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 dolos. 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 focused 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.

![Core-loc dimensions](image-url)

*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-loc's 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-loc's 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](image_url)
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-loc 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.

**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.

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Core-loc</th>
<th>Dolos</th>
<th>Accropode</th>
<th>Tribar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsion</td>
<td>1.00</td>
<td>1.86</td>
<td>1.36</td>
<td>2.66</td>
</tr>
<tr>
<td>Flexure - fluke tip load</td>
<td>1.00</td>
<td>2.15</td>
<td>1.36</td>
<td>3.00</td>
</tr>
<tr>
<td>Flexure - fluke center load</td>
<td>1.88</td>
<td>3.05</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Combined flexure and torsion</td>
<td>1.70</td>
<td>3.42</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

$\sigma_e$ 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**
Future core-loc research, prototype projects, and licensing

Basic research on core-loc response continues, both in two- 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


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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.
Dredging Research Program


The report describes a computer-based software package (SHORELINE MODELING SYSTEM) that contains a collection of generalized computer programs assembled to enable users to perform complete longshore sediment transport processes and shoreline evaluation assessments. This software package was developed at the Coastal Engineering Research Center (CERC) to facilitate the technology transfer of recent research findings to coastal engineering managers throughout the Corps. The modeling system is presently comprised of 2 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.


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 transported or lost at a designated coastal reach 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 coastal and oceanographic processes on sediment movement.
- Effects of tidal and other coastal currents on sediment movement.
- Sediment accretion rates at barriers and bars.
- Historical shoreline changes.
- Long-term measurements of littoral profiles.

Sediment sources and transport paths must be identified as part of the sediment budget program. In many cases, important sources are apparent from visualization of the geomorphic characteristics 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 the identification of all sources. Techniques for source identification and quantification of sediment supply and loss are important areas of continued research efforts to improve the methodology.


This report provides guidance for implementing SBEACH, the Storm-Induced Beach Change (SB) model, via a user interface available for the personal computer. SB EACH simulates beach profile change, including the formation and movement of major morphologic features such as shoreline bars, troughs, and berms, under varying storm waves and water levels. The personal computer version of SB E ACH 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 SB E ACH 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.


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 en- screen displays of data and results and can be used to post-process results and results can be 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 Dior Operating System (DOS) running on a personal computer (PC).


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


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-distributed currents impacting bridge piers at project sites. Model DYNLETT1 is used to compute the storm-induced velocities near bridge piers. DYNLETT1 is a one-dimensional (1-D), shallow-water, hydrodynamic model for predicting velocities and water level fluctuations in a system of inlets and bays (Amein and Kraus 1992). An important feature of the model is its 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 DYNLETT1 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.


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

Presque Isle is a unique and significant coastal feature on the south shore of Lake Erie at Erie, Pennsylvania. It is a compound, recurved sand spit that arches lakeward about 2½ miles from an offshore point, to which it tapers landward. 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. Processes responsible for the geologic evolution of this feature will also be responsible for its eventual destruction unless steps 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 a truly rich ecological laboratory that allows the process of primary plant and animal succession to be studied in a relatively diverse range of 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 vicinity of the beach radius, environmental, engineering, and socioeconomic issues could not be presented here. 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.


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 analyzing shorefront erosion problems along Revere Beach and Point of Pines (POP) coastal area. 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. CERC was to evaluate the beach profile changes. A review of historical information pertaining to the evolution of Presque Isle Peninsula and an analytical-empirical "desktop" analysis were performed.


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


This report describes the observed and modified wind and wave parameters during the first intensive observation period (IOP-1) from October 30-31, 1990, of the Surface Wave Dynamics Experiment. The measurements include wind speeds and directions, wave heights and periods, and air and sea temperatures, and atmospheric pressures. Four wave meteorological buoy systems, four meteorological buoys, and several wave propagation systems were used. The data were collected from the National Data Buoy Center (NDBC). In addition, a number of directional wave spectra are 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.


A 2.5-D finite element laboratory and field tests were conducted to examine effects of waves and currents on a simulated dual-rocket distributed explosive array deployment (DRDEAD) system. DRDEAD system consists of a large array of explosive material which can be deployed by rockets launched from Navy vessels across the surr area. A review of historical information pertaining to the evolution of Presque Isle Peninsula and an analytical-empirical "desktop" analysis were performed.


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This report includes comparisons of the present year's data with cumulative statistics from 1982 to the present. Meteorological and oceanographic data, monthly bathymetric survey results, samples of biological communities and observations of 18 storms that occurred during the year are summarized in this report. The year was highlighted by a major storm (the Hallowe Phone Storm) in late October. Waves with 6m significant height and periods exceeding 25 sec were measured 6 km from shore. This year is the 13th in a series of annual summaries of data collected at the FP, that began with a Miscellaneous Report CERC-82-16, which summarized data collected during 1977-1979.


