# Event-Based Erosion

## FEMA Coastal Flood Hazard Analysis and Mapping Guidelines Focused Study Report

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**Acronyms**

| | |
|---|---|
| BFEs | Base Flood Elevations |
| CCCL | State of Florida’s Coastal Construction Control Line |
| CCM | Connecticut Conference of Municipalities |
| CEDAS | Coastal Engineering Design and Analysis System |
| CERC | Coastal Engineering Research Center |
| CFR | Code of Federal Regulations |
| CHL | Coastal and Hydraulics Laboratory |
| D&D | Dewberry & Davis |
| DHI | Danish Hydraulic Institute |
| EBE | Event-Based Erosion |
| EBEACH | time-dependant, two-dimensional beach and dune erosion model |
| ERDC | Engineer Research and Development Center |
| FEMA | Federal Emergency Management Agency |
| FIRM | Flood Insurance Rate Map |
| FIS | Flood Insurance Study |
| HAZUS | Flood Loss Model |
| LIDAR | Airborne Light Detection and Ranging |
| NAS | National Academy of Sciences |
| NFIP | National Flood Insurance Program |
| NOAA | National Oceanic and Atmospheric Administration |

| | |
|---|---|
| PNW | Pacific Northwest |
| REFDIF | wave model |
| SBEACH | Storm-induced Beach Change numerical model |
| SF | square feet |
| SHORECIRC | Quasi-3D nearshore circulation model |
| SWEL | Stillwater Flood Elevation |
| TWG | Technical Working Group |
| USACE | U.S. Army Corps of Engineers |
| USGS | U.S. Geological Survey |

# 1 INTRODUCTION

This report provides recommendations for a program leading to improvement of the current Federal Emergency Management Agency (FEMA) Guidelines related to Event-Based Erosion (EBE) and develops preliminary time estimates to accomplish these improvements. Fourteen technical categories related to EBE were developed by the Technical Working Group (TWG) during the December 2003 Workshop. Some of the EBE category needs and priorities were revised during Workshop 2 in February 2004. Four of these topics are prioritized as "Critical" with two of the Topics (Topic Nos. 33 & 35) applied to all three geographic areas (Atlantic, Gulf, and Pacific Coasts), five were designated "Important", four were designated "Available," and two were "Helpful." Topic 39, Primary Fontal Dune, was moved to topics covered under Hazard Zones. All thirteen remaining Topics addressed by the EBE Team are listed below (*Items in parentheses were revised at WS-2, 02-26-02*) and discussed in this report. Erosion during tsunamis and erosion due to winds (aeolian erosion) are topics not considered in the Focused Studies.

EBE Topic priorities were categorized by The TWG in light of the project schedule, which allowed approximately six months for development of new guidelines for the Pacific Coast. Based on this practical consideration, topics were characterized as follows:

- *Critical* – topics that were considered important to improve coastal flood hazard analysis and mapping for the NFIP, that required significant effort to analyze or develop, but could be developed or resolved in six months or less.
- *Important* – topics that were considered important to improve coastal flood hazard analysis and mapping for the NFIP, that required significant effort to analyze or develop, and are likely to require more than six months to be developed or resolved.
- *Available* – topics that could be improved with relatively available data or procedures in less than six months.
- *Helpful* – topics that would be helpful to the NFIP, but were considered less significant or lower priority.

**Event-Based Erosion Topics and Priorities**
(Items in parentheses were revised at WS-2, 02-26-02)

| Topic Number | Category | Topic Description | Atlantic / Gulf Coast | Pacific Coast | Non-Open Coast |
|---|---|---|---|---|---|
| 30 | Geometric Techniques - PC | Review empirical geometric techniques and pre- and post-event data for CA, OR, WA; review OR setback methods, develop geometric techniques for pacific shorelines, including sea cliff, bluff, dunes beaches | -- | C | -- |

| **Event-Based Erosion Topics and Priorities**<br>(Items in parentheses were revised at WS-2, 02-26-02) | | | | | |
|---|---|---|---|---|---|
| Topic Number | Category | Topic Description | Atlantic / Gulf Coast | Pacific Coast | Non-Open Coast |
| 31 | Bluff Erosion - AC/GC/(PC) | Add/revise *G&S* language regarding bluff erosion in Atlantic/Gulf areas – better descriptions and discussions needed | A | (A) | (A) |
| 32 | Geometric Method for Bluffs - AC/GC/(PC) | Develop geometric method for bluff erosion in Atlantic/Gulf areas | I (A) | (A) | (A) |
| 33 | Cobble/ Shingle Effects | Add *G&S* descriptions/discussion regarding effect of cobble/shingle materials (including sediment mixtures/layers) on geometric erosion techniques | C | C | C |
| 34 | Cobble/ Shingle -Geometric Method | Develop improved geometric methods which consider cobble/shingle effects | I | I | I |
| 35 | Erosion – Sheltered Waters | Add *G&S* descriptions/discussions regarding erosion assessments in sheltered areas | (C) | (C) | C |
| 36 | Geometric Method – Sheltered Waters | Review data and develop geometric methods for determining eroded profiles in sheltered areas | (I) | (I) | I |
| 37 | Review 540 SF Criterion | Expand database from which 540 was determined; review use of median value | I | -- | -- |
| 38 | Process-Based Approach | Develop assessment procedures that consider temporal and longshore effects/variability | I | I | I |
| 39 | PFD | Develop better definition of landward limit of PFD (used for V zone limit);gather and evaluate MA CZM and other approaches NOTE: Topic 39 moved to Hazard Zones | C *(H)*<br>39 moved to Hazard Zones | I *(H)*<br>39 moved to Hazard Zones | I *(H)*<br>39 moved to Hazard Zones |
| 40 | Vertical Erosion Depths | Maintain data and make available for use in building performance and insurance tasks | H<br>Nominal Needs | H<br>Nominal Needs | H<br>Nominal Needs |
| 41 | Long-Term Erosion | Revise *G&S* D.5 language and put warning on the FIRM to state that "present methods may understate/overstate future flood hazards; reference CCM and other reports; discuss implications of study data selection" (e.g., older data may have better resolution, but be out of date as a result of erosion, sea level change, effects of subsidence, etc.) | A | A | A |
| 42 & 43 | Nourished Beaches | Ensure clarity in *G&S* that references FEMA policy statement regarding treatment of nourished beaches | A | A | -- |
| Key: C = critical; A = available; I = important; H = helpful<br>(Recommend priority italicized if focused study recommended a change in priority class) | | | | | |

## 1.1 THE EBE TEAM AND APPROACH

The EBE study team consists of Kevin Coulton, Bob Dean, Darryl Hatheway, Maria Honeycutt, Jeff Johnson, Chris Jones, Paul Komar, Chia-Chi Lu, Ron Noble, Trey Ruthven, and Dick Seymour. Robert MacArthur served as Team Leader for this effort and Bob Dean provided significant guidance and review.

In order to provide structure to our efforts and to avoid unnecessary duplication of effort, the following approach was employed. The Team Leader assigned lead technical and writing responsibilities for specific topics to the following individuals: Paul Komar, Trey Ruthven, and Robert MacArthur (Topics 30-34), Ron Noble and Chia-Chi Lu, (Topics 35, 36, 38, and 41), Chris Jones (37, 40, 41, 42, and 43). All EBE Team Members contributed significant information of which they were uniquely aware, critiqued and contributed to the draft write-ups, and accomplished specific components of the overall effort leading to this report.

## 1.2 PRESENT FEMA GUIDANCE ON EVENT-BASED EROSION RELATED TO ALL PRIORITY CATEGORIES

Prior to 1986, specific FEMA guidance and objective procedures were not available for treating the effects of erosion in coastal flood hazard assessments. Studies by Hallermeier and Rhodes (1988) and Dewberry & Davis (1989) developed and discussed the method recommended in present FEMA "*Guidelines and Specifications for Flood Hazard Mapping Partners: Appendix D – Guidance for Coastal Flooding Analyses and Mapping*" (April 2003), hereinafter referred to as *Appendix D*. Present geometric erosion assessment methods in *Appendix D* rely on empirical results from an assessment of 38 notable dune erosion cases documented primarily along the Atlantic and Gulf Coasts of the U.S. Present methods apply only to coastal sandy dunes and erodible bluffs according to the FEMA criteria associated with the definition of a primary frontal dune and only apply to coasts along the Atlantic, Gulf, or Great Lakes. In order to enact and adopt the procedures recommended by Dewberry & Davis, FEMA published new rules and definitions in the May 6, 1988 *Federal Register*, pages 16269-16273 (that became effective on October 1, 1988), which included the following revised definitions in 44 CFR sec. 59.1 and 65.11 of the National Flood Insurance Program (NFIP) regulations:

> "*Primary frontal dune* means a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms. The inland limit of the primary frontal dune occurs at the point where there is a distinct change from a relatively steep slope to a relatively mild slope." (From 44 CFR sec 59.1)

> *Evaluation criteria.* Primary frontal dunes will not be considered as effective barriers to the base flood storm surges and associated wave action where the cross-sectional area of the primary frontal dune, as measured perpendicular to the shoreline and above the 100-

year stillwater flood elevation and seaward of the dune crest, is equal to, or less than, 540 square feet [from 44 CFR sec 65.11 (b)].

The adopted procedure established a relationship of dune erosion area (and volume as a function of beach length) to storm intensity as measured by flood recurrence interval. For the 1-percent-annual-chance storm, *Appendix D* determined that, “to prevent dune breaching or removal, an average cross-sectional area of 540 square feet is required above the SWEL and seaward of the dune crest.” This standard for dune cross section continues to occupy a central role in erosion assessment procedures (also known as the 540 SF criterion). Material characteristics and storm duration are empirically included in this simple geometric relationship; however, application of this criterion may be limited to the coastal region for which it was developed.

Previous research by the Corps of Engineers Coastal Engineering Research Center (CERC, 1987) determined that quantitative (process-based) numerical models had not been developed to the point necessary for reliable application in FEMA-type assessments and mapping projects. Therefore, it was recommended by CERC that only empirically based models (for storm-induced or event-based erosion) produced reasonable results with a minimum of effort and input data. Further, it was recommended that this approach be used even though it has certain limitations, and that dune overwash processes are poorly documented and unquantified. FEMA performed additional investigations on erosion models and procedures before adopting the 540 SF criterion in 1988, but decided to employ these very simplified procedures for erosion assessments based upon empirical data from historical storm-induced erosion events. These procedures were considered capable of reasonable depiction of documented effects of extreme storms (resulting from either Atlantic and Gulf hurricanes, or extratropical storms such as northeasters) and were judged appropriate for treating dune erosion in Flood Insurance Studies (FISs) for coastal communities along the Atlantic and Gulf Coasts. As presented above, FEMA included a new section in 44 CFR sec. 65.11 of the NFIP regulations, identifying an (average) cross sectional area of 540 square feet as the basic criterion to be used in evaluation whether a primary frontal dune will serve as an effective barrier during a 1-percent-annual-chance (100-year) flood event. Figure D-4 from the *G&S* provides a flowchart summarizing FEMA’s present approach for assessing the effects of erosion during a Coastal Flood Insurance Study.

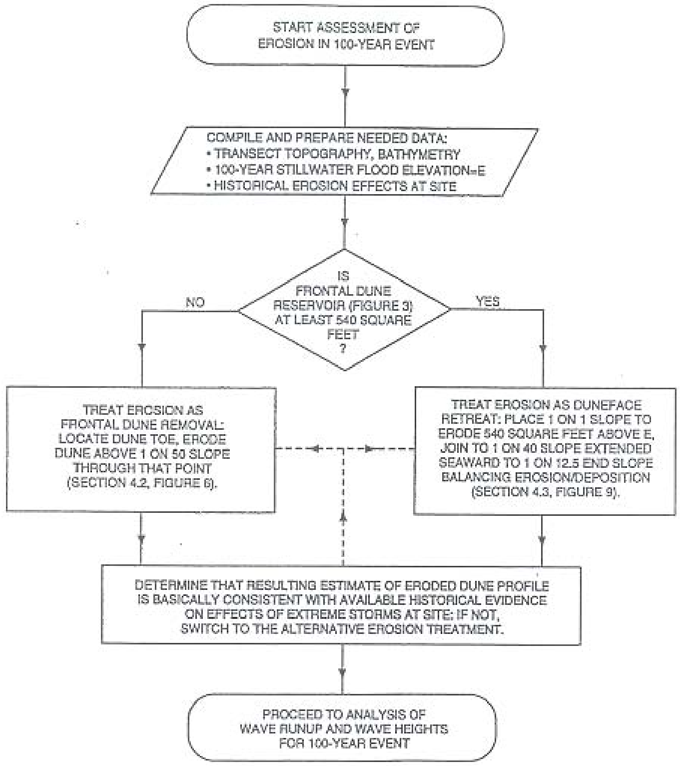



Figure D-4. Flowchart of Erosion Assessment for a Coastal Flood Insurance Study

The following Figures 1 and 2, summarize the "frontal dune reservoir" and "dune removal and dune retreat geometries" according to present FEMA criteria.

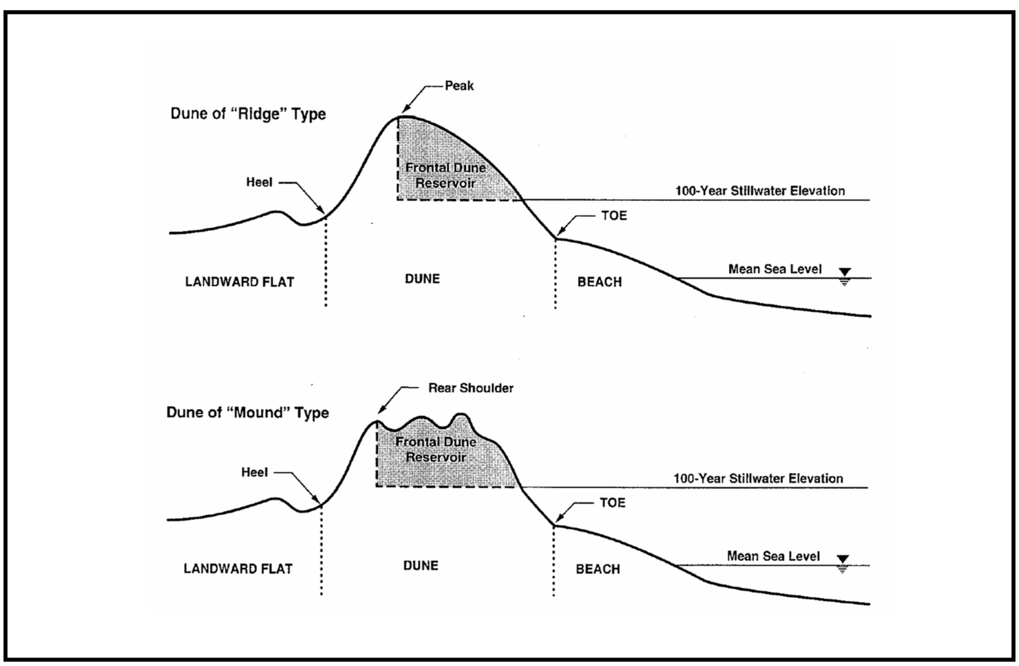



**Figure 1. Definition sketch of frontal dune reservoir (from FEMA, 2003).**

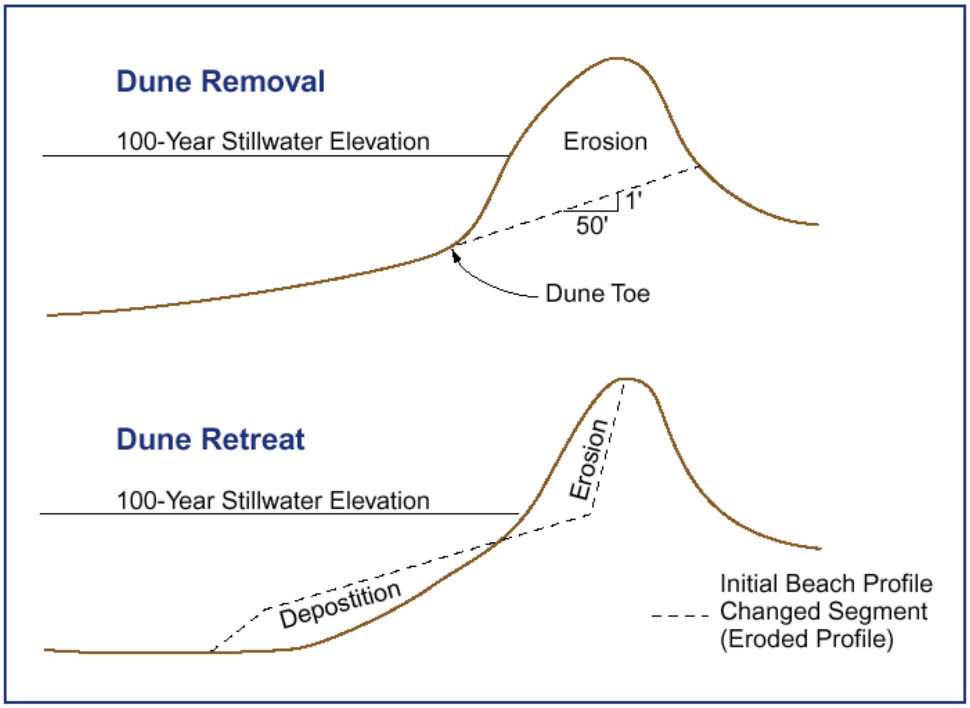
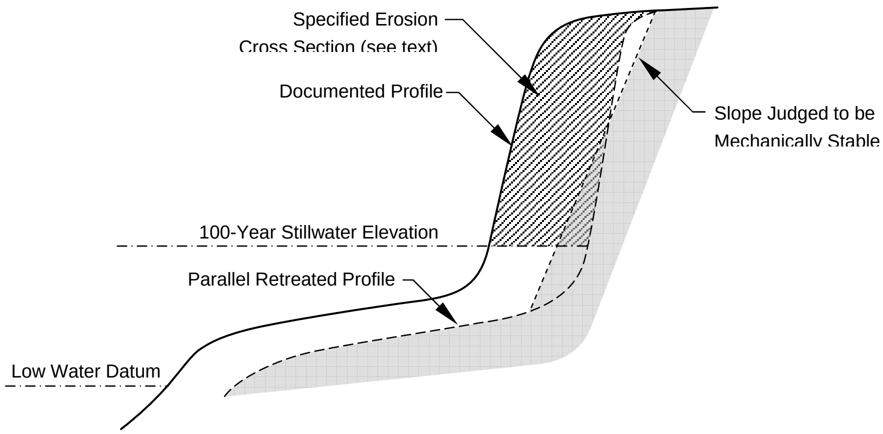
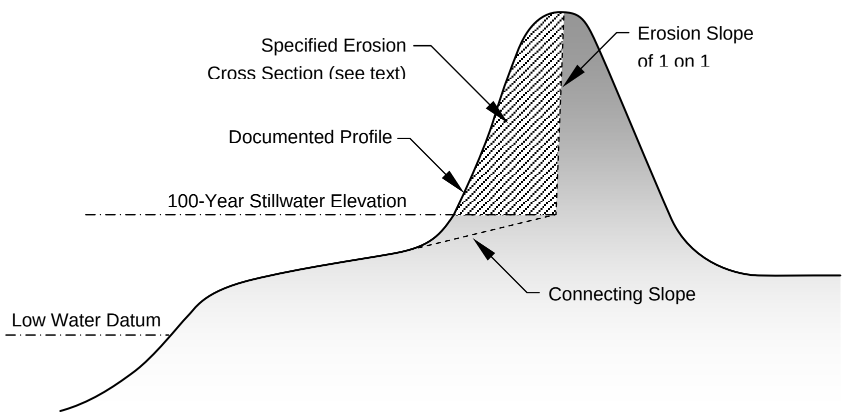



**Figure 2. Current FEMA treatment of dune retreat and dune removal.**

*Appendix D* also provides similar recommended procedures for assessing the effects of event-based erosion in the Great Lakes regions (see Section D-3). In the case of the Great Lakes, the average cross sectional area of the dune reservoir (above the 100-year stillwater level) required to prevent dune breaching and removal is 270 square feet for Superior, Michigan, Huron and Erie, and 190 square feet for Lake Ontario. These criterion were developed from observed data in each of the geographic areas. These same values are used to estimate bluff retreat in those locations, see Figures D-38 and D-39 from Appendix D, shown below. Although presented here, the Great Lakes geometric erosion assessment may be a lower value than expected for Pacific erosion events or other Sheltered Water locations. However, these values developed for the Great Lakes show how different material types and wave climates affect the limiting dimensions of the frontal dune reservoir for retreat and removal in different regions and will not be considered further in this study.




**Basic Erosion Considerations for Coastal Bluff Provides Shaded Shore Profile for Great Lakes Base Flood. (from Figure D-38, Appendix D.)**




**Basic Erosion Considerations for Coastal Sand Dune Provides Shaded Shore Profile for Great Lakes Base Flood. (from Figure D-39, Appendix D)**

Sheltered areas and coastlines with mixed grain-size, cobble-shingle or muddy bottom beaches and dunes are not explicitly covered by *Appendix D*. It is also clearly stated in Section D.4 that: "No FEMA guidance documents have been published for Pacific Ocean coastal flood studies. Guidance is to be developed based on existing methodologies recommended by FEMA and coastal states for coastal analyses in the Pacific Ocean. Mapping Partners that are undertaking a flood hazard analysis of a Pacific Coast site should consult with the FEMA Regional Project Officer for that area." Phase 2 of the present FEMA mapping project will develop such guidance for the Pacific.

Therefore, present *G&S* do not provide specific guidance for assessing event-based erosion in coastal areas of the Pacific, Sheltered Waters on either coast, or non-sandy beach and dune coastal areas, and provide only simplified empirical-based geometric relationships for the Atlantic and Gulf. Therefore, the following sections of this report discuss specific topics deemed important for consideration by the TWG during the December 2003 and February 2004 Workshops in order to improve the present guidelines for the Atlantic and Gulf and to develop recommendations for the development of new guidelines for the Pacific Coast and all Sheltered Water coastal areas of the continental U.S.

