# Highlight

# Underwater Imaging and GIS Integration with Side Scan Sonar

**By Brett Phaneuf**

When the topic of remote sensing comes up, most people don't think of underwater research. Instead they envision elaborate and highly detailed aerial photography and possibly a team of geologists, archaeologists, or surveyors working with a magnetometer, total station, or GPS. In some cases, ground penetrating radar may even come to mind. However, in recent years advances in computer technology, microelectronics, and materials science, coupled with a decrease in cost, improved portability, and cost reduction make high resolution underwater imaging more available for an array of remote sensing applications in the sea, as well as in rivers and lakes.

The principle instrument for imaging underwater is a side scan sonar. Side scan sonar technology has been available for several decades, employed in many applications and in a variety of system configurations. Development has been spurred on by the U.S. Navy, and is also supported by commercial interests seeking to exploit the petroleum and mineral resources on the continental shelf. Government agencies charged with monitoring commercial activity in our coastal and inland waters, and with enforcing environmental protection legislation, have also influenced technical advances. Sonar technology can be utilized in archaeology, biology, geophysics, cultural resource management, environmental monitoring, and more.

A basic side scan sonar system consists of a towfish, the device towed behind a vessel generating the ultrasonic pulse that is used to build an image; a towcable; a processing and display device; and, of course, a global positioning system. For the most part, the topside processing and display devices are not computer integrated; opting instead to produce the side scan image on a high resolution thermal printer. (For years PCs were used to design systems that did not incorporate the computer itself into the control or processing hardware. There are, however, several companies exploring this avenue, and having great success.)
Essentially, side scan sonars emit an ultrasonic pulse that is reflected by the sea floor and the object lying on it. These return pulses generate an electronic impulse in the transducers (the same portion of the towfish that emits the sound). This impulse is carried up the towcable to the control and display system. In modern, computer integrated side scan sonar systems each pulse corresponds to one video line of display. As the towfish is towed through the water "pinging," the computer basically stacks the reflected pulses as video lines one on top of the other, creating an image of the sea bottom or river bed that resembles an aerial photograph. The rate at which the system "pings" is determined by range setting (5 to 500 meters) and speed through the water. Each pixel of image that is generated by the system is correlated to a lat/long fix so that an identified target can be relocated simply by clicking on the image record when reviewing the data. The value of having the data GPS correlated and in digital form is that it can be integrated into most GIS systems along with other hydrographic, textual, numerical, or image data; however, it is on this front that underwater imaging, and research in general is most lacking.

The use of GIS software in the "underwater world" is exceedingly limited when compared to the terrestrial side of the coin. The level and complexity of software for displaying, interpreting, and interrelating the collected data is unquestionably behind terrestrial remote sensing technology by at least a decade. As mentioned above, many of the systems in use are still analog, and the records they produce must be hand digitized, dramatically increasing cost in man hours as well as the error factor. However, cutbacks in government funded research, and the privatization of most underwater research formerly conducted by state agencies, in conjunction with low-cost, high-resolution systems (mentioned above) which are easily operated on low power from any craft of opportunity, has led to a proliferation of firms involved in underwater imaging.

The personal computer, now commonplace, has unleashed new power on underwater research. Small remote sensing firms formerly interested only in terrestrial projects can, for about $20,000, enter the realm of underwater research and produce startling results utilizing third party and manufacturer software packages and processing techniques once only applied to aerial photography and GIS integration of imagery. Length, width, height, area and exact, real-world position is available with a click of the mouse. Currently, some work is being done to explore the adaptation of a mosaicing engine from PCI Remote Sensing Corp. to Marine Sonic Technology Ltd.'s (MSTL) Sea Scan PC. The cost estimate is somewhere under $5,000 for the software which is on average an order of magnitude less than similar products in the underwater research community. It also has the advantage of allowing the user to import underwater image data directly into any number of GIS platforms, almost unheard of in the field, until recently.

These advances have led to the proliferation of applications. Side scan sonar is now used in every aspect of environmental protection, for example: monitoring beach erosion and sediment transport.

