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Proceedings 15th Western Dredging Association Conference, May 17-20, 1994,
San Diego, CA, Center for Dredging Studies, College Station, TX, pp. 223-235.

Shoreward Movement and Other 5-Year Changes at the Sand Island Berms, Alabama

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ABSTRACT: The concept of inexpensively placing dredged sand close to shore, where natural currents can incorporate it into the active coastal sediments, has a long history. Ten attempts were reviewed at WEDA XII, and details were given on two tests that were underway off the Alabama coast. Two berms (thick, but submerged deposits of dredged material) had moved slightly toward the Alabama coast. These Sand Island berms were expected to continue migrating landward until they merged with the longshore transport. A simple model was given to predict if berms at other locations, with differing sediments and waves, would also migrate shoreward.

Two additional years of monitoring now confirm continued landward migration of one of the Sand Island berms and the merging of segments of the other berm with shallow ebb-delta deposits. Berm shape and orientation appear to be significant factors affecting long-term fate. Direct measurements were obtained of landward migration under different wave conditions and of a slower lateral diffusion of sediment expected as a result of reversing longshore mean currents.

Prediction models and case studies from other parts of the country show gradual shoreward migration under a variety of mild to storm wave conditions. Nearshore nourishment could probably be established as a regular, inexpensive, and safe bypassing practice at many coastal inlets.

INTRODUCTION

Purpose

This paper updates the fate of Sand Island berms as reported at WEDA 91 (Hands 1991 *a*). In 1989, the Mobile District wanted to transfer beach-quality sand from the entrance of the Mobile Navigation Channel to the active, downdrift littoral zone. A prominent berm was sited in water shallow enough so that sand would not disperse into an offshore sink, yet close enough to the channel and deep enough so that contract dredges could place the sand at no additional cost to the project. Bathymetry, currents, and sediment measurements taken from December 1986 to August 1989 showed the placed sand was moving shoreward and away from the channel (Hands 1991 *a, b*). Two additional years of data are used here to describe continued berm evolution.

National Berm Demonstration off Mobile Bay

The U.S. Army Corps of Engineers (USACE) established a National Berm Demonstration to assess the physical and biological effects of dredged material placed in open water (Langan 1987). Both stable and feeder berms were built using material dredged from the Mobile Ship Channel (Figure 1). Results of monitoring the demonstration have lead to recommendations for better use of dredged material in the coastal arena (Bradley and Hands 1990; Burke, McLellan, and Clausner 1989; Douglass, Resio, and Hands, in preparation; Hands 1991 *a, b*; Hands and Allison 1991; Hands, Allison, and McKinney 1990;

Hands and Bradley 1990; Kraus 1991; McGehee 1990; McGehee et al. in preparation; McLellan and Imsand 1989; McLellan, Pope, and Burke 1990; Murden 1987, 1988; Permanent International Association of Navigation Congresses 1992; Resio and Hands 1993; Scheffner 1991; Williams and Pollock 1993).