### 1.2.1 Factors in Beach, Dune and Bluff Erosion

To set the stage for discussions that follow on the various topics, it is useful to consider key characteristics of the erosion processes. The main erosion related factors are: 1) The forcing elements that include the time histories of the wave characteristics, currents and water levels, and runup, and 2) The response elements that include the physiographic setting and the beach and dune/bluff characteristics. The elevated water level places the profile out of equilibrium and the waves provide the energy and the offshore extent of sand redistribution to result in a reestablishment of equilibrium. If the forcing elements occur over a relatively short time period, there may not be enough time for the erosion processes to reestablish equilibrium. This is especially the case if the bluff is composed of durable material in which the processes proceed on more of a geological time scale than a storm event time scale. Some researchers prefer to relate periodic changes in beach and dune profiles to the exceedance of an erosion threshold within the beach setting with a new resultant state dependant on the forces imposed on it. This concept recognizes the importance of antecedent beach conditions when a storm event occurs and that erosion thresholds will vary between events of different duration, intensity and location.

Because the physics are the same for erosion on all types of shorelines, it is desirable in further developments and recommendations related to FEMA applications, to attempt to develop and recommend procedures that embody the same fundamental structure, and are applicable to different physiographic regions. In brief, this requires that the following considerations be included: 1) Physiographic setting, 2) Sediment characteristics across the active profile, 3) Time histories of wave and storm tide characteristics, and 4) Local or regional oceanic (El Niño) or topographic (recent tectonic adjustments) characteristics that may affect the study area. Within this common framework, it will be necessary to make assumptions and approximations in which, depending upon local conditions, some factors can be neglected; however, the fundamental structure of the erosion process will be consistent for all applications.

# 2 CRITICAL TOPICS

As noted, outcomes from the December 2003 Workshop identified four “Critical Topics” for Event-based erosion: 1) Topic 30 for the Pacific, 2) Topic 33 for all coastal regions, 3) Topic 35 for non-open coasts, 4) and Topic 39 for the Atlantic coast. (NOTE: Topic 39 is now covered in the Hazard Zones Focused Study.) Workshop 2 (February 23-26, 2004) adjusted the priorities and needs to those now listed in Table 1, with Topic 35 critical for *all three* geographical areas, and Topic 39 now being covered by the Hazard Zones Technical Working Group.

## 2.1 CRITICAL TOPIC 30: GEOMETRIC EROSION ASSESSMENT FOR THE PACIFIC

### 2.1.1 Description of Topic and Suggested Improvement

Dunes backing beaches along some of the U.S. coasts can reach sufficient elevations that they provide a barrier to the flooding of backshore areas. However, these dunes can be subject to significant erosion during extreme storms, potentially leading to their failure as a barrier. FEMA procedures divided EBE effects into two basic categories, retreat and removal (failure), as was shown in Figure 2.

The primary factor controlling the basic type of dune erosion is the pre-storm cross section lying above the 1-percent-annual-chance SWEL (frontal dune reservoir). This is recognized in the FEMA methodology as applied to the Atlantic and Gulf coasts, which first assesses the vulnerability of the dunes to erosion failure (using the 540 $ft^3/ft$ dune-volume criterion). If the median dune volume above the 100-year SWEL is greater than 540 $ft^3/ft$ of dune length, then the dune does not fail during the event but retreats with the dune remnant remaining as a surge and wave barrier. If there is less than this available volume per foot of dune length it is assumed that the dune will be breached and will fail, and will be washed away, resulting in a new “eroded beach profile” for use in calculating: 1) wave propagation landward, 2) surf transformation at the shoreline, and 3) wave runup at the coast. According to *Appendix D* guidance on dune retreat and dune removal, “different treatments for erosion are required for these two conditions because no available model of dune erosion suffices for the entire range of coastal [settings] situations.”

Similar problems with dune erosion processes exist along the Pacific Coast, although dunes are a less common feature in this region. No FEMA methodology has been established for the Pacific coastal environment where shoreline characteristics are more complex and where the cumulative effects of multiple storms must be considered rather than the single extreme storms typically found along the Atlantic and Gulf. Methodologies have been developed for application to West Coast conditions, but have been directed primarily toward the establishment of erosion hazard setback lines rather than focusing on short-term EBE impacts.

Therefore, new improved methods for assessing coastal erosion hazards according to FEMA standards and guidelines for conducting such assessments are required for the Pacific region. It is also agreed that improved methods are needed for the Pacific, Atlantic, and Gulf, especially where beaches, dunes, and bluffs are comprised of sediment materials other than uniform sand.

### 2.1.2 Description of Procedures in the Existing Guidelines

The methodology employed by FEMA to assess the potential extent of primary frontal dune erosion during a major storm on the U.S. Atlantic and Gulf Coasts is based on analyses developed in the 1989 report by Dewberry & Davis (D&D), with a published summary by Hallermeier and Rhodes (1988). There are two components to their analyses supporting the FEMA methodology, first the establishment of the average 540 $ft^3$/ft frontal dune volume as that required to survive the estimated 100-year stillwater flood elevation (measured tide) produced by either a hurricane or extratropical storm (northeaster), and second to establish an erosion profile needed for subsequent wave height and wave runup analyses. An additional analysis deals with the case where the dune is breached and failure of the dune as an effective barrier to storm surge and wave propagation occurs, leading to backshore flooding and wave effects. However, this application of the dune removal geometric erosion assessment technique has received far less evaluation and testing on the West Coast because there are very few Pacific Coast study areas with significant dune formations protecting highly developed coastal areas. Additional discussions of “geometric erosion assessment techniques” found in the Existing Guidelines are presented in Section 1.2, “Present FEMA Guidance on EBE Related to all Priority Categories, Critical, Important and Available,” above.

### 2.1.3 Application of Existing Guidelines to Topic – History and/or Implications for NFIP

As previously stated, there is no specific *Appendix D* guidance presently available for the Pacific, and the existing empirical database of pre- and post-storm erosion events used to develop the 540 SF Criterion are specific to the Atlantic and Gulf coasts and are not intended to be applied in the Pacific. Therefore, new improved and specific methods for assessing coastal erosion hazards, according to FEMA standards and guidelines for conducting such assessments, are required for the Pacific region.

#### *Application of Geometric Models on the U.S. Pacific Coast and Their Use for Establishing Setback Distances (Erosion Hazard Zones)*

Although there is no established FEMA methodology for dune-erosion assessments on the U.S. Pacific Coast, methodologies have been developed for the evaluation of coastal setback distances on the coast of the Pacific Northwest (Oregon and Washington), herein referred to as PNW methods. With appropriate modifications, these methodologies could be adapted to the FEMA applications. The California Coast represents a more complex problem, exacerbated by significantly greater coastal development, with wide variations in exposure to storms and a variety of geological settings and material characteristics. California has no adopted program with formal coastal setback distance methodologies that can guide FEMA efforts.

There are two stages in the PNW method, the first to determine the "design" erosion event, the second yielding a projected dune erosion or susceptibility assessment for potential sea cliff erosion.  Considerable research has been undertaken documenting the processes responsible for the erosion of beaches and backshore properties in the Pacific Northwest (Komar, 1997; Komar, et al., 1999 and 2002). This coast experiences high wave energies generated by intense extratropical storms that cross the North Pacific, with landfall generally occurring on the coast from Northern California to British Columbia. The most recent wave climate assessment has yielded approximately a 16-meter deep-water significant wave height for the 100-year storm, and with winter storms frequently producing 10-meter significant wave heights.  Of interest and concern, research has shown that the wave heights along the West Coast have been increasing during the 25- to 30-year records provided by buoy data, with studies of the intensities of the storm systems indicating that the increase likely extends back to at least 1950 (Allan and Komar, 2000, 2001; Graham and Diaz, 2001).  Based on such studies of West Coast wave conditions and their climate controls, a fairly firm basis exists for a determining wave conditions for establishing the design erosion event.

While an extreme extratropical storm can occur during any winter, the overall greatest erosion impacts on the West Coast have occurred during major El Niños like those in 1982–83 and 1997–98.  It is well documented that on average the storm-wave heights are greatest during El Niños, this increase being most significant on the coast of Central and Southern California because of the more southerly tracks of El Niño storms (Seymour, 1996).  Also important are the elevated tides during an El Niño, produced by reversals in the average wind stress across the Pacific, the thermal expansion of the warmer water, and the geostrophic effects of stronger northward flowing currents.  Monthly mean water levels are elevated by about 0.3 meter in Southern California to 0.5 meter on the coast of the Pacific Northwest, and are maintained by those amounts throughout the entire El Niño winter.

From this, the assessment of the design erosion event for application in the Pacific Northwest is represented by the occurrence of an extreme storm during a major El Niño winter.  The methodology for this assessment was developed by Ruggiero et al. (2001), a procedure that in essence involves the summation of the processes that determine the total water level at the shore—the sum of the predicted tide, the effects of the several processes that elevate measured tides above predicted levels during El Niño, and the addition of the surge and swash runup produced by a storm. Ultimately of importance is the total water level achieved during the storm in comparison with the elevation of the dunes or bluffs.

In the assessments of setbacks for the long-term protection of homes on the Pacific Northwest coast, Komar included the local relative sea level and its potential rise during the next 50 to 100 years, and also an increase in the storm surge and swash runup levels that could result from a continued increase in storm intensities and generated wave heights at the rates experienced during the past 25 years.  Having defined the design erosion event, the next step in the analysis to establish recommended setback distances is the application of a geometric dune-erosion model that has been adapted to conform with the conditions found on the Pacific Northwest coast.

Those conditions include: (1) most beaches in the Pacific Northwest are "dissipative" as defined in the classification of Wright and Short (1983), that is, they are low in slope with a wide surf zone, being effective in dissipating the energy of the waves so the beach profile does not experience marked changes in sand levels during storms and through the seasons; (2) during major storms the surf zone is hundreds of meters wide and the waves and currents rapidly disperse the sand eroded from the dunes; and (3) the beach face within the swash zone at the base of the dunes has a nearly uniform slope (typically about 1:25), which is maintained and extended landward as the dunes are eroded. These observed conditions made it possible to formulate a simple geometric model (Komar et al. 1999). Like geometric erosion models adopted by the Dutch (Vellinga, 1982, 1983, 1986), it is accepted that the cut back of the dunes will originate at the level reached by the water, but rather than focusing on the storm surge which is only a minor factor on the Pacific Northwest coast, the total water level as analyzed by the Ruggiero et al. (2001) model governs, with the level reached by the intense wave-swash runup being a particularly important factor. Unlike the Dutch model, the Komar et al. model is not concerned with the conservation of sand because the sand released by the dune erosion is rapidly dispersed, rather than raising the elevation of the beach immediately in front of the dune. Quite the opposite, the geometric model includes a factor that accounts for the local lowering of the beach in that embayments eroded by rip currents into the beach face have been observed to be important to the zones of maximum dune erosion, and therefore could be included in the analysis as a lowered beach elevation.

### 2.1.4 Alternatives for Improvement

In that the level of a Pacific Northwest beach within the inner surf zone undergoes little change during the erosion event, the Komar et al. (2002) geometric procedure simply extends that slope landward, cutting away the dunes up to the total water-level elevation established by the design storm event. Accordingly, the derivation yields the simple formulation:

$$DE_{\max} = \frac{(WL - E_J) + \Delta BL}{S} \tag{1}$$

Where $DE_{\max}$ is the horizontal distance of dune erosion, $WL$ is the total water level achieved by the design event relative to the elevation of the toe of the dunes prior to the erosion, $E_J$ is the elevation of the beach-dune junction and $\Delta BL$ is beach level change or vertical shift in the profile that might be produced by a rip-current embayment or other process. $DE_{\max}$ represents the “maximum dune erosion” and forms the horizontal leg of a right triangle, while the other parameters combine to determine its vertical leg, so they are related by $S = \tan\beta$ the slope of the beach within the swash zone fronting the dunes. Figures 3 and 4 provide schematic sketches of these variables.

This model yields the maximum potential dune retreat for the total water level *WL*, in that it does not account for the duration over which the water may only reach the design erosion level and the erosional response will lag behind the causative processes. Attempts to assess this lag through application of process-based models for beach profile and dune erosion, specifically SBEACH (Larson and Kraus, 1989), EBEACH (Kriebel and Dean, 1985) and COSMOS (Nairn and Southgate, 1993) were not successful. It was found that these models are inadequate in applications on the Pacific Northwest coast due to their having been calibrated to much lower energy beaches (or in laboratory wave tanks), and in particular because processes important to the erosion of West Coast beaches are not included (e.g., long-wave infragravity surf motions, important on dissipative beaches). Thus, it is possible that if the hydrodynamic variables (infragravity processes) were better defined, process models could be applied. These models not only predicted less dune retreat during a storm than the geometric model, they also under predicted the actual extent of dune erosion that has been experienced during major storms. The USACE Waterways Experiment Station is presently evaluating SBEACH and other process-based models to see if they can be modified for reliable applications on the West Coast. Further detailed discussion of SBEACH and EBEACH are provided in Section 3.

The use of the Komar geometric model to assess the potential extent of dune erosion and to establish setbacks has been supported by tests under extreme storm conditions experienced on the Pacific Northwest Coast in recent years. The winters of 1997–98 and 1998–99 caused unusually extreme erosion and thus provided the opportunity to test these methodologies developed to assess the potential extent of foredune erosion. Before and after beach and dune profiles were obtained at a number of sites, documenting the resulting extent of the cumulative erosion. Confirmation of the calculated total water levels, *WL*, resulting from the combined processes, was provided by general agreement with the surveyed elevations at the seaward toe of the eroded duneface. This also represented partial confirmation of the geometric dune-erosion model in that a basic assumption in its derivation is that the total water level controls the elevation at which the dunes are cut back. However, as expected, it was found that the surveyed horizontal retreat of the dunes was less than the calculated $DE_{max}$. On the other hand, under the "one-two punch" of those successive winters, with the last storm in the series having been the largest and yielding the highest total water levels at most coastal sites, the resulting surveyed cumulative dune retreat increased to the extent that it nearly reached the calculated $DE_{max}$. Thus, although one storm may not have sufficient duration to produce dune erosion to the extent calculated with the geometric model, a series of storms could, justifying the use of the evaluated $DE_{max}$ in coastal management to establish setback distances. This emphasizes the need to incorporate the effect of storm duration in the models as was done by Ruggerio, et al. (2001) by calculating the number of hours per year that the 2% runup exceeded the dune toe elevation. Ruggerio et al.'s estimate of the 2% runup elevation includes the vertical component of runup as well as setup and the swash runup elevation. Komar et al. (2002) have shown good results and agreement with measured beach profiles for applications of the relationships shown in Equation 1 and Figures 3 and 4 at sites along the Oregon Coast for a wide range of beach slopes.

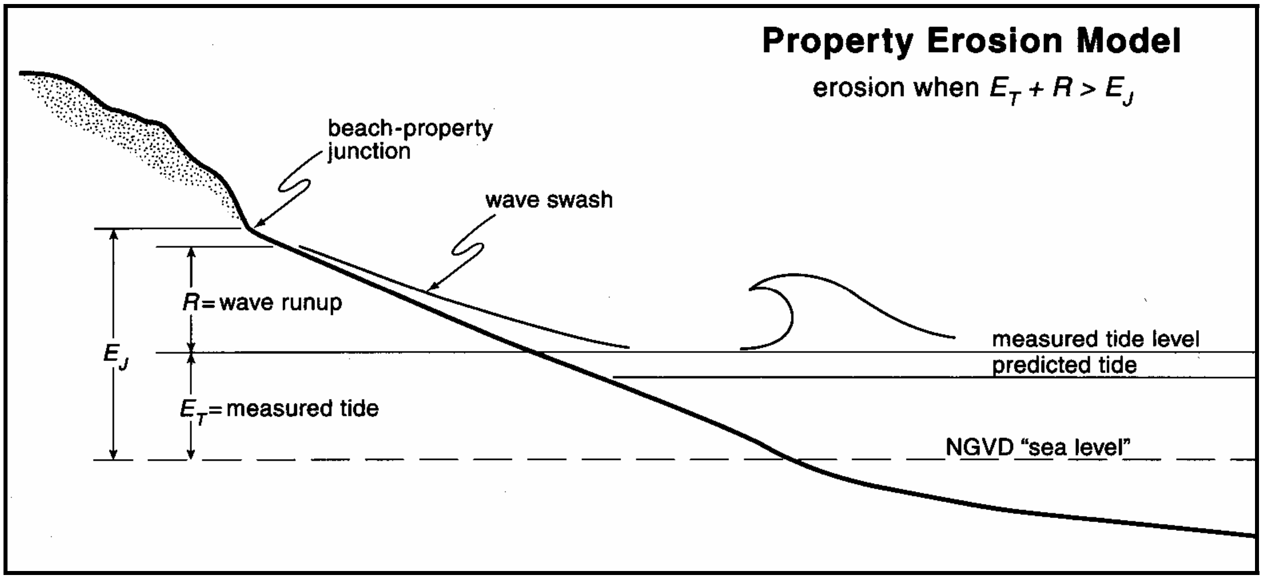



**Figure 3. Pacific Northwest erosion model (Komar et al., 2002).**

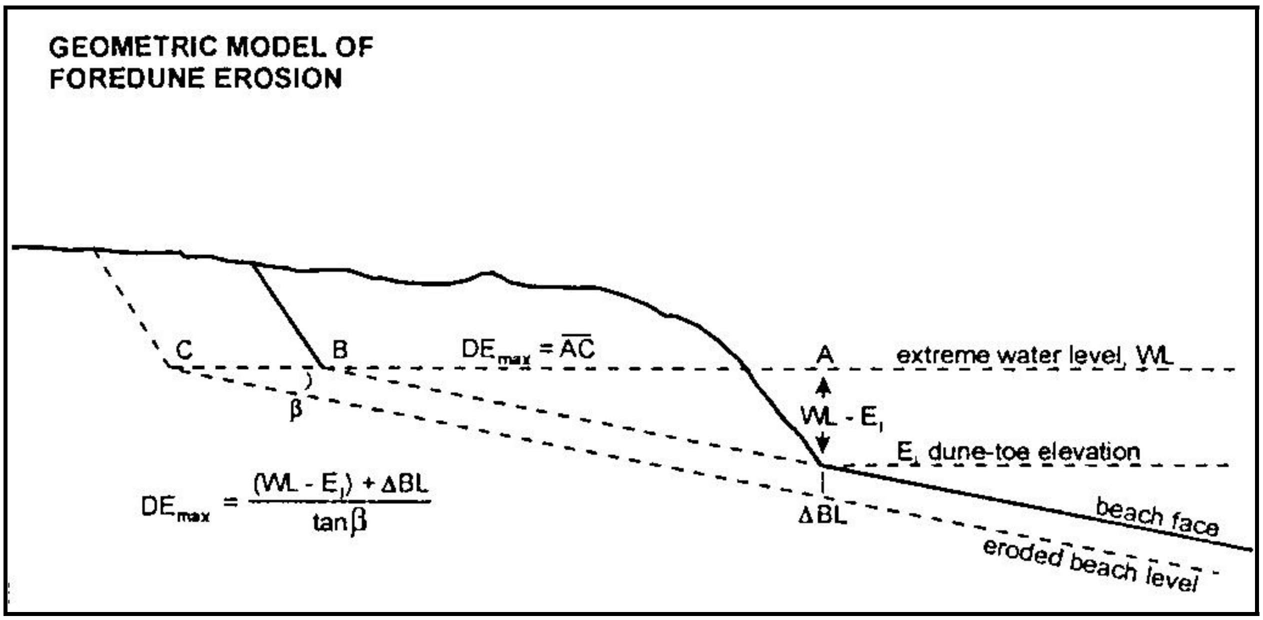



**Figure 4. Pacific Northwest geometric dune erosion model (Komar et al., 2002).**

This methodology has been applied to establish setback distances along significant stretches of the Oregon Coast, with the geometry of the dunes and fronting beach determined from LIDAR surveys, together with spot checks from ground surveys. Other methods by Judge et al. (2003) may have applicability to sandy Pacific Coast beaches and dunes. Their approach includes use of a new dune vulnerability indicator that shows promise for improving predictions of dune failure during hurricanes. At this time, this focused study cannot present a discussion on studies to test Judge et al.'s methods for the Pacific. Such tests are recommended.

Two essential items are needed for effective estimates of beach and dune erosion. It is essential to have a reliable definition of the most likely 100-year storm event and SWEL, and it is important to understand the primary geomorphic and geologic characteristics of the study site in order to address the dominant erosion processes responsible for changes in beach, dune or bluff geometry during the 100-year event. Seasonal winter beach profile data should be gathered and examined for each study site to determine whether there is an average, or most-likely, profile that represents winter beach conditions for the site.

Note that dune backed beaches represent only a small fraction of the California coastline and that many of these are further backed by bluffs or cliffs of differing erodibility and may be undeveloped. As a result, coastal engineering efforts to develop predictive tools for erosion effects in California have concentrated on losses to low slope beaches and cliff or bluff damage.

In relating the geometric model by Komar and colleagues to the framework discussed previously, it appears that a main difference is that there is no explicit dependency on duration or specific material properties. It is possible that some of the principles elucidated in process-based models combined with characteristics of the Komar geometric model could yield improved model transient predictions and a model consistent with the desired consistent framework.

### 2.1.5 Conclusions for Topic 30 (Geometric Erosion Assessment for the Pacific)

Following are key points and conclusions related to the evaluation of geometric techniques for assessing erosion effects on dune-backed beaches along the Pacific Coast and brief descriptions of possible alternatives for improving these methods:

- Existing and new guidelines need to clearly state that EBE is “storm induced erosion.”

- There is no specific *Appendix D* guidance presently available for the Pacific. The existing empirical database of pre- and post-storm erosion events used to develop the 540 SF criterion are specific to the Atlantic and Gulf coasts and are not intended to be applied in the Pacific. Therefore, new improved and specific methods for assessing coastal erosion hazards, according to FEMA standards and guidelines for conducting such assessments, are required for the Pacific region.

- Studies by Kuhn and Shepard (1983) have shown that bluffs in Southern California tend to retreat most during “wet years”. Therefore, rates and extent of cliff and bluff erosion may also be affected by material characteristics and geotechnical stability processes as well as coastal erosion processes.

- Geometric models employed to assess the dune erosion produced by extreme storms are useful for simple determinations of the maximum potential dune retreat and sand volume loss. While the use of empirical data sets for development and validation of geometric erosion assessment procedures for the Pacific region (like those in the Atlantic and Gulf) may be a viable alternative, there may only be limited pre- and post-storm beach profile data available on which to base the procedure. Further research and inquiries are necessary with state resource agencies, universities, the USGS, and NOAA to determine whether such historical storm-induced erosion data sets are readily available.

