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# The CERCular

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# CORE-LOC™ Concrete Armor Units



*by*
*Jeffrey A. Melby and George F. Turk*

## Introduction

Concrete armor units are increasingly being used to protect coastal structures for several reasons. First, quality stone sources are becoming scarce and environmental restrictions are allowing fewer new quarries to be opened. Second, more structures are being built in harsh wave environments where stone armor is simply not effective. This movement toward previously underdeveloped high wave energy areas is, at least partially, due to increased confidence in rubble-mound structure designs. And this confidence is due to decades of experience and the resulting increased knowledge of structure design and construction. Improvement in local incident wave energy measurement and prediction also has helped. Finally, concrete armor performance is becoming more predictable as we learn in detail how armor layers respond both hydraulically and structurally. The above developments have led to more efficient concrete armor shapes and, in turn, better performance from concrete armor layers.

On the Corps' 19 concrete-armored structures, tribar and dolos have been used most commonly (Figure 1) with tetrapods, quadripods, and blocks used to a lesser extent. Recent prototype, laboratory, and numerical structural and hydraulic stability investigations of dolos and tribar units have shown several weaknesses in the basic armor shapes (Melby and Turk 1994a). The large massive outer members and relatively long legs produce high moments in the slender central sections where the section modulus is not sufficient to resist the moments. Also, Melby and Turk (1994b) have shown that rocking stresses in these units are extraordinarily high and reinforcing for the associated high impact loads is not economically feasible. For conservative "no-rocking" designs, 1 to 2 percent of the dolos and tribar units will be rocking and, it can therefore be assumed, will break. More units will loosen and break over time and many armor layers will experience wave conditions

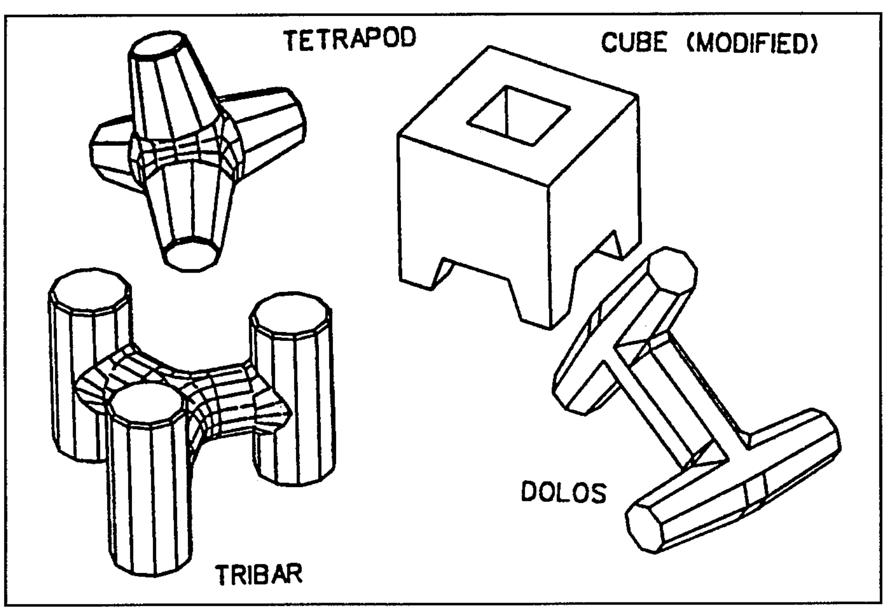


*Figure 1. Concrete armor units used by the Corps*

that exceed the design event, resulting in further breakage. Therefore, even conservative designs tend to show continuous armor breakage over the structure life. For less conservative designs, where significant rocking is allowed, armor breakage can be pervasive. Field surveys of existing Corps concrete armor layers to assess both armor hydraulic and structural performance have confirmed these conclusions (Melby and Turk 1994a). Although the slender legs of tribar and dolos units enhance hydraulic stability, they also promote breakage. The pieces have little stability and may contribute to the breaking of adjacent units. Tetrapods exhibit lower stability than dolosse. Their legs extend a shorter distance from the centroid so interlocking is less and their rounded sections promote rocking on slope and, when destabilized, rolling. Block shapes do not have shape interlocking or high porosity and therefore require far more concrete than slender shapes.

Historical research has been conducted at the U.S. Army Engineer Waterways Experiment Station concerning hydraulic and structural stability of dolosse and tribars. Recent research within the Coastal Engineering Research Center's Coastal R&D Program Work Unit *Concrete Armor Unit Design* has focussed on improving design methods for concrete armor units and improving concrete armor performance through shape modification. One of the goals of this research is to develop optimal concrete armor unit shapes that can be used for both new construction and repair of existing rubble structures. This development requires incorporating all engineering features from various existing armor shapes into a single unit while eliminating major weaknesses. Melby and Turk (1995a) summarized optimal armor engineering characteristics as follows:

- High hydraulic stability when placed in a single-unit-thickness layer.
- Reserve stability for wave conditions that exceed the design event.
- Little to no on-slope rocking.
- Continued stability even when broken or following renesting resulting from local instability.
- Efficient combination of porosity and slope roughness to dissipate the maximum wave energy with a minimum concrete armor layer volume.
- Hydraulically stable when placed as a repair with other shapes.
- Low internal stresses, so no required steel reinforcement.
- Easy to cast.
- Easily constructed armor layer even in low visibility water.
- Minimal casting yard or barge space required.
- Conventional construction materials and techniques utilized.

# CORE-LOC

A new series of concrete armor units called CORE-LOC™ (hereafter referred to as core-loc) which represents an attempt to incorporate the aforementioned optimal features, has been developed within the Concrete Armor Unit Design Work Unit (Figure 2) (Melby and Turk 1993, 1995a, 1995b). The core-loc units have been designed to be placed in a single-unit-thickness layer. The core-loc shape has been optimized to provide maximum hydraulic stability, unreinforced strength, and reserve stability. The primary intent of this shape optimization is to have a very stable armor layer, with good wave energy dissipation characteristics, and yet have stresses low enough that normal strength unreinforced concrete can be used with little or no armor

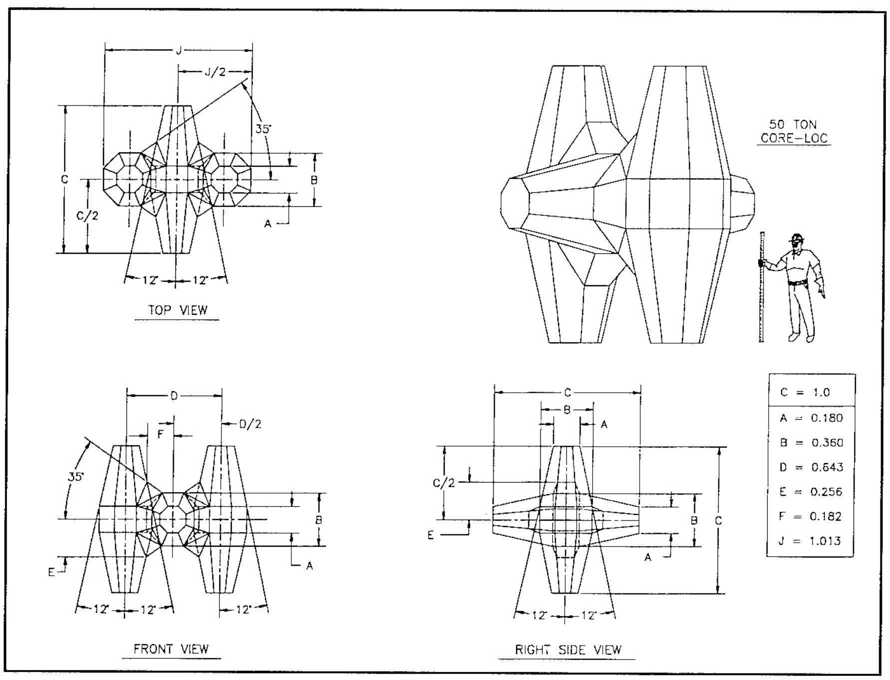


*Figure 2. Core-loc dimensions*

breakage occurring during the life of the structure.

In addition to using the unit for new construction, core-loc was designed to interlock well with dolosse, so that it can be used as a repair unit for dolos structures. The separation and taper of the core-loc's outer members are designed for superior interlocking with dolosse. When core-locs are placed on a slope with dolosse, the two units have a natural affinity and are almost indistinguishable from each other.

## Core-loc hydraulic testing

Over the past 2 years, a large number of core-loc hydraulic stability tests have been conducted under a variety of situations and research on core-loc stability is still ongoing (Carver and Wright 1994). Tests completed to date show that the core-loc armor layer is two-dimensionally stable for wave heights far exceeding those causing damage to most other armor shapes. During testing, researchers made note of the fact that the units showed very little movement on the slope, including in-place rocking. No-damage Hudson stability coefficients have exceeded 150 in several instances, and for most tests the wave generation capacity of the flume was reached before damage to the armor layer occurred.

A conservative armor layer design would never specify armor weights using very high stability coefficients. Regardless of armor type, designs should not vary drastically from the non-interlocked armor stability because of the many uncertainties involved with breakwater design which add to the risk of failure. Also no structure is truly two-dimensional. For example, the least stable area on a breakwater is usually at a transition. The transition can be a lateral stone-to-concrete armor unit transition, toe, or crown. Even if buttressed, any of these areas can loosen over time and become a localized area of unraveling.

Therefore, a Hudson stability coefficient of $K_D = 16$ is recommended for trunk sections and $K_D = 13$ for head sections, for both breaking and non-breaking waves. When designed conservatively using these coefficients, core-loc armor will have considerable reserve stability beyond the design wave or when repeatedly subjected to the design wave. During stability tests, reflection coefficients from the core-loc layer were almost indistinguishable from those of dolosse, being slightly less, indicating that existing dolos reflection and runup design information could be used for preliminary estimation of reflection and runup on core-loc slopes. As always, site-specific physical model tests should be used to validate this preliminary design guidance.

