Coastal Engineering Technical Note

The SHOALS System - A Comprehensive Surveying Tool

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PURPOSE

The U.S. Army Corps of Engineers (USACE) conducts extensive hydrographic surveying in support of the planning, design, construction, maintenance, and operation of Federal coastal projects. The USACE surveying program covers a broad range of project types including storm damage reduction, navigation, shore protection, and emergency response operations. Most USACE coastal surveys are performed by small launch-type vessels with acoustic fathometers. The Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system was developed to achieve an orders-of- magnitude increase in survey speed while collecting densely spaced high-resolution data, and SHOALS has demonstrated its ability to achieve those goals. The information presented here is intended to provide essential knowledge about this new technology and its applications.

BACKGROUND

In 1988, USACE began a cost-shared project with the Canadian government under the U.S./Canadian Defense Development Sharing Program for design, construction, and field verification of the SHOALS system. The term "lidar" stands for LIght Detection And Ranging. USACE accepted the SHOALS system in March 1994, following field testing which indicated that the system met or exceeded all design and operational specifications. Since then, SHOALS has surveyed over 250 projects (as of March 1998) covering more than 3,000 km^2. These surveys range from navigation and beach monitoring, to coastal structure evaluation, to emergency response operations. SHOALS has also performed several missions for the National Oceanic and Atmospheric Administration (NOAA), as well as the U.S. Navy, with projects varying from coral-reef damage assessment to nautical charting of international waters.

SHOALS consists of an airborne data collection system and a ground-based data processing system (Figure 1). The system operates by emitting laser pulses 200 times per

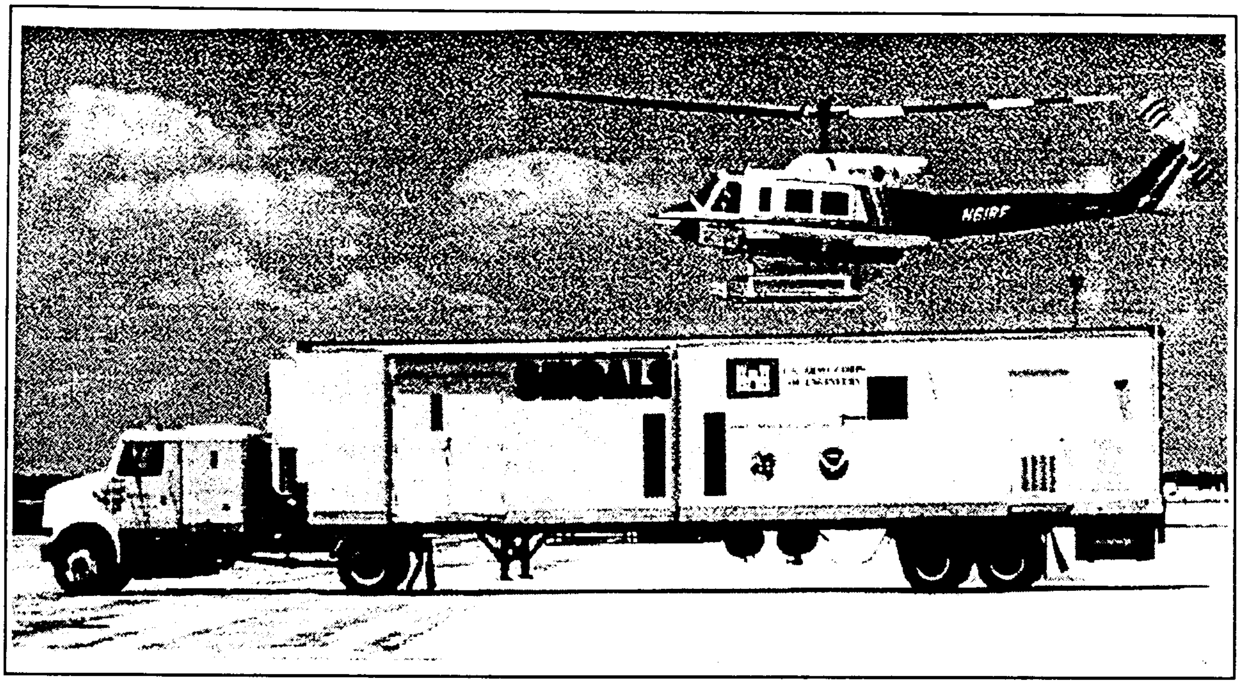

Figure 1. SHOALS Airborne lidar survey system. Capable of providing high resolution surveys of coastal projects