- The most extensively developed geometric model for dune erosion is that of the Dutch as presented by Vellinga (1982, 1983, 1986), which yields a calculated dune volume loss and position of the fronting beach for a 5-hour storm tide elevation, with guidelines for the additional erosion that occurs for each hour beyond that 5-hour duration. (This type of short duration event may not be appropriate for Pacific storms.)

- Existing FEMA methodology is based on a modified form of the Dutch model (Vellinga, 1986), with a two-segment profile approximation to the Dutch concave profile, employed to analyze the wave runup and potential for dune overwash on the erosion adjusted profile. The FEMA methodology uses a geometric erosion assessment procedure to adjust the post-erosion profile for varying stillwater elevations and dune configuration, but does not utilize a geometric model to evaluate the volume of sand eroded from the dune by the storm, having opted instead to fix that volume at the average volume of 540 $ft^3$/ft for the estimated 100-year event for each erosion assessment application (dune removal or dune retreat).

- FEMA analyses comparing dune-erosion volumes to storm recurrence flood levels is very sensitive to an accurate determination of the stillwater elevation and return period of the storm, which in itself can have a significant degree of uncertainty. The return periods for the median erosion values for the Atlantic and Gulf Coast data set are based on a comparison of the measured tide gauge data or observed high-water marks from the storm with the published FIS return period elevations. Measured tide gauge data for each storm are considered the best available information for storm recurrence interval determination. Development of similar procedures for the Pacific Coast require the location and development of similar data sets.

- The geometric model by Komar and others (2002) that has been applied on the U.S. Pacific Coast to evaluate dune erosion during recent El Niño related storms and high-water levels should be tested and refined as a possible method for evaluating the extent of sandy beach and dune retreat.

- Methods developed by Judge et al. (2003) may have applicability to sandy Pacific Coast beaches and dunes, and merit further investigation. However, it is noted that this model does not include the duration of storm characteristics nor the erodibility of the sediments.

- It is essential to understand the primary geomorphic and geologic characteristics of the Pacific Coast study site in order to address the dominant erosion processes responsible for changes in beach, dune or bluff geometry during the 100-year event. Therefore, one of the first steps during an erosion assessment is to clearly define the project setting, the underlying erosion processes, and the erodibility of the sediments.

- In areas where sea cliffs or bluffs are present, but not composed of sand, geometric models may not be appropriate. A second approach consistent with Pacific Northwest methods discussed earlier is to define the erodibility time scales differently for loose sand and other materials.

- Research for this focus study found no reliable geometric models applicable to mixed grain sizes and/or cobble and gravel based beaches and dunes. Simplified methods for evaluating single-event erosion hazards in coastal regions comprised of coarse grained materials may not be readily available for the Pacific Coast or the North Atlantic. This is discussed further in Topics 33 and 34, herein.

### 2.1.6 Recommendations for Topic 30 (Geometric Erosion Assessment for the Pacific)

Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time required to accomplish tasks recommended for this topic. Following are recommendations for Topic 30 (Geomtric Erosion Assessment for the Pacific).

1. In the short term: A review should be undertaken for the Pacific Coast, based on available LIDAR, photogrametric, or physical surveys of beach and dune erosion produced by major storms, including periods of El Niño conditions, to see if available data sets can successfully document dune volume losses and beach profile changes for a variety of beach types and settings in California, Oregon and Washington. Limited data sets are available from the NOAA Coastal Services Center from LIDAR investigations conducted before and after the 1997–98 El Niño event. The goal is to develop a geometric model capable of: 1) predicting the extent of dune retreat during a 100-year storm scenario, 2) determining whether the dune persists or fails as a flooding barrier, and 3) determine the ultimate beach and dune profile during the 100-year event upon which runup and overtopping can be computed. It may be determined that the issue of the magnitude of the “100-year erosion” may be less important than concurrent or sequential EBE (duration of erosion) assumptions for whatever return frequency storm event is being assessed for the FEMA NFIP.

2. New EBE assessment methods are needed and should be applicable to different physiographic regions and must consider the following: 1) physiographic setting, 2) sediment characteristics across the active profile, 3) time histories of wave and storm tide characteristics, and 4) whether local or regional oceanic (El Niño) or topographic (recent tectoic adjustments) characteristics affect the study area and the magnitude of runup.

3. Study Contractors should examine available state and federal coastal resources mapping and documentation to determine the geomorphic, geologic and erosional setting for each

Pacific Coast project site. A determination of the erosion assessment procedure to be utilized should be based upon the history of significant erosion at the site and whether there are data and evidence of a consistent seasonal winter beach profile for the study region. The seasonal winter beach profile, and perhaps a "Most Likely Winter Beach Profile" would represent the typical beach profile configuration expected for the storm events and upon which the procedure would be applied.

4. The geometric model by Komar and others (2002) that has been applied on the U.S. Pacific Coast to evaluate dune erosion during recent El Niño related storms and high-water levels should be tested and refined as a possible method for evaluating the extent of sandy beach and dune retreat. Study Contractors may use the "Most Likely Winter Beach Profile" as an interim approach for estimating the eroded beach profile shown in Figure 4.

5. A longer term program (possibly a multi-agency cooperative program) could include expansion of the present USGS/NOAA coastal survey program for the Pacific Coast. Results from this program will help determine the "Most Likely Winter Beach Profile" to use for Pacific Coastal areas prior to the 100-year event.

6. The post-storm profiles obtained in the long-term field studies could be used to develop and test new geometric models (or process-based models) for sandy beach and dune systems along the Pacific Coast.

7. The performance and reliability of geometric versus numerical modeling procedures should be tested for sand beaches and dunes on the Pacific Coast and verified with available data sets.

8. Methods for assessing other types of non-sandy beach settings, such as cobble and gravel beaches, should be developed and based as much as possible on the underlying physical processes controlling those coastal settings.

9. Establish the definition of the most likely 100-year storm event and SWEL for any location along the Pacific coastline. A program to measure and determine the magnitude and approximate recurrence frequency of Pacific storms is necessary. It is essential to define the most likely 100-year storm event and SWEL for use in FEMA coastal hazard assessments.

## 2.2 CRITICAL TOPIC 33: (SHINGLE/COBBLE EROSION ASSESSMENT)

### 2.2.1 Description of Topic and Suggested Improvement

Present guidance in *Appendix D* focuses primarily on simplified methods for estimating single storm event erosion for sand-dominated beaches and dunes. The *G&S* do not provide methods for estimating erosion in coastal systems comprised of mixed grain sizes, gravel, cobbles or shingle. Note that shingles are not a standard American Geophysical Union size class descriptor and refer to very coarse beach gravel consisting of flat cobble and flattish pebbles found on higher parts of the beach. The TWG recommends developing and adding new guidelines with the capabilities to address erosion in these types of coastal areas found along the Atlantic, Gulf, Pacific, and in Sheltered Water areas.

### 2.2.2 Description of Procedures in the Existing Guidelines

The *G&S* do not provide methods for estimating erosion in coastal systems comprised of mixed grain sizes, gravel, cobbles, or shingles. Shingle/cobble beaches do not have a similar response to the storm induced erosion on a sand beach. This may preclude the use of a simplified "540 SF-type" method. It is likely that different methods are required, in part because there is a greater degree of variability found in mixed- and coarse-grain beaches.

### 2.2.3 Application of Existing Guidelines to Topic – History and/or Implications for NFIP

The key issues with cobble and shingle beaches and dunes are defining their degree of similarity to sandy beach areas during significant storms, and whether the present "540 SF" approximation is appropriate for application in these areas. If cobble/shingle areas are unique enough to require their own technical approach, existing historical beach profile data and literature may provide sufficient information for the derivation of an assessment method. This problem has significant implications along the North Atlantic, portions of the Pacific and in some Sheltered Water areas. Therefore, this topic is considered "Critical" for all three regions.

Historically, cobble beaches, also commonly referred to as gravel or shingle beaches, have not received as much scientific and engineering focus as sandy beaches in the United States. However, there is a rich literature in the United Kingdom because of the considerable extent of beaches of this type. Cobble beaches tend to be stable over a wide range of wave conditions and thus tend not to be as erosive as sandy beaches. Therefore, the level of research focused on cobble beach design is relatively limited. Previous studies and design involving cobble beaches have utilized existing formulas and concepts to describe the dynamics of sand beaches to explain and predict cobble beach behavior with varied results. In recent years, more studies have been undertaken to understand cobble beaches because of their stable nature. Cobble beaches are being explored as viable alternatives to hard coastal engineering structures for beach stabilization.

There are a few main physical differences between sandy beaches and cobble beaches. First, cobble beaches have much steeper foreshore slopes (~1:10) than sandy beaches (~1:40 to 1:100). Cobble beaches are also usually marked by steep berms that correspond to the maximum height reached by the swash runup. Cobble beaches tend to contain a wide range of materials, varying from sand to cobbles. This results in beach profiles with a steep foreshore slope, which is naturally armored with coarsest material in the littoral system. Along the lower portion of the beach profile, sand and finer materials commonly form a very shallow or flatly sloped low tide terrace. Figure 5, illustrates the difference in profile shape for cobble, sand, and mixed beaches. Since gravel and cobbles also are less susceptible to motion in a given wave environment, these beaches are more stable under wave and current attack. However, cobble beaches still remain very dynamic, with constant readjustment to variations in wave climate and tidal conditions. Another feature is the high hydraulic conductivity of the stone. This increases the potential for infiltration during swash and is probably responsible for the formation of the berm at the maximum swash runup (Van Wellen, 2000).

Nourishment of cobble beaches along the coasts of England and Wales and the North Atlantic shores of the U.S. has led to the development of procedures for assessing the dynamics of cobble beaches and dunes during significant storm events. Similarly, along the Pacific and New Zealand coastlines, researchers and engineers have designed “cobble berms” or “dynamic revetments” to reduce severe erosion of back beach areas subjected to high water levels and wave action (Komar et al., 2003; Powell, 1988; Powell, 1990; Ahrens, 1990). Research has determined that there is a great variety of so-called “mixed grain size” beaches. Depending on the relative proportions of sand versus coarse particles (gravel/shingle and cobbles) the patterns of grain sorting and beach morphology vary depending on the tide range and local wave energies. It is well established that a sand beach responds by the cross-shore movement of sand from the berm to offshore bars, its average slope decreasing in the process so that is more dissipative of the wave energy. While many field studies have found a similar pattern for gravel and cobble beaches, Bluck (1967) for example found a net landward movement of coarse particles and beach accretion during storms, so both the crest elevation and slope of the beach increased. Pacific Coast researchers found the same response in the study of the cobble berm constructed at Cape Lookout State Park, and for the natural cobble beaches in the Pacific Northwest. Everts et al. (2002) also found similar patterns for cobble beaches on the Southern California Coast. At both West Coast sites the cobble beach was fronted by a sand beach, and when impacted by storms, the sand beaches decreased in slope to become more dissipative, while the cobble beaches on their landward sides increased in slope and become more reflective. There has not been sufficient study to understand this response of cobble beaches, or to discern why it is different from one site to another. Researchers suspect it is related to the content of sand within the otherwise coarse-grained deposit, which affects the permeability of the beach and hence the balance between the swash and backwash, and the competence of the landward-flowing swash to transport cobbles up the beach face. However, further research and field validation is needed.

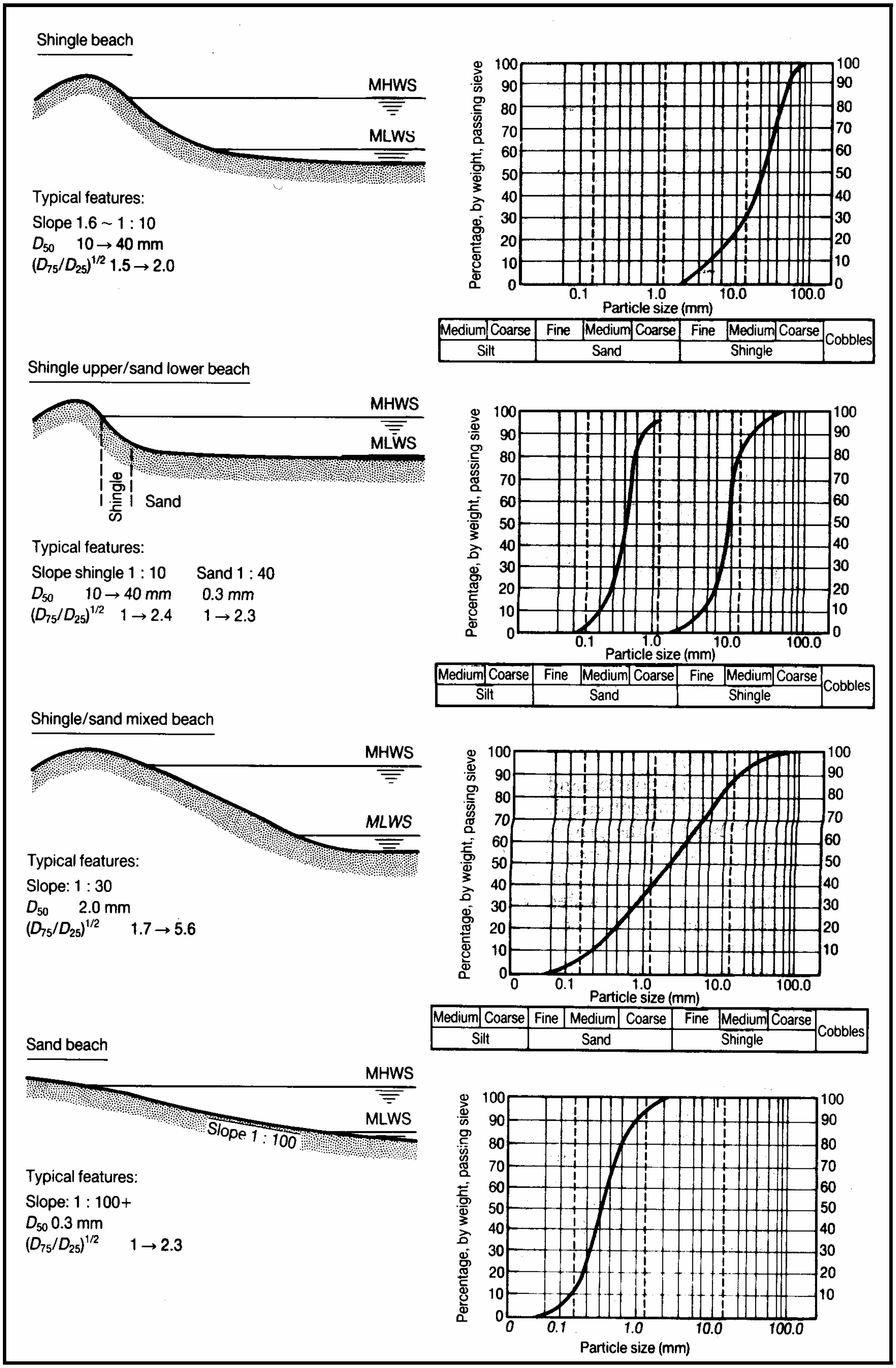



**Figure 5. Variation in beach profiles and gradations (CIRIA, 1991).**

### 2.2.4 Alternatives for Improvement

In summary, present guidance in *Appendix D* does not provide methods for estimating erosion in coastal systems comprised of mixed grain sizes, gravel, cobbles, or shingles. Shingle/cobble beaches do not have a similar response to storm induced erosion as a sand beach that would allow the use of a simplified “540 SF-type” method. It is apparent that different methods (more process-based) are required and that there is a greater degree of variability found in mixed- and coarse-grain beaches. Further research is required to better describe erosion processes in gravel and cobble beach settings.

### 2.2.5 Recommendations

Following are recommendations for this Topic. Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time needed to accomplish tasks recommended for this topic.

1. Prepare new sections in the existing *Appendix D* guidance to describe differences between sand dominated beaches and mixed- and coarse-grained beaches. Provide photos and profile information.

2. Gather existing literature on natural cobble, shingle, and coarse-grained beaches to summarize the existing state of knowledge and provide references until specific guidelines can be developed and adopted.

3. Review literature on the design of and construction of dynamic revetments and cobble berms to provide guidance on their stability and long term development.

4. Examine other possible guidance and available beach and dune data sets for possible clarifications to the 540 SF Criterion for sand-dominated beaches versus mixed- and coarse-grained beaches. Attempt to develop “equivalents” between sand and coarse grained beaches. Attempt to develop methodology that will allow computation of erosion within framework described.

5. Discuss the limitations of applying geometric models to cobble/shingle beach and dune areas.

6. Examine the applicability of existing equilibrium beach profile concepts and relationships to represent the response of cobble and mixed grain beaches to storms, for example, Dean (1991).

7. Prepare case studies of actual coarse grained beaches demonstrating application of the recommended methodology.

8. Prepare new guidelines for the Pacific Coast describing the physical processes associated with mixed- and coarse-grained beaches.

## 2.3 CRITICAL TOPIC 35: GUIDANCE FOR EROSION ASSESSMENTS IN SHELTERED AREAS

### 2.3.1 Description of Topic and Suggested Improvement

EBE in major sheltered areas such as San Francisco Bay, Puget Sound, and Chesapeake Bay, is dependent on fetch-limited wave characteristics, inshore water levels that consist of the stillwater level and wave-induced setup, and beach morphology defined by sediment type, inshore slope, etc. Sheltered water areas tend to have a wide variety of shoreline sediment/material types and beach/shoreline profiles due to their local geomorphology, local geology, and watershed characteristics. Watershed size, hydrology, geology, land use, and resulting sediment production and delivery to the coastal zone affect the beach characteristics and processes found within sheltered water areas.

For example, although much of the San Francisco Bay shoreline is composed of silty sediment (bay mud), marshes, and steep coarse cobble and revetted areas that are more resistant to the EBE induced by wind-driven waves, some existing sandy beach areas are still prone to erosion, particularly in shoreline segments that are semi-exposed to ocean swells (e.g., Crissy Field). Past field observations indicate that horizontal bank erosion without vertical scouring is most likely to occur in shoreline segments that consist of bay mud only. Unlike the open-coast EBE where recovery processes do occur depending on the subsequent wave climate, no recovery of bank erosion is to be expected after the sheltered bank is eroded away.

In Puget Sound, the shorelines in sheltered areas may be characterized as consisting of narrow to non-existent sandy to cobble beaches backed by high, wave cut coastal cliffs. The sandy beach has only a thin lens of sand topping the cobble or the natural bedrock planform. The rocky and steep shorelines mostly resist EBE, and the event-based vertical scouring for sandy pocket beaches would be limited to the upper thin sandy lens, as fetch-limited wind-driven waves are probably not capable of removing the underlying cobble material. However, most of the depleted thin sandy shorelines do however recover afterwards. As cliff erosion occurred over time, the eroded material contributed to the formation of low-tide terraces fronting the cliffs. These wide terraces now provide a shallow water zone where wave energy is dissipated. Thus, the majority of the shorelines within Puget Sound have experienced relatively stable conditions in the recent past.

Historical beach and dune erosion events have been documented along inland bays and sheltered waters in the Atlantic/Gulf Coast regions. It is believed that the physical processes of the event-based dune erosion are similar to those occurring along the open coast. Although the original guidance on the 540 SF Criterion for EBE was primarily based upon historical field investigations along open coast beaches in the Atlantic and Gulf regions, no *G&S* of erosion assessment in sheltered areas for any coastal regions, including the Atlantic/Gulf and Pacific

Coasts, are presented in *Appendix D.* Based upon historical field observations of the EBE pattern between these regions that demonstrate a strong dependence of EBE on individual beach morphology, suggestions can be made to establish the guidance to the EBE in sheltered waters as presented in the recommendation section.

### 2.3.2 Description of Procedures in the Existing Guidelines

Guidelines and procedures for assessing erosion in sheltered areas for any coastal regions, including the Atlantic/Gulf and Pacific coasts, are not presently available in *Appendix D* (FEMA, 2003).

### 2.3.3 Application of Existing Guidelines to Topic

In sheltered water areas along the Pacific Coast, large sand dune systems are not typical and the NFIP regulations and existing Guidelines that provide methods for delineating Base Flood Elevations (BFEs) with Primary Frontal Dunes, typically exclude the lower energy EBE (horizontal erosion and vertical scouring) in sheltered waters that are induced by wind-driven waves. In some occasions, even the effects of these smaller wind-driven waves are not incorporated into hazard zone delineations in these coastal flood studies and only the 1-percent-annual-chance stillwater elevation is used to define the sheltered water BFE.

In the Atlantic/Gulf region, the 540 SF Criterion has been applied for inland bays where beach and dune erosion has been documented and known to be a historical EBE associated with the base coastal flood event (Hatheway, 2004). The application usually results in minor but necessary adjustments to the beach profiles prior to the wave height analyses in these applications (e.g., recent Mobile Bay coastal analyses in Baldwin County). Although the 540 SF Criterion commonly used for the Atlantic/Gulf open coast has been applied to the sheltered waters in the same region, this appears to be a very conservative approach and could result in unrealistically large flood level assumptions. For example, extreme water levels can extend well inland of the open coast as seen in the extensive flooding of the Severn River at Annapolis during Hurricane Isabel in 2003. However, the local wave field which is implicit in the 540 SF Criterion cannot exist in such a width-limited and length-limited fetch. Therefore, application of the typical 540 Criterion for this scenario is not recommended. Dune erosion rates will necessarily be greatly reduced or non-existent in that scenario. In all likelihood, a much smaller geometric prism will provide equivalent protection in these environments. Additional field verification is necessary to confirm the applicability of this geometric criterion to the sheltered water zones. However, given the scarcity of extensive natural dunes in most sheltered waters, relevant field data will be difficult to obtain. Reductions in the recommended eroded cross-sectional area, based upon adjustments to the probable local wave conditions, may provide the only practical solution to this problem.

The existing Guidelines focus on the erosion of open coast sand dune systems and do not provide guidance for addressing EBE of sheltered water beaches and backshore low bluffs and coastal cliffs.

### 2.3.4 Alternatives for Improvement

The alternatives for improvement to the *G&S* regarding erosion assessments in sheltered areas are:

1. Classify the specific characteristics of EBE in sheltered waters based on the location of the flood study site with respect to the geographic setting, local shore forms, and past field observations for different types of beach sediment such as bay mud, cobble, and coarse to fine sand.