## Core-loc structural analysis

Structural analysis has been conducted using finite element methods (FEM) to compare the structural response of dolosse, tribars, and accropodes with core-locs for several static loading modes. An example flexural load and the FEM grids are shown in Figure 3. The weights of each

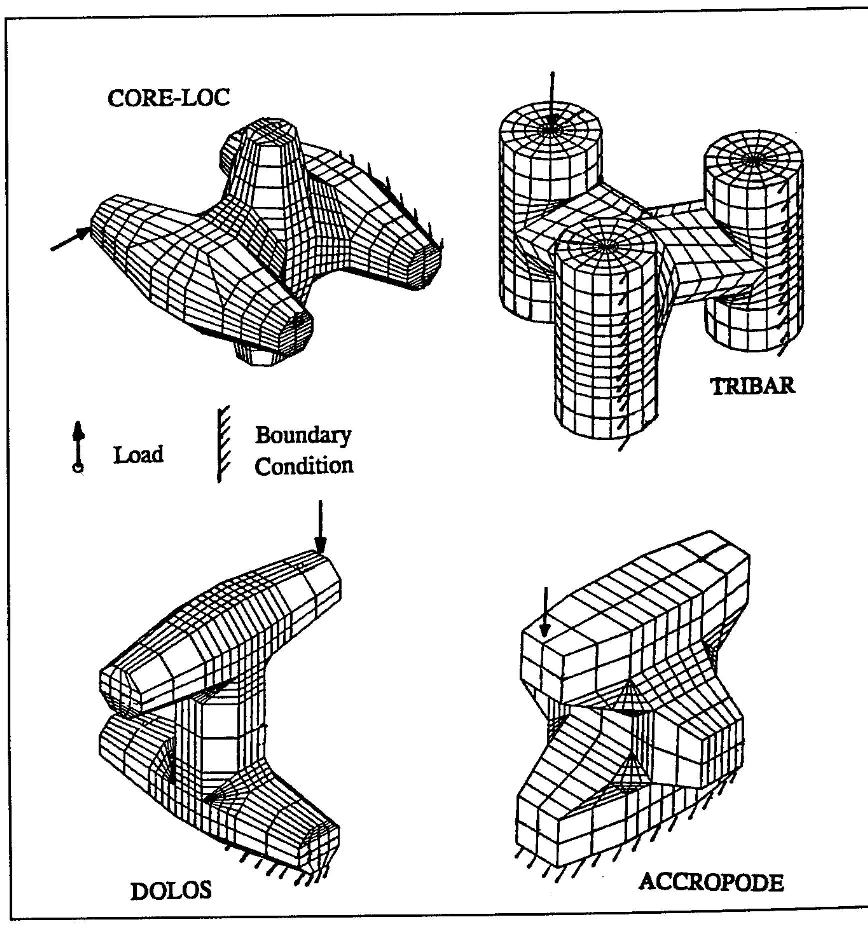


*Figure 3. Loading and boundaries for flexural stress comparison of core-loc, tribar, accropode, and dolos*

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unit were arbitrarily set at 10 tons. Similar flexure, torsion, and combined loads were applied to each. Maximum tensile stresses obtained from the FEM analyses are summarized in Table 1 and Figure 4. The figure shows that maximum static tensile stresses in core-locs are similar to those in accropode and approximately half those of dolosse and a third those of tribar.

The significance of the FEM stress reductions can be realized by examining an actual design case. For Crescent City 42-ton dolosse, the design tensile stress corresponding to a 2-percent exceedance was approximately 696 psi. This structure is performing reasonably well with 2-percent breakage since the 1986 rehabilitation. The concrete specification for Crescent City produced a high strength metal-fiber-reinforced mix with a 28-day splitting tensile strength of 725 psi. For the same size core-locs the maximum design stress could be relaxed to 62 percent of this value, or approximately 430 psi. This stress is below the plain concrete 28-day splitting tensile strength met on Corps concrete armor projects. The improved strength of the core-loc will result in cost savings through reduced-strength concrete mix requirements and increased reliability.

**Table 1. FEM Static Stress Comparison**

| Load Case | Maximum Tensile Stress Ratio, $\sigma_S/\sigma_{CL}$ [1] Core-loc | Dolos | Accropode | Tribar |
|---|---|---|---|---|
| Torsion | 1.00 | 1.86 | 1.36 | 2.66 |
| Flexure - fluke tip load | 1.00 | 2.15 | 1.36 | 3.00 |
| Flexure - fluke center load | 1.88 | 3.05 | — | — |
| Combined flexure and torsion | 1.70 | 3.42 | — | — |

[1] $\sigma_S$ is the maximum tensile stress for the armor unit in a specific loading configuration and $\sigma_{CL}$ is the maximum tensile stress for the core-loc in flexure.

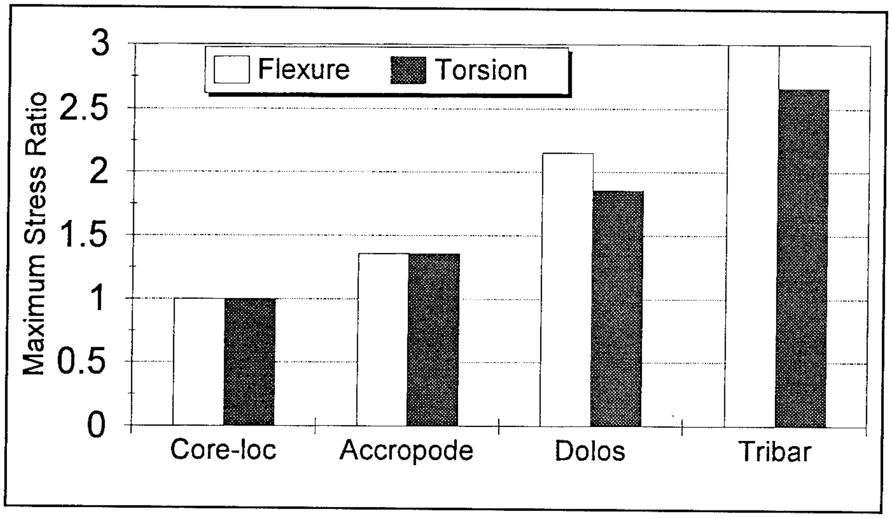


*Figure 4. Maximum tensile stress ratio from FEM static analysis*

# Core-loc armor volume efficiency

The cost of an armor layer depends on the volume of concrete on the slope, number of units, unit material cost, and unit construction costs. Unit construction costs include casting yard, transport, and placement costs. Yard costs include construction of formworks; concrete pouring, storage, and handling; and the cost of equipment necessary to handle the units. The total armor material volume dominates armor layer cost and can be minimized by maximizing porosity and minimizing armor layer thickness.

Because of core-loc's high stability, high porosity, and single-unit-thickness layer, building an armor layer from core-locs requires less concrete than other commonly used armor units. When designing for breaking waves on a 1V:1.5H trunk section, dolosse require 53 percent more concrete than core-loc, randomly placed tribars require 110 percent more, accropodes require 41 percent more, and tetrapods require 159 percent more concrete. Similar savings can be achieved when designing for head sections and other slope configurations when using core-locs.

## Future core-loc research, prototype projects, and licensing

Basic research on core-loc response continues, both in two-dimensional and three-dimensional hydraulic and structural testing. Large-scale testing of the core-loc at the Oregon State University Large Wave Flume is planned for 1995, as are prototype impact tests using both 1.5-ton and 20-ton core-loc. Several projects are planned using this new armor unit. Site-specific model studies using core-locs have been conducted on the Noyo, California, offshore breakwater (Smith et al. 1994), and the Kodiak, Alaska, breakwater. The Kaumalapau breakwater in Hawaii is currently being tested with core-loc armoring at WES. Core-locs have been proposed for armoring the Barber's Point breakwater, and model tests are planned for later this year. Consideration is being given to using core-locs on the U.S. Naval Air Facility Wake Island Revetment; Ouzinkie, Alaska, breakwater; a dredged material containment island retaining structure in New York; Maalaea, Hawaii, breakwater; Grays Harbor, Washington, jetty; and Manasquan, New Jersey, jetties. The U.S. patent for core-loc is pending and foreign patents in most industrialized countries are being filed. Licensing of these patents will be advertised in the Federal Register in early 1995. For more information about the technical aspects of core-loc, please contact Jeffrey Melby (601)634-2062 or George Turk (601)634-2332. For information about licensing core-loc, contact Phillip Stewart (601)634-4113.

## References


Carver, R. D., and Wright, B. J. (1994). "Stability of CORE-LOC armored, rubble-mound breakwater trunks." Progress Report, Coastal R&D Program, U.S. Army Engineer Waterways Experiment Station.

Melby, J. A., and Turk, G. F. (1993). "CORE-LOC concrete armor units initial stability results." Progress Report, Coastal R&D Program, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Melby, J. A., and Turk, G. F. (1994a). " Scale and Modeling effects in concrete armor experiments." *Proc. Coastal Dynamics '94 Conf.* ASCE, New York, NY.

Melby, J. A., and Turk, G. F. (1994b). "Concrete armor unit performance in light of recent research results." *ASCE/WPCO Sem. on Case Histories of Design, Constr., and Maint. of Rubble Mound Struc.* ASCE, New York, NY, in publication.

Melby, J. A., and Turk, G. F. (1995a). "The CORE-LOC: optimized concrete armor." *Proc. 24th Int. Conf. on Coast. Engr.*, ASCE, New York, NY, in publication.

Melby, J. A., and Turk, G. F. (1995b). "CORE-LOC concrete armor units." *Technical Report*, in publication, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Smith, E. R., Cole, J., Bonigut, T., and Hennington, L. (1994). "Stability tests of proposed breakwater at Noyo, California." *ASCE/WPCO Sem. on Case Histories of Design, Constr., and Maint. of Rubble Mound Struc.* ASCE, in publication.



