Cape Cod National Seashore, MA

PART II

COASTAL PROCESSES AND SEDIMENT TRANSPORT

Great Egg Harbor Inlet, Ocean City. N.J.

CHAPTER EIGHTY THREE

ADDED EVIDENCE ON NEW SCALE LAW FOR COASTAL MODELS

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Abstract

Further positive results on appropriate scaling of movable-bed models support an analytical expression developed in 1983. That development examined a simple parameter for a profile view of nearshore sedimentation, making a distinction between small and large situations by the incorporated threshold of sand motion. The resulting scale laws proved fairly consistent with various empirical results, including those by E. Noda and P. Vellinga.

The focus here is on full utilization of 25 available tests of profile development in large wave tanks. Seven published small tests are found to be notably accurate as unintended models of various large tests, giving support to the new scale law. Also, the occurrence of shore erosion or accretion in all large tests is seen to be in accordance with the basic sedimentation parameter.

INTRODUCTION

Two distinct approaches to predictive capability for nearshore changes are mathematical and physical modeling. In mathematical models, the appropriate level of detail seems a fundamental quandary: relatively simple treatments using some overall conditions offer intuitive appeal but have not yet managed impressive results in correlating measured beach changes (Seymour and King, 1982), while intricate computer models are still subject to fundamental questions about advisable numerical techniques and adequately detailed physics (McDowell and O'Connor, 1982). It is well known that prediction of average sand transport rates by waves is subject to large uncertainties, and this places limits on the present potential of mathematical models.

On the other hand, physical models are subject to criticism because of known differences in sand-bed processes in large prototype and small laboratory situations. However, scale effects do not preclude accurate reproduction of natural nearshore changes, if important transport mechanics are clearly enough identified that the model's design permits it to function as a meaningful physical analog for the prototype. Identification of dominant

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transport mechanisms is a central topic of the present research on physical modeling (and conclusions might also be pertinent to adequate mathematical models).

This paper is the last in a series of three concerning laboratory models for sandy nearshore regions dominated by wave action. All considerations have been based on distinct thresholds in wave-sand interactions, with quantitative deductions about accurate modeling compared to empirical evidence. The first paper (Hallermeier, 1984) examined two types of wave-cut features occurring outside the breakers, and concluded that practical models should omit the extensive region of moderate bed agitation and be confined mainly to the surf zone. The second paper (Hallermeier, 1985) developed a new analytical viewpoint for accurate profile modeling, and showed it to be supported by many published empirical results and by a new test program. This paper presents additional evidence on the validity of the new design guidance for physical surf-zone models.

Examining literature on coastal models from the past 15 years, actual treatments seem to separate into categories somewhat different from the three given by Keulegan (1966). Customary approaches to design guidance for physical models with sand and waves might be classified according to three types of basis, here called formal, empirical and parametric. The first type considers basic principles for replicating flows in terms of conserving force ratios (Froude, Reynolds, Archimedes, etc., numbers) between model and prototype. This formal approach is exemplified by modeling guidance presented by Yalin (1971) and Kamphuis (1975, 1982). A judgment on relative importance of various processes must enter such developments if they provide practical guidance about compromises always necessary between the contradictory formal requirements for physical modeling.

The empirical approach to model design recommendations proceeds solely from correlation of actual successes and failures, as in guidance by Noda (1972) and Vellinga (1982). Although disguised by usual expressions of results in generalized form, such conclusions strictly pertain only to prototype and model conditions actually investigated.

Fundamental limitations of formal and empirical routes has led to model design guidance based on preserving some parameter(s) judged most crucial to coastal processes. One example is research examining the sediment excursion ratio H/wT, where H is wave height, w is sediment fall velocity, and T is wave period (Dean, 1973). However, investigations to date (Noda, 1978; Vellinga, 1978; Gourlay, 1980; Sayao and Guimaraes, 1984; Hallermeier, 1985) have indicated that preserving H/wT between model and prototype is neither sufficient nor necessary to reproduce nearshore profiles.

The development pursued here is based on a different parameter meant to indicate sand movement in the surf zone: sand mobility is measured in terms of the threshold of sand motion rather than the fall velocity. To some extent, this corresponds to considering the stage of bedload or total sand transport rather than suspended sand movement alone.

