ERDC/CHL CHETN-I-88
April 2016

US Army Corps of Engineers®

Capabilities of the Large-Scale Sediment Transport Facility

by Ernest R. Smith, Duncan B. Bryant, and Anthony M. Priestas

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes the Large-Scale Sediment Transport Facility (LSTF) and recent upgrades to the measurement systems. The purpose of these upgrades was to increase instrument reliability and accuracy while reducing maintenance and to expand facility capabilities for cohesive sediment erosion and transport experiments in wave/current environments.

INTRODUCTION: The LSTF (Figure 1) is a large-scale laboratory facility capable of simulating conditions comparable to low-wave energy coasts. The facility was constructed to address deficiencies in existing methods for calculating longshore sediment transport. The LSTF consists of a 30 m wide, 50 m long, 1.4 m deep basin. Waves are generated by four digitally controlled wave makers capable of producing a maximum height of 0.5 m. The generators are positioned at a 10 degree angle to shore normal and are synchronized to create a unidirectional, long-crested wave. Twenty variable speed pumps are used to minimize the boundary effects of a finite-length beach by supplementing the wave-driven currents. A 21 m long instrumentation bridge spans the entire beach and serves as a rigid mount for instruments and as an observation platform. The computer-controlled bridge can be positioned at any location along the shore. Historically, the basin has included a 27 m (alongshore) by 18 m (cross-shore) sand beach. The sand beach consists of 150 m^3 of fine quartz sand having a mean diameter, d_{50}, of 0.15 mm. Twenty sand traps at the downstream boundary of the model are instrumented with load cells to weigh trapped sand and are used to measure total cross-shore distribution of the total longshore sand transport rate generated under obliquely incident waves. The LSTF instrumentation includes acoustic Doppler velocimeters (ADVs), wave gauges, pump flow meters, sediment trap weigh tanks, and beach profiling lidar. A detailed discussion of the original LSTF features and capabilities can be found in Hamilton et al. (2001).

FACILITY PROJECTS: A variety of littoral studies have been performed in the LSTF with diverse partners. A list of projects performed in the LSTF is given in Table 1 and includes projects such as nearshore hydrodynamic, longshore sediment transport, cross-shore suspended sediment transport, inner surf zone and swash zone, nearshore placed mounds, shoreline change due to structures, notched groins, and morphological change due to submerged geotextiles. The following paragraphs briefly discuss the research performed in the LSTF.

Johnson (2003) developed NEARshore HYDrodynamics, Steady model (NEARHYDS) from two movable-bed tests performed in the LSTF. The NEARHYDS model is a physics-based, two-dimensional (2D) model that efficiently predicts wave height, setup, bed ripple formation, boundary layer thickness, and depth-dependent steady cross-shore and longshore currents.

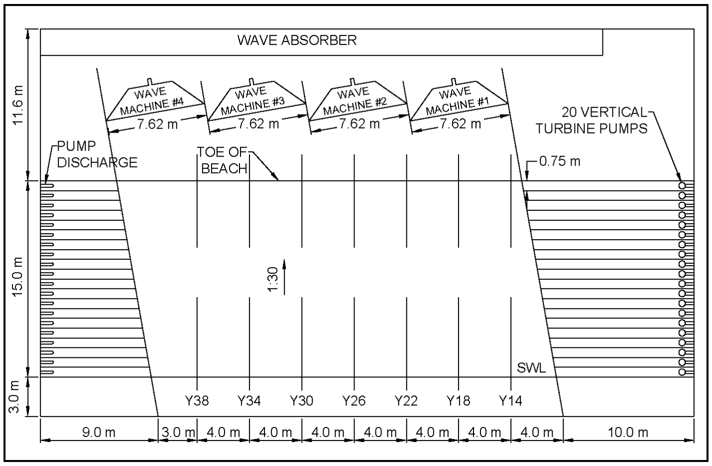

Figure 1. The Large-Scale Sediment Transport Facility (LSTF).