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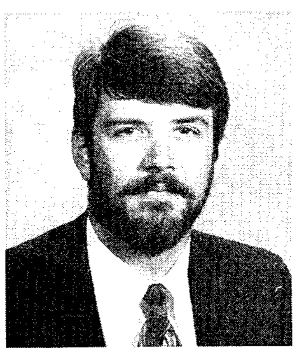


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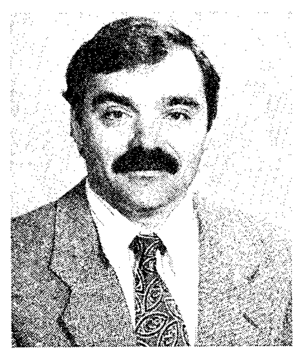

# ACES 2 Release Notes

*by Wayne W. Tanner, Ann R. Sherlock, David A. Leenknecht*

The Automated Coastal Engineering System (ACES) work unit is developing an integrated system (ACES 2) connecting prediction technology with large coastal data sets and visualization software in a user-friendly environment. The ACES Pilot Committee, consisting of Headquarters, District, and Division coastal engineers, established the ACES work unit to provide the field with access to more complex numerical models and visualization techniques. This work is being done in a workstation graphical user interface (GUI) environment using X-Windows and Motif running on a Unix workstation platform. Visualization software uses Advanced Visual Systems agX/Toolmaster for graphics and device support. The Network Common Data Form (NetCDF) libraries are used for direct access storage and retrieval of coastal data and to provide portability across platforms. Data formats for all technologies within the system have been standardized for increased communication between existing and planned technologies. GUI codes are written in C, modeling technologies in FORTRAN.

## Applications

To date, several methodologies have been built or incorporated into this environment. The GUI codes assist in data access, editing and initial preparation, model operation, and scientific visualization. Predictive technologies currently available in ACES 2 include wave transformation using WIS Phase III methodology (WISPHS3), nearshore wave transformation using RCPWAVE, simplified longshore sediment transport at a point or along a reach (SLXPORT), or more detailed analysis including shoreline change using GENESIS. Visualization capabilities are included for the two-dimensional wave transformation technologies such as the wave model visualization (WMV) application as well as for GENESIS simulations.

## WISPHS3

The WISPHS3 application transforms two-component offshore wave data to a shallower water site. A discrete history of wave height, period, and direction such as WIS Phase II wave series can be employed as the offshore data. The method employs spectral transformation of the offshore data and produces WIS Phase III wave conditions at a location in shallower water. Additional data requirements include a local water depth, local shoreline orientation and wave energy sheltering configuration of the target site by a land mass or shoal. An important assumption for this application includes straight and parallel bottom contours.

## RCPWAVE

The RCPWAVE application is a two-dimensional uniform rectilinear grid finite difference model used to predict linear wave propagation across an arbitrary bathymetry. Wave events to be propagated across the given bathymetry are the primary input. RCPWAVE outputs the wave height and direction at each grid cell along with ancillary data including the wet-dry status of each cell and the cells in which wave breaking is estimated. RCPWAVE can also provide this data at specifically selected points (stations) to provide a nearshore data set for use in GENESIS, SLXPORT, and simulations with other technologies planned for inclusion in the system.

## WMV

The WMV application displays various views of bathymetry and output from two-dimensional wave models. At present only RCPWAVE provides the data necessary to use WMV, although support for other models, including STWAVE, is built into the application. WMV displays two- and three-dimensional plots of bathymetry, wave heights, and wave spectra. The two-dimensional views can be presented as either contour or isoline displays. Wave direction can be displayed as scaled vectors and a time series of wave height, period, and direction can be displayed as a line plot. In addition, various views of data sets can be combined by stacking or overlaying the data sets into the display. The package also allows rotation of three-dimensional plots and zooming in on areas in two-dimensional plots. All plot colors and scaling options are user configurable for custom application.

## SLXPORT

The methodologies represented in the SLXPORT application provide simplified estimates of potential longshore sediment transport

# CERC Publications

*Reports listed below having AD numbers can be purchased from the National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; telephone (703) 487-4600. For those reports that do not have the AD number, the report can be obtained from the U.S. Army Engineer Waterways Experiment Station (601) 634-2571.*

## Dredging Research Program

MP DRP-94-1, NTIS No. AD A279 942, "Dispersion Analysis of Charleston, South Carolina, Ocean Dredged Material Disposal Site," Norman W. Scheffner, James R. Tallent, March 1994.

The dispersive characteristics of the Charleston, SC, Ocean Dredged Material Disposal Site were investigated to determine whether dredging operations could pose a threat to recently discovered live coral reef areas. Two levels of investigation were employed. A short-term analysis of the disposal operation was conducted to examine the immediate fate of material following release from the barge and subsequent descent to the ocean bottom. The second phase examines the long-term fate to determine whether local ocean currents are capable of eroding and transporting deposited material from the site to the reef area. Results of this study indicate the site to be dispersive and recommendations are made as to locations within the designated limits which will minimize the possibility of reef area effect as a result of the disposal operation.

TR DRP-94-1, NTIS No. AD A277 022, "Understanding and Interpreting Seabed Drifter (SBD) Data," Donald T. Resio, Edward B. Hands, January 1994.

Seabed drifters (SBD's) are inexpensive, current-following drogues widely used in oceanographic studies. This report gives new methods for interpreting SBD results, especially for coastal applications. The general forces responsible for SBD movement are described and contrasted with those responsible for moving sediment on the seafloor. Specific recommendations include that a prerelease desk study be done to rank the transport processes at the site of any contemplated SBD application. This ranking will help indicate how useful SBD's may be and provide the basis for selecting an experimental design appropriate for the site. A typical SBD design might include repeated releases of batches of SBD's from a number of stations during varying conditions. Recovery patterns will indicate the relative importance of spatial and temporal variations in the currents. Proper SBD interpretations include assessment of potential human and natural influences on the recovery patterns. Natural dispersion can be divided into a mean (or deterministic) component and a diffusive (or random) component. A methodology is given for quantifying these components. It is shown that the mean displacement of materials suspended in bottom water can exceed 100 km in a few days during a frontal passage or storm. It is important to understand large variations in the mean and random components of displacement to improve predictions of the likely fate of bottom materials. Better predictions can help maximize beneficial uses for dredged materials and minimize adverse effects from accidental ocean discharges that may be unrelated to dredging.

## Instruction Reports

IR CERC-92-1, NTIS No. AD A256 243, "User's Guide to the Shoreline Modeling System (SMS)," Mark B. Gravens, August 1992.

This report documents a microcomputer-based software package (SHORELINE MODELING SYSTEM) that contains a collection of generalized computer programs assembled to enable the user to perform complete longshore sediment transport processes and shoreline evolution assessments. This software package was developed at the Coastal Engineering Research Center (CERC) to facilitate the technology transfer of recently developed coastal engineering tools throughout the Corps. The modeling system is presently comprised of two major numerical models (RCPWAVE and GENESIS) packaged together with more than 15 system support programs. The system support programs automate the data analysis and input data generation tasks necessary to execute RCPWAVE and GENESIS in design-oriented applications.

Technical documentation with example applications of each of the computer programs and numerical models is provided in the GENESIS report series (CERC-89-19, Reports 1 and 2). This report provides general instructions for the operation of the SHORELINE MODELING SYSTEM and outlines the capabilities of the individual components contained in the system.

IR CERC-93-1, NTIS No. AD A262 158, "Review of Geologic Data Sources for Coastal Sediment Budgets," Edward P. Meisburger, February 1993.

Sediment budget studies are of great importance in many coastal engineering projects. In general, a sediment budget is a compilation of sources and amounts of sediment that are gained or lost in designated coastal reaches during a specific interval of time. Sediment supply for a given coastal area may be derived from several sources and may involve different means of transport. Analysis of sediment budgets includes the study of:

- Influence of waves on alongshore and onshore-offshore sediment movement.
- Effects of tidal and other coastal currents on sediment movement.
- Sediment accretion rates at barriers and traps.
- Historical shoreline changes.
- Long-term measurements of littoral profiles.

Sediment sources and transport paths must be identified as part of the sediment budget process. In many cases, important sources are apparent from observation of the geomorphic aspects of the coastal terrain. Often sources are obscure and study of much more complex aspects of the sediment, such as particle composition and shape characteristics, is needed. In many cases, existing methods are not sufficient for positive identification of all sources. Techniques for source identification and quantitative accounting of sediment supply and loss are important areas of continued research efforts to improve the methodology.

IR CERC-93-2, NTIS No. AD A267 191, "SBEACH: Numerical Model for Simulating Storm-Induced Beach Change," Julie D. Rosati, Randall A. Wise, Nicholas C. Kraus, Magnus Larson, May 1993.

This report provides guidance for implementing SBEACH, the Storm-Induced **BEA**ch **CH**ange model, via a user interface available for the personal computer. SBEACH simulates beach profile change, including the formation and movement of major morphologic features such as longshore bars, troughs, and berms, under varying storm waves and water levels. The personal computer version of SBEACH is accessed through a user interface which facilitates data entry and manipulation, graphical representation of input and output, and execution of the model. The interface also provides considerable error and range checking prior to actual running of the model. The first two chapters of the report present information about applying the model, including hardware requirements, loading SBEACH onto a hard disk, discussion of the interface structure through which the numerical model is operated, and guidance for model calibration. The final chapter is written as a tutorial, guiding the user in installing, running, and working through several example simulations.

IR CERC-94-1, NTIS No. AD A278 200, "BFM: Beach Fill Module; Report 1, Beach Morphology Analysis Package (BMAP) User's Guide," Barry G. Sommerfeld, John M. Mason, Nicholas C. Kraus, Magnus Larson, March 1994.

This report is a user's guide for the Beach Morphology Analysis Package (BMAP), which consists of automated and interactive procedures to analyze morphologic and dynamic properties of beach profiles. The BMAP includes a graphical interface that produces on-screen plots of user-selected profiles and calculation results that are easily exported to a printer. The present report covers Version 1 of BMAP which is capable of two- dimensional analysis, that is, analysis of each profile. This guide provides information to operate BMAP as a stand-alone program under the Disk Operating System (DOS) running on a personal computer (PC).

IR CERC-94-2, NTIS No. AD A284 650, "User's Guide for the Littoral Environment Observation (LEO) PC Data Retrieval and Analysis System," Leonette J. Thomas, August 1994.