NEW VIEWPOINT OF NEARSHORE SEDIMENTATION

The new parameter treating sedimentation on nearshore profiles is defined by characteristic flow velocities:

$$\psi = (V_h/U_o)/V_v \tag{1}$$

where V is peak wave-induced velocity, U_o is the threshold (horizontal) velocity for sediment motion, and subscripts h and v indicate horizontal and vertical components. The postulate is that planar similarity between model and prototype exists when identical values of ψ occur. Development of model design guidance proceeds (Hallermeier, 1985) by noting that these peak velocities share a common time scale, the wave period T, so their ratio can be given by the ratio of characteristic length scales L_h/L_v. The other step is to invoke convenient asymptotic expressions (Hallermeier, 1980) for sand motion thresholds in small and large situations, i.e., with laminar shearing of the boundary layer (for relatively high frequency waves) versus with a thoroughly mixed boundary layer (for lower frequency waves).

Preservation of ψ in an overall sense between small model and large prototype requires a scale ratio of

$$N_v/N_h = 0.0494\ (T_m)^{0.5}(s_m)^{0.75}(gD_m)^{0.25}(s_pD_p)^{-0.5}\ . \tag{2}$$

N indicates (fairly large) length scale between the two situations; subscripts p and m refer to prototype and model; D is sediment grain diameter; s is relative immersed sediment density in the fluid; and g is acceleration due to gravity. Besides Eq. (2), customary Froude scaling of waves requires time scale between prototype and model to be

$$N_t = (N_v)^{0.5} \tag{3}$$

giving a dynamic and a kinematic requirement for accuracy.

Perhaps the most encouraging evidence regarding the proposed scaling law in Eq. (2) is its quantitative similarity to the empirically-based conclusion by Vellinga (1982). That result was expressed using the scale between sediment fall velocities, and omitted any independent effect of wave period as in Eq. (2), but values for appropriate model distortion $\Delta = (N_h/N_v)$ by the two approaches show generally fair agreement in common open-coast conditions with quartz sands. Thus, Eq. (2) is supported by many of the Vellinga test results on dune erosion by extreme storm events on The Netherlands coast. The present relationship also appears to help correct the weakness noted by Vellinga (1982) in his recommended modeling law.

Another persuasive item of general evidence is that the present approach can nearly recover an empirical scaling law given by Noda (1972). In his laboratory investigations, all tests were evidently small in an absolute sense so the identical (laminar) asymptotic expression for sand motion is applicable to each. In that case, preservation of between two situations requires

$$\frac{N_h}{N_v} = \left[\frac{D_p T_p^2 s_p^3}{D_m T_m^2 s_m^3}\right]^{0.25} = (N_D N_v)^{0.25} (N_s)^{0.75} \quad \text{(small replicas; 4)}$$

using Eq. (3) and introducing the scales of sand diameter and immersed density between the two cases. Noda's results were given as two independent equations yielding

$$N_h/N_v = (N_v)^{0.25} (N_D)^{0.127} (N_s)^{-0.151} \quad \text{(E. Noda; 5)}$$

or, if N_s is eliminated because the major empirical emphasis was on $N_s = 1$ with quartz sediment in both situations,

$$N_h/N_v = (N_v)^{0.205} \ (N_D)^{0.209} \quad \text{(E. Noda; 6)}$$

There is a striking similarity between Eqs. (6) and (4) for the case of $N_s = 1$, so the present viewpoint seems to point out the mistaken nature of the scaling law deduced by Noda (1972): that it pertains to appropriate design giving profile replication between a pair of small situations, and not to the design of an accurate model for a large prototype.

The opposite case of replication consists of two large profiles. Then sand motion is governed by the same equation in each situation, that for a thoroughly mixed boundary layer. This yields for the preservation of ψ

$$N_h/N_v = (N_D N_s)^{0.5} \quad \text{(large relicas; 7)}$$

a form quite different from Eqs. (2) or (4).

From the present viewpoint, scale relations are not continuous. Distinction between models and either small or large relicas seems necessary for consistent treatment of scaled profile development. The idea that models and replicas are fundamentally different concepts has never received proper emphasis, but some evidence is apparent in a recent empirical analysis by Ito and Tsuchiya (1984).

The present approach and results on accurate scaling are entirely consistent internally, including an objective classification of "small" and "large" situations in terms of sand motion initiation. An intermediate range of transitional situations must be expected, but "small" has an upper size bound related to cessation of laminar boundary flow while "large" has a lower size bound related to onset of thoroughly-mixed flow in the boundary layer (Sleath, 1974, 1984). These size bounds are sensibly consistent with usual laboratory models being small and natural coastal situations of engineering interest being truly large.

