INSTITUTE OF MARITIME HISTORY

UNDERWATER ARCHAEOLOGICAL RECONNAISSANCE IN LOW VISIBILITY

David P. Howe and Raymond L. Hayes *

CONTENTS

* Members of the board of directors, Institute of Maritime History.

This book has been a joint effort by many members and friends of IMH. The valuable contributions of Tom Berkey, Dawn Cheshaek, Dr Rick Ducey, Scott Hagedorn, Dr Brian Jordan, Kurt Knoerl, Dr Susan Langley, Mark Little, Dan Lynberg, Isabel Mack, Chuck Meide, Lee Nelson, Troy Nowak, Mike Nowotny, Kirk Pierce, Todd Plaia, Buzz Rosenberg, Joyce Steinmetz, and Dr Sam Turner are very gratefully acknowledged. Cover photo by Chuck Meide. Photos in Chapter 7 by Dan Lynberg. The book is a work in progress. Please email comments and suggestions to david.howe@maritimehistory.org

INTRODUCTION

This book will familiarize avocational divers with some of the basic issues and methods of conducting archaeological reconnaissance and site assessment in murky waters for State Historic Preservation Officers (SHPOs). *

Many archaeological sites lie submerged in coastal, estuarine, or riverine waters with strong currents, muddy bottoms, and poor visibility. Even if diving conditions are inhospitable, work can proceed safely and yield reliable and positive results if the divers are competent and comfortable, which requires training and experience.

The reconnaissance diver's job is to observe and to collect and report data, not to reach conclusions about the site, and certainly not to move or disturb anything. <u>For reconnaissance purposes artifacts should never be moved, disturbed, or recovered.</u> Never. Period. After the SHPO reviews the reconnaissance report he or she will decide whether to conduct a more thorough investigation, which might or might not include site disturbance under professional supervision.

CHAPTER 1 PURPOSE OF RECONNAISSANCE

Goal: Find and assess submerged historic sites.

a. Purpose.

Sites need to be found, reported, evaluated for their archaeological or historical significance, and protected as necessary to preserve their integrity. IMH and other avocational groups conduct voluntary reconnaissance in various states for these purposes.

b. Objectives of reconnaissance.

- ✓ Find all sites within selected areas, to the maximum extent possible.
- ✓ Determine the general characteristics of each cultural site (length, breadth, depth, structure, etc.), and enough detailed characteristics to support a good decision regarding further investigation.
- ✓ Report all finds to the appropriate officials.
- ✓ Study the sites in greater detail, as needed.

* The term "State Historic Preservation Officer" comes from the National Historic Preservation Act of 1966, as amended, Title 16, U.S. Code, §§ 470 et seq. In this book "SHPO" is used generically to mean all government officials charged with inventorying, managing, and protecting submerged historic resources.

Reconnaissance is extensive, not intensive. For inventory and management purposes it is better to find and get basic data on all sites, than to get great detail on some sites and not have time to find the others.

c. Ethics: No take, no talk.

Reconnaissance has no impact on sites. As mentioned above, nothing is moved, disturbed, or removed. To protect sites from looting, their locations are not disclosed to anyone except the appropriate officials.

d. Clients

Sites in state waters are reported to the following offices:

Delaware:	Division of Historical and Cultural Affairs 21 The Green, suite B Dover, DE 19903-1401
Maine:	Maine Historic Preservation Commission 55 Capitol Street, Station 65 Augusta, ME 04333-0065
Maryland:	Maryland Maritime Archaeology Program Maryland Historical Trust 100 Community Place Crownsville, MD 21032-2023
Massachusetts:	Massachusetts Historical Commission Coastal Zone Management 251 Causeway Street, # 800 Boston, MA 02114-2138
New Hampshire:	Division of Historical Resources 19 Pillsbury Street, 2nd floor Concord, NH 03301-3570
Virginia:	Virginia Department of Historic Resources 2801 Kensington Avenue Richmond, VA 23221

Other SHPOs are listed at http://www.ncshpo.org

US Navy sites must not be disturbed and should be reported to the Naval History and Heritage Command (Underwater Archeology Branch), 805 Kidder Breese Street SE, Washington Navy Yard DC 20374-5060.

Foreign warship sites also must not be disturbed and should be reported to the US Department of State (L/OES), 2201 C Street NW, Washington DC 20520.

CHAPTER 2 SEARCH PLANNING

Goal: Plan a search that will find all sites, to the extent possible.

a. Navigational background

A basic understanding of navigation is essential for reconnaissance.

(1) Latitude and longitude

These are angular measurements that define positions on the surface of the Earth. Latitude is the distance north or south of the Equator. Longitude is the distance east or west of the Prime Meridian, an arbitrary line that passes through the Royal Observatory in Greenwich, England.

One degree of latitude equals 60 nautical miles (or it would if the Earth were perfectly spherical), so one minute of latitude equals one nautical mile — a mile a minute. A mean nautical mile equals 6,076 feet 1⅜ inches, often rounded off to 6,000 feet or 2,000 yards for convenience.

The meridians of longitude (the north-south lines on the globe) converge at the poles, so one degree of longitude equals 60 nautical miles only at the Equator. Off the Equator, it equals 60 miles times the cosine of the latitude. Because of this, you can use the latitude scale printed on the right and left sides of a nautical chart to measure distances, but you cannot use the longitude scale printed at the top or bottom of the chart.

Latitude and longitude can be expressed in different formats — degrees and decimal degrees; or degrees, minutes, and decimal minutes; or degrees, minutes, seconds, and decimal seconds. Electronic navigation systems use degrees and decimal degrees to perform complex calculations of spherical trigonometry, but they can display the results in other formats. Navigators often prefer degrees, minutes, and decimal minutes for ease in estimating distances (a mile a minute). Some people use degrees, minutes, seconds, and decimal seconds. This can be confusing. In many cases, you can tell which format is being used only by looking at the physical arrangement of digits, dashes, spaces, and decimal points. Clearly indicate whichever format you choose to use.

Most nautical charts use the Mercator system, in which the three-dimensional Earth is "projected" onto an imaginary north-south cylinder wrapped around the Equator. That cylinder is then unrolled and laid flat, as a map. The Mercator projection has many advantages, and a few disadvantages including the exaggeration of distances at "higher" latitudes, nearer the Poles. Because the Earth is so large and our reconnaissance areas are so small, relatively, it is safe to pretend the Earth is flat and to ignore those errors.

US Geological Service topographical maps use a different "Universal Transverse Mercator" system that defines positions by metric distances east and north of arbitrary reference lines.

(2) Nautical charts

Charts are drawn in different "scales" to cover smaller or larger areas in more or less detail. "Scale" is the ratio between the size of an object on the chart and its size in real life, expressed as a fraction. For example, a chart scale of 1:20,000 means 1 inch on the chart equals 20,000 inches (1,666.67 feet or 0.2743 nautical mile) in real life. A "large scale" chart (1/20,000 is a larger number than, say, 1/80,000) covers a smaller area than a "small scale" chart. A "harbor chart" may have a scale as large as 1:5,000 (1" = 416' 8"), while a "sailing chart" may have a scale as small as 1:1,500,000 (1" = 20.6 n.m.).

Large scale charts offer greater precision and more detail than small scale charts. For reconnaissance, use the largest scale available.

Bear in mind, however, that precision is not the same as accuracy. For example, while transiting the Chesapeake & Delaware Canal on a cold night in 2006 our very precise electronic navigation system with its very precise WAAS Differential Global Positioning System said we were very precisely near the starboard (right) side of the canal and safely out of the way of big ships that need to stay in the center. In fact, we were to the left of center and very precisely in the path of a huge freighter whose black hull was very precisely invisible until we were so close that we avoided getting run down only by making an urgent, hard turn. We were very precisely where the GPS said we were, but the canal was not very precisely where the chart said it was. Reality always trumps paper.

Charting is a work in continual progress by the federal government. Charts are based on hydrographic surveys of the shoreline and the bottom, and they can only show what those surveys reveal. Sometimes a survey will miss an item. Even if the survey was accurate and complete when it was made, shorelines and bottoms move and change, and hazards and aids to navigation come and go (deliberately or accidentally). Those changes will not be shown on the chart, especially if you use an old edition. The latest charts can be downloaded in Electronic Navigational Chart (ENC) format from the NOAA website, www.nauticalcharts.noaa.gov/staff/chartspubs.html.

Some items that are shown on charts have been moved or removed without notification to the National Oceanic and Atmospheric Administration (NOAA), who makes the charts, so they remain on the charts even though they are not actually there.

Some items are known to exist but are not considered significant for navigation, so they are omitted to avoid useless clutter on the charts. Other items might be reported but not added to the chart until NOAA confirms their existence and location, which depends partly on NOAA's confidence in the reporter and in the reported data.

Other items have been charted with only a rough idea of their locations. This may be shown by a "PA" ("Position Approximate") note on the chart. Other chart notes include "PD" (Position Doubtful) and "ED" (Existence Doubtful).

An item may be reported at different locations by different people at different times, and therefore is charted at several different places. In the days before GPS the determination of position was difficult and often inaccurate, especially in bad weather.

(3) GPS

The Global Positioning System was developed by the US Department of Defense. It comprises a constellation of satellites (32 at the present time) that transmit time and location signals, and receivers that convert those signals to positions on the Earth.

The GPS system transmits three different signals: a Coarse Acquisition ("CA") code on one radio frequency ("L1"), a Precision code ("P1") on that same frequency, and a second Precision code ("P2") code on another frequency ("L2"). The P codes are for military use only, while the CA code is available to all. The signals can be degraded or shut off for security or defense purposes. This is called Selective Availability ("SA"). The current policy is not to use SA, but the capability is there.

Without SA, a basic GPS receiver typically has an accuracy of about 100 feet, depending on the number and positions of satellites within view and the number of satellites the receiver is programmed to use.

To improve accuracy the US Coast Guard developed Differential GPS, where a series of precisely located stations continually calculate their CA positions, compare those numbers to their known positions, calculate the difference, and transmit that "differential" as a correction to DGPS receivers within radio range. The newer Wide Area Augmentation System ("WAAS") uplinks those differential signals to satellites that rebroadcast them over wider geographic areas. WAAS DGPS usually has an accuracy of about 10 feet. It varies.

Most reconnaissance is conducted by remote sensing with sidescan sonar or a magnetometer. Anomalies or "hits" are then investigated by divers. A GPS or DGPS or WAAS DPGS receiver calculates the location of its

antenna. It does not know or care where the rest of the boat is, or where the sonar transducer, magnetometer sensor, or target might be. For navigational safety it is usually best to mount the antenna near the center of the boat. For reconnaissance it may be convenient to mount it as close as possible to the transducer or sensor. The reasons for this are explained in Chapter 4.

b. Designing a search

Searches must be carefully designed to maximize the likelihood of success within the limitations of the available time, equipment, and personnel.

(1) Define the area to be searched, based on the purposes of the reconnaissance, the depth of water, the draft of the search boat, and other navigational factors.

(2) Searches are best conducted by running a series of uniformly spaced lanes to cover the area. Select an appropriate lane orientation, which depends mainly on geography, and an appropriate lane spacing, which depends on the capabilities of your sensor and the desired coverage factor.

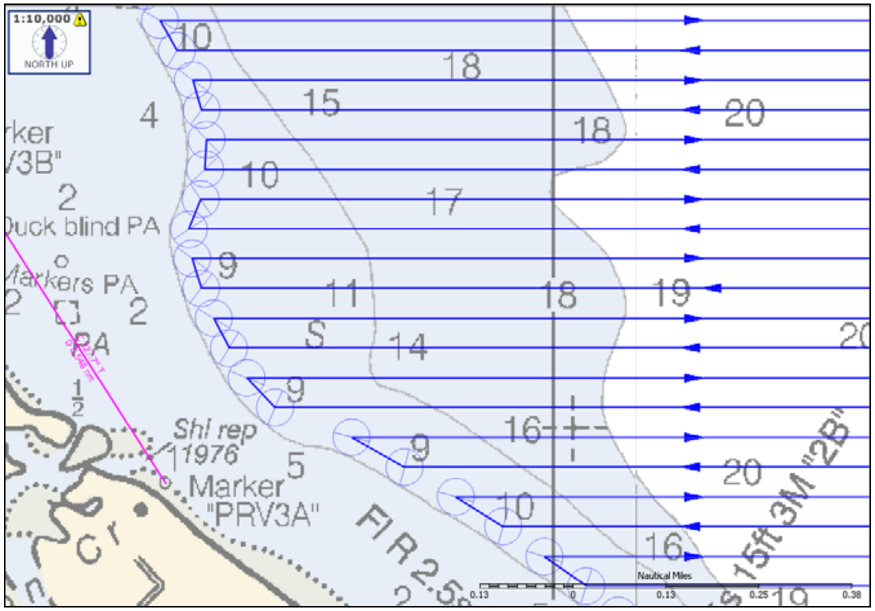
200% coverage is the usual minimum coverage. To achieve that, the lane spacing should be equal to or less than the effective range of your sensor. That way, search coverage on each lane will reach to the two adjacent lanes (the prior one and the next one), and you will have two opportunities to see each target — if you actually steer the intended lanes. See Steering, in Chapter 3. Some steering error is inevitable, and the search plan should allow for it.

(3) Establish a series of lanes and "waypoints" to build the search route. Each lane of the route will run from one waypoint to the next. Examine each lane on the chart, and look for shallows and other hazards along the lane, but remember that all charts are incomplete. If possible, connect the lanes to visible landmarks. Most people find it easier to stay on course visually than by following a compass or an electronic chart display. If possible, the lane should extend some distance beyond the area being searched, so all turns will lie outside the search area and all lanes within the area will be straight.

(4) Turning the boat will cause the sonar or magnetometer towfish to sink, which can be hazardous in shallow water. Turning also causes data to become distorted, and makes it difficult to determine the location of an object detected during the turn. It might be impossible or unsafe to make a particular turn. The location, diameter, and direction of every turn must be considered while planning the route.

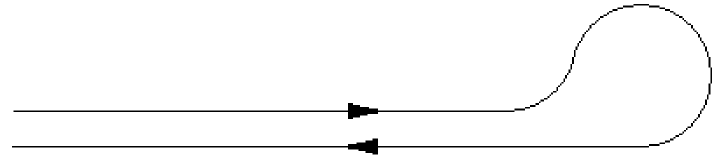
(5) To program the search into a navigational computer enter all the route lanes or waypoints in the correct sequence. Most electronic navigation programs allow you to enter or refine waypoints digitally to ensure precise lane spacing. Enter the data as precisely and accurately as possible.

Example: The chart excerpt below is taken from the search design for the SHIP project conducted by IMH in the Chesapeake Bay. It shows search lanes with 50-yard "arrival circles" or "gates" at the end of each lane. When the search boat reaches an arrival circle the electronic navigation system shifts to the next waypoint as its new destination.

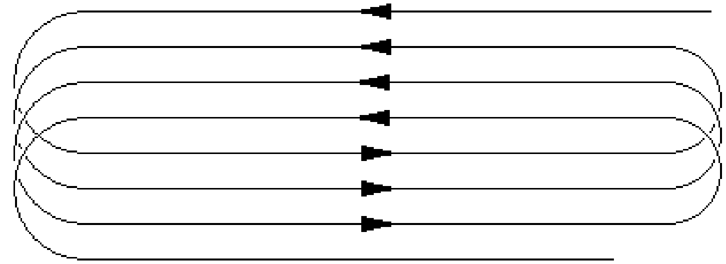


For easy math, this search used east-west lanes spaced at 0.04 minutes of latitude (= 80.92 yards or 74 meters), and north-south lanes spaced at 0.05 minutes of longitude (= 79.7 yards or 72.9 meters, at 38° North latitude). That allowed the helmsman to steer digitally by keeping to the desired latitude or longitude, which is not possible when the lanes run at odd angles.

If the lanes are tightly spaced, teardrop or "Williamson" turns can be made between the lanes, or the route can be run in a helical or "tractor" search pattern.



