CHAPTER 286

NEARSHORE PLACEMENT OF SAND

By Scott L. Douglass[1], Member ASCE

ABSTRACT:

A methodology that evaluates the influence of depth on the rate of onshore migration of sand placed in the nearshore is presented. The results appear appropriate for the Atlantic and Gulf coasts of the United States. Migration rate is found to be extremely dependent, to the 4th or 5th power, on the water depth. This implies that doubling the rate of migration requires placement in only about 15% less depth. It is argued that accounting for the net shoreward bottom stress due to the velocity asymmetry under finite-amplitude waves is the appropriate way to model the fate of nearshore placed sands.

BACKGROUND

Nearshore placement of sand is becoming a more popular option in two related types of coastal engineering projects; beach nourishment and inlet dredging. "Nearshore" is defined rather loosely here as beyond the day-to-day surf zone but within the depths that are disturbed by storm waves. Nearshore placement is an alternative to direct placement on the beach that has been called "profile nourishment" or "shoreface nourishment" since the placement is farther out on the beach profile than the dry beach.

---

[1] Associate Professor, Civil Engineering Department, University of South Alabama, Mobile, Alabama, USA (334) 460-6174

Placing the sand in the nearshore instead of directly on the beach can reduce costs and improve the overall cost-benefit ratio of a beach nourishment project (Laustrup, et al. 1996). There may also be a perception that construction-related aesthetic and environmental impacts to the beaches are improved with nearshore placement instead of direct beachfill because the sand moves ashore in the form of migrating sand bars instead of being placed there by construction equipment.

Nearshore placement of sand is also an option in navigation dredging projects for similar reasons. First, it may be less expensive than other dredged material disposal options such as hauling to offshore disposal. Second, there may be a recognition that inlet sand transfer is required for the long-term maintenance of the downdrift beaches. The goal of nearshore placement of sand in this case would be to keep the sand resource in the littoral system for the least cost.

The primary question is, "what is the fate of sands placed in the nearshore?" More specific questions are:

1. does the sand move?
2. If so, which way does it move?
3. How fast does it move?
4. What is the influence of depth on this fate?

Depth is one of the primary parameters that the design engineer can specify.

Several tools to answer these questions have been developed in the United States as part of the Corps of Engineers Dredging Research Program in the last decade. Hands and Allison (1991) and Hands (1991) developed an empirically based answer to the first question concerning movement. The stability of bathymetric features (mounds or bars) constructed with dredged sands at eleven locations discussed in the American literature is summarized. A method based on combining extreme wave statistics and Hallermeier's estimates of the limits of sand movement successfully discriminates between mounds that moved and mounds that did not move.

Larson and Kraus (1992) suggest using empirical estimates of surf zone sand bar migration and beachface accretion/recession for estimating the direction of movement of sand placed in the nearshore. A design option is to place the sand in a long, linear, shore-parallel bathymetric feature that is similar to natural sand bars. They validate their method by comparison to the onshore migration of a constructed bar feature at Silver Strand, California (Andrassy 1991).

Scheffner (1991, 1996) suggests combining a hydrodynamic model with a sediment transport model for evaluating the fate of sand placed in the nearshore. The influence of waves on the bottom friction factor is considered, but mean currents provide the transport mechanism for the sand movement. The migration of a mound south of Dauphin Island, Alabama (Hands and Allison 1991) is used for validation.

The answer to the primary question concerning the fate of sands placed in the nearshore is tied to a broader, underlying question that has been the focus of much research in the nearshore oceanography community for the past decade: "What moves sand in these depths beyond the day-to-day surf zone but within the influence of storm waves?" Considering the rich variations in sediment transport processes such as bed and suspended load, ripple and dune migration, sheetflow, and bed-ventilation; combined with the varying time-scales of the hydrodynamic forcing conditions and our limited understanding of the near-bottom boundary layer of the fluid column under real waves, the answer is only marginally understood at this time. Solving applied problems requires the use of that part of the available science that is considered to be the most important of the geophysical processes for the problem.

One concept for modeling surf zone sand bars is a balance between the cross-shore movement of sand due to the velocity asymmetry of waves and the undertow (Stive 1986, Roelvink and Stive 1989). Simplistically, the waves drive the sand bar landward and the undertow drives it seaward. Considering that the location of constructed mounds is offshore of the location of the typical sand bar, the undertow should be reduced and the wave asymmetry mechanism should dominate. This is the fundamental concept used in this paper.

