FIELD DATA ON SEAWARD LIMIT OF PROFILE CHANGE

By William A. Birkemeier,[1] A. M. ASCE

INTRODUCTION

Many coastal engineering problems require a measure of the "closeout depth," defined as the minimum water depth at which no measurable change in bottom elevation occurs. This depth can be thought of as separating the active cross-shore sediment transport zone from a deeper zone of negligible sediment movement, and is an important parameter in the design of jetties, breakwaters, and ocean outfalls, as well as for sediment budget computations. Hallermeier (3,4,5,6) used laboratory profile geometry to develop a procedure for predicting this depth which works reasonably well for the limited field data available from the Pacific Ocean and the Gulf of Mexico (4). This note evaluates Hallermeier's method using a new set of field measurements collected at the Coastal Engineering Research Center's (CERC) Field Research Facility, located along the Atlantic Ocean in northeastern North Carolina.

PREDICTION TECHNIQUE

Hallermeier (5) defines two limts to an area he calls the *shoal zone*: "a buffer region, where surface wave effects on a sand bed have an intermediate significance." Sediment movement occurs in the shoal zone, but net movement is negligible. The nearshore limit or closeout depth, d_l, is defined as the seaward limit of extreme surf-related effects, while significant cross-shore transport during normal waves is restricted to a depth less than the deeper limit depth, d_i.

According to Hallermeier (4,5) d_l can be estimated, relative to mean low water (MLW), for eroding quartz sand beaches in seawater by

$$d_l = 2.28\,H_e - 68.5\left(\frac{H_e^2}{gT_e^2}\right) \qquad (1)$$

in which H_e = the nearshore storm wave height that is exceeded only 12 hr/yr; T_e = the associated wave period; and g = acceleration of gravity. Eq. 1 indicates that d_l is primarily dependent upon wave height, with an adjustment for wave steepness. This adjustment becomes important (greater than 1.6 ft or 0.5 m) when H_e/T_e exceeds 0.88 ft/sec (0.27 m/s). Coefficients in Eq. 1 result from a Froude number relationship describing sediment suspension.

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[1] Research Hydraulic Engr., U.S. Army WES, Coastal Engrg. Research Center, Field Research Facility, Duck, N.C. 27949.

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J. Waterway, Port, Coastal, Ocean Eng. 1985.111:598-602.

FIELD DATA

Eq. 1 was evaluated using wave measurements and repetitive surveys collected from June, 1981, to December, 1982. The beach in the study area is narrow, has a 1:20 foreshore slope, and is composed of sediments ranging in diameter from 0.25–4.0 mm, and averaging about 0.45 mm. The nearshore region, to a depth of 30 ft (10 m), has a gradual slope of 1:100 and, in the region where d_l is measured, is composed of well-sorted fine sand with a mean diameter of 0.14 mm. Birkemeier, et al. (1) provide a complete description of the study area.

Wave measurements were collected every 6 hr by a Waverider buoy gage located in 60 ft (18 m) of water. Two profile lines, 62 and 188, were