A step-by-step procedure for the operation of the Littoral Environment Observation (LEO) personal computer (PC) Data Retrieval and Analysis System is provided. The program provides a quick and economical means of acquiring littoral environmental data at over 350 sites on the Pacific, Atlantic and Gulf Coasts, and in the Great Lakes Region.

## Miscellaneous Papers

MP CERC-93-6 NTIS No. AD A269 932, "DYNLET1 Application to Federal Highway Administration Projects," Mary A. Cialone, H. Lee Butler, Michael Amein, August 1993.

This study was sponsored by the U.S. Department of Transportation (DOT) whose primary interest is in the development of a statistical approach for estimating frequency- indexed currents impacting bridge piers at project sites. Model DYNLET1 is used to compute the storm-induced velocities near bridge piers. DYNLET1 is a one-dimensional (1-D), shallow-water equation, hydrodynamic model for predicting velocities and water level fluctuations in a system of inlets and bays (Amein and Kraus 1991, 1992). An important feature of the model is the ability to accurately represent flow distribution across any cross section, given the inherent limitations of a 1-D model.

This report describes the process of applying DYNLET1 to a tidal inlet, specifically to Brunswick Harbor , Georgia, for the purpose of estimating tide and storm response at U.S. Department of Transportation (DOT) project sites.

MP CERC-93-7 NTIS No. AD A269 753, "Wind Products for Use in Coastal Wave and Surge Models," Zeki Demirbilek, Steven M. Bratos, Edward F. Thompson, August 1993.

Winds over the ocean surface are the essential driving force in creating waves. Winds also have important effects on currents and nearshore water levels. Wind information is often used within the Corps of Engineers (CE) as input to numerical models of waves, storm surges, and circulation. The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy routinely produce global wind information. Recent advances in atmospheric modeling capabilities and operational numerical models, particularly within the Navy, have made available new and improved products applicable to CE hydrodynamic modeling. Available products from NOAA and the Navy are described, including both climatological archives and real-time forecasting products. Interfaces to assist CE users in obtaining and using the Navy products are presented. Sources of surface wind (10-m elevation) information of greatest potential value for CE modeling are evaluated using the wave model WISWAVE and NOAA National Buoy Center measurements along the

U.S. Atlantic coast. Necessary tools are provided and recommendations are given for further evaluation and use of Navy wind information in future modeling efforts.

MP CERC-93-8 NTIS No. AD A270 183, "Coastal Geologic and Engineering History of Presque Isle Peninsula, Pennsylvania," Richard J. Gorecki, Joan Pope, August 1993.

Presque Isle is a unique and significant coastal feature on the south shore of Lake Erie at Erie, Pennsylvania. It is a compound, recurved sandspit that arches lakeward about 2-½ miles from an otherwise straight mainland to its distal end where it turns sharply shoreward. It is the only major positive depositional feature along the generally sand-starved south shore of Lake Erie. Presque Isle Peninsula is an old-age geomorphic feature which is migrating eastward into deeper water, thereby resulting in a net annual loss to the sand body. The processes responsible for the geological evolution of this feature will also be responsible for its eventual destruction unless attempts are undertaken to slow its migration. The history of coastal engineering measures for shore protection on the peninsula has been extensive and dates back to the early 1800's. The peninsula is truly a rare ecological laboratory that allows the process of primary plant and animal succession to be studied in habitat diversity ranging from pioneer vegetation on newly formed shore zones to climax woodland communities on old beach ridges, all within a distance of about 3 miles. The peninsula is developed as a state park and is a popular recreational area.

In the interest of brevity, many of the complex geologic, environmental, engineering, and socioeconomic issues could not be presented herein. The purpose of this paper is purely academic and is designed to enlighten the reader by providing an understanding of the geologic evolution of Presque Isle Peninsula and the history of man's attempts at stabilization.

MP CERC-93-9, "Evolution of Popponesset Beach and Its Effect on Popponesset Bay," Mary A. Cialone (Compiler), September 1993.

Popponesset Beach is an approximately 1-mile-long barrier beach (or spit) fronting Popponesset Bay located on Nantucket Sound in Mashpee, Cape Cod, Massachusetts. Popponesset Spit has experienced dramatic changes in the last 40 years, beginning with a major breach in 1954, which resulted from a series of hurricanes (Carol, Edna, and Hazel). Breaches near Popponesset Island, Little Thatch Island, and Big Thatch Island were observed at various times between 1892 and 1991.

The main purpose of the study was to determine the likelihood of a breach of Popponesset Spit and the impact (in terms of water quality, storm protection, and navigation) of breaching and/or slow degradation of the spit on Popponesset Bay. A review of historical information pertaining to the evolution of Popponesset Spit and an analytical/empirical "desktop" analysis were performed.

MP CERC-94-1 NTIS No. AD A277 170, "Revere Beach and Point of Pines, Massachusetts, Shore Front Study," W. Gray Smith, Julie D. Rosati, Stephen A. Bratos, John McCormick, January 1994.

The U.S. Army Engineer Division, New England (CENED) requested assistance from the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center in quantifying storm-induced coastal processes, including beach erosion and overtopping along the Revere Beach and Point of Pines (POP) coastal reach. Specifically, CERC was asked by CENED to evaluate the degree of protection provided by a coarse-grained beach fill at Revere Beach, as well as to assess the benefits and optimize the design of a revetment and/or beach-fill and dune system at POP. Wave and water level conditions associated with a set of 50 storms were defined using measured water level data and hindcast wave data. The cross-shore profile response model Storm-Induced **BEA**ch **CH**ange (SBEACH) was applied to evaluate beach profile change. A runup and overtopping module was developed during the study, and a set of physical modeling tests were conducted to further test and improve the module. Each of the 50 storms was used as input to the runup and overtopping module.

MP CERC-94-2, "Index and Bulk Parameters for Frequency-Direction Spectra Measured at CERC Field Research Facility, September 1989 to August 1990," Charles E. Long, Wendy L. Smith, March 1994.

A multiyear series of wind wave frequency-direction spectral measurements has been undertaken at the Field Research Facility of the Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station. Cross-spectra of surface-corrected signals from a linear array of nine bottom-mounted pressure sensors have been used in conjunction with an iterative maximum likelihood algorithm to estimate frequency-direction spectra in about 9 m of water, approximately 900 m offshore. This report provides an index of and describes a means of access to 1,505 spectral observations obtained from September 1989 to August 1990. This period represents the fourth year of data collection. In addition to a list of data collection start times, a set of bulk parameters are provided to characterize the observations. Included are characteristic wave height, spectral peak frequency and corresponding peak period, peak wave direction, and directional spread. Time series graphs of these parameters, as well as local winds and currents, illustrate some of the salient climatology.

## Technical Reports

TR CERC-93-6, NTIS No. 266 384, "Observations and Modelling of Winds and Waves During the Surface Wave Dynamics Experiment; Report 1, Intensive Observation Period IOP-1, 20-31 October 1990," Michael J. Caruso, Hans C. Graber, Robert E. Jensen, Mark A. Donelan, April 1993.

This report describes the compilation of observed and modelled wind and wave parameters during the first intensive observation period (IOP-1) from October 20-31, 1990, of the Surface Wave Dynamics Experiment. The measurements include wind speeds and directions, wave heights and periods, air and sea temperatures, and atmospheric pressures from three directional wave buoys, four meteorological buoys, and several routinely operated buoys from the National Data Buoy Center (NDBC). In addition, a summary of directional wave spectra is presented for this period. The model data include examples of wind fields from six numerical weather prediction models and the corresponding wave height maps as derived from the 3G-WAM ocean wave model. Estimated surface current velocities and directions from the Harvard quasi-geostrophic model are also presented for this time period.

TR CERC-93-6, NTIS No. AD A 278 368, "Observations and Modelling of Winds and Waves During the Surface Wave Dynamics Experiment; Report 2, Intensive Observation Period IOP-3, 25 February - 9 March 1991," Michael J. Caruso, Hans C. Graber, Robert E. Jensen, Mark A. Donelan, March 1994.

This report describes the compilation of observed and modelled wind, wave and current parameters during the third intensive observation period (IOP-3) from February 25 to March 9, 1991, of the Surface Wave Dynamics Experiment. The measurements include wind speed and direction, wave heights and periods, air and sea temperatures, and atmospheric pressures from four directional wave buoys, two meteorological buoys, and several routinely operated buoys from the National Data Buoy Center (NDBC). Examples of directional wave spectra obtained from two airborne radars and from a Swath ship are presented along with surface currents from airborne expendable current profilers (AXCP) and acoustic doppler current profilers (ADCP). In addition, a summary of directional wave spectra is presented for this period. The model data include examples of wind fields from six numerical weather prediction models and the corresponding wave height maps as derived from the 3G-WAM ocean wave model. Estimated surface current velocities and directions from the Fleet Numerical Oceanographic Center (FNOC) model and selected satellite images of sea surface temperature fields are also presented for this time period.

TR CERC-93-7, NTIS No. AD A266 082, "Cooperative Laboratory and Field Study to Investigate Effects of Wave and Current Action on Dual-Rocket Distributed Explosive Array Deployment," Jimmy E. Fowler, William Birkemeier, Jodie A. Denson, David Krivich, May 1993.

A series of 2-D (flume) laboratory and field tests were conducted to examine effects of waves and currents on a simulated dual-rocket distribution explosive array deployment (DRDEAD) system. the DRDEAD system consists of a large array of explosive material which can be deployed by rockets launched from Navy vessels across the surf zone in a mine-clearing operation. The U.S. Army Engineer Waterways Experiment station (WES) Coastal Engineering Research Center's mid-scale 2-D facility was used to examine various wave conditions, methods of deployment, and anchoring systems for a simulated (inert) DRDEAD. Waves simulating sea state 3 conditions and lower (i.e. calm seas to 5-ft prototype waves) were used in the laboratory study. Laboratory tests indicated that sea state 3 will be a limiting condition for deployment of the array without additional weights or anchors. Field tests to assess effects of waves and current were conducted during the summer of 1992 at CERC's Field Research Facility (FRF) in Duck, North Carolina. Results of the field tests supported laboratory findings, but also indicated that longshore currents are likely to have equal or greater effects on the DRDEAD system and must be considered in the final design.