Figure 1 is one of a series of images gathered along Marconi Beach, Cape Cod just after hurricane Eduoard tore through the region. The disturbance in the bottom sediment is apparent, due to the high wave action and current shifting. The study of outfall pollutants is also possible, as evidenced in Figure 2. The image clearly indicates an outflow of waste material invisible underwater or on the surface to the naked eye. Until recently it was believed that this particular outfall was inactive. Previous imaging with lower resolution, older side scan systems could not detect the material in the water column. In addition, it is now possible to effectively map and track the health and growth of artificial and natural reefs. Prior to high resolution sonar becoming available, artificial reefs were mapped by divers measuring the distances between components of the reef structure with tape measures, often in near zero visibility water. It was not inconceivable that a single reef structure could take weeks to map, with dozens of divers producing marginally accurate results. In contrast, an entire reef system can be thoroughly mapped with dramatic accuracy in two or three days by two persons in a small boat and at tremendous savings to the state; not to mention with increased safety to the personnel no longer diving in sometimes difficult conditions.

Along with environmental applications, a host of biological research can be accomplished. The mapping of oyster beds and various subaquatic grasses was hitherto impossible. Traditionally, "grab" samples of the bottom were taken by divers or with a dropped device that scooped up a sample of sediment or biological material from the bottom. The positions were then plotted and the extend of various bottom types and organisms estimated. With state-of-the-art sonar systems, oyster beds are visible, as are sea grasses.

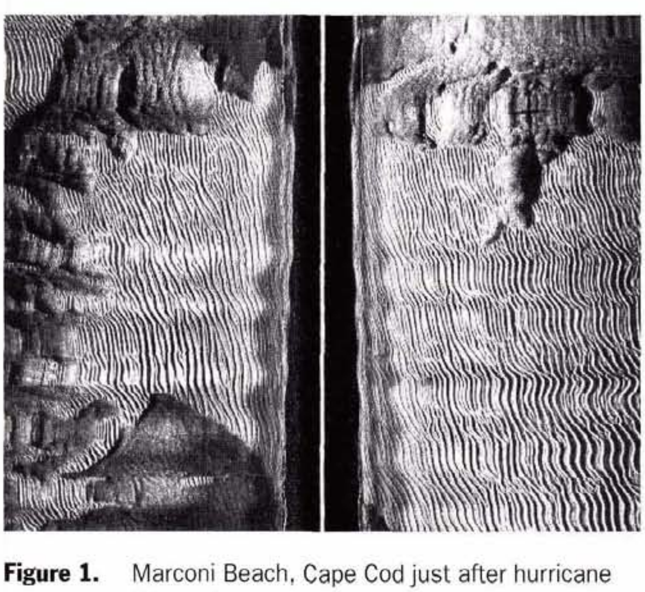

**Figure 1.** Marconi Beach, Cape Cod just after hurricane Eduoard.

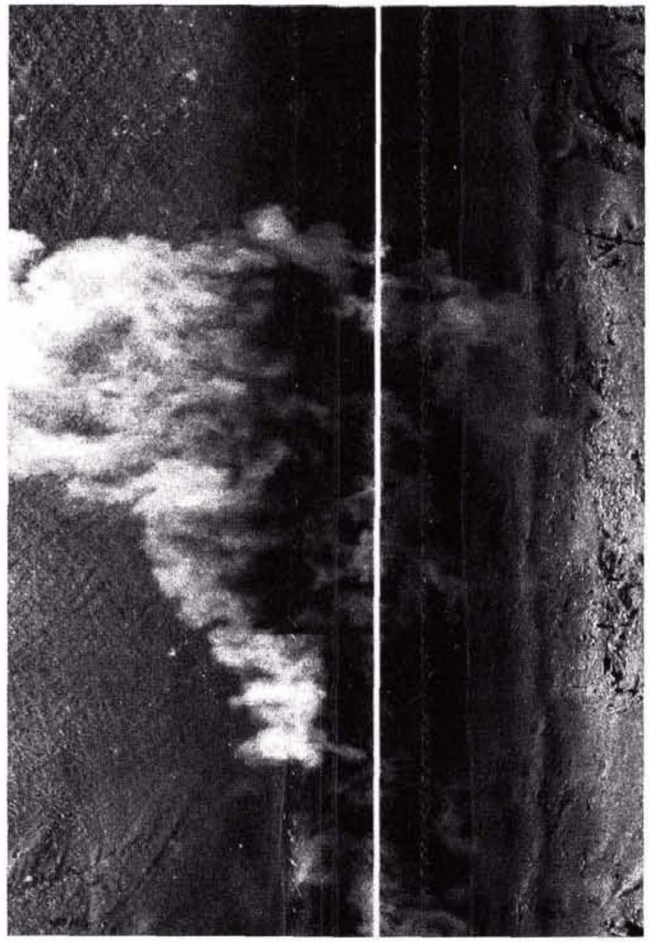

**Figure 2.** A small sewage outfall in the Connecticut River)

Georeferenced image data can be correlated with some ground truth data and an accurate map of the seafloor bio-community can be constructed quickly. This can then be overlaid with previous surveys and accurately track the health, growth and extent of various biological resources. Fish populations can also be studied. An estimate of the number and type of species present can be gathered and checked against earlier data to ensure that commercial fishing, construction, or pollution is not detrimentally affecting the habitat or population (Figure 3).