2. Differentiate guidance, if guidelines are required, based on observed historical event-erosion patterns that are applicable to each setting and geomophic category.

3. For the Atlantic/Gulf region where some applications have been made using the established 540 SF Criterion, existing historical data and publications related to the application of the 540 SF Criterion should be reviewed to determine inland bay and sheltered water response to coastal storms so that the existing or revised 540 SF Criterion can be readily added to the erosion assessment in sheltered areas for the Atlantic/Gulf region.

4. A survey of coastline types in major West Coast sheltered water areas should be made to determine the extent of regions in which the 540 SF type geometric criterion, might be applicable and an assessment made of the need for development of revised geometric criteria for this region (as presented previously in Topic 30).

5. As defined in the NFIP regulations, "flood-related erosion means the collapse or subsidence of land along the shore of a lake or other body of water as a result of undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as a flash flood or an abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding." Since FEMA is to provide the data upon which floodplain management regulations for flood-related erosion-prone areas shall be based (44 CFR sec. 60.5), guidance should be provided to Mapping Partners on how to obtain, review and reasonably utilize these data.

6. Explore the possibility of developing a rational basis for predicting erosion in sheltered waters which is consistent with the general framework discussed previously. Such a framework should account for the time histories of water level and wave forcing, and the durability of the eroded material.

### 2.3.5 Recommendations

Following are recommendations for this Topic. Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time needed to accomplish tasks recommended for this topic.

1. Prepare a new *G&S* description of EBE for sheltered waters in accordance with typical beach morphology and sheltered-water wave characteristics.

2. Provide the interim *G&S* for EBE in sheltered waters, based primarily on historical field observations during various storm events.

3. Attempt to develop rational guidance based on a model consistent with the general framework discussed previously.

4. Develop case studies for testing new guidance in previously studied sheltered area settings.

5. Future research: Incorporate the EBE models that may ultimately be developed from Topic 36 to establish the final *G&S* that can be applied to all identified major sheltered waters for the Atlantic/Gulf and Pacific coasts (i.e., San Francisco Bay, Puget Sound, and Chesapeake Bay) and other small sheltered waters including those located in Southern California if the EBE conditions are justified.

## 2.4 CRITICAL TOPIC 39: PRIMARY FONTAL DUNE

This topic was determined to be more appropriately associated with Hazard Zones, and so it was moved to that section and will be included in the TWG for Hazard Zones.

This completes the discussion of Critical Topics.

# 3 IMPORTANT TOPICS

## 3.1 TOPIC 34: DEVELOP IMPROVED GEOMETRIC METHODS WHICH CONSIDER COBBLE/SHINGLE EFFECTS

### 3.1.1 Description of Topic 34 and Suggested Improvement

Present guidance in *Appendix D* focus primarily on simplified methods for estimating single storm event erosion for sand-dominated beaches and dunes. The Guidelines do not provide methods for estimating erosion in coastal systems comprised of mixed grain sizes, gravel, cobbles, or shingles. The TWG recognizes the need for addressing beach profile changes that occur during base flood events and how those changes may affect runup and flooding along coasts comprised of mixed grain sizes, gravel, cobble, and boulders. Given the need to assess these types of coastal settings, one key issue with FEMA is whether the present 540 SF Criterion used for sand-dominated beaches can be used or modified for shingle/cobble beaches and dunes. Therefore, this is considered to be an "Important Topic." The TWG recommends developing new guidelines with the capabilities to address erosion in these types of coastal areas found along the Atlantic, Gulf, and Pacific Coasts and in some Sheltered areas.

#### 3.1.2 Description of Procedures in the Existing Guidelines

The present Guidelines do not provide methods for estimating erosion in coastal systems comprised of mixed grain sizes, gravel, cobbles, or shingles. Coastal engineering research has focused primarily on preventing or controlling erosion along shingle/cobble beaches rather than predicting how such beaches may erode during rare storm events. Shingle/cobble beaches do not display similar responses to storm induced erosion as do sand-dominated beaches; therefore, application of the present simplified "540 SF-type" method should be avoided. It is apparent that different methods are required and that there is a greater degree of variability found in mixed- and coarse-grain beaches.

#### 3.1.3 Alternatives for Improvement

There has been sporadic interest in mixed grain, gravel, cobble, or shingle beaches over the years by engineers and scientists. The result is a scattered body of literature and knowledge that has never been organized and combined into a coherent base of knowledge on the dynamics, characteristics, and variability of the cobble, shingle, and mixed grain systems. The first step in developing a quantitative guidance for assessing the dynamics of these systems is to conduct extensive research of the available literature on natural gravel, cobble, and mixed sand and gravel beaches to summarize the knowledge that has been developed and to examine the quantitative methodologies that have been used and proposed.

It is not clear whether the morphological differences between systems will allow direct application of knowledge and typical system responses during storm events from one site to another. For example, some of the local gravel, cobble, boulder beaches found in California, Washington, and Oregon contain substantial quantities of natural, rounded large cobble and boulders, whereas in Europe and Japan the common constituent is flat shingle. Therefore, where possible, available data should be compared to see how the various systems differ. It may be found that the systems comprised of similar material characteristics (grain size, shape, and density) respond similarly regardless of the variations in morphology and wave climate. Making this determination may allow currently developed methodologies to be applied and developed for a wide range of different systems and locations. However, until those relationships are understood, caution is required when attempting to use data developed in regions with significantly different wave climates and geomorphic characteristics and beach material characteristics.

The writers are unaware of reliable numerical models that are capable of simulating dynamic beach morphology. Available models are very simplified (Powell, 1990), but may eventually be refined as more is learned of these types of beach processes (see Figure 6). However, studies examining dynamic revetments and berm breakwaters should be reviewed. The physics governing how dynamic revetments and berm breakwaters respond during storms differ somewhat from cobble and shingle beaches because of increased grain size and reduced grain size composition (dynamic revetments and berm breakwaters generally do not contain fine material to allow for wave absorption). These types of structures rely on profile development and response to dissipate wave energy. This is very similar to what naturally occurs on natural cobble, shingle, and coarse-grained beaches and may closely correspond to processes important to FEMA. Certainly, qualitative information can be extracted from previous studies. Van der Meer (1992) has done extensive model tests on the stability of different cobble slopes and how they relate to hydraulic and structural parameters of berm breakwaters. Those relationships were used to develop the computational model called BREAKWAT for assessing and designing cobble berm, breakwater. It is possible that the basis for this model could be further developed to predict the profile evolution of cobble and shingle beaches. Sayao (2004)has done extensive 2- and 3-dimensional flume tests on profile development and stability in berm breakwaters and dynamic revetments which could also be incorporated. The Dutch have used similar methods to protect dikes in the Netherlands. Dynamic revetments are beginning to be more commonly used in Massachusetts in place of more traditional seawalls and revetments.

Development of simple geometric (empirical) models is possible, but it will require careful evaluation of regional and perhaps site-specific data. Case studies of historical and current profile data along with site-specific information would provide examples of the shoreline types encountered and summarize the differences in beach characteristics and wave conditions found along natural cobble, shingle, and coarse-grained beaches. Combining this information with the approaches and methodologies already in use could provide the necessary guidance for evaluation of natural cobble, shingle, and coarse-grained beaches. Also, available equilibrium beach profile concepts and relationships may provide useful information (Dean, 1991).

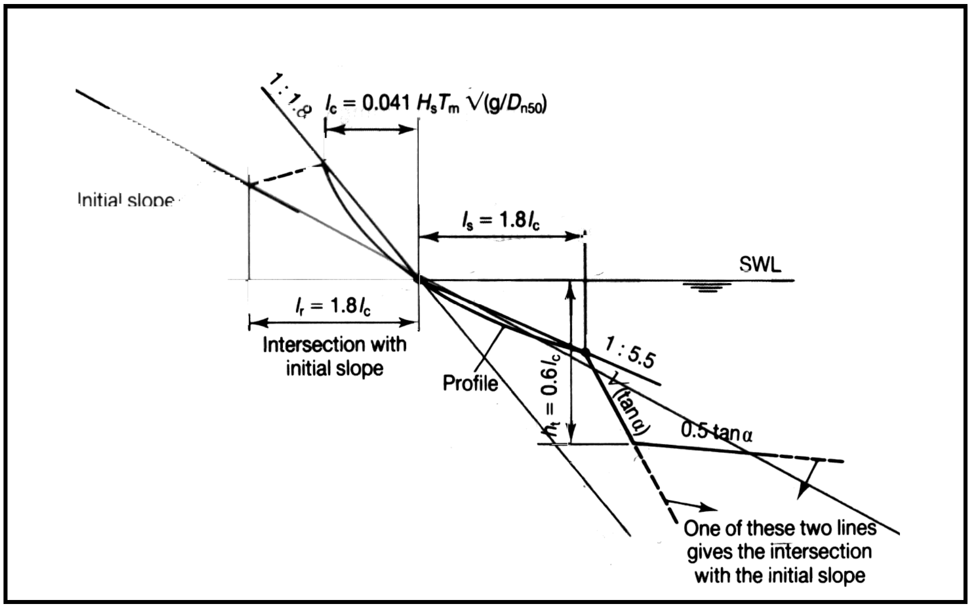



**Figure 6. Schematized pre- and post- storm profiles of rock and gravel beaches (CIRIA, 1991).**

### 3.1.4 Recommendations

Following are recommendations for this Topic. Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time required to accomplish tasks recommended for this topic.

1. Gather, compile, and summarize existing literature on natural cobble, shingle, and coarse-grained beaches to summarize the existing state of the knowledge and provide references Mapping Partners can use until specific guidelines are developed and adopted.

2. Review literature on the design of and construction of dynamic revetments and cobble berms to provide guidance on their stability and long-term development (morphologic changes during varying wave conditions).

3. Review and assess historical applications of the existing geometric model (540 SF Criterion) to the Atlantic/Gulf for natural gravel, cobble, and mixed sand and gravel shorelines to determine its validity for these types of beach conditions.

4. Perform a demonstration test of 540 SF Criterion on a natural gravel, cobble, and mixed sand and gravel beach to assess its reliability (or not). Document results in terms of a case study; recommend discussion paragraph for *G&S*.

5. Gather and summarize documentation of historical erosion and beach profile surveys during extreme storm events, particularly for Northeasters on the Atlantic and El Niño years such as 1982–1983 and 1997–1998 for the Pacific Coast. Develop interim eroded

gravel, cobble, and mixed sand and gravel beach profiles for the Atlantic and Pacific Coast regions separately, based primarily on the historical data.

6. Examine the applicability of existing equilibrium beach profile concepts and relationships to represent the response of cobble and mixed-grain beaches to storms.

7. Determine whether generic process-based models can be developed in a relatively short period of time for application to both the Atlantic and Pacific coasts.

8. A process-based model would be consistent with the desirable framework discussed earlier. If a model is recommended that is not process based, ensure that the model incorporates elements consistent with the framework.

## 3.2 TOPIC 36: GUIDANCE FOR EROSION ASSESSMENTS IN SHELTERED AREAS

### 3.2.1 Description of Topic and Suggested Improvement

As described in Topic 35, the physical processes of the EBE in sheltered waters are similar to those along the open coast. Beach morphology for major sheltered waters can be categorized as those described in Topic 30, except that silty sediment instead of sandy material is more common in many Pacific Coast regions (e.g., San Francisco Bay). In San Francisco Bay, past field observations during storm events indicate that horizontal bank erosion without vertical scouring is most likely to occur in the shoreline segments that consist of bay mud only. Eroded beaches within sheltered water areas may not recover in the same manner as seasonal beach profiles do along the open coast because the post-storm wave characteristics are significantly different in sheltered waters. In Puget Sound, the event-based vertical scouring for sandy pocket beaches is likely to be limited to the upper thin sandy lens, as described in Topic 35. Since no *G&S* regarding EBE are available for sheltered waters, new guidance is needed. Potential alternatives and suggestions are presented in Section 3.2.4.

### 3.2.2 Description of Procedures in the Existing Guidelines

As discussed in Topic 35, no guidance is provided in the present *G&S* for assessing erosion in sheltered areas for any coastal region along the Atlantic, Gulf, or Pacific.

### 3.2.3 Application of Existing Guidelines to Topic

See Section 2.1.3

### 3.2.4 Alternatives for Improvement

Alternatives for improving the *G&S* regarding erosion assessments in sheltered areas include:

- Characterize beach, back beach, bluff, and cliff morphology, historic stability, and dominant material properties typically found in Sheltered Waters and discuss the differences with those properties found along open coasts.

- Determine whether available process-based erosion models for the open coast are applicable to the sheltered water areas.

- Consider/recommend possible guidance clarifications or modifications to the 540 SF Criterion for sheltered waters. Review existing historical data and literature for the Pacific to determine inland bay and sheltered water responses to coastal storms, and their consistency with the Atlantic and Gulf coastal areas. Test the applicability of the 540 SF Criterion for sheltered with reliable beach profile data.

- Evaluate the process-based models (e.g., EBEACH) that are presented in Topic 38 to determine if they would be suitable for estimating storm induced erosion along inland bays and sheltered waters for Atlantic/Gulf and Pacific coastal areas.

### 3.2.5 Recommendations

Following are recommendations for this Topic. Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time required to accomplish tasks recommended for this topic.

1. Review and assess the historical applications of the existing 540 SF Criterion to sheltered shorelines. Summarize the results regarding its applicability to the sheltered water regions.

2. Develop interim eroded profiles for the Pacific Coast region, based primarily on documented histories of erosion and beach profile surveys during extreme storm events, particularly in El Niño years such as 1982–1983 and 1997–1998 to provide interim *G&S* suitable to the Pacific Coast.

3. Conduct case studies to test and illustrate the recommended approach using actual data sets.

4. Explore the possibility of developing a rational basis for predicting erosion in sheltered waters which is consistent with the general framework discussed previously. Such a framework should account for the time histories of water level and wave forcing, and the durability of the eroded material.

5. Test process-based models that are to be developed under Topic Number 38 to determine if they are suitable for implementation in sheltered waters in all regions.

## 3.3 TOPIC 37: REVIEW ATLANTIC-GULF COAST 540 SF CRITERION

### 3.3.1 Description of Topic and Suggested Improvement

Section D.2.4 of *Appendix D* directs the Study Contractor to perform an erosion assessment of open coast shorelines bordering the Atlantic Ocean and Gulf of Mexico, that is, to determine any erosion likely to occur during the base flood event, and to adjust the existing profile to reflect the anticipated eroded profile shape prior to use of the wave height and wave runup models.

As previously stated in earlier sections, the present default erosion assessment procedure determines the cross-sectional area of a sand dune above the 100-year stillwater elevation (without wave setup) and seaward of the dune peak* (see Figure 7), then compares that cross-section against the critical value required to prevent dune loss (removal) during the base flood event – 540 SF. If this “frontal dune reservoir” is less than 540 SF, the dune is presumed to be destroyed (removed) by the base flood event. If the primary frontal dune reservoir is at least 540 SF in size, then the dune is presumed to sustain retreat, but survive the storm (see Figure 8). In other words, the 540 SF Criterion for the frontal dune reservoir is a trigger for dune removal (less than 540 SF) and retreat (greater than 540 SF).

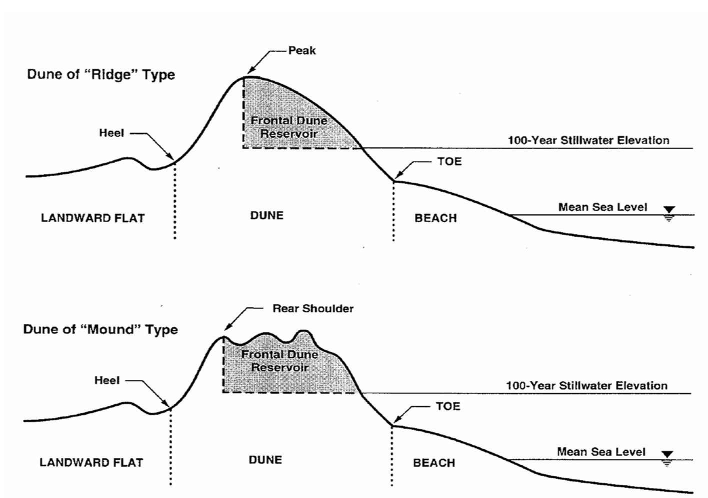



**Figure 7. Frontal dune reservoir.**
**(from Appendix D, FEMA, 2003)**

* Section D.2.4.1 of FEMA (2003) states that the dune erosion treatment is also appropriate in cases with sandy bluffs or headlands extending above the 1-percent-annual-chance stillwater elevation.

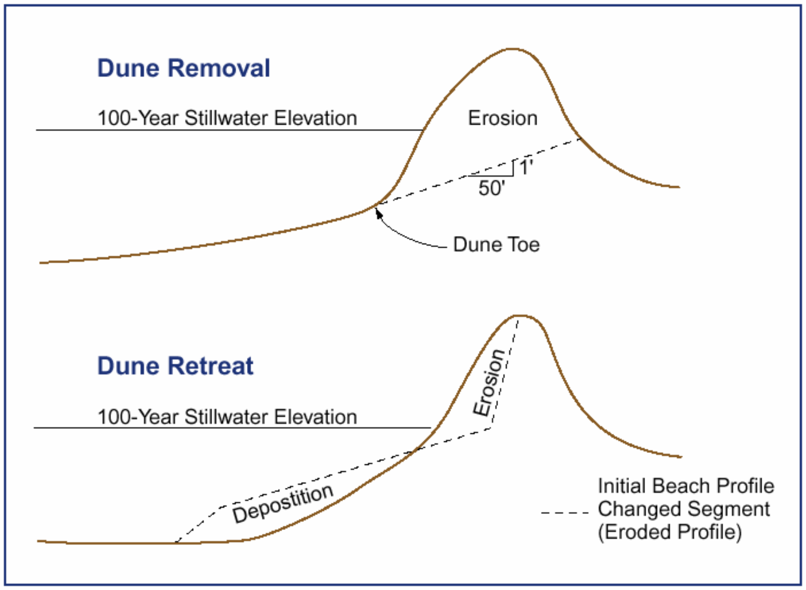



**Figure 8. Dune removal and dune retreat geometries.**

The critical value used by FEMA – 540 SF – was determined to be the *median* erosion area above the stillwater elevation during the 100-year event. The value was determined by a review of pre- and post-storm profile data for 38 erosion events on the Atlantic, Gulf or Mexico and Dutch Coasts [Hallermeier and Rhodes, 1986; Dewberry & Davis, 1989].

The 540 SF Criterion became effective following a change to the NFIP regulations (see Appendix A at the end of this discussion Topic 37, for a copy of the final rule published in the Federal Register [Vol. 53, No. 88, pages 16,269 to 16,275]).

### 3.3.2 Review of 540 SF Criterion

The 540 SF Criterion is reviewed and discussed below in terms of two central questions:

1. What is the best estimate for an erosion area-frequency relationship (and is 540 SF the correct value for median erosion above the 100-year stillwater elevation)?

2. Is use of the median erosion area appropriate for dune removal-retreat determinations?

Regarding the first question, Hallermeier and Rhodes (1986) reviewed storm erosion data for 38 storms between 1894 and 1985. Dewberry & Davis (1989) added eight storm erosion events to the databases and repeated the analysis. Both analyses yielded the erosion-frequency relationship

$$E = 85.6\ T^{0.4} \qquad (2)$$

where:

E = erosion area above storm stillwater elevation ($ft^2$, or $ft^3/ft$)

T = storm return interval (years)

The 540 SF value corresponds to the 100-year stillwater recurrence interval.

Many storm-related beach profile data have been collected since the relationship was developed, and much of that data have been very detailed (much more detailed than the original 38-storm database). It is recommended that the erosion-frequency relationship be revisited by adding more data to the 38-storm database, and by a second evaluation of the 38 storms. It is noted that Judge et al. (2003) have documented dune erosion at 90 transects on Topsail Beach, North Carolina, as a result of Hurricane Fran (1996).

Regarding the second question, FEMA Typically analyzes coastal flood hazards by considering the 100-year stillwater level in conjunction with other flood parameters at the mean (50%) level. Review of *Appendix D* shows the median erosion value, mean runup elevation, and mean overtopping rate are all used in mapping the 1% flood elevations in coastal areas. However, for Atlantic/Gulf of Mexico open coast situations where uplands are submerged by storm surge, FEMA establishes BFEs using the “controlling” (1%) wave height, not the mean wave height. Use of the 1% wave height was recommended by the National Academy of Sciences (1977). The NAS committee obviously believed mapping and regulating to a lower wave height was inappropriate, given the consequences of breaking waves striking buildings in coastal areas (severe building damage or destruction).

The current practice of using the median value to trigger dune removal will, by definition, underestimate dune erosion 50% of the time. This is not a concern where variability about the median value is small or where the consequences of underestimation are minor. However, the reports upon which the 540 SF criterion is based (Hallermeier and Rhodes, 1986; Dewberry & Davis, 1989) documented significant variability about the median value. Other studies (e.g., Chiu 1977, USACE 1984, Savage and Birkemeier 1987, and Birkemeier et al., 1988 ) also found wide variability in above-stillwater level erosion from one location to another —generally, the maximum eroded area was found to range from 1.5 to 6.6 times the median value. The State of Florida’s Coastal Construction Control Line (CCCL) erosion model uses a factor of 2.5 to adjust the average erosion upward to a value more consistent with post-storm observations of maximum vs. average erosion.

### 3.3.3 Recommendations

Thus, it is recommended that the review of the erosion-frequency relationship consider – if preliminary assessments suggest – that a larger cross-section (than the median erosion value) be considered as a trigger between dune removal and dune retreat.

Note that the above recommendation is not inconsistent with FEMA guidance to Study Contractors in Sec. D.2.4.4, which recognizes the variability of dune erosion during a given storm, and which cautions that use of a single value to characterize dune erosion may be inaccurate. *Appendix D* recommends historical data be used, wherever possible, to guide erosion assessments for the 100-year flood event.

An other consideration is the use of the present 540 SF value may or may not be the best characterization of the median erosion value during a 100-year event, but a 540 SF frontal dune reservoir represents a large dune, and few dunes exceed this value. The net result of using 540 SF is that most dunes are removed during the erosion assessment. Moreover, frontal dune reservoir determinations are not the source of flood insurance study appeals or challenges.

