DRP-1-05
April 1992

Dredging Research Technical Notes

Acoustic Resuspension Measurement System (ARMS): Announcement of Availability

Purpose

This technical note describes the Acoustic Resuspension Measurement System (ARMS) and how it can be used to measure sediment resuspension and movement in the water column at existing and proposed dredged material placement sites. This announcement describes the ARMS capabilities presently available through the Dredging Research Program (DRP).

Background

Until recently, technology was not sufficient to obtain in situ measurements of sediment entrainment and bottom response (erosion or accretion) at dredged material placement sites. Advances in the field of high-frequency acoustics have made available an assortment of instruments using sound frequencies that allow direct observation of fluid and sediment motion to within 0.1 cm/sec. Parallel advances in high-speed, low-power integrated electronics enable these instruments and their controlling circuitry to be combined in compact, battery-powered packages. These instrument packages can be contained in relatively small pressure housings and mounted unobtrusively on a bottom-standing tripod. The resulting portable instrument/electronics system can be deployed from many dredging-related or Corps survey vessels to collect field data that will characterize fluid motion and sediment transport properties for site designation and monitoring. Such data also may be used to verify environmental numerical simulation models.

Additional Information

The ARMS is presently operated as part of research and development activities of Technical Area 1 of the DRP. In the future, the ARMS will be available under a Task Order delivery contract with Ohio State University, Coastal Engineering Laboratory (CEL), Dr. Keith W. Bedford, Director. For further information, call Dr. Nicholas C. Kraus, (601) 634-2018, or the DRP manager, Mr. E. Clark McNair, Jr., (601) 634-2070. This Technical Note was prepared by Mr. Robert E. Van Evra III (CEL) and Dr. Bedford, with the assistance of Dr. Kraus and Mses. Terri L. Prickett and Michelle M. Thevenot.

Introduction

In order to measure in situ properties of the boundary layer above dredged material mounds in open-water disposal areas, an optimally arranged ensemble of specialized underwater instruments must be used. The instruments must be carefully mounted into specific positions on a rugged yet portable frame and interrogated at sampling rates high enough to allow observation of short-term as well as long-term physical processes. The instrument array can be deployed at field sites to acquire data necessary to facilitate analysis of the movement or potential movement of dredged material placed at the sites.

The ARMS is an integrated ensemble of specialized underwater sensors designed to accurately measure in situ properties of the bottom boundary layer in open-water areas. The seven instruments that comprise the ARMS are an acoustic sediment concentration profilometer, four acoustic velocity sensors, a pressure gage, a thermistor, a transmissometer, a multifrequency sediment particle sizer, and an optional video camera, as illustrated in Figure 1. This system was designed and constructed by the Coastal Engineering Laboratory at Ohio State University under contract with the DRP Technical Area 1 work unit Measurement of Entrainment and Transport (Noncohesive Sediments). The ARMS has been verified as a practical engineering tool in the laboratory. It also was successfully deployed in the field during the Mobile, Alabama, Field Data Collection Project (Bedford and others 1991). Ongoing data

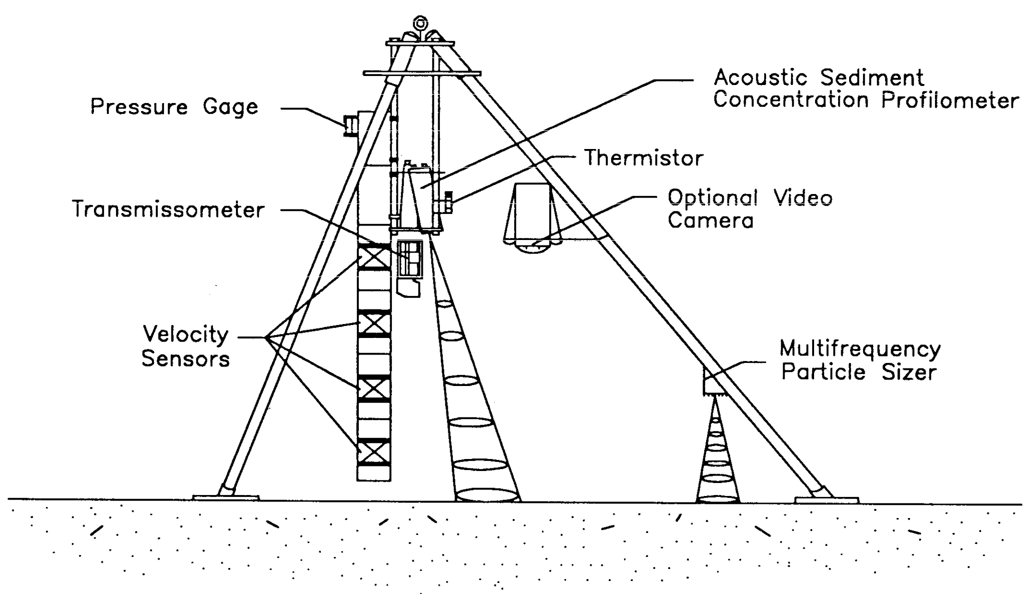

Figure 1. The ARMS instrument ensemble and tripod

collection with ARMS will characterize dredged material placement sites and provide data for developing and validating numerical sediment transport simulation models.

Instrumentation

Acoustic Sediment Concentration Profilometer

The central instrument in the ARMS ensemble is an Edo-Western Model 563 3-MHz acoustic transceiver, referred to as a profilometer. Created originally as a high-accuracy depth indicator, the electronics of the self-contained device were modified to increase its sensitivity near the face of the transducer. This increased sensitivity allows the profilometer to detect minute-intensity sound reflections from individual sediment particles that can be interpreted as sediment concentration by use of the methodology presented by Libicki, Bedford, and Lynch (1989). The transducer was custom-built for the ARMS in a diamond shape that narrows the transmitted 3-MHz beam to 0.3 deg. The side lobes near the sensor were thereby decreased in size, reducing spurious reflective signals. The profilometer operates by first transmitting a finite-length pulse of 3-MHz sound, called a ping, and immediately switches into a receive mode, sequentially reading the intensity of sound reflected from any suspended particles located along the ensonified beam. By collecting data returns in short time windows, the relative sediment concentration in each of the corresponding depth intervals or bins along the beam path can be measured.

Velocity Sensors

A Benthic Acoustic Stress Sensor (BASS) measures the 3-dimensional (3-D) water velocities rapidly and accurately. The BASS detects the time of travel of high-frequency sound to determine the water velocity producing variations along the direction of travel between pairs of small transducers. Each BASS sensor is a cylindrical cage of stainless steel that holds eight 1.75-MHz transducers (four in an upper ring and four in a lower ring). The sensors are evenly spaced around the rings and are tilted at 45 deg. Each sensor is aimed through the center of the cage toward an opposite sensor on the opposing ring. In operation, the four transducers in the upper ring are pinged, and their signals are received by the corresponding transducers on the lower ring. The lower-ring transducers then are pinged to be received by the upper transducers. The travel times for each pair of sensors are calculated (to cancel electronic drift), and the velocity along the path results. By using trigonometric relationships between the four mutually orthogonal velocity vectors, three velocity components of water motion are obtained. Measurements are taken several times per second to a resolution of approximately 0.03 cm/sec. With four BASS cages, the ARMS can make as many as 20 3-D velocity measurements each second.

Pressure Gage

To correlate surface wave and tidal activity with measurements being taken on the bottom, a sensitive pressure transducer records the hydraulic pressure time history. A Wika Model ST-420 pressure sensor, which has a linearity of 0.05 percent of full scale and a water surface resolution of approximately 1 cm (in shallow water), is used.

Thermistor

A Yellow Springs, Inc., 44018 linearized thermistor takes measurements of ambient water temperature. This instrument has 0.1 °C accuracy.

Transmissometer

The transmissometer measures the total suspended mass concentration at a fixed point in the water column. The ARMS uses a Sea Tech, Inc. transmissometer with a 5-cm path length and wavelength of 660 nm.

Sediment Particle Sizer

A multifrequency device under development at the CEL will yield the necessary particle size information to convert the profilometer returns into concentration data without in situ water sampling. Information obtained from the acoustic sediment concentration profilometer and knowledge of the suspended particle size allow calculation of absolute sediment concentration in each range bin, yielding a sediment concentration profile for each transmitted ping from the profilometer.

Optional Video Camera

The optional video camera records the bottom floor roughness, for example, as a smooth or rippled bottom. This measurement aids in interpreting sediment transport processes. A drop video camera can be used to make periodic checks of the system during the deployment, and to inspect for damage, new obstructions, evolving bottom ripple formations, and biofouling. Even though the ARMS instruments are able to measure changes in orientation and settling into the bottom, the camera can record changes at the base of each leg of the tripod, as well as in the center of the array, for visual corroboration of the bottom transport events. In deep water or in situations where use of a drop video camera proves difficult, a remotely operated vehicle equipped with video provides the same functions. For deployments where neither are available, a passive underwater still camera mounted on the tripod could provide a visual record.

Controller Circuitry

The central processing core of the system performs all of the onboard timing, communications, and data manipulation functions necessary to process the desired information. The CEL custom-built microcontroller is a highly efficient unit with sufficient ports and timers to handle all tasks.

The central processing unit (CPU) can be programmed for many different sampling routines to conserve battery power. Direct hookup to a PC-compatible device allows the user to check all instruments and other hardware and software before deployment. The programs are written in a compartmented fashion, commanding the power controller board to turn on instruments only when needed. In the overall scheme, the microcontroller's capability to shut down almost completely while retaining only clock function allows the ARMS to perform multiple interrupted sampling schemes in which all instruments and electronics shut down completely while the system waits to begin another sampling run. These power-down periods may be pre-arranged to allow longer deployments, or conditionally inserted during periods when the physical activity (for example, wave height) at the site has dropped below a pre-determined threshold level. The deployments can last from 24 hr for constant data collection to 3 months for intermittent usage. The CPU also has the capability to perform an "enroute" error checking of the instruments, shutting individual areas down for the preservation of data from other probes, if a problem cannot be corrected, and to limit damage to the whole system from a failed device, board, or chip. The instruments of the ARMS are mounted into specific positions on a rugged yet portable tripod and interrogated at sampling rates high enough to allow the observation of short-term as well as long-term phenomena.

Data from the instruments are processed onboard the CPU circuitry. The resulting complete data sets are sent via serial line to a streaming tape drive for mass storage. This tape drive is housed in a separate pressure case with its own battery supply so that its relatively noisy operation does not interfere with other devices. The tape drive uses standard DC-600A computer tapes that hold 60 megabytes of data. The tape drive lies dormant except for the 128-kilobyte memory buffer, which constantly accepts data while the ARMS is operating. When the buffer is full, the drive turns itself on and dumps the contents of the buffer onto tape in approximately 5 sec and then shuts itself off.

Deployment

The inherent stability of the tripod makes lowering the ARMS a straightforward procedure. The ARMS can be deployed at sites up to 100 ft in depth. It is optimal to place the tripod on a flat bottom that is clear of large debris, not only because the BASS cage protrudes down through the middle of the space under the tripod, but also because measurements in nonobstructed conditions are preferred. To guarantee this, if divers are not available to check before- and after-placement, inspection of the bottom with a drop video camera run from the surface is required. Small amounts of inclination can be accounted for, however. Tilt is measured using a Lucas-Shaevitz AccuStar II dual axis inclinometer, and the orientation of the tripod is indicated by an Aanderaa Instruments Model 1248 potentiometric compass mounted in the tripod's horizontal plane.

The profilometer is mounted in a nearly vertical orientation and aimed at the sea floor, with the sensor located about 1.5 m above the bottom. Each sediment concentration profile includes a strong return from the bottom. The bottom spike in the profile provides an ideal positional reference as well as a check for diminished transmitted intensity produced by large objects, such as fish, entering the beam path. To obtain statistically correct sediment concentration data, the profilometer is pinged 32 times per second, and the average of the 32 profiles is calculated and retained. The resulting 1-sec averaged values provide an accurate record of changes in the suspended sediment concentration profile over time.

A standard practice when deploying the ARMS is to ring the study area with a group of no less than four guard buoys. The guard buoys do not guarantee protection, but are intended to discourage boaters from running directly over the tripod, possibly dragging lines or nets into it, or even picking it up with heavy tackle. The guard buoys are placed around the site as tightly as possible, yet spread out enough so that the lines and anchors do not interfere with water flow moving at the study site. The buoys also mark the location of the tripod. A buoy hooked directly to the tower can cause undesirable tugging in rough seas, or may allow curious fishermen to easily find and remove the tripod.

To decrease susceptibility to damage, the pressure canisters holding the ARMS electronics and the streaming tape drive are mounted on the undersides of the upper portion of the legs, with the underwater cables contained beneath the metal structure at the top of the tripod. The canisters are distant from the flow field area being measured and are arranged to provide as much protection as possible from collision or snagging. This arrangement also protects the canisters during deployment and recovery operations, in case the tripod grazes the ship's hull. The canisters are also protected if the tripod needs to be laid on its side once on deck, if there is insufficient room to stand the tripod upright.

Information Provided

Information to quantitatively characterize fluid and sediment transport processes at deployment sites may be provided in three levels. Each succeeding level is more costly due to the increased complexity and detail of analysis.

Level 1

The first level consists of information that can be obtained directly from the sensor equipment. This includes sediment concentration profiles, grain size distribution, temperature, wave conditions, and horizontal and vertical water particle velocities. The ARMS deployment, along with this level of data analysis, can be obtained for less than $50,000 in most applications. This cost includes equipment and personnel mobilization, deployment, demobilization, and data analysis. Figure 2 shows an example of such output. The left side of the figure illustrates large suspended sediment concentrations at a sandy shallow-water (14-ft) site; after 42 hr, when the sea became calm, very little sediment was suspended. This figure also describes the onshore current, longshore current, water surface elevation, kinetic energy, and total suspended mass during this observation.

Level 2

Level 2 includes information derived from the directly obtained data. Sediment flux (magnitude and direction of sediment motion), including whether the transport process is dominated by horizontal advective flux or by vertical resuspension flux (entrainment), is one of the principal quantities that can be obtained.

Level 3

Level 3 is the most complex of the data reduction efforts. It includes determining the best numerical model to predict the sediment movement in the area. The level 2 information is inserted into the model to obtain the long-term fate of the dredged material deposited at the site (or the potential for such material to be entrained and moved at a new placement site). This level could also include developing a new model if an existing one is not a sufficient predictor of the sediment suspension caused by the local environmental conditions.

Summary

The self-contained, highly accurate instruments comprising the ARMS tripod make this system a valuable and reliable tool in the acquisition of field boundary layer data for dredged material site designation and monitoring. The ARMS has been tested in open water and is available for use by Corps field offices.

References

Bedford, K. W., Wai, O., Velissariou, R., Van Evra, R. and Lee, J. 1991. "Fine Material Entrainment and Flux at a Shallow-Water Dredged Mound," *Proceedings, Marine Technology Society Conference*, Vol 1, pp 260-264.

Libicki C. M., Bedford, K. W., and Lynch, J. L. 1989. "The Interpretation and Evaluation of a 3-MHz Acoustic Backscatter Device for Measuring Benthic Boundary Layer Sediment Dynamics," *Journal of the Acoustical Society of America*, Vol 85, No. 4, pp 1501-1511.

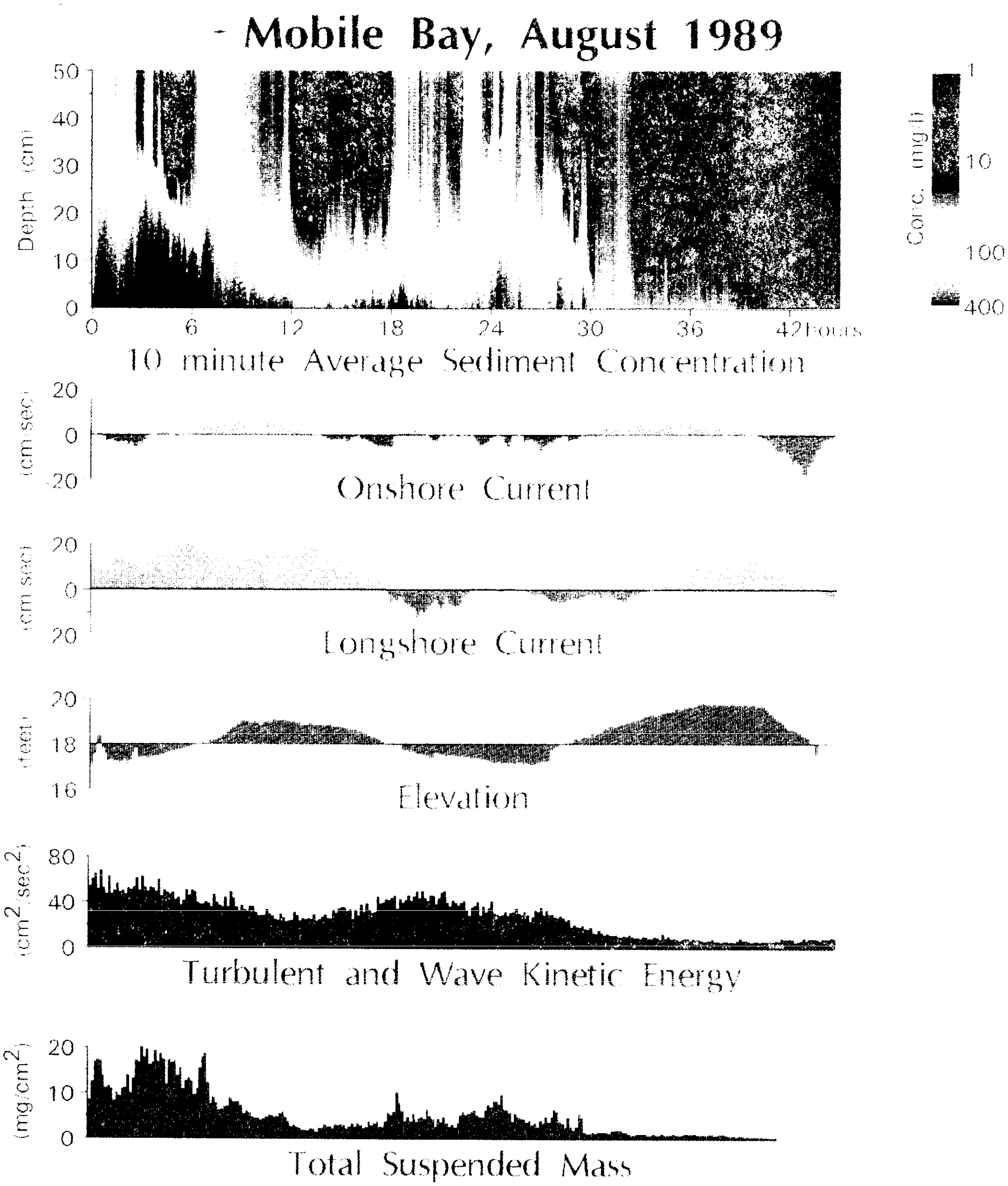

Figure 2. Example of level 1 output from the ARMS