As an archaeological mapping tool, high resolution sonar is unparal-

**Figure 3.** A 600kHz image of a Tarpon at the New England Auqarium.

leled (Figure 4). Again, much of the diving associated with underwater research is potentially hazardous. Low visibility, and potential entanglement hazards such as fishing line and net can be problematic at best for an archaeologist. "Scanning" an area for the resource or shipwreck in question allows the researcher to narrow the list of potential targets, thus maximizing diving and research time. It also provides a virtual map of the dive site allowing the archaeologist to spend more time on areas of high artifact concentration with a greater margin of safety. Beyond simply locating archaeological resources, long term monitoring can be carried out to ensure that the integrity of a site has not been violated by salvers, storm damage, or the occasional anchor dragging through the site.

Other applications include construction and obstruction monitoring shown in Figure 5.

Again, using the side scan sonar to limit dive time and focus the effort on the appropriate location without having to "feel" your way along the bottom allows for safer diving and construction as well as more accurate estimates of the time and material required to complete a particular job. Also, locating and removing obstructions to shipping and fishing dramatically reduces insurance claims, and ultimately the consumer price of products transported by sea.

A more somber task is drowning victim and evidence recovery. Frequently, state agencies spend hundreds of thousands of dollars on drowning related searches. One example is a case wehre MSTL was called to assist in locating two missing fishermen and their boat. The search had been raging for almost two weeks prior to my arrival, and included ten boats, two helicopters, one airplane and dozens of state employees and volunteers, to no avail. Within four hours, the MSTL team had located the small watercraft, and after analysis of the images, determined the position of the two drowning victims with great accuracy. Buoys were placed to mark the approximate location and then the site was re-imaged. This allowed MSTL to show the police dive team where the boat and bodies were relative to the buoy weight. After only 30 minutes of diving in zero visibility water, the boat and victims were recovered. In comparison to the search that had been conducted before contacting MSTL, the cost of MSTL personnel and