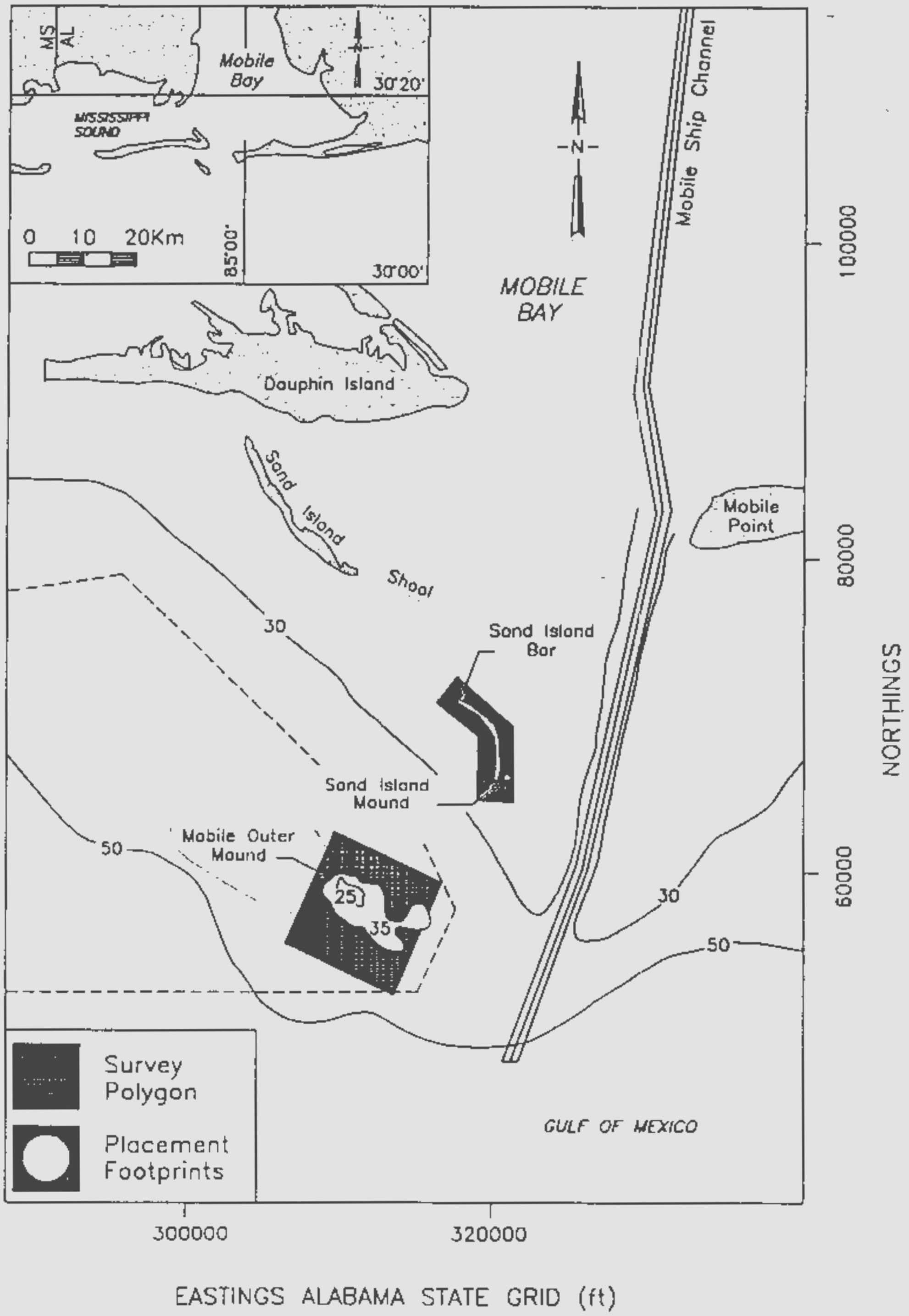

Figure 1. Three berms south of the entrance to Mobile Bay, AL

THREE BERMS

Mobile Outer Mound (MOM)

The 16-million-cu-yd MOM is by far the largest of three berms south of Dauphin Island, Alabama (Figure 1). Preplacement depths were around -45 ft mean lower low water (mllw), making MOM the deepest of the Alabama berms. MOM is also farthest from shore (5 miles south of Dauphin Island) and the most recently completed. Its construction began as part of the deepening of the Mobile Ship Channel in February 1988 and continued for 27 months. Being too large for detailed monitoring in its entirety, the earliest completed section was identified as the primary monitoring section (the 8,000 by 8,000-ft survey polygon in Figure 1). Surveys were repeated in this polygon nine times over a 3-year period. MOM (also referred to as the Mobile Stable Berm) was monitored for compliance purposes, insight into the behavior of fine material, and the effect that such a large mound would have on wind waves crossing it (McLellan, Pope, and Burke 1990; Williams and Pollock 1993).