Table 1. Examples of research performed in the LSTF.	
Topic	**Reference**
Nearshore Hydrodynamics	Johnson (2003)
Nearshore Hydrodynamics Sediment Transport	Qin et al. (2002)
Nearshore Hydrodynamics Sediment Transport	Tajima and Madsen (2005)
Swash and Inner Surf Zone Hydrodynamics	Puleo et al. (2002)
Longshore Sediment Transport	Smith (2006)
Notched Groins	Wang and Kraus (2004)
Headland Structures	Gravens and Wang (2007)
Nearshore Placed Mounds	Smith and Gailani (2005)
Nearshore Placed Mounds	Smith et al. (2015)

The University of Delaware applied fixed- and movable-bed LSTF data in the development of SHORECIRC (SC), a nearshore sediment transport model and a kinematics wave model (Qin et al. 2002). SHORECIRC (SC) predicts nearshore hydrodynamics, cross-shore and longshore sediment transport and beach evolution and compared well to LSTF measurements. The LSTF data also were used by Tajima and Madsen (2005) to validate an efficient and flexible theoretical model to predict nearshore hydrodynamic characteristics and the local sediment transport rate on long, straight beaches. The Tajima and Madsen model, formulated at the Massachusetts Institute of Technology, allows for periodic or random waves, plane or barred beaches, and fixed or movable sand beds.

The Naval Research Laboratory utilized the LSTF to collect swash and inner surf zone data for validation of two surf and swash zone hydrodynamic numerical models, RBREAK2, a one-dimensional model, and RIPPLE, a 2D model (Puleo et al. 2002). In addition to the LSTF instruments, Puleo et al. installed three additional ADVs in the inner surf and swash zone to record water surface elevations and wave orbital velocities.

Smith (2006) developed an equation to predict the bulk and cross-shore distribution longshore transport rates from experiments in the LSTF. The equation is based on time-dependent shear stress calculated from the total velocity, including the wave orbital velocity. The equation compared well to measured transport rates in the field.

Wang and Kraus (2004) installed a notched groin in the LSTF and performed experiments to examine the processes and responses of longshore transport through the structure. Wang and Kraus determined that a notch located in the swash zone produced the greatest direct benefit to the subaerial beach and was considered the most efficient.

Enhancements to the GENESIS (Hanson et al. 2006) shoreline change model have been implemented from experiments conducted in the LSTF (Gravens and Wang 2007). Incorporation of notched groins, detached breakwaters (Figure 2), and T-head breakwaters into GENESIS resulted from experiments in the facility.

Figure 2. Experiments showing a tombolo forming leeward of a detached breakwater.

Experiments examining the fate of nearshore placed dredged material were performed by Smith and Gailani (2005) for a mound placed in the outer surf zone. Displacement of the mound was downdrift and onshore. Later, Smith et al. (2015) conducted experiments on three nearshore mounds placed in the inner surf zone. The study showed that nearshore placed material remained in the surf zone and moved onshore and downdrift of the original placement site (Figure 3).

With improvements in instrumentation being made over the past decade, changes have been made to keep the facility up-to-date. Major upgrades have been made to the wave gauges and pump flow meters with improved ADVs also being added. The following section will detail these improvements and their advantages.

Figure 3. Beneficial use of nearshore placed dredged material (in red) experiments.

INSTRUMENTATION

Wave Gauges. The previous wave gauges at CHL were a collection of capacitance sensors developed and built at the Engineer Research and Development Center from the 1990s to 2000s. These capacitance gauges were much more reliable and stable than the previous resistance gauges used. However, the previous capacitance gauges had reached the end of their life cycle and required extensive effort to maintain and repair. After carefully examining the instrument market, it was concluded that advancements in electronics and decreases in cost made it economically advantageous to buy new capacitance wave gauges. The Akamina AWP-24-3 wave gauge is a capacitance-type sensor which measures the change in capacitance as a function of water level. These gauges were selected to replace the previous Waterways Experimental Station gauges due to their increased temperature compensation, reliability, and reduced maintenance cost. The capacitance is measured digitally and converted to an analog voltage output (±5 V), which is linearly proportional to the water level. The sensor unit has no moving parts and consists of few components—electronics enclosure, BNC cable, probe head (consisting of mounting clamp, support rod, and sensing wire) and instrument cable (Figure 4; instrument cable not shown). While the sensor can be deployed in the field or laboratory, its small dimensions and high precision make the Akamina wave gauge ideal for laboratory use in wave flumes and physical models. The Akamina wave gauge can measure water levels and both uni- and multidirectional waves. Probe heads are available in standard sizes (30 cm, 60 cm, 100 cm, 150 cm, and 200 cm) or custom sizes. Probe head sizes correspond to the maximum range of water level that can be measured, as the sensing wire is actually slightly longer. The output voltage is a function of water depth and is exceptionally linear. Published data from the manufacturer indicates that the maximum errors of 10 calibrated instruments are on the order of 0.12% of range for 1 m probes and 0.28% of range for 20 cm probes (1.2 mm and 0.55 mm, respectively). There were only minor changes in output voltage within a 9 ^{0}C (48 ^{0}F) temperature change and exhibited little short-term drift ±0.04% of range over a 1 hr period. Long-term (72 hr) drift tests revealed water elevation changes of ±0.25 mm which was correlated to a temperature changes between 16 and 24 ^{o}C. Manufacturer tests also indicated that background noise slightly increased with increasing cable length; however, for a 60 m instrument cable, the noise range represented only 0.08% of the output range.

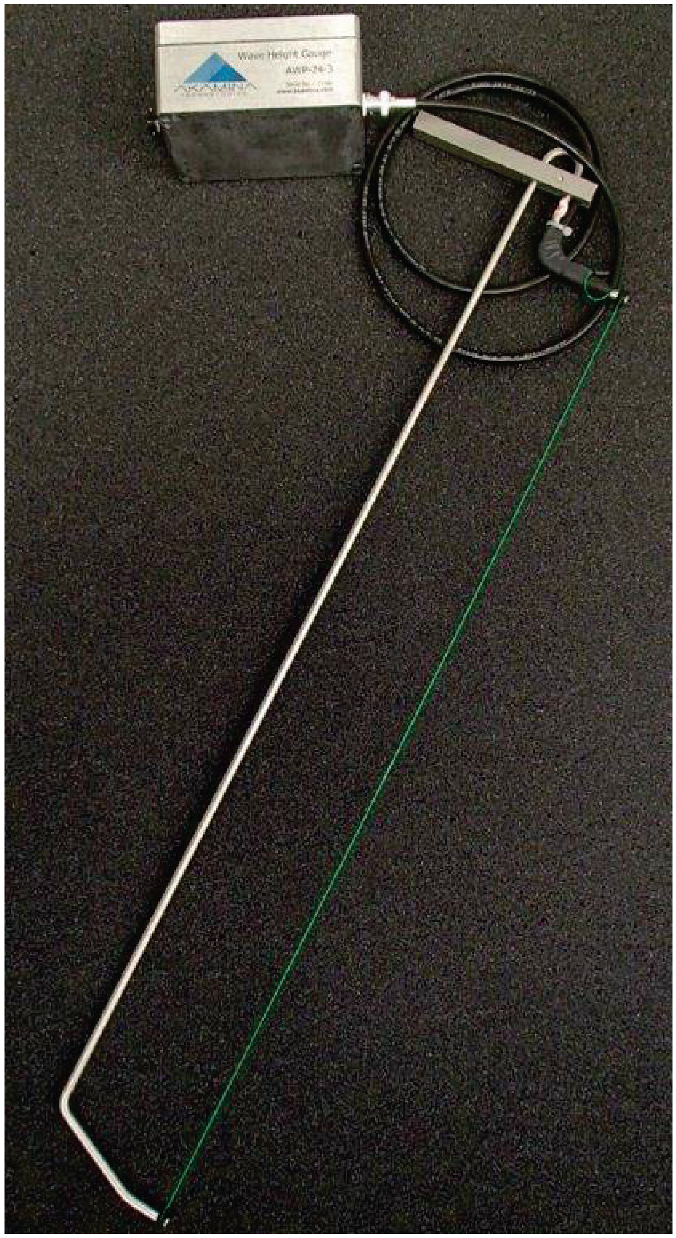

Figure 4. Components of the Akamina capacitance wave gauge.

Flow Meters. The LSTF previously used a series of paddle wheels to measure the flow rates from each of the 20 pumps used to match the wave-driven currents in the flume. Paddle wheel flowmeters have a limited operational flow rate. The limited range resulted in the LSTF facility requiring two paddle wheel flowmeters for each pump, one for low flow and one for high flow. A series of valves allowed the user to select the low-flow or high-flow paddle wheel. This instrument configuration resulted in a number of issues. First, paddle wheel flowmeters have a tendency to jam if sediment, especially sand, is flowing in the fluid. Due to the piping configuration, the ability to clean the paddle wheels or change the piping from the low-flow to high-flow settings was difficult and inefficient.

The decision was made to replace the flow measurement system to reduce maintenance and improve efficiency. Twenty EESIFLOW Sonalok 7SZ nonintrusive ultrasonic flow meters are used to measure the flow rate of each pump. These gauges offer a greater range, eliminate the chance of becoming clogged with sediment, and are easy to service and replace. The ultrasonic sensors clamp onto the pipe and are fully functional on PVC, steel, stainless steel, or iron pipes. Figure 5 shows a diagram of ultrasonic flowmeters. A transmitter and receiver are mounted on the outside of the pipe, in the direction of flow. The transmitter produces a high-frequency sonic pulse that is projected across the pipe wall into the liquid. The sound travels across the liquid and then reflects off the opposite side of the pipe before returning to a receiver downstream outside of the pipe. The LSTF flowmeters are set up for the sonic pulse to pass through the pipe four times as shown in Figure 5, before being received by the receiver. Using the time it takes for the sound to travel with the flow to the receivers, the average velocity in the pipe is calculated.

The flowmeters measure velocities between 0.01 to 25 m/s with a resolution of 0.025 cm/s and a repeatability of 0.15% of the measured value. The response time of the flowmeters is 1 s. The flowmeters come with a wall-mounted display but also have an analog output of 4 to 20 mA for the full range. Additionally, the flow meter can communicate its data serially by the RS485 protocol. The operating temperature range of the unit is –30 to 80 °C.

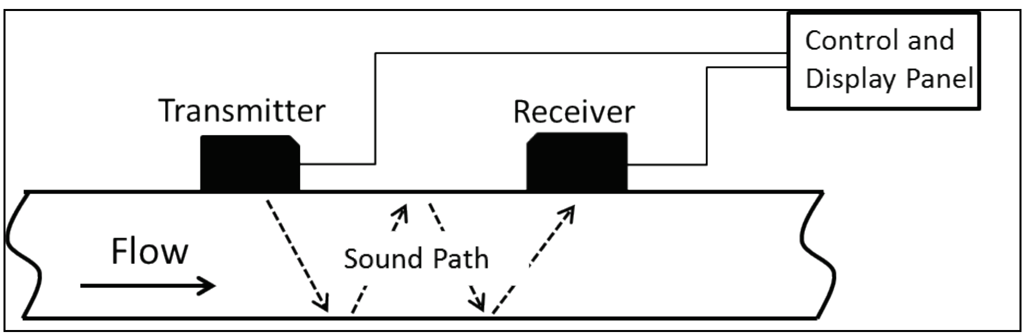

Figure 5. Diagram of ultrasonic flowmeter operation for measuring flowrate.

Data Acquisition System. The new wave gauges and flow meters are integrated into a new data acquisition system via a National Instruments Labview program. The physical components of this system communicate with the host computer via a gigabit local area network. The wave gauge signals are directed into a cDAQ-9184 CompactDAQ Chassis via a 16-channel NI 9220. The four offshore wave gauge signals are broadcasted wirelessly via a National Instrument 9201 paired with a cDAQ-9191. A wireless router then moves this data onto the local area network. A Cisco SG 200 switch is used to manage the local area network. The Nortek ADVs are not integrated directly into the LabVIEW program but still transmit data to the Nortek Polysync program via the local area network. A Comtrol Device Master 16-Port is used to link the ADVs into the network. The ADVs data acquisition does commence with the other instruments via a sync signal and sync configuration. The combination of ADVs and Wave Gauges use 1.5% of the Gigabit network, allowing for expansion to support future instrumentation.

EXPANDED SEDIMENT CAPABILITY: In addition to new instrumentation, the LSTF now includes a sediment pit for studying the erosion and hydrodynamics of waves and currents over mixed sediments. The pit is 3 m by 3 m and 30 cm deep. Monitoring of the sediment surface can be done by ADVs, profiling ADVs, surveying, or lidar. The pit can accommodate engineered sediment mixtures or naturally occurring mixtures. When not in use, the pit can be covered, allowing the facility to retain all of its other function and features associated with sand transport or nearshore structures. The addition of the mixed sediment pit greatly expands the facility's ability to study mixed sediment transport processes.

CONCLUSIONS: The recent modernization of the LSTF instruments allows for continued focus on sediment transport in the littoral zone, including cohesive sediment erosion and transport experiments in wave/current environments. The updated instruments are expected to have a life span of 15 to 20 years with minimal maintenance. The Labview program will need to be updated on a yearly to bi-yearly basis to ensure compatibility with newer operating systems and the addition of future instrumentation. Upcoming studies in the facility will focus on nearshore berms, wave-current boundary layers, and flow over visco-plastic sediment beds. The LSTF will continue to serve as a state-of-the-art testing facility for the Coastal and Hydraulic Laboratory for years to come.

ADDITIONAL INFORMATION: This CHETN was prepared as part of the Sediment Management Marketing and Business Development Plan and was written by Ernest R. Smith (*Ernest.R.Smith@usace.army.mil*), Duncan B. Bryant (*Duncan.Bryant@usace.army.mil*), and Anthony M. Priestas (*Anthony.M.Priestas@usace.army.mil*) of the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). This CHETN should be cited as follows:

> Smith, E. R., D. B. Bryant, and A. M. Priestas. 2016. *Capabilities of the large-scale sediment transport facility*. ERDC/CHL CHETN-I-88. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://chl.erdc.usace.army.mil/chetn.

REFERENCES

Gravens, M. B., and P. Wang. 2007. *Data report: Laboratory testing of longshore sand transport by waves and currents; Morphology change behind headland structures*. ERDC/CHL TR-07-8. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Hamilton, D. G., B. A. Ebersole, E. R. Smith, and P. Wang. 2001. *Development of a large-scale laboratory facility for sediment transport research*. ERDC/CHL TR-01-22. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Hanson, H., M. Larson, N. C. Kraus, and M. B. Gravens 2006. Shoreline response to detached breakwaters and tidal current: Comparison of numerical and physical models. In *Proceedings of the 30th International Conference on Coastal Engineering*, ASCE, 3630–3642.

Johnson, B. D. 2003. *Model for the computation of time-steady nearshore currents.* ERDC/CHL CHETN-VI-39. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Puleo, J. A., T. K. Holland, D. N. Slinn, E. Smith, and B. M. Webb. 2002. Numerical modeling of swash zone hydrodynamics. In *Proceedings of the 28th International Conference on Coastal Engineering,* 968–979.

Qin, W., I. A. Svendsen, B. A. Ebersole, and E. R. Smith. 2002. Modeling sediment transport at the LSTF at CHL. In *Proceedings of the 28th International Conference on Coastal Engineering*, 3020–3032.

Smith, E. R. 2006. *Longshore sediment transport rate calculated incorporating wave orbital velocity fluctuations*. ERDC/CHL TR-06-18. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Smith, E. R., and J. Z. Gailani. 2005. *Nearshore placed mound physical model experiment.* ERDC TN-DOER-D3. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Smith, E. R., R. L. Permenter, M. C. Mohr, and S. A. Chader. 2015. *Modeling of nearshore placed dredged material*. ERDC/CHL TR-15-9. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Tajima, Y., and O. S. Madsen. 2005. *Waves, currents, and sediment transport in the surf zone along long, straight beaches*. ERDC/CHL CR-05-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Wang, P., and N. C. Kraus. 2004. Movable-bed model investigation of groin notching. *Journal of Coastal Research* 33:342–367.