MODELS OF LARGE-SCALE PROFILE CHANGES

New test results reported in Hallermeier (1985) gave some support for present guidance on accurate models, and clearly contradicted preservation of H/wT as a scaling law. Positive evidence consisted of only a few accurate models from a program of about 50 tests, each aiming to reproduce some profile developed in a large wave tank at the Beach Erosion Board, U.S. Army Corps of Engineers (Saville, 1957). Successful models were in fair accord with Eq. (2), whereas unsuccessful tests were usually not; H/wT had about the same value in most pairs of situations.

Reproduction of profile development from an initially plane sand slope provides a stringent test of modeling guidance: success indicates that the spatial pattern of net transport through corresponding times was identical on model and prototype profiles. Successful models do not imply that nearshore transport processes have been reproduced, but do demonstrate that net effects have been accurately scaled in a sensitive situation. Besides scale effects, possible laboratory effects on test results should be considered: for example, there are start-up effects in mechanical wave generation (Madsen, 1970) and the artificial borders to the sand bed can affect transport processes, as when a bulkhead eventually becomes exposed to waves. Some care was taken in the test program described by Hallermeier (1985) to reproduce steady wave durations in meaningful situations, but undesirable laboratory complications must be present in an additional data base on models assembled here.

The following results pertain to unintended models of the 25 available tests in large wave tanks, so timing of wave stops and fully consistent scales are quite unlikely. The large-scale data base includes 15 BEB tests mentioned above, and 10 recent tests at CRIEPI, Japan. Full documentation of the two BEB test series has never been published, but original test data are available at the Waterways Experiment Station (WESCR), Vicksburg, Mississippi. A brief report by Kajima, et al. (1982) on CRIEPI tests does not provide full details such as stopping times or intermediate profiles. Together the 25 large tests of profiles developed by steady wave action include H between 0.5 and

Table 1. CONDITIONS FOR SMALL-TANK TESTS TREATED AS UNINTENDED MODELS OF LARGE-TANK PROTOTYPES.

Test I.D.*	H_o, cm	T, sec	H_o/L_o	d, cm	D, mm	Sand s	Time, t, hr	Start Slope	N_{H_o}	N_T^2	N_d	N_t^2	Distortions: Test	Distortions: Eq.(2)
Model test by Shinohara et al. (1958)														
a. S/901	147	7.87	0.015	396	0.4	1.65	50	1/15						
b. Fig.2a	3.84	1.40	0.0127	35	0.2	1.66	6	1/10	38.7	31.6	11.3	69	1.50	1.43
Model test by Fairchild (1959)														
e. K/3-2	105	6.0	0.019	450	0.27	1.71	98.1	1/20						
f. 53°	10	1.8	0.02	38.1	0.22	1.65	31.5	1/18	10.5	11.1	11.8	9.7	1.11	1.03
Model test by Ijima and Aona (1959)														
i. S/101	100	11.33	0.0050	457	0.4	1.65	(15.0)	1/15						
j. Fig.3b	6.8	3.00	0.0048	40	0.28	1.9	(4.0)	1/20	13.7	14.3	11.4	14.1	0.75	0.81
Model test by Nicholson (1968)														
k. S/801	83	3.75	0.0377	457	0.4	1.65	50	1/15						
l. 78	5.8	1.00	0.0365	40	0.42	1.61	15	1/10	14.3	14.3	14.3	11.1	1.50	1.44
Model test by Monroe (1969)														
n. S/301	118	11.33	0.0059	427	0.4	1.65	50	1/15						
q. 3Qrtz	13.85	3.58	0.0069	42.7	0.26	1.58	16	1/15	8.5	10.0	10.0	9.8	1.00	0.87
Model test by Paul et al. (1972)														
r. K/2-1	176	6.0	0.0313	350	0.47	1.69	35	3/100						
u. Fig.2d	3.9	0.91	0.03	19	0.52	0.6	6	1/10	45.1	43.5	18.4	34.0	3.33	3.28
Model test by Chesnutt and Stafford (1977)														
e. K/3-2	105	6.0	0.019	450	0.27	1.71	98.1	1/20						
x. 72D-06	11.8	1.9	0.021	71	0.22	1.65	(30.0)	1/20	8.9	10.0	6.3	10.7	1.00	1.10

*First of pair is prototype, distinguished by S for Saville (unpub.) or K for Kajima et al. (1982).

