Coastal Engineering Technical Note

Analysis of the Performance of the Prefabricated Erosion Prevention (P.E.P.) Reef System Town of Palm Beach, Florida

by Thomas R Martin and J. Bailey Smith

INTRODUCTION

A prefabricated erosion prevention (P.E.P.) reef was installed during the summer months of 1992 and 1993, at the Town of Palm Beach in Palm Beach County, FL (Figure 1). The

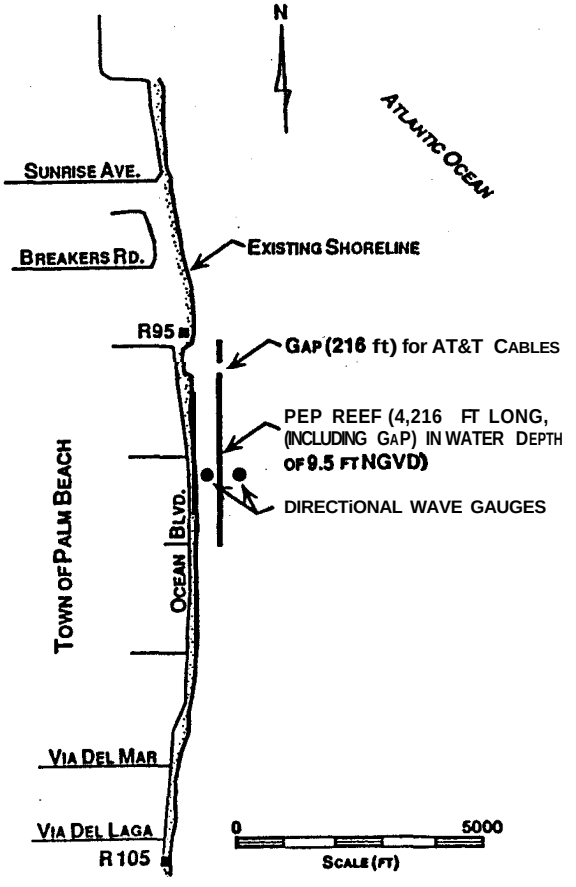

Figure 1. Palm Beach, FL, P.E.P. reef installation

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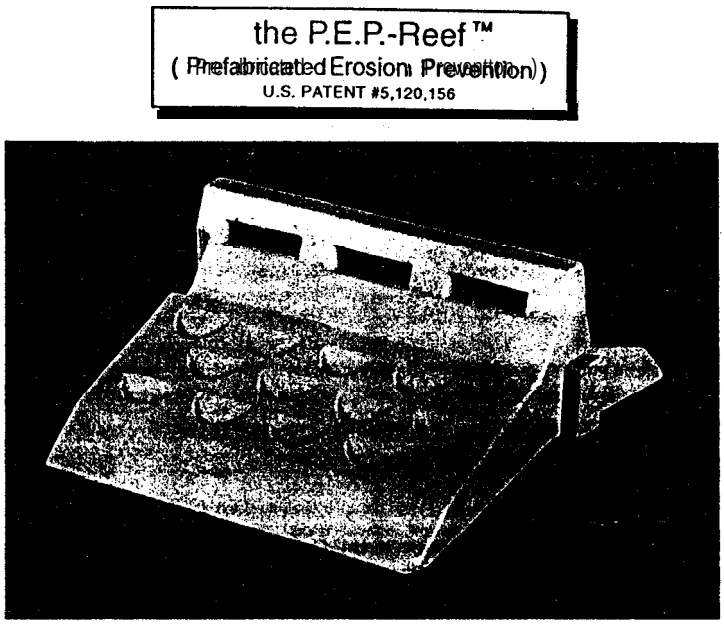
reef was constructed at the Midtown segment of the Palm Beach Shore Protection Project. The structure consists of 330 interlocking wedge-shaped concrete modules (Figure 2) placed approximately 76 m (250 ft) offshore, in 2.9 m (9.4 ft) (National Geodetic Vertical Datum) (NGVD)) of water. The total length of the structure is 1,273 m (4,176 ft), including a 66-m (216-ft) gap near the north end for a submerged cable easement. The purpose of the structure is to reduce incident wave energy, allowing accretion of sediment in the lee of the structure.



Length	12 ft.
Width..	15 ft.
Height..	6 .
Concrete	5000 P.S.I. Reinforced
Approx.	Weight 50,000 Ibs.

Figure 2. P.E.P. reef module

AUTHORIZATION

The fiscal year 1995 Energy and Water Development Appropriation bill directed the Corps to evaluate the performance of the reef and report its plans to reimburse the Town of Palm Beach. State permits for the P.E.P. reef at this location required monitoring surveys and periodic reports evaluating the reefs performance over a 3-year period and assessing the impacts of the reef system on littoral processes in the project area.

HISTORY

Construction of the P.E.P. reef began with the placement of 56 units by mid-August 1992. On August 24, 1992, the area was impacted by Hurricane Andrew. Following the passage of Andrew, the 57th unit was placed and the area was surveyed. This survey determined that the reef had exceeded the limits of settlement expectations, and further installation of the units was postponed while the settlement issue and P.E.P. reef performance criteria were analyzed. Further monitoring over a 4-month period indicated that additional settlement was minimal, and the reef units appeared to be approaching an equilibrium depth. In May 1993 construction resumed, and in August 1993 placement of 273 additional units was completed.

MONITORING

A monitoring program has been under way since completion of the P.E.P. reef installation. The University of Florida's Department of Coastal and Oceanographic Engineering has performed physical monitoring of the project and has produced several reports (University of Florida 1994a, 1994b). A four-month monitoring report on the P.E.P. reef was prepared by Coastal Technology Corporation (1992). Physical surveys were performed in July 1992, April 1993, August 1993, December 1993, and July 1994. Each survey consisted of 75 profile lines. Wave gauges were placed landward and seaward of the reef in about 1.8 m (6.0 ft) and 3.7 m (12.0 ft) of water, respectively. Volumetric analyses for the 356,736-sq-m (3,840,000-sq-ft) area were performed based on the four surveys. Volumetric changes were analyzed for each of the following six regions: landward and seaward of the structure along the 1,220-m (4,000-f?) reach of shoreline west of the reef (cells 1 and 2, respectively), landward and seaward of an extension of the reefs axis along the 610-m (2,000-ft) northern reach (cells 3 and 4, respectively), landward and seaward of the structure along the 610-m (2,000-ft) reach south of the structure (cells 5 and 6, respectively).

SETTLEMENT

Updated measurements of the settlement of the concrete units were taken during the two 1994 surveys; the 57 units placed in 1992 appear to have stabilized at an average settlement of 0.8 m (2.7 A). The remaining 273 units have settled an average of 0.5 m (1.6 ft) and are approaching equilibrium. The greater settlement (0.3 m (1.1 R)) of the original 57 units is attributed to the effects of Hurricane Andrew immediately following placement of the units. During this period, the scour rods indicated scour depths around the reef ranging from 0 to over 0.6 m (2 ft).

WAVES

The wave gauges landward and seaward of the structure were operational for the study period, and continued to indicate transmission coefficients of 0.65 for larger waves to 0.85 for smaller waves. These values are lower than those predicted by theory for the structure placed at the design crest elevation. In order to determine the difference in wave height attenuation due to the structure, and due to shoaling effects, additional field wave gauges were placed first adjacent to the long-term gauges, and then as control gauges at similar water depths as the long-term gauges 500 ft to the

south of the structure. Analyses of these data show that the transmission coefficients resulting from the absence of the reef are in the range of 0.85 to 0.95, which are much larger than determined from the analysis of the two long-term gauges alone (0.65 to 0.85). Apparently, wave energy dissipation occurs between the locations of the two gauges, even in the absence of the reef

VOLUMES

The total volumetric change over the 356,735-sq-m (3,840,000-sq-fi) area from July 1992 through July 1994 was -38,230 cu m (-50,000 cu yd) (University of Florida 1994b), which translates to an annualized volume change of - 19,115 cu m. Except for the 4-month period following installation of the first 57 P.E.P. reef units (the net volume change within the project area was +9,372 cu m (+12,257 cu yd) (Coastal Technology Corporation 1992)), net volumetric changes within the project area have been erosive. The volumetric changes measured from July 1992 to July 1994 for the six regions defined above are presented in
Table 1.

