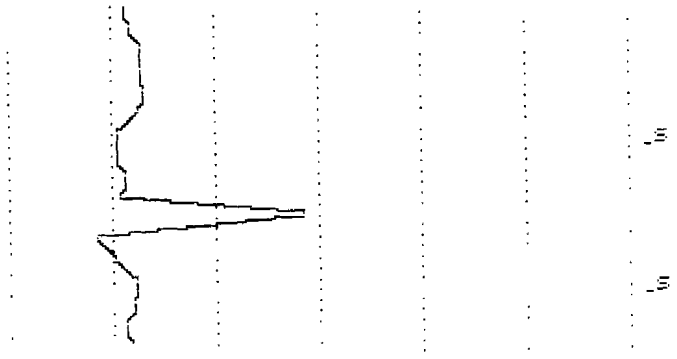
ANOMALY



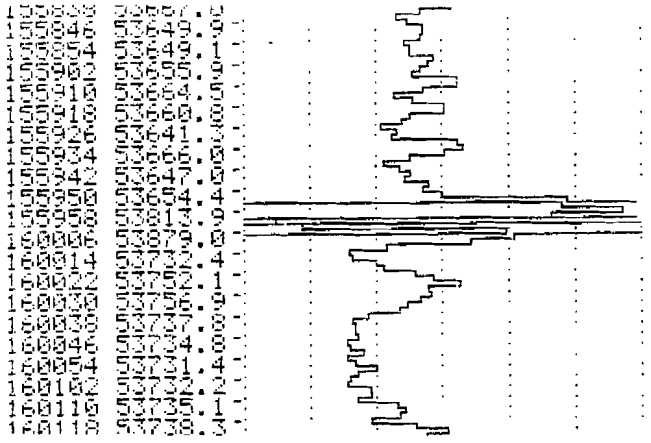
ANOMALY

FIGURE 41

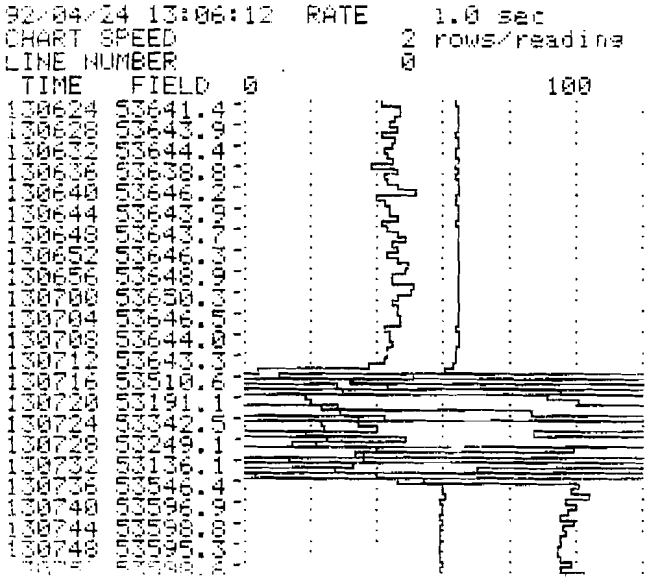
Examples of Anomaly Signatures (Barringer M-234 Mag Strip Chart)



ANOMALY



ANOMALY



ANOMALY

The measurable strength of a magnetic anomaly varies inversely with the cube of the sensor's distance from it. In other words, an iron artifact's detectable distortion of the magnetic field attenuates rapidly as distance from it increases. For example, an iron hammer may be detectable no more than three feet away while an automobile may be detectable from a distance of fifty feet or more. The farthest distance at which an artifact's anomaly can be detected is also influenced by other factors, such as the effects of local geology on the ambient magnetic field's "background noise," sunspot activity, and other culturally associated anomalies in the vicinity.

Since the data collected during a remote sensing survey consists of measurements taken at the sensor head, it is very important that the sensor be properly positioned relative to the terrain being investigated. For example, the closer a sensor is to the terrain being surveyed, generally speaking, the better its ability to reveal the presence of weak (low amplitude) or small anomalies such as are often associated with very old shipwrecks, buried hearths and foundations, or other cultural deposits. If the mag sensor is not placed in close enough proximity to a magnetic anomaly, the magnetometer will not reveal the anomaly's presence. If the sensor head is positioned too far away, such as too high above submerged terrain, the mag will not reveal an anomaly's presence amidst the ambient magnetic field's background noise.

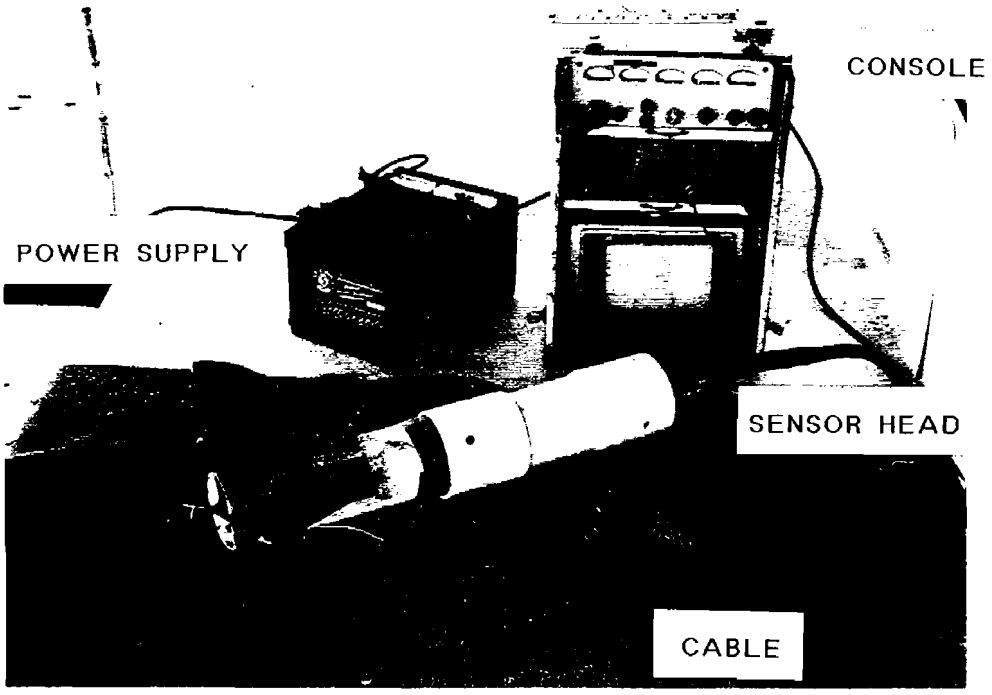
It is a truism in the field of underwater archeological remote sensing (including magnetometry) that the results achieved depend at least as much on the experience and skill of the instrument operator and data interpreter as on the remote sensing equipment employed. For example, while marine proton magnetometers are widely used in the ocean engineering industry, the ability to accurately employ and interpret them for archeological purposes is very rare. There are relatively few archeologists with more than minimal practical experience in addition to academic training in underwater archeology. Only a very small percentage of those few have the requisite expertise to perform and/or accurately interpret the results of underwater remote sensing surveys.

A marine proton magnetometer instrument system consists of three main components (Figure 42). The magnetometer console is the electronics package that operates the instrument system (Figure 43). It often includes a built-in paper chart recorder that displays the data readings in analog graphic and/or digital format.

The amplitude of the magnetic field is measured at the console in gammas (nanoteslas). The magnetic field's gamma value is normally displayed digitally on the mag console and recorded on an automatic strip chart recorder. The strip chart represents cultural magnetic anomalies visually as abrupt deviations from the stable ambient background magnetic field (Figures 40 and 41). During normal operation the mag readings remain fairly constant until an anomaly is encountered, causing an abrupt deviation indicating a cultural target.

FIGURE 42

Proton Magnetometer System (circa 1970)



(Koski-Karell 1976)

FIGURE 43

Barringer M-234 Proton Magnetometer Console

A shielded electrical cable connects the console to the sensor "head." The sensor and cable assembly make up the second component of the instrument system. The "head" contains an electrical coil surrounded by a liquid containing millions of protons. During operation the coil is alternately energized and de-energized in short cycles to collect data (for example, one to three second cycles).

A marine proton magnetometer's sensor head is normally towed submerged behind the survey vessel at a distance sufficient to avoid any anomaly associated with the vessel itself. The sensor's depth should be adjusted in accordance with the local environmental setting and goals of the survey. For example, whenever very shallow water was encountered during this investigation, the sensor was placed in the bow of the survey boat and positioned to avoid any anomalies associated with the boat's equipment.

The third component of the magnetometer system is the power supply. Portable marine proton magnetometers are commonly powered by a 24-volt direct current (DC) power source consisting of two 12-volt wet cell automobile batteries connected in series. The use of DC batteries alleviates the electrical field interference often associated with alternating current (AC) power supplies, but does not guarantee the total absence of electrical field interference. Additional measures are sometimes necessary to avoid problems with interference caused by other electrical equipment on board a survey boat.

Two models of proton magnetometer were utilized in this investigation. Both were manufactured by Barringer Research at its plant in Rexdale, Ontario, Canada. They were the models M-234 (Figure 44) and M-123 (Figure 45) magnetometers. Both were equipped with data chart recorders and submersible sensors.

The sensitivity of the M-123 magnetometer conforms to the industry standard of plus or minus one gamma. It was operated at a cyclic sampling rate of one reading every 1.2 seconds. The M-123 uses an analog recorder with a paper strip and ink pen. The pen draws a linear graph of the magnetometer readings with the value of each reading being marked at its appropriate numerical position on the strip chart.

During this investigation the magnetometer recorders were adjusted to provide a full-scale variation of 100 gammas, which is standard for underwater archeological surveys. Figure 46 provides an example data record showing how a magnetic anomaly might appear on the M-123 magnetometer's chart record.

During the Phase I survey, the magnetometer's cyclic rate and the speed of the survey vessel were coordinated to obtain measurements of magnetic value at intervals no greater than every six feet along the transects. The maximum speed of the survey boat did not exceed 3.5 statute miles (four nautical miles) per hour. This allowed the magnetometers to record data with great efficiency and ensured precise navigational control along the transect lines.

FIGURE 44
Barringer M-234 Magnetometer System

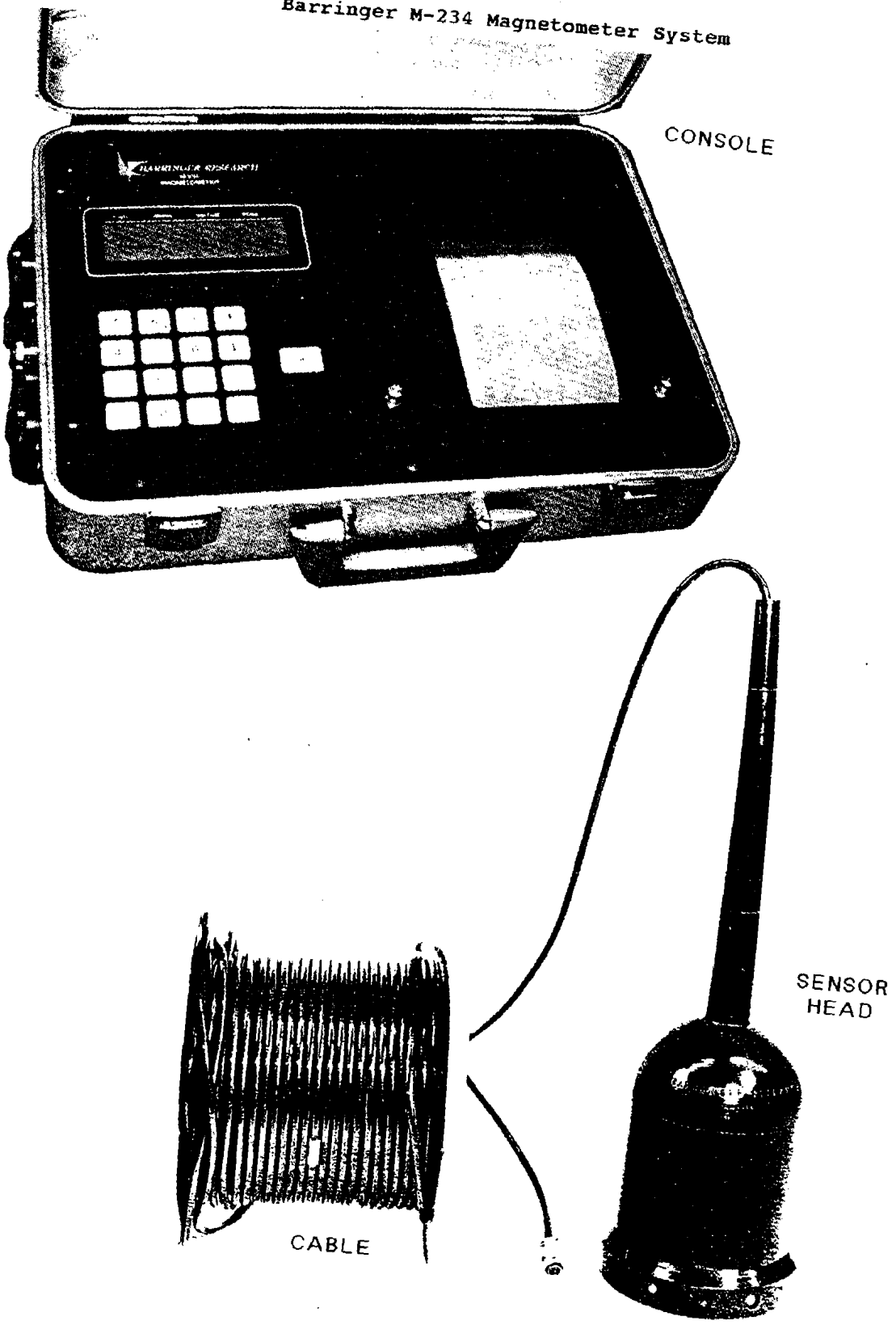
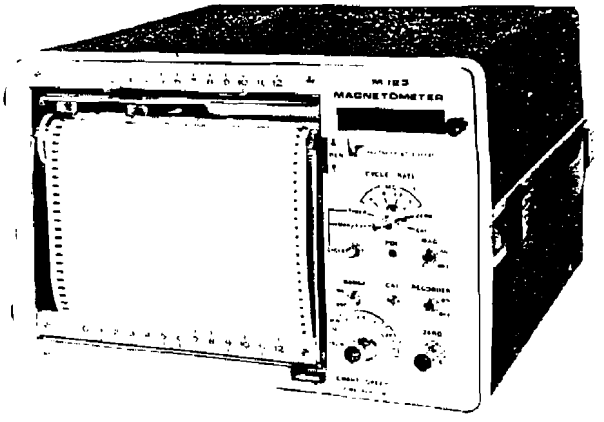
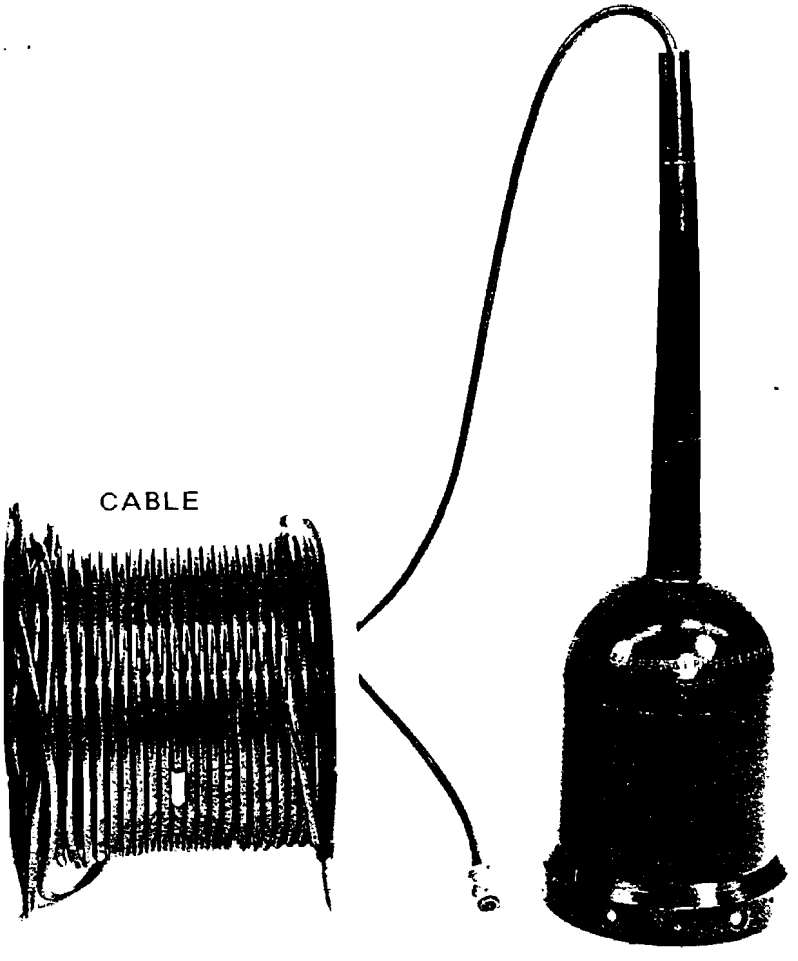


FIGURE 45

Barringer M-123 Proton Magnetometer



CONSOLE

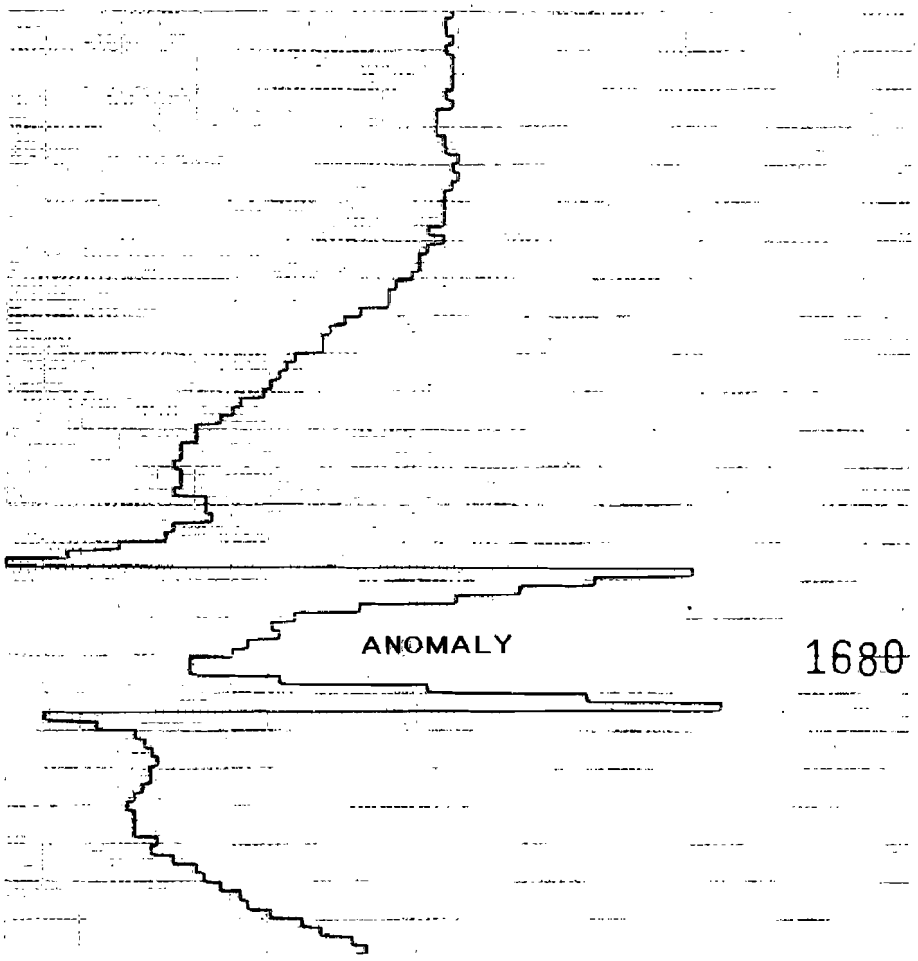


CABLE

SENSOR
HEAD

FIGURE 46

Magnetic Anomaly on Barringer M-123 Chart Record



The M-234 mag is an improved instrument first introduced in 1988. It has a sensitivity is 0.1 gamma. In addition to providing magnetometer data, this instrument can display and record the water depth of the sensor to provide continuous monitoring of the sensor's elevation above submerged terrain. The console of the M-234 provides a data output that can be directly interfaced with a computer for logging magnetometer data, sensor head depth, and positioning system coordinates simultaneously.

The built-in chart recorder on the M-234 provides both an analog linear chart trace and digital printout of the numerical value of readings. An example of a combination analog chart and digital data record is provided in Figure 41.

A cultural anomaly is shown both by an abrupt deviation in the lineal chart trace and a significant increase and/or decrease in the recorded digital gamma value of the magnetic field.

During the survey the M-234 was operated at a cyclic rate of one reading every 1.0 seconds. The speed of the survey vessel was adjusted to obtain measurements of magnetic value at intervals no greater than every 4.5 feet along the survey lines.

Both the M-123 and M-234 magnetometers were employed during the field survey in order to compare their performance. As may be expected, the M-234 was found to be a major improvement over the older M-123 model. The M-123, however, performed efficiently and its data effectively revealed the presence of each potentially significant anomaly in the terrain investigated.

The other remote sensing instrument used in the survey was a depth recording bathymetric sonar. This instrument was used to obtain and record continuous soundings of water depth. Its output was a scaled strip chart record of the bottom topography directly beneath the survey boat along each transect line run. These strip charts provided a permanent record of underwater topographic profiles in the bridge crossing areas (Figure 47, bottom).

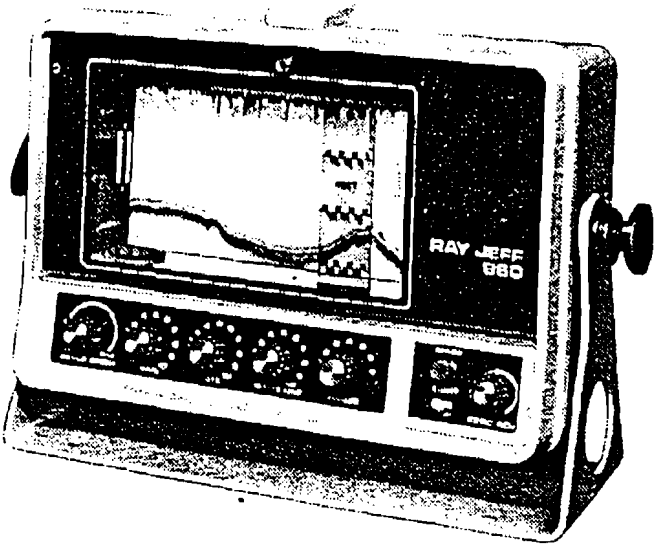
The bathymetric sonar employed was a Ray Jefferson Model 960 (Figure 47, top). It operates on a frequency of 200 kHz (kilohertz) and has an operating range of water depths from two feet to 960 feet.