TR CERC-93-8, NTIS No. AD A266 658, "Coastal Scour Problems and Methods for Prediction of Maximum Scour," Jimmy E. Fowler, May 1993.

The most common coastal scour-related problems are toe scour at rubble-mound structures and vertical seawalls, and scour at the base of piles and horizontal pipelines. Existing scour prediction methods for these problems vary from rules of thumb to empirically derived equations to theoretically derived relationships. Recent studies at the U.S. Army Engineer Waterways Experiment Station's Coastal Engineering Research Center indicate that sufficient design guidance exists for vertical walls, pipelines, and vertical piles; however, additional research is still needed for rubble-mound structures.

TR CERC-93-9, NTIS No. AD A268 755, "Annual Data Summary for 1991 CERC Field Research Facility; Volume I: Main Text and Appendixes A and B," NTIS No. AD A268 755, Volume II: Appendices C through E," Michael W. Leffler, Clifford F. Baron, Brian L. Scarborough, Kent K. Hathaway, June 1993.

This report provides basic data and summaries for the measurements made during 1991 at the U.S. Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center's (CERC's) Field Research Facility (FRF) in Duck, NC. The report includes comparisons of the present year's data with cumulative statistics from 1980 to the present.

Meteorological and oceanographic data, monthly bathymetric survey results, samples of biannual aerial photography, and descriptions of 18 storms that occurred during the year are summarized in this report. The year was highlighted by a major storm (the "Halloween Storm") in late October. Waves with 6-m significant height and periods exceeding 21 sec were measured 6 km from shore.

This report is the 13th in a series of annual summaries of data collected at the FRF that began with Miscellaneous Report CERC-82-16, which summarized data collected during 1977-1979.

TR CERC-93-10, NTIS No. AD A268 161, "Dolos Design Procedure Based on Crescent City Prototype Data," Jeffrey A. Melby, June 1993.

This design procedure includes statistical methods for determining a design stress in a dolos armor layer. The methods characterize the structural response as a single parameter: the maximum principal tensile stress in each dolos. Using this approach, the dolos shape can be optimized for structural integrity and hydrodynamic stability, and the design can be verified in the physical model. Also, the structural response to most significant loading mechanisms can be computed separately and the individual statistical distributions combined to yield a design stress distribution. The design stress is computed using this design stress distribution and then compared to a fatigue-reduced strength. The iterative optimizing design process can be accomplished using a user-friendly PC-based computer program.

It is shown that unreinforced normal-strength dolosse above 20 tons are often underdesigned with respect to strength and can tolerate only slight movement and the associated impacts. It is also shown that increasing the dolos waist ratio can add significantly to the unit's strength, while sacrificing little hydrodynamic stability, and that large dolosse over 30 tons require some strengthening scheme. The methods discussed in this paper provide a complete procedure for determining a design stress within a hydrodynamically stable dolos and can be used as an outline in the design of other slender armor unit shapes.

## TR CERC-93-11, NTIS No. AD A268 810, "Nearshore Wave Breaking and Decay," Jane M. Smith, July 1993.

This report summarizes the nearshore wave breaking and decay research performed under the Nearshore Waves and Currents Work Unit. The topics covered in the report include incipient wave breaker indices, surf zone wave decay expressions, spectral shapes in the surf zone, wave breaking on reefs, and decay of multiple wave trains.

## TR CERC-93-12, NTIS No. AD A269 839, "Surf Beat in Coastal Waters," Edward F. Thompson, Michael J. Briggs, August 1993.

As ocean waves propagate into shallow water, they exhibit increasingly strong nonlinearities. One important nonlinear effect is the emergence of low-frequency energy as a consequence of interactions between higher frequency incident wave components. The low-frequency components can dominate the inner surf zone during storm conditions. Amphibious and LOTS operations can be seriously impacted by currents, water-level variations, and runup induced by surf beat. Data were obtained from the U.S. Army Engineer Waterways Experiment Station laboratory and field facilities. A theoretical formulation for the growth of low-frequency energy in shallow water is evaluated against the data sets and used to develop guidelines for predicting surf beat.

## TR CERC-93-13, NTIS No. AD A272 577, "Beach Nourishment Project Response and Design Evaluation: Ocean City, Maryland; Report 1, 1988-1992," Donald K. Stauble, Andrew W. Garcia, Nicholas C. Kraus, William G. Grosskopf, Gregory P. Bass, August 1993.

Detailed monitoring of the performance of a two-phase beach nourishment project has provided valuable information on beach fill behavior and long-term response of a beach fill to prevailing coastal processes. The Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project began with placement of a recreational beach by the State of Maryland during the summer of 1988. Within three months of placement, four storms impacted the area. Recovery was monitored for an additional 2 years. In the summers of 1990 and 1991, additional fill material including a storm protection dune was placed by the U.S. Army Corps of Engineers as a second phase for the purpose of storm protection. Within a year of the first placement, two large storms impacted the project. Initial recovery was also documented. Project monitoring included 12 profile survey lines, sediment collection and placement of two dedicated wave gauges. The beach nourishment project performed well in protecting the beach front infrastructure of Ocean City from storm damage. The fill material was eroded from the foreshore after the major storms of 1989 and 1991/92, but could be accounted for in the nearshore between the shoreline and closure. Representative profile survey locations show the differential behavior of the fill controlled by nearshore bathymetric variability along the project length. The 37th Street location represents the flatter, bar/trough type profile typical of the southern portion of the fill. Localized "hot spots" of erosion occurred in areas where a shoal system attaches to the shoreface, as shown at 81st Street. The erosion pattern associated with these shoals was probably produced by wave convergence and divergence over these features. Analysis of sediment characteristics of samples collected during the State fill project showed the influence of the fill material on the native beach and the change in sorting after the passage of four storms. Composites were constructed of the foreshore and finest nearshore samples to account for cross-shore variability in grain size distribution. The coarsest foreshore and finest nearshore composite fill material was found in the northern end of the project, with the opposite found to the south. Storm impact placed coarse foreshore lag material at the erosional 81st Street location and finer material at the more stable 37th Street location. After 9 months, the fill material was taking on the characteristics of the pre-fill native beach.

## TR CERC-93-14, "Revetment Stability Tests for Sargent Beach, Texas," Robert D. Carver, Willie J. Dubose, John M. Heggins, Brenda J. Wright, August 1993.

The objective of this study was to investigate, via a two-dimensional coastal model, alternate designs for the proposed revetment. Tests were conducted at a geometrically undistorted scale of 1 : 24, model to prototype. Based on test results, it was concluded that:
a. 4- to 6-ton armor stone is stable for the maximum wave heights that can be expected to occur for 8- and 10-sec waves at still-water levels (swl's) of +4.0 to +14.0 ft mean low tide (mlt) with assumed scour depths of -3.5 and -8.6 ft mlt, b. stability of the original concrete blocks, which were 6.0 ft by 5.5 ft by 2.5 ft and had 0 percent porosity, was only marginally acceptable for the maximum wave heights that can be expected to occur for 8- and 10-sec waves at swl's of +4.0 to +14.0 ft mlt with an assumed scour depth of -3.6 ft mlt, and c. several modified block plans were tested and it was determined that the optimum block size was 5.75 ft by 5.75 ft by 2.5 ft. These blocks, weighing 6 tons and having a porosity of 4 percent, should prove stable for the maximum wave heights that can be expected to occur for 8- to 10-sec waves at swl's of +4.0 to +14.0 ft mlt with an assumed scour depth of -10 ft mlt.

## TR CERC-93-15, NTIS No. AD A272 004, "Rubble-Mound Breakwater Wave-Attenuation and Stability Tests, Burns Waterway Harbor, Indiana," Robert D. Carver, Willie J. Dubose, Brenda J. Wright, August 1993.

A two-dimensional model study of the damaged Burns Waterway Harbor breakwater was conducted. The 1:36-scale undistorted flume tests were used to evaluate various repair options that included placing a submerged breakwater lakeward of the existing breakwater, attaching a berm breakwater to the lakeside of the structure, the addition of an 18-ton angular stone overlay, and reworking the existing stone into special placement at the crest.

Generally, the submerged breakwater and restacking of the existing armor were the least effective approaches to reducing wave transmission; whereas the toe berms and large-stone overlays were the most effective. However, the submerged reefs proved to be the most effective in reducing or eliminating damage to the existing breakwater.

## TR CERC-93-16, NTIS No. AD A270 195, "Hydrodynamic and Water Quality Modeling of Lower Green Bay, Wisconsin; Volume I: Main Text and Appendixes A-E," David J. Mark, Norman W. Scheffner, H. Lee Butler, Barry W. Bunch, Mark S. Dortch, September 1993.

A confined disposal facility (CDF) for dredged material presently exists in lower Green Bay, Wisconsin. A planned expansion of the CDF was studied to assess its impact on current patterns and subsequent redistribution of dissolved oxygen in the immediate vicinity of the proposed expansion. The redistribution is, in part, dependent on the magnitude and direction of currents generated by storm-induced seiches occurring in Lake Michigan and within the bay itself. Two-dimensional, vertically averaged hydrodynamic and water quality models were applied to make this assessment by investigating the spatial and temporal variations in dissolved oxygen concentrations for existing and proposed configurations. Field data collected over three summers were used for calibrating and validating the hydrodynamic model. The water quality model was calibrated with field data collected over one summer. Results and conclusions of the modeling effort are summarized in this report.

## TR CERC-93-17, NTIS No. AD A271 607, "Los Angeles and Long Beach Harbors Model Enhancement Program, Improved Physical Model Harbor Resonance Methodology," William C. Seabergh, Leonette J. Thomas, September 1993.

Three long-period wave spectra were selected for use in the Los Angeles - Long Beach Harbors physical model for harbor resonance studies. They included two storms: 1 February 1986 and the Martin Luther King Day Storm on 17 January 1988. An average condition wave spectrum was developed based on long-term wave information. These spectra were used to program the wave generators, and wave data were collected at seven harbor gages in the model where prototype data had been collected. A comparison of model and prototype data indicated good correlation. The model was constructed to the most recent harbor configuration and included Long Beach Harbor's Pier J expansion. Additional long-period wave data were collected at berth locations throughout the harbors for the three wave spectra conditions in order to have base data to compare with data collected for proposed plans of harbor development. This work will minimize time and cost for harbor resonance studies of Los Angeles and Long Beach Harbors.