However, use of the 540 SF median value does not account for the effects of multiple storms on large dunes (or bluffs, if the method is applied there). In addition to capturing more of the erosion affected areas during a 100-yer event, use of a value higher than the median value may extend the “shelf life” of Flood Insurance Rate Maps by compensating for multiple storms or erosion over a period of time.

### *Determine erosion area-frequency relationship (is 540 SF the median?)*

Following are specific recommendation for re-evaluating the area-frequency relationship:

- Update 38-storm database to include other Atlantic and Gulf of Mexico open coast storm (profile and water level) data
- Re-evaluate existing 38-storm and updated data set, including use of updated flood elevation-frequency data and wave setup information in published FISs.
- Consider effects of storm duration in the analysis of 38 original storms and more recent storm erosion data
- Develop an updated erosion-frequency relationship, determine median and other values
- Evaluate data from the 38 original storms and the more recent storm erosion data to determine whether FEMA eroded geometries for retreat and removal profiles are appropriate

### *Review use of the median value as the trigger for dune retreat*

Following are recommendations for further evaluation of the uses of the median value as the trigger for dune retreat. Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time needed to accomplish tasks recommended for this topic.

- Review erosion variability for the 38 original storms and more recent storm erosion data

- Contingent on the results of the erosion area-frequency and variability analyses, determine whether the median value trigger should be maintained or revised. If a revised trigger is indicated, determine the appropriate value(s)

## 3.4 TOPIC 38: PHYSICS- OR PROCESS- BASED EROSION ASSESSMENT

### 3.4.1 Description of the Topic and Suggested Improvement

The severity of a storm-induced erosion event for a subject sandy beach can be characterized by vertical scouring and horizontal erosion. The vertical scouring establishes the likely lowest beach elevation in front of a coastal protective device or in the frontshore area during a storm event. The potentially highest wave runup associated with the storm-induced waves and a high tidal water level during the wave attack period can then be estimated. The horizontal erosion is used to determine a safe setback of coastal dwellings as well as ground clearance required to prevent wave-runup flooding. Typical beach conditions applicable to the coastal regions including the Atlantic/Gulf, Great Lakes, and Pacific regions are:

a) Sandy beach backed by protective dune formation

b) Sandy beach with shore protective device (i.e., revetment or seawall)

c) Sandy beach without either shore protective device or dune formation

d) Wave-cut coastal bluff fronted by narrow sandy beach

e) Cobble or shingle beach with or without the presence of sea cliff

***Sandy Beach Backed by Protective Dune Formation***

This type of beach morphology exists mostly in the Atlantic/Gulf region. Coastal sand dunes usually extend above the designated Stillwater Flood Elevation (i.e., one-percent occurrence), but such barriers used for storm flood protection may not be permanent, as the protective dunes will be eroded away during a severe storm event and may require decades to rebuild under the action of wind. Storm-induced erosion that removes and modifies the geometric formation of the barrier dunes allows impinging waves to propagate further inland and results in overwash flood in the coastal low-lying areas. The 540 SF Criterion (i.e., geometric dune-erosion model) has been extensively applied to the Atlantic/Gulf Coast to determine the required Stillwater Flood Elevation (SWEL). A detailed review of this criterion is being presented under Topic 37 of this focus study. In addition, process-based erosion models (e.g., EBEACH) can also be used in some settings to simulate the erosion scenario based on the physical process of storm wave attack combined with the induced high water level.

### *Sandy beach with shore protective device (i.e. revetment or seawall)*

A shore protective device is constructed when the fronting sandy beach cannot provide an adequate buffer against storm wave attack, even if the subject sandy beach is in relatively stable conditions, except for experiencing seasonal variation in beach width. There is an ongoing debate among coastal engineers and coastal geologists as to the long-term effects of a shore protective device on the fronting sandy beach. However, there is little argument as to the additionally induced short-term impacts. The degree of the short-term impacts depends on the type of shore protective device. Under conditions of large storm surges, a shore protective device can be subject to wave impacts before any substantial erosion of the beach can occur. Waves reflecting from the shore protective device, particularly during the storm-attacking period, can result in increased scour at base of the structure. Additionally, seawalls and revetments have been documented to place additional erosional stress on the adjacent shorelines during storms. The short-term scouring potential on the beach fronting a shore protective device is critical to the estimate of wave runups and potential overtopping that would subsequently determine the Stillwater Flood Elevation (SWEL). On low storm surge conditions, such as found along much of the West Coast beaches, appropriately sited seawalls at the back of the beach are not subjected to significant wave reflection until after the beach has been eroded, typically to bed rock or cobble – usually by a series of storm events. An applicable process-based model should be able to account for the effects due to the presence of a shore protective device.

### *Sandy beach without either shore protective device, a bluff or dune formation*

A sandy beach without a shore protective device and not backed by a bluff or a coastal dune generally implies a relatively wide backbeach berm that provides an adequate buffer against storm wave attack. In Southern California, beach profiles in the low-lying coastal area typically consist of an inshore zone, a foreshore with beach fronting slope, and a backshore berm without a dune formation. Under this type of beach morphology it is necessary to characterize a storm-induced erosion event for the subject sandy beach into two primary parameters; vertical scouring and horizontal erosion, as addressed in the previous section. However, much of the Southern California beach consists of a thin layer of sand overlying a wave-cut rock terrace, such that there is a well-defined limit to both the vertical scour and the horizontal erosion, regardless of the storm intensity.

### *Wave-cut coastal bluff fronted by narrow sandy beach*

The bluff base is exposed to wave attack after the narrow sandy beach acting as a buffer is stripped away, particularly during the winter months. Bluff toe erosion occurs mostly during severe storm events when waves impinge upon the coastal cliff and induce mechanical abrasion at the base, forcing impact on small joints and fissures in consolidated earth and rock units, and hydraulic action on the bluff face. When bluff toe erosion extends to a threshold depth, the upper bluff loses its support at the base and subsequently collapses. Strictly speaking, this failure mechanism is not EBE in that no single storm event is responsible and the failure could occur under benign conditions. However, if the collapse itself is considered the event, it can be assigned a probability of occurrence. Kuhn and Shepard (1983) have documented the significant contribution of heavy rainfall years to episodic bluff failure along the Southern California coast.

***Cobble or shingle beach with or without the presence of sea cliff***

This type of beach morphology is commonly observed in Oregon and the Atlantic Northeast region. The shoreline segments with a cobble berm backed by sea cliff are also observed in Southern California. The resistance capability of a cobble berm/shingle beach against short-term wave-induced erosion is still not well understood. Field applications of constructing a cobble berm that acts as a shore protective device against storm wave attack have been initiated in Oregon and Southern California. A more detailed discussion of its erosion processes during a storm event can be found in Topics 33 and 34.

### 3.4.2 Description of Procedures in the Existing Guidelines

Presently, there are no guidelines and procedures for applying process-based erosion methods for any coastal regions, including the Atlantic/Gulf and Pacific coasts, are presently available (FEMA, 2003). Only an empirical geometric model (i.e., 540 SF Criterion) with detailed guidelines and procedures is provided for the applications of erosion assessment in the Atlantic/Gulf Coast and Great Lakes regions. Topic Numbers 30 through 33 provide a thorough discussion of this erosion assessment method.

### 3.4.3 Application of Existing Guidelines to Topic

Several process-based erosion models are available, particularly the SBEACH model that was developed by the USACE. Such models have been applied with limited success along the Atlantic and Gulf Coasts. Presently available process-based models have not been fully tested for wide-spread application and are therefore not recommended by present guidance in *Appendix D*. Such models are discussed further in the following section.

### 3.4.4 Alternatives for Improvement

Researchers have developed several process-based models, which are applicable to beach conditions of Categories a, b and c, which are briefly described above. These models that may improve the predicting capability of erosion assessments can be classified into two groups; simple (or “closed loop”) and comprehensive (or “open loop”) models. Closed loop models signify that the profile is constrained to converge to a specified (equilibrium) profile for constant wave and water level conditions whereas there is no such constraint for open loop models. The open and closed loop terminology was introduced by Dean (1995) in a review of cross-shore sediment transport models. Brief discussions of several of the models are provided in the following sections. In addition, a statistical model that can be used to predict the episodic occurrence of coastal bluff failure for the beach condition described in Category d, “Wave-cut coastal bluff fronted by narrow sandy beach,” is also presented. It is noted that most profile evolution models can account for additions or removals of sand from the profile; however, most applications have not included this capability. The applicability of geometric and numerical models for the cobble/single beach is addressed in Topic Numbers 33 and 34.

### *1) Simplistic (Closed Loop) Process-Based Models for Storm-Induced Beach Erosion*

**SBEACH**

The Storm-induced BEAch CHange (SBEACH) numerical model was developed by the U.S. Army Corps of Engineers as an engineering tool for simulating beach profile evolution in response to storms. Detailed information on model development and application is provided in a series of technical and instruction reports (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990; Rosati et al. 1993; Wise, Smith, and Larson 1996; Sommerfeld, Kraus and Larson 1996; Larson and Kraus 1998).

SBEACH is an empirically based numerical model for simulating two-dimensional cross-shore beach change. The model was initially formulated using data from prototype-scale laboratory experiments and has been further developed and verified with laboratory and field data primarily from beaches on the Atlantic Coast. SBEACH calculates meso-scale beach profile change with emphasis on beach and dune erosion as well as bar formation and movement. The model is intended for predicting the short-term profile response to storms (i.e. single- or multiple-storm events)

As noted, a fundamental assumption of SBEACH and other closed loop models is that the profile change is produced solely by cross-shore processes, resulting in a redistribution of sediment across the profile with no net gain or loss of material. Longshore processes are considered to be uniform and neglected in calculating profile change. This assumption limits the model to be valid only for short-term storm-induced profile response on open coasts away from tidal inlets and coastal structures. However, if the details of volume change are available, this can be taken into consideration by this and other closed loop models.

In SBEACH the beach profile change is calculated from application of the mass conservation equation and a cross-shore sediment transport equation. The mass conservation equation relates the temporal change of the beach profile to the cross-shore gradient of the net cross-shore sediment transport. The net sediment transport rate relationships are developed based on physical considerations and analysis of large wave tank data. The sediment transport computations are separated into four zones: swash zone, broken wave zone, breaker transition zone, and pre-breaking zone.  A transport formula similar to that used by Kriebel and Dean (1985) in the development of EBEACH is applied for the surf zone, and transport relationships in the other zones are empirical and based directly on the data from the wave tank experiments. In applications, sand is exchanged between the four zones of the profile, and the volume of total sediment is conserved to maintain a balance within the evolving profile.

SBEACH requires data typically available in engineering studies to calculate beach profile response. For project applications, primary input to SBEACH includes time-histories of storm wave height and period (direction is optional) and water level; beach profile survey data; and median sediment grain size. Sampling intervals of input wave and water level time-histories usually range from 1 to 4 hours. Input required for model configuration includes parameters such as grid size, time-step, and calibration coefficients (default values are available). Typical values of model grid size and time-step are 3 meters and 5 minutes, respectively. SBEACH can be operated as a module in the commercial software package such as the Coastal Engineering Design and Analysis System (CEDAS) with a user-friendly interface.

The model enhancements after initial development of SBEACH include a random wave model and refined sediment transport relationships to improve calculation of beach response under random waves, an algorithm to simulate beach and dune erosion produced by overwash, seawall representation, and simulation of profile change over non-erodible bottoms. The wave model is now relatively sophisticated and computes wave shoaling, refraction, breaking, breaking wave-re-formation, wave- and wind-induced setup/setdown, and runup. Areas of future model development include representation of variable sediment grain size across the profile, and improved calculation of sediment transport in the offshore zone to describe movement of dredged material placed in submerged mounds.

Because of the empirical foundation of SBEACH and natural variability that occurs along the beach during storms, the model should be tested or calibrated using data from specific beach profiles surveyed before and after storms on the project coast. The model prediction should be carefully evaluated based on coastal engineering experience and knowledge, and observation of the project coast. If reliable calibration data are not available, SBEACH should be used with caution and validation is recommended.

The SBEACH model has been calibrated with data from prototype-scale wave basin, field research facility, and field studies. It has been successfully applied to numerous field case studies on the East and Gulf Coasts, and to a degree in the Great Lakes, environments that most closely fit the conditions for which it was developed and calibrated. However, several less-successful experiences using SBEACH on the coast of California (USACE-LAD, 1994) and Oregon (Komar, 2004b) seem to indicate that SBEACH may under-predict the erosion during storms on the West Coast, where the beach morphology and storm characteristics differ from its development. Recently, the USACE has officially recognized the inadequacy of SBEACH to predict erosion on West Coast beaches and has funded a research program to determine the causes and to suggest ways to overcome the deficiencies. One likely cause of the problem is that SBEACH contains a switch to turn on the erosion prediction methodology which is based upon calculating the fit of the profile to the Dean $Ay^{2/3}$ model. Another possibility is the lack of infragravity swash predicted by SBEACH, but which is central to erosion of Pacific Coast beaches. The importance to the USACE of a viable SBEACH-type tool for the West Coast would seem to indicate that the model will eventually be improved or replaced. However, as of this writing, no schedule is set for completing this.

**EBEACH**

The EBEACH model, a closed-loop-type model, was developed by Kriebel and Dean (1985) for predicting time-dependent, two-dimensional beach and dune erosion during severe storms due to elevated water levels and waves. Detailed information on model development and application can be found in a series of publications (Kriebel, 1982, 1984a, 1984b; Kriebel and Dean, 1985; Kriebel, 1986, 1990).

While conceptually similar to the geometric dune erosion models (as e.g., Edelman, 1968; Vellinga, 1982), the EBEACH model represents a distinct improvement in that it evaluates the dissipation of the wave energy within the nearshore and calculates the cross-shore sediment transport based on that wave dissipation. Therefore, while the geometric models predict the maximum potential dune erosion that might occur during a storm, EBEACH and SBEACH provide an evaluation of the actual cross-shore profile adjustment of natural beaches to storm conditions and account for the time varying wave heights and water levels in a natural manner.

As SBEACH does, a fundamental assumption of EBEACH is that profile change is produced solely by cross-shore processes. Like the geometric models and SBEACH, EBEACH assumes the existence of an equilibrium beach profile that is governed by the median grain size or fall velocity of the beach sediment. In EBEACH and SBEACH, the local cross-shore sand transport rate in the surf zone is linked to the difference between the local wave energy dissipation per unit volume and equilibrium wave energy dissipation per unit volume corresponding to the equilibrium beach profile. In EBEACH, a general equilibrium beach profile found by Bruun (1954) and further developed by Dean (1977) was used in the outer surf zone, while the profile of the inner surf zone is taken to have a uniform slope, the angle depending on the sediment grain size.

The model employs an equation of sediment mass conservation to relate the time-dependent profile evolution to the cross-shore gradient of the cross-shore sand transport rate, and a dynamic equation governing the cross-shore sand transport due to the disequilibrium of wave energy dissipation levels. This methodology was essentially used in the development of SBEACH.

The recent enhancements to EBEACH include the addition of the swash runup of the waves at the shore, calculated with the Hunt formula, and a more accurate depiction of the dune profile variations.

EBEACH has also been calibrated to the large-scale laboratory wave-tank experiments and field data on the East and Gulf Coasts. EBEACH can be operated as a module in a commercial software package such as the Automated Coastal Engineering System (ACES). Komar, et al (1999) has tested both SBEACH and EBEACH and found that they tend to under predict erosion on the Oregon Coast. This may be due, in part, to the infragravity wave setup and runup that are present on the Pacific Coast during severe events, but not included in the inputs to these models.

**SBEACH versus EBEACH**

SBEACH is conceptually similar to EBEACH in many respects. Although, they both assume the beach profile evolution during a storm is solely caused by the cross-shore gradient of the cross-shore sand transport and thus use the same equation to link beach evolution to sand transport rate, if sand addition or removal were specified along with the cross-shore locations of the addition and removal, these models could take this effect into account. The semi-empirical formulas for the cross-shore sand transport rate in the surf zone are both based on the similar concept in that the transport rate is linked to the difference between the wave energy dissipation and the equilibrium energy dissipation. Both models have been calibrated to laboratory experiments and field data on the East and Gulf Coasts, but with less effort and success for the West Coast.

While SBEACH is conceptually similar to EBEACH in many respects, the capability of SBEACH appears to be more comprehensive. SBEACH accounts for the formation of break-point bars, has a relatively detailed consideration of sand transport rate, has a more appropriate wave model, and is capable of being applied to cases with more complex bottom features such as non-erodible hard bottoms. In addition, SBEACH is designed to be run by technicians having only modest training and thus has been well documented by accompanying manuals.

Both SBEACH and EBEACH can be potentially used as the simple process-processed models for the short-term beach and dune evolution during storms. Both models have been calibrated and successfully applied to the East and Gulf Coasts. As discussed previously, significant efforts to reformulate and validate these models are necessary in order to apply them to the West Coast.

### *2) Comprehensive (Open Loop) Process-Based Models for Storm-Induced Beach Erosion*

The major advantage of the simplistic models, such as SBEACH and EBEACH, lies in their theoretical simplicity and computational efficiency. However, many aspects of these models are empirical rather than based directly on the nearshore processes. The fundamental assumption of the beach profile evolution solely caused by cross-shore sand transport and the empirical formulations of cross-shore sediment transport rate result in these models being used with limited application and less accuracy. A more accurate and detailed analyses of beach evolution demands a more sophisticated model that is less empirical, but based more on the nearshore processes and a "state-of-the-art" assessment of the sediment transport processes. Such models have been developed during the last two decades, but may not be fully tested, documented and ready for application in coastal FISs.

**European Models**

Several sophisticated models for nearshore processes have been individually developed by European research institutes such as the Danish Hydraulic Institute (DHI), Delft Hydraulics, and the University of Liverpool. These models are fundamentally similar but differ in detail as to how they simulate nearshore hydrodynamics and sediment transport, and differ in their computational procedures. Hedegaard et al. (1992) has presented a thorough review of European cross-shore sediment transport models available at the time of her review.

These models variously incorporate simulations of wave transformations, wave-induced mean water level variation (setup or setdown), wave induced undertow, and alongshore currents, the transport of the suspended and bedload sediments as well as the beach evolution. The wave and circulation modules incorporated in these models predict wave transformation and wave induced circulation in the nearshore region, and provide the flow particle velocity consisting of the wave induced current component and wave orbital velocity component as inputs to the sediment transport modules. Some models include both suspended load and bedload while others only include the suspended sediment load. The bedload transport rate is calculated using formulas that directly link the transport rate to the flow velocity or bottom friction. The suspended load transport rate is obtained by solving the sediment diffusion equation and is dependent on flow conditions such as flow velocity, bottom friction and turbulent diffusion as well as the sediment characteristics. By using the sediment mass conservation equation the temporal evolution of the beach profile is related to the spatial variation of the total sediment transport rate in both the cross-shore and alongshore directions.

These sophisticated models provide a more comprehensive depiction of coastal processes and the mechanism of nearshore sediment transport and beach evolution, and thus are superior in their physics. These models are also capable of providing more comprehensive and detailed information about nearshore processes and beach response. These models continue to be improved and have been tested against extensive laboratory experiments and a few field cases. Application requires significantly more data and effort than SBEACH- or EBEACH-type models. However, the results provide far more information on beach adjustment during and after storm events. The sophistication of these models is offset, to some degree, by the possibility of them providing unrealistic results and tendencies for instability.

**A Nearshore Processes Model developed by University of Delaware and U.S. Army Engineer Research and Development Center**

Another effort in the modeling of nearshore processes (Qin, 2003; Svendsen, 2003) has recently been performed at the University of Delaware in a joint research effort with the U.S. Army Engineer Research and Development Center's (ERDC) Coastal and Hydraulics Laboratory (CHL). The primary developer of this model, Wenkai Qin, is currently employed with Noble Consultants, Inc. in California.

The capability of this model is similar to the European models in that the complex nearshore processes including wave transformation, wave-induced circulation, sediment transport and beach evolution can be comprehensively simulated. However, other important improvements have also been incorporated in the model.

The wave module in this model can be selected from REFDIF (Kirby and Dalrymple, 1994), a cnoidal wave-bore model (Svendsen, Qin and Ebersole, 2003), or a kinematic irregular wave (Qin and Svendsen, 2003). The Quasi-3D nearshore circulation model SHORECIRC (Svendsen et al. 2002) is used as the circulation module. In the sediment transport module, the Engelund and Fredsøe (1976) formula, the Bailard and Inman (1981) formula or their modified version can be selected to calculate the bed load transport rate, and the suspended transport can be estimated either by solving the sediment diffusion-convection equation or by using the modified Bailard (1981) equation after including the contribution of the wave breaking process. The model is capable of predicting both alongshore and cross-shore sediment transport rates, the breaker bar formation and migration as well as erosion in the surf zone during a storm.

It is also important to mention that by developing a kinematic irregular wave model, not only the averaged quantities but also the long-wave infragravity motions of the nearshore hydrodynamics and their effect on sediment transport can be accounted for by this model.

### *A Statistical Model for Bluff Failure*

For the beach morphology that is characterized as a hard bottom backed by a coastal bluff, the evolution of this bluff-type shoreline is significantly different from that of a sandy shoreline. Storm waves that directly impinge on the bluff initially induce toe erosion at the base of the bluff, and the accumulation of individual storm-related toe erosion ultimately triggers the bluff face to steepened ultimately collapse. This type of bluff failure is frequently observed along north Atlantic and in many locations in California, Oregon, and Washington.

Previous estimates for coastal bluff retreat have always resorted to a temporally averaged rate over a long period (an average annual rate of retreat) based on long-term records. Though the annualized rate of coastal cliff erosion is a good indicator of the gradual retreat of the bluff top, it does not adequately represent the episodic nature of bluff failure, when several meters of bluff top can instantaneously fail and fall to the beach face below. An annualized retreat rate essentially accounts for the long-term average effect of various episodic failure events combined with the periods of little or no erosion activity. As a result, the annualized retreat rate tends to yield a misleading picture of coastal cliff erosion as well as the resulting damage to bluff-top development and hazards to coastal communities often located on top of coastal bluffs.