second while being scanned in a 180 deg arc pattern across the flight path of the airborne platform (Figure 2). Each laser pulse travels from the airborne transmitter to the water where some light energy is reflected and detected by onboard optical sensors. The remaining light passes through the water column, reflects from the sea bottom, and returns to the optical sensors as illustrated in Figure 3 (Guenther et al. 1996). The time difference between the water-surface and sea-bottom returns indicates the water depth. SHOALS operates from a Bell 212 helicopter at an altitude of 200 m and a speed of 30 m/s providing depth measurements on a 4-m horizontal grid, covering 8 km^2 per hour (Lillycrop, Parson, and Irish 1996). Sounding densities can be adjusted by flying higher or lower, at different speeds, or by selecting different scan widths.

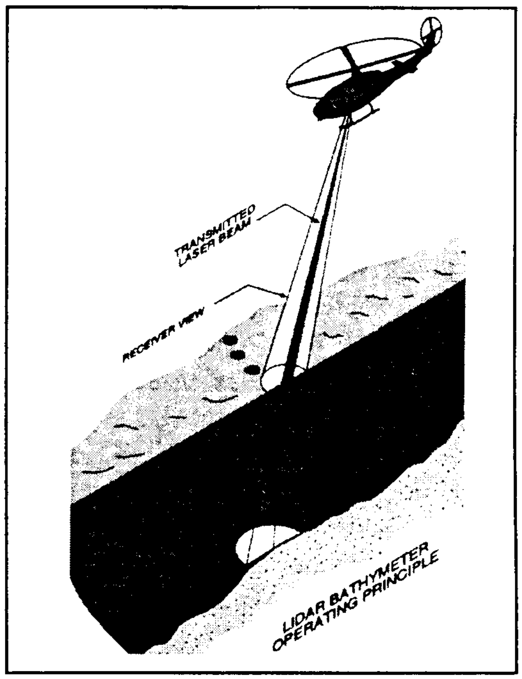

Figure 2. SHOALS operating principle, laser pulses at 200 Hz while being scanned 180 deg across the flight path of the helicopter

The main constraint of any lidar bathymeter is water clarity. In clear waters, SHOALS is effective to about 40-m depths. In less clear waters, SHOALS is

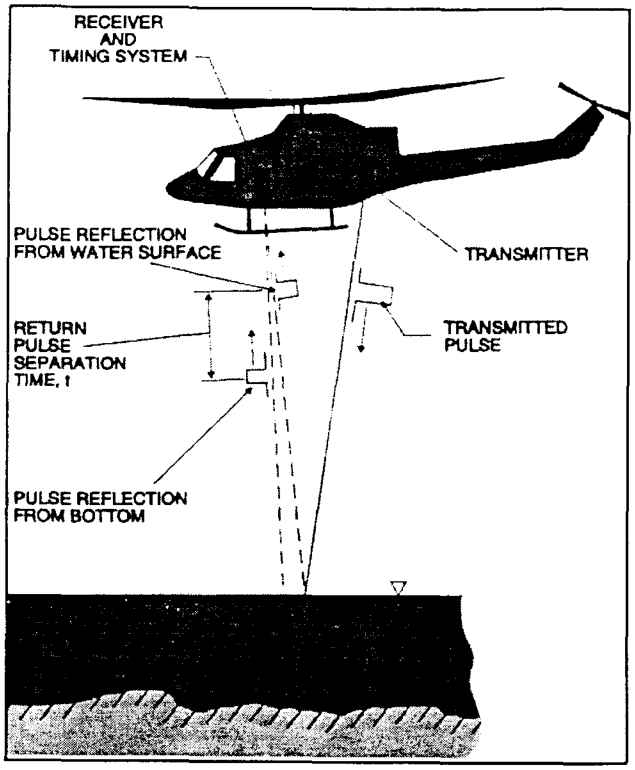

Figure 3. Lidar returns from the water surface and sea bottom. The time difference between the two returns indicates the depth