Williamson turn



Helical search pattern

CHAPTER 3 BOAT SAFETY AND BOAT DIVING

Goal: Don't get hurt or hurt anyone else.

a. Principal safety hazards

- ✓ Slipping and falling.
- ✓ Getting knocked around by rough seas.
- ✓ Tripping over loose gear and lines.
- ✓ Falling overboard.
- ✓ Sunburn, hypothermia, and seasickness.
- ✓ Fire.
- ✓ Low headroom in cabins of small boats.

b. Precautions

- ✓ Wear non-skid footwear — boat shoes, dive booties, or sneakers if that is all you have. Going barefoot is dangerous, especially on wet decks.
- ✓ Always hold on to something until you get your sea legs.
- ✓ Stay inside the lifelines or bulwarks.
- ✓ Sit often, walk little, stand rarely.
- ✓ Prevent tanglefoot! Control your dive gear. Coil all ropes and hang them up, out of the way.
- ✓ Do not fall overboard unless you are diving.
- ✓ Do not go out on deck alone, especially at night.

- ✓ Wear a lifejacket in bad weather.
- ✓ Know where the lifejackets are stowed and how to put them on. If you don't know, ask.
- ✓ Use sun protection — sunscreen, hat, and sunglasses.
- ✓ Dress warmly. Wear or bring adequate clothing.
- ✓ Take seasick prevention medication if you need it. If nauseous, heave over the lee (downwind) rail while someone holds you on board.
- ✓ Prevent, fix, or report all potential fire hazards.
- ✓ Know where the fire extinguishers are and how to use them. If you don't know, ask.
- ✓ If the boat is large and heavy, do not try to fend her off while approaching a pier. It is better to break the boat or pier than your arm.
- ✓ Avoid lines under a heavy strain. They will pinch your fingers. When they break they will snap back and hurt you.
- ✓ Watch your head when you go below decks.

c. Boat gear

The equipment, supplies, and information needed on a boat include everything required by Coast Guard regulations and good seamanship, plus the following items for diving and mapping:

- ✓ Dive plans that list emergency assistance facilities, local hospitals, the nearest recompression chambers, etc.
- ✓ A marine VHF radio to call the Coast Guard or other emergency assistance (Channel 16).
- ✓ A GPS unit to know and report your exact position, especially when out of sight of land.
- ✓ A cell phone to call 911 when close to land.
- ✓ A medical oxygen (O_2) kit.
- ✓ A first aid kit, with antiseptics, bandages, seasick pills, and jellyfish sting wipes.
- ✓ A dive platform and a sturdy dive ladder.
- ✓ ALFA and "diver-down" flags.
- ✓ Diver recall signals.
- ✓ A float line of 50 to 200 meters (depending on depths and currents) with a dive flag at the end, for surface extension from the boat.

- ✓ A life ring with a floating line, to be thrown to a surfaced diver.
- ✓ A long boathook.
- ✓ Marker buoys and 10-pound mushroom anchors.
- ✓ Short lines rigged to the gunwale to hold surfaced divers, dive gear, and other equipment alongside the boat. These lines should be attached to cleats and ready for immediate use.
- ✓ Dive slates and Mylar™ sheets.
- ✓ Basic hand tools and generic dive spares (O-rings, mask and fin straps, mouthpieces, extra weights, weight belts, &c.).
- ✓ Spare dog clips, carabiners, and shackles.
- ✓ Spare AA, C, and D cell batteries.
- ✓ Spare ropes and light lines in various sizes and lengths.
- ✓ Duct tape and plastic cable ties.
- ✓ Lift bags and nets if recovery will be attempted
- ✓ Drafting instruments, pencils, erasers, pens, and graph paper.

CHAPTER 4 SEARCH EXECUTION

Goal: Conduct a good search, with complete coverage and no holes.

a. Navigation

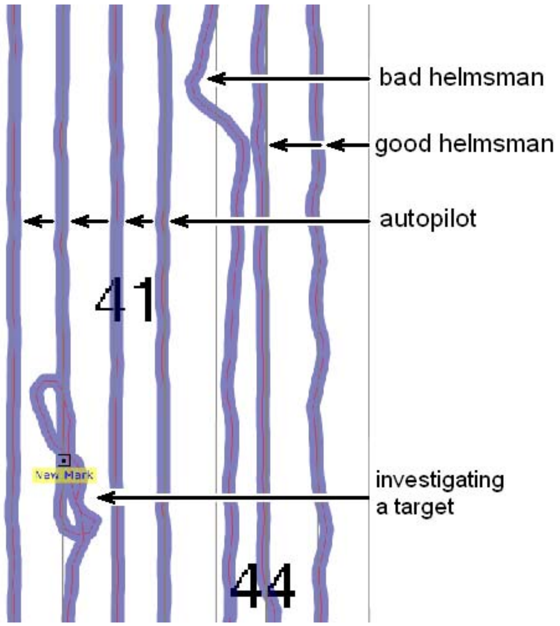
Remember, the search plan will be based on nautical charts that are not always correct or complete. Shallow depths, obstructions and other hazards might not be charted. Despite those omissions the search must be conducted safely without injury to crew or damage to boat and gear. So watch out on all sides, watch for other boats, watch the actual depth under your boat, and watch for overhead obstructions like power lines and bridges.

While conducting a search your vessel is physically free to maneuver, so you do not have any special priority for right of way, and you must follow the normal "Rules of the Road."

b. Steering

Good helmsmanship is essential for complete coverage of the search area. An autopilot programmed to follow the search plan is very helpful. It does not get tired or distracted. But it does not keep a lookout and it sometimes crashes, so it must always be watched.

Gaps caused by bad helmsmanship must be filled in by more search runs.



plot of actual search tracks

Winds and currents will affect the movement of the boat. Rough seas will throw her off course and reduce sidescan image quality, and they may make operations unsafe.

It is important to realize there will be a time lag between your actual position and the position displayed on the GPS or navigational computer, depending on your speed, the sea conditions, and how frequently the image updates. You will need to get a feel for how your vessel acts in a variety of conditions so you can stay on the search line.

c. Sidescan sonar characteristics, capabilities, and considerations

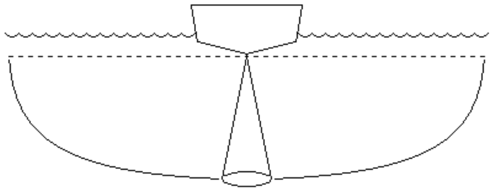
A sidescan sonar detects objects that protrude above the seabed. It has very little penetration into the seabed. Sensitivity (the ability to detect objects) and resolution (the ability to differentiate between objects) depend mainly on the frequency, power, and pulse duration of the sonar signal; and on the distance, reflectivity, and shape of the object.

Most small sidescans operate on 120 volts AC or 12 volts DC. In varying degrees all are affected by electrical "noise" and interference from other electronic devices, especially depth sounders and "fishfinders."

d. Sidescan sonar deployment

The transducer can be hard-mounted to the hull, mounted on a movable pole or arm, or towed on a "towfish." In calm seas it can be mounted off the bow of the vessel to avoid propeller and wake turbulence.

"Vertical beam width" is the vertical arc covered by the sidescan signal. Different sidescan units have different beams. The top of the beam is usually angled from 0 to 20 degrees below the horizontal, and the bottom is usually from 6 to 10 degrees off the vertical. That leaves a blind spot under the transducer. Some units have a third, down-looking channel to cover that.



Transducer depth affects the area of coverage. A shallow depth may give better detection of large objects at long range. A deep depth improves detection of deep objects and of small objects at short range. Do not run the transducer so deep that it might snag on the bottom or obstructions.

High frequency sonars give better resolution but have a shorter range than low frequency units. Some units offer dual frequencies.

A towfish is usually best positioned at an altitude (distance above the bottom) between 8% and 20% of the range setting. NOAA's "Rule of Thumb." At transducer depths below 8% the achieved range approximately equals 12.5 times the towfish height, if the top of the beam is horizontal.

The towfish depth is determined by the length of the towing cable, the speed of the boat, and the weight and towing characteristics of the towfish. Some units have a depth gauge on the towfish, some have an "altimeter" that shows the distance of the towfish off the bottom, some have both — and some have none, so you have to guess.

To protect the towfish in shallow water it can be floated at or near the surface with a life jacket or "pool noodle." To make it run deep extra weights or a "depressor vane" can be mounted on the towfish.

The towing speed should be adjusted so that at least three acoustical hits ("pings") are made on each object. This will depend on the maximum range and the "pulse repetition rate" or "ping rate" of the specific sonar unit in use.

e. Sonar image interpretation

The ability to distinguish anomalies improves with experience. Some sites are obvious, and some are not. Factors to look for include —

Protrusion: An object lying flat on the bottom will not give an echo. A high or abrupt protrusion will show a shadow behind it.

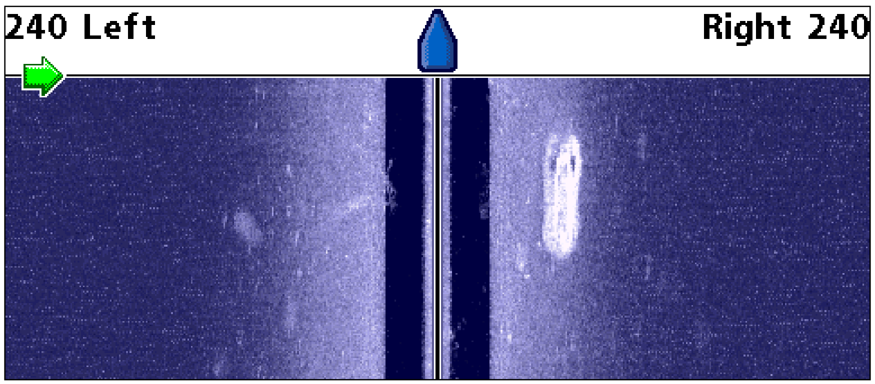
Reflectivity: Hard objects give a strong echo and a bright return on the scope.

Texture: Does the echo appear uniform, or is it blotchy and contrasty?

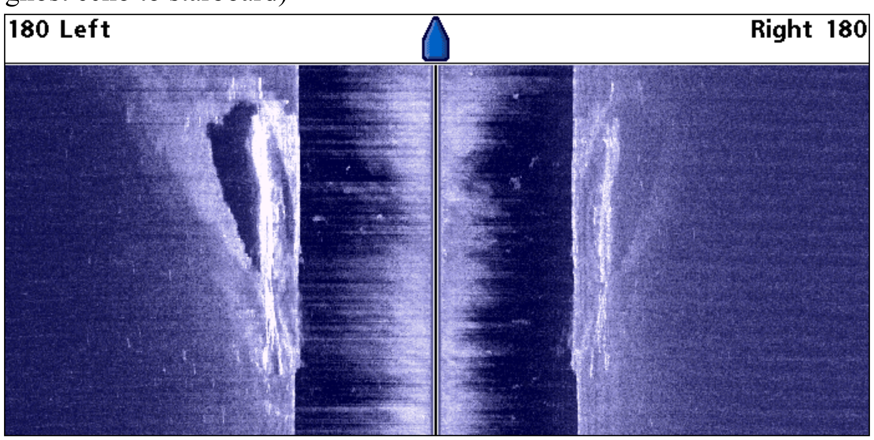
Shape: Is the object distinct and angular, or a shapeless blob?

Examples — (The numbers in the upper corners of the seven blue images below show the sonar range settings, in feet.)

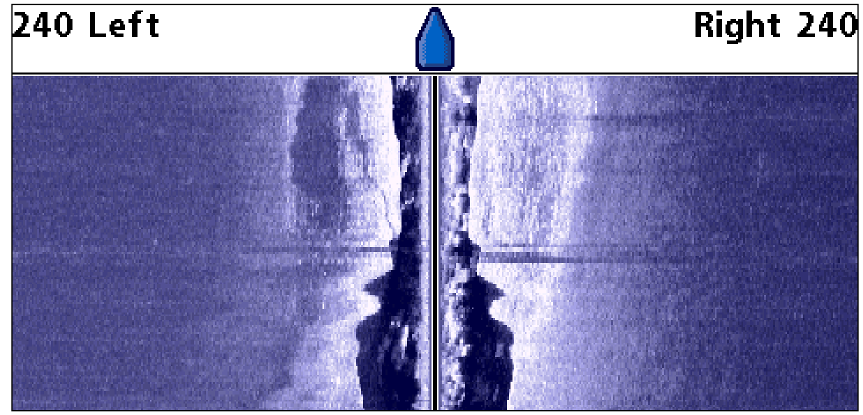
small wreck, to starboard:



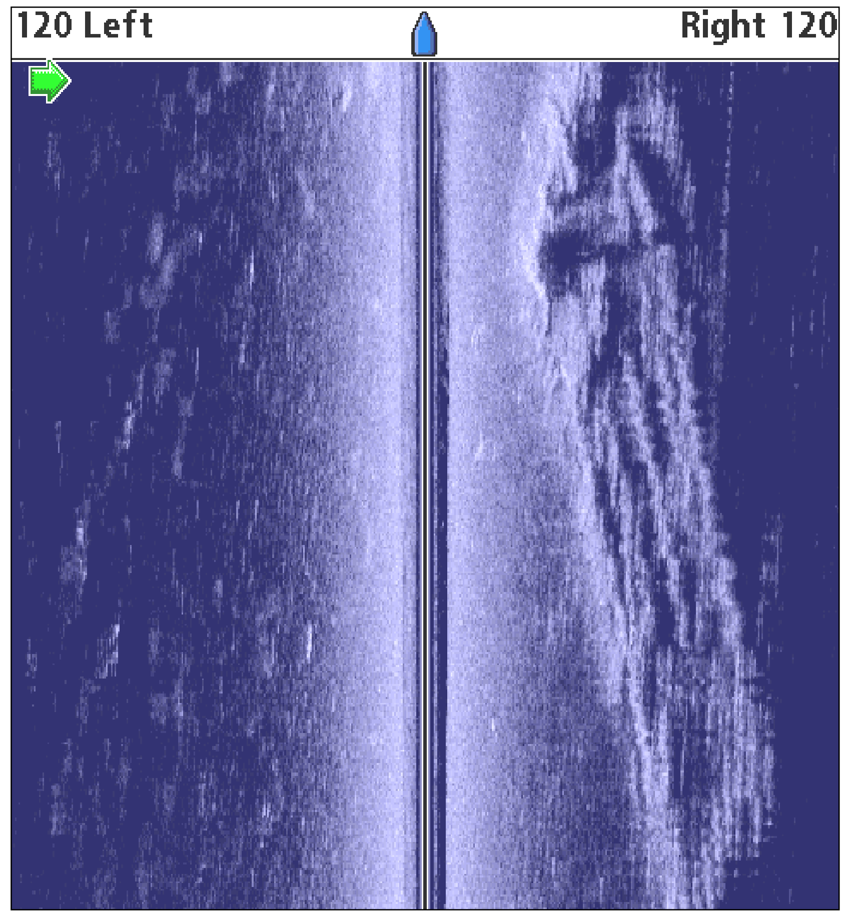
big wreck, to port: (note the dark shadow behind the wreck, and the ghost echo to starboard)



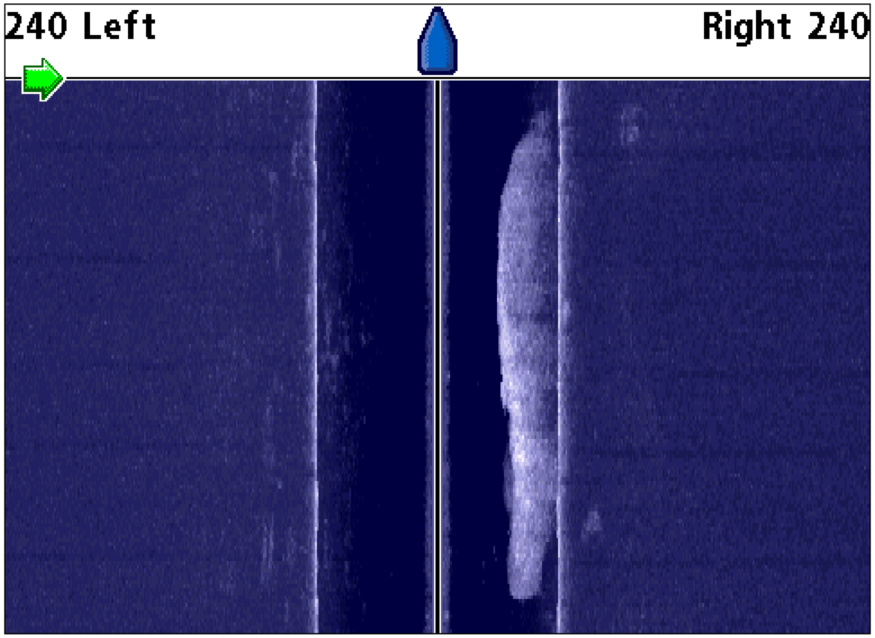
big wreck, right underneath:



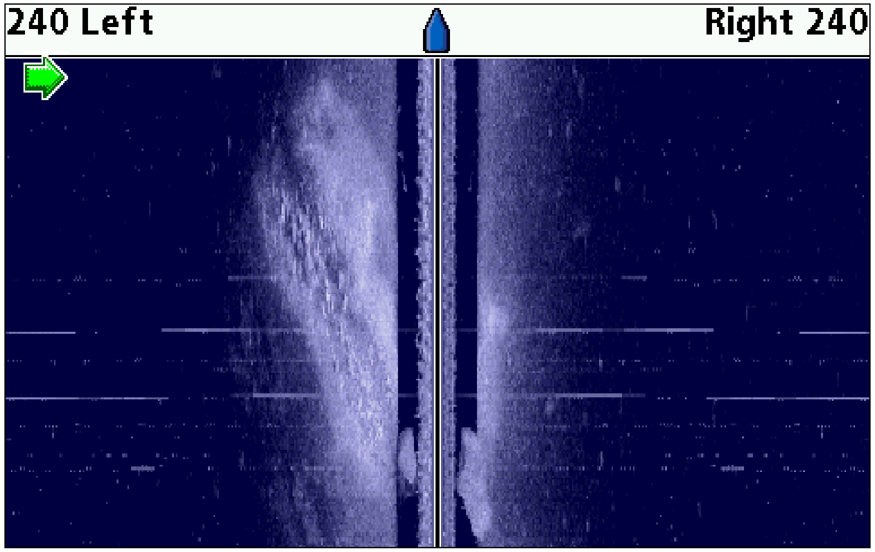
big wreck, to starboard:



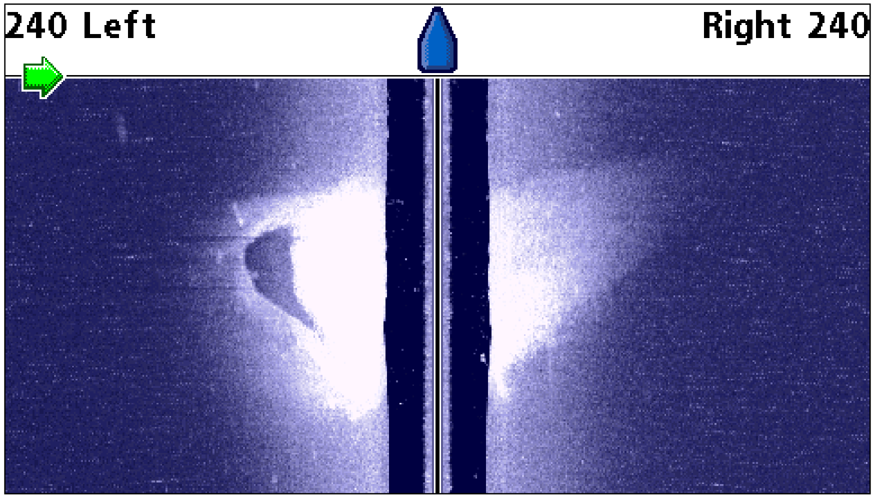
non-wreck, to starboard: (school of fish)



non-wreck, mostly to port: (pile of rock)

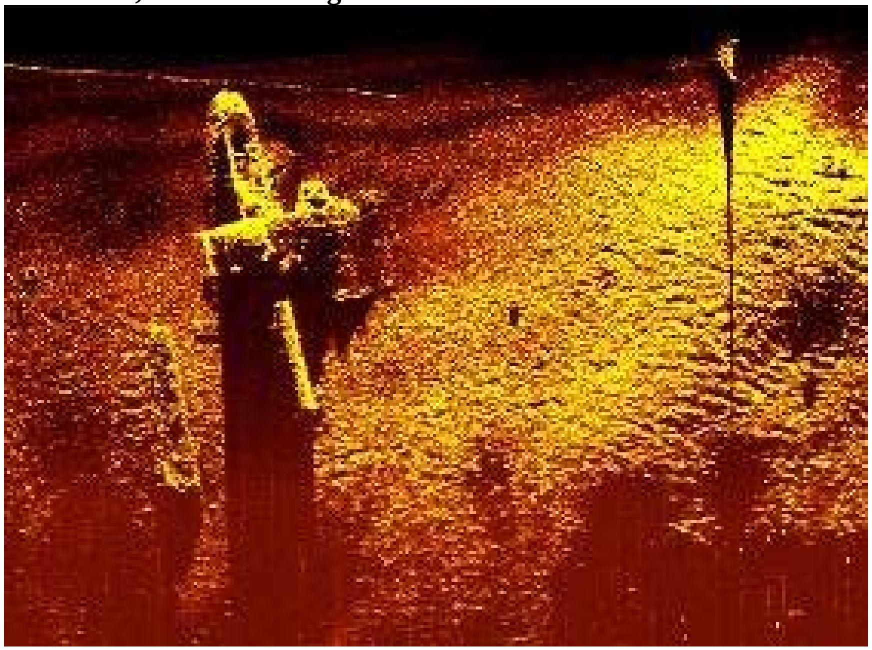


non-wreck, mostly to port: (oyster mound)

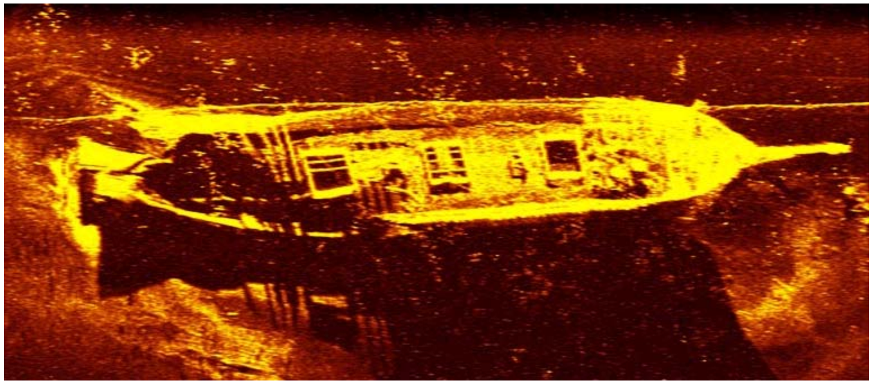


The images above were taken with a Humminbird 987 CSI sidescan sonar at a frequency of 262 kHz.

Navy PBM-3 seaplane, port engine missing, tail and port wing broken off, starboard wing buried in mud:



schooner wreck:

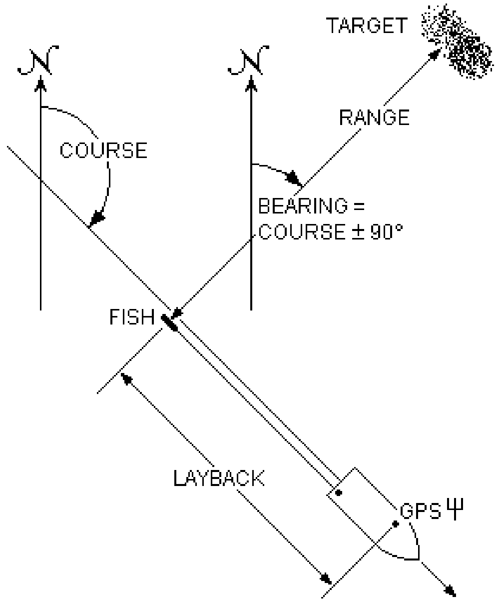


Schooner Herbert D. Maxwell, *184 feet long, built in 1905, sank 16 March 1912 in a collision off Annapolis MD. Note the beakhead, hatches, damage to stern and starboard quarter, and the shadows of the hull and of the broken deck beams aft.*

The two images above were taken with a Marine Sonic Technologies "Sea Scan PC" unit at 600 kHz.

f. Location of the target

Accurate target location is essential. In murky waters, divers will not find the target unless you drop them within a few feet of it. The position of the target be calculated by applying the direction and distance from the towfish to the target, and from the GPS antenna to the towfish.

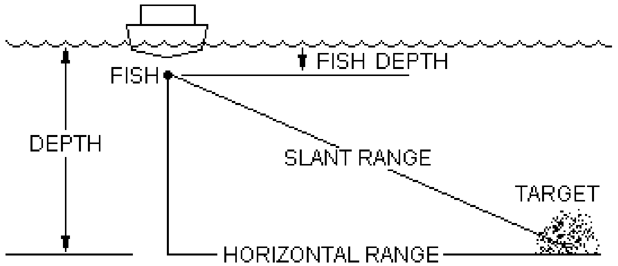


The direction and distance from the towfish to the target are affected by:

the boat's course,

the horizontal range (as distinct from the "slant" range), and

the target depth and towfish depth, which affect the slant range.



The horizontal range can be calculated by the Pythagorean theorem if the bottom is flat and you know the slant range and the towfish altitude (= the water depth minus the towfish depth).

The direction and distance ("layback") from the GPS antenna to the towfish are affected by —

the distance and direction from the GPS antenna to the towfish cable attachment point, which depend on the vessel's arrangement and the course;

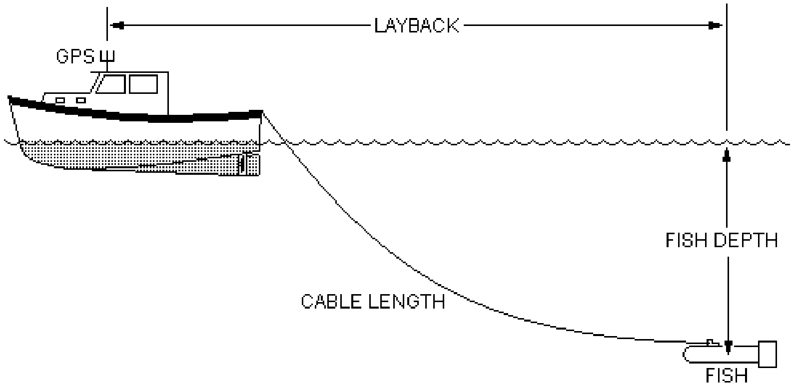
the direction from the attachment point to the towfish, which depends on the course, and

the horizontal distance from the cable attachment point to the towfish, which is affected by —

the length of the towfish cable,

the boat speed, and

the weight and towing characteristics of the towfish.



The towfish usually will rise when the boat goes faster and sink when she slows down. Speed is lost and the towfish sinks when the boat is turning, unless you speed up or make a big, gentle turn, which might not be possible in confined waters.

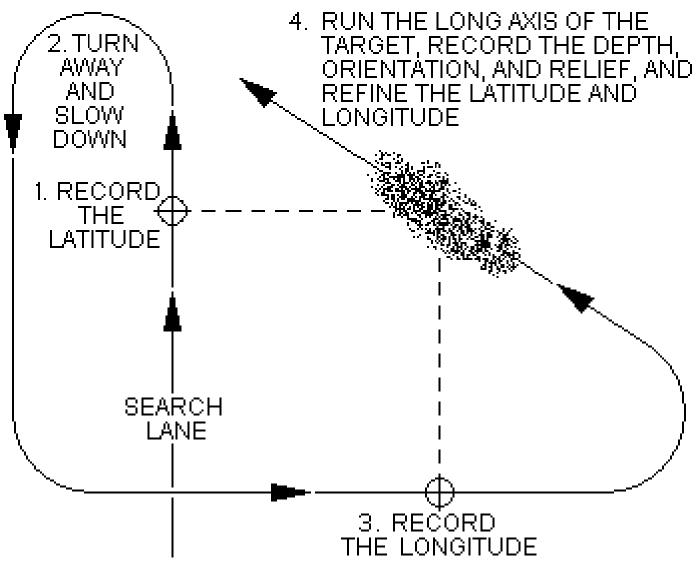
Delays in recognizing a target will confuse things even further.

All the above calculations take time. A good hydrographic survey computer program will do the arithmetic and enable you to get lat/lon coordinates for a target merely by placing a cursor on it — but don't trust that too much, unless you thoroughly understand the underlying algorithms and assumptions.

g. The easy, low-tech fix: Put the boat directly over the target so you can see it on a down-looking fishfinder. Ideally the fishfinder transducer will be directly under the GPS antenna, or at least the displacement between them will be small and known.

(1) First, refine the target position by supplemental search lanes.

Supplemental lanes should be run at slow speed to minimize the boat's wake, which will clutter the sidescan. It may take 10 or 15 minutes for wake turbulence to subside. Watch the towfish depth when you slow down!



(2) Record the position when the target is right under the boat.

(3) Alternatively, have divers put a marker buoy on the target with a short line, and take a GPS reading at the buoy.

CHAPTER 5 DIVING

Goal: Conduct all dives safely and productively without damaging the site.

a. Diving protocols

IMH follows and recommends the diving standards of the American Academy of Underwater Sciences (AAUS), available at http://www.aaus.org/mc/page.do?sitePageId=29798&orgId=aaus. Most academic diving programs also adhere to AAUS.

In its volunteer support to the Maryland Historical Trust on the *U-1105* site IMH follows the diving standards established by the state. They are posted on-line at www.marylandhistoricaltrust.net/u1105saf.pdf.

b. Diver safety

Murky water increases the risks and stresses of diving. Unfamiliarity and lack of visibility breed insecurity and increase air consumption. Entanglements, overhead structure, and other hazards are more difficult to see, avoid, and escape. Gauges may be impossible to read. The water may be polluted, increasing the risk of infection or disease from a minor scratch or cut.

Projects nonetheless must be conducted with the highest standards of personal safety and the best practices of scientific diving. Safety requires increased underwater teamwork, topside support, and advanced planning. With proper preparation, good gear management, and advanced diving skills, the problems can be avoided or minimized and the tasks successfully completed.

Divers must be prepared for all eventualities. Comfort requires a calm, positive attitude and an understanding of the realities to be confronted. Black water diving skills are best acquired by practicing how to respond appropriately to the lack of vision, under controlled conditions.

Task-oriented diving requires the diver to focus both on safety and on the work to be done. Diving becomes a tool, not an end in itself. Skills therefore must be automatic and reflexive, which usually requires the gradual accumulation of experience over time.

Essential skills for individual divers include buoyancy control, underwater navigation, equipment configuration, and non-horizontal positioning. Essential skills for buddy teams include maintaining communications, coordinating activities, recognizing problems, and assisting each other as necessary.

Some techniques developed for rivers, caves, and caverns may be useful in low-visibility diving. See Taylor, 1990; van Tillburg, 1994; von Maier, 1991; and Zumrick et al., 1988.

Decompression dives and penetration of structures should not be attempted in low visibility. Dives deeper than 10 meters (33 feet) should include a safety stop for 3 minutes at 4.5 meters (15 feet). Repetitive dives may be required, but conservative tables should be used for surface intervals and repetitive bottom times.

c. The buddy system and stand-by divers

All dives should be conducted by two-diver buddy teams under a Divemaster protocol. A pre-dive briefing before each dive should cover task assignments, safety procedures, communications, loss of buddy contact, dive times, recall signals, and potential risks.

Because of the increased risks, diving in low visibility requires cooperative and supportive buddy teams. The buddy system does not diminish the need for self-sufficiency. Despite a greater need for underwater teamwork, diving in black water is close to solo diving because divers cannot easily communicate visually (von Maier, 1991). It may be difficult for one diver to know if his buddy has a problem and to intervene effectively. Self-reliance and mutual assistance are both essential.

Roles for each diver in the buddy team must be prearranged. Usually, one diver is the leader and the other follows for safety and for tasks that require two people. For example, when measuring a large object one diver may hold the end of the tape at the zero point while the other diver takes measurements at other points. When conducting a circle search one diver might hold the line at the center while the other swims the circle. When searching along a line of bearing one diver navigates by compass while the other diver searches.

Signals can use sound, touch, or pulls along buddy lines. A code system is necessasry. See page 29 for a sample. When two divers separate to take measurements over a long distance the measuring tape serves as a buddy and signal line. Although not in visual contact, they must maintain that connection.

"Lost contact" procedures for each dive must be specified in advance. They will depend on the site conditions and the skills of both divers. If separation occurs, one diver might remain stationary and use audible signals to call the other, or one might surface while the other deploys a buoy, or they both might surface. On some sites an agreed rendezvous point might be established.

Whenever divers are in the water a stand-by buddy team must maintain a continuous watch for bubbles and emergency buoys, and be ready for immediate entry in an emergency. When a diver deploys an emergency buoy the stand-by team enters the water with a spare tank and regulator, descends the buoy line to the diver, assists as needed, and ensures that the distressed diver and his buddy are safely recovered.

The stand-by team usually will be the divers scheduled to dive next in sequence after the in-water team. On a small site only one dive team should be in the water at a time, to prevent interference and to minimize silt disturbance.

d. General dive procedures

- ✓ Prepare dive plans that include the expected site conditions, the tasks to be done, and emergency contacts including emergency assistance, hospitals, and recompression chambers.
- ✓ Conduct pre-dive briefings to ensure everyone knows the plan and knows what to do in case of problems.
- ✓ Use the buddy system, and stay in contact.
- ✓ Arrange a system of signals by touch.
- ✓ Establish and follow lost contact procedures.
- ✓ Avoid entanglement in lines.
- ✓ Avoid sharp or dangerous objects — fishing gear, sharp features, and nasty creatures.
- ✓ Avoid overhead structures that might collapse.
- ✓ Do not penetrate into structure.
- ✓ Focus on your safety and surroundings first. Work comes second. It is much better to come up without data than not to come up at all.

The Dive Supervisor should personally check every diver before every dive to ensure the air is on and all gear is present and appropriately rigged.

e. Dive gear

Basic gear for each diver will include the italicized items on almost all dives, and may include the other items as well, depending on the task to be done.

- ✓ *A cut- and abrasion-resistant dive suit, boots, gloves, and hood, for protection from cold and abrasion.*
- ✓ *A regulator with octopus.*
- ✓ *Mask, fins, BC, weights.*

- ✓ *No snorkel.*
- ✓ *A sharp knife and EMT shears.*
- ✓ *A large light and a smaller back-up light.*
- ✓ *A console-mounted compass, depth gauge, and pressure gauge.*
- ✓ *A dive watch.*
- ✓ *A Jon line.*
- ✓ A wreck reel.
- ✓ Marker buoys.
- ✓ A slate with Mylar™ sheets and pencils.
- ✓ A folding ruler.
- ✓ A 50- or 100-foot (15- or 30-meter) measuring tape.
- ✓ Some way to carry it all.

All dive gear must be serviced by a qualified technician annually or as recommended by the manufacturer. Each diver should bring the appropriate spares, and test all gear before arriving on site and again before each dive.

Contact with sharp or toxic objects can easily occur. Protection for body, hands, and head is needed even in warm water. Even a slight injury can inconvenience the other divers and disrupt the project.

An "octopus" rig is needed to share air and to inflate marker buoys.

It is difficult to read digital gauges and watches in black water. Analog devices are easier. Gauges should be worn at chest level, not stuffed into a BC pocket. An instrument console is important, because wrist-mounted instruments can easily get fouled or ripped off.

Wear your mask strap under your hood. It is less likely to get knocked loose.

Snorkels are entanglement hazards. Do not wear one. Carry one if you must.

EMT shears are needed to cut steel fishing leaders, and are useful for monofilament and net. For easy access and to reduce entanglement, knives and shears should be worn on the HP hose, power inflator hose, BC shoulder strap, or other location near the chest. The diver must be able to find it, free it, use it, and put it away by feel, even if entangled. Knives must be sharp. Shears must be sharp and tight.

Carry a primary light and a back-up light. Powerful lights are essential. Cave lights are best. A strong light may be seen at a short distance in black water and will illuminate gauges. Lights should be tested before

every dive, and batteries replaced or recharged as needed. Handheld lights should be carried in a BC pocket, not dangling.

Each diver should carry a 2-meter Jon line, with an eye in one end and a large dog clip in the other, to use as a buddy line, a holding line to maintain position, or for short circle searches.

The wreck reel should hold at least 50 meters of abrasion-resistant line. The line can be used as a buddy line, for taking bearings, for ascent, or for deployment of a buoy. Divers can use different colors to distinguish their lines from other divers' lines, entanglements, or baselines. Bright colors can be seen even in low visibility. Wreck reel lines should be thick, at least 1/8-inch, to reduce snarling and "bird-nesting."

On most dives, each diver should carry a small buoy to signal the boat if assistance is needed or to mark a submerged object. He must be able to deploy the buoy without getting tangled in its line. It is best if each diver uses a different color buoy.

Slates must be big enough to carry all the drawings and notes that will be made during the dive, but small enough to be handy. A 12-inch (30cm) plastic square with a ruler or scale on one edge is best. It should have a lanyard, a way to carry two pencils (2B or softer), and perhaps a polymer eraser. Surgical tubing or a tube made of duct tape can hold pencils and eraser when not in use. The Paper Mate ® SharpWriter ® mechanical pencil works well.

f. Air management

- ✓ Don't run out!
- ✓ Watch your pressure gauge.
- ✓ Know your air consumption. Allow for greater consumption with cold water, hard work, stress, and excitement.
- ✓ Wear a big tank, doubles, or a pony bottle.

Even if the planned dive time has not elapsed or the tasks have not been completed, all dives should end when tank pressure reaches a specified level, which will depend on the depth and tank size. Those pressure levels must be established in advance for each dive. For example, using a single 80 CF tank, a pressure of 500 psi might require the end of a dive to 10 meters (33 feet), or 800 psi for a dive to 15 meters (50 feet) or 1,000 psi for a dive to 20 meters (66 feet).

g. Alternate air source

Divers must have an alternate air source if there is any risk of entanglement or entrapment, or if the depth or environment might restrict emergency access to the surface. The alternate source can be a pony bottle or doubles. Doubles may be yoked or independent. Yoked doubles are preferred.

h. Tank valves

If the tank valve becomes entangled or rubs against structure the diver must ensure the valve is fully open and was not partly or fully closed by the entanglement or contact. The tank should be worn high enough on the back for the diver easily to reach the valve.

A "J" valve provides an extra layer of safety when the water is so murky that the diver cannot read his pressure gauge. However, the "J" valve must be properly rigged, the diver must be able to move the handle, and he must periodically ensure the handle has not been flipped accidentally to the reserve position. A "J" valve is not a substitute for an alternate air source.

i. Sharing air

A diver should normally breathe from the regulator he will give to a buddy who needs air. That way, the diver who needs air will know where to get it and will know it works.

That regulator should be fitted with a long hose, 2 meters or 7 feet. The hose must not be so loose that it gets entangled, nor so short that it prevents the safe administration of air.

The hose should not be wrapped around the donor diver’s neck. It may be wrapped around his body or tucked into flexible bands (surgical tubing, bungee cords, or sections of inner tube) on the tank or the side of the BC so it does not get tangled but is immediately and fully available to the buddy. The hose may have a 45° or 90° swivel that allows it to run downward next to the diver’s body and under the arm to reduce the risk of entanglement but still allow free use by the other diver.

The other second stage — the one the donor will use when sharing air — should have a short hose and be held by surgical tubing just below the chin where it is immediately available to the donor but will not get snagged or fouled with mud or sand. Test both second stages before every dive.

j. Entanglement

Entanglement is a risk in black water. Minimize the snag hazards ("endanglements" or "enstranglements") on your rig. Stow them, tuck them, or tape them down. Tanks, valves, fins, knives, wrist-mounted instruments, weight belts, strap ends, and other gear will easily foul on fishing lines, nets, ropes, seaweed or grass. Monofilament fishing lines

is a common hazard, and they often have steel leaders and sharp hooks and lures.

In many cases you will not be able to avoid or identify what you are tangled in. Managing dive gear before and during the dive to minimize the risk of entanglement will make problems less likely to occur and easier to fix.

Early recognition and communication of entanglement can prevent a bad situation from getting worse. In this way one diver may assist another before they both become entangled and release becomes more difficult. Movements should be slow and careful, not erratic or jerky, to keep entanglements to a minimum.

It might be necessary to doff your tank and BC to escape. This requires blind release techniques, which must be practiced in advance. Doff-and-don is an emergency measure to be used only as a last resort, but all divers must be capable of doing it by feel. For the greatest safety in doffing and donning, the diver and the dive rig each should be weighted for neutral buoyancy.

k. Control and buoyancy

Great care is needed to avoid disturbing or damaging sites and to avoid stirring up silt and reducing visibility. especially by fin wash. Features are measured and mapped *in situ* without moving them and without touching them any more than necessary to obtain good data.

For reconnaissance and general mapping divers should be neutrally buoyant with minimal weight. For detailed work on specific features, divers should wear approximately 10 pounds of extra weight to make it easier to stay on location. The choice between belts, integrated weights, tank weights, or a combination, is up to the diver. However, many dives will be in a head-down feet-up position, so integrated weights or back- or tank-mounted weights may not be suitable.

Working in a head-down, fins-up position helps avoid stirring up silt. Divers must be able to clear their masks, adjust their buoyancy, and use their tools in that position. Archaeological diving usually requires limited horizontal movement. The diver may need to hover in one spot for much of the dive, and should minimize bottom disturbance by eliminating unnecessary movements. Proper thermal insulation is important for comfort during long periods of immobility.

l. Underwater navigation

Learn your way around the site. Exploratory dives and familiarization dives are appropriate and necessary, especially on large, complex sites.

To minimize site disturbance a specific entry point should be established and used. That point typically will be a conspicuous feature with a temporary buoy, a tag line to the dive boat's anchor, or a buoy at one end of a baseline. Once the entry point is established, each diver should conduct at least one familiarization dive to understand the site and to learn the routes and approximate distances to the features he will map.

A diver must always know where he is on the site. A compass is needed to take bearings. Lines can be rigged to orient divers, to divide the site into segments for mapping, and as baselines for trilateration. The lines should be tight, and strong enough to hold divers in a current.

m. Protect the site!

Do not cling to structure. You might damage it, or it might collapse and damage you. Be careful of fin wash, which can be extremely destructive to sites and can move artifacts.

Ascend and descend using anchor or marker buoy lines. Drift ascents are bad, especially in strong currents, or if the dive boat is anchored with no "chase boat" to fetch wandering divers.

n. Task loading

Individual and team skills must be considered when assigning tasks. The tasks must be realistic, and the time to perform those tasks must be adequate, to minimize stress and ensure the job gets done.

Because of the likely difficulty of reading a watch in turbid water and the increased likelihood of distraction while concentrating on tasks, a time limit for each dive and a series of diver recall signals should be set in advance. In all cases, dives should end when the assigned tasks are completed.

o. Dive logs

The Dive Supervisor shall log the following information for every diver on every dive —

- ✓ The breathing gas, tank size, and tank pressure(s).
- ✓ The time when each diver enters the water.
- ✓ The time when the divers begin their descent.
- ✓ The expected time to surface, assuming 30 feet (9 meters) per minute ascent plus a safety or decompression stop.
- ✓ The time when the divers actually surface.
- ✓ The time when each diver exits the water.
- ✓ The tank pressure(s) upon exiting the water.

p. Communications

(1) Boat to diver

A general recall signal and an emergency recall signal should be established and understood by all divers before water entry. A general recall signal should be made to the dive team two minutes before their scheduled ascent, and again when they should start their ascent. An emergency recall signal should also be available for urgent, life-threatening situations.

Recall signals may include an underwater horn (e.g., DiveAlertPlus®), firecrackers, revving the boat's engine in neutral, or other distinctive noise.

(2) Diver to boat

As mentioned above, the dive plan might provide that a diver's buoy will be used only to call for help. In other cases it might be used to mark objects for further work. Divers can carry two — a small lift bag to mark objects, and a safety sausage to call for help.

(3) Diver to diver

Visibility is often so bad that normal hand signals cannot be seen. Underwater signals can use hand squeezes or tugs on a buddy line or measuring tape. A prearranged code allows effective communication without visual contact. One distinctive signal, such as three tugs, should be reserved only for emergencies. The following tugs and squeezes have been found useful for reconnaissance work.

1	Are you OK? I am OK. Yes.	
2	Surface. No.	(up, no)
2 + 2	Come to me, or follow me.	(to me)
3	I have a problem. Help me.	(SOS)
3 + 3	Give me air.	(air now!)
4	Stop, or stay here.	(stop, stay)

Other signals might also be used, depending on the tasks to be done. They need to be arranged, understood, and practiced before diving. For example, if the dive will involve measurement of features, two tugs or squeezes could mean "go to the next feature." On another dive to recover an object with a lift bag, two squeezes might mean "blow the bag" (up), while four might mean "deflate the bag" (down).

To relay a measurement or a distance one diver can hold the other diver's hand and poke his palm the correct number of times, with a line to separate units. Palm pokes will not be confused with the hand squeezes used for other messages. If using metric units, 3.6 meters (12 feet) would be three pokes, a line, and six pokes — the same way it would be written on a slate (see page 51). If using feet and inches, the same signal would mean 3' 6" (1.1 meters).

Divers who know Morse Code can spell anything, but skill in Morse takes a great deal of practice. A-A-A is used to get the other diver's attention, and as a period or decimal point. C ("Charlie") means yes, N ("November") means no, and R ("Roger") means "I understand."

Morse Code —

A	· —	N	— ·	1	· — — — —
B	— · · ·	O	— — —	2	· · — — —
C	— · — ·	P	· — — ·	3	· · · — —
D	— · ·	Q	— — · —	4	· · · · —
E	·	R	· — ·	5	· · · · ·
F	· · — ·	S	· · ·	6	— · · · ·
G	— — ·	T	—	7	— — · · ·
H	· · · ·	U	· · —	8	— — — · ·
I	· ·	V	· · · —	9	— — — — ·
J	· — — —	W	— — ·	0	— — — — —
K	— · —	X	— · · —	period	· — · — · —
L	· — · ·	Y	— · — —	?	· · — — · ·
M	— —	Z	— — · ·		

q. Boat duties

The boat crew must maintain a constant lookout for divers' bubbles, divers' signals, surfacing divers, and other vessels. Whenever divers are in the water the boat must fly the sport diving "diver down" flag and the ALFA flag, and tell oncoming boats and ships by radio that divers are down. If anchored, the boat should also fly an anchor ball.

The boat should not anchor into the site itself, but should anchor so the wind or current will swing her near the site — but not directly over it in shallow water. Especially on large sites with several dive teams in the water at the same time, it may be better for the dive boat not to anchor but to idle or drift near the site and stand ready to recover or assist divers as needed.

If the boat is anchored, the anchor line should be buoyed so it can be cast off instantly without raising the anchor in case of emergency.

CHAPTER 6 SITE DIAGNOSTICS

The dimensions, structural components, equipment, and cargo or armament of a vessel provide crucial diagnostic data, indicating the age, purpose, origin and other characteristics of the vessel.

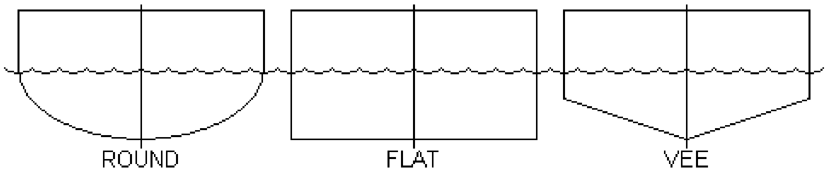
The best way to learn about the design, construction and equipment of ships is to study actual vessels and accurate models. An exhaustive study of wooden ship design and construction would be the work of many lifetimes. This chapter only explains some of the common features and components seen on wooden commercial vessels dating from the 18th to 20th centuries in American waters, to help divers recognize those objects and their component parts even when they are broken, scattered, and half-buried. Shipwrecks are three-dimensional jigsaw puzzles with many pieces broken or missing and no picture on the box — but most of them can be solved.

a. Vessel design and construction

There are almost as many ways to build a vessel as there are nations, ports, designers, yards, builders, and vessels. Each vessel is unique to some degree, but there are common features. Like construction methods and designs, many of the terms and spellings are flexible and have changed over the years. E.g., in modern usage a "sloop" is a sailing vessel with one mast and two sails, but in naval usage in the 18th and 19th centuries it also meant a warship with three masts, smaller than a frigate.

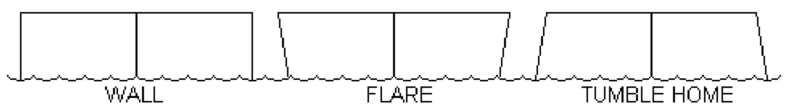
The name of a type of vessel might indicate her design, or construction, or purpose, or sailing rig or propulsion, or builder, or regional or ethnic association. E.g., the term "dory" may come from the Portuguese word *pescadore*, fisherman, but it has come to mean a specific type of flat-bottomed hull. Sometimes a type name is a local nickname (complimentary, neutral, or derogatory). Thus, a particular fishing (purpose) schooner (rig) might be called a Gloucesterman (origin) or a sharpshooter (design nickname) or a jackass schooner (rig nickname) by some people for some purposes, and a different name by others.

The shapes of hull bottoms fall into three general categories, each with different advantages and disadvantages in the cost of construction, seaworthiness, strength, stability, speed, and load-carrying capacity. Looking at the shapes in "section," as though you cut the hull in half and looked at the cut end —

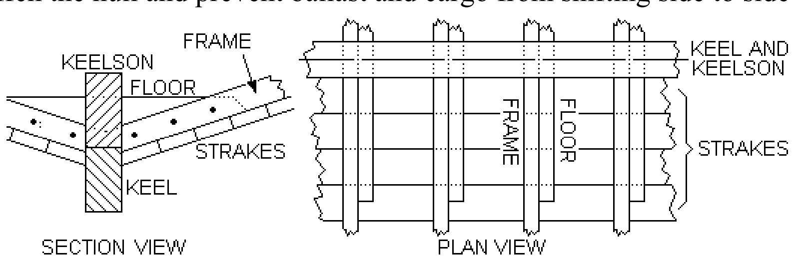


The angle of the vee above the horizontal is called "deadrise." It is often very steep at the bow.

A vessel's sides might be vertical ("wall") for easy construction and greater carrying capacity, or angled outward ("flared") for greater stability — i.e., as the vessel is forced over to one side by winds, weights, or seas, the buoyancy of the lee (downhill) side gains leverage and helps the vessel stay upright. The bow of most vessels has significant flare to ease her motion in the water and to help her ride over waves. On some vessels the sides slope inward. This was done in sailing warships to make it more difficult for men to jump on board from an enemy ship alongside. Because it was intended to cause boarders to fall between the ships, the inward slant is called "tumble home."



Most wooden vessels have a keel, a heavy timber that forms the backbone of the hull and runs almost the entire length of the vessel. Each side of the keel may be cut with a groove or rebate ("rabbet") to receive the edge of the first plank (the "garboard strake"). The keel may be reinforced on top by a similar or even larger timber called a "keelson," which usually is notched to fit over the frames and floors. Some vessels have several layers of keelson, as tall as 6 or 8 feet in a large vessel, to stiffen the hull and prevent ballast and cargo from shifting side to side.



The outer skin is formed of "strakes" (planks) supported by "frames" (ribs) that are locked to the keel and keelson by timbers called "floors." A frame might be made of one continuous length of timber that is bent into shape, or made from naturally curved timbers ("grown frames"), or built up from shorter sections called "futtocks" that fastened together,

usually overlapping each other. Floors might lie on top of the frames or alongside them, usually aft of the frames in the forward half of the vessel, and forward of the frames in the after half. Most frames are perpendicular to the keel, but in the bow and stern they might be "canted" at an angle for easier construction.

Other fore-and-aft timbers called "stringers" might lie inside the hull, outboard of the keelson and nearly parallel to it, to reinforce the structure. If they lie right next to the keelson they are called "sisters."

In a flat- or vee-bottom vessel the bottom and sides meet at a distinct angle called the "chine." A heavy timber called a "chine log" may reinforce the joint. The bottoms of some vessels, especially in the Chesapeake, are planked cross-wise rather than fore-and-aft, with heavier stringers and fewer frames.

"Limber holes" may be cut into the undersides of frames and floors, next to the keelson, to allow water to run down to the deepest point of the bilge where it can be pumped out. Small "limber chains" might run through those holes to break up the inevitable accumulation of dirt that would clog them.

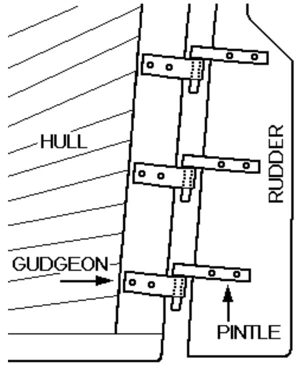
Internal ballast of stone, metal ingots, concrete, or other material can be stowed between the frames, often on "cleats" or a "ceiling" to lift it off the strakes for cleanliness and better preservation of the wood.

The bottoms of keels may be protected by "shoes" made of metal or thin, sacrificial wood. During the 18th century vessels began to protect their bottoms from shipworm and abrasion by nailing on a thin layer of copper "sheathing." In northern waters heavy sheathing might be attached near the waterline as protection from ice. Copper sheathing can survive long immersion and is an important diagnostic on wrecks.

The main upright timber at the bow is called the "stem"; at the stern, the "stern post." Both those timbers are locked to the keel by heavy braces called "knees."

The stern is usually square or nearly so, with a flat or gently curved "transom." In some vessels the stern is round, or is pointed ("sharp") like the bow. Barges and some sailing vessels ("scows") have square, raking bows.

Rudders are usually hung on metal hinges that include "pintles" on the rudder and "gudgeons" on the hull. A block of wood might be used to prevent the rudder from lifting off. The rudder might have heavy metal eyes for chains to limit its movement in heavy seas.

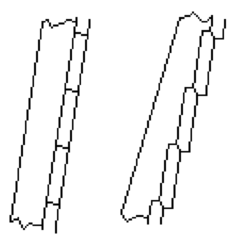


The rudder might be hung on the transom and sternpost if they have a straight profile, or it might be tucked under the hull if the vessel has a "counter" stern where the transom protrudes aft of the sternpost.

The topmost strake may be called the "sheer strake," "sheer plank," or "planksheer," because it defines the "sheer" or curve in the top profile of the hull. It might also be called the "gunwale" (pronounced "gunnel"). A wale is a heavy strake for extra strength where needed. In wooden warships, heavy wales reinforced the hull at the gun deck(s), which had to be very strong to take the weight and recoil of the guns. The term "gunwale" evolved to mean the upper edge of the hull. The sheer strake may have an additional "rubbing strake" to protect the hull from contact with wharves and other vessels. If the sides tumble home the rubbing strake will be lower, at the level of greatest "beam" or width.

In most large vessels the edges of the strakes are cut nearly square to lie against the adjacent strakes. This is called "carvel" planking. Caulking made of rope fibers, oakum (rope fibers soaked in some kind of tar), cotton, or putty is forced into the seams to seal them.

In other vessels the edges of strakes are beveled and the bottom of each strake overlaps the top of the strake beneath it — "lapstrake" or "clinker" planking. Lapstrake construction tends to be lighter and more flexible than carvel, but more laborious and expensive to build, and weaker. It was used for Norse or Viking vessels, but now is usually limited to small craft and pleasure boats.



CARVEL LAPSTRAKE

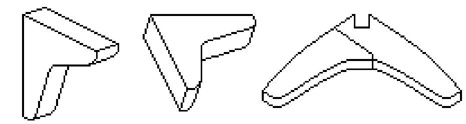
The seams in carvel planking might be backed by thin wooden "battens." "Composite" vessels have metal frames and wooden planking. Some heavy vessels have two layers of planking outside the frames. Some have an inner layer of planking, called "ceiling," inside the frames. The ceiling might be watertight as an extra barrier against leaks, or open to allow ventilation and preservation of the wood while still reinforcing the hull and protecting it against cargo.

To prevent her from being blown sideways by the wind, a sailing vessel usually has a deep keel, or a movable underwater fin if she is intended for shallow water. If the fin is large and heavy, and rides on a pivot, it is called a "centerboard." If it is fairly light and can be lifted vertically, it is called a "daggerboard." It rides in a watertight structure called a "trunk," and drops through a slot that might be cut through the keel and keelson, or through the garboard strake to avoid weakening the keel. Centerboard trunks are long, narrow structures, usually slightly forward of amidships. Some vessels had two centerboards, one forward and one aft. A very few vessels had three. Trunks often survive on wrecks. Even if the trunk is gone, the slot might survive.

At the upper edge of a hull the heads of the frames are usually supported by a fore-and-aft timber called a "clamp" if it lies on edge or a "shelf" if it is horizontal.

Decks are usually built of fore-and-aft planks lying on crosswise "beams." The beam ends are notched and fastened into the clamp or shelf, and may be reinforced by braces called "hanging knees" if vertical, or "lodging knees" if horizontal. Lodging knees may also support the joints between the clamp or shelf and the transom.

Where the sides join the stem at the bow, the structure is usually locked together with a "breast hook," a symmetrical lodging knee. A breast hook may be made up of several pieces.



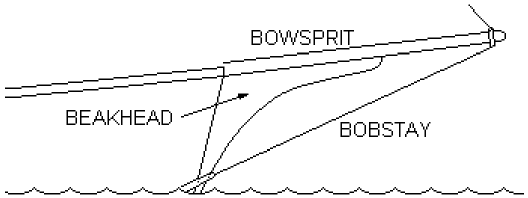
HANGING KNEE LODGING KNEE BREAST HOOK

Decks may be supported by "stanchions," timbers that rise vertically from the keelson to the underside of the beams, and by "bulkheads," walls dividing the vessel into compartments. Some bulkheads are heavily built, and watertight.

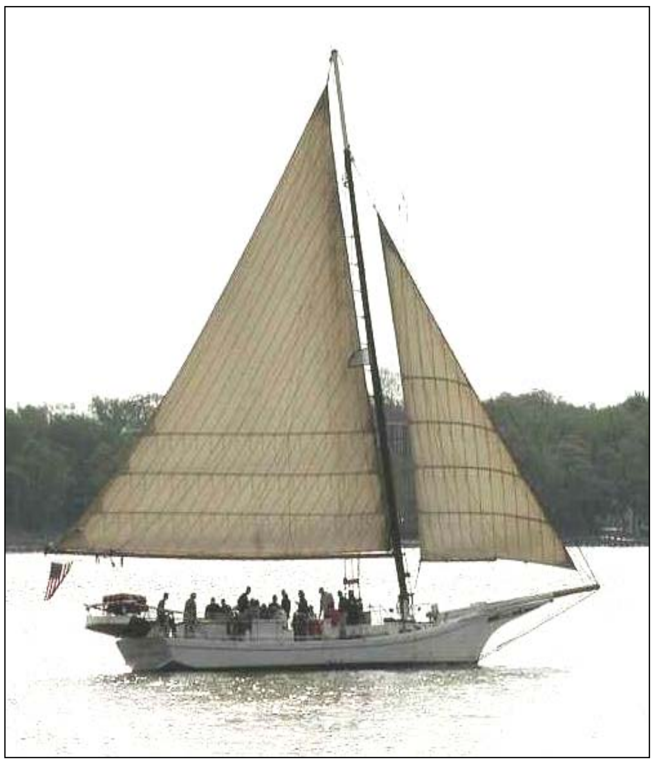
The outermost deck plank covers the frame heads and the shelf or clamp, and may be called the "covering board." It is often thicker than the other deck planks. The "king plank" along the centerline of the deck also may be thicker than the other deck planks. Other deck planks might be straight and lie parallel to the king plank, with their outboard sides trimmed to lie against the covering board, or the covering board might be notched to receive them. Alternatively, the deck planks might curve to match the covering board, with the king plank notched to receive them.

The sides of hatches, cabin trunks, and other deck structures rest on fore-and-aft timbers called "carlins." Where the deck is pierced for a mast, "partners" between the beams hold the mast, perhaps supported by knees.

On many sailing vessels a large timber called a "beakhead" extends forward of the stem to support the bowsprit. The bowsprit may be removable, but the beakhead is permanently attached to the stem. One or more heavy lines, wires, or chains called "bobstays" hold the bowsprit (and perhaps the beakhead) down against the pull of the masts and sails. The beakhead might also be braced on the sides by rope or wire "guys," or by wood or metal "trail boards" which often carry the vessel's name and some decoration.



Beakheads and bowsprits on traditional Chesapeake Bay craft are extremely long, to increase the amount of sail the vessel can carry and to allow the mast to be stepped further forward, out of the way.



a Chesapeake Bay "skipjack" sloop.
Image revised from www.projectdorian.co.uk

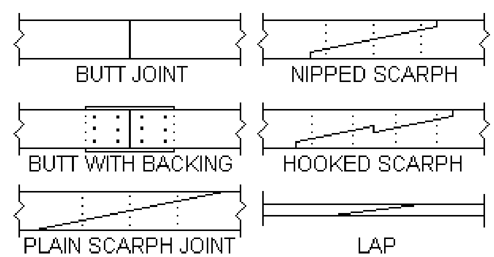
To keep crew and gear from going overboard many seagoing vessels have a wall or "bulwark" around the deck, braced by vertical stanchions. The top of the bulwark is the "rail." To reduce leakage through the covering board the stanchions usually are not extensions of the frames. Holes in the bulwark, often called "scuppers" but more properly called "freeing ports," allow water on deck to go overboard. The inside of the bulwark might be fitted with "kevels," horizontal timbers spanning two or three stanchions, with protruding ends as convenient places to attach or hang lines. Kevels are often located near freeing ports, for docking lines to run out the ports.

All these many pieces of wood are held together by different types of fasteners, including wooden dowels or "treenails" (pronounced "trunnels"), metal spikes (big), nails (smaller than spikes), "drifts" (bigger than spikes), bolts, screws, and lags (big screws with square or hexagonal heads). Metal fasteners can be made of iron, steel, copper, or bronze (an alloy of copper and nickel, perhaps with other metals added for various properties) — but not brass. Although some old texts use the words "brass" and "bronze" interchangeably, what we now call brass is an alloy of copper and zinc that is quickly destroyed by galvanic or electrolytic corrosion.

Lapstrake hulls are usually fastened with "clench nails," copper nails that are driven through the strakes and frames from the outside, and bent or peened down like rivets around washers or "clench rings" on the insides of the frames.

The larger the vessel, the more difficult and expensive it is to obtain timber in the desired lengths, and structural members are often built up from shorter pieces of wood, using different kinds of joints. A "butt" joint has no inherent strength, but with a backing board it might be good enough to join strakes.

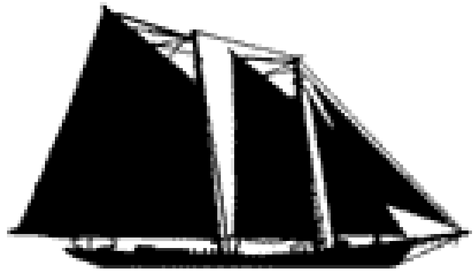
A tapered "scarph" joint is stronger. To avoid weak feather ends on the pieces being joined, their ends scarph might be "nipped." To prevent it from stretching the scarph might be "hooked." A "lap" joint is a scarph on edge.



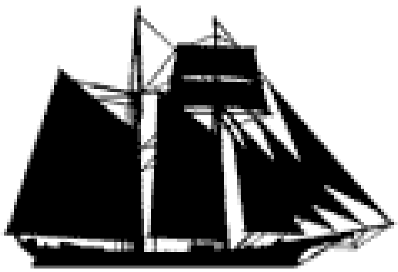
b. Sailing rigs

These are the most commons types of rigs used by commercial sailing vessels in the US during the 18th to early 20th centuries. Generally, the smaller the vessel, the simpler the rig — and vice versa.