Douglass (1995) briefly proposed a model for estimating migration of sand mounds constructed in the nearshore. The model assumes that landward migration is due primarily to the net landward transport by the velocity asymmetry of finite-amplitude waves. Conservation of sand considerations in the cross-shore direction lead to the classical convection-diffusion model equation. The "convection" and "diffusion" coefficients are functions of the wave conditions and depth and are based on the wave and transport theory, not traditional concepts of convection and diffusion. The model produced results which were in reasonable agreement with measured migration directions and rates at both Silver Strand and Dauphin Island. The implication of the diffusion is that mounds should spread out while moving landward. This type of behavior has been noticed to different degrees in many of the monitoring reports on mounds (Hands and Allison 1991; Andrassy 1991; Bodge 1994; Foster, et al. 1996; Mesa 1996) and is shown schematically in Figure 1.

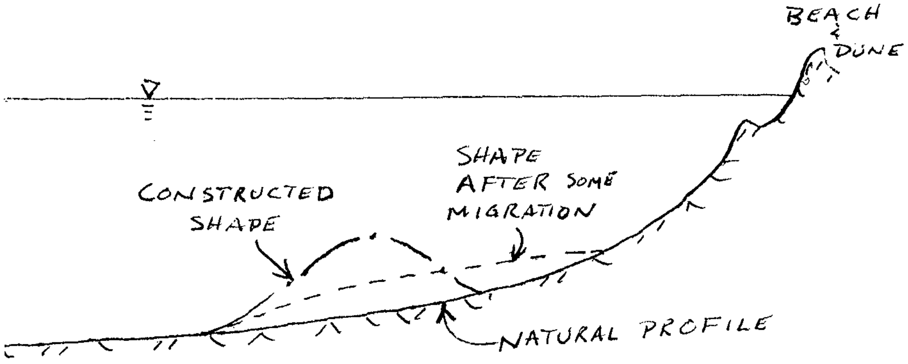

Figure 1. "Typical" migration of sand placed in the nearshore.

This present paper briefly discusses the results and implications of a study of the near-bottom current field at a nearshore sand placement site. The Douglass (1995) model is further developed. Modifications include the use of a calibration coefficient and a simple adjustment for wave breaking when using WIS wave climatology data as input. Results for a few locations on the Atlantic and Gulf coasts of the United States are presented. The implications of the dependence of migration on depth of placement are discussed. Some of the practical limitations of the model as well as the theoretical problems are briefly discussed. The implications concerning the important geophysics dominating the problem are discussed. The conclusion is that some form of modeling based on the influence of wave asymmetry is probably appropriate concerning the fate of sand placed in the nearshore.

DAUPHIN ISLAND, ALABAMA NEAR-BOTTOM CURRENT STUDY

The fate of sand mounds constructed in about 6 m depths south of Dauphin Island, Alabama in 1987 was monitored extensively by the US Army Corps of Engineers. A number of reports by Mr. Edward Hands and other co-authors documented the movement of these nearshore mounds (e.g. Hands and Bradley 1989, Hands and Allison 1991). Repetitive bathymetric surveys showed that the mounds moved landward.

Instantaneous, near-bottom currents were measured, along with waves, at the site. These near-bottom currents were examined in detail by Douglass, et al. (1995).

A number of possible mechanisms for mound migration; including mean currents, large wave correlation with mean currents, and mound-induced differences in current fields; were not able to satisfactorily explain the observed shoreward direction of mound migration. Douglass, et al. (1995) concluded that some unknown mechanism that moves the bottom back towards its equilibrium shape may be responsible for the landward migration of mounds and that the velocity asymmetry of storm waves might be part of such a mechanism. These finding played a role in the development of this work.