## TR CERC-93-18, NTIS No. AD A273 022, "Barbers Point Harbor, Oahu, Hawaii Monitoring Study," Linda S. Lillycrop, Michael J. Briggs, Gordon S. Harkins, Stanley J. Boc, Michele S. Okihiro, September 1993.

This report summarizes the field monitoring program and physical and numerical model studies that have been conducted to date for Barbers Point Harbor, Oahu, HI. This harbor was selected for study as part of the Monitoring Completed Coastal Projects (MCCP) Program in FY 85. The report describes the following: (a) previous physical and numerical model studies conducted in the planning stages of the harbor, (b) state-of-the-art physical and numerical model studies used to estimate harbor response in the existing harbor complex, (c) a field monitoring program for collecting wind wave and long-period waves outside and inside the harbor, (d) intercomparison among previous and current model studies and field data relative to harbor response and deepwater and nearshore coupling between infragravity and wind waves, and (e) evaluation of the effectiveness of the existing rubble-mound wave absorber in dissipating wave energy inside the harbor. Conclusions and recommendations are presented and an extensive appendix containing monitoring program results is provided.

## TR CERC-93-19, NTIS No. AD A275 241, "Engineering Design Guidance for Detached Breakwaters as Shoreline Stabilization Structures," Monica Chasten, Julie D. Rosati, John W. McCormick, Robert E. Randall, December 1993.

Detached breakwaters can be a viable method of shoreline stabilization and protection in the United States. Breakwaters can be designed to retard erosion of an existing beach, promote natural sedimentation to form a new beach, increase the longevity of a beach fill, and maintain a wide beach for storm damage reduction and recreation. The combination of low-crested breakwaters and planted marsh grasses is increasingly being used to establish wetlands and control erosion along estuarine shorelines.

This report summarizes and presents the most recent functional and structural design guidance available for detached breakwaters and provides examples of both prototype projects and the use of available tools to assist in breakwater design. functional design guidance presented includes a review of existing analytical techniques and design procedures, functional design considerations, and data requirements. The chapter on structural design guidance includes static and dynamic breakwater stability and methods to determine performance characteristics such as transmission, reflection, and energy dissipation. Also included is a discussion of numerical and physical modeling as tools for prediction of morphological response to detached breakwaters, and a case example of a breakwater project designed and constructed at Bay Ridge, Maryland.

## TR CERC-94-1, NTIS No. AD A278 532, "Three-Parameter Characterization of Shallow-Water Directional Wind Wave Spectra," Charles E. Long, January 1994.

A 5-year, 6,759-case database of high resolution, shallow-water, frequency-direction spectra is examined by classifying spectra in discrete ranges of three parameters: characteristic wave height, spectral peak frequency, and spectral peak direction. Counting the number of cases in each classification reveals the distribution of the spectral population in the three-parameter domain. Averaging spectra within parametric classes defines characteristic spectra that can be used to describe nearshore wave conditions more completely when only three parameters are known or estimated. Though the results are specifically unique to the North Carolina outer banks experiment site (the Field Research Facility of the U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center), they are illustrative of the variability of wave energy distribution possible in nature. Computation of longshore energy fluxes and radiation stress tensor components using characteristic spectra and the three-parameter guidance of the Shore Protection Manual reveals significant differences, and suggests that the ability to measure directional distributions of wave energy with high resolution is critical to the further improvement of modeling and predictive ability.

## TR CERC-94-2, NTIS No. AD A278 541, "Storm Evolution of Directional Seas in Shallow Water," Charles E. Long, February 1994.

Measured storm wave frequency-direction spectra are presented to illustrate the evolution of wind wave energy distribution near times of high energy. Twenty-nine storm events, extracted from a 5-year database, are identified and described. Instrumentation consists of a nine-element linear array of bottom-mounted pressure gauges distributed along the 8-m isobath about 900 m offshore of Duck, NC, site of the Field Research Facility (FRF) of the U. S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center. Iterative Maximum Likelihood Estimation is used to determine directional distributions of wave energy. Events, identified by elevation and duration of wave energy, are due to both localized storms and long-period swell radiating from major weather events in the distant, deep Atlantic Ocean. Frequency-direction spectra associated with storms known as "northeasters" have a curiously recurrent pattern of broad directional distributions at low frequencies near the spectral peaks and distinct bimodal distributions over a broad range of high frequencies. Reasons for this behavior are not obvious but require clarification because such wave patterns do not conform to conventional models used in engineering design. The differences may lead to substantial variations in design results.

## TR CERC-94-3, NTIS No. AD A275 975, "SUPERTANK Laboratory Data Collection Project; Volume I: Main Text," Nicholas C. Kraus, Jane McKee Smith, January 1994.

This report provides information and data documenting a coastal processes project called the SUPERTANK Data Collection Project performed at the O. H. Hinsdale Wave Research Laboratory, Oregon State University, over the period 29 July to 20 September 1991. the objectives of the project were to (a) collect data to verify and improve existing macro-scale beach profile change numerical simulation models, (b) collect data to develop advanced hydrodynamic, cross-shore sand transport, and meso-scale beach profile change numerical simulation models, (c) collect data to quantify performance of sandbars constructed offshore as a beneficial use of dredged material, (d) test and compare sediment-sensing acoustic instruments in a controlled, field-scale environment in support of dredging research, and (e) collect data to improve understanding of micro-scale fluid and sand motion. SUPERTANK was conducted as a multidisciplinary and multi-institutional cooperative effort in which the investigators shared instrumentation and expertise.

## TR CERC-94-4, NTIS No. AD A284 879, "New York Bight Study, Report 1: Hydrodynamic Modeling," Norman W. Scheffner, S. Rao Vemulakonda, David J. Mark, H. Lee Butler, Keu W. Kim, August 1994.

## TR CERC-94-5, NTIS No. AD A279 878, "Noyo River and Harbor, California, Design for Harbor Entrance Protection; Coastal Model Investigation," Robert R. Bottin, Jr., April 1994.

A 1:75-scale undistorted hydraulic model was used to determine wave conditions at the entrance to Noyo River and Harbor as a result of an offshore breakwater. The impact of the improvements on long-period wave conditions in the harbor as well as wave-induced and riverine bed-load sediment patterns was evaluated. The model reproduced the river from its mouth to a point approximately 15,000 ft upstream, both Noyo Harbor and Dolphin Marina located on the south bank, approximately 3,400 ft of the California shoreline on each side of the river mount, Noyo cove, and sufficient offshore area in the Pacific Ocean to permit generation of the required test waves. A 45-ft-long wave generator, crushed coal sediment tracer material, and an automated data acquisition and control system were utilized in model operation. It was concluded from the model investigation that:

a. Existing conditions are characterized by rough and turbulent wave conditions in the Noyo River entrance. Maximum wave heights ranged from 8.5 to 13.7 ft in the entrance for operational conditions (incident waves with heights of 14 ft or less) and from 12.2 to 15.2 ft for extreme conditions (waves up to 32 ft in height) depending on incident wave direction.

b. The offshore breakwater plan will result in maximum wave heights ranging from 6.3 to 9.3 ft in the entrance for operational wave conditions and 8.7 to 14.6 ft for extreme conditions depending on incident wave direction.

c. The offshore breakwater plan will not meet the 6.0-ft wave height criterion in the entrance for all incident waves of 14 ft or less (operational conditions). Based on hindcast data, however, the breakwater plan will result in the criterion being achieved 37 percent more of the time than it currently is for existing conditions when operational waves are present. The magnitude of wave heights also will be decreased by about 27 percent as a result of the offshore breakwater for operational waves.

d. With no waves present, the offshore breakwater resulted in riverine sediment patterns similar to those obtained for existing conditions except for the 100-year (41,000-cfs) discharge. For this condition, the breakwater prevented material from moving as far seaward in the cove as it did for existing conditions.

e. With waves present from west-northwest and west, the offshore breakwater slightly changes the paths of riverine sediment migration and subsequent deposits for some river discharges and does not for others. In general, considering all test conditions, riverine sediment will deposit in an area in the cove between the existing jettied entrance and the proposed structure location, both with and without the breakwater installed.

f. The offshore breakwater will not interfere with the migration of wave-induced sediment into the cove for waves from the northwest; however, for waves from southwest, the breakwater will prevent some sediment from penetrating as deeply shoreward in the cove as it did under existing conditions.

g. The offshore breakwater plan will have no adverse impact on surge conditions due to long-period wave energy in Noyo Harbor, Dolphin Marina, and the lower reaches of the river.

## TR CERC-94-6, NTIS No. AD A278 555, "Rehabilitation of the South Jetty, Ocean City, Maryland," Gregory P. Bass, Edward T. Fulford, Steven G. Underwood, Larry E. Parson, March 1994.

Frequent dredging requirements and scouring at the foundation of Ocean City Inlet's south jetty resulted in a study to determine the source of the shoaling and scouring. The study concluded that sand was being transported northward along Assateague Island, through and over the south jetty, and deposited inside the inlet. The sand was then transported north by ebb currents where it encroached on the Federal navigation channel. A rehabilitation program was initiated to create a littoral barrier to eliminate the shoaling problem and to repair the scour hold. Three headland breakwaters were constructed to stabilize Northern Assateague Island. The site was selected as part of the Monitoring Completed Coastal Projects (MCCP) Program to determine how well the rehabilitation project accomplished its design purpose. The monitoring program extended from October 1986 through January 1989. Activities included beach and offshore surveys, aerial and ground photography of the inlet and adjacent shorelines, inlet hydraulic surveys, nondirectional wave gauging, and side-scan sonar surveys of the scour area. The monitoring program indicated that the south jetty performed as expected. The rehabilitated jetty eliminated the source of material to the shoal area while the headland breakwaters stabilized North Assateague Island. No further erosion within the scour area was observed.

