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DISCUSSION

Discussion of Orrin Pilkey, Robert S. Young, Stanley R. Riggs, A. W. Sam Smith, Huiyan Wu and Walter D. Pilkey, 1993. The concept of shoreface profile of equilibrium: A critical review. *Journal of Coastal Research,* 9(1), 255–278.

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The article presented by PILKEY *et al.* (1993) examines the underlying assumptions that provide the foundation for the concept of an equilibrium shoreface profile, and concludes that several assumptions are not met in real world studies. The authors, therefore, question the usefulness of the equilibrium concept as applied by coastal engineers. Although this article raises valid concerns about the applicability of the equilibrium concept, in the end it does not reconcile the concept and its application. This reader comes away with the feeling that the equilibrium concept is of little use to anyone. Thus, the purpose of this discussion is to emphasize that the equilibrium profile can conceptually exist in the *predicted* and the *observed* form, and to demonstrate that the predicted and the observed equilibrium profile can serve as conceptual models which, when properly used, can lead towards a better understanding of the coastal environment.

The *predicted equilibrium shoreface profile* assumes that if (1) sea level and (2) the wave dimensions are constant through time, (3) the shoreface profile is formed on potentially mobile sediments, (4) the texture, density, and shape of shoreface sediments are homogeneous along the length of the profile, and (4) there is no net sediment loss or gain in the longshore and cross-shore directions, then the shoreface profile is regarded as being in a state of equilibrium. In turn, the profile will be geographically fixed through time and will exhibit an upward concave shape such that the depth (y) relative to the offshore distance (x) follows the power function (BRUUN, 1954)

$$y = px^{[illegible]}, \qquad (1)$$

where p is a scale parameter dependent on the texture of bottom sediments (DEAN, 1977), and the exponent is the shape parameter. More specifically, Equation 1 is formulated from the following physical assumptions: (a) the shear stress per unit bottom area is constant, and (b) the rate of transported wave energy per unit wave area is constant. Energy is assumed to be primarily dissipated by bottom friction, with some small loss from wave spilling and internal friction. Depths and offshore distances are also related as a power function if all of the energy is assumed to be lost from bottom friction (BRUUN, 1954). Thus, Equation 1 represents the predicted equilibrium shoreface profile as generated solely from the interaction between monochromatic waves and homogeneous bottom sediments. Because wave action is the only process being considered, Equation 1 also portrays the simplest of all possible theoretical models. Real world depths and offshore distances across shorefaces have been shown to be related as a power function, but with varying scale and shape parameter values (DEAN, 1977).

The predicted equilibrium shoreface profile should be viewed as a valuable tool for structuring primary research questions. By representing the ideal in its simplest form, the equilibrium profile serves as the ultimate reference profile to which all observed profiles can be compared. In virtually all cases a match between an observed shoreface profile and the predicted profile will not be a good one; the residuals will require explanation. That in turn leads to a primary question: what assumption(s) is (are) not being met so as to cause the difference between the observed and the predicted profile? The correct answer to this question advances our basic understanding of the referent coastal setting. Clearly, after this analysis is repeated for a variety of coastal settings, a general model of the coastal environment will become apparent. The alternative is to potentially limit our knowledge of the processes that shape the coastal environment.

As previously mentioned, the chance of an observed profile exactly matching the predicted profile is extremely small; the shape parameter of the predicted profile may differ from that calculated for an observed profile (WRIGHT *et al.*, 1991). One reason why exponents may differ is that the assumption of a shoreface profile having been developed from uniform (sand) material (BRUUN, 1993) will not be met. On a shoreface, sediment size varies across the profile, generally grading seaward from coarse to fine. In turn, the rate at which particle size changes in the cross-shore direction should have an impact on the shape of the profile, and that rate may also change from one coastal setting to another. Therefore, when the constants in Equation 1 are empirically solved for observed data, the exponent value may vary from the theoretical two-thirds. For real world studies, the equation of a shoreface profile should be simply expressed as

$$y = px^m, \qquad (2)$$

assuming the theory which relates y and x as a power function is correct. Equation 2 can represent the model for an *observed equilibrium shoreface profile* at a study site if a high correlation coefficient is registered between observed depths and corresponding offshore distances. If the shape and geographic position of a profile remain reasonably constant through time, then for a unit bottom area, the sum of all forces generating a shear stress can be assumed to be equal to the shear strength of bottom sediments. Because all of the assumptions of Equation 1 can not be reasonably met, PILKEY *et al.* (1993) are correct in suggesting that Equation 1 should not be used in applied studies; however, given a good fit between depths and corresponding distances across a shoreface, Equation 2 can serve as a useful model for basic and applied studies.