successful to depths of 2 to 3 times the visible depth,as measured by a simple device called a Secchi disk. For each sounding, SHOALS obtains horizontal position using a differential global positioning system (DGPS) while vertical position is directly correlated with measured water-surface locations. SHOALS meets both USACE Class I survey requirements and International Hydrographic Organization (IHO) charting standards. Performance characteristics and accuracy specifications are listed in Table 1.

In response to USACE's increased needs to map beaches, dunes, and above-water structures, SHOALS possesses the capability to utilize kinematic GPS (KGPS) capability. Since the need to use water surface as a vertical reference is eliminated, KGPS allows more extensive measurements of adjacent beach and dune systems. With the ability to collect both hydrographic and above-water survey data, SHOALS can simultaneously conduct complete beach and structure surveys above and below the waterline providing a useful tool for post-storm erosion assessments or in areas where human access is difficult or restricted. SHOALS data are being used to generate vertical profiles, cross sections, and contours, and to perform volumetric analysis.

Table 1
SHOALS Performance Characteristics

Maximum Depth	**40 m or 2-3 Times Secchi Depth**
Vertical accuracy	+/- 15 cm
Horizontal accuracy	+/- 2 m
Sounding density	4-m grid
Operating altitude	200 m
Scan swath width	110 m
Operating speed	60 to 120 knots (approx. 30-60 m/sec)

CAPABILITIES

Navigation and Structure Capabilities

Since becoming operational, SHOALS has performed a wide variety of missions including many navigation projects at tidal inlets, where USACE is typically concerned with channel depths, navigation structure condition, and project impacts to adjacent shorelines. Using SHOALS, these types of surveys are completed in a few hours, resulting in high-resolution coverage of an entire inlet system as well as associated structures and adjacent beaches. The surveys provide adequate information to quantify channel dredging requirements, the condition of the associated jetties both above and below the water including the structure toe, and the entire beach and nearshore areas adjacent to the inlet. Figure 4 presents the results of a SHOALS survey conducted at Ft. Pierce Inlet on the east coast of Florida. Ft. Pierce was among the first missions completed with KGPS during the winter of 1997. Analysis of the data shows exceptional coverage of the upland beach and dune system along with the nearshore bathymetry. This high-resolution survey quantifies several of the inlet's features such as coral reefs, rock outcrops, the rock-blasted channel, navigation jetties, shoal features, and beach and nearshore morphology.