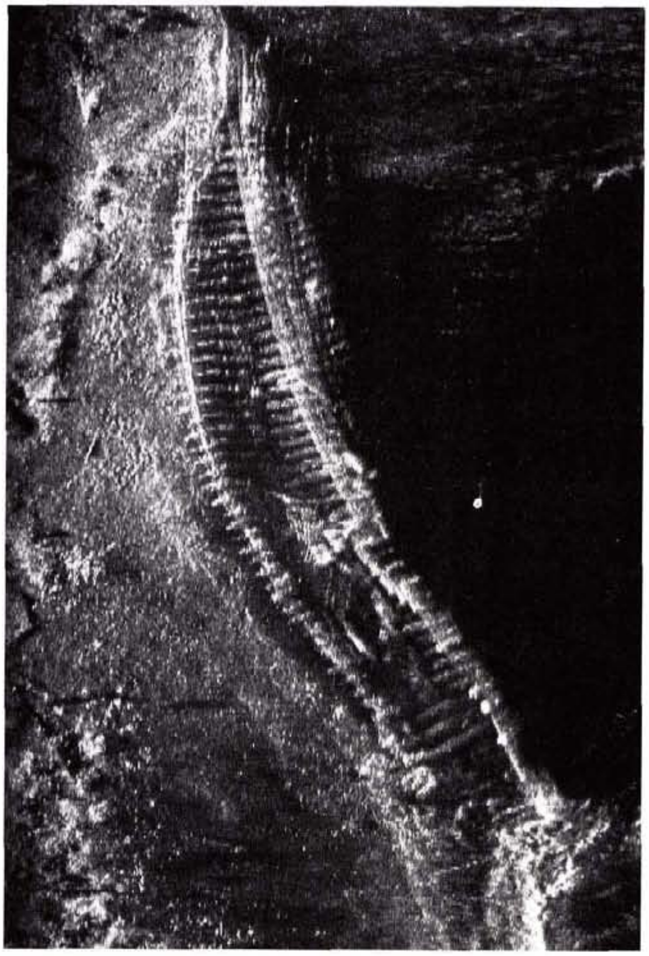

**Figure 4.** Shipwreck E.C. Waters in Yellowstone Lake - the frames of the ship are clearly visible.

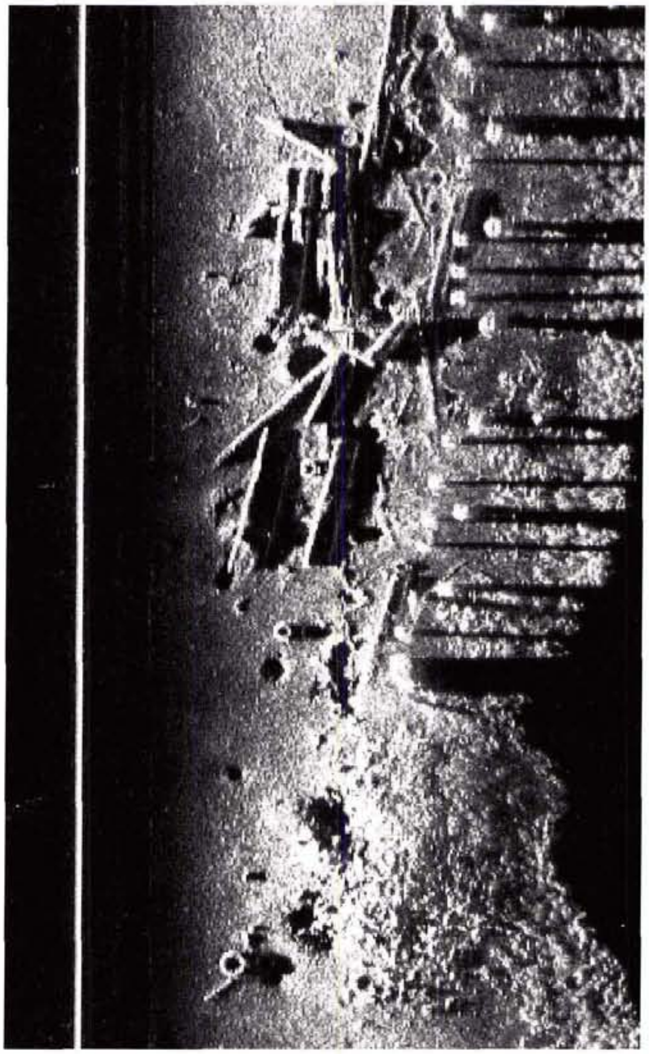

**Figure 5.** An old dock knocked down and left underwater while building a new pier.

equipment ($30,000) had been exceeded by a factor of ten. Several systems now in service with various police agencies on the east coast have been successful in locating stolen automobiles, evidence in murder cases, and drowning victims. (Figure 6 stolen automobile dumped in the Connecticut River at approximateiy 25 feet deep.)

Of course, a variety of tasks related to geophysical exploration can also be accomplished: mapping pipelines, faults, gas

**Figure 6.** Automobile in 25 ft. water.

seeps, thermal vents, erosion, and sediment movement. The images gathered, whether out at sea, in coastal and wetland regions, or riverine environments can then be transferred into a GIS database and used to construct seamless maps and charts of any area, terrestrial and submerged, with no gaps in the data. Incorporating this high resolution imagery with all sorts of hydrographic data (temperature, current, wind direction and speed, depth, to name a few), historical and archaeological data, shipping traffic data, population growth studies, and economics will allow future scientists to construct predictive models. Models such as: where to place a house or complex of houses relative to waste sites, erosion, construction, biological hazard or sensitive zones and commercial areas. How that construction will affect fish stock, health of occupants, the local economy, or the environment over the next 20, 30, 50 years? The potential is truly limitless.

Unfortunately, underwater research in general still lags behind technologically, when compared to terrestrial remote sensing. More often that not, data gathered is still in analog form and not readily useable in GIS databases. In fairness, working on and under the water poses difficult problems for scientists who are not present in the "dry" side of remote sensing. The environment is very tough on equipment and people; mistakes can be at best costly, at worst fatal. However, great strides are being made to bring the two sides together to more effectively collect and analyze data. As technology advances and becomes less expensive, more and more people will choose to work on and under the water, and the lines between various fields of remote sensing will blur further.

## Note

All of the images in this article were collected with a Marine Sonic Technology, Ltd. 600kHz Sea Scan PC side scan sonar.

## About the Author

Brett A. Phaneuf is an archaeologist by training, having received his BA in Anthropology and Classical Studies from the University of Massachusetts at Amherst. He studied at Texas A&M, in the Nautical Archaeology Program and Physical Oceanography Department, focusing on remote sensing technology. Phaneuf is employed by Marine Sonic Technol ogy, Ltd., and can be reached at mstl@ccsinc.com.