WAVE-BASED MODEL OF MOUND MIGRATION RATE

Assuming that wave-induced near bottom velocity asymmetries are the dominant mechanism for the net transport of sand in the depths of interest, net sand transport can be expressed as (Douglass 1995),

$$Q=\frac{9\pi^2}{64}\frac{\rho g C_f \epsilon_b}{(\rho_s-\rho)\,a'\tan^2\phi}(\tan\phi-\tan\beta)\frac{H^4 T}{L^3}\operatorname{sech}^2\left(\frac{2\pi h}{L}\right)\operatorname{csch}^4\left(\frac{2\pi h}{L}\right)$$

where Q=net volumetric transport rate, ρ = density of water, ρ_s=sand density, C_f=a friction coefficient, ϵ_b = Bagnold's efficiency of transport coefficient, ϕ = angle of internal friction of the sediment, β = angle of slope of the bottom, a'=ratio of total volume to volume of solids, H=wave height, T=wave period, L= wave length, and h=water depth. This is an expression for cross-shore bedload transport rate using Stokes wave theory in Bailard and Inman's (1981) form of Bagnold's (1963) bedload transport equation assuming all motion is in the cross-shore direction.

It can be assumed that transport due to irregular waves with a spectral significant wave height, H_{mo} , with a period corresponding to the peak of the energy density spectrum, T_p, will be proportional to transport due to the corresponding monochromatic conditions. Also, given that several of the empirical coefficients, in particular ϵ_b, have typical values based on limited tests, it seems logical to modify this transport equation with an empirical coefficient that can be used to fit the results to observed data specific to the migration problem. Therefore another empirical coefficient, A, has been added to the above transport equation modified to use the spectral estimates of wave climate:

$$Q=A\frac{9\pi^2}{64}\frac{\rho g C_f \epsilon_b}{(\rho_s-\rho)\,a'\tan^2\phi}(\tan\phi-\tan\beta)\frac{H_{mo}^4 T_p}{L_p^3}sech^2\left(\frac{2\pi h}{L}\right)csch^4\left(\frac{2\pi h}{L}\right)$$

where L_p =wave length corresponding to T_p computed with linear wave theory. The A will be used to fit the results to observed migration rate data below.

Considering conservation of sand in the cross-shore direction,

$$\frac{\partial h}{\partial t}-\frac{\partial Q}{\partial x}=0$$

where t= time and x = the cross-shore direction.

Substitution of the above transport equation into the conservation equation results in a form of the convection-diffusion equation (Douglass 1995):

$$\frac{\partial h}{\partial t}+C\frac{\partial h}{\partial x}-D\frac{\partial^2 h}{\partial x^2}=0$$

where

$$C=A\frac{9\pi^3}{16}\frac{\rho g C_f \epsilon_b}{(\rho_s-\rho)\,a'\tan\phi}\frac{H_{mo}^4 T_p}{L_p^4}\left\{2\,csch^5\left(\frac{2\pi h}{L}\right)sech\left(\frac{2\pi h}{L}\right)\right.$$

$$\left.+csch^3\left(\frac{2\pi h}{L}\right)sech^3\left(\frac{2\pi h}{L}\right)\right\}$$

$$D=A\frac{9\pi^2}{64}\frac{\rho g C_f \epsilon_b}{(\rho_s-\rho)\,a'\tan^2\phi}\frac{H_{mo}^4 T_p}{L_p^3}sech^2\left(\frac{2\pi h}{L}\right)csch^4\left(\frac{2\pi h}{L}\right)$$

C has the role of the "convection" coefficient and D has the role of the "diffusion" coefficient. The expressions for C and D originated from the consideration of conservation of sand with the wave theory and transport model and not on physical concepts of convection or diffusion. The equation implies that the form of a submerged mound will "convect" or move at speed C while it diffuses. Similar behavior of constructed bottom mounds has been observed (Hands 1991, Bodge 1994, Foster et al. 1996, Mesa 1996).

The equations outlined above can be used as a planning and design tool when combined with an estimate of wave climate at a specific site. The equations predict the behavior of a mound under a given, specified sea state. To apply it to a non-constant sea state, either the time history of sea must be estimated or a statistically valid estimate of the overall wave climate must be evaluated in terms of an "expected value of migration." Given a tabular estimate of the onshore portion of the wave climate, the expected value of mound movement in any given depth, E[C(h)], can be estimated with C, the "convection" coefficient as

$$E[C(h)]=\sum p(H,T)\,C(H,T,h)$$

where the summation is across all (H,T) bins, p(H,T)= probability or percentage of time that the wave height and period is of that magnitude.

APPLICATION

The migration rate equation above can be roughly calibrated by matching the predictions to the observed migration of constructed mounds. The "expected value" of the migration rate can be estimated with an estimate of the "expected" wave climate such as the US Army Corps of Engineers Wave Information Study (WIS) wave hindcast data for the Atlantic and Gulf coasts of the United States (Hubertz, et al. 1993). Using WIS data provides a consistent estimate of wave climatology when comparing different locations.

WIS data is given at specific depths. Since this methodology evaluates migration rate at varying depths, some form of transformation of wave climatology is needed. For the purposes of this study, a very simple, depth-induced, wave height reduction was used. It was assumed that the maximum spectral significant wave height in any depth of water was half of the water depth, i.e. $(H_{mo})_{max} = 0.5\ h$. Wave heights were reduced to that level to evaluate migration for the shallower depths. A more sophisticated wave transformation scheme could be used.

The first comparison is for the mounds constructed in around 6 m depth off the Alabama coast in 1987-88. Hands and Allison (1991) showed survey data that indicated the mounds moved roughly 30 m/yr initially. The methodology outlined above with the WIS climatology for that location matches this expected value when the calibration coefficient is A=0.5.

The second comparison is for a disposal mound created in about 6 m depth off Cocoa Beach in the Cape Canaveral area in 1992. Bodge (1994) found that mound moved roughly 30 m to 45 m landward in the first six months. Most of this movement occurred during and immediately after construction. By the time of the second post-construction survey at six months, the peak of the constructed mound had been flattened to the extent that there was not a clear crest, i.e. the bottom elevation profile had no significant decrease in depth in the offshore direction. Apparently the top of the mound moved about 60 m/yr to 100 m/yr during the first 6 months and then slowed down as the mound or bar-like feature was lost. The methodology presented here with the WIS data for Cape Canaveral, matches this expected migration rate when the calibration coefficient is A=0.2 to 0.33.

Based on these two comparisons, A (using WIS data) can be set to roughly A=0.3 with a reasonable expectation that it may vary from $0.1 < A < 1$. The use of observed migration rates for comparison to expected migration rates is not optimum since the observations are based on much less time than the overall WIS estimate of wave climate, 20 years. The waves would be expected to be larger or smaller than typical for any 6-month to one-year time spans because of the natural variability in wave climate. The observed migration rates were due to the actual waves for that time period and not the long-term wave climate.

Any calibration of this methodology is probably dependent on the wave climatology estimate used. For example, wave climatology based on long-term, in-situ wave gages will probably have different calibration coefficients.

Figure 2 shows the results of this methodology at three locations with very different wave climates. The calibration coefficient was set to A=0.3 for Figure 2. Alabama is on the Gulf of Mexico and has a relatively mild wave climate. Cape Canaveral on the Atlantic coast of Florida has a moderate wave climate. Cape Hatteras has one of the more severe wave climates on the Atlantic coast of the United States. Figure 2 shows that the model estimates migration rates that vary significantly, up to an order of magnitude, for these three locations. For a given depth, migration rate estimates

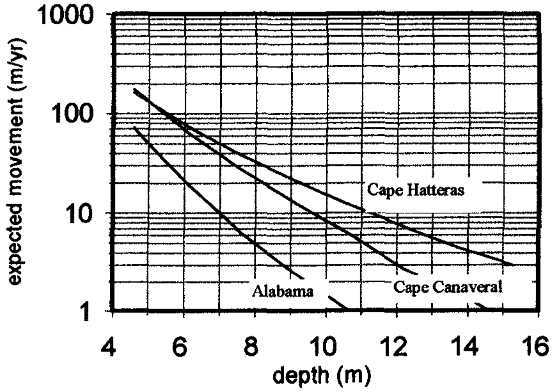

Figure 2. Expected migration rate at three U.S. locations

are higher for the Atlantic sites than for Alabama. Such variation would be expected for any process based on wave climate. In particular, wave lengths are typically significantly longer for the Atlantic Ocean than the Gulf of Mexico. For deeper depths, Cape Hatteras migration rates are higher than Cape Canaveral. The estimates for the two Atlantic sites become close to each other in shallower depths. This closeness is due to the depth-induced, wave height reduction employed to transform the data into shallower water as discussed above. The infrequent, largest waves at Hatteras are more influential in the deeper depths but are less so after breaking as the depths decrease.