During an investigation of the Encinitas/Solana Beach, California, shoreline area, Noble Consultants, Inc. developed a statistical model for the prediction of bluff failure induced by a series of storm attacks (USACE-LAD, 2003). A semi-empirical formulation was developed to quantify the short-term bluff toe erosion rate as a function of the intensity of impinging waves and the rock resistance of the bluff according to Sunamura (1982 and 1983). A Monte Carlo technique was then applied to simulate the random process of storm waves impinging upon the bluff base, inducing toe erosion, and subsequently triggering a bluff failure. The same statistical technique was also used to randomly select the size of upper bluff failure when it occurs. The entire simulations consisted of two Monte Carlo type random sampling procedures based on two formulated statistical distributions: (1) wave height at the bluff base, and (2) bluff failure size on the top. Statistical random populations of wave height at the bluff base were derived from hind cast deepwater waves via the wave propagation process. Bluff-top failure size was randomly selected from a detailed, comprehensive, historical database of bluff failures in the study area.

The results from the Monte Carlo simulations provide a synoptic accounting of bluff failure that closely resembles the natural process of bluff failure in both the short and long term.

This statistical model procedure is in the process of being certified by the U.S. Army Corps of Engineers, CERC as the designated numerical model for storm damage analysis related to coastal bluff failure. A flow chart of this modeling procedure is presented in Figure 9.

### 3.4.5 Recommendations

Since no existing guidelines and procedures are available for process-based modeling approaches flood hazard mapping partners, recommendations are herein presented to provide some preliminary guidelines for assessing EBE for beach conditions of Categories a through d. The procedure of assessing process-based erosion under beach conditions of Categories a, b and c includes two primary steps of 1) choosing an appropriate model for the simulation of the short-term erosion process; and 2) determining the oceanographic parameters (including storm waves and tides) during a storm event that are responsible for the process-based evolution. For Category d, the previously discussed statistical model can be applied. In addition, prior to any final validation of existing process-based erosion models, an interim approach is also recommended to provide a means for estimating the eroded beach profile during a severe storm event.

***Simplistic Models versus Comprehensive Models***

Both the simplistic and comprehensive processes-based models described above can potentially serve as FEMA models for the assessment of process-based erosion of a sandy beach. The simplistic models such as SBEACH and EBEACH are more empirically oriented and involve more assumptions that may limit their application. However, they are theoretically simple and computationally efficient. On the other hand, the more comprehensive models are more physics-based and capable of directly addressing the complex nearshore processes, including the mechanisms of nearshore hydrodynamics, sediment transport, and beach response. They can provide more comprehensive and detailed information of nearshore processes including beach evolution. The disadvantages of more comprehensive models lie in model complexity which may require more detailed data and boundary condition specifications, answers that may vary widely, instabilities, and computational inefficiency (longer model setup and run times).

It is therefore recommended that the selection of a simplistic or comprehensive model should be based on considerations of the specific project objective, beach material properties, and environment specific data requirements and overall budget. If numerous model executions are required for various storm conditions, the simplistic models are recommended to save on computations. On the other hand, if only a few executions are required, or the beach environment is too complex to apply the simplistic models, comprehensive models may be a preferred alternative.

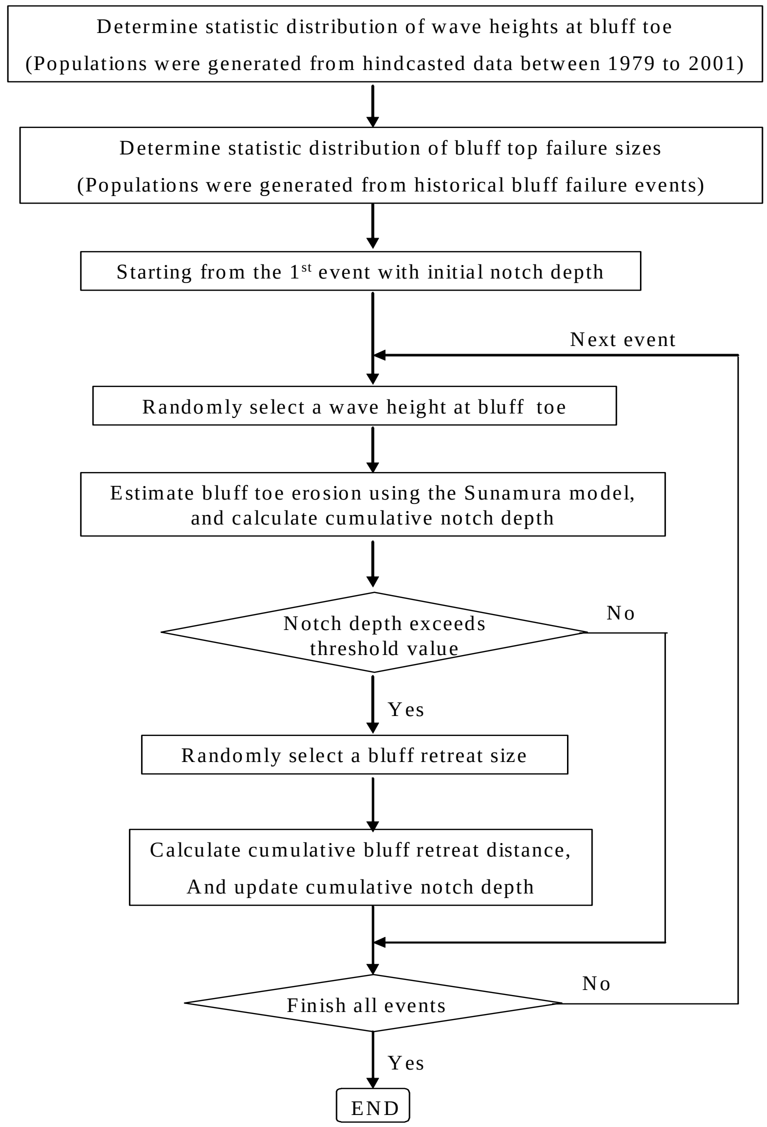



**Figure 9. Flow chart of the statistical model for bluff failure.**

**Random Coincidence Between Storms and Tides**

Not only wave conditions, but also water depth, determine the severity of beach erosion during a storm event. The peak storm condition coincident with high or low tides will result in significant differences in the short-term beach erosion. Different combinations of storms and tides may induce the same amount of beach erosion. A 100-year storm may not be necessary to induce beach erosion that is equivalent to a 100-year erosion event, if return storm waves of 100 years arrived at a subject beach during the low tide condition. Therefore, it is essential to include various coincidences (joint occurrences) between the storms and tides in the analyses of the EBE.

It is recommended that a methodology be developed to include the randomness of storm waves, tidal elevations, and coincidence of these two oceanographic parameters. The preliminary concept of this methodology is illustrated in Figure 10. By analyzing all of the calculated results of beach erosion for all possible events, the event-based beach erosion for various return frequencies (as e.g., the one-percent EBE) can be determined.

### *Interim Approach for Assessing Eroded Beach Profile*

Until process-based models are fully developed and tested, the EBE study group recommends that an interim approach be employed to estimate the eroded beach profile during a severe storm event so that wave runup and overtopping can be computed using the methodology detailed in Topics 11 through 14 (runup and overtopping). In the Atlantic, Gulf, and Great Lakes regions, the existing geometric model (referred to as the 540 SF Criterion) can be used to estimate the eroded beach profile conditions. Until specific methods are developed and accepted by FEMA for the Pacific region, eroded beach profiles can be estimated, using past field observations during historical severe storm events for various types of beach morphology and site conditions.

- For beach profiles that consist of a thin lens of sand overtopping the natural bedrock planform, it can be assumed that all sands will be stripped away during severe storm events. Thus, the profile of the bedrock planform (previously referred to as the "most likely winter beach profiles") can be used as the beach profile in the calculation of the one-percent wave runup and flood base elevation. Topics 30 and 37, herein discuss this recommended procedure further.
- For sandy beaches that have a thick sand layer, the most eroded beach profiles documented during past storm events should be employed as the storm-eroded beach profiles for wave runup calculations. These most depleted beach profiles probably occurred in the 1983 El Niño year during which a cluster of severe storms sequentially impinged upon the Pacific Coast from California to Washington and resulted in the most wide spread of coastal damages along the West Coast. Historical and recent beach profile surveys that have been regularly conducted by the USACE, NOAA, regional governments, and local agencies such as counties and individual cities.

Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time needed to accomplish tasks recommended for this topic.

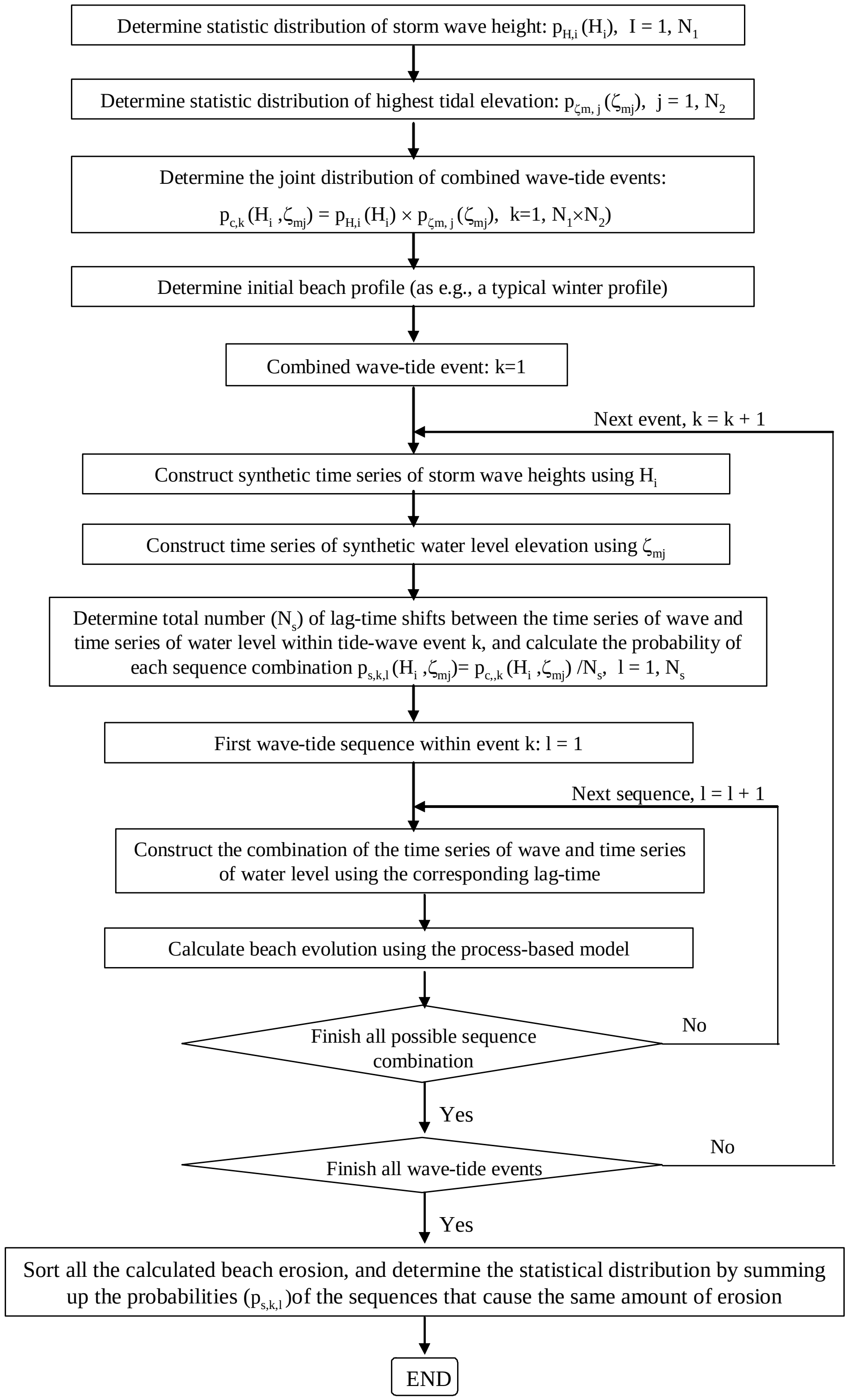



**Figure 10. Flow chart of statistical analysis of event-based erosion.**

# 4 AVAILABLE TOPICS

## 4.1 TOPIC 31: ADD/REVISE *G&S* LANGUAGE REGARDING BLUFF EROSION IN ATLANTIC/GULF AREAS

Topic 31 is categorized as an “Available Topic” for the Atlantic and Gulf areas. Sand-dominated dune erosion is reasonably covered in the present guidance in *Appendix D* by the 540 SF criterion for most Atlantic/Gulf areas with slight modifications to that criterion used in the Great Lakes. Other topics (33 and 34) discuss the needs to develop and provide new guidance for beach, dune, and back beach areas comprised of mixed grain materials, gravel, cobble, and shingles. Topic 31 is directed at better addressing “bluff erosion” in *Appendix D* and discussing whether a simple geometric model similar to the 540 SF criterion is necessary and can be developed for the Pacific Coast.

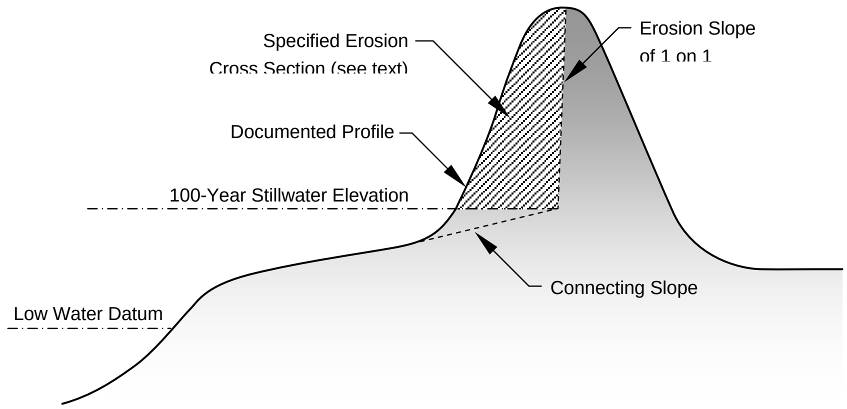
### 4.1.1 Description of Procedures in the Existing Guidelines

Present guidance in *Appendix D* focuses primarily on addressing erosion as sand-dominated dune face retreat or sand dune removal based entirely on the size of the frontal dune reservoir. These guidelines do not specifically address bluff erosion for the Atlantic, Gulf, or Pacific Coasts.

### 4.1.2 Application of Existing Guidelines to Topic

Because bluffs are often comprised of older, more consolidated materials with cohesive mixtures of soil, sand, and gravel materials, they are more erosion resistant than sand dunes. They may erode and retreat landward only periodically during or following rare intense storm events. However, unlike noncohesive sand dunes, bluffs rarely prograde (recover) back toward the ocean on a seasonal basis. Therefore, FEMA assumes that “bluff erosion is more of a long-term process” and not a present concern for FEMA according to present regulations.

The only place in the *G&S* where bluff erosion is mentioned is in Section D.3.4, Erosion Assessment for the Great Lakes areas. In this section of the *G&S* (page D-132), bluff erosion (projection of the retreating bluff face) “is based on a retreated profile assumed parallel to the existing bluff, but with a potential adjustment to the eroded face governed by soil stability consideration for the site.” Figure D-39 from *Appendix D* shows a typical eroding bluff scenario.




**Basic Erosion Considerations for Coastal Sand Dune Provides Shaded Shore Profile for Great Lakes Base Flood. (from Figure D-39 in Appendix D)**

The *G&S* assume that there is unlimited material behind the face of an eroding bluff (or cliff) and that approximately the same beach and back beach-bluff face profile will exist during and after a large storm event. Therefore, all that occurs is that the bluff face retreats landward by an unpredictable amount every so often, but the barrier to landward flooding (the bluff face) remains as it did prior to the event.

### 4.1.3 Alternatives for Improvement

The present guidance in *Appendix D* would benefit from the addition of more in-depth discussions of the characteristics, settings, and physical processes associated with coastal bluffs and bluff erosion. Many reports and papers are available (Bruun, 1988; Komar, 1997; Komar, Marra, and Allan, 2002; Kriebel and Dean, 1985, Nairn and Southgate, 1993; Roelvink and Broker Hedegaard, 1993; The Heinz Center, 2000; National Research Council, 1990) to provide this type of information. Several states and local agencies have also published coastal erosion mapping and management program documents that are very informative and cover large portions of the Pacific and Atlantic coastlines. A recent report by the U.S. Geological Survey (2004) provides a summary of historical shoreline changes and associated coastal land loss along the Gulf of Mexico. This report represents the first in a series that will eventually include the Atlantic Coast, Pacific Coast, and parts of Hawaii and Alaska.

Inclusion of these types of discussions and more explicit explanations of the physical processes responsible for bluff and cliff retreat will provide valuable information to Mapping Partners.

***Considerations for future development:***

The capabilities and reliability of process-based numerical models is improving each year. Noble Consultants, Inc. (2003) documents successful and practical methods for assessing bluff erosion using statistical procedures and numerical modeling (see detailed discussion in Topic 38, Physics- or Process-Based Erosion Assessments). Refer to “A Statistical Model for Bluff Failure” for a detailed discussion of a statistical model for bluff failure.

### 4.1.4 Recommendations

1. Review available literature and reporting and select appropriate information for inclusion in the *G&S* to describe the physical and geotechnical processes responsible for bluff (and cliff) erosion and retreat. Include characterization of the durability of the bluff material.

2. Examine reports and documents used to develop the present bluff erosion guidelines for the Great Lakes. Select appropriate information for enhancing the *G&S*.

3. Similar descriptions should be included in the new Pacific *G&S*.

4. Further testing and application of Process-Based numerical/statistical modeling methods is encouraged. These methods are presently being applied in some locations with success. Further development looks promising. FEMA should consider these tools for future inclusion in the NFIP program.

## 4.2 TOPIC 32: DEVELOP IMPROVED GEOMETRIC METHODS FOR BLUFF EROSION IN THE ATLANTIC AND GULF AREAS

### 4.2.1 Description of Topic 32 and Suggested Improvement

Topic 32 is categorized as an “Available Topic” for the Atlantic and Gulf areas. Sand-dominated dune erosion is reasonably covered in the present guidance in *Appendix D* by the 540 SF criterion for most Atlantic/Gulf areas. This Topic 32 is directed at addressing “bluff erosion” and whether a simple geometric model similar to the 540 SF criterion can be developed for such applications along the Atlantic.

### 4.2.2 Description of Procedures in the Existing Guidelines

Present guidance in *Appendix D* focuses primarily on addressing erosion as sand-dominated dune face retreat or sand dune removal based entirely on the size of the frontal dune reservoir. The present guidance in *Appendix D* does not specifically address bluff erosion.

### 4.2.3 Application of Existing Guidelines to Topic

See Section 4.1.3 for a discussion of this topic.

#### 4.2.4 Recommendations and Approach

At the present time FEMA considers periodic bluff (and cliff) erosion as long-term processes that are not considered under present regulations.

1. It is recommended that further descriptions of the physical processes responsible for bluff (and cliff) erosion to the *G&S* be added as described in Topic 31, emphasizing the durability of the bluff material.

2. Development of geometric models may not be necessary at this time to estimate beach and back beach profiles for runup and overtopping calculations.

3. As an interim method, prepare an estimate of the most likely amount of retreat during the 1% event from available information (maps, photos, documentation of the area, and survey data) and develop typical beach and back beach profiles for use in run up/overtopping calculations.

4. If it is determined that the bluffs are retreating rapidly and regularly, then the Mapping Partner should conduct further investigations regarding the rates and causes of the erosion and consult with their FEMA contract manager regarding how that may affect their zoning estimates.

5. Development of more detailed methods is not necessary unless FEMA determines how to change the regulations to include periodic bluff (and cliff) erosion in the NFIP.

6. The writers suggest changing the priority of this topic to "Available" while continuing to investigate opportunities for future implementation of more advanced modeling methods.

### 4.3 TOPIC 41: LONG-TERM EROSION/FUTURE CONDITIONS

#### 4.3.1 Description of Procedures in the Existing Guidelines

The focus study considered the topic of mapping long-term erosion on FIRMs and any necessary changes to the *G&S*. In short, the project team believes mapping long-term erosion is technically feasible, but problematic, given unresolved NFIP policy and implementation issues. This topic has received considerable attention by others (at the federal, state, and local levels), but time and budget constraints prevented this project team from contributing to the topic beyond reiterating its importance.

The project team considered the long-term erosion issues identified at Workshop 1 (expand *G&S* text on the topic; put warning notes on FIRMs, etc.) and concluded that until the many issues related to mapping future conditions on FIRMs are resolved, incorporation of long-term erosion in the *G&S* are premature. However, the project team strongly believes that the topic is important, that the topic should continue to be evaluated, and that better communication regarding erosion risk, impacts and mitigation should be undertaken in the period prior to the mapping of long-term erosion on FIRMs.

#### 4.3.2 Recommendations and Approach

This topic should continue to be evaluated by FEMA. New guidance can be developed once FEMA decides how best to account for long-term erosion processes within FIS's and FIRM's *G&S*.

### 4.4 TOPICS 42 & 43: ADD GUIDANCE REGARDING THE TREATMENT OF NOURISHED BEACHES IN FLOOD HAZARD MAPPING

#### 4.4.1 Description of Procedures in the Existing Guidelines

There is not much dispute that nourished beaches can protect upland development and reduce flood- and erosion-damage. However, there is considerable dispute over certain technical and policy issues, i.e., the longevity of nourishment projects, and whether and how they should be considered for flood hazard mapping purposes. One of the more thorough treatments of these topics is contained in the National Academy of Sciences report, *Beach Nourishment and Protection* (NRC, 1995). Dean (2002) presents methodology for predicting longevity of beach nourishment projects.

At present, the *G&S* provide no specific guidance to Mapping Partners and Study Contractors relative to beach nourishment. FEMA policy on the matter is best summarized by Davison, et al. (1996), written in response to the National Academy of Sciences report. In essence, FEMA policy has been to ignore the presence of nourishment projects in the establishment of flood hazard zones/BFEs and in the setting of coastal building standards. This procedure is similar to that used to remove "uncertified" coastal structures (structures not capable of withstanding the base flood event and/or structures without acceptable maintenance plans) from transects before erosion and wave analyses are performed.

What is not clear, however, is how a Mapping Partner or Study Contractor would actually "remove" a nourishment project before conducting erosion and wave analyses for flood hazard mapping. The result has been that some flood insurance studies have become effective using city- or county-wide topographic mapping updates (that include the nourished area) obtained through surveys following nourishment, while at the same time other communities have been discouraged from seeking revisions to FIRMs following beach nourishment.