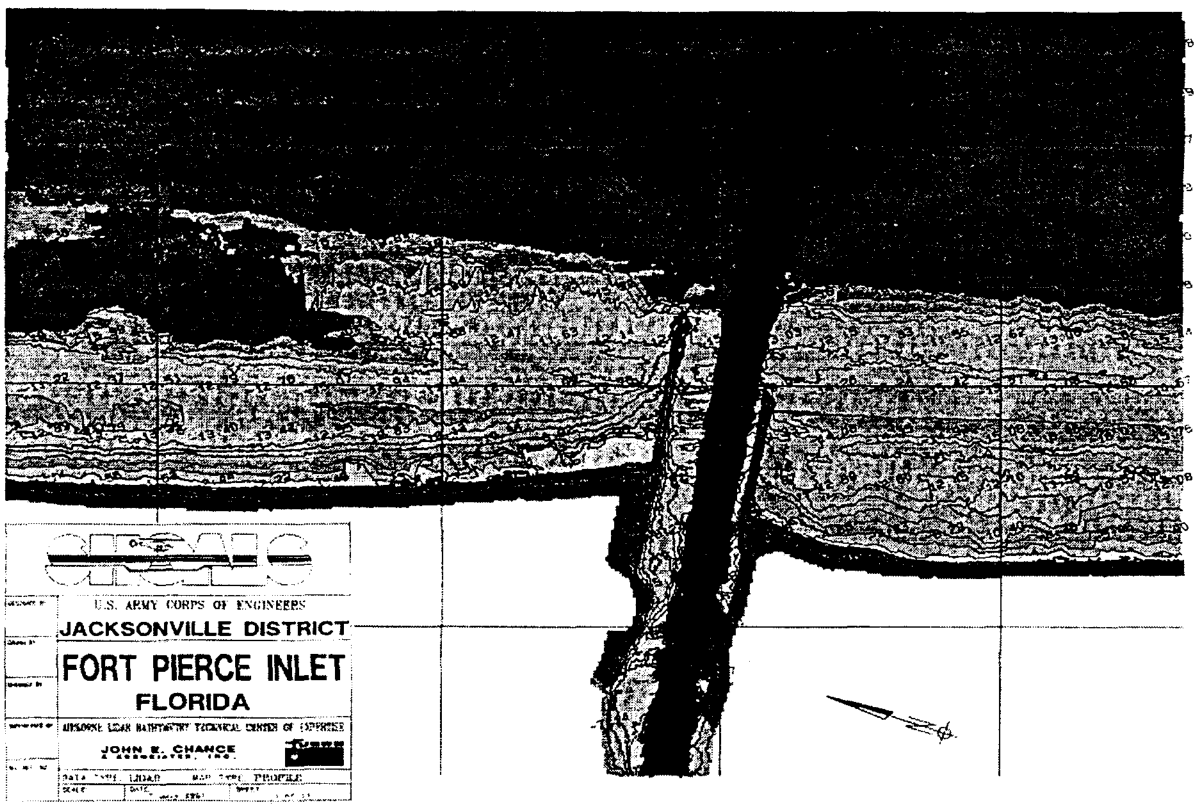

Figure 4. Lidar survey of Ft. Pierce Inlet on the east coast of Florida

Nautical Charting Capabilities

During the past two years, SHOALS surveys were conducted for the NOAA National Ocean Service and the U.S. Navy explicitly for creation of nautical charts and identification of navigation hazards. These included Miami Harbor and Port Everglades, Florida, and Elwood and Gaviota, California, and SHOALS' first international mission off the Yucatan Peninsula, Mexico. The Mexico project, completed for the U.S. Navy, was the largest single survey mission for SHOALS (Figure 5). Over 56 days of data collection, SHOALS completed 800 km^2 totaling over 100 million depths. In preparation for this mission, SHOALS auxiliary sensor capabilities were augmented to include a geo-referenced video for establishing positions of above-water features such as piers, lighthouses, and navigation aids as well as some underwater features in clear water. During the Mexico mission, SHOALS bathymetry and video located and mapped two previously uncharted shipwrecks.

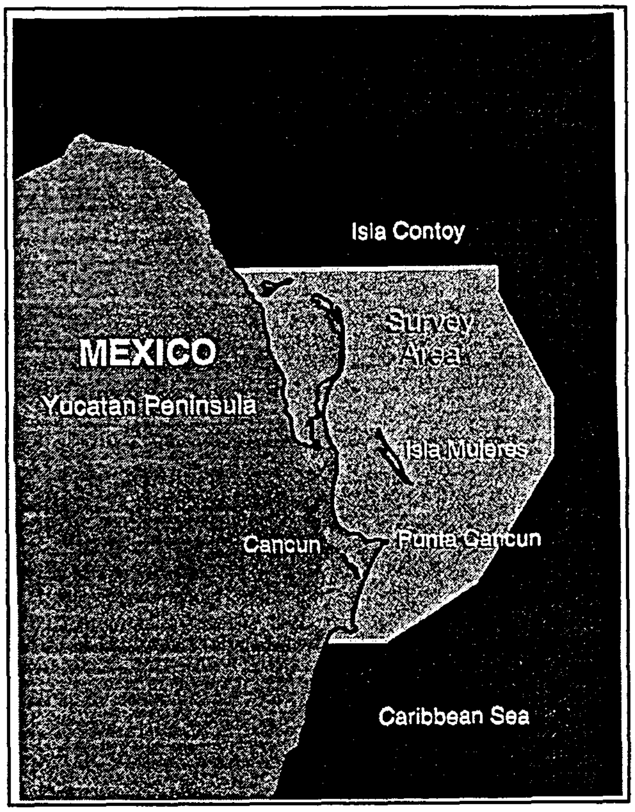

Figure 5. SHOALS survey area near Cancun, Mexico. 800-km^2 area surveyed for nautical charting and navigation hazards