Historical volumetric changes were also computed, in order to more accurately determine the effect of the P.E.P. reef on the sediment budget of the project area. Analysis of beach profiles surveyed in 1987 and 1992 shows that the area generally accreted material naturally, prior to installation of the P.E.P. reef. The total volumetric change over the entire study area during the 1987-1992 time period was +81,812 cu m (+107,000 cu yd), which translates to an annualized volume change of . +16,362 cu m (+21,399 cu yd). These results indicate that the general trend throughout the study area was accretionary prior to placement of the P.E.P. reef, turning to erosional following the placement of the structure. Volumetric changes during the period 1987-1992 for the six regions of the project area are presented in Table 1.

ANALYSIS

As noted in the 12-month monitoring report, an overall erosional trend occurred within the project area. All areas of the study area eroded except for the region south and landward of the reef In addition, some minimal accretion was noted near the north end of the reef This pattern of volumetric change suggests that the physical mechanism of longshore current generation caused by wave mass transport over the reef as described in the 6-month monitoring report may be valid. This phenomenon is described as “ponding,” since mass transport over the reef due to wave action creates a rise in water surface elevation, which is relieved by longshore flow. This process transports sediment from the region landward of the reef toward the north and south ends of the reef In the presence of a longshore current, this localized circulation near the reef will be superimposed on the longshore current. Since the direction of peak wave energy is from the northeast, localized circulation near the reef is skewed to the south, resulting in the high rates of accretion observed in recent surveys, while much less accretion is noted to the north. This “ponding” phenomenon was demonstrated in a laboratory study performed at the University of Florida (University of Florida 1996).

Table 1
Volumetric Changes of the Six Cell Network of the Palm Beach, FL, P.E.P. Reef Project

Cell Number and Location	July 1992 - July 1994		July 1987 - July 1992	
	Annualized Volumetric Change (cu m)	Annualized Volumetric Change/Linear Foot of Shoreline (cu m/yr/ft)	Annualized Volumetric Change (cu m)	Annualized Volumetric Change/Linear Foot of Shoreline (cu m/yr/ft)
1 - Landward of Structure	-22,020	-5.5	+2,156	+0.5
2 - Seaward of Structure	-612	-0.3	+3,517	+0.9
3 - Landward and North of Structure	-5,887	-2.9	+2,523	+1.3
4 - Seaward and North of Structure	+497	+0.2	-428	-0.2
5 - Landward and South of Structure	+16,057	+8.0	+2,798	+1.4
6 - Seaward and south of Structure	-7,149	-3.6	+5,796	+2.9
Total Volume Change (cu' m/yr)	-19,115		+16,362	

One mechanism which may be responsible for the shoreline and physical process response in the vicinity of the Palm Beach P.E.P. reef system may be the single solid sill configuration. Physical and numerical model tests have been performed subsequent to the Palm Beach installation to improve the P.E.P. reef system configuration plan (Florida Institute of Technology 1995). As a result of these tests, a new configuration has been implemented at a P.E.P. reef system installation recently completed (i.e. September 1996) at Vero Beach, Indian River County, FL. This installation includes both a staggered and gapped configuration (Figure 3).