#### 4.4.2 Recommendations and Approach

Table 1, at the conclusion of this report, summarizes the key findings and recommendations for this topic, and Table 2 provides an estimate of the amount of time needed to accomplish tasks recommended for this topic.

- The project team considered the beach nourishment issues identified at Workshop 1, and concluded that the *G&S* should be revised to direct mapping partners/study contractors to use the following procedure:

- Notify FEMA when a study area contains a shoreline that has been nourished in the past.

- Research the nourishment project(s) and conduct preliminary analysis to determine whether the nourishment is likely to have an impact on hazard zone designations or BFEs over the long term.

- If the presence of nourishment is likely to affect hazard zone designations or BFEs over the long term, contact FEMA to discuss a possible exception to existing FEMA beach nourishment policy.

- The project team also recommends that the *G&S* be revised to include a listing of the types of information that may be required to assess special cases where exceptions to FEMA's beach nourishment policy may be granted.

#### 4.4.3 Topics 42 & 43: Availability

Information to address Topics 42 & 43 is available and easily incorporated into existing guidance.

# 5 HELPFUL TOPICS

## 5.1 TOPIC 40: CALCULATE VERTICAL EROSION DEPTHS

### 5.1.1 Description of Topic and Suggested Improvement

Topic 40, Calculate Vertical Erosion Depths, is the only topic categorized as "Helpful" during Workshop 1 in December 2003. Most economic flood damage models use "depth-damage" functions to calculate flood damages. Depth-damage functions relate the percentage of building damage to the depth of flooding (from the top of the wave crest or the stillwater surface to the ground). Functions vary by flood hazard zone and building type.

There is a trend in flood loss modeling to include other flood-related hazards. For example, HAZUS considers flood depth and vertical erosion depth (the vertical distance between the original ground elevation and the [event-based] eroded ground elevation). These analyses require erosion depth-damage functions, which relate the percentage of building damage to the vertical erosion depth. Erosion depth-damage functions vary with foundation type.

This topic is merely a placeholder for future use–as flood hazard methods and models are coded, we should build in the capability to calculate and store vertical erosion depths (along transects or grids). These vertical erosion depths can then be used by economic models to estimate building damages due to erosion.

### 5.2 AVAILABILITY

No specific information is required to address Topic 40 at this time. Future development and refinement of erosion depth-damage functions will be required, but these tasks are not included in the time and cost estimate below.

## 6 SUMMARY

Present *G&S* do not provide specific guidance for assessing EBE in coastal areas of the Pacific, Sheltered Waters on either coast, or non-sandy beach and coastal dune areas, and provide only simplified empirical-based geometric relationships (the 540 SF Criterion) for the Atlantic and Gulf. Therefore, new or improved methods are needed for the Pacific, Atlantic and Gulf, especially where beaches, dunes and bluffs are comprised of sediment materials other than uniform sand.

The EBE Study Team was tasked to: 1) develop improved language, descriptions and discussions related to coastal erosion assessments for consideration in revised and/or new FEMA *G&S*, 2) to review empirical geometric techniques and process-based methods for estimating beach and back beach profiles resulting from a 1-percent-annual-chance storm event in various settings along the Atlantic Coast, Gulf Coast and Pacific Coast, 3) review the present 540 SF Criterion for assessing EBE, 4) review and discuss methods for assessing EBE along cobble/shingle beaches, 5) recommend improved geometric model procedures for the Atlantic, Gulf and Pacific coastal regions, 6) prepare descriptions and discussions regarding erosion assessments in sheltered areas, 7) discuss steps to take and list the types of information that Study Contractors should provide to FEMA in cases where beach nourishment may be considered in determining hazard zones and BFEs, and 8) recommend approaches for improving or preparing guidelines in each topic area.

Following are brief summaries of the findings and recommendations for the key topics associated with EBE. The following tabular summaries are grouped into *Critical*, *Important,* and *Available* categories of topics as were defined by the TWG during Workshops 1 and 2. Table 2 provides an estimate of the amount of time required to accomplish tasks that are recommended for each topic.

**Table 1. Summary of Findings and Recommendations for Event Based Erosion**

| Topic Number | Topic | Coastal Area | Priority Class | Availability/ Adequacy | Recommended Approach | Related Topics |
|---|---|---|---|---|---|---|
| 30 | Geometric Techniques | AC | -- | -- | 1. Select and evaluate existing geometric methods and models for application along Pacific Coast. Methods should include effects of storm duration and sediment erodibility. Document results.<br>2. Develop guidance for determination of a Most Likely Winter Beach Profile (Pacific) including areas of beach nourishment for Pacific coastal areas prior to the occurrence of the 100-year event. These profiles will be developed from historical beach profiles and recent LIDAR mapping of the Pacific coastline.<br>3. Evaluate geometric versus numerical modeling procedures for sand beaches and dunes on Pacific Coast and test with available data sets. Document results.<br>4. Recommend that FEMA to expand/support the present USGS/NOAA coastal survey program for the Pacific coast;<br>***Future, Long-Term Program Considerations:***<br>1. Expand/support the present USGS/NOAA coastal survey program for the Pacific coast; update likely winter profiles for various geomorphic settings; determine whether joint probability methods related to initial beach profiles, duration and material erodibility are necessary.<br>2. Develop and test new geometric models (or process-based models) for sandy beach and dune systems along the Pacific using data from the long-term program above.<br>3. Develop methods for assessing other types of non-sandy beach settings, such as cobble and gravel beaches based on the underlying physical processes controlling those coastal settings (See Topics 33 and 34)<br>4. Develop long-term data sets for model testing and validation. | 31, 32, 35, 36, 37 |
| | | GC | -- | -- | | |
| | | PC | C | MAJ | | |
| | | SW | | | | |

| Table 1. Summary of Findings and Recommendations for Event Based Erosion | | | | | | |
|---|---|---|---|---|---|---|
| Topic Number | Topic | Coastal Area | Priority Class | Availability/ Adequacy | Recommended Approach | Related Topics |
| 33 | Cobble/ Shingle Effects | AC | C | MAJ | 1. Prepare new section of Guidelines to describe differences between sand dominated beaches and gravel/cobble/shingle beaches found along the north Atlantic, Gulf, Pacific and in sheltered areas. Provide photos and profile information.<br>2. Gather existing literature on cobble, shingle and coarse-grained beaches to summarize the existing state of knowledge until specific guidelines can be developed and adopted.<br>3. Review literature on the design of and construction of dynamic revetments and cobble berms to provide guidance on their stability and long term development.<br>4. Examine other possible guidance and available beach and dune data sets for possible clarifications to the 540 SF Criterion for sand-dominated beaches versus gravel/cobble/shingle beaches.<br>5. Discuss the limitations of applying geometric models to cobble/shingle beach and dune areas.<br>Future Considerations:<br>6. Examine the applicability of existing equilibrium beach profile concepts and relationships to represent the response of cobble and mixed grain beaches to storms.<br>7. Prepare case studies using actual coarse grain beaches demonstrating application of the recommended methodology.<br>8. Prepare new guidelines for the Pacific Coast describing the physical processes associated with gravel/cobble/shingle beaches. | 30-32, 34, 37 |
| | | GC | C | MAJ | | |
| | | PC | C | MAJ | | |
| | | SW | C | MAJ | | |
| 35 | Erosion - Sheltered Waters | AC | (C) | Y | 1. Provide definitions and discussion for Guidelines for sheltered water types of beach morphology, materials, & wave characteristics.<br>2. Provide interim *G&S* based primarily on historical beach profiles & field observations. | 5, 6 36, 41 |
| | | GC | (C) | Y | | |
| | | PC | (C) | Y | | |
| | | SW | C | Y | | |

| Table 1. Summary of Findings and Recommendations for Event Based Erosion | | | | | | |
|---|---|---|---|---|---|---|
| Topic Number | Topic | Coastal Area | Priority Class | Availability/ Adequacy | Recommended Approach | Related Topics |
| 34 | Cobble/ Shingle -Geometric Method | AC<br>GC<br>PC<br>SW | I<br>I<br>I<br>I | PRODAT<br>PRODAT<br>PRODAT<br>PRODAT | 1. Review literature on natural cobble, shingle and coarse-grained beaches. Provide key results to Mapping Partners for interim consideration.<br>2. Review literature regarding design and project response of "dynamic revetments and cobble berms." Summarize useful guidance and methodologies for application to cobble and single beaches.<br>3. Perform assessment and test of 540 SF criterion for cobble and single beaches. Document results as Case Studies.<br>4. Summarize pertinent national and international literature on gravel, shingle, cobble beach assessment methods.<br>5. Examine the applicability of existing equilibrium beach profile concepts and relationships to represent the response of cobble and mixed grain beaches to storms.<br>6. Determine whether process-based models can be developed in a relatively short period of time for application to both the Atlantic and Pacific coasts.<br>7. Provide interim *G&S* based primarily on historical beach profiles and documented case studies (AC and PC will be presented separately).<br>8. Recommend how to incorporate new procedures into *G&S*. | 12, 21, 33, 35, 38, 42 |
| 36 | Geometric Method – Sheltered Waters | AC<br>GC<br>PC<br>SW | I<br>I<br>I<br>I | Y<br>Y<br>Y<br>Y | 1. Provide interim *G&S* for the AC & GC based primarily on historical applications of the 540 SF criterion on AC/GC.<br>2. Provide interim *G&S* for the PC based primarily on historical field observations developed on PC.<br>3. Perform pilot studies; refine procedures and describe methods for *G&S*.<br>4. Test models and incorporate event-based models where feasible into final *G&S* Sheltered Waters.<br>5. Provide guidance on appropriate models for erosion in sheltered waters. | 5, 6, 35, 38 |

| Table 1. Summary of Findings and Recommendations for Event Based Erosion | | | | | | |
|---|---|---|---|---|---|---|
| Topic Number | Topic | Coastal Area | Priority Class | Availability/ Adequacy | Recommended Approach | Related Topics |
| 37 | Review 540 SF Criterion | AC<br>GC<br>PC<br>SW | I<br>I<br>--<br>-- | DAT<br>DAT<br>--<br>-- | 1. Expand database beyond 38 storm events for AC and GC using more recent data.<br>2. Re-evaluate existing data points,<br>3. Consider storm duration in analyses,<br>4. Evaluate geometry of retreat and removal profiles.<br>5. Consider variability of erosion about median at each data point.<br>6. Contingent on 1–5, determine whether median erosion trigger should be maintained or revised. | 32, 34, 36 |
| 38 | Process-Based Approach | AC<br>GC<br>PC<br>SW | I<br>I<br>I<br>I | Y<br>Y<br>Y<br>Y | 1. Further develop & test process based models using field data and compare results with geometric models.<br>2. Develop method to include randomness of return storm waves & tides & coincidence in Item 1.<br>3. Provide *G&S* for erosion assessment to coastal bluff fronted by a narrow beach<br>4. As an interim method continue to use the 540 SF Criterion for AC & GL, and mos likely winter beach profile or best documented winter profile for the PC | 30-32, 35, 36 |
| 31 | Bluff Erosion | AC<br>GC<br>PC<br>SW | A<br>(A)<br>(A)<br>(A) | Y<br>Y<br>Y<br>Y | ***Interim Task;***<br>1. Review available literature and reporting and select appropriate information for inclusion in the *G&S* to describe the physical and geotechnical processes responsible for bluff (and cliff) erosion and retreat. Try to characterize the durability of the bluff material.<br>2. Provide appropriate definitions and process descriptions in the Pacific *G&S*.<br>***Future considerations:***<br>1. Provide interim *G&S* based primarily on historical beach profiles and documented case studies.<br>2. Provide interim *G&S* based primarily on historical field observations.<br>3. Incorporate event-based models to establish final *G&S*.<br>4. FEMA should consider process-based numerical/statistical modeling methods for future inclusion in the NFIP program. In the mean time completed case studies should be documented and provided to FEMA for review. | 30, 32, 35, 36-38, 41 |

| Table 1. Summary of Findings and Recommendations for Event Based Erosion | | | | | | |
|---|---|---|---|---|---|---|
| Topic Number | Topic | Coastal Area | Priority Class | Availability/ Adequacy | Recommended Approach | Related Topics |
| 32 | Geometric Method for Bluffs | AC | I (A) | Y | ***Interim recommendation:***<br>1. Review and summarize existing bluff erosion assessment procedures and selected literature.<br>2. Consider development of geometric procedure for bluff erosion and cliff retreat.<br>***Future Tasks to consider;***<br>1. Develop geometric procedure for bluff erosion and cliff retreat.<br>2. Add further descriptions of the physical processes responsible for bluff (and cliff) erosion to the *G&S* as described in Topic 31.<br>3. Recommend how to incorporate new procedures into future *G&S*. | 12, 21, 33, 35, 38, 42 |
| | | GC | I (A) | Y | | |
| | | PC | (A) | Y | | |
| | | SW | (A) | Y | | |
| 41 | Long-Term Erosion | AC | A | Y | 1. Topic considered important to NFIP, but FEMA action on previous work pending, therefore, guidance best developed outside of current project.<br>2. Provide better risk communication to public - outside of *G&S*. | 30-32, 35, 36 |
| | | GC | A | Y | | |
| | | PC | A | Y | | |
| | | SW | A | Y | | |
| 42 & 43 | Beach Nourishment | AC | A | Y | Prepare guidance to:<br>1. Notify FEMA that study area includes beach nourishment area;<br>2. Conduct research and preliminary analysis to determine whether beach nourishment is likely to have an effect on hazard zone designations and/or BFEs;<br>3. Provide list of types of information that may be required to assess special cases where beach nourishment may be considered in determining hazard zones and BFEs (as an exception to existing FEMA policy). | 39, 41 |
| | | GC | A | Y | | |
| | | PC | A | Y | | |
| | | SW | A | Y | | |
| 40 | Vertical Erosion Depths Erosion depths | AC | H | Y | Document depths of erosion following storm events and maintain data for depths of erosion and damages to buildings in order to better determine “depth-damage” relationships. As methods and models are coded, calculate and store vertical erosion depths along transects and grids. . These vertical erosion depth data can then be used in economics models to estimate building damages due to EBE. | 30-36 |
| | | GC | H | Y | | |
| | | PC | H | Y | | |
| | | SW | H | Y | | |
| | | | | | | |

| Table 2. Preliminary Time Estimate for Guideline Improvement Preparation | | |
|---|---|---|
| Topic Number | Item | Time (Person months) |
| 30 | **Review empirical geometric techniques and pre- and post-event data for CA, OR, WA; review OR setback methods, develop geometric techniques for pacific shorelines, including sea cliff, bluff, dunes beaches** | |
| | 1. Select and evaluate existing geometric methods and models for application along Pacific Coast. Methods should include effects of storm duration and sediment erodibility. Document results. | 4 |
| | 2. Develop guidance for determination of a Most Likely Winter Beach Profile (Pacific) including areas of beach nourishment for Pacific coastal areas prior to the occurrence of the 100-year event. These profiles will be developed from historical beach profiles and recent LIDAR mapping of the Pacific coastline. | 3 |
| | 3. Evaluate geometric versus numerical modeling procedures for sand beaches and dunes on PC and test with available data sets. Document results. | 3 |
| | ***Long-Term Program:***<br>4. Expand/support the present USGS/NOAA coastal survey program for the Pacific coast; update likely winter profiles for various geomorphic settings; update likely winter profiles for various geomorphic settings. | Future Programs |
| | Total | 10 |
| 33 | **Add *G&S* descriptions/discussion regarding effect of cobble/shingle materials (including sediment mixtures/layers) on geometric erosion techniques** | |
| | Prepare new section of Guidelines to describe differences between sand dominated beaches and gravel/cobble/shingle beaches found along the north Atlantic, Gulf, Pacific and in Sheltered areas. Provide photos and profile information | 1 |
| | Gather existing literature on cobble, shingle and coarse-grained beaches to summarize the existing state of knowledge until specific guidelines can be developed and adopted | 1 |
| | Review literature on the design of and construction of dynamic revetments and cobble berms to provide guidance on their stability and long term development | 0.5 |
| | Examine other possible guidance and available beach and dune data sets for possible clarifications to the 540 SF Criterion for sand-dominated beaches versus gravel/cobble/shingle beaches | 1 |
| | Discuss the limitations of applying geometric models to cobble/shingle beach and dune areas | 0.5 |
| | Prepare New Guidelines for the Pacific coast describing the physical processes associated with gravel/cobble/shingle beaches | 1 |
| | Future Research: Examine the applicability of existing equilibrium beach profile concepts and relationships to represent the response of cobble and mixed grain beaches to storms. | N/A |
| | Future Research: Prepare Case Studies using actual cobble and coarse grain beaches demonstrating application of the recommended methodology. | Future Research |
| | TOTAL | 5 |
| 35 | **Add *G&S* descriptions/discussions regarding erosion assessments in sheltered areas** | |
| | 1. Provide definitions and discussion for Guidelines for sheltered water types of beach morphology, materials, & wave characteristics. | 1 |
| | 2. Provide interim *G&S* based primarily on historical beach profiles & field observations. | 2 |

| Table 2. Preliminary Time Estimate for Guideline Improvement Preparation | | |
|---|---|---|
| Topic Number | Item | Time (Person months) |
| | 3. Attempt to develop rational guidance based on a model consistent with the general framework discussed previously | Future Research |
| | 4. Develop Case Studies based on actual settings. | Future Research |
| | TOTAL | 3 |
| 34 | **Develop methods that consider cobble/shingle effects** | |
| | Gather, compile and summarize existing literature on natural cobble, shingle, and coarse-grained beaches to summarize the existing state of knowledge and provide references Mapping Partners can use until specific guidelines can be developed and adopted. | 2.5 |
| | Develop geometric procedure for estimating eroded profiles for cobble/shingle beaches | 3 |
| | Review literature on the design of and construction of dynamic revetments and cobble berms to provide guidance on their stability and long-term development (changes) | Future Research |
| | Review and assess the historical applications of the existing geometric model (SF540 Criterion) to the Atlantic/Gulf for natural gravel, cobble and mixed sand and gravel shorelines to determine its validity for these types of beach conditions. | Future Research |
| | Perform a demonstration test of 540 Criterion on a natural gravel, cobble and mixed sand and gravel beach. | Future Research |
| | Examine the applicability of existing equilibrium beach profile concepts and relationships to represent the response of cobble and mixed grain beaches to storms. | Future Research |
| | Determine whether generic process-based models can be developed in a relatively short period of time for application to both the Atlantic and Pacific coasts. | Future Research |
| | TOTAL | 5.5 |
| 36 | **Review data and develop geometric methods for determining eroded profiles in sheltered areas** | |
| | Review and assess the historical applications of the existing geometric model (540 SF Criterion) to the Atlantic/Gulf sheltered shorelines to determine the reliability of its applicability to the sheltered water regions. | 1 |
| | Develop interim eroded profiles for the Pacific Coast region, based primarily on historical erosion and beach profile surveys during extreme storm events, particularly in El Niño years such as 1982–1983 and 1997–1998 to provide interim *G&S* suitable to the Pacific Coast | 2 |
| | Test process-based models that are to be developed under Topic Number 38 to determine if they are suitable for the implementation in sheltered waters in all regions. | 3 |
| | Explore the possibility of developing a rational basis for predicting erosion in sheltered waters which is consistent with the general framework discussed previously. Such a framework should account for the time histories of water level and wave forcing, and the durability of the eroded material. | 3 |
| | Conduct Case Studies illustrating application of recommended approach using actual situations. | 3 |
| | TOTAL | 12 |
| 37 | **Expand database from which 540 was determined; review use of median value** | |
| | 37a. Determine erosion area-frequency relationship (is 540 SF the median?) | 4 |

| Table 2. Preliminary Time Estimate for Guideline Improvement Preparation | | |
|---|---|---|
| Topic Number | Item | Time (Person months) |
| | 37b. Review use of the median value as the trigger for dune retreat | 2 |
| | TOTAL | 6 |
| 38 | **Develop assessment procedures that consider temporal and longshore effects/variability** | |
| | Select simplistic or comprehensive process-based models based on site conditions & perform further model development & testing. | 4 |
| | Develop methodology to include random-ness of return storm waves, tidal elevations & coincidence of these two oceanographic parameters. | 4 |
| | Provide *G&S* for erosion assessment to coastal bluffs fronted by a narrow beach | 2 |
| | Develop and use interim “Most Likely Winter Beach Profile” approach until process based models are acceptable. | 1 |
| | TOTAL | 11 |
| 31 | **Add/revise *G&S* language regarding bluff erosion in Atlantic/Gulf areas – better descriptions and discussions needed** | |
| | Review available national and international literature and reporting and select appropriate information for inclusion in the *G&S* to describe the physical and geotechnical processes responsible for bluff (and cliff) erosion and retreat. Provide descriptions and examples. Include characterization of the durability of the bluff material. | 1.5 |
| | Future consideration: Examine reports and documents used to develop the present bluff erosion guidelines for the Great Lakes. Select appropriate information for enhancing the *G&S*. | 1 |
| | Future consideration: Improve descriptions of the physical processes affecting bluff (and cliff) erosion in Atlantic and Gulf areas. | 1 |
| | Future consideration: FEMA should consider Process-Based numerical/statistical modeling methods for future inclusion in the NFIP program. In the mean time completed case studies should be documented and provided to FEMA for review. | -- |
| | TOTAL | 3.5 |
| 32 (Assumed SAME as 31) | **Develop geometric method for bluff erosion in Atlantic/Gulf areas** | |
| | Review available national and international literature and reporting and select appropriate information for inclusion in the *G&S* to describe the physical and geotechnical processes responsible for bluff (and cliff) erosion and retreat. | 1.5 |
| | Examine reports and documents used to develop the present bluff erosion guidelines for the Great Lakes. Select appropriate information for enhancing the *G&S*. | 1 |
| | Improve descriptions of the physical processes affecting bluff (and cliff) erosion in Atlantic and Gulf areas. | 1 |
| | TOTAL | 3.5 |
| 42, 43 | **Ensure clarity in *G&S* that references FEMA policy statement regarding treatment of nourished beaches** | |
| | Develop methodology for determining whether a beach nourishment project and procedures in place will provide long-term storm damage reduction benefits | 2 |
| | Provide Clarification in *G&S* to Study Contractor providing procedures to be followed for cases where beach nourishment projects are present | 1 |
| | TOTAL | 3 |

| Table 2. Preliminary Time Estimate for Guideline Improvement Preparation | | |
|---|---|---|
| Topic Number | Item | Time (Person months) |
| 40 | **Maintain data and make available for use in building performance and insurance tasks** | |
| | 40a. placeholder topic | -- |
| | 40b. future development and refinement of erosion depth-damage functions | Not included |
| | TOTAL | -- |

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# APPENDIX A

Final Rule, 540 SF Criterion

Federal Register, May 6, 1988

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| Sections in 42 CFR that contain collections of information | Current OMB control numbers |
|---|---|
| | 0990-0058 and 0938-0247 |
| 433.138 | 0938-0502 |
| 433.139 | 0938-0459 |
| 434.6-434.20, 434.23-434-27, 434.30, 434.32, 434.36, 434.50, 434.53, 434.55 | 0938-0326 |
| 435.910, 435.919, 435.920, 435.940 | 0938-0467 |
| 435.945 | 0938-0467 and 0938-0502 |
| 435.948, 435.952, 435.955 | 0938-0467 |
| 435.960 | 0938-0467 and 0938-0502 |
| 435.965 | 0938-0467 |
| 441.56, 441.58, 441.60, 441.61 | 0938-0354 |
| 441.255-441.259 | 0938-0481 |
| 441.301 | 0938-0449 |
| 441.302 | 0939-0268 and 0938-0449 |
| 441.303 | 0938-0272 and 0938-0449 |
| 442.118 | 0938-0488 |
| 442.307, 442.308, 442.309, 442.311, 442.313, 442.314, 442.318, 442.319, 442.320 | 0938-0370 |
| 442.402, 442.404-442.407, 442.412, 442.413, 442.417, 442.421, 442.423-442.425, 442.427, 442.430, 442.434, 442.441, 442.443, 442.457, 442.460, 442.463, 442.466, 442.468, 442.475, 442.482-442.487, 442.490, 442.492, 442.497, 442.500-442.503, 442.505, 442.506, 442.512 | 0938-0366 |
| 447.30 | 0938-0067 |
| 447.31 | 0938-0287 |
| 447.53 | 0938-0429 |
| 447.253(a) | 0938-0193 |
| 447.255 | 0938-0193 |
| 456.654 | 0938-0445 |
| 466.70, 466.72, 466.74, 466.78, 466.80, 466.94 | 0938-0445 |
| 473.18, 473.34, 473.36, 473.42 | 0938-0443 |
| 474.36, 474.38-474.40 | 0938-0444 |
| 476.104, 476.105, 476.116, 476.134 | 0938-0426 |
| 482.12, 482.22, 482.27, 482.30, 482.41, 482.53, 482.56, 482.57 and 482.60-482.62 | 0938-0328 |
| 488.56, 488.60, 488.64 | 0938-0267 |
| 498.22, 498.40, 498.58, 498.82 | 0938-0508 |

(Catalog of Federal Domestic Assistance Program No. 13.714, Medical Assistance Programs; No. 13.773, Medicare—Hospital Insurance; No. 13.774, Medicare—Supplementary Medical Insurance)

Dated: March 18, 1988.