Sand Island Bar (SIB)

Surveys of smaller inner berms (Figure 1) began a year before MOM work began and continues under coordinated USACE programs to obtain a better understanding of migrating berms. The 6,000-ft-long SIB was built specifically to test a plan for inexpensively bypassing channel-shoaled sand to the drift west of Mobile Bay.

Sand Island Mound (SIM)

The SIM was included in the initial (December 1986) survey for the Sand Island Bar. SIM had apparently formed during construction of a gas-well platform that year. Both SIM and SIB lay along the 19-ft contour and were composed of the same well-sorted, fine-grained sand that covers the outer Mobile ebb-tidal delta (D_{50} = 0.2 mm). On the initial survey, both berms crested near -12 ft mllw.

FATE OF THE ACTIVE SAND ISLAND BERMS

Scope of Monitoring

Figure 2 shows the positions of the two Sand Island Berms (SIB and SIM) and the edge of the Mobile ebb-tidal delta. The area shown in Figure 2 was surveyed 22 times over 5-years, providing a clear record of gulfward accretion on the surveyed portion of the ebb delta and slow, persistently landward movement of the placed sands. Waves and instantaneous near-bed currents were measured four to six times per day for 950 days (at intervals spread over most of the first 4 years). These results and their implication for generalizing mound response will be published this year (McGehee et al. in preparation; Douglass, Resio, and Hands, in preparation). Surface and/or core samples were taken across the berms on nearly every survey and less frequently on the delta (Hands and Bradley 1990). Though SIM and SIB were composed of similar sands and exposed to the same hydrodynamics, they responded differently. Their fates are described separately in the next sections.