Emergency Response Capabilities

Since SHOALS is rapidly deployable and quickly collects both bathymetry and information above the water, it is an ideal tool for emergency damage assessment. At the request of NOAA, SHOALS performed an emergency response survey to quickly assess coral reef damage at Maryland Shoal in the Florida Keys resulting from the grounding of a cargo vessel. The mission was completed in less than an hour and successfully quantified the damage to the reef system.

In October 1995, following Hurricane Opal, SHOALS surveyed two projects along Florida's panhandle: East Pass and Panama City Beach (Irish et al. 1996). East Pass is jettied on both sides and provides the only direct access from the Gulf of Mexico into Choctawhatchee Bay through a maintained navigation channel. On the east side of the pass is a sand spit, known as Norriego Point. The surveys were completed (Figure 6) within an hour and included over 300,000 soundings within the 3-km^2 area. Elevation measurements ranged from the dry beach and above-water structures to 10-m depths and detailed the entire inlet system including Norriego Point, the two jetties, the inlet throat, and the ebb shoal. Within 6 hr of the survey, hard-copy maps were generated, dredging requirements inside the navigation channel were calculated, and jetty damages were assessed.

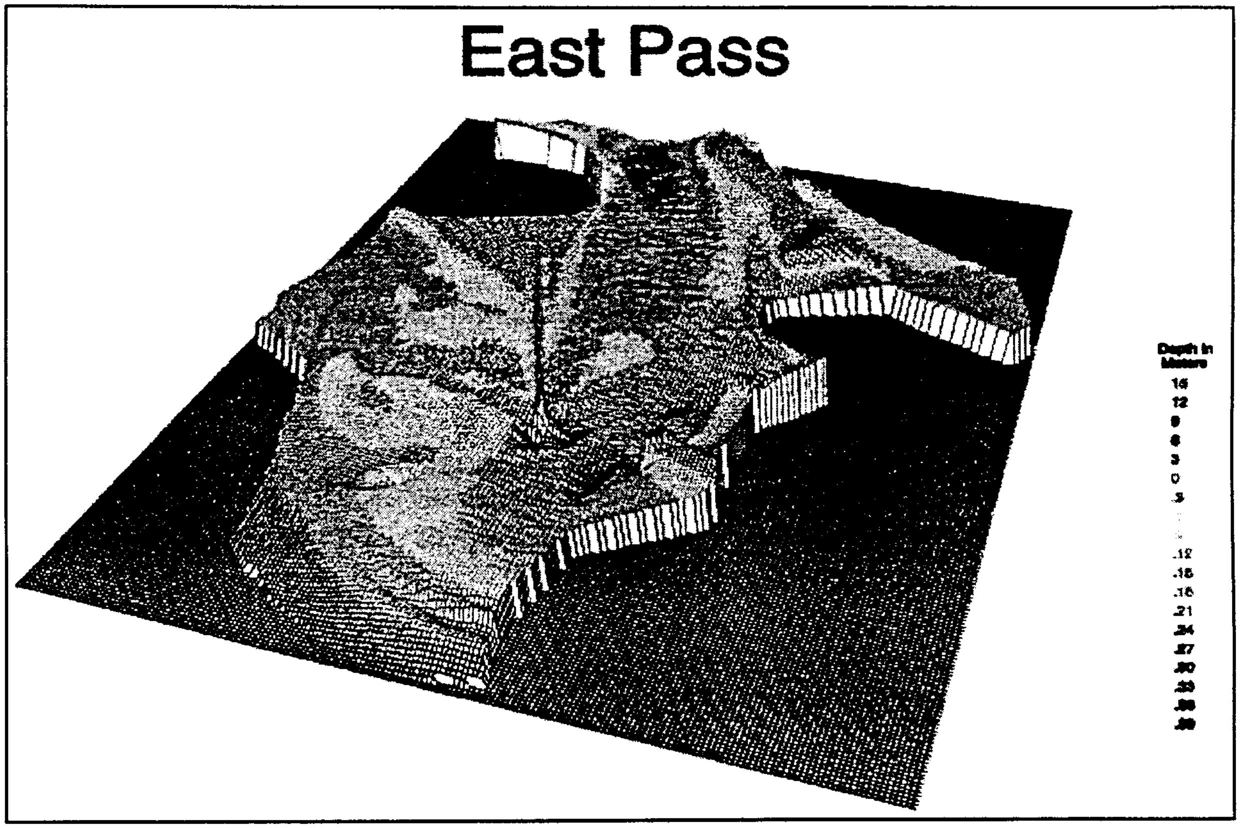

Figure 6. SHOALS survey of East Pass at Destin, Florida, after the passage of Hurricane Opal

Shallow-Water Capabilities

An additional benefit of remotely collecting bathymetric data is the ability to collect data in shallow and environmentally sensitive waters that are typically unaccessible using conventional survey techniques. Additionally, environmentally sensitive areas, like those with sea grass beds, may restrict boat usage, making data collection with conventional techniques impossible. SHOALS is capable of collecting high-resolution shallow-water bathymetry without disturbing the environment. In 1994 and in 1997, SHOALS performed surveys in the shallow areas of Florida Bay (Parson et al. 1996). Florida Bay is the focus of an inter-agency program involving a modeling effort to define internal water circulation exchanges with surrounding waters. Models such as these require detailed resolution of the Bay's morphologic features which are characterized by extensive shallow-water networks of mud banks, cuts, and basins. Prior to the SHOALS mission, this shallow-water depth information did not exist. The area surveyed exhibited numerous channel cuts transecting shallow mudbanks that are believed to influence water flow between the Atlantic Ocean and Florida Bay. These channels range from 0.5 to 3 m deep. SHOALS surveyed the 6-km^2 area in a few hours. The survey data clearly revealed these channel features and quantified their dimensions for use in the modeling effort.