This design procedure includes statistical methods for determining a design stress in a dolos armor layer. The methods involve the use of the stress response function: the maximum principal tensile stress in each class. Using this approach, the dolos shape can be optimized for structural integrity and hydrodynamics, and this design can be verified in the physical model, without necessitating additional specific design.

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.


As ocean waves propagate into shallow water, they exhibit increasingly strong nonlinearity. One important nonlinear effect is the occurrence 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. Amplitude and LOTS operations can be seriously impacted by currents, water level variations, and surf zone surf beat induced by surf beat. Data were obtained from the U.S. Army Engineer Waterways Experiment Station's laboratory and field facilities. A theoretical formulation for the surf zone was developed to evaluate the data sets and used to develop guidelines for predicting surf beat.


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 project to prevailing coastal processes. The Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project has shown the successal placement of a beach nourishment 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. Reconnaissance 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 steeper, bar-trough type profile typical of the southern portion of the fill. The "hot spots" of erosion occurred in areas where a shoal system attaches to the shoreline, as shown at 81st Street. The erosion pattern associated with these shoals was probably caused by waves and currents diverging and diverging 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. Composite samples were constructed of the foreshore and nearshore 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 surface layer of four meters of coarse nearshore lag and the nearshore lag and material at the more than 81st Street location and finer material at the more stable 81st Street location. After 9 months, the fill material was taking on the characteristics of the pre-fill native beach.


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 uniform, model to prototype. Barretet test that a 4- to 6-ton armor stone is stable for the maximum wave heights that can be expected to occur for 8- to 10-soc waves at still-water levels (swells) of 4.0 to 14.0 m long, with assumed scour depths of 3.5 to 6.8 m, and that a concrete block, which was 6.0 lb 5.5 ft 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- to 10-soc waves at swells of 4.0 to 14.0 m with an assumed scour depth of 3.6 m, and c. Several modified block plans were tested and it was determined that the optimum block size was 5.75 ft 5.75 ft 2.5 ft. These blocks, weighing 5 tons and having a 40 percent porosity, would be able to withstand the maximum wave heights that can be expected to occur for 8- to 10-soc waves at swells of 0.0 to 14.0 m with an assumed scour depth of 10 m.


A 3-dimensional model study of a damaged Burns Waterway Harbor breakwater was conducted. The 1/3-scale undrained fume tests were used to evaluate various repair options that included placing a submerged breakwater lateral of the existing breakwater, attaching a berm breakwater to the lateral of the existing breakwater, the construction of an 8-ft concrete block, and placing the existing breaker into structural placement at the crest.

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


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 oxygen and its immediatevicinity of the proposed expansion. The redesign of the study, 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 these summer season 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.


Three long-period wave spectra were selected for use in the Los Angeles - Long Beach Harbors physical model for harbor studies. They included two storms: 1) Feb 1996 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 areas. It is required that the light water model where pre-conditions are included. 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 six 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.


This report summarizes the field monitoring program and physical and numerical model studies that have been conducted to date for Barbers Point Harbor, Oahu, Hawaii. The harbor has been selected for study as part of the Monitoring Component of the Pacific Oceans Project in FY 1995. 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 for the study area, (c) a comparison of model and prototype data, and (d) a comparison of model and prototype data. Recommended additions to the study include the development of a more detailed water quality model and the collection of additional field data to better understand the bar formation process. A more detailed water quality model would be useful for evaluating 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.


Detached breakwaters can be a valid method of shoreline stabilization and protection in the United States. Breakwaters are 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 detached breakwaters and beach fill is increasingly important in the management of coastal resources as established 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 and the use of available tools to assist in breakwater design. Functional design guidance includes a review of existing analytical techniques and design procedures. Functional design considerations include maximum wave heights and wave directions. 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 the natural and physical processes that contribute to a morphological response to detached breakwaters, and a case example of a breakwater project designed and constructed at Bay Ridge, Maryland.
A 5-year, 7,500 case database of high-resolution, shallow-water, frequency-direction spectra is examined by means of the frequency-direction characteristics of wave height, peak spectral frequency, and spectral direction. Counting the number of cases in each classification reveals the distribution of the spectral population in the three-parameter directional spectrum. The characteristics of wave height, peak spectral frequency, and spectral direction can be used to describe nearshore wave conditions more completely than when only three parameters are known or estimated. The results are significant and unique to the North Carolina data region, both in relation to characteristic spectra that can be used to describe nearshore wave conditions more completely when only three parameters are known or estimated. The results are significant and unique to the North Carolina data region, both in relation to characteristic spectra that can be used to describe nearshore wave conditions more completely when only three parameters are known or estimated.

Measured storm wave frequency-direction spectra are presented to illustrate the evolution of wind wave energy distribution near beaches of high energy. Twenty-nine storm events, extracted from a 5-year database, are identified and described. Inconsistency of a nine-element linear array of bottom-mounted pressure gauges distributed along the 6-km isobath around 800 ft depth in the Cape Fear Research Facility (CFRF) of the U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC): 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 localized storms known as “northeasters” have a curious recurrent pattern of broad directional distributions. The results are significant and unique to the North Carolina data region, both in relation to characteristic spectra that can be used to describe nearshore wave conditions more completely when only three parameters are known or estimated.

This report provides information and data documenting a coastal processes project called the SUPERTANK Data Collection Project performed at the H. H. Howland Wave Research Laboratory at Purdue University, between the 25th and 30th of each month. The objectives of the project were: (a) collect data to verify and improve existing macroscale 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, test-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 information and expertise.

A 1:75-scale undisturbed 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 were evaluated. The model reproduced the river from its mouth to a point approximately 15,000 ft upstream, both Noyo Harbor and Dolpin Marina located on the south bank, approximately 3,400 ft of the California coastline on each side of the river mouth, Noyo cove, and sufficient offshore area in the Pacific Ocean to permit generation of the required test waves. A 40-ft-long wave generator, cohoat 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 ranging from 8.5 to 13.7 ft, and for operational conditions (incidence 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 conditions and 8.7 to 14.0 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 beach being achieved on approximately 90% of the time with correspondingly high winds present. More than 150 percent of the time it is currently present for operational conditions when operational waves are present. The magnitude of wave heights will also decrease by about 25 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 under 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, the breakwater will tend to deposit in an area in the cove between the existing jetted entrance and the proposed breakwater location, both in the breakwater area and at the head of the breakwater area.

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 seaward 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, Dolpin Marina, and the lower reaches of the river.

Frequent dredging requirements and scouring at the foundation of Ocean City’s south jetty resulted in a study to determine the source of the scouring and sealing. 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 byebb currents where it encroached on the Federal navigation channel. A rehabilitation program was initiated to create a littoral barrier to elimnate the shooing problem and to repair the scour field. Three headland breakwaters were constructed to stabilize South Jetty, Assateague Island. The site was selected as part of the Monitoring Completed Coastal Projects (MCSCP) Program to determine how well the rehabilitation project accomplished its design purpose. The monitoring program continued from October 1990 through January 1994. Activities included beach and offshore surveys, aerial and ground photography of the inlet and adjacent shorelines, inlet hydraulic surveys, non-directed wave gauging, and side-scan sonar surveys of the scour area. The monitoring indicated that the south jetty performed as expected. The rehabilitated jetty eliminated the source of material to the inlet while the headland breakwaters stabilized North Assateague Island. No further erosion within the cove area was observed.

A previously calibrated 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, front systems, typical of winter weather patterns, were simulated. Results indicated the effects of wind can be significant.

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 the two stages of the proposed Pier 400 dredging and landfill project. Angel’s Gate entrance, the spectral peaks and troughs of the existing breakwaters, and sufficient bathymetry in San Pedro Bay to permit performance of the required test waves. An 80-ft-long electroacoustic, nondirectional, spectral wave generator and an automated data acquisition and control system were used in model operation.

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. Mary’s 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.


d. No adverse impact on the beaches of Cumberland Island and Amelia Island by U.S. Navy navigation channel modification and maintenance at St. Mary’s 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

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1 - 4, 1995</td>
<td>Offshore Technology Conference, Houston, Texas, POC: FAX (214) 952-9435</td>
<td></td>
</tr>
<tr>
<td>May 10, 1995</td>
<td>Coastal Engineering Research Board, public meeting, Galveston, TX,</td>
<td>POC: Sharon Hanks, (601) 634-2004</td>
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<tr>
<td>May 24, 1995</td>
<td>Annual Dredging Seminar, Minneapolis, Minnesota</td>
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<tr>
<td>May 25 - 26, 1995</td>
<td>Western Dredging Association, Annual Meeting, Minneapolis, Minnesota</td>
<td></td>
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<tr>
<td>May 28 - Jun 1, 1995</td>
<td>Conference on Great Lakes Research, Kellogg Center, Michigan State Univ., East</td>
<td>Lansing, Michigan, POC: David T. Long, (517) 353-9618, FAX (517) 353-8787,</td>
</tr>
<tr>
<td></td>
<td>Lansing, Michigan, POC: David T. Long, (517) 353-9618, FAX (517) 353-8787,</td>
<td>E-mail: <a href="mailto:14790dtl@msu.edu">14790dtl@msu.edu</a> or John P. Giesy, (517) 353-2000, FAX (517) 423-1699,</td>
</tr>
<tr>
<td></td>
<td>E-mail: <a href="mailto:14790dtl@msu.edu">14790dtl@msu.edu</a> or John P. Giesy, (517) 353-2000, FAX (517) 423-1699,</td>
<td>E-mail: <a href="mailto:16990gny@msu.edu">16990gny@msu.edu</a></td>
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<tr>
<td>Jun 5 - 9, 1995</td>
<td>Conference on Great Lakes Research, University of Windsor, Ontario,</td>
<td>POC: (519) 253-4232, ext. 2732, FAX (519) 971-3616</td>
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<tr>
<td>Jul 17 - 22, 1995</td>
<td>Coastal Zone ’95, Tampa, Florida, POC: Dr. Billy Edge, (409) 847-8712,</td>
<td>FAX (409) 845-6156, E-Mail: <a href="mailto:bie1010@sigma.tamu.edu">bie1010@sigma.tamu.edu</a></td>
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<tr>
<td>Jul 23 - 29, 1995</td>
<td>Coastal Zone ’95, Tampa, Florida, POC: Dr. Billy Edge, (409) 847-8712,</td>
<td>FAX (409) 845-6156, E-Mail: <a href="mailto:bie1010@sigma.tamu.edu">bie1010@sigma.tamu.edu</a></td>
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<td>Aug 5 - 12, 1995</td>
<td>Inter. Assoc. for the Physical Sciences of the Oceans, General Assembly, Hilton</td>
<td>Hawaiian Village, Honolulu, POC: Internet: <a href="mailto:iapso@oceans.org">iapso@oceans.org</a></td>
</tr>
<tr>
<td>Sep 4 - 9, 1995</td>
<td>Coastal Dynamics ’95, Gdansk, Poland, email: <a href="mailto:cdsec@hapcio.ibwpan.gda.pl">cdsec@hapcio.ibwpan.gda.pl</a>,</td>
<td>FAX: (+4858) 524211</td>
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<tr>
<td>Sep 6 - 8, 1995</td>
<td>Coastal ‘95, Cancun, Mexico, email: <a href="mailto:cmi@ibrl.ac.uk">cmi@ibrl.ac.uk</a></td>
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<tr>
<td>Oct 9 - 12, 1995</td>
<td>Oceans ’95, San Diego, California</td>
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<tr>
<td>Oct 18 - 21, 1995</td>
<td>7th Canadian Coastal Conference, Bedford Institute of Oceanography, Nova Scotia,</td>
<td>Canada, POC: FAX (902) 426-4104, Internet: <a href="mailto:solomon@agc.bio.ns.ca">solomon@agc.bio.ns.ca</a> or</td>
</tr>
<tr>
<td></td>
<td>7th Canadian Coastal Conference, Bedford Institute of Oceanography, Nova Scotia,</td>
<td>Internet: <a href="mailto:tony.bowen@dal.ca">tony.bowen@dal.ca</a></td>
</tr>
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<td>Canada, POC: FAX (902) 426-4104, Internet: <a href="mailto:solomon@agc.bio.ns.ca">solomon@agc.bio.ns.ca</a> or Internet:</td>
<td><a href="mailto:tony.bowen@dal.ca">tony.bowen@dal.ca</a></td>
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<tr>
<td></td>
<td>Estuarine and Coastal Modeling Conference, San Diego, California</td>
<td>Ralph T. Cheng (415) 354-3358, FAX (415) 354-3363</td>
</tr>
<tr>
<td>Nov 12 - 16, 1995</td>
<td>Estuarine Research Federation Conference, Marriott Bayfront, Corpus Christi,</td>
<td>Texas, POC: Mary Garrett &amp; Assoc., (512) 888-5400, FAX (512) 888-7401</td>
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<tr>
<td>Nov 14 - 17, 1995</td>
<td>14th World Dredging Congress, Amsterdam, The Netherlands</td>
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<tr>
<td>Nov 20 - 23, 1995</td>
<td>International Symposium on Ocean Cities, Monaco, POC: Dr. Jean-Pierre Damiano,</td>
<td>E-mail: <a href="mailto:damiano@alto.unice.fr">damiano@alto.unice.fr</a></td>
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<tr>
<td>Apr 1 - 2, 1996</td>
<td>Tsunami 1996, Hilo, Hawaii, POC: Tsunami Society, PO Box 25218, Honolulu, HI</td>
<td>96825, E-Mail: <a href="mailto:gcurtis@uhunix.uhcc.hawaii.edu">gcurtis@uhunix.uhcc.hawaii.edu</a> or <a href="mailto:jlander@ngdc.noaa.gov">jlander@ngdc.noaa.gov</a></td>
</tr>
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</table>
Book Chapters

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


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.


Publications by Contractors

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

Publications of Interest

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


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. Edg
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.
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