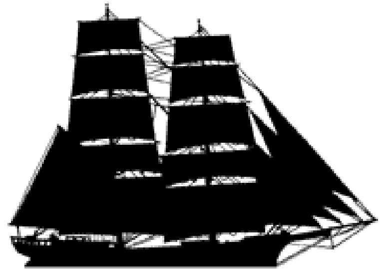
sloop



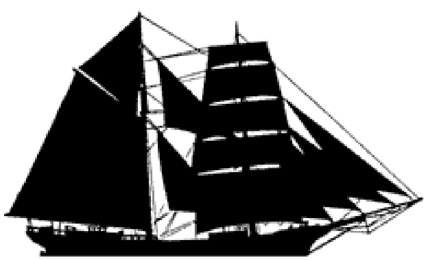
schooner (2 masts)



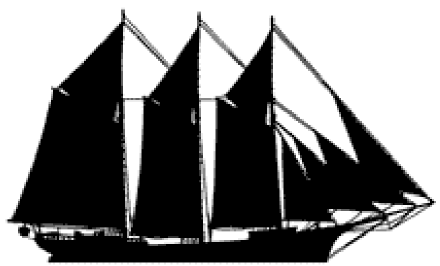
topsail schooner



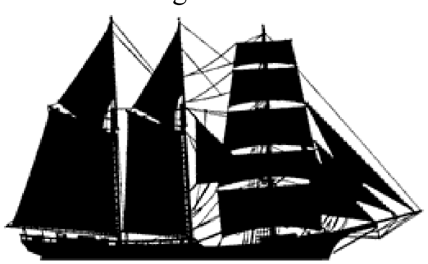
brig



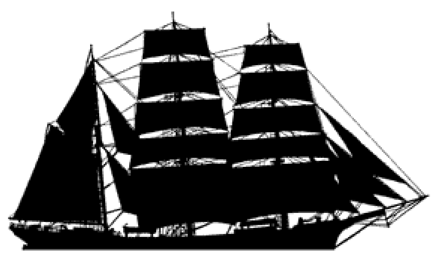
brigantine



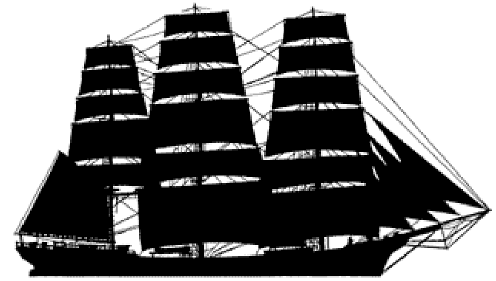
schooner (3 masts or "tern")



barkentine



bark



ship

Many variations exist in each type, but basic proportions in the heights and locations of masts follow practices that have proven to work. For example, in a two-masted schooner the foremast is usually located at somewhere between 20 and 25% of the overall length, and the mainmast between 55 and 60%. In a ship the distance between the foremast and mainmast is always greater than that between the main and the mizzen.

A "knockabout" schooner has no bowsprit. Large schooners of the late 19th and early 20th centuries had up to six masts. The *Thomas W. Lawson* had seven masts, named after the days of the week.

A schooner with square topsails on the mainmast and the foremast might be called a "hermaphrodite schooner" or a "brig schooner."

A "snow" is a brig with an additional short mast stepped on deck a foot or two aft of the mainmast for easier handling of the "spanker," the aft-most sail. Most naval brigs were actually snows.

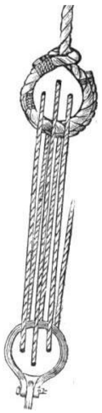
The sails and rigging of vessels seldom survive long enough to be found on historic sites, but some rig components may endure. Mast steps often survive. Their locations may be the best indicators of a vessel's rig.

The foremast of a schooner is shorter than the mainmast, but it carries both the foresail and the staysails and jibs, so it is usually heavier than the main, and the step may be correspondingly larger. This (and the locations of the steps) might show the orientation of the wreck if the bow and stern cannot be identified.

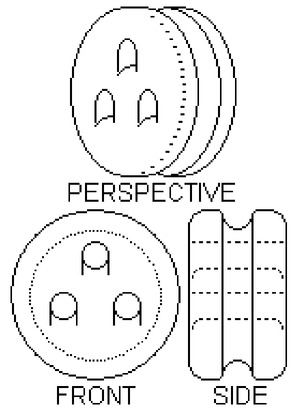
(1) Standing rigging components

"Standing rigging" is the system of lines and fittings that support the mast(s) of a vessel.

Until the late 19th century "deadeyes" were used to adjust the tension on "shrouds," the lines that support masts from the sides. Deadeyes are often found on sites. They are flat cylinders of tough wood (elm, lignum vitae, or white oak) with three holes, and a groove cut around the outside.



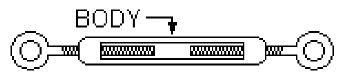
Deadeyes are rigged in pairs, connected by a "lanyard." The bottoms of the holes are rounded to reduce chafe on the lanyard.



The upper deadeye fits in an eye in the lower end of the shroud. The lower deadeye is attached to the hull. The deadeye groove is cut round if it is held by fiber rope, or flat if held by a metal strap, as was usual after the mid 19th century. The shape of the groove is a useful diagnostic.

In the late 19th and 20th centuries shrouds were often made of wire rope, and deadeyes were replaced by metal turnbuckles or "bottle screws." Turnbuckles may indicate a site dates from the late 19th century or after.

An open body allows lubrication and inspection of the metal. Turnbuckles might be covered with grease or tar and wrapped in canvas to protect them from water.



The lower deadeyes, or the lower ends of the shroud turnbuckles, are attached to the sides of the hull or to platforms that are mounted outside the bulwarks and held down by chains or metal straps connected to "chain plates" on the sides of the hull. The groupings of those chain plates will show the number of masts the vessel carried. Chain plates are long enough to span several strakes in order to spread the load. They usually are bolted through the strakes, and sometimes through a sister plate inside the hull.

Bobstays are attached to heavy metal straps bolted through the stem. Those straps generally lie parallel to the bobstays, so the locations and angles of the straps will indicate the approximate length of the beakhead and bowsprit.

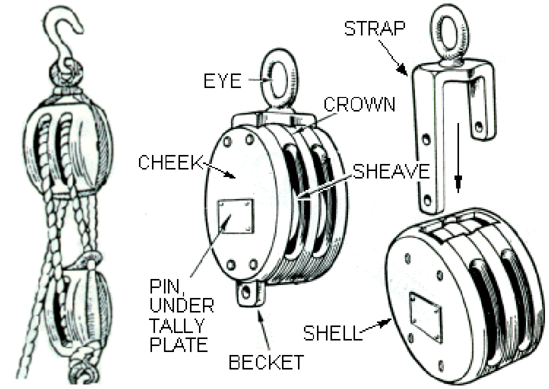
(2) Running rigging components

"Running rigging" is the system of lines and fittings that raise and control the sails.

"Sheets," the lines used to control the lower corners of sails, are often led through "fairleads," heavy rings or eyes that are mounted on the deck, on the rail, or outside the bulwarks. Fairleads are used to obtain a good angle of pull on the sail in different wind conditions.

"Blocks" (pulleys) are often used on fairleads, halliards, sheets, and a hundred other places on a vessel's rig.

Blocks are made with one or more metal wheels ("sheaves") in a wood or metal shell, with a rope or metal strap through or around the shell.

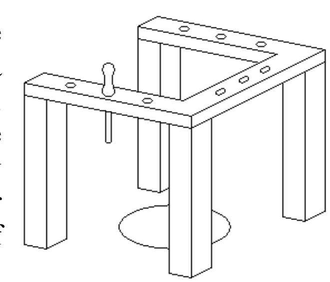


The sheet of a "fore-and-aft" sail, such as a staysail, jib, or the foresail and mainsail of a schooner, is often led to a "traveler," a ring that slides on a "horse," a horizontal bar mounted just above the deck. The purpose of the horse and traveler is to change the direction of pull of the sheet to give the sail a better shape in different wind conditions.

From the 18th to the mid 19th century horses were made of wood, usually a 2- to 6-inch diameter pole, from 1 to 6 feet long, depending on the size of the sail. It often has a metal rod or strap on the underside to protect the wood from chafe. After the late 19th century horses were usually made of iron or steel rod, 1 to 3 inches in diameter. A horse might have eyes for lines to pull the traveler into position, and holes for pins to lock it in place.

Many lines, including halliards, sheets, and "braces" (lines that control the yards in square-rigged vessels) would be "belayed" (tied) to "belaying pins" carried in "pin rails" lashed to the shrouds, or mounted along the sides of the vessel near the shrouds, or at the bases of the masts. Belaying pins are made of metal or wood and are seldom found on wrecks, but pin rails often survive.

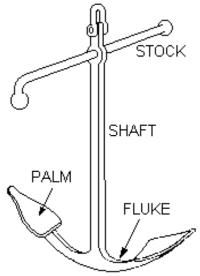
Pin rails along the sides of vessels are horizontal timbers inside the bulwarks, with a series of holes, 1 to 2 inches in diameter, spaced a foot or two apart. Pin rails at the bases of masts are of two types: a heavy railing on deck, open aft, with a square or semicircular front, or a flat timber shelf bolted or clamped to the mast itself.



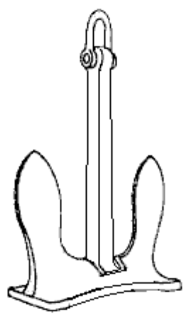
c. Ship's gear

A vessel's gear is as important for site assessment as her structure, but remember, the gear is often newer than the vessel herself.

Anchors are often found on sites. Most vessels carried several anchors of different types and sizes for different conditions. Anchor designs fall into two general categories: stocked ("Admiralty," "old-fashioned," or "kedge") and stockless. Stocked anchors were usually slung from protruding timbers called "catheads." Beginning in about 1840 to 1850 they were fitted with folding metal stocks as shown to the right. Many variations occur in size, proportions, and the size and shape of the flukes and palms.

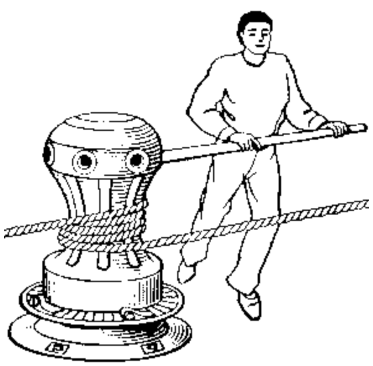


stocked anchor


stockless anchor

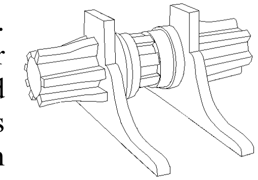
Stockless anchors came into use in the late 19th century. There are many different designs, including "Navy," "Eells," "Hall," "Danforth," and others. The flukes pivot on the shaft or shank.

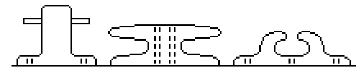
Stockless anchors are usually carried in "hawse pipes" on the sides of the bow. Hawse pipes are heavy metal tubes or troughs. The upper part is usually curved to lead the anchor chain toward the capstan, and the lower part is straight to hold the anchor in place. Various devices are used to lock the anchor in the hawse pipe.



An anchors is "weighed" (lifted) by a machine that is called a "capstan" if the rotating axis is vertical, or a "windlass" if horizontal. Capstans are large rotating drums used on large vessels. Before steam power, they were turned by men pushing on bars in holes in the drum head. The bottom of the capstan might have a "wildcat" with teeth to grab chain. The top often has a metal plate with the maker's name and perhaps the date of manufacture.

Windlasses are lighter machines on smaller vessels. They have horizontal drums turned by hand levers or by steam or hydraulic power, and ratchets called "pawls" to prevent them from turning backwards under a load. They are made of wood or metal in many different designs.

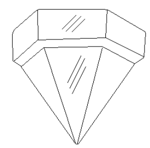




Deck fittings include bitts and cleats made off wood or metal in different shapes, sizes and strengths, to tie or belay lines to, and chocks to lead lines through to protect the vessel and the lines from chafe.

The aft end of a bowsprit is usually braced to two heavy vertical timbers called "bitts" that are bolted to the keelson and rise through the deck with heavy reinforcement. Small vessels might use a single timber, called a "Samson post." Many different designs are used. Bitts or Samson post can also be used to belay the anchor rode and often have a crosswise pin or bar to prevent the rode from lifting off.

Deadlights are portholes that do not open. They are usually circular, from 5 to 10 inches in diameter, with glass set in a metal frame. To withstand abuse and heavy seas they are small and heavily built.


deck prism

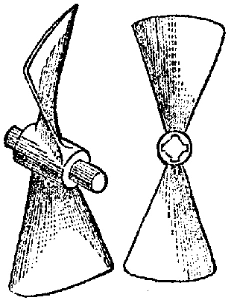
Deck prisms are small, heavy glass prisms embedded into wooden decks to allow daylight below. They usually are 3 to 6 inches in diameter and height. Deadlights, deck prisms, and portholes have been in use since the early 19th century or longer, but are useful diagnostics if a maker's mark can be seen.

Bilge pumps come in many designs and sizes, from the simplest hollow log with a pole and leather flap, to elaborate mechanical pumps that often bear the maker's name. Mechanical pumps cannot be identified or assessed unless they are recovered and conserved, which is beyond the scope of reconnaissance.

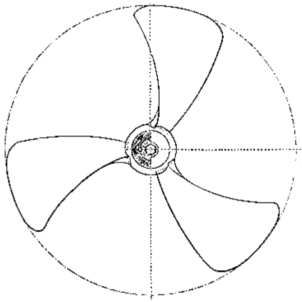
d. Paddlewheels, propellers, boilers, and engines

Paddlewheels may be fairly simple with rigid blades, or complex affairs with blades that mechanically "feather" to be vertical for maximum thrust in the water, and horizontal above the water to reduce the impact of waves.

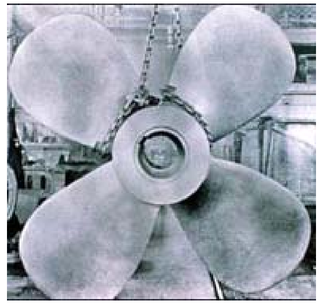
Screw propellers had squarish tips from about 1830 until about 1875-1890. Almost all had rounded tips after that. Some early steam vessels retained a sailing rig and sometimes used 2-bladed propellers that could be lifted into a slot in the hull or locked vertically behind the sternpost to reduce drag while under sail. The comparative efficiency of paddlewheels and screw propellers was settled by a contest in 1845 between H.M.S. *Rattler* (screw) and H.M.S. *Alecto* (sidewheel), each displacing about 1,000 tons with engines of about 200 hp. *Rattler* beat *Alecto* in speed and won a tug-of-war, pulling *Alecto* back at 2 knots.



1842



1874



1912

Marine steam engines usually have heavily insulated pipes of large diameter to carry steam from the boiler to the engine, and even larger pipes to return the used steam to the boiler to be reheated. Gauges and pumps often carry the maker's name and may be useful diagnostic artifacts, but they cannot be identified unless they are recovered and conserved, which is beyond the scope of reconnaissance.

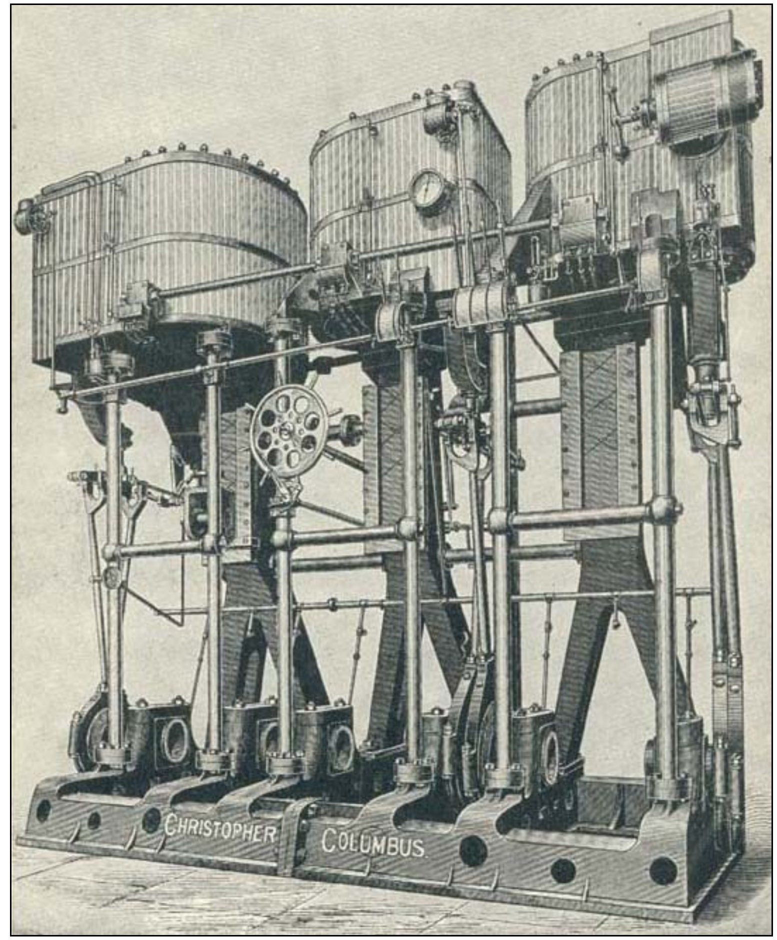
Ship's boilers come in many sizes and shapes. They are made or iron or steel, either riveted or welded. Some are cylindrical and may range in size from 4 to 12 feet in diameter and 6 to 20 feet in length. Others are boxes of comparable size, often with tops that slope up toward the exhaust stack.