**William L. Roper,**

*Administrator, Health Care Financing Administration.*

Approved: April 8, 1988.

**Otis R. Bowen,**

*Secretary.*

[FR Doc. 88-10083 Filed 5-5-88; 8:45 am]

BILLING CODE 4120-01-M

**DEPARTMENT OF THE INTERIOR**

**Bureau of Land Management**

**43 CFR Public Land Order 6675**

[NM-940-08-4220-10; NM NM 66022]

**Withdrawal of Public Land for Protection of Recreational Values Along the Rio Grande; New Mexico**

**AGENCY:** Bureau of Land Management, Interior.

**ACTION:** Public Land Order.

**SUMMARY:** This order withdraws 264.39 acres of public land from surface entry and mining for a period of 20 years for the Bureau of Land Management to protect, preserve, and maintain existing and future recreational values located along the "Pilar" section of the Rio Grande. The lands have been and remain open to mineral leasing.

**EFFECTIVE DATE:** May 6, 1988.

**FOR FURTHER INFORMATION CONTACT:** Clarence Hougland, BLM, New Mexico State Office, P.O. Box 1449, Santa Fe, New Mexico 87504-1449, 505-988-6554.

By virtue of the authority vested in the Secretary of the Interior by section 204 of the Federal Land Policy and Management Act of 1976, 90 Stat. 2751; 43 U.S.C. 1714, it is ordered as follows:

1. Subject to valid existing rights, the following described public lands are hereby withdrawn from settlement, sale, location, or entry under the general land laws, including the United States mining laws (30 U.S.C., Ch. 2), but not from leasing under the mineral leasing laws, to protect two sites important for recreational use on the Rio Grande:

New Mexico Principal Meridian

County Line Site

T. 23 N., R. 10 E.,
Sec. 14, lot 4;
Sec. 15, lot 4.

Fishing Hole Site

T. 24 N., R. 11 E.,
Sec. 32, lots 5, 6, 7, 8, SW¼SE¼.

The areas desc... aggregate 264.39 acres in Taos and Rio Arriba Counties.

2. The withdrawal made by this order does not alter the applicability of those public land laws governing the use of the lands under lease, license, or permit or governing the disposal of their mineral or vegetative resources other than under the mining laws.

3. This withdrawal will expire 20 years from the effective date of this order unless, as a result of a review conducted before the expiration date pursuant to section 204(f) of the Federal Land Policy and Management Act of 1976, 43 U.S.C. 1714(f), the Secretary determines that the withdrawal sh... extended.

May 3, 1988.

**James W. Ziglar,**

*Assistant Secretary of the Interior.*

[FR Doc. 88-10087 Filed 5-5-88; 8:45 am]

BILLING CODE 4310-FB-M

**FEDERAL EMERGENCY MANAGEMENT AGENCY**

**44 CFR Parts 59, 60, 61, 62, 65, 70, and 72**

**National Flood Insurance Program; Flood Plain Management Standards**

**AGENCY:** Federal Insurance Administration (FIA), Federal Emergency Management Agency (FEMA).

**ACTION:** Final rule.

**SUMMARY:** This final rule revises the National Flood Insurance Program (NFIP) regulations dealing with: flood plain management standards; criteria for the identification of coastal high hazard areas, more commonly referred to as V-zones, and delineated as Zone V, VO, V1-30 or VE on NFIP maps; requirements for maintenance of altered watercourses; criteria under which communities may permit flood plain and floodway developments which could increase base flood elevations; procedures for map correction; reimbursement procedures for the review of proposed projects to determine if they would qualify for NFIP map revisions upon their completion; and changes in the Standard Flood Insurance Policy (SFIP) terms and provisions.

**EFFECTIVE DATE:** October 1, 1988.

**FOR FURTHER INFORMATION CONTACT:** Charles M. Plaxico, Federal Emergency Management Agency, Federal Insurance Administration, 500 C Street SW., Washington, DC 20472; telephone number (202) 646-3422.

**SUPPLEMENTARY INFORMATION:** On November 3, 1987, FEMA published for comment in the Federal Register (Vol. 52, page 42117) a proposed rule containing revisions to the NFIP which were the result of a continuing reappraisal of the NFIP to achieve greater administrative and fiscal effectiveness in the operation of the program and to encourage sound flood plain management so that reductions in loss to life and property and in disaster expenditures can be realized. This reappraisal included the risk assessment (i.e., mapping of flood hazard areas) component of the NFIP, the loss

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reduction (i.e., flood plain management) component and the claims, coverage, rating and sale of insurance component of the NFIP.

In the process of developing this final rule 32 comments were received, logged and analyzed based on the 7 subject areas discussed in the proposed rule supplementary information. The tally of comments included 1 individual, 17 representatives of private companies, 3 associations (including one on behalf of three associations), 4 local governments and 7 State governments. Many of the comments generally concurred with the proposed rule while specifically addressing one or more of its provisions. The comment contents ranged from strong support for, to strong opposition to, one or more of the proposed changes.

The analysis of the comments resulted in language clarification, a minor change to the numbering of provisions and, due to editorial oversight in the proposed rule, inclusion of changes to §§ 60.3(d) and 60.3(e) to incorporate appropriate cross references for consistency. Also, the Standard Flood Insurance Policy duplicate policy provision in the proposed rule was revised to make it more flexible. The comments received are addressed under the subject headings below.

**Community Ordinances**

Two commentators expressed a general concern that the final rules will require corresponding changes in community ordinances. In fact, the final rules are primarily procedural and will not require ordinance revisions at the local level. However, the new provisions at §§ 60.3(c)(13) and 60.3(d)(4), requiring a community to apply to FEMA for a conditional Flood Insurance Rate Map (FIRM) revision prior to permitting development or encroachments within the special flood hazard areas or within the regulatory floodway that would result in an increase in base flood elevations exceeding NFIP's standards, are voluntary and need only be adopted by a community if it wishes to permit such development. FEMA believes these situations should affect relatively few communities.

As for the final rule amending § 60.3(d)(3) which specifies use of hydraulic and hydrologic analyses in connection with a community's review of proposed development in floodways, this requirement is a clarification of the meaning implicit in the current regulations and, therefore, local ordinances do not need to be changed to reflect this clarification.

**Coastal High Hazard Area and Erosion Considerations for Sand Dunes**

Six commentators addressed this proposed rule and all expressed general support for including primary frontal dunes in V-zones and considering dune erosion during the base flood event in order to better reflect coastal areas actually at risk. However, clarification of the intent of the final rule is necessary to resolve apparent misunderstandings of the proposed rule as expressed by several of the commentators.

The final rule definition of coastal high hazard area includes all primary frontal dunes. Therefore, the boundary line of the V-zone, at a minimum, becomes the landward "toe" of the dune. Figure 1 clarifies the evaluation criterion for considering such dunes as effective barriers to base flood storm surges and associated wave action and depicts the inland limit of the dune. This figure also illustrates another provision of the rule that the cross-sectional area of the dune, as measured from the ocean side of the dune crest and above the 100-year stillwater flood level (SWFL), must be at least 540 square feet in order for the dune to be considered effective in attenuating wave action. Under the rule all dunes with a cross-sectional area less than 540 square feet will be treated as completely eroded during the 100-year storm in the preparation of FIRMs. Such a dune will not be credited with offering any protection against flooding or wave action to areas on the landward side of that dune. For dunes with a cross-sectional area smaller than 540 square feet, the methods used to determine areas subject to wave action will be employed as if the dune did not exist. Conversely, any dune with a cross-sectional area greater than 540 square feet may not be totally destroyed during the 100-year event and the dune will be credited with offering some level of protection to areas on its landward side. In this case, the method used to determine areas subject to wave action will be employed in conjunction with a dune erosion model which predicts how much of the dune will be eroded and how much protection it provides.

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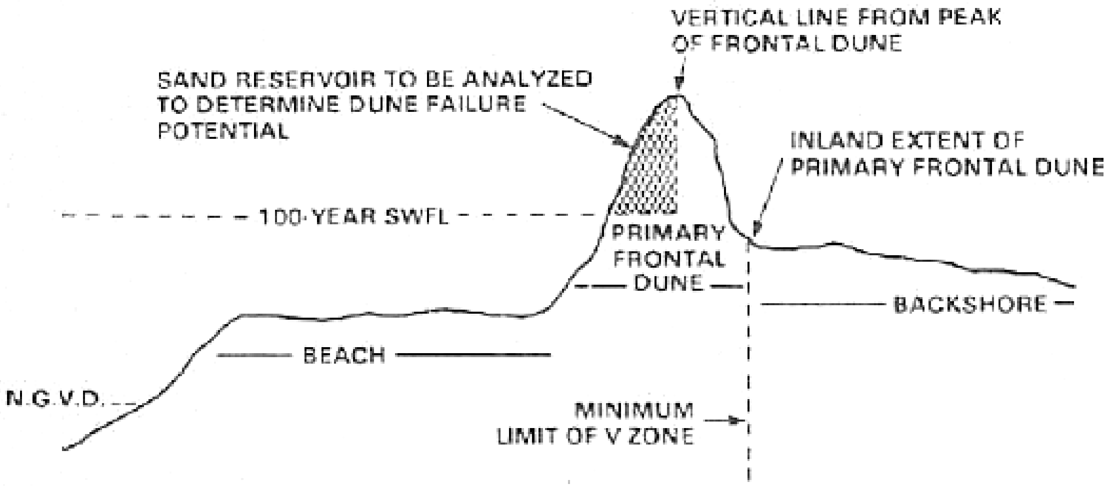
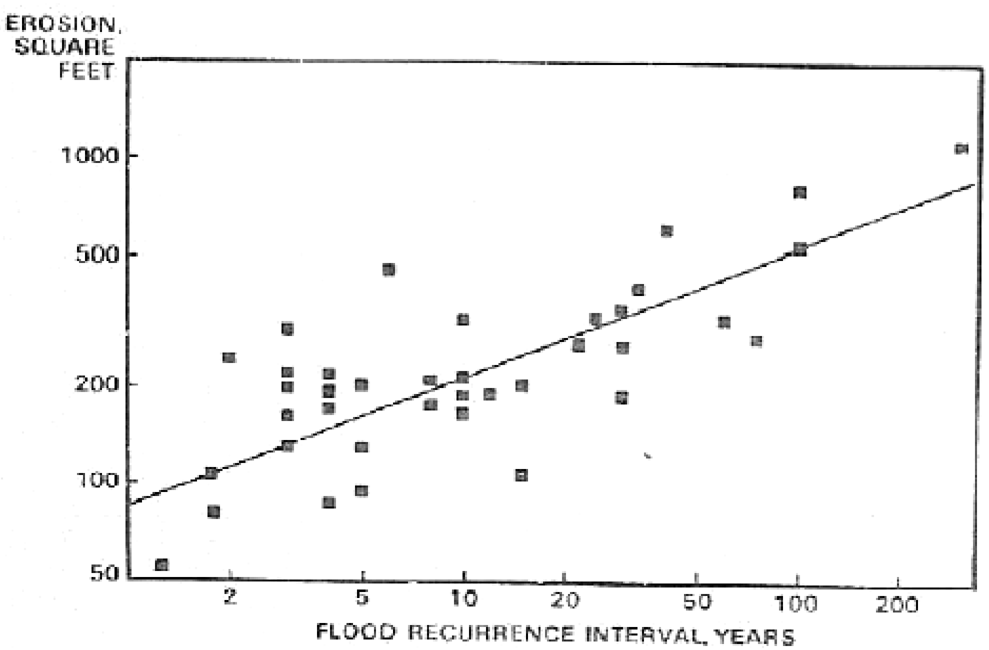



FACTORS TO BE CONSIDERED IN DETERMINING DUNE FAILURE POTENTIAL AND V ZONE MAPPING

FIGURE 1




MEDIAN CROSS-SECTIONAL EROSION ABOVE FLOOD ELEVATION VERSUS FLOOD RECURRENCE INTERVAL BASED ON 38 CASES OF DUNE RETREAT DURING VARIOUS COASTAL STORMS.

FIGURE 2

BILLING CODE 6718-01-C

1. One State government and one association commented that by choosing the 50 percentile (median) cross-sectional area of 540 square feet as a criterion, FEMA has, by definition, underestimated dune erosion in half of all base (100-year) flood events (see figure 2). The commentators suggested using the 90–95 percentile in figure 2, which represents a cross-sectional area of 1,000 square feet or more.

The risk analysis methodology decisions incorporated in the NFIP have traditionally been based on selection of a median value, i.e., an estimate that has an equal chance of being too high or too low. Such has been the case in estimation of 100-year flood discharges and base flood elevations. It would be inconsistent to select a criterion for evaluating dune integrity which would overestimate dune erosion more than 50% of the time. Further, a value other than the median value would be inequitable in the determination of actuarial insurance rates.

In addition, dunes that meet the cross-sectional criteria of 540 square feet will not necessarily be considered as providing total protection from the 100-year flood. A post-flood eroded profile of the dune will be considered in computing wave runup on the dune face and overtopping on the dune crest when appropriate.

It is important to note that a criterion of 540 square feet for the cross-sectional area above the storm surge elevation and seaward of the dune crest represents a dune of significant size. FEMA believes use of this area is appropriate because it is consistent with other median values utilized in the NFIP and is based on an empirical relationship between the quantity of sand that would be removed from a frontal dune and the recurrence interval of the local storm tide.

2. Several commentators expressed concern that site-specific conditions should be analyzed in determining potential dune erosion rather than adopting a criterion for general dune integrity. FEMA has assessed the state-of-the-art in erosion modeling approaches and determined that they are not always effective in differentiating between local conditions. Moreover, site specific analyses will be considered in each flood risk analysis performed. Measurements of dunes will be taken locally to determine the volume of sand in the dune and whether the dune meets the 540 square feet criterion. Where the dune does not meet the 540 square feet criterion, site specific conditions will be considered in estimating a post-storm dune profile for wave runup and overtopping computations. Where the dune does meet the criterion, the protection afforded by the post-storm configuration of the dune will be factored into the wave runup calculations.

3. A State commentator suggested that FEMA develop provisions which take into account long-term erosional retreat rates of oceanfront shorelines in its mapping. The issue of using future risk conditions, such as long-term erosion effects, in flood risk analysis and mapping has been previously examined by FEMA. The NFIP legislation has not previously addressed long-term erosion and a consistent data set does not now exist to allow FEMA to uniformly consider long-term erosion in the mapping of flood risks. FEMA has addressed this issue in the past by striving to maintain the accuracy of its maps through periodic map revisions. Additional efforts in erosion risk analysis and management will be forthcoming as FEMA implements the provisions of section 544 of the Housing and Community Development Act of 1987 pertaining to erosion.

4. Several associations and a State agency commented that FEMA should incorporate restrictive building requirements in areas subject to wave action. Language to amend § 60.3(e)(7) was suggested. It was also suggested that FEMA establish regional coastal construction requirements for structural foundations and that FEMA incorporate its Coastal Construction Manual into the final rule. Revision of flood plain management regulations for coastal areas is not being considered by FEMA during FY 1988 rulemaking. Presently, the NFIP regulations for construction in V-zones at § 60.3(e)(4) and § 60.3(e)(5)(ii) do require more rigorous construction standards such as piling or column foundations and anchoring for wind and water forces designed to exceed 100-year values for wind and water loading. With the final rule, these restrictive standards will become more comprehensive in geographic extent by the inclusion of all primary frontal dunes in the V-zone, and the extension of V-zones into areas behind dunes which do not have substantial cross sections.

Further, § 60.3(e)(7) prohibits any man-made alteration of sand dunes in V-zones which would increase potential flood damage. Most development that currently alters frontal dunes occurs on dunes mapped as outside the V-zone. The final rule incorporates all primary frontal dunes into the V-zone and thereby makes § 60.3(e)(7) much more encompassing and effective in protecting the integrity of frontal dune systems. It is envisioned that, as new V-zone delineations are established under the rule, construction activity (e.g., excavation and grading) which would jeopardize the integrity of primary frontal dunes will be prohibited by communities participating in the NFIP.

With regard to coastal foundation construction, while § 60.3(e)(4) does not specifically state that foundation design should incorporate an increase in foundation loadings due to erosion of supporting soil during a base flood event, this requirement is implicit in subparagraph (ii) of this section.

The current regulation is in agreement with the Coastal Construction Manual and, thus, the latter does not need to be incorporated into the rule. However, communities and interested parties are encouraged to utilize the manual for additional design considerations. Further, FEMA recognizes and encourages those local and State governments that wish to adopt more restrictive requirements than FEMA's standards to do so.

5. Another State suggested that FEMA include a definition in the rule for "alterations of sand dunes." FEMA believes the term, "man-made alteration of sand dunes" as used in § 60.3(e)(7), is self-explanatory; therefore, a definition is not necessary.

6. A joint comment submitted by three associations suggested that bluffs, secondary dunes, wetlands and other coastal barriers be included in V-zones. This suggestion is outside the realm of the proposed rule. Further, the definition of coastal high hazard area (V-zone) remains related to areas impacted by significant wave action. Primary frontal dunes are being included in V-zones because they are features that absorb the brunt of the wave action. Areas such as coastal wetlands, secondary dunes, and bluffs are not consistently affected by wave action during flood events and, thus, should not be included in V-zones by definition. Where such features can be shown to be subject to significant wave action in major storms through the engineering analyses performed in a flood risk study, they will be included in V-zones.

7. A State agency suggested that FEMA immediately provide revised FIRM's reflecting the new criterion for erosion consideration for sand dunes to any coastal community requesting such a revision, rather than waiting to incorporate the changes in new flood risk assessment studies or restudies. It is FEMA's intention to eventually revise all FIRM's where the V-zones may be presently underestimated. These revisions must be processed through the

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normal map revision procedures rather than by special restudy effort because of current budgetary constraints. Priorities for performing map updates through the restudies and revisions procedures for communities impacted by the new erosion criteria will be based on cost/benefit considerations, as is presently the case with determining priorities for other types of restudies. A community's need for revised V-zone mapping will be a factor in determining its priority. Where costs can be reduced through local cost-sharing, or other approaches, adjustments in priority will be made.

**Requirements for Maintenance of Altered Watercourses**

Seven commentators addressed this proposed rule including three State governments, two local governments and two associations. Four commentators generally supported the rule but proposed modifications or substitute language; one commentator did not directly address the issue; and two commentators objected to the proposed rule, citing problems with access to private property, cost and legal liability associated with mandatory maintenance.

1. Two local governments and two associations pointed out that not all altered or relocated watercourses will require maintenance of their flood carrying capacity by virtue of their design. They asserted that the design criteria for a watercourse may include factors that account for regrowth of vegetation, sediment deposition, etc., thus obviating the need for maintenance. FEMA agrees that such situations should be addressed in the final rule and a new paragraph (a)(13) has been added to § 65.6.

The new paragraph provides that in lieu of the requirement to submit documentation that the provisions of § 60.3(b)(7) will be met prior to FEMA's revising the NFIP map to reflect the flood hazard mitigation effects of the altered or relocated watercourse, a community may submit certification by a registered professional engineer that the project has been designed to retain its flood carrying capacity without periodic maintenance.

2. A local government and an association suggested that altered or relocated watercourses on open space areas such as golf courses where no existing development will be impacted should be exempted from the maintenance requirement. FEMA's concern in this rule deals only with the maintenance of modifications of watercourses for which flood control benefits have been reflected or are proposed to be reflected on flood maps. This is very rarely, if ever, the case in undeveloped areas. Further, if a map revision is not sought on the basis of watercourse alteration, then FEMA agrees that the data submission requirement regarding watercