
Survey Technique for Underwater Digital Photography with Integrated GPS Location Data

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Abstract

This underwater survey technique developed by the U.S. Environmental Protection Agency ([EPA](#)) [Region 10 Dive Team](#) is an inexpensive method of conducting impact analysis and shoreline inventory of submerged aquatic resources by means of geo-located photo documentation. This technique is capable of identifying, mapping, and recording the x & y coordinates of submerged aquatic resources in low visibility waters with minimal error. The geo-referencing of these objects is accomplished by a two person SCUBA dive team surveying the underwater environment by documenting the seafloor with an underwater digital camera taking photos at regular intervals along a contour of the shore. An inexpensive recreational Wide Area Augmentation System (WAAS) enabled Global Positioning System (GPS) device is diver-towed in a raft directly above the dive team which records positions throughout the dive. Commercial software is later used to relate the GPS information to the digital photos resulting in geo-located digital photos that can be viewed on a map or in a Geographic Information System (GIS) for later analysis of the seafloor environment.

Introduction

As EPA continues to heavily focus on water and sediment quality issues, expanding the agency's capabilities relating to marine and benthic surveys is vital. New techniques for geo-referencing underwater digital photos, developed by the Region 10 Dive Team, provide location data of previously unobtainable accuracy for specific sample sites, hazards, and marine resources.

Identifying, mapping and recording the exact locations of submerged aquatic resources and unwanted hazards in low visibility waters throughout the Northwest has always proved challenging. The Region 10 EPA Dive Team has the task of documenting and geo-locating these objects which stem from projects such as: drum dumping investigations, pre-capping and pre-dredging surveys, chemical product seepage from groundwater to surface water, pipe outfall compliance inspections, various reconnaissance and recovery operations, [sampling, and ecological shoreline inventories and assessments](#). Involved in any of these projects is the need to record the physical location of submerged objects for future mapping and analysis through the use of Geographic Information Systems (GIS).

Assisted by the use of underwater digital photography a diver can descend, survey the project area, and photo document any objects of interest for future analysis. Unfortunately, the diver has not been able to accurately record where those photos were taken under the water because traditional Global Positioning System devices (GPS) do not work beneath the water's surface.

Poor underwater geo-positioning accuracy has usually caused fundamental difficulties in accomplishing the mission of EPA dive projects, which typically include delineating areas of contamination, identifying areas needing localized cleanup, or identifying areas which otherwise need to be revisited. Other types of missions that we have found difficult to accomplish because of poor underwater positioning technology include determining locations of: an anchor line, an illegally scuttled ship, an unknown sewer overflow outfall, and a protected species habitat.

The challenge presented to the Region 10 EPA Dive Team was to devise a method of recording a diver's location and path underwater while simultaneously photo-documenting the seafloor project area with a digital camera in a waterproof housing. This kind of survey must be performed without the use of acoustic based underwater positioning systems, which have proved to be costly, involving lengthy setup procedures, requiring cumbersome underwater observation recording consoles, and subject to performance errors due to haloclines, thermoclines, and acoustic shadows. Although commercial systems are available that place a GPS unit in a waterproof housing with a long extension to a surface antenna (Sound Ocean Systems, 2008), our method is even simpler, more cost-effective, and just as efficient. The simplicity and improved accuracy of geo-referenced photos used with recreational (i.e. less than \$1000 in cost) GPS units has shown that better data can be made available at a fraction of the cost and time invested.

Methods

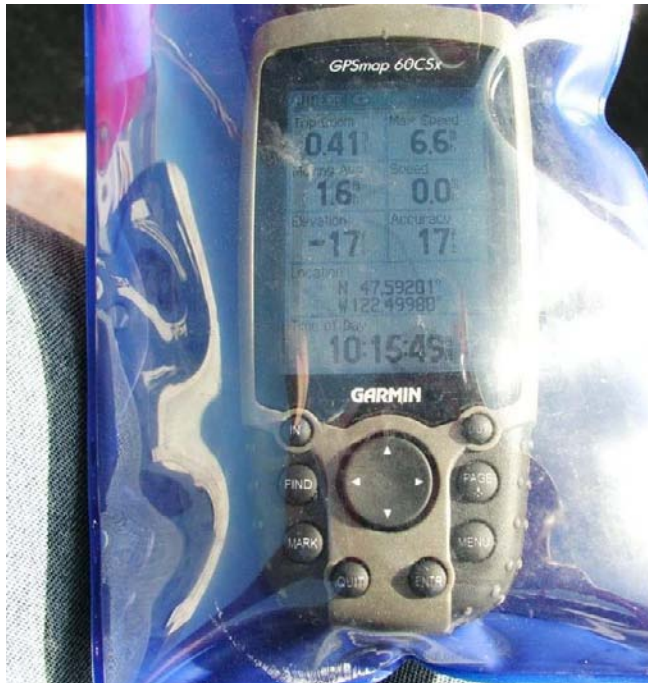
To address this underwater geo-location challenge the “*Survey Technique for Underwater Digital Photography with Integrated GPS Location Data*” was created. This procedure is conducted by a two person dive team who surveys the underwater environment in search of relevant submerged aquatic objects and documents them with digital photos. An inexpensive recreational GPS device is towed by a diver in a raft directly above the dive team which records time-stamped positions throughout the dive. Commercial software is later used to relate the GPS information to the digital photos resulting in geo-referenced digital photos that can be viewed on a map or Geographic Information System (GIS) for later analysis of the benthic environment. This technique has been successfully used previously in a terrestrial environment with a high level of success (Directions Magazine, 2007).

The result of this collaborative effort between EPA GIS staff, dive team, scientists, and field support personnel is a system that demonstrates an inexpensive method of relating a common timestamp of photos of submerged aquatic objects of interest and a GPS track log. This produces a GIS shapefile. “A shapefile stores nontopological geometry and attribute information for the spatial features in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates.” (ESRI, 2008). The shapefile produced shows point locations of each photo's physical x and y coordinates.

The technology behind this survey technique consists of: a recreational grade Wide Area Augmentation System (WAAS) GPS device (we use a Garmin 60CSX) placed in a water tight

drybag, attached to a four foot long Styrofoam raft equipped with a dive flag, a reel of line to connect the diver to the raft, a digital still camera (or video camera with still capability) with time-stamping capabilities within an underwater housing, an inexpensive digital photo GPS integration software package (e.g., GPS Photo Link version 4), and a laptop running GIS software (such as ArcGIS 9).

Photo: GPS device inserted in drybag



The survey procedure:

1. GPS device is placed in a drybag and clipped atop a diver-towed raft.
2. Before the dive the GPS device screen is photographed by the underwater digital camera to record the exact difference in device clocks.
3. Divers descend, tighten the scope on the tow line to bring the raft vertically overhead, take a photograph to document the survey start point, and survey the underwater environment by following a compass bearing, a depth contour, or directions from surface support, while recording results via the underwater digital camera.
4. During the dive the GPS device continuously records the location of the divers below through the GPS's track log. The divers tighten the scope on the tow line to ensure the raft is directly overhead for all critical pictures. At the conclusion of a transect, the divers take a photo to document the location of the end of the survey.
5. After the dive the track log data and the digital photos are offloaded to a laptop located on the dive boat for additional processing.
6. An inexpensive digital photo GPS integration software package is used to relate the GPS data time stamps to the digital photo time stamps, and create a geospatial data set with hyperlinks to photographed locations.

Photo: GPS device carried atop diver towed raft, augmented with a dive flag for safety purposes



After the dive, the data is exported into a shapefile format and the photo-hyperlinked geospatial dataset is brought into a GIS application along with a time- and coordinate- stamped copy of the photos.

Photo: Example georeferenced photo of eelgrass



Photo: Example of Georeferenced photo of bottom debris



Once in the GIS application a user can click on a seafloor point to see the photo from that corresponding location. In addition, a track log of the path the divers traveled underwater can be displayed in the GIS application for further navigation, verification, and ground truth purposes.

Results and Discussion

The availability of new, inexpensive, innovative and effective tools that facilitate marine and benthic survey work is critical to addressing water quality issues. SCUBA-based underwater geo-located digital photography is a new technique for locating specific hazards and marine resources with previously unobtainable accuracy at such low cost. This survey technique has already been implemented in EPA's Puget Sound Regional Priority Project Area and is scheduled to be used in the Columbia River Basin Regional Priority Area in the future (USEPA, 2006).