Interestingly, Figure 2 shows a similar general shape and dependence with depth at the three locations. This similar shape apparently is a function of the model equations. The same general shape has been found using wave climatology based on wave gages for the Santa Anna River, California nearshore placement of sand (Mesa, personal communication, 1996). This dependence with depth has practical value for planning and design. The results shown on figure 2 can be fit to a simple power relation:

$$E[C]=ah^{-b}$$

where E[C] = expected value of migration rate (m/yr), a=coefficient, b=exponent, and h=depth (m). For most of Figure 2 and all of the deeper depths at each location, the best fit for the exponent is b=5. These are the depths where the wave height decay due to depth ($(H_{mo})_{max} = 0.5$ h) was small. This was all of the depths shown for the Alabama site, most of the depths for Cape Canaveral, and the deeper depths for Cape Hatteras. In the portion of Figure 2 where the depth reduced the largest waves in the climatology, the depth dependence exponent is b=4. Thus, this methodology implies that migration rate is dependent on depth to the 4th or 5th power.

DISCUSSION

Implications of influence of depth on migration

The depth dependence of migration rate outlined above provides some useful concepts for planning and design of nearshore placement. The above equation implies that migration is extremely sensitive to depth at any specific site. Doubling the depth of placement will decrease the rate of migration by a factor of 16 to 32. Considering it another way, to double the migration rate, it is necessary to place the sand in only 13-16% shallower depth. This guidance should be of value in evaluating the cost vs. depth-of-placement issues typical of nearshore placement of sand.

The extreme sensitivity to depth implied by this methodology has not been verified by observations. Verification would require placement at different depths at the same general location and time with adequate monitoring.

Theoretical limitations

There a number of theoretical limitations to the methodology presented here. First, many of the physical mechanisms that influence sediment transport in these depths including the effects of suspended sediment load, wave groups, ripple and dune migration, sheetflow, bed-ventilation, wave grouping, undertow, wind, bottom streaming and other bottom boundary layer complexities have been ignored. Second, the one physical mechanism modeled, the influence of wave asymmetry on net bedload sand transport could be modeled in a more sophisticated manner. A primary limitation is the use of Stokes 2nd order theory - particularly in shallow water. It was used because it is the lowest order theory with asymmetry. Better representations of the actual velocities should be used. Thus, this methodology can be considered as a rough first attempt at applying such a model to the problem at hand. Its abilities, in spite of this serious limitation, are encouraging in that they indicate the proper physics may be included.

Practical limitations

One serious practical limitation of this methodology is the use of a single depth for modeling migration rate. Nearshore placement in a mound-like feature implies that different parts of the feature are in different depths. More importantly, the equations given above are extremely sensitive to depth. This presents a practical problem in specifying the single, appropriate depth for the use of this model. For this work, that single depth was chosen as the pre-existing depth at the middle of the feature. Conceptually, the top, or shallower portion, of the feature should move fastest and be flattened out by landward movement of sand into the deeper depth shoreward. There is evidence at many observed mounds that this has occurred (Bodge 1994, Mesa 1996, Hands and Bradley 1990, Foster et al. 1996).

Appropriate physics for modeling migration

The implication of the observations and the results presented here is that a net sand transport equation that is dependent on depth could be used with the conservation of sand equation to model the fate of nearshore disposed sands. More specifically, the use of a model that accounts for the influence of velocity asymmetry on sand transport is recommended for modeling the fate of nearshore placed material. Such models have been proposed by Stive (1986) and several of the investigators in the European NOURTEC project (Houwman and Ruessink 1996, Roelvink, et al. 1996, Hoekstra, et al. 1996). The results presented in this paper and the detailed simulation of the behavior of the Silver Strand, California mound shown in Douglass (1995) imply that such modeling is an appropriate approach. The use of some form of Bailard's model (Bailard and Inman 1981) is common to all of these approaches. This present work does not endorse the use of Bailard's model specifically. Other approaches that explicitly account for the effect of net onshore bottom stress due to wave asymmetry should also be considered.