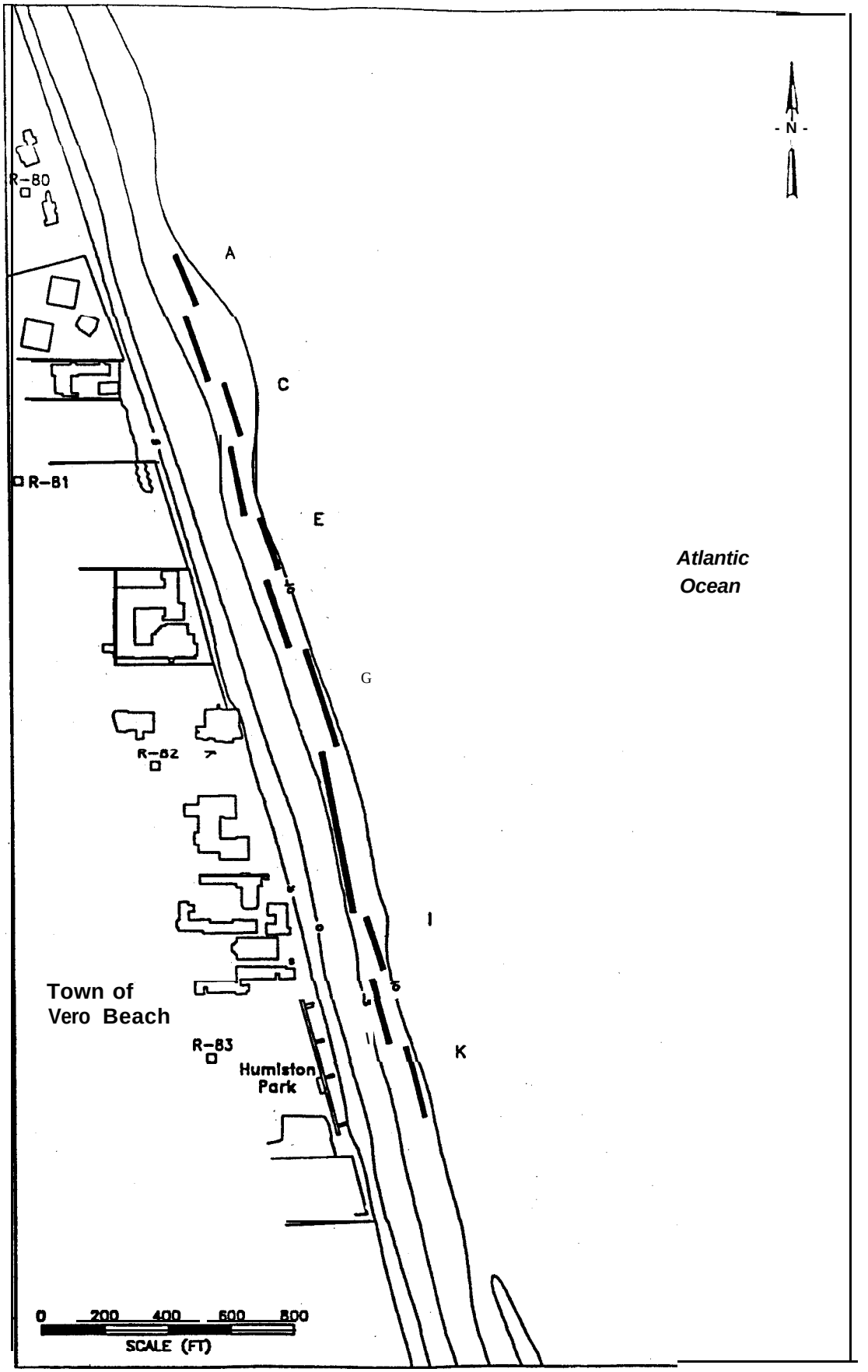


Figure 3. Vero Beach, FL, P.E.P. reef installation

The Coastal and Hydraulics Laboratory (CHL) of the U.S. Army Engineer Waterways Experiment Station is coordinating the monitoring program as an independent agency for Indian River County, FL (Coastal Engineering Research Center 1995). Monitoring results will be released in the future.

CONCLUSIONS

Monitoring data contained in reports by the University of Florida (1994a, 1994b) indicate that the P.E.P. reef at Palm Beach, FL, provided little benefit to the area behind the structure, and to the adjacent beaches. Volumetric changes were computed in the University of Florida reports (1994a, 1994b) based on beach profile monitoring surveys. These surveys indicate that during the July 1992 to July 1994 period, a net loss of material was observed throughout the project area. These losses became more significant when compared to the accretionary trend in the area prior to placement of the P.E.P. reef All portions of the project area eroded consistently, except for the region south and landward of the P.E.P. reef This area consistently accreted material during the study period, and the "ponding" process described in the University of Florida reports provides an explanation for this phenomenon. The Palm Beach P.E.P. reef did not demonstrate its design intent to effectively increase accretion of material within the project area. In fact, the physical data indicate accelerated erosion over a large percentage of the project area. The structure provides limited benefit due to wave height reduction in the lee of the structure, but this benefit is minimal at the higher water levels which typically accompany storms. The new configuration plan implemented at Vero Beach, FL, will offer new insight into the effectiveness of nearshore thin-crested submerged breakwaters in impacting the landward and adjacent beach and nearshore environments.

ADDITIONAL INFORMATION

For more information on the Palm Beach Installation, contact Mr. Thomas R. Martin, Coastal Design Section, USACE, Jacksonville, FL, (904)232-2428, Tom.R.Martin@usace.army.mil.

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