Confined Disposal Facilities

Disposal sites consist of both upland (confined) sites and subaqueous (open-water) sites. To obtain maximum long-term usage of a site, an accurate account must be obtained of the changes in storage capacity resulting from gains or losses and consolidation of disposed dredged material (Poindexter-Rollings 1990). Comprehensive surveys of confined upland disposal facilities are not easily obtained using conventional topographic surveying methods. With the ability of SHOALS to collect high-resolution topographic survey data over large areas, confined dredged disposal facilities can be easily monitored. Near Mobile, Alabama, a survey was performed exclusively as a topographic survey and was collected using KGPS positioning. In this case, the disposal dike surrounded the containment area and detailed interior features were formed by spur dikes and cross dikes. Structures were placed within the interior containment area to increase the water retention time, allowing for maximum settling of sediment from the dredged material. The high resolution of this survey allowed for accurate volume calculations when compared to subsequent lidar surveys.

SUMMARY

SHOALS is a fully operational bathymetric survey system capable of surveying a variety of project types. When deployed to a region, a typical survey mission is completed at two-thirds the cost of conventional technology or less. SHOALS operates from the newly formed Airborne Lidar Bathymetry Technical Center of Expertise (ALBTCX), which is headquartered at the Mobile District. ALBTCX's mission is to operate the SHOALS system and to develop new products and applications. Future goals for the SHOALS program include expansion of mapping and charting capabilities through software enhancements, and the fusion of lidar bathymetry with additional auxiliary sensors such as a hyper-spectral imaging system.

ADDITIONAL INFORMATION

For further information pertaining to SHOALS operations and capabilities, contact Jeff Lillycrop at the Airborne Lidar Bathymetry Technical Center of Expertise (ALBTCX) at (251) 694-3721, Jeff.Lillycrop@sam.usace.army.mil or Larry E. Parson at (251 690-3139, Larry.E.Parson@sam.usace.army.mil.

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