Other existing American methods

The other existing American methods for estimating the fate of nearshore placed sand are not explicitly based on this physical mechanism (wave asymmetry) although it may be implicitly included through the empiricism. The Hands and Allison (1991) method for movement or non-movement is essentially empirical and does not attempt to explain migration direction. The Hands and Allison method is based on extreme wave heights and a sand movement initiation criterion, and thus is really is not incompatible with the wave asymmetry mechanism proposed here. The Hands and Allison method may be successful because it adequately captures the wave asymmetry mechanism through the empiricism.

The Larson and Kraus (1994) method is purely empirical so the same argument could be made. However, that method is based on empirical expressions for surf zone sand bars and beaches. It does not seem likely that the dominant physical mechanisms in the inner surf zone occur in the same relative proportions in the offshore depths for a number of obvious reasons. Any skill shown by methods based on inner surf zone empiricism may be due to fortune as much as physics.

The physical mechanism modeled by Scheffner (1991, 1996), the sediment response to the mean currents with transport rate modified by the presence of waves, seems relatively unimportant to the migration of nearshore placed sand. The evidence from the Mobile, Alabama site demonstrates the fundamental problem with a model based on mean currents. Douglass, et al. (1995) found that the measured mean near-bottom currents in the area were shore-parallel during the time that the mounds migrated shoreward. Shore-parallel mean currents are consistent with expectations for tidal currents near the coast, i.e. along the bathymetric contours. The cross-shore component of the mean near-bottom current was offshore during the time the mounds migrated landward! This offshore dominance was more pronounced during times of large waves, presumably due to downwelling due to onshore wind stress during storms. It appears that Scheffner (1991, 1996) was only able to verify his model at the Mobile, Alabama site by the explicit specification of shoreward mean currents. This was apparently based on a numerical, tidal simulation of a selected seven month period. Given that the actual measured, mean near-bottom currents at the site were in the other direction, Scheffner's method seems incorrect.

Diffusion concept

The diffusion coefficient, D, presented above has also been investigated. It is notable that the diffusion coefficient does not have any free parameters. It has the same coefficient, A, that is in the C equation. No results are presented here for two reasons. One, the methodology estimated more diffusion was was observed at Cape Canaveral. Other mounds; such as Mobile, Alabama and Perdido Pass, Florida; have shown less diffusion than the one at Cape Canaveral. The primary reason for not focussing on the diffusion portion of the model is conceptual. The "diffusion" term results directly from the way that bottom slope, $\tan \beta$, is included in the Bagnold/Inman and Bailard formulation for quasi-instantaneous transport. It accounts for influence of gravitational effects to pull sand down-slope. None of the observed mounds have shown a tendency for sand to move offshore down the slope, only onshore down the slope.

CONCLUSIONS

A design and planning tool for the nearshore placement of sand that estimates the expected onshore migration rate is presented. The results appear appropriate for the Atlantic and Gulf coasts of the United States. For any specific wave climate, the results indicate an appropriate way to evaluate the influence of depth on migration rate. Specifically, doubling the depth of placement will decrease the rate of migration by a factor of 16 to 32. Doubling the rate of migration requires placement in 13-16% shallower depths.

The physical basis for the model is the velocity asymmetry of large waves. This is consistent with observations reported in the literature and the findings of a field study off the Alabama coast that eliminated several other potential physical mechanisms for controlling mound migration. This model is limited by several theoretical and practical shortcomings. It abilities, however, indicate that a wave-based model that accounts for the net onshore transport or shear stress under finite-amplitude wave is the appropriate way to model the fate of nearshore placed sands.

REFERENCES

Andrassy, C. J. (1991). "Monitoring of a nearshore disposal mound at Silver Strand State Park." *Proc., Coast. Sediments 91 Conf.,* ASCE, New York, N.Y., Vol 2, 1970-1984.

Bagnold, R. A. (1963) "Mechanics of marine sedimentation," in *The Sea*, vol. 3, Interscience, New York.

Bailard, J.A. and Inman, D. L. 1981 "An Energistics Bedload Model for a Plane Sloping Beach: Local Transport" *J. Geophysical Res.*, 86(C3):2035-2043.

Bodge, K. R. (1994) "Performance of 1992 nearshore berm disposal at Port Canaveral, Florida." Olsen Associates, Inc. report to the Canaveral Port Authority, Jacksonville, FL, 55 p.