## TR CERC-94-7, NTIS No. AD A280 259, "Los Angeles and Long Beach Harbors, Model Enhancement Program, Effects of Wind on Circulation in Los Angeles-Long Beach Harbors," William C. Seabergh, S. Rao Vemulakonda, Lucia W. Chou, David J. Mark, April 1994.

A previously calibrated numerical three-dimensional hydrodynamic model for Los Angeles-Long Beach Harbors, California, was applied to study the combined effects of tide and wind on circulation. The model was calibrated and verified successfully with field data for a summer wind condition. In this report the calibration is compared to a no-wind condition to understand the effects of typical wind conditions on circulation. Also, wind conditions for approaching (winds from the southeast) and passing (winds from the north) frontal systems, typical of fall-winter weather patterns, were simulated. Results indicated the effects of wind can be significant.

## TR CERC-94-8, NTIS No. AD A , "Wave Conditions for Pier 400 Dredging and Landfill Project, Los Angeles Outer Harbor, Los Angeles, California," Robert R. Bottin, Jr., Hugh F. Acuff, May 1994.

A physical model study, using a 1:100 scale (undistorted) hydraulic model of Los Angeles Outer Harbor, California, was conducted to investigate short-period storm wave conditions for proposed harbor development located near the Angel's Gate entrance. The model reproduced two stages of the proposed Pier 400 dredging and landfill project, Angels' Gate entrance, portions of the existing breakwaters, and sufficient bathymetry in San Pedro Bay to permit proper reproduction of the required test waves. An 80-ft-long electrohydraulic, unidirectional, spectral wave generator and an automated data acquisition and control system were used in model operation.

## TR CERC-94-9, NTIS No. AD A "Kings Bay Coastal and Estuarine Physical Monitoring and Evaluation Program: Coastal Studies, Volume I: Main Text and Appendix A," Nicholas C. Kraus, Laurel T. Gorman, and Joan Pope, August 1994.

The objective of this study was to assess the impacts of U.S. Navy-sponsored navigation channel modification and maintenance activities conducted from 1985-1992 on the shoreline in the vicinity of the area traditionally called St. Marys Entrance. This inlet, separating Cumberland Island, Georgia, to the north and Amelia Island, Florida, to the south contains a large estuary, a commercial and recreational port, Fernandina Harbor, Florida, and, since the 1970s, a U.S. Navy submarine base located at Kings Bay, Georgia. A study of the coastal area included the following components:

a. Review of historical data and previous studies.

b. Numerical simulation of waves and shoreline change.

c. Monitoring of waves, water level, shoreline position, beach profile and sediments, and ebb-tidal bathymetry over the period 1988-1992.

No adverse impact on the beaches of Cumberland Island and Amelia Island by U.S. Navy navigation channel modification and maintenance at St. Marys Entrance could be detected in any of the analyses or monitoring in this study.

rates based on energy flux in the surf zone. Rates may be estimated at a point or integrated over a project reach. Both approaches require offshore wave conditions for input data, while the second option, estimates over a project reach, requires nearshore wave conditions as well. Results include estimated longshore sediment transport volume and rates. Both approaches produce estimates of left-directed, right-directed, net, and gross values for sea, swell, and combined sea/swell wave events. Options are available to visualize and save results.

## GENESIS

Presently, the GENESIS GUI represents the largest application in the ACES 2 package. The GENESIS model simulates long-term shoreline change based upon longshore sediment transport in response to an input time series of wave events. The GUI is used to prepare model data, control model execution, and analyze simulation results. It provides many new features to GENESIS users. Structures may be entered and edited in world coordinates, GENESIS cell numbers, or by graphically drawing them using the mouse. The initial shoreline and a measured shoreline may be plotted. After completion of the simulation, the shoreline evolution may be animated or stepped through by using data saved at a user-specified interval. Other post-simulation displays include left-directed, right-directed, gross and net longshore transports and rates.

## Additional applications

At present there are two other applications under development. The first is the Wave Station Analysis and Visualization code. It will provide statistical analysis of wave event time series and frequency distribution displays, and provide data editing for selected representative events. Storm Induced Beach Change (SBEACH) which models cross-shore sediment transport and profile response to storms is the other application under development. This code will provide many of the same tools as the GENESIS GUI adapted to the unique requirements of SBEACH.

## Future plans

Currently, the package is limited to USACE distribution and support, and initially available for Hewlett Packard (HP) 9000/700 series workstations. Minimal hardware recommendations for using ACES 2 include the above Unix-based workstation with at least 64 MB of memory, 2 GB of hard disk space, a 19-in. color monitor and a network connection. In addition to the Unix operating system, X Windows, Motif, TCP/IP services, and Internet connection are required. A postscript printer is supported but not required. Additional hardware information is available by anonymous ftp from puck.wes.army.mil in file "pub/a2.hrdwr.doc." Future plans for ACES 2 include porting the package to the Sun SPARC workstation, integrating HARBD (Harbor Wave Oscillation Model) and another wave transformation model (STWAVE or REFDIF) into the system. For additional information about ACES 2, contact David Leenknecht (email: david@puck.cerc.wes.army.mil).

# Tsunami '96

An international commemoration, Tsunami '96, will be held on the big island of Hawaii on April 1-2, 1996. This event will mark the 50th anniversary of the 1946 Hilo, Hawaii, tsunami and the centennial of the great Sanriku tsunami of 1896, and will coincide with the opening of the Hilo Tsunami Museum. The commemoration will review the lessons of the last 100 years and assess what still must be accomplished. Sponsors are the Tsunami Society, the International Tsunami Information Center, and others. For details contact the Tsunami Society, P.O. Box 25218, Honolulu, HI 96825, E-Mail: gcurtis@uhunix.uhcc.hawaii.edu, or E-Mail jlander@ngdc.noaa.gov.

# Calendar of Coastal Events of Interest

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| May 1 - 4, 1995 | Offshore Technology Conference, Houston, Texas, POC: FAX (214) 952-9435 |
| May 10, 1995 | Coastal Engineering Research Board, public meeting, Galveston, TX, POC: Sharon Hanks, (601) 634-2004 |
| May 24, 1995 | Annual Dredging Seminar, Minneapolis, Minnesota |
| May 25 - 26, 1995 | Western Dredging Association, Annual Meeting, Minneapolis, Minnesota |
| May 28 - Jun 1, 1995 | Conference on Great Lakes Research, Kellogg Center, Michigan State Univ., East Lansing, Michigan, POC: David T. Long, (517) 353-9618, FAX (517) 353-8787, E-mail: 14790dtl@msu.edu or John P. Giesy, (517) 353-2000, FAX (517) 423-1699, E-mail: 16990gny@msu.edu |
| Jun 5 - 9, 1995 | Conference on Great Lakes Research, University of Windsor, Ontario, POC: (519) 253-4232, ext. 2732, FAX (519) 971-3616 |
| Jun 11 - 16, 1995 | Offshore and Polar Engineering Conference, The Hague, The Netherlands POC: FAX (303) 420-3760 |
| Jul 17 - 22, 1995 | Coastal Zone '95, Tampa, Florida, POC: Dr. Billy Edge, (409) 847-8712, FAX (409) 845-6156, E-Mail: ble1010@sigma.tamu.edu |
| Aug 5 - 12, 1995 | Inter. Assoc. for the Physical Sciences of the Oceans, General Assembly, Hilton Hawaiian Village, Honolulu, POC: Internet: iapso@oceans.org |
| Sep 4 - 9, 1995 | Coastal Dynamics '95, Gdansk, Poland, email: cdsec@hapcio.ibwpan.gda.pl, FAX: (+4858) 524211 |
| Sep 6 - 8, 1995 | Coastal '95, Cancun, Mexico, email: cmi@ib.rl.ac.uk |
| Sep 18 - 20, 1995 | Remote Sensing for Marine and Coastal Environments, Seattle, Washington POC: FAX (313) 994-5123, Internet: wallman@vaxb.erim.org |
| Oct 9 - 12, 1995 | Oceans '95, San Diego, California |
| Oct 18 - 21, 1995 | 7th Canadian Coastal Conference, Bedford Institute of Oceanography, Nova Scotia, Canada, POC: FAX (902) 426-4104, Internet: solomon@agc.bio.ns.ca or Internet: tony.bowen@dal.ca |
| Oct 26 - 28, 1995 | Estuarine and Coastal Modeling Conference, San Diego, California POC: Malcolm Spaulding (401) 792-2537, FAX (401) 789-1932 Ralph T. Cheng (415) 354-3358, FAX (415) 354-3363 |
| Nov 12 - 16, 1995 | Estuarine Research Federation Conference, Marriott Bayfront, Corpus Christi, Texas, POC: Mary Garrett & Assoc., (512) 888-5400, FAX (512) 888-7401 |
| Nov 14 - 17, 1995 | 14th World Dredging Congress, Amsterdam, The Netherlands |
| Nov 20 - 23, 1995 | International Symposium on Ocean Cities, Monaco, POC: Dr. Jean-Pierre Damiano, E-mail: damiano@alto.unice.fr |
| Apr 1 - 2, 1996 | Tsunami 1996, Hilo, Hawaii, POC: Tsunami Society, PO Box 25218, Honolulu, HI 96825, E-Mail: gcurtis@uhunix.uhcc.hawaii.edu or jlander@ngdc.noaa.gov |

# CERC Book Chapters and Journal Papers

## Book Chapters

The following book chapters published in 1994 were authored or co-authored by CERC engineers and scientists.

Graber, H., V. Cardone, R. Jensen, S. Hasselmann, H. L. Tolman, and L. Cavaleri, "The Accuracy of Wind Field Description," Part IV.3.2., and Tolman, H. L., S. H. Hasselmann, H. Graber, R. E. Jensen, and L. Cavaleri, "Application to the Open Ocean," Part IV.8.4., Chapter IV, "Applications to Wave Hindcasting and Forecasting," in G. L. Komen, et al., (ed.) *Dynamics & Modelling of Ocean Waves*, Cambridge University Press, 1994.

## Journals

Listed below are journal papers authored or co-authored by CERC personnel published in 1994. This listing provides sources of information about CERC activities that are readily available in open literature.

Camfield, F. E., and D. R. Green, "Effect of the Next Data Point on Tsunami Flood Level Prediction," *Science of Tsunami Hazards*, Vol 12, No. 1, 1994.