There are two basic types of boilers: "fire tube" or "Scotch" boilers where the hot combustion gases pass through tubes in a water bath, and "water tube" in which water passes through tubes in a fire bath. For a given horsepower, the tubes in a Scotch boiler are larger and fewer. Both types were in use until the 1930s or 40s. Water-tubes are the only type still in marine service. Coal was the primary marine fuel until surpassed by oil in the 1920s to 1940s.

Steam engines come in two basic categories: "reciprocating," in which the steam operates one or more pistons, and "turbine," where a steam jet rotates a shaft with fan blades. Turbines were invented in 1884 and entered naval service in the early 20th century but were not used in commercial vessels until after World War II. They need large "reduction gears" between the turbine and the propeller shaft, because turbines are

efficient at high speed but propellers need to turn more slowly. Diesels began to enter marine service in the early 20th century.

The 19th century was a period of frantic innovation in steam propulsion. Many different designs and manufacturers came and went. Propulsion machinery is so complex and the types are so and varied that no quick synopsis would be useful. For reconnaissance purposes it is enough to say a particular wreck is a steam vessel or a motor vessel (diesel or gasoline) and to map the major components.



One of two triple-expansion steam engines in the Great Lakes steamship Christopher Columbus *built in 1892. Each engine was powered by three cylindrical Scotch boilers measuring 11 feet in diameter by 12 feet long. Note the bearings for the propeller shaft on the bottom of the engine. The ship had a single four-bladed screw propeller, 14 feet in diameter. Image from wikipedia.org/wiki/Steam_Engine#Reciprocating_engines.*

CHAPTER 7 SITE ASSESSMENT

Goal: Obtain enough data to enable the SHPO to determine if the site is potentially significant or merits further investigation.

As mentioned in the Introduction, the reconnaissance diver's job is to observe, and to collect and report data, not to reach conclusions about the site, and certainly not to move or disturb anything.

The whole purpose of archaeological diving is to obtain and record accurate and complete data. If the data are incomplete, illegible, or just plain wrong the entire effort will have been wasted.

a. Procedures

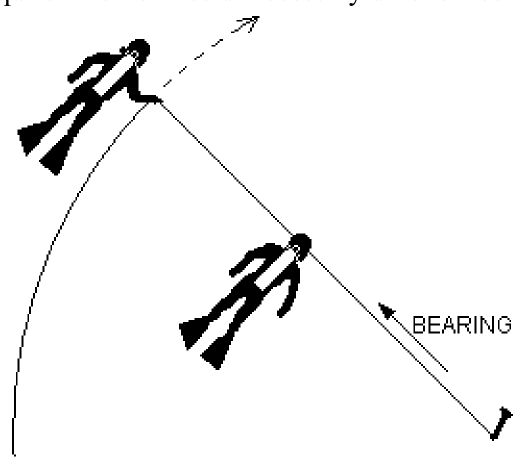
(1) Put divers down on the site.

This usually begins by dropping a small mushroom anchor with a marker buoy. Dropping the boat's anchor into the site could damage it. A small mushroom is unlikely to damage a site, but try to drop it next to the site, not right on it.

The "rode" or buoy line should be at least twice the water depth, or even longer in strong currents. In strong currents, when divers are likely to pull hard on the rode, two or three mushrooms can be used on a single rode. Divers should swim down the rode without pulling on it.

If the mushroom does not land on or right next to the site, the first dive team should execute a circle search, using a wreck reel or the slack in the buoy rode as a radius line. When they find the site they should move the mushroom right next to it for later teams to use.

Do not attach the rode to the site, because that might damage the structure or require an otherwise unnecessary dive to free it.



In calm seas where the divers' bubbles are clearly visible the boat can continue to search and drop other marker buoys while divers are down.

(2) Determine if the site is natural or cultural. If it is cultural, divers should record the —

(a) General characteristics:

<u>Site dimensions</u>: Measure the overall site length, breadth, greatest depth, least depth, and relief (height above seabed).

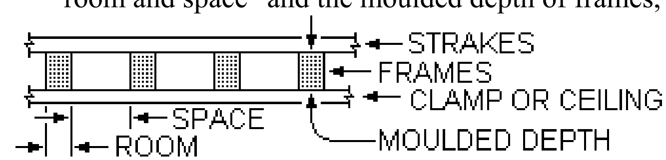
<u>Material</u>: Is the structure wood, metal, or both?

<u>Orientation</u>: Record the compass heading of the long axis of the site. Compasses must be corrected for local magnetic variation, which depends on geographic location and is noted on nautical charts. Iron or steel on dive gear or on the site may cause other compass errors, which might be large. To minimize them, take one compass bearing from bow to stern, and another from stern to bow.

(b) Detailed characteristics: These include —

<u>Construction</u>:	metal:	iron, steel, or aluminum; riveted or welded; plates lapped or butted.
	wood:	log, carvel, lapstrake, plywood, cold-molded, battened, or strip-planked.
	bottom:	round, flat, or vee (deadrise); hull sheathing.
	bow:	plumb (vertical), raked (angled), reverse; straight or curved.
	stern:	square (transom), round, or sharp; plumb, raked, or reverse.
	sides:	wall, flare, or tumble home; strakes, ceiling, rubbing strakes, wales.
	deck:	flat or crowned (curved).

<u>Scantlings</u> (dimensions of structural components), including — "room and space" and the moulded depth of frames,



the width, thickness, and length of other structural members, including strakes, wales, ceiling planks, deck planks, keelson, keel, frames, futtocks, floors, knees, stem, sternpost, and beakhead.

Fasteners: types, sizes and locations of trunnels, drifts, spikes, nails, lags, screws, and bolts.

Propulsion: mast(s): number, size, location, steps; number and location of chain plates.

engine(s): number, type, size, locations; number, type and size of boilers; "bunkers" (ship's fuel): coal bins or oil tanks.

propeller(s): number and type of propellers; diameter and shape of blades; type of metal (ferrous or bronze); length and diameter of shaft(s).

Other diagnostics: anchors, capstans, windlasses, hawse pipes, winches, deck machinery, hatches, deck structures, pin rails, blocks, portholes, deadlights, ventilators, rudder, gudgeons, pintles, cargo, armament, &c. This list includes every item that might help assess or identify the vessel. Most of the terms used above are explained in Chapter 6.

Cause of loss: collision or grounding damage, burn marks, etc.

Sea growth and encrustation, as an indication of the age of the site.

Extent and causes of disturbance, decomposition, and degradation.

(3) Map the site. See Chapter 8.

b. Photography

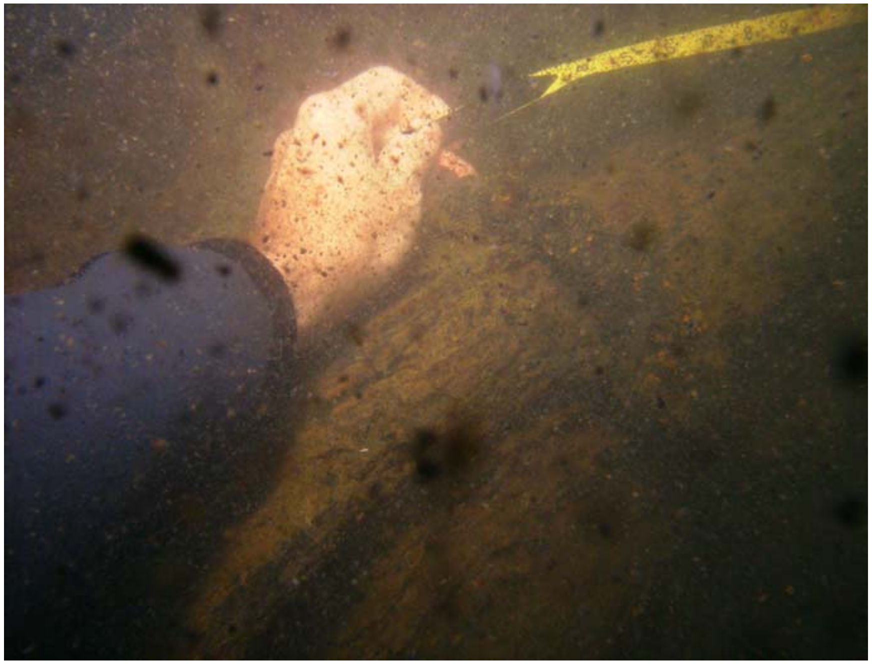
In addition to maps and sketches of the site, photographs of details and features can be of great help in assessing the site and showing the general site conditions. Cameras can often "see" better than divers, and photographs may capture details the divers missed.

The following four examples were taken with a digital camera in visibility of three to four feet.

frame heads, planking, and ceiling

unidentified fitting on rail

iron deck bitts



diver measuring a timber

CHAPTER 8 MAPPING

Goal: Make an accurate scale drawing of the entire site.

a. Procedure

(1) Select the measurement techniques to be used (see below), based on the size, complexity, fragility, and depth of the site, the available time, the water visibility and current, and the skills of the divers.

(2) Select an appropriate map scale, based on the size of the site or the area being mapped and the size of paper on which the map will be drawn. The site map should be as large and detailed as necessary to depict the entire site. If appropriate, make more detailed "zoom in" drawings or maps of specific features or areas of the site. Select the measurement units to be used (English or metric).

(3) Select the reference points from which the measurements will be taken. These may be existing features, new points established for the purpose (e.g., a baseline), or a combination of both. After some prominent features have been accurately mapped they can be used as new datum points to map other objects.

(4) Have the necessary mapping gear. Measure and record the distances between the datum points and the key points of each object being mapped. Those measurements will be used to create the site map.

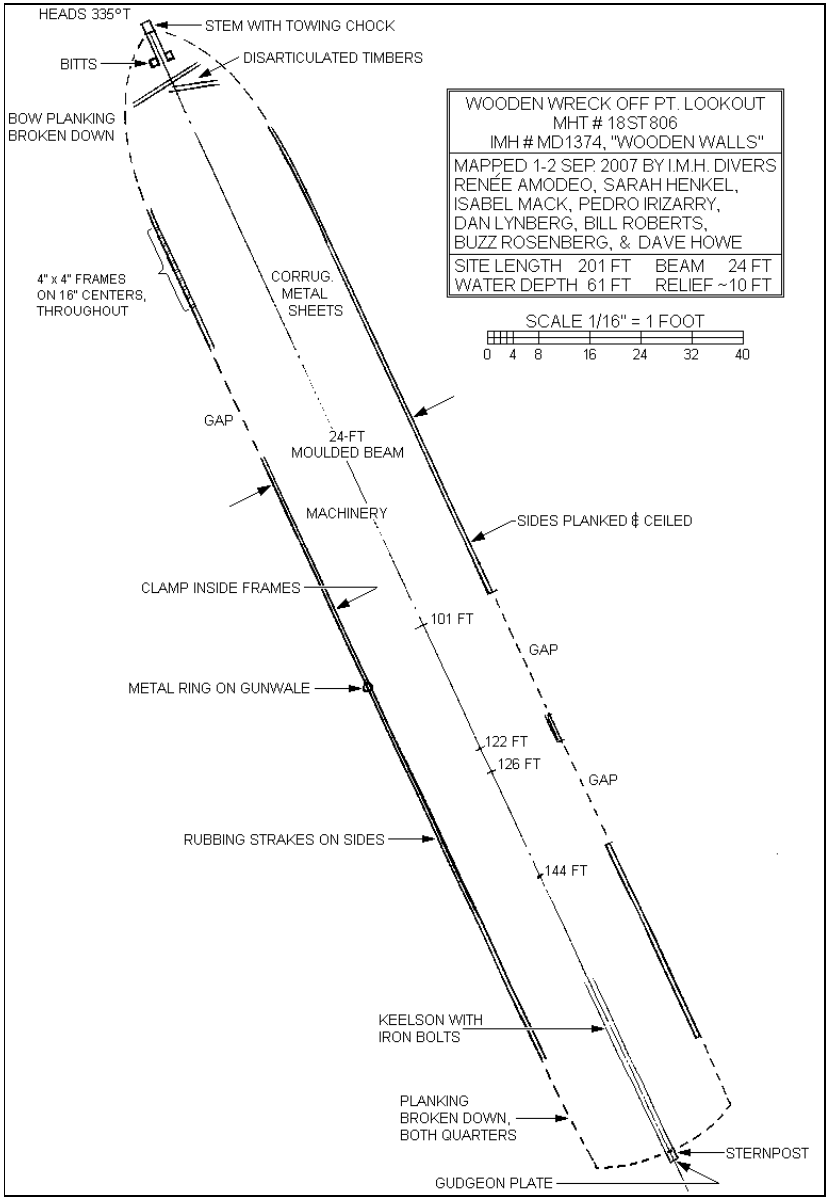
(5) Dive and measure the site. All measurements and other data should be written on Mylar sheets attached to the diver's slate with duct tape, not metal clips. A sample data form is given in the Appendix to this booklet. Any form that works is good.

Writing must be legible and clear enough to be understood by someone unfamiliar with the site, minutes or months after the dive. Use dashes instead of decimal points, because a decimal point may get smudged off. Two and a half meters should be written as 2 – 5, not 2.5. Sketches should include the principal dimensions. Each data sheet should show the name of the site, the date of the dive, and the names of the divers, in case someone needs an explanation of the data later. Sketches should have a North arrow or other indication of orientation.

Immediately after the dive each diver should ensure the data sheets are complete and legible, and correct them as necessary. The sheets should then be rinsed in fresh water, air dried, and sprayed with fixative (clear Krylon™ or hair spray) to prevent smudging or accidental erasure.

(6) Prepare a site map by plotting all points and measurements in a plan view, either with pencil and paper or by digital mapping. If mapping the heights of features by DSM or another three-dimensional technique, note

the important heights on the site map. A sample site map follows as an example of reconnaissance work. The photographs in Chapter 7 were taken on this site. The map should indicate where the photographed features are located. Make detailed "zoom-in" maps of specific areas or features that might help in assessing the site.



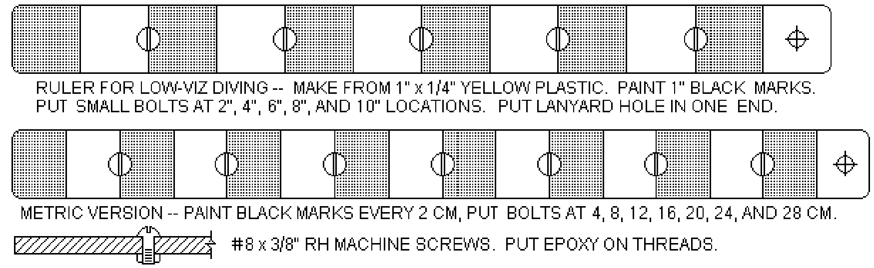
sample site map after an initial reconnaissance

b. Measurement techniques

Most measurements will be made with measuring tapes or rulers. To prevent confusion all measurements must be in the same units, i.e., feet and inches, feet and tenths, or meters and centimeters.

Tracings, rubbings, and clay impressions can be made of small details. Larger details can be sketched by feel.

If the visibility is so bad that the divers cannot read a measuring tape or ruler, a homemade "Braille" ruler can use bumps or grooves to mark inches or centimeters.