Table 2. SUMMARY OF MAJOR PROFILE FEATURES DEVELOPED IN PROTOTYPE AND UNINTENDED MODEL TESTS.

SUBAERIAL BEACH	INSHORE REGION	SEAWARD PROFILE	OVERALL COMPARISON
a. Accreted; peak to 0.4m at 10m from start shoreline	1.5m shore retreat; eroded to 0.8m deep, 2.5m offshore	Double bar; main peak 1.1 m high at 40m offshore	Features mostly similar but scale appears to be about 20 to 30 rather than N_v = 40, N_h = 60
b. Accreted sharp peak to 5 cm at 35cm from shoreline	7cm shore retreat; eroded to 2.5cm deep, 1m offshore.	Muted bar; peak 1.6cm high at 125cm offshore	
f. Accreted; sharp peak to 5 cm at 1m from shoreline	45cm shore retreat; eroded to 7cm deep & 3.7m offshore	Thin deposit on slope toe & more on tank floor	Nearshores similar but variable smaller scales than deduced 11 or 12
e. Accreted; peak 20cm high at 8m from shoreline	2m shore retreat; eroded to 50cm deep & 24m offshore	Large double bar, thin erosion along slope toe	Major nearshore changes all scale appropriately near about N_v=N_h=7
x. Accreted; peak 3cm high at 1m from shoreline	Neutral shoreline; eroded to 7cm deep & 4m offshore	Deposition to 4cm thick out to 8.5m offshore	
i. Accreted; peak 80cm high at 9m from shoreline	3m shore advance; slight erosion to 21m offshore	Erosion along slope toe, thin deposit landward	Similarity limited to large shore accretion; detailed features and sand sources different
j. Accreted; sharp peak 16cm high, 15cm from shoreline	65cm shore advance; major erosion to 4.3m offshore	Variable relatively thin accretion and erosion	
k. Mixed slight changes; eroded high, accreted low	0.6m shore advance, broad accretion from offshore	35cm high bar out at 14m & trough to 35m offshore	Bar and seaward trough, dominant features, have scale near N_v=15, N_h=25; differences elsewhere
l. Mixed slight changes; accreted high, eroded low	6cm shore retreat, some accretion from offshore	3cm high bar out at 60cm & trough to 1.4m offshore	
n. Accreted; broad peak to 1m high at 7m onshore	1m shore advance; neutral just beyond shore bulge	Deeply eroded slope toe, some accretion landward	Beach features nearly scale at intended N=10, but subaqueous features are radically different
q. Accreted; peak to 10cm high 1.2m from shoreline	15cm shore advance; 11cm deep trough 2m offshore	Mainly slope erosion and deposition on tank floor	
r. Deposit to 25cm thick, up to 11m onshore	Low deposits out to 23m, erosion to 55m offshore	Sizable bar and trough near slope toe	Small nearshore changes scale at N_v=30, N_h=60, rather than deduced values of N_v=40, N_h=130
u. Deposit to 1cm thick, up to 20cm onshore	Low deposit out to 35cm, erosion to 1m offshore	Nearly no development	

1.8 m, T between 3 and 16 sec, three initial slopes, and four fine to medium quartz sands; a wide range of conditions is represented but coverage is not intensive.

Potential unintended models for these 25 prototypes can be sought in over 50 reports documenting profile development in small situations. For the present search, attention was limited to 20 accessible recent reports, which include about 150 profile development tests. The search for unintended models began by requiring a good match between a small and large test in deep-water wave steepness (H_o/L_o) as required by Eq. (3). Then fairly consistent scaling in wave height, water depth, wave period, and duration of profile development was sought. In this way, seven model/prototype pairs listed in Table 1 were located; model slope distortion relative to the prototype is in each case fairly consistent with the requirement of Eq. (2). (Besides space limitations here, full comparison of all small and large profiles is not provided because the present partial search aimed only at extending the scant data base of successful models, and definitive contradiction of present modeling guidance would be doubtful, in that laboratory effects are unknown.)

Table 2 provides a summary of profile features arising in model/prototype pairs. There is a distinct similarity in nearshore profile development for each case, with matches tending to be more quantitative than qualitative in pairs of situations with more consistent overall scaling. Given the startling variety of profile developments which can occur on an initial plane slope, in terms of number, location, and dimensions of major features, these seven cases distinctly provide support for Eq. (2) as a scale law.