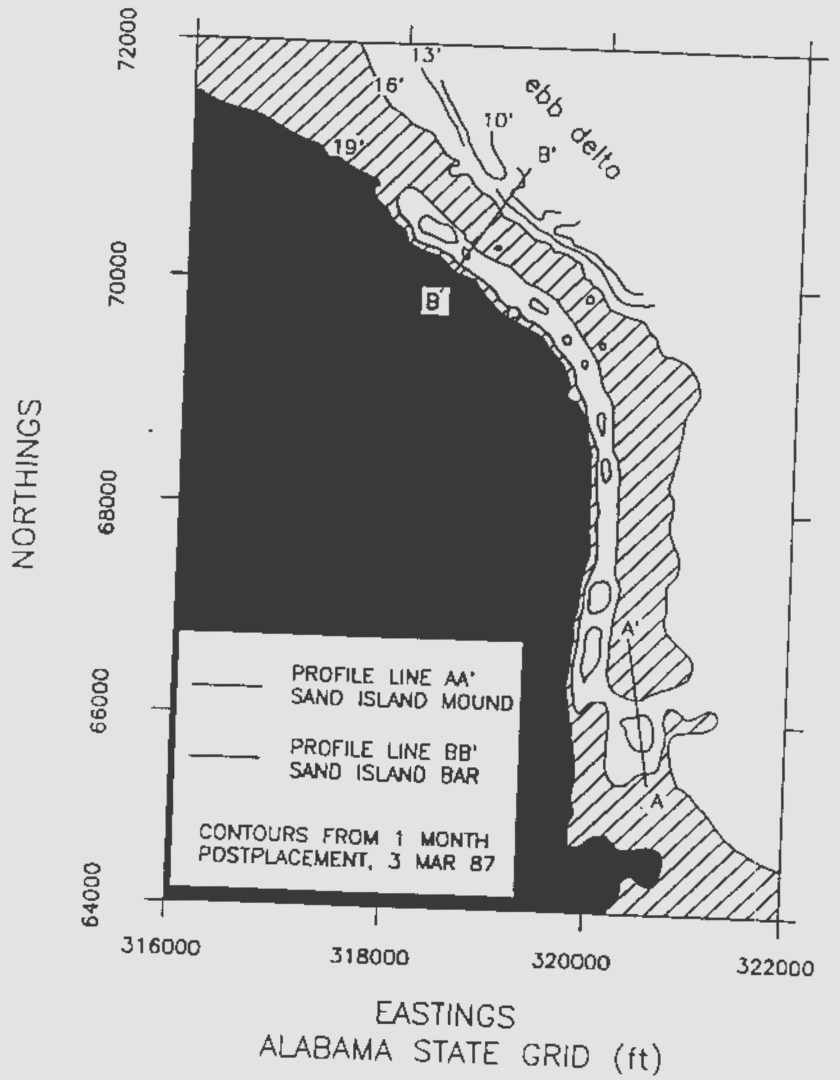

Figure 2 Layout of Sand Island Berms

Fate of SIM

The Sand Island Berms are shallow enough that waves agitate surface sediments almost daily. Wave agitation does not necessary imply net sediment displacement, but changes were evident when comparing most surveys. Though the rate of mound movement was not constant, it remained remarkably unidirectional. Net displacement was slightly west of north as shown by line *AA'* in Figure 2. SIM migration was persistently toward land and slightly away from the navigation channel. An asymmetry developed with the leading slope steeper than the trailing slope. The mound became lower and more elongate in the direction of travel. Over the 56-month survey period, the average crest elevation gradually dropped by about 1.5 ft (from -12.3 to -13.8 mllw). For simplicity, only a few of the 22 surveys are used in Figure 3 to illustrate the changing profile in the direction of migration.

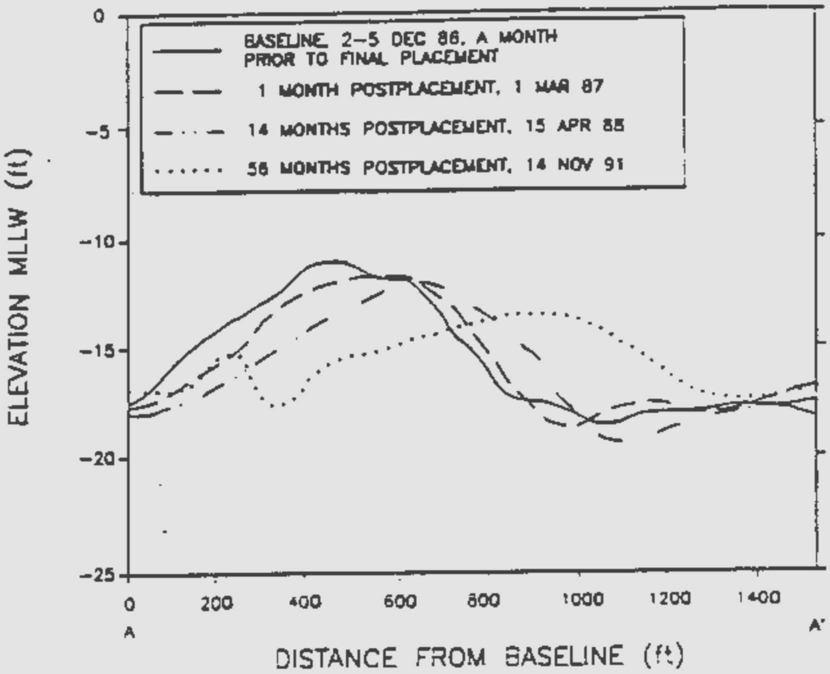

Figure 3. Movement of the SIM along profile AA'

Not visible in Figure 3 is progressive spreading perpendicular to the direction of migration. In map view (Figure 4), the gradual spreading, change in shape, and remarkably consistent direction of migration are clear.