The boat used as the survey vessel was a Coleman Marine "Crawdad." This craft is ten feet in length and constructed of plastic and aluminum, making it non-magnetic. The "Crawdad" is a highly portable and lightweight craft that can be carried by two people. It was easily carried overland to otherwise inaccessible launching points. The vessel was powered with a 7.5-horsepower air-cooled outboard motor which has a small magnetic mass. The minimal magnetic anomaly associated with the survey boat's engine allowed the mag head to be towed close astern or mounted in the vessel's bow when very shallow water was encountered.

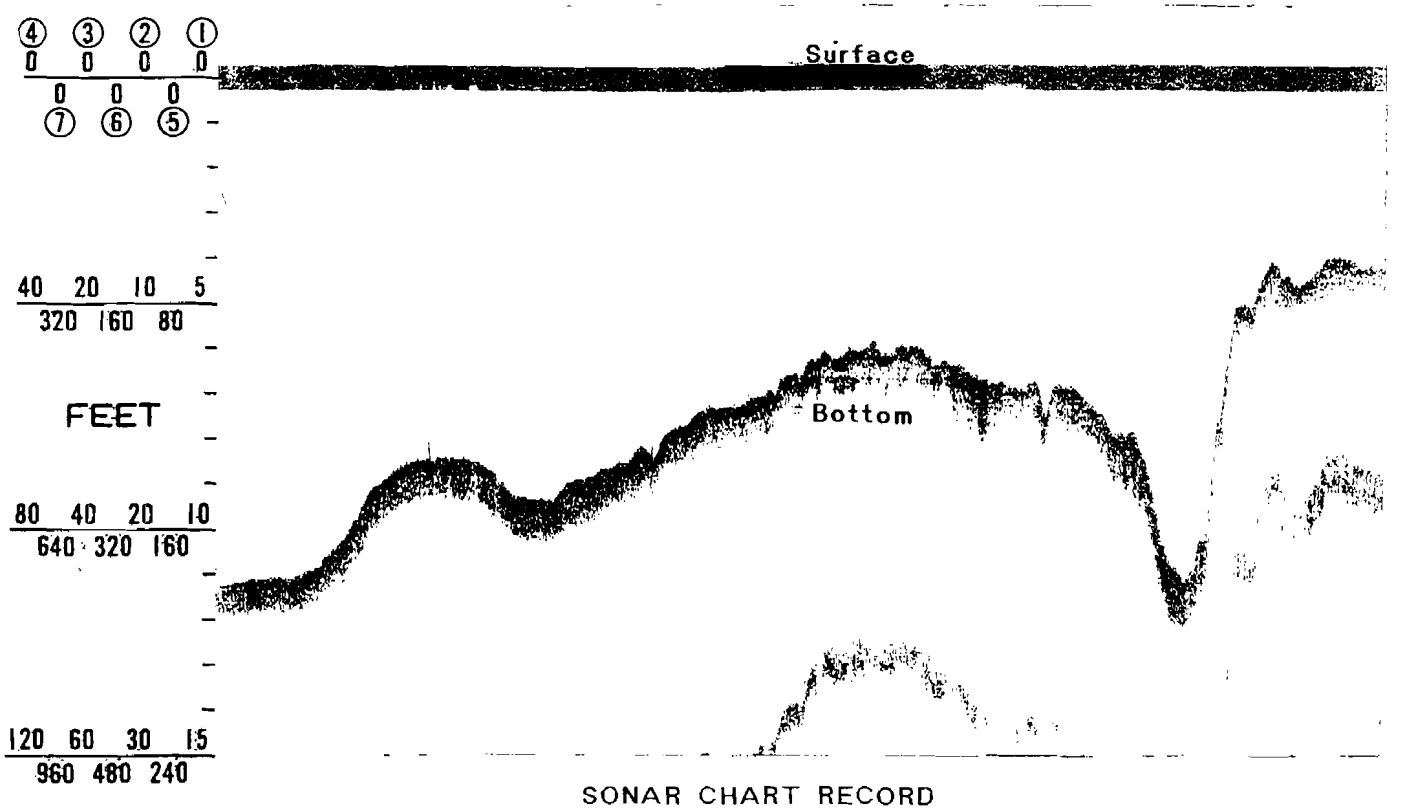
During the field survey it was found that the extant bridges over Smyrna River and Mill Creek downstream of the bridge crossings were so low that they prevented watercraft from proceeding upstream to the project areas. As a consequence, the survey boat was carried overland from the closest vehicle parking locations and launched directly into the bridge crossing areas. In addition, the Leipsic River project area was four miles from the nearest boat launching ramp. In that instance, the Crawdad was launched into water one foot deep at the foot of the Garrisons Lake Dam, a short distance from the survey area. This launching procedure made it possible to conduct the remote sensing survey without becoming stranded by falling tide. At low water all three bridge crossings were inaccessible by boat because of exposed mud flats.