Photo: Example Results of Underwater Survey Technique



The outcomes of this survey technique are photo-hyperlinked geospatial datasets consisting of water resource information including: [National Pollution Discharge Elimination System \(NPDES\)](#) (USEPA, 2008) outfalls locations, water, soil, and biota sampling locations, illegal dumping locations, or benthic impact analysis. These data are easily fed into project, regional and national EPA databases such as the [Permit Compliance System \(PCS\)](#), [STORET \(short for STORage and RETrieval\)](#), or [Water Quality Exchange \(WOX\)](#) (USEPA, 2008).

Cost and usability of this navigation and photo linking technology is also a major advantage of this survey technique. The cost of our GPS receiver is approximately \$400, the off the shelf photo linking software (Geospatial Experts, 2008) retails for approximately \$200, and the raft was fashioned from previously acquired foam pontoons and supplies for approximately \$100. While other acoustic based underwater navigation and tracking systems advertise “submeter accuracy” for a long baseline (LBL) system (Desert Star Systems, 2008) or in the case of ultra short baseline systems (USBL) “up to 0.15 degree” accuracy (LinkQuest Inc., 2008) most retail starting at \$13,000 and can cost over \$100,000. In addition, these have proven more difficult to setup during Region 10 dive operations, prone to failure (e.g. from haloclines, thermoclines, physical obstructions, battery drain on sonar buoys or diver units, etc.), and problematic to interpret and extract the resulting location data. In addition to the qualification of the advertised accuracies of LBL and USBL being highly dependent on field conditions they are also highly dependent on ancillary equipment accuracy. For example, the digital compass component can introduce significant error to a USBL system that propagates with increasing distance between the surface tracking platform and underwater target. For this reason, it is not uncommon for manufacturers to qualify USBL accuracy excluding heading errors (Applied Acoustics, 2008).

“The Survey Technique for Underwater Digital Photography with Integrated GPS Location Data” is a more effective tool for achieving project goals and extracting underwater locations into a usable GIS compatible format. It is also much more efficient and cost-effective. GIS data are easily exported due to the simplicity and compatibility of data integration tools and shapefile export functionality included in the off-the-shelf digital photo GPS linking software. In addition, such a system costs less than five percent of acoustic technology alternatives, saving increasingly scarce budget resources to better focus on other project needs. Logistically, we find that more dive time is available due to the limited time required to setup and remove the equipment when out on the water. While line scoping of the GPS float may diminish the accuracy of this technique at depths greater than 30 feet, error introduced by line scoping is also endemic to LBL system setup in open water, particularly when deploying transducers to compensate for haloclines or thermoclines mid-water column.

“The Survey Technique for Underwater Digital Photography with Integrated GPS Location Data” has been tested, utilized, proven successful and accurate within the last year on a handful of regional dives throughout the Puget Sound including a [Blakely Harbor, WA](#) habitat survey, a pre-capping debris survey at the [Wyckoff Superfund Site, WA](#), a habitat survey at Henderson Inlet (USEPA 2007), and an ordnance/habitat survey at the [Jackson Park Superfund Site](#) (USEPA 2008). More experimentation will be required for diving depths greater than 30 feet, but on shallower dives less than 30 feet we have observed the overhead raft to be directly above the diver’s photographed object, and the WAAS enabled GPS to be approximately at a three to five meter level of accuracy. Further, depth and accuracy limitations to this technique relating to line scoping issues are endemic also to LBL acoustic based systems, which rely on triangulation of three or more buoyed transponders, making the ease of data acquisition in this survey technique a true advantage.

Expanded use and awareness of GIS throughout the EPA’s environmental assessment and dive team communities has also been an added benefit from this survey technique. Region 10 EPA divers now have ArcGIS installed on their field laptops for mapping and tracking support in the field and on the dive boat. In addition more regional field staff is now using GIS products including: aerial imagery, base map data, and EPA databases to compliment the geo-referenced location of their digital photos on other non-diving related projects.

Disclaimer: This paper is an illustration of the application of an underwater survey technique and does not represent the official view of the USEPA. Mention of any specific brand or model instrument or material does not constitute endorsement by the USEPA.

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