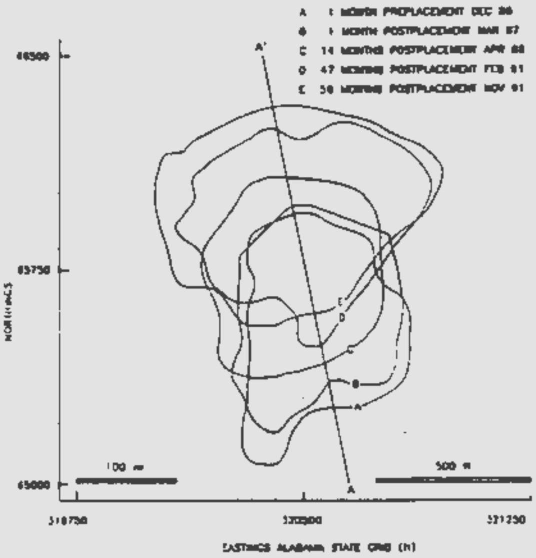

Figure 4. Movement of SIM depicted by -16 ft contour

Fate of SIB

The SIB was placed along the -19-ft contour, to form a long narrow bar. The bar did not respond as a single unit; therefore its fate can not be so easily characterized as the smaller, symmetrical SIM. The northern segment of SIB was aligned northwest/southeast while the southern segment was oriented north/south. The main change to SIB during the first year was a flattening of scattered peaks that rose above -13 mllw and erosion of the southern end of the 6,000-ft-long bar. The gulfward-extending tip retreated about 300 ft northward during that first year (Hands 1992).

The length of SIB has continued to shrink as erosion prevails on the gulfward tip. By 1991 the SIB had broken into three segments. The northernmost segment, migrated northeastward. The middle segment gradually lost volume and disappeared. The southern segment continued to lose sand from the gulfward tip throughout the full 56-month monitoring period. That part of the southern section that survived remained almost exactly where initially placed.

Sands that were eroded from the tip of the southern segment and the middle (leveled) segment of SIB could not be tracked by examining bathymetric or grain-size changes even though surveys and samples were conducted initially on a monthly interval (Table 1). We believe that sand disappearing from these segments probably stayed within the survey polygon, but was widely dispersed.

Table 1
Mobile, Alabama
Sand Island Berms
Placement and Sounding Schedule

Activity	Dates	Months Since Placement
Baseline survey 0	02 Dec 86 to 05 Dec 86	-1
Placement Operations -	12 Jan 87 to 23 Feb 87	--
Postplacement survey 1	02 Mar 87 to 05 Mar 87	0
Postplacement survey 2	16 Mar 87 to 19 Mar 87	1
Postplacement survey 3	01 Apr 87 to 02 Apr 87	1
Postplacement survey 4	16 Apr 87 to 17 Apr 87	2
Postplacement survey 5	06 May 87 to 09 May 87	2
Postplacement survey 6	20 Aug 87 to 21 Aug 87	6
Postplacement survey 7	25 Oct 87 to 25 Oct 87	8
Postplacement survey 8	01 Dec 87 to 02 Dec 87	9
Postplacement survey 9	06 Jan 88 to 08 Jan 88	10
Postplacement survey 10	15 Apr 88 to 16 Apr 88	14
Postplacement survey 11	16 Jun 88 to 17 Jun 88	16
Postplacement survey 12	01 Aug 88 to 23 Aug 88	17
Postplacement survey 13	18 Sep 88 to 21 Sep 88	19
Postplacement survey 14	18 Oct 88 to 23 Oct 88	20
Postplacement survey 15	14 Dec 88 to 20 Jan 89	22
Postplacement survey 16	16 Apr 89 to 17 Apr 89	26
Postplacement survey 17	12 Aug 89 to 13 Aug 89	30
Postplacement survey 18	24 Feb 90 to 21 Mar 90	36
Postplacement survey 19	01 Jul 90 to 05 Jul 90	40
Postplacement survey 20	07 Feb 91 to 20 Feb 91	47
Postplacement survey 21	14 Oct 91 to 14 Nov 91	56

Nov 92

In contrast, the northern segment of SIB remained intact as an identifiable berm form persistently moving northward, though diminishing a little in volume as it moved. Sands accreted on the ebb delta leeward of this northern section of SIB. The delta grew shallower and prograded gulfward toward this section of SIB. Figure 5 illustrates these changes in a cross-section looking in the direction of the migration vector *BB'* shown in Figure 2.