FIGURE 47

Ray Jefferson Model 960 Sonar Depth Recorder



BATHYMETRIC RECORDING SONAR

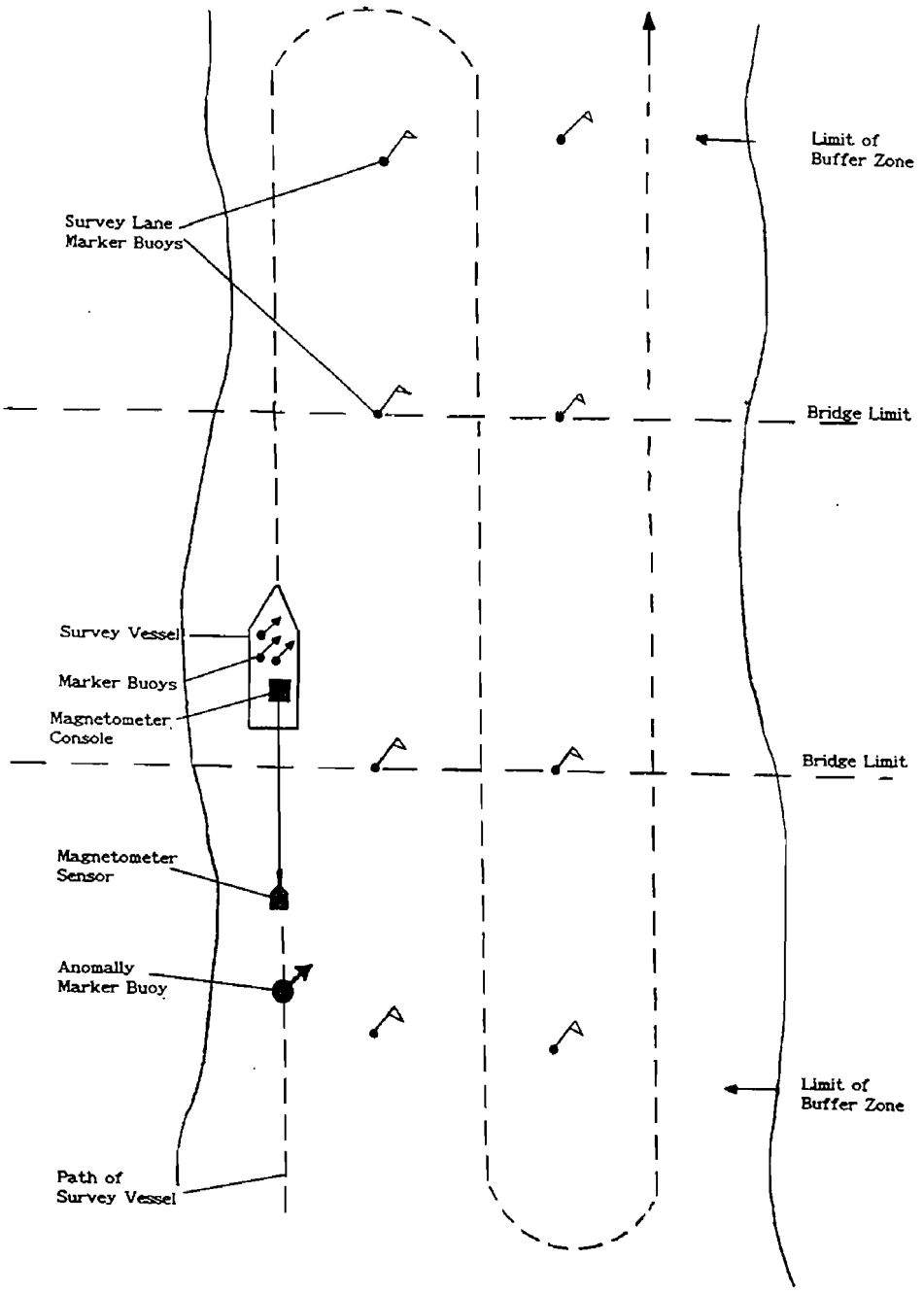


SONAR CHART RECORD

The field survey consisted of a series of equally spaced systematic traverses across the individual bridge crossing areas to collect and record magnetic field data. Figure 48 is a diagram illustrating that procedure. This use of systematic traverses facilitated the subsequent analysis of the data and allowed the findings to be readily plotted on project area maps.

FIGURE 48

Remote Sensing Survey Procedure



Horizontal directional control of the survey vessel was maintained using a system of buoys placed parallel with the main axis of the waterways being investigated. Prior to the field survey, the boundaries of the project areas were marked on shore. A rope with flagging tied at thirty foot increments was subsequently stretched across each project area. Marker buoys were placed at the flagged intervals to ensure proper spacing between lines. The rope was then relocated no more than 50 feet away upstream or downstream and additional marker buoys positioned. These buoy arrays provided well marked lanes for the survey boat to follow along its transects. They also served as locational reference points for position recording along each transect.

The initial survey consisted of a series of transects along which the survey vessel traveled from one end of the bridge crossing area to the other. The spacing between these lines never exceeded 30 feet. The magnetometer was always switched on no less than 50 feet before commencing a transect and switched off no less than that distance beyond the bridge crossing buffer area limit.

During the remote sensing survey, data output was constantly monitored. This allowed anomalies to be noted in "real time" (immediately, as opposed to later during data analysis). The locations of anomalies encountered in real time were immediately marked with buoys. After repositioning the buoys with greater accuracy, their positions were recorded using sextant triangulation and compass bearings. While electronic positioning systems are available (such as range-azimuth and range-range positioning systems) their use in this particular survey would have served no significant purpose. Frequently, simple and inexpensive optical positioning navigation procedures are sufficiently accurate, easier to operate, more reliable, and much less costly than electronic systems (e.g. Koski-Karell 1988b, 1990).

The initial survey line coverage compiled mag data along each transect and revealed the distribution of magnetic anomalies. These lines were supplemented with shorter transect lines following varying orientations at individual anomaly locations. The supplementary transects compiled additional data on anomalies discovered during the initial transects.

Magnetic anomalies were detected, examined, and initially evaluated using the remote sensing instrumentation. Their locations were marked with buoys and the positions recorded. The data compiled provided information concerning target amplitude (magnitude), configuration, distribution, clustering, and location.

The two remote sensing systems employed were complementary in their data output. The proton magnetometers provided data concerning the presence and characteristics of cultural materials while the sonar provided information on water depth. Analysis of the survey data enabled anomalies to be identified and plotted on project area maps.

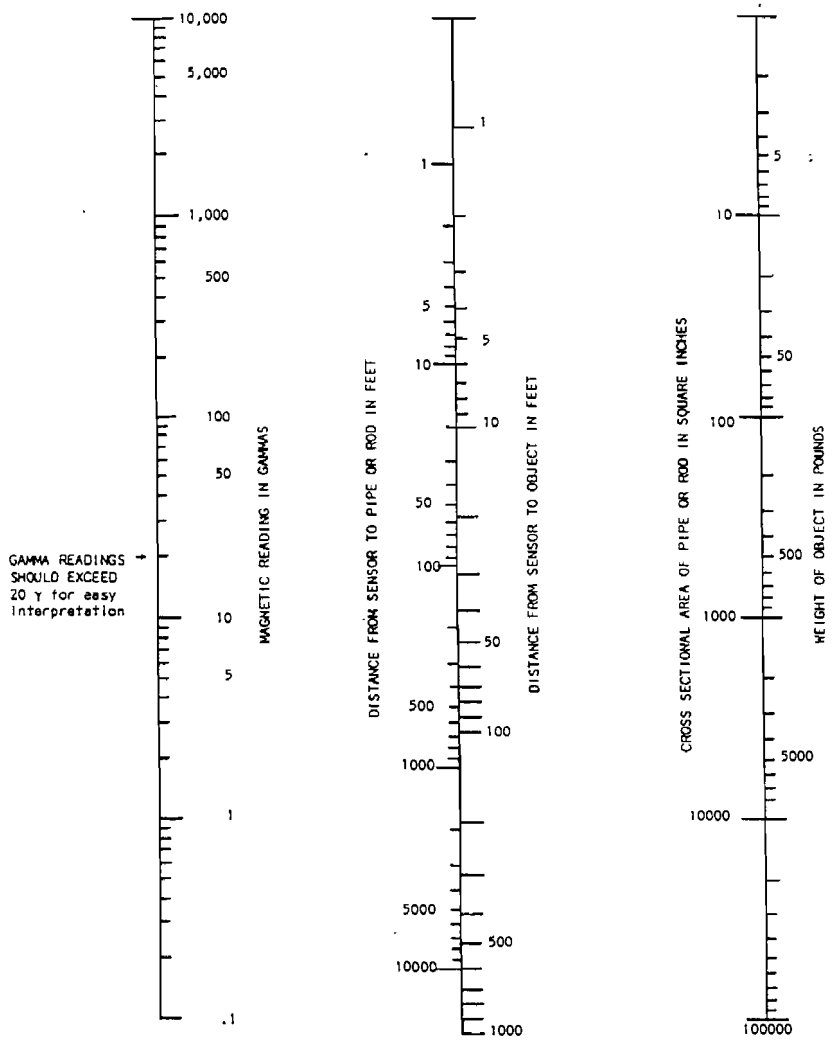
In interpreting the mag data two categories of cultural anomalies were identified, isolated ones and anomaly clusters. Both isolated and clustered

anomalies were identified by the term "target" and assigned a number. Targets that were isolated anomalies were interpreted as likely to be associated with individual objects. Targets that were anomaly clusters were interpreted as indicating the presence of two or more objects situated in close proximity. When the patterning of a group of two or more targets indicated an associated relationship, they were interpreted to represent a cultural deposit. The cultural deposits identified consisted of groupings of anomaly clusters and isolated targets.

Estimates of the amount of iron mass associated with the various magnetic anomalies were made using a "nomograph" and a "nomogram." A nomograph or nomogram is a graphic illustration of relationships between anomaly amplitude versus distance for several categories of magnetic material (Figures 49, 50).

FIGURE 49

Nomograph for Estimating Readings of Objects or Pipelines

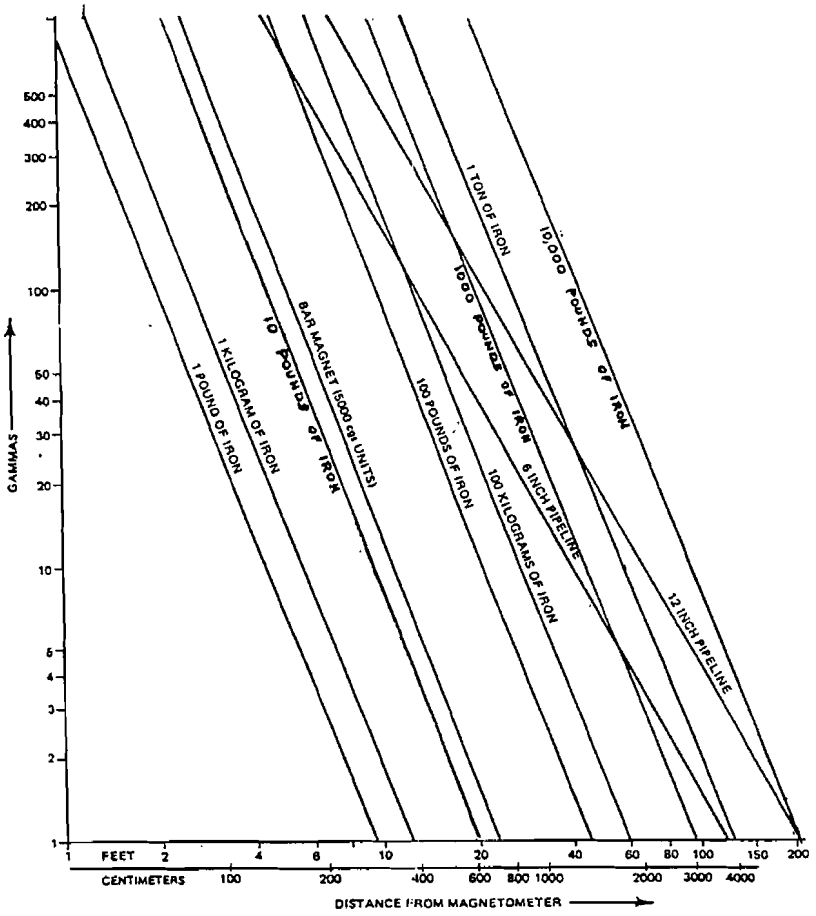


(Barringer Research, Ltd. 1988)

FIGURE 50

Nomogram for Estimating Anomalies of Typical Objects

Nomogram for Estimating Anomalies from Typical Objects (assuming dipole moment M = 5 X 10^4 cgs/ton, i.e., k = 8 cgs. Estimates valid only within order of magnitude)



INSTRUCTIONS FOR USE:

To use the nomogram, select a given weight or type of object from among the diagonal labeled lines. Then choose a distance along the bottom line (abscissa) of the graph and follow a vertical line upwards from that distance until it intersects the diagonal line of the selected object. At that point, move horizontally to the left to a value on the vertical axis (ordinate) of the graph and read the intensity in gammas.

At a given distance, the intensity is proportional to the weight of the object. Therefore, for an object whose weight is not precisely that of the labeled lines, simply multiply the intensity in gammas by the ratio of the desired weight to the labeled weight on the graph. If the distance desired does not appear on the graph, remember that for a typical object the intensity is inversely proportional to the cube of the distance and for a long pipeline the intensity is inversely proportional to the square of the distance between magnetometer sensor and object. Due to the many uncertainties described herein, the estimates derived from this nomogram may be larger or smaller by a factor of 2 to 5 or perhaps more.

(Breiner 1975)

These interpretive aids enable estimates of mass to be interpreted. The estimates are tentative, however, because the amplitude of an anomaly varies inversely with the cube of the distance. Therefore, a small variation in distance commonly has a major effect on observed anomaly amplitude. During a

field survey, the distance between the magnetometer sensor and the object creating the anomaly is almost never precisely known. As a consequence, the sensor to anomaly distances required for using the nomogram can only be estimated. It is common that the actual mass of an object will be greater or lesser than the nomogram interpreted mass "by a factor of two to five or perhaps more" (Breiner 1973:43).

Even under controlled conditions when both amplitude and distance are known, the measured anomalies sometimes vary a great deal from those presented in a nomogram. This is because there are several other factors influencing magnetometer measurements. These include the shape of the object and its orientation in relation to the magnetic field, orientation of the mag sensor, the position of the sun in relation to the location of the target object, weather or sunspots, roughness or calmness of the waterway where the survey is being conducted, the presence and positioning of other anomaly-inducing artifacts in the vicinity, as well as other factors.

The results of this investigation's remote sensing survey provided locational and magnetic field data relating to underwater archeological sites and other submerged cultural material. Sites were characterized by targets and target clusters of types indicating the presence of cultural deposits. Preliminary assessments of potential historical significance were made during data analysis, and Delaware archeological site forms were prepared for cultural deposits of archeological interest. Following completion of the remote sensing field survey and data analysis, a site evaluation investigation was initiated.

Site Evaluation Methods

Evaluation field work was conducted at each of the underwater archeological sites interpreted as having the potential to be considered historically significant. The goal of this effort was to evaluate the eligibility of those sites for nomination to the National Register of Historic Places.

Sites designated for evaluation were relocated and investigated. The work performed was directed towards identifying the cultural materials that had been earlier documented during the remote sensing survey as magnetic anomalies, and making an assessment of their context and archeological merit. During this effort, additional non-magnetic artifacts were frequently encountered. Some of these artifacts were made of non-ferrous materials that themselves did not create magnetic anomalies. Other artifacts found contained magnetic materials that were too small to have been detected during the initial remote sensing survey.

Artifacts of archeological interest were collected whenever found during the site evaluation work, either on the surface or in test excavations. Modern vintage material was also recovered if size allowed it to be easily transported. Otherwise, it was left in place. Artifact recovery was necessary to "clean up" sites so they could be rechecked to see if additional materials were present.

During the evaluation field work, another type of remote sensing equipment was used to relocate the magnetic anomalies recorded during the previous magnetometer survey. These remote sensing instruments were hand-held underwater metal detectors. Metal detectors designed for underwater use were necessary because the environment in which the work took place was underwater or contained water-saturated silty mud. Normal terrestrial metal detectors could not be used because they would have quickly become waterlogged and inoperable.

The underwater metal detectors were employed to scan site locations to pin-point locations of metal objects. The objects detected included iron artifacts that had produced the magnetic anomalies, as well as other non-magnetic metal objects such as those containing brass, copper, or aluminum. The use of metal detectors enabled a substantial number of non-ferrous artifacts to be found and recovered.

The metal detectors employed were especially manufactured for underwater use by divers. They were of the generic class known as the Pulse Induction (PI) type. Pulse induction metal detectors are very useful for finding ferrous and non-ferrous metal objects located in mineralized environments, such as in seawater having a high salt content or estuaries having a brackish mix of salt water and fresh water (Garrett 1985:172-177).

PI metal detectors transmit a pulsed electrical field from their coils. When metal objects interfere with the electrical field, an audible signal is heard in the instrument's earphone. Two different underwater PI metal detectors were utilized. These were the Garrett Sea Hunter (Figure 51, top) and the White's Electronics PI-1000 (Figure 51, bottom). Both proved to be very effective.

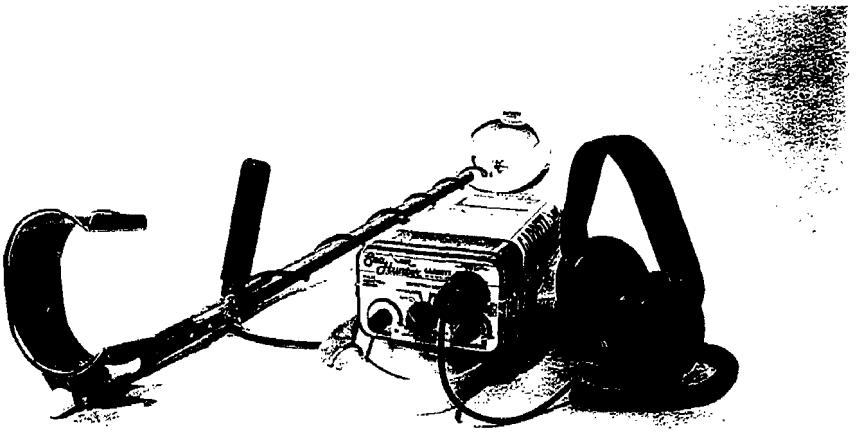
Pin-pointing targets was more quickly achieved with the small (5.5 inch) coil mounted on the Garrett Sea Hunter. The White's Electronics PI-1000 was fitted with an eleven-inch coil that localized a target to a larger area which necessitated more excavation to recover it. However, searching could be conducted quicker using the PI-1000 with 11-inch coil than with the detector fitted with 5.5 inch coil because of the larger coil's greater surface area.

Whenever possible, buried objects found using the metal detectors were recovered by thrusting the arm down into the mud. If that means was not successful, shovels were used to remove sufficient overburden to allow artifact recovery.

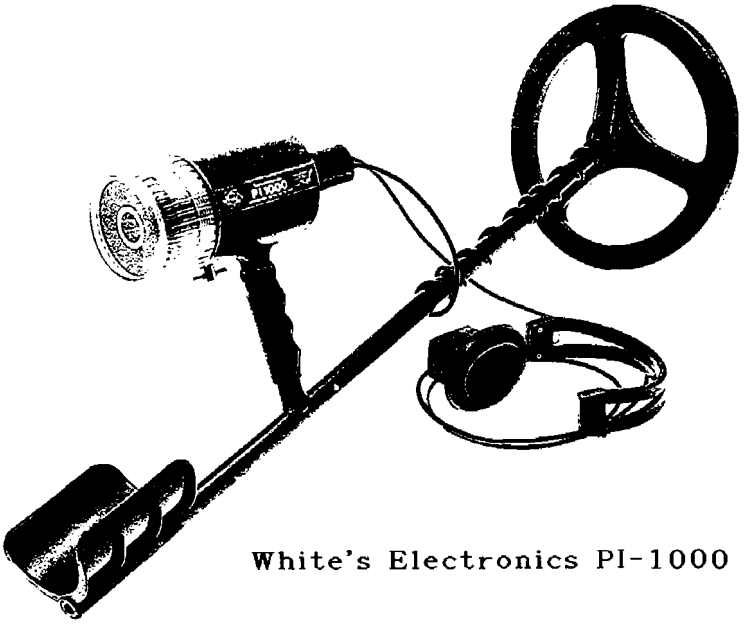
All recovered artifacts were tagged with flagging marked with an identification number corresponding to an entry in the field notes recording their location. They were then expeditiously brought to the archeological laboratory for cleaning and cataloging. If appropriate, they were subsequently drawn and photographed. Artifacts less than fifty years old were cataloged and later discarded. Cultural material of greater age was conserved, marked, and prepared for long term curatorial storage.

FIGURE 51

Pulse Induction (PI) Underwater Metal Detectors



Garrett Electronics Sea Hunter XL500 Pulse



White's Electronics PI-1000

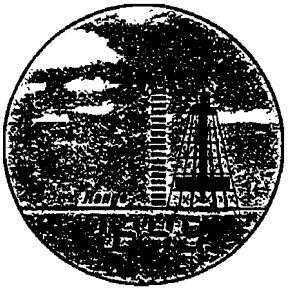
Positions of the cultural materials located were recorded on plan maps of the bridge crossing areas. Positioning reference points were established onshore for recording the bearing and distance to each artifact encountered. For objects close to the reference points, bearings were determined using a Brunton pocket transit and distances were measured with a tape.

Distances to artifacts in most of the terrain investigated were too great for efficient measurement using a tape. In those situations, a "KVH Datascope" was employed (Figure 52). This electronic instrument is a combination digital compass and range finder.

FIGURE 52
KVH Datascope

Data Output

Compass


Rangefinder

Chronometer

The KVH Datascope is hand-held and battery powered. It contains a sensitive fluxgate compass that displays azimuths digitally and has a built-in range finder for measuring distances to sighting points.

The compass azimuths provided by the KVH Datascope have a resolution of 0.1 degree. When a compass bearing was desired, the operator centered the selected sighting point in the viewfinder cross hairs and pressed a button to read the compass bearing digitally in degrees and tenths.

The Datascope's distance-finding option displays a vertical scale in the viewfinder adjacent to the crosshairs. The height of the vertical scale is increased or decreased by pushing a button until it is equivalent to the known height of the sighting point (for example, a stadia rod ten feet tall). The distance to the sighting point is then displayed digitally in the viewfinder in units equal to the sighting point's height. For example, if the range finder indicated that the ten-foot tall stadia rod was "17" units away then the distance was 170 feet (17 times 10 feet).

This instrument was also used for calculating distances between reference points and targets. To accomplish this it was necessary to know the height of an object at the selected sighting point. During this investigation, a stadia rod having a height of five feet was used as the standard height for Datascope distance measurements. When the distance between a reference point and a sighting point was needed, the stadia road was positioned vertically over the target and the range was measured using the Datascope. Locational data sightings were either made to the individual artifact positions from the onshore datum reference points, or vice versa from the artifact locations to the reference points, depending on the circumstances.

The location of each target investigated was recorded according to its distance and azimuth from a reference point. Target positions were subsequently plotted on a plan map of the project area using the recorded azimuths and distances.

The tidal waterway settings of the three bridge crossings were not conducive to the application of standard underwater or terrestrial archeological field techniques. The average variation between high and low tide was about three feet with the amount of time between high and low tide being about six hours. The water level in the project areas was continuously either rising or falling at a rate of about six inches per hour. The majority of the terrain investigated was submerged at high water but exposed as mud flats at low water.

Scuba diving was restricted to the channel of Smyrna River where the main channel contained water about five feet deep at low water. The other areas were intermittently submerged and were investigated at low tide when water depth was minimal and much of the terrain was exposed as tidal flats. The Mill Creek and Leipsic River project areas were both almost entirely drained of standing water at low tide except for small rivulets less than knee deep. In that tidal mud

flat terrain it was found that much of the silty sediments were semi-liquid even at low tide, with the water table being at the surface or at most only a few inches below.

As a consequence, a variety of techniques were developed to enable the operations to be conducted as efficiently as possible. These procedures may be collectively grouped using the term, "Mud Flat Archeology." The techniques of Mud Flat Archaeology that were used during this investigation are described below.

The Ice Walk Technique was employed during the coldest winter months (January and February) when low temperatures caused Smyrna River to freeze over. Those conditions enabled field workers to walk out on the ice to target locations in the river (Figure 53). The Ice Walk was not performed in the channel portion of the river that contained water at low tide because the ice there was not sufficiently strong to bear the weight.