For some data, the power function relationship between depth and offshore distance will be poor, and under these circumstances Equation 2 should not be used. One reason for a poor relationship can be a function of the offshore geology (PILKEY *et al.*, 1993). The shoreface profile may be irregular because of the exposure of stratigraphic beds consisting of consolidated or semi-consolidated material that resist, to various degrees, transport by wave and current action. Another reason for a poor fit between depth and offshore distance could be the presence of longshore bars (PILKEY *et al.*, 1993). A barred profile when compared to the ideal profile (Eq. 1) raises a primary question: why should a permanent bar (or bars) exist? What assumptions pertaining to Equation 1 are not met so as to cause the interaction between waves and sediment to develop permanent bars? However, the presence of a permanent nearshore bar should not deter us from using Equation 2, if this equation is employed for the shoreface seaward of a bar. Indeed, BRUUN (1954) stated that Equation 1 must be used seaward of a bar.

Sediments may be lost from a shoreface, thereby violating another assumption of the predicted equilibrium profile (PILKEY *et al.*, 1993). During storms, downwelling currents can transport sediments from the shoreface to the inner continental shelf and deposit them at a depth where fair-weather waves and upwelling currents are unable to return the materials to the shoreface (SWIFT *et al.*, 1985; WRIGHT *et al.*, 1991). Overwash can also remove sediment from the shoreface. A net loss of shoreface sediment causes the profile to be displaced landward. The fact that the shoreface profile is no longer geographically fixed through time raises a primary question: why are sediments being lost from both ends of a shoreface? Clearly, the answer to this question involves rising sea level, which can increase the frequency of overwash and cause a potential sediment sink over the inner continental shelf. If sea levels were not rising, continuous deposition resulting from the downwelling transport of shoreface sediment would elevate a shelf to a depth where swells and upwelling currents could re-transport sediments to the shoreface. With a stable sea level, a cross-shore profile could achieve equilibrium between storm and fair-weather coastal processes. However, so long as sea level rises and strong downwelling currents prevail, shoreface sediments should continue to be lost to the inner shelf. Even though sediments are lost from both ends of a shoreface thereby causing the profile to transgress, Equation 2 can be applied so long as the profile shape remains reasonably constant through time. For example, DUBOIS (1990) employed Equation 2 in the form of

$$\Delta x = (y_l/p)^{1/m} - [(y_l - S)/p]^{1/m}, \quad (3)$$

where y_l is limited depth of sediment transport and S is the rate of rising sea level to predict beach erosion rates (Δx). This approach yielded encouraging results (DUBOIS, 1990), but additional research using this model is needed.

In conclusion, several issues raised by PILKEY *et al.* (1993) are valid and need to be addressed by coastal scientists and engineers. A high standard must be maintained when applying coastal concepts for practical use, and in the name of high standards their article has been severely critical of the predicted equilibrium profile (Eq. 1) as it is now being applied. Yet their article could have provided guidance towards a reconciliation between the equilibrium concept and its use. This discussion has attempted to shed some light by noting that the predicted equilibrium profile can be used to assist in formulating primary questions while an observed equilibrium profile can be used for basic and applied research in the area where shoreface profile data are gathered. Unquestionably, both types of equilibrium shoreface profiles merit more research. Efforts should be directed towards developing a theoretical model of a shoreface profile that evolves under the influence of fair-weather waves and upwelling currents. Such a model would become the reference profile to which observed profiles, collected from a coastal regime reflecting the theoretical model, could be compared. Progress is being made towards developing a model that includes the variability of sediment size across a shoreface (LARSON, 1991). Finally, more temporal and spatial field measurements of depths and corresponding offshore distances across shorefaces are needed so that theories can be tested against real world profiles and basic data are available to help solve practical problems.

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