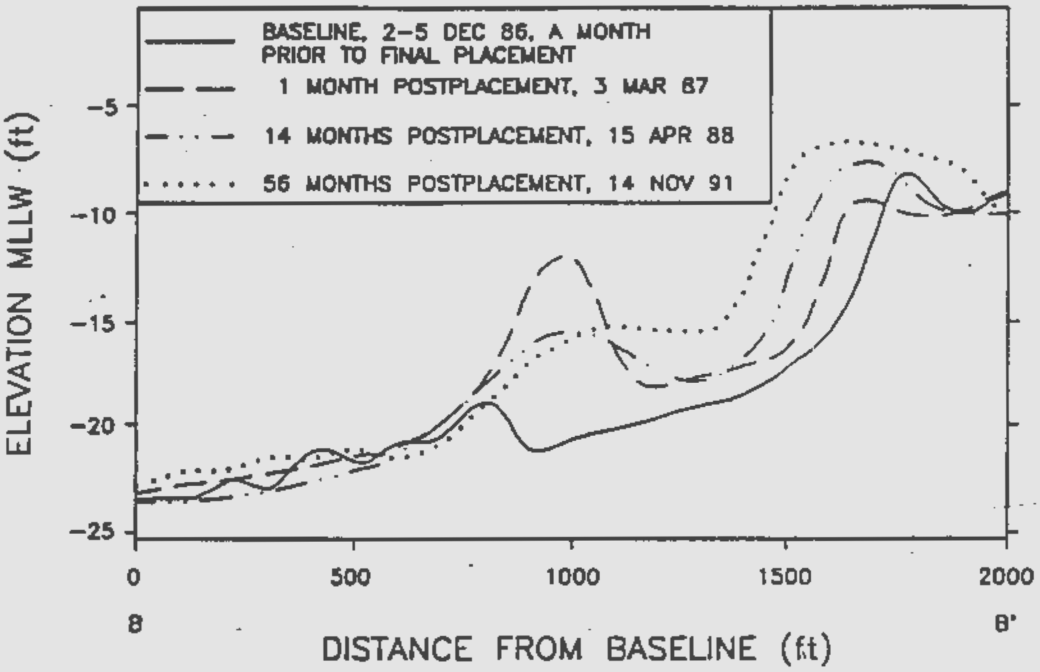

Figure 5 Merging of the northern section of the SIB with the ebb-tidal delta

INTERPRETATION

Sand Island Berms

The northern segment of SIB has had an uninterrupted history of moving upslope toward the delta. This bar segment gradually diminished in height. Part of the volume loss from the crest went into widening the base in the direction of migration. The wider base did not account for all the loss. Some moved out ahead of the identifiable berm form to settle in a trough between the berm and the shoreward tidal delta. The total volume that accumulated in the trough exceeded that lost from evolving berm.

There were no large lateral berm displacements as might have been expected as this northern section of SIB (a) moved into shallower water, (b) closed the gap between itself and the delta deposit, and (c) finally formed a bench or terrace at the base of the delta face (Figure 5). There was little deviation in the direction of berm migration from the bottom gradient. Both the direction of migration and the zone of accretion are, at most, only slightly northward of the slope gradient. The direction of movement coincided with the direction of predominate wave propagation.

The sequence of surveys shows that placed material migrated shoreward and merged with the delta. The volume of local delta accretion exceeded the quantities placed in the northern segment of SIB. The additional volume may have come from some combination of:

- Placed sand that was eroded from the tip of the southern segment of SIB or leveled central SIB segment.
- Ambient drift that may have settled into calmer water leeward of the northern segment of SIB.
- Natural patterns of shifting erosion and accretion that may have occurred independent of dredging and berm effects.

The shallowest surveyed depths on the ebb delta were around -8 ft mllw on the preplacement survey. The delta shoals got progressively shallower—rising to -4 ft mllw by the end of the 56-month monitoring period. Because documented accretion on the ebb delta began immediately after berm placement and well before the berm and the delta merged, it appears that reduction of wave energy passing over the berm was responsible for enhanced accretion on the delta. McLellan, Pope, and Burke (1988) reported a large reduction in wave energy at the National Data Buoy station landward of the MOM as compared to a seaward buoy. Williams and Pollock (1993) presented further analyses of these data and used sediment fall velocity to address the possible reduction in erosion potential landward of MOM. Accretion of the ebb delta landward of SIB appears to be the first firm data documenting a large-scale sedimentary response to wave attenuation over a berm.

Mean currents in the vicinity of SIB alternate between the two longshore directions with speeds of 10-20 cm/sec during times of frontal passage and other large-scale weather changes (Douglass, Resio, and Hands; in preparation). The direction of berm movement is, however, nearly perpendicular to these mean currents. While the mean currents do not control Alabama mound displacement, Figure 4 shows gradual changes in the shape of SIM that may be related to the mean currents. Lateral spreading of SIM can be interpreted as diffusion over a 5-year period during which the mean longshore currents reversed many times. Analysis of the documented lateral spread can provide a first-order estimate for a mound diffusion coefficient with some indicated range of variation as flow intensities varied at this site. At other wave-dominated berm sites, effects of lateral diffusion should slowly transform mounds into more bar-like shapes that become increasingly elongate perpendicular to the coincident wave and migration vectors.

Berm size also affects material fate. For a berm in a given depth, the greater the relief (difference in base and crest elevations), the shallower the crest, and the more vigorously waves attack a larger portion of the berm. Diversion and intensification of mean currents will likewise increase with berm size. These two major effects are relatively easily parameterized. There may be another size effect related to the ratio of diffusion (spread) versus advection (form migration). The ratio of the rate of volume loss to migration rate was large on the two nearly stationary segments of SIB. The ratio was small on SIM and the northern SIB segment. Prediction of this ratio is important for assessing berm benefits. If the berm's steep slope helps promote shoreward migration, at what point will diffusion flatten the berm to such an extent that it disappears or ceases to migrate? The ratio of dispersion to migration should depend on berm size and composition as well as the type and intensity of erosional forces. The wider a berm is (in the direction it is migrating), the longer sediment moving across the berm will be exposed to the intense erosional forces over the crest. This width factor may alter the probability that entrained sand ever reaches the lee side.

Sand that moved up the seaward slope of the smaller SIM reached an area of increasing depth and calmer water immediately on the lee side without spending any time on or traversing a flat crest. The same would be true of sand moving across the northern bar segment. The southern segment was geometrically no wider, but because of its orientation, had no receptive lee side to promote retention of entrained sand and preservation of the berm volume. Diffusion dominated on the southern tip. The sand that remained in this southern segment stayed where it had been placed nearly 5 years earlier. Most of the sand eroded from the gulfward tip was exposed to continued transport while near the berm which would promote diffusion. These effects of berm size and shape are not well formulated, but qualitatively fit Sand Island berm observations.

Suggestions for Future Analysis

Long-term physical fate of placed material is critical for quantification of berm benefits and model verification. Continued collection of field data is necessary to advance confidence in prediction models and methods for evaluating placement options.