FIGURE 53

Ice Walk Metal Detecting Technique

It was found that the Ice Walk target recovery technique was best conducted during times of low tide. At low tide the ice sheet was closest to the river bottom minimizing the distance between the metal detector coil and the objects being investigated. In near shore and mud flat locations, the ice sheet rested directly on the river bottom at low water providing additional support for the weight of the ice walkers.

When targets were located their positions were recorded using the KVH Datascope. A pick was then used to make a hole in the ice (Figure 54). Depending on the thickness of the ice, either a large full-size pick was used or a small hand pick. Once a hole was made in the ice, the target was recovered (Figure 55). If it was buried, shovels were used to dig it out.

FIGURE 54

Target Identification Using Ice Walk Technique

FIGURE 55

Target Recovery Using the Ice Walk Technique

With the Ice Walk technique, safety was a primary consideration. It was never performed alone. The minimum team used for field work was three persons. Whenever one person was out on the ice, the other two were on shore ready to provide assistance. A stout rope was always available to haul out the ice walker in the event he fell through the ice and became mired in the mud.

Care was be taken to assess whether the ice was sufficiently thick for supporting the weight of the ice walker. Even though the ice sheet usually rested on the muddy tidal flat at low tide, the danger of the ice breaking and the walker falling through into the mud was always a concern.

The Direct Approach Walk Technique consisted of walking out across the tidal mud flats to the location being investigated. Since the sediments were quite soft, it was normal that the feet and legs sank into the mud (Figure 56). This technique proved effective in areas where the walker sank no farther than knee deep into the mud. Progress was extremely difficult in mud where the person sank further than the knees.

FIGURE 56
Direct Approach Technique

As utilized in this investigation the Direct Approach was performed systematically by moving along a series of parallel transects spaced at five-foot intervals. These transects were oriented perpendicular to the shoreline (Figure 57). The walker was equipped with an underwater metal detector for locating metallic cultural material.

FIGURE 57

Direct Approach Technique Transects

Shovels were used for conducting excavations to recover each object located (Figure 58). Positioning was accomplished by taking bearing and distance readings with the KVH Datascope from reference points to the walker. The shovel, which was of known length, was held vertically in place of the stadia rod for calculations of distance using the Datascope.

The Direct Approach was facilitated by the use of waist-high waders. These waders are commonly used by fishermen engaged in sport fishing in shallow waters deeper than those suitable for hip waders. The waders used were basically a pair of rubberized waterproof pants attached to rubber boots. They enclosed the feet, extended up to the waist, and were held up with suspenders.

Performing the Direct Approach shod only with boots or shoes was not very efficient. As the walker's feet sank into the mud, the foot gear often became mired in the muddy sediments. As the leg was drawn upward for the next step, a person's foot tended to slip out of the footwear, leaving it in place.

As with the Ice Walk Technique, the standard field crew consisted of three persons. While one was working on the mud flats, the other two recorded bearing and distance to the cultural objects encountered and stood ready with rescue equipment in the event the walker required assistance.

FIGURE 58

Direct Approach Technique Target Recovery Team

Another technique was the Mud Walk. It proved to be very effective for traversing wide mud flat areas where the soft sediments were too deep to conduct a Direct Approach. It was also substituted for the Direct Approach Technique when the terrain being investigated contained muddy sediments of such stickiness that the direct approach walker quickly became physically exhausted while making transects.

The Mud Walk employed two rectangular sheets of 1/4-inch plywood per walker (Figure 59). It was found that sheets two feet wide by eight feet long were quite suitable. In this technique, the walker stood atop one sheet of plywood while the other sheet was moved forward. The walker then stepped onto the forward sheet and the trailing one was moved ahead.

This technique was applied using two walkers working together, or separately but nearby one another. An additional person was stationed on shore.

When working separately, each mud walker was equipped with an underwater metal detector and shovel. Out on the flats, one mud walker was always deployed with or nearby the other so that if one required assistance the other was close at hand. Since this technique was often used at substantial distances from the shoreline, it would have been difficult and time consuming for a rescue to be affected from shore in the event of distress.

FIGURE 59

Mud Walk Technique

Plywood Sheets

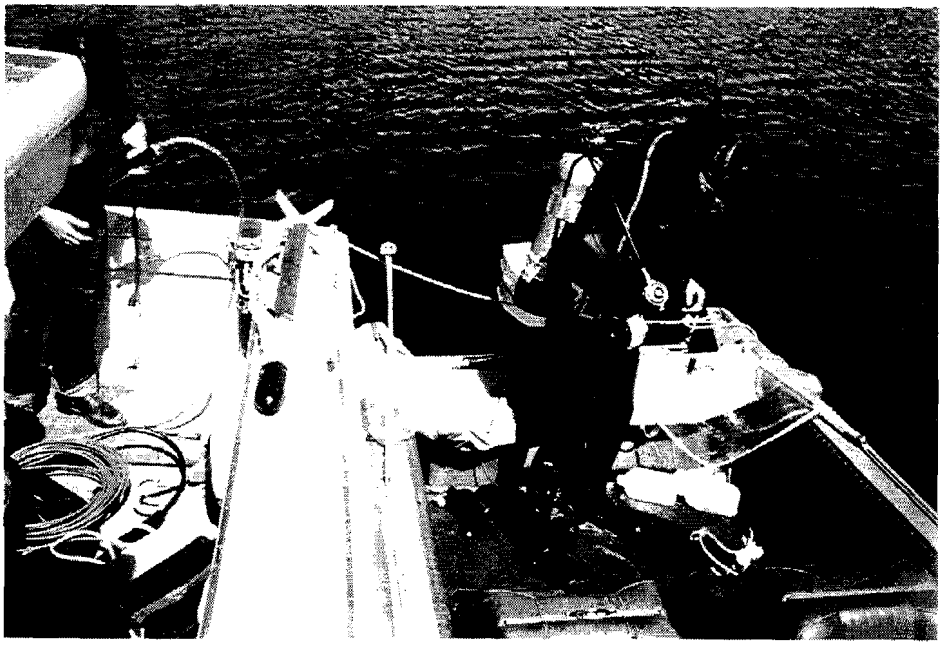
Metal Detector

The third team member remained on shore at a reference point to take bearing and distance readings using the KVH Datascope when the mud walkers encountered cultural material. This team member also was responsible for watching the level of the tide. When rising waters threatened to isolate, maroon, or inundate the walkers out on the mud flats, the onshore team member would alert them to the danger so they could move to an appropriate location.

The Scuba Diving Technique was employed in the Smyrna River. "Scuba" stands for **S**elf-**C**ontained **U**nderwater **B**reathing **A**pparatus, and it is the most commonly used underwater diving life-support system. The channel of Smyrna River was the only portion of the three bridge crossings that contained water deep enough at low tide to permit scuba diving. The water in the channel was very turbid which made for zero underwater visibility on the river bottom.

In this technique, the anomaly being sought was relocated with the proton magnetometer deployed from a boat and marked with a buoy. A scuba-equipped diver then searched the vicinity of the marker buoy using an underwater metal detector and feeling with his hands (Figure 60). In each instance during the investigation, the target was found within five feet of the marker buoy and could be dug out by hand.

FIGURE 60
Scuba Diver Preparing to Enter the Water



After the target was pin-pointed the marker buoy was repositioned for final locational data recording. Datascope bearings were taken from an onshore reference point while the diver held a PVC pipe vertically above the object. The upper five feet of the PVC pipe was marked to permit determining distance using the Datascope's range finder. The diver then brought the object to the surface. If it was too heavy he secured a rope for raising it.

The following portion of the report presents the results of the investigation of the three bridge crossing areas. Each is discussed individually in order from north to south (Smyrna River, Mill Creek, Leipsic River).