To give a quantitative indication of Eq. (2) guidance, Figure 1 presents a nomogram constructed by standard means (Levin, 1946). Taking the prototype to be s_p = 1.6 (quartz in saltwater), remaining parameters are arranged by like exponents into three ratios: D_p/T_p, N_v/D_m, and N_h/N_v. The dual central axis of Figure 1 shows necessary distortion for either quartz or coal in water as model materials.

Figure 1 also indicates some of the range of validation provided by models newly described here or in Hallermeier (1985). Conditions for all 9 models shown by dashed lines include quartz sand. This display of various cases supporting Eq. (2) may be deceptive in exaggerating the range of model conditions: individual values of five parameters rather than three ratios actually gives the empirical basis for the new scaling law. However, this indicated basis excludes other published model tests whose support for Eq. (2) was discussed previously (Hallermeier, 1985).

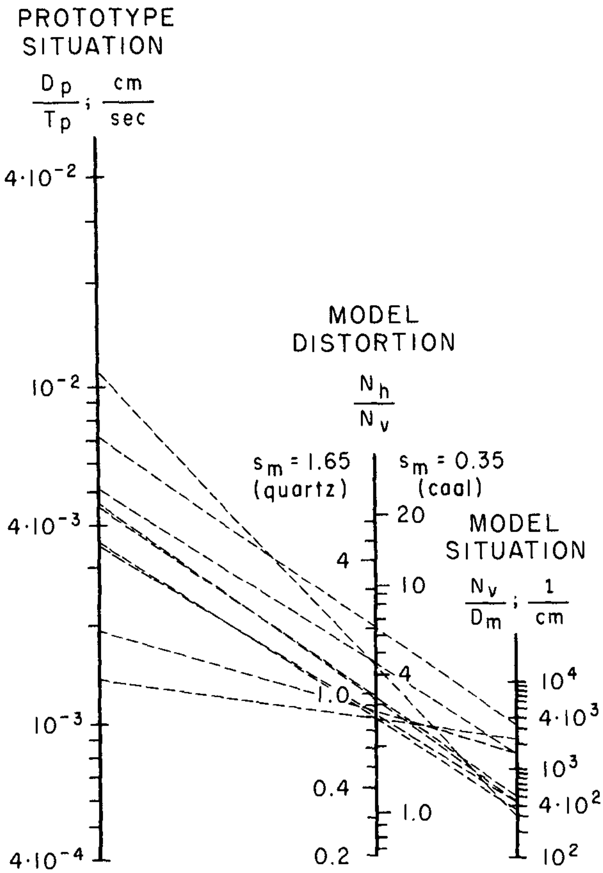

Figure 1. Nomogram for sedimentation similitude with either quartz or coal as model material, based on Eqs. 2 and 3, along with presumption that prototype has s_p = 1.6 [quartz in saltwater]. Support for this scale law, related here or in Hallermeier (1985), is indicated by dashed lines showing approximate conditions for quartz models of large tank tests.

The overall range of verification with radically different prototype situations provides extensive corroboration for the new parametric viewpoint of sedimentation.

SOME BASIC EFFECTS IN LARGE PROFILE CHANGES

Situations in large tests of profile development have been idealized, but the present viewpoint indicates scale effects are absent so recorded changes should be exactly pertinent to net onshore/offshore sand transport in large field waves. Results in large tests can be directly applicable to several cases of engineering interest. One example is immediate adjustment of a beach fill which might be placed as a direct berm extension into the usual surf zone. Another example is erosion of a simple accreted beach profile by relatively steady storm waves.

The latter case can be illustrated using results of a BEB test along with the well-documented (Gable, 1981) storm event which occurred during a Nearshore Sediment Transport Study experiment at Santa Barbara, California. Quartz sand of 0.227 mm diameter and foreshore slope about 1 on 15 at Leadbetter Beach matched the first series of large tank tests, so Eq. (7) shows a relationship is possible between field and laboratory events. Representative wave conditions may be approximated as $H = 1.25$ m and $T = 14$ sec for the 5-day California storm during February 1980; near this is laboratory test number 7 with steady waves of $H = 1.6$ m and $T = 16$ sec. This yields a match in wave steepness, so the tank test can be an undistorted replica of the Leadbetter Beach event, at about 30% linear magnification. Such a viewpoint is seen to be consistent with recorded shore effects (Figure 2) which include fairly steady shoreline retreat totaling 40 m over the 5-day storm.