The slope of the Mobile ebb delta, below which berm material formed a terrace, is comparable to beach slopes. If the berm material continues to climb the delta face, this will be directly analogous to shoreline accretion due to feeder berm migration. Comparisons should be made of rates at which the SIB segment moves up the steep delta face with rates documented while that segment and SIM traversed flatter terrain. Continued tracking of SIM and of the SIB/delta bulge will be important to understanding the following:

- Rates of berm movement.
- Expected drop in the diffusion/advection ratio and possible longshore deviation in migration vector when berm sands enter the surf zone.
- Ultimate value of building feeder berms.

Future monitoring at Sand Island berms should shift westward in anticipation of greater longshore transport. To better isolate the effects of the berms from independent, ongoing processes, a reference area on the adjacent delta should be included in the monitoring. Westward extension of surveys could also provide this measure of background changes.

Relationship to Other Berms

Hands (1991 *a*, *b*) reviewed previous CE feeder berm tests. A few of those berms failed to move from their placement sites. None of the remaining *active* berms moved seaward. Most moved quickly landward out of the areas that were being surveyed. There is only indirect evidence that sand from the New River, North Carolina (Schwartz and Musialowski 1980); Silver Strand, California (Juhnke, Mitchell, and Piszker 1989); or Humboldt, California (Hands 1993) berms ever reached adjacent shallow beaches. Retention of most of the sand in easily discernable berms and the long-term measurement of migration and currents at Sand Island makes this a valuable site for improving recent numeric (Scheffner 1991) and empirical models (Hands 1991*b*) of berm response.

CONCLUSIONS

As hoped, no placed sand was lost into deeper water over the 5-year period of extensive monitoring in spite of several remote hurricanes. Shoreward migration persisted summer and winter throughout the 5 years. Offshore losses might have occurred if a hurricane or other extreme storm had prolonged direct impact or if berms had been composed primarily of silts. Shape and orientation of berms appear important for maintaining their integrity as identifiable forms. Because a prominent form is the simplest, most reliable, and least expensive method for tracking the fate of large quantities of material, the size, shape, and orientation of future test berms should be carefully chosen with these factors in mind. Size and shape may also be important in promoting shoreward transport.

The contrast between the disappearance of sand from two of the three segments of SIB and the retention of a large fraction of the sand in the migrating northern segment may be attributed to the different berm orientations with respect to the dominant waves. Berm size may likewise affect berm fate. Until the interaction of berms and waves is better understood, it would be prudent to continue making all *feeder* berms narrow in the direction of wave propagation and high in relief above the seafloor as well as siting them inside the *active* berm depth (Hands 1991 *b*).

Slow, but positive, results from the Sand Island berms indicate successful bypass berms can be built in depths accessible by many commercial dredges. A substantial and growing number of successful feeder berms have been documented. Most were test berms built during channel maintenance operations that added little to project costs. Comparison of Alabama berms with other field measurements suggests that faster movement and focused nourishment on critical sections of shore may be obtained by placement of coarser sand in shallower depths directly opposite problem reaches, but very shallow placement may be costly with conventional equipment. Recent berm prediction models, design guidance, and demonstrations should dredged material managers expand the practice of using clean, inlet-dredged sand to mitigate chronic widespread coastal erosion problems.

ACKNOWLEDGEMENTS

Monitoring was guided by members of a Steering Committee: Messrs. Thomas W. Richardson and Charles C. Calhoun, Jr., and Ms. Joan Pope (CERC); Hugh A. McClellan (CESAM); James M. Kelly, Jr. (CESAD); David B. Mathis (CECW-D); and Dr. Susan I. Rees (CESAM). Work at the U.S. Army Engineer District, Mobile, was coordinated with Messrs. Jim Baxter, K. Paul Bradley, and Wendell Mears (CESAM-OP); Jim Reaves and Mike Nettles (CESAM-S); and Mr. Paul Warren (SAMFO-M). Data analysis and report preparation were done principally under the "Field Techniques and Data Analysis to Assess Open-Water Disposal" Work Unit in the Corps' Dredging Research Program conducted at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. Permission was granted by the Chief of Engineers to publish this information.

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