Each diver should be able to use his body parts to obtain reasonably accurate measurements of a feature and its distance to other features. This technique uses ancient measurement units that were originally derived from body parts:

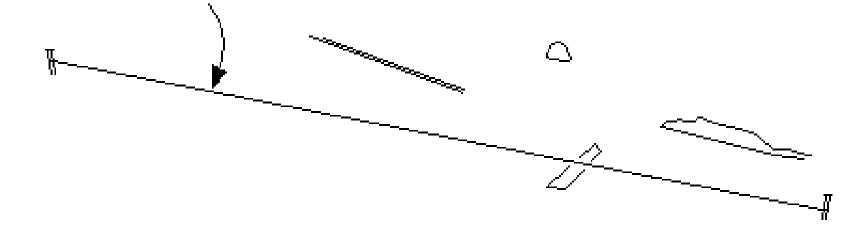
inch:	second digit of index finger (1 – 1.5 inches, 2.5 – 4 cm)
hand:	width of hand at base of fingers (3.5 – 4.5 inches, 9–11 cm)
hand span:	tip of thumb to tip of little finger, hand fully outstretched (8–9.5 inches, 20–24 cm)
cubit:	elbow to tip of middle finger (~ 18–20 inches; 45–50 cm)
yard:	nose to fingertip of outstretched arm (~ 33–36 inches; 83-91 cm)
arm span:	hand to hand, moving sideways (~5 feet; 1.5 m)
fathom:	fingertip to fingertip of outstretched arms (~6 feet; 2 m)

Knowing the length and width of dive gear items can also be helpful. This includes slate, knife, fins, etc.

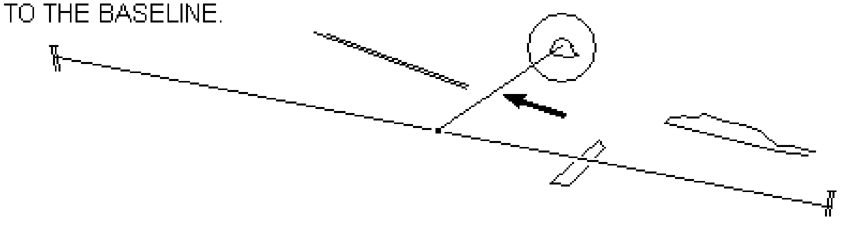
Each diver should know approximately how far he will move with normal fin kicks in still water. The technique must be adjusted for current, for moving cautiously in black water, and when trailing a tape or line. As noted above, however, keep your fins off the structure! Fin wash will damage it.

c. PERPENDICULAR OFFSETS

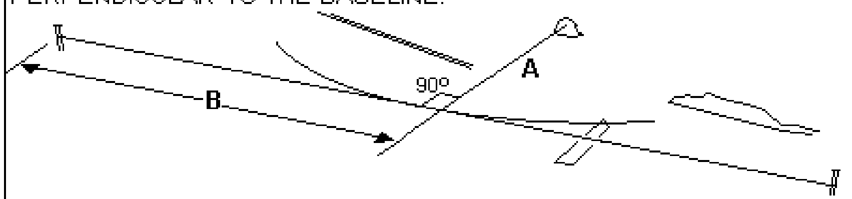
STEP 1. RIG A BASELINE



STEP 2. LAY A MEASURING TAPE FROM THE OBJECT BEING MAPPED, TO THE BASELINE.



STEP 3. SWING AN ARC WITH THE MEASURING TAPE, SO IT BARELY TOUCHES THE BASELINE. THE MEASURING TAPE WILL THEN BE PERPENDICULAR TO THE BASELINE.



STEP 4. RECORD THE DISTANCE ("A") FROM THE BASELINE TO THE OBJECT, AND THE POINT ("B") ON THE BASELINE WHERE THE MEASURING LINE TOUCHES.

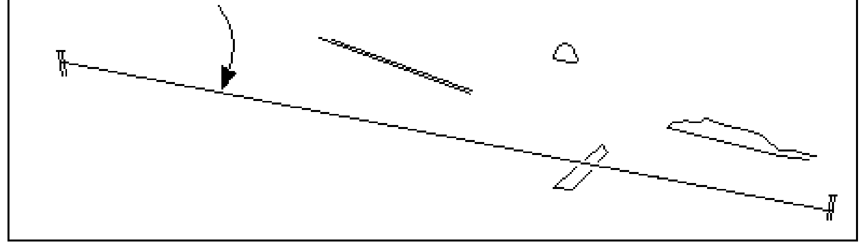
For better accuracy, use a square slate corner to make sure the tape is perpendicular to the baseline.

Record the following data —

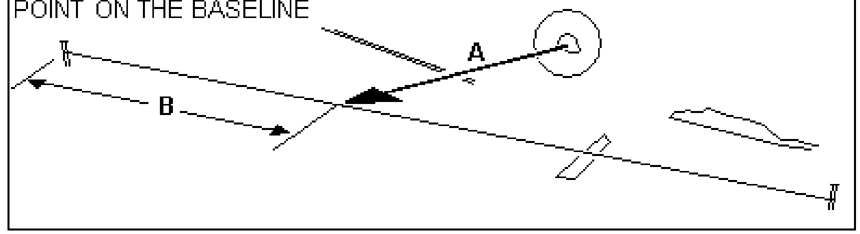
- ✓ name or description of object being mapped;
- ✓ side of baseline (L or R) looking from the 0 point toward the far end;
- ✓ distance of object off the baseline (A); and
- ✓ point of tangency (B).

d. TRILATERATION

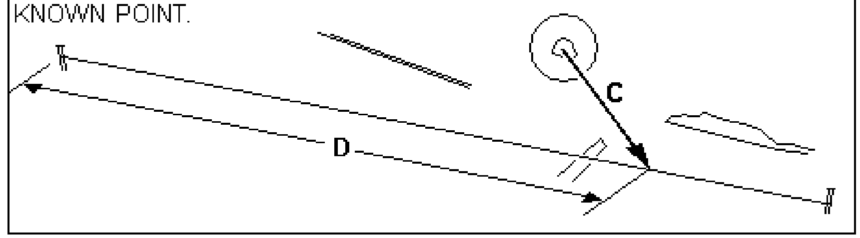
STEP 1. RIG A BASELINE



STEP 2. MEASURE THE DISTANCE FROM THE OBJECT TO ONE KNOWN POINT ON THE BASELINE



STEP 3. MEASURE THE DISTANCE FROM THE OBJECT TO A SECOND KNOWN POINT.



Make sure the measuring line lies straight and true and is not bent around some obstruction. For best accuracy, the angle between the baseline and the measuring line should be approximately 60°. You need at least two measurements. A third measurement will reduce error and refine the location.

If the baseline and the object are at different depths an allowance must be made for the slant in order to obtain an accurate horizontal distance. This can be done either by recording the slant angle or by running the measurement line horizontally from the shallower item (the feature or the baseline) and dropping a plumb line to the deeper item. A "pop buoy" can ensure the measuring line is horizontal. A good depth gauge is close enough unless the site is very shallow.

It is helpful to buoy both ends of a baseline, using different colors at each end. Key features may also be buoyed, unless that would damage them.

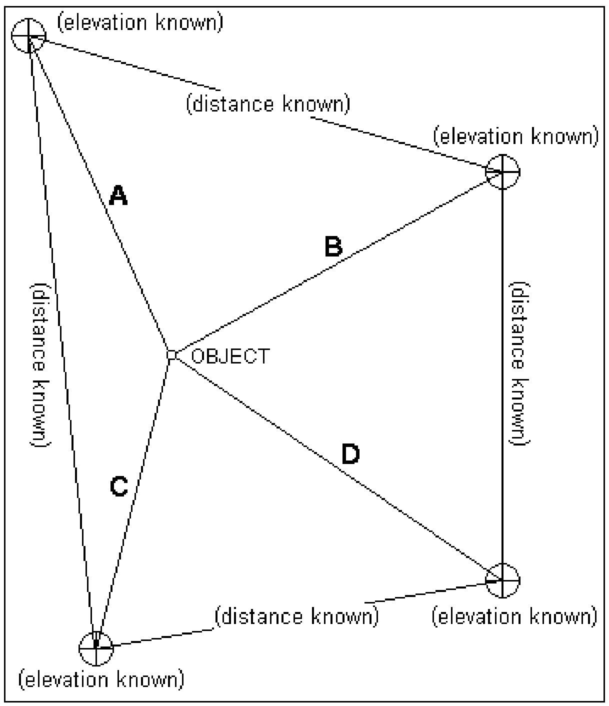
Record the following data —

- ✓ name or description of object being mapped,
- ✓ side of baseline (L or R) looking from the 0 point toward the far end;
- ✓ first baseline reference point (B), and first distance (A); and
- ✓ second baseline point (D), and second distance (C).

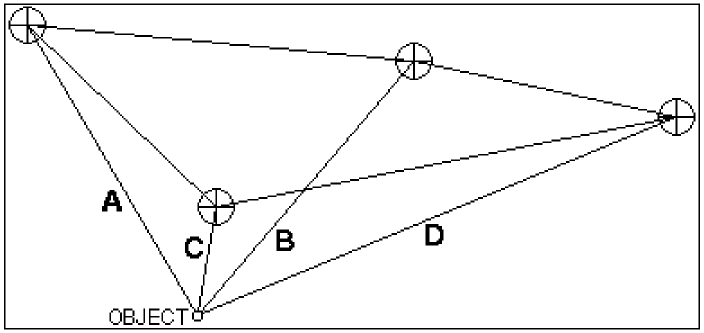
e. DIRECT SURVEY METHOD (DSM)

This is a three-dimensional technique that is mathematically complex but easy for divers to use. It is very effective on sites with large vertical dimensions.

The technique employs four reference or "datum" points that are precisely mapped to each other in three dimensions — latitude, longitude, and height (depth). The points do not need to be on the same plane. Divers record the slant distance from each datum point to the object being mapped (A, B, C and D in the sketch below). A computer program then calculates the position of the object in three dimensions. The results can be shown as a two-dimensional map (noting the height of each object) or as a three-dimensional computer model.



DSM, plan view



DSM, perspective view

The datum points can be inherent to the site or artificial, so long as they are precisely mapped to each other. Heights can be measured with an accurate digital depth gauge, but they need to be corrected for tide so that all measurements are correlated.

Theoretically DSM can work with only three datum points, but a fourth point is needed to confirm the other three or disclose errors in measurement.

The measuring tapes can be attached to the datum points to allow all measurements to be taken simultaneously, but the diver will need to keep the tapes from getting tangled and keep careful track of which tape goes to which point. Tape reels can be of different colors or sizes, or be marked with labels that can be seen or felt.

Record the following data —

- ✓ name or description of object being mapped; and
- ✓ measurements A, B, C and D

f. Other mapping techniques:

(1) Triangulation. This technique uses visual angles between objects, and can be done only in clear water.

(2) Grid. For precise mapping of a large, complex site, a grid can be constructed of metal or PVC pipe. This technique is too cumbersome and detailed for reconnaissance.

CHAPTER 9 PROJECT FILES

a. FIELD RECORDS

Goal: Create and keep a complete and accurate record of the site.

The measurements, sketches, photographs, and field notes are used to create and supplement a site map, which is the main initial goal of a project.

All original notes, drawings, and maps are kept in the project file. Scanned copies or photocopies can be made when needed for reports and publications. The project file can be turned over to the SHPO, or kept by IMH or by the project manager. The report to the SHPO should say what the project file contains, where it is kept, and who has custody of it.

b. REPORTS TO THE SHPO

Goal: Submit a report that describes the site in enough detail to support good decisions about further action.

See the Maryland site forms and instructions * as an excellent example of the kinds of data that are important for assessment and inventory purposes. Delaware has not yet established a standard form of report. Virginia is working on one but has not yet implemented it. IMH uses the Maryland forms for those other states, to ensure all important data are reported and gaps in the data are clearly identified.

Reports should be printed on acid-free, archival paper, not on cheap copy paper that will become brown and brittle with age.

FURTHER READING

Bowens, Amanda, ed. *Underwater Archaeology: the NAS Guide to Principles and Practice* (2d edition, 2008.) Wiley-Blackwell, UK.

Robert H. Burgess and H. Graham Wood. *Steamboats out of Baltimore* (Cambridge, MD: Tidewater Publishers, 1968)

Robert Scott Burn *The Steam Engine: Its History and Mechanism* (London: Ward & Lock, 1857) on line at books.google.com/books/

Howard I. Chapelle *The History of American Sailing Ships* (New York: W.W. Norton Co., 1935)

* http://www.marylandhistoricaltrust.net/MASSform.pdf and http://www.marylandhistoricaltrust.net/MASSinstr.pdf

" *Yacht Designing and Planning* (New York: W.W. Norton Co., 1936)

" *Boat Building* (New York: W.W. Norton Co., 1941)

" *Chesapeake Bay Crabbing Skiffs*, in *Yachting* magazine, June and October 1943 (reprint, Chesapeake Bay Maritime Museum, St.Michaels MD, 1979)

" *Notes on Chesapeake Bay Skipjacks*, in *The American Neptune*, October 1944 (reprint, Chesapeake Bay Maritime Museum, St.Michaels MD, 1979)

" *The History of the American Sailing Navy* (New York: Bonanza Books, 1949)

" *American Small Sailing Craft* (New York: W.W. Norton Co., 1951)

" *The Search for Speed Under Sail* (New York: W.W. Norton Co., 1957)

" *The American Fishing Schooners*, 1825-1935 (New York: W.W Norton Co., 1973)

" *American Sailing Craft* (Camden ME: International Marine Publishing Co., 1975)

" *The Baltimore Clipper* (New York: Dover Publications, 1988)

Fredrik H. Chapman *Architectura Navalis Mercatoria* (Sweden, 1768), a classic treatise on 18th century ship design. The text is in Latin. The drawings are on line at www.sjohistoriska.se/sitecore/content/Sjohistoriskamuseet/InEnglish/Collections/Chapman.aspx

Ernest M. Eller *The Chesapeake Bay in the American Revolution* (Cambridge: Tidewater Publishers, 1981).

H. Cole Estep *How Wooden Ships are Built* (Cleveland, Penton Publishing Co., 1918), on line at books.google.com/ books/

Eric M. Mills *The Chesapeake Bay in the Civil War* (Cambridge: Tidewater Publishers, 1996).

Thomas J. Oertling — *Ships' Bilge Pumps: A History of Their Development, 1500–1900* (Texas A&M University Press, 1996).

Library of Congress — (a huge archive of photographs on line at memory.loc.gov/ammem/index.html)

Richard J. Sennett and Henry J. Oram *The Marine Steam Engine* (London: Longmans, Green & Co., 1902) on line at books. google.com/books/

Donald G. Shomette — *Shipwrecks on the Chesapeake* (Centreville MD: Tidewater Publishers 1982).

" — *Tidewater Time Capsule* (Centreville: Tidewater Publishers 1995).

" — *The Ghost Fleet of Mallows Bay* (Centreville: Tidewater Publishers 1999).

Sheli O. Smith — *Low-Tech Archaeological Survey Manual* (lulu.com)

J. Richard Steffy — *Wooden Ship Building and the Interpretation of Shipwrecks* (Texas A&M University Press, 1994).

Robert H. Thurston — *A History of the Growth of the Steam Engine* (New York: D Appleton & Co., 1878) on line at www.history.rochester. edu/steam/thurston/1878

US Department of War — *Official Records of the Union and Confederate Navies in the War of the Rebellion* (Washington: Government Printing Office, 1894-1922) at cdl.library.cornell.edu/moa/browse.monographs/ofre.html

van Tilberg, Hans K. — *Zero-Visibility Diving on the Maple Leaf*. International Journal of Nautical Archaeology, 23(4), 315-318. (Harcourt, Brace & Company 1994)

Von Maier, R. 1991. — *Solo Diving: The Art of Self-Sufficiency*. (San Diego, CA, Watersport Publishing)

Zumrick, J.L., Prosser, J.J., and Grey, H.V. *NSS Cavern Diving Manual*. (National Speleological Soc., Branford FL, 1988).

The books listed above that are not on-line can be studied at IMH's office.

APPENDIX **SITE DATA FORM**

IMH

Date ____________ Site ____________________________

Divers ____

feature name or description	datum	distance	side

NOTES:

IMH

INSTITUTE OF MARITIME HISTORY

www.maritimehistory.org

P.O. Box 9
Tall Timbers, MD 20690
U.S.A.
301-949-7545