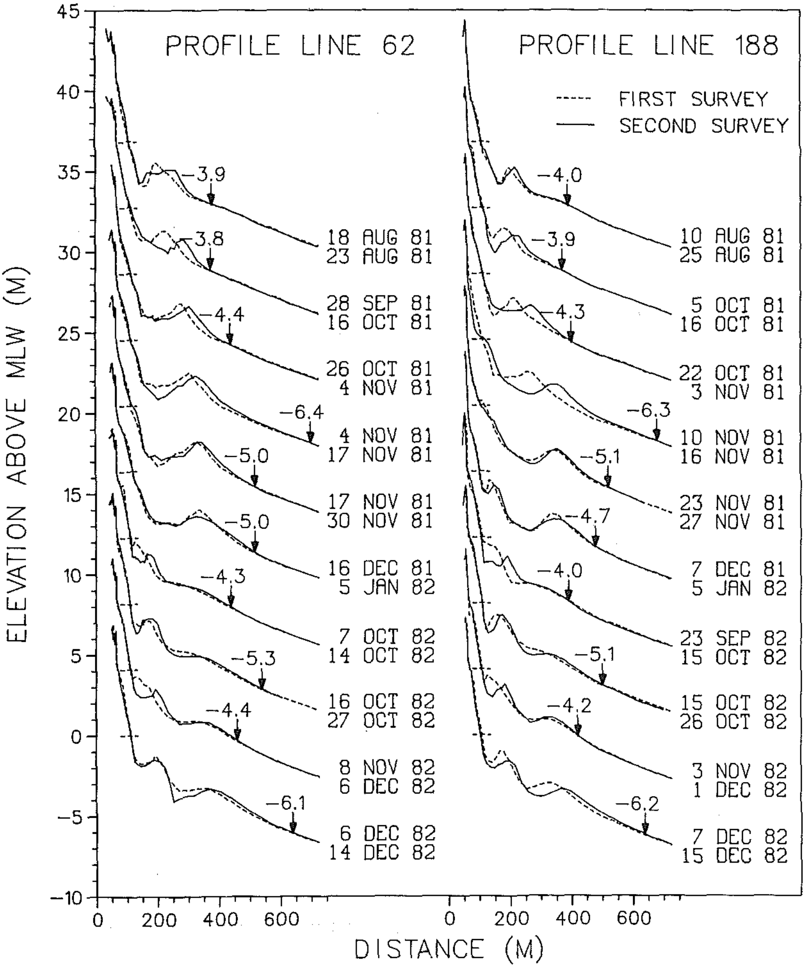

FIG. 1.—Survey Data Used in Determining d_l; Closure Locations and Depths Indicated by Vertical Arrows

TABLE 1.—Wave and Limit Depth Data

Closure estimate (1)	Wave Data			LIMIT DEPTH, d_l, IN METERS BELOW MLW			
	Date (2)	H_e, in meters (3)	T_e, in seconds (4)	Measured (5)	Predicted (Eq. 1) (6)	Best Fit (Eq. 2) (7)	Best Fit (Eq. 3) (8)
1	8/20/81	3.3	10.2	4.0	6.8	5.2	5.2
2	10/12/81	2.7	6.8	3.9	5.1	3.8	4.2
3	10/31/81	2.3	9.3	4.3	4.8	3.7	3.6
4	11/14/81	3.9	12.9	6.4	8.3	6.3	6.1
5	11/25/81	3.0	8.4	5.0	6.0	4.5	4.7
6	1/1/82	2.9	10.9	4.8	6.1	4.7	4.5
7	10/12/82	2.4	12.0	4.2	5.2	4.0	3.8
8	10/24/82	3.8	10.8	5.2	7.8	5.9	6.0
9	11/23/82	2.5	14.0	4.3	5.5	4.2	3.9
10	12/13/82	3.7	10.0	6.1	7.5	5.7	5.8

Note: 1 m = 3.281 ft.

surveyed from the dune to −30 ft (−9 m) MLW. Line 62 is located 1,605 ft (489 m) north of the research pier, and line 188 is 1,695 ft (517 m) south, and both are well away from the pier's influence (7). Surveys were conducted using the Coastal Research Amphibious Buggy (CRAB), a 35 ft (10 m) high motorized tripod which is capable of operating in waves up to 6 ft (2 m) in height, and a Zeiss Elta-2 electronic total station (2). Based on a repetitive series of tests with this system, vertical and horizontal accuracies of ±0.1 ft (±3 cm) are obtainable. Profile lines were generally surveyed on alternating weeks and after storms.

Since Hallermeier's formulation requires a cross-shore erosional sequence, and since it attempts to predict the maximum depth of change in a year, data were selected based on the following criteria:

1. The erosional event must have produced offshore movement of the bar crest with a measurable zone of deposition seaward of the crest.
2. The event produced similar changes at both profile lines.