In the laboratory, waves ultimately exposed a concrete wall behind the sand slope so only the first 20 hours of testing should be considered; in that time, the still-water shoreline retreated 10 m (Caldwell, 1959). Mean-sea-level shoreline at Leadbetter Beach retreated 9 m during the first storm day, exactly consistent with laboratory effects being at the stated magnification. Agreement of recorded shore changes persists into finer details: in each case the foreshore steepened with lesser retreat at higher elevations up to the berm crest; also, behind the berm crest there was slight sand deposition. These effects indicate marked similarity of shore hydraulics and net sand transport in the two cases. However, the laboratory situation was in fact much simpler: nearly two-dimensional with no alongshore transport and with steady waves and no tide on a plane slope.

Still, this example reveals a fundamental congruence of large-tank profile development to natural effects, and encourages classification of basic results from large lab-

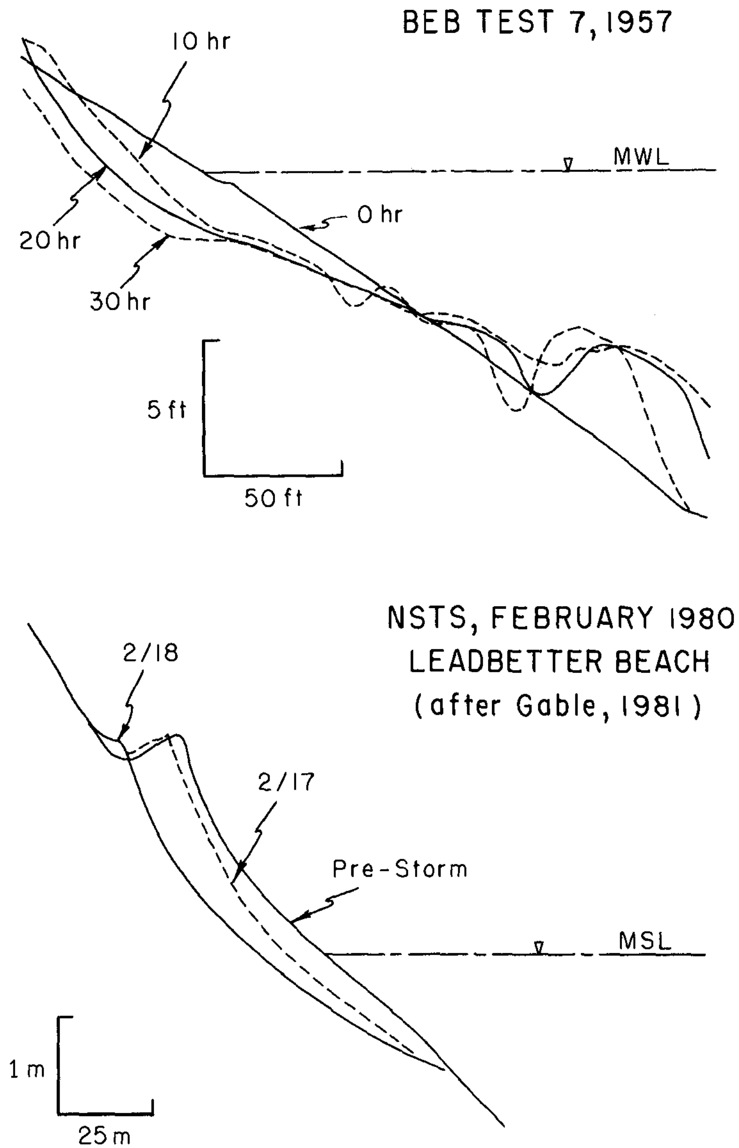

Figure 2. Similar shore changes recorded in large tank test and during storm at Leadbetter Beach, California.

oratory tests. The occurrence of shore erosion or accretion at large scale will be examined in terms of two published treatments and the present viewpoint.

The two treatments of profile modification considered here are those by Dean (1973), who introduced sediment fall velocity as a crucial parameter, and Sunamura and Horikawa (1974), who developed a more detailed parametric model for net sand transport. Dean (1973) reported a successful break of storm/eroded vs. normal/accreted profiles for 184 (mainly small) tests by a linear relationship between H_o/L_o and w/gT (parameters combined in H/wT). Sunamura and Horikawa (1974) distinguished shore erosion or accretion in terms of a linear relationship between H_o/L_o and a semi-empirical parameter including D, L_o, and initial slope; their main data base was about 75 long-term small tests but the same functional result was judged pertinent to shore changes in 23 large situations. (In each treatment results indicated marked change between small and large situations in the numerical coefficient of the relationship, and those changes can be shown to be roughly consistent with Eqs. (4) and (7) for usual conditions; however, the present viewpoint indicates a different correlating parameter should arise for changes in small and large situations.)

For the 25 available tests in large wave tanks, Figures 2a and 2b display types of shore change (above still water line) in terms of those two relationships. Conditions in terms of those parameters provide a useful demarcation of test results, although the originally proposed relationships (45^o lines in this format) cannot be retained. The dashed lines shown provide a clear break between shore erosion and accretion, with only one outlier in Figure 2a and none in Figure 2b. Close examination reveals the break in Figure 2b to be somewhat more clear, with better ordering of marked erosion through neutral development to marked accretion. This verifies the importance of initial slope M.

The third panel of Figure 2 evaluates the usefulness of sedimentation similitude considerations in attempting such a demarcation of conditions for shore erosion or accretion. The Appendix develops from Eq. (1) the abscissa

$$\psi' = \pi(8sD)^{0.5}/(TM'g^{0.5}) \qquad (8)$$

where M' denotes initial slope divided by 1 on 15, slope for a majority of the tests. Results in Figure 2c upon close inspection show a somewhat clearer break of actual effects than is obtained in the other panels. The major difference in the third plot is that the Eq. (8) parameter has a stronger dependence on initial slope (derived from the requirements for sedimentation similitude in large-scale replications). Empirical results of Sunamura and

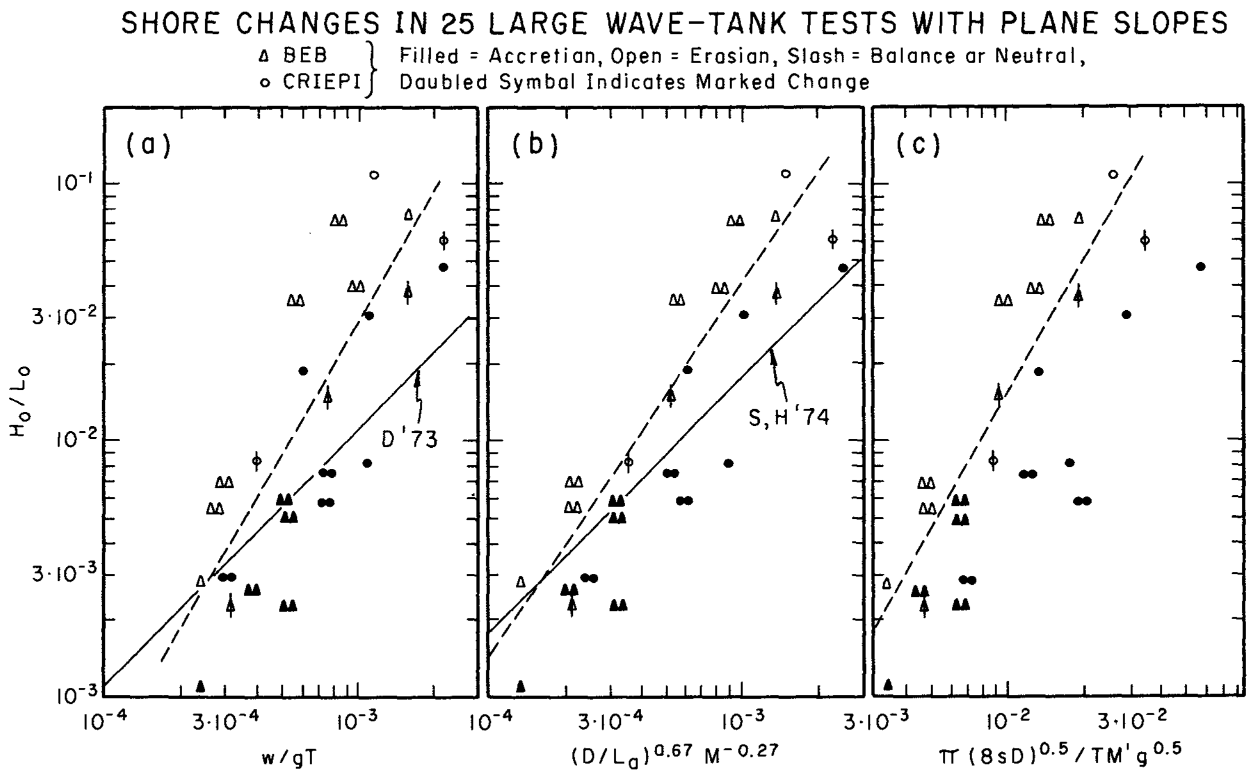

Figure 3. Three classifications with erosion at left and accretion at right of dash lines: a. Dean (1973); b. Sunamura and Horikawa (1974); c. new sedimentation parameter.

Horikawa (1974) indicating a relatively weak slope dependence were primarily from small-scale profile developments, where the independent effects of slope and wave steepness, when combined into the surf-similarity parameter, apparently tend to cancel (Hallermeier, 1984).

Although only large-scale data have been considered, these findings definitely support the new viewpoint of nearshore sedimentation and thus of appropriate model design. Note that preceding examinations do not exhaust the usefulness of available large tests. The few situations exhibiting little profile development or a switch in shoreline movement seem worth special study. Also, inshore and offshore profile changes remain of basic interest, even though profile forms developed in large tanks may be somewhat unnatural due to the steep initial slopes, i.e., the marked distortion of natural surf zones.

CONCLUDING REMARKS

Evidence presented above and in Hallermeier (1985) is favorable rather than definitive regarding the accuracy of the proposed scaling law for coastal models. The approach yielding Eq. (2) has been shown to explain various previously reported empirical results including fairly successful movable-bed models. However, the new modeling relation has not yet been subjected to a stringent test program designed to define its usefulness and limitations.

Several unverified aspects of the guidance in Eq. (2) should be mentioned. If a model is to use prototype sediment for convenience and accuracy in size distribution, and to be undistorted for accurate wave patterns near structures, the new scale law provides no free choices: one value of N_V will be appropriate. Whether or not distortion of a chosen magnitude can be successfully imposed on a sand model remains unanswered. Also largely unknown is the usefulness of Eq. (2) with lightweight model sediments and in design of three-dimensional models. Finally, with prototype wave period figuring in basic model design (because of the sand motion process in the laboratory), a representative period must be determined.

One way to evaluate present guidance further would be review of the designs for three-dimensional models documented to have been either accurate or erroneous. Preliminary examination of some successful models reveals that it is possible to find designs basically agreeing (Fried, 1976) or disagreeing (Noda, 1966) with Eq. (2). However, detailed consideration of prototype sites with regard to littoral drift, dominant structures, etc., would be required for firm assessments. Also needing consideration are different procedures and informal approaches to the "modeling art" arising in various laboratories.

To summarize available evidence, Eq. (1) gives a direct and rational viewpoint of nearshore sand movements on the profile. Horizontal flow velocity divided by the threshold velocity for sand motion is a primary indicator of transport stage, and ψ seems a more fundamental sedimentation indicator than a parameter with sediment settling velocity can be. Also, settling velocity for common sands depends on fluid viscosity, so its absence for present guidance prevents an awkward requirement to control water temperature in laboratory models. Although limited, empirical results give clear support to the new viewpoint of modeling.

APPENDIX - DERIVATION OF EQUATION (8)

The fundamental definition of Eq. (1) is invoked along with linear wave theory at mid-depth in shallow water and the threshold for sand motion in large situations, giving

$$V_h = 0.5\ H\ (g/d)^{0.5} \tag{A1}$$
$$V_v = 0.5\pi\ H/T \tag{A2}$$
$$U_o = (8sgD)^{0.5} \tag{A3}$$
$$\psi = T/\pi(8sdD)^{0.5} \tag{A4}$$

where d is nearshore water depth. To measure profile changes by a meaningful dimensionless form, the last expression is multiplied by wave clerity $c = (gd)^{0.5}$, propagation rate of mobilizing impulses. For comparable dependences with other sedimentation parameters used in Figure 3, the present measure must be inverted.

Adjustment is needed for effect of varying initial slope since Eq. (7) indicates large tests are related by

$$N_h/N_v = (N_M)^{-1} = (N_D N_S)^{0.5} \tag{A5}$$

where M is bed slope. This indicates the functional trade-off, e.g., between a steeper slope and a finer, less dense sediment, with respect to replicating some standard large situation. Choosing test conditions with the most common slope (M = 1/15) to remain unadjusted, a parameter for profile changes based on Eq. (1) may thus be written as

$$\psi' = \pi(8sD)^{0.5}/(TM'g^{0.5}) \tag{A6}$$

where M' = (15M). This is the form provided in Eq. (8).

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