Camfield, F. E., "Tsunami Effects on Coastal Structures," *Coastal Hazards, Journal of Coastal Research*, Special Issue No. 12, Chapter 12, 1994.

Chasten, M. A., J. W. McCormick, and J. D. Rosati, "Using Detached Breakwaters for Shoreline and Wetland Stabilization," *Shore & Beach*, Vol 62, No. 2, April 1994.

Cialone, M. A., "The Coastal Modeling System (CMS): A Coastal Processes Software Package," *Journal of Coastal Research*, Vol 10, No. 3, Summer 1994.

Estep, L., J. Lillycrop, and L. Parson, "Estimation of Maximum Depth of Penetration of a Bathymetric Lidar System Using a Secchi Depth Database," *Marine Technology Society Journal*, Vol 28, No. 2, Summer 1994.

Hubertz, J. M., R. M. Brooks, W. A. Brandon, and B. A. Tracy, "Hindcast Wave Information for the U.S. Atlantic Coast," *Journal of Coastal Research*, Vol 10, No. 1, Winter 1994.

Kraus, N. C., A. Lohrmann, and R. Cabrera, "New Acoustic Meter for Measuring 3D Laboratory Flows," *Journal of Hydraulic Engineering*, Vol 120, No. 3, March 1994.

Larson, M., and N. C. Kraus, "Temporal and Spatial Scales of Beach Profile Change, Duck, North Carolina," *Marine Geology*, Volume 117, 1994.

Mathiesen, M., Goda, Y., Hawkes, P.J., Mansard, E., Martin, M.J., Peltier, E., Thompson, E.F., and Van Vledder, G. "Recommended practice for extreme wave analysis." *Journal Of Hydraulic Research*, 32(6), 803-814.

McAneny, D. S., "Regional Coastal Databases for Corps of Engineers Districts," *Journal of Coastal Research*, Vol 10, No. 2, Spring 1994.

Smith, J. B., and D. M. FitzGerald, "Sediment Transport Patterns at the Essex River Inlet Ebb-Tidal Delta, Massachusetts, U.S.A.," *Journal of Coastal Research*, Vol 10, No. 3, Summer 1994.

Thompson, E. F., and J. Oliver, "Wave Grouping in Locally Generated Seas on Short Fetches," *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol 120, No. 2, March 1994.

Thompson, E. F., and D. A. Leenknecht, "Wind Estimation for Coastal Modeling Applications," *Journal of Coastal Research*, Vol 10, No. 3, Summer 1994.

Vincent, C. L., and R. E. Jensen, "Wave Current Interaction at an Inlet," *Shore & Beach*, Vol 62, No. 4, October 1994.

Walton, T. L., "Shoreline Solution for Tapered Beach Fill," *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol 120, No. 6, November 1994.

Yeh, H., P. Liu, M. J. Briggs, and C. Synolakis, "Propagation and Amplification of Tsunamis at Coastal Boundaries," *Nature*, Vol 372, 24 November 1994.

## Publications by Contractors

The following journal paper was prepared under a contract issued by CERC.

Weisman, R. N., and G. P. Lennon, "Design of Fluidizer Systems for Coastal Environment," *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol 120, No. 5, September 1994.

# Publications of Interest

*The following publications are available from the sources indicated. They are not available from CERC.*

*Alabama's Artificial Reefs*, Report MASGP-94-006, and *Artificial Reefs: Design, Placement and Permitting*, Report MASGP-94-010. Available from Mississippi-Alabama Sea Grant, P.O. Box 7000, Ocean Springs, MS 39566-7000.

*Governor's Coastal Erosion Task Force: Final Report - Summary of Recommendations*, 1994, 9 pages; *Volume I: Emergency Response to Coastal Storms*, 1994, 71 pages; *Volume II: Long-Term Strategy*, 1994, 291 pages. Single copies of the Summary are available free from Bill Daley, State of New York, Department of Environmental Conservation, 50 Wolf Road, Albany, NY 12233-3507; telephone (518) 457-3157. Contact Bill Daley at above address for information on availability of Volumes I and II.

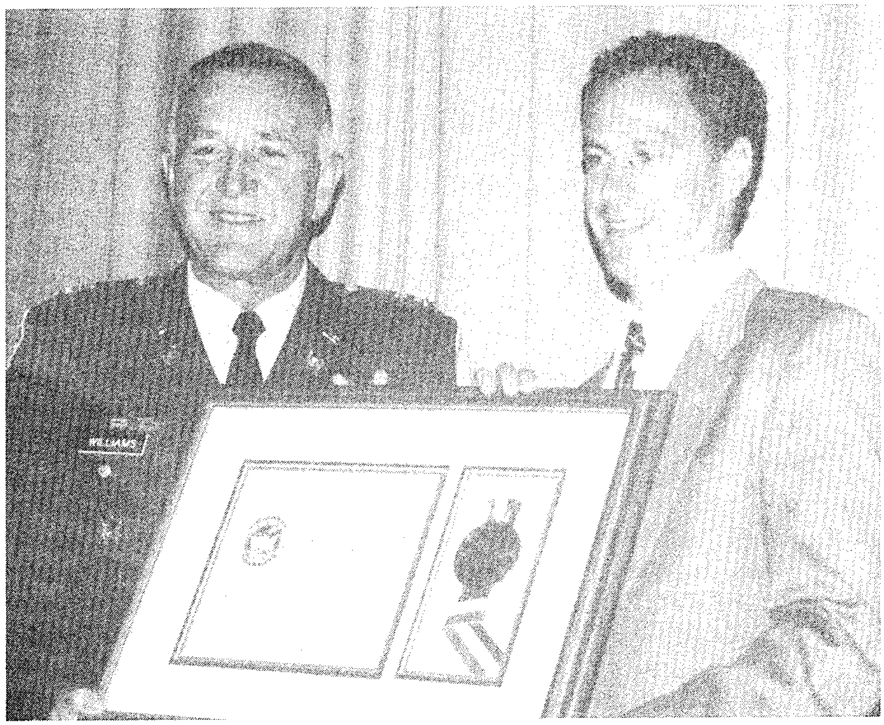
*Mitigation of Flood and Erosion Damage to Residential Buildings in Coastal Areas: Report on the State of the Art*, FEMA 257, 1994, 34 pages, free. Copies can be requested from the Federal Emergency Management Agency, Publications, 8231 Stayton Drive, Jessup, MD 20794; telephone (202) 646-3484.

*An Introduction to Coastal Zone Management*, 1994, 212 pages, $29.95 paperback, $49 hard cover, plus $4.25 shipping for the first copy, $1 shipping for each additional copy. Add sales tax where applicable. Copies available from Island Press, PO Box 7, Covelo, CA 95428; telephone (800) 828-1302.

*Geologic Hazards Photos*, CD-ROM, two-volume set, $71, prepayment required, MasterCard, VISA, and American Express accepted. Photos include general tsunami photos, earthquakes, volcanos, etc. Images on the CD's are in both a 24-bit TIF image and a compressed 8-bit PCX image. Included with each image is a caption. Windows-based access software is provided for PCX images only. Order from National Geophysical Data Center, E/GC4, Dept. 953, 325 Broadway, Boulder, CO 80303-3328; telephone (303) 497-6607, E-mail: info@ngdc.noaa.gov.

# Gustave Willems Award

General Williams, Chief of Engineers, presented Gordon Harkins with U.S. Section, Permanent International Association of Navigational Congress (PIANC) Gustave Willems Award for 1994. The Gustave Willems competition was created for "young" engineers or scientists (under the age of 35) who are required to submit a paper on port and waterways development. Mr. Harkins' paper entitled "The Effectiveness of Rubble Mound Breakwaters at Barbers Point Harbor" summarized the decrease in long period (greater than 25 seconds) energy due to very oblique wave incidence on the rubble-mound structure. Mr. Harkins is a physical modeler in the Wave Dynamics Division in the Coastal Engineering Research Center, Waterways Experiment Station.



# ICCE '96 Announcement and Call for Papers

The Silver 25th International Conference on Coastal Engineering (ICCE '96) will be held at the Peabody Hotel, Orlando, FL, on September 2-6, 1996. ICCE '96 will be preceded by optional three-day short courses on a variety of subjects. Registration will begin on Sunday, September 1, and there will be an opening mixer that evening. Technical sessions will be held from Monday, September 2, to noon on Friday, September 6. Conference dress will be casual, and conference attendees are encouraged to bring their families to enjoy the attractions in Orlando.

Original papers will be presented on the theory, measurement, and case studies on the following and related topics:

- Coastal Oceanography and Meteorology (wind, waves, currents, water levels).
- Coastal Sediment Processes (sediment motion, sediment transport, morphology change).
- Shore Protection (beach nourishment, bypassing, hard structures, hybrid projects).
- Coastal Structures (stability, construction techniques, performance).
- Coastal Environment (recreation, water quality, wetlands, estuaries).
- Dredging (harbors, ports).

Authors are invited to submit five copies of a summary in English (not longer than two A4 pages including figures, tables, and references). The summary should include a title, and affiliations and complete addresses of the authors. Deadline for summaries is September 15, 1995. Authors will be notified of the status of abstracts in January 1996. Summaries should be mailed to:

Dr. Billy L. Edge
Secretary, Coastal Engineering Research Council
Ocean Engineering Program
Texas A&M University
College Station, Texas 77843-3136
USA

English will be the official language of the conference.

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***East Beach and Ninigret Pond, Rhode Island. Aerial photograph taken from about 1,000-ft altitude, view to west. April 1977.*** **Photo by Andrew Morang**

# The CERCular
## *Coastal Engineering Research Center*

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the US Army Engineer Waterways Experiment Station. The publication is part of the technology transfer mission of CERC. Results from ongoing research programs will be presented. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. Contributions of pertinent information are solicited from all sources and will be considered for publication. Communications are welcomed and should be addressed to the Coastal Engineering Research Center, ATTN: Dr. Fred E. Camfield, US Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call 601/634-2012, FAX 601/634-3433. Internet: CAMFIELD@COAFS1.WES.ARMY.MIL

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