The second criterion restricts the data set to predominantly cross-shore changes with measured closure deeper than 12.8 ft (3.9 m). Using these criteria, ten survey periods were selected. They are shown in Fig. 1. Note that because of a mechanical problem with the CRAB, survey data from line 190, located only 300 ft (100 m) south of line 188, have been used for the line 188 data between September 23 and October 15, 1982. Vertical arrows indicate the depth and point of closure, i.e., the point on the profile where the offshore deposition zone "closed out" to a thickness less than 0.1 ft (3 cm), a much more rigorous criteria than the 1 ft (0.3 m) originally proposed by Hallermeier (3) as a limit to resolvable nearshore changes with fathometer surveys.

Average closure measurements, along with the average maximum 12-hr significant wave height and associated period, are given in Table 1.

RESULTS

Estimates of d_l using Eq. 1 (see Table 1) were on average 4.6 ft (1.4

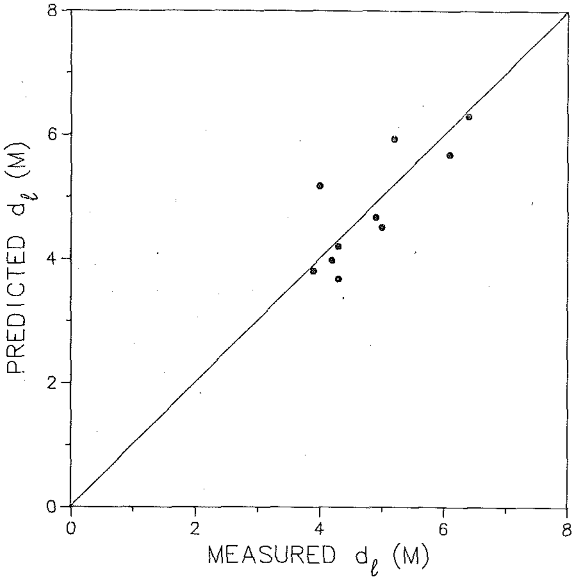

FIG. 2—Best Fit Comparison between Predicted (Eq. 2) and Measured d_l

m) deeper than the measured values with a maximum difference of 9.2 ft (2.6 m). A better fit to the data was obtained by a linear regression (forced through the origin) which yielded

$$d_l = 1.75H_e - 57.9\left(\frac{H_e^2}{gT_e^2}\right) \quad \text{(2)}$$

Values of d_l predicted using Eq. 2 are given in Table 1 and plotted in Fig. 2. Predicted values are within 3.9 ft (1.2 m) of the measured ones with an average difference of 1.3 ft (0.4 m). Eq. 2 improves the prediction and preserves the relative ratio between the wave height and wave steepness terms. Apparently for this data set, the functional relationship yielding Eq. 1 appears valid, though a site-specific adjustment of the coefficients to account for variables such as grain size and bottom slope may be required.

Though Eq. 2 maintains the original form of Eq. 1, a reasonable fit of the data can also be obtained using only H_e and, again, forcing the regression through the origin. This resulted in Eq. 3 below

$$d_l = 1.57\,H_e \quad \text{(3)}$$

Predicted values of d_l using Eq. 3 are given in Table 1. The average difference was 1.6 ft (0.5 m). Most importantly, both Eqs. 2 and 3 estimate to within 1 ft (0.3 m) the deepest measured d_l which occurred November 14, 1981 during the most significant storm of the study period.

SUMMARY AND CONCLUSIONS

Coastal engineers must often determine the region of the most active sediment transport. Based on the field data presented here, Eq. 1 provides a conservative depth estimate of the seaward limit to intense surf-related sediment movement. A more accurate prediction was obtained using site-specific data to adjust the coefficients. It was also found that a reasonable closure estimate could be obtained based only on the wave height, H_e.

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Results presented herein, unless otherwise noted, were obtained from research conducted at the Coastal Engineering Research Center, Waterways Experiment Station, under the Waves and Coastal Flooding Program. Permission was granted by the Chief of Engineers to publish this information.

APPENDIX I.—REFERENCES

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APPENDIX II.—NOTATION

The following symbols are used in this paper:

d_i = limit depth of sediment movement by usual waves;
d_l = limit depth of extreme surf-related effects;
g = acceleration of gravity;
H_e = nearshore wave height exceeded only 12 hr/yr;
MLW = Mean Low Water; and
T_e = period associated with waves of height H_e.