Douglass, S. L. (1995) "Estimating Landward Migration of Nearshore, Constructed, Sand Mounds," *J. Wtrwy, Port, Coast. and Oc. Engrg.*, ASCE, 121:5:247-250.

Douglass, S. L., Resio, D. T., and Hands, E. B. (1995) "Impact of near-bottom currents on dredged material mounds near Mobile Bay," *Tech. Rep. DRP-95-6*, US Army Engrs. Wtwys. Exper. Sta., Vicksburg, MS.

Foster, G. A., Healy, T. R., and DeLange, W. P. (1996) "Presaging beach renourishment from a nearshore dredge dump mound, Mt. Maunganui Beach, New Zealand." *J. Coastal Res.*, 12:2:395-405.

Hands, E. B. (1991) "Unprecedented migration of a submerged mound off the Alabama coast." Proc., 12th Annu. Conf. Western Dredging Assoc. And 24th Annu. Texas A&M Dredging Seminar, Oc.Engr. Program, Texas A&M Univ., College Station, Tx.

Hands, E. B. and Allison, M. C. (1991) "Mound migration in deeper water and methods of categorizing active and stable berms," *Proc. Coast. Sediments 91*, ASCE, 2:1985-1999.

Hands, E. B. and Bradley, K. P. (1990) "Results of monitoring the disposal berm at Sand Island, Alabama; report 1: construction and first year's response." *Tech. Rep. DRP-90-2*, US Army Engrs. Wtwys. Exper. Sta., Vicksburg, MS.

Hoekstra, P., Houwman, K. T., Kroon, A., Ruessink, B. G., Roelvink, J. A., and Spanhoff, R. (1996) "Morphological Development of the Tershelling shoreface nourishment in response to hydrodynamic and sediment transport processes," *Pre-Conf. Paper Summaries*, 25th Inter. Coastal Engrg. Conf., Orlando, Fl., Amer. Soc. of Civil Engrs., pp. 548-549.

Hubertz, J. M., Brooks, R. M., Brandon, W. A., and Tracy, B. A. (1993) "Hindcast Wave information for the US Atlantic coast," *WIS Report 30*, US Army Corps of Engrs. Wtwys. Exper. Sta., Vicksburg, MS, 502 p.

Larson, M. and Kraus, N. C. (1992) "Analysis of cross-shore movement of natural longshore bars and material placed to create longshore bars," *Tech. Rep. DRP-92-5*, US Army Engrs. Wtwys. Exper. Sta., Vicksburg, MS, 115 p.

Laustrup, C., Madsen, H. T., Sorensen, P., and Broker, I. (1996) "Comparison of Beach and Shoreface Nourishment Torsminde Tange, Denmark" *Pre-Conf. Paper Summaries*, 25th Inter. Coastal Engrg. Conf., Orlando, Fl., Amer. Soc. of Civil Engrs., pp. 550-551.

Mesa, C. 1996. Paper presented at 25th Inter. Coastal Engineering Conf., Orlando, Fl.

Roelvink, J. A., and Stive, M. J. F. (1989) "Bar generating cross-shore flow mechanisms on a beach," *J. Geophysical Res.*, 94:C4:4785-4800.

Roelvink, J. A., Meijer, Th., Spanhoff, R., and Hoekstra, P. (1996) "Process-based modelling of the behavior of barred coastal profiles" *Pre-Conf. Paper Summaries*, 25th Inter. Coastal Engrg. Conf., Orlando, Fl., Amer. Soc. of Civil Engrs., pp. 546-547.

Scheffner, N. W. (1991) "A systematic analysis of disposal site stability." *Proc., Coast. Sediments 91 Conf.*, ASCE, New York, N.Y., Vol. 2, 2012-2025.

Scheffner, N. W. (1996) "Systematic analysis of long-term fate of disposed dredged material." *J. Wtrwy, Port, Coast. and Oc. Engrg.*, ASCE, 122:3:127-133.

Stive, M. J. F. (1986) "A model for cross-shore sediment transport." *Proc., 20th Inter. Coastal Engrg. Conf.*, ASCE, New York, N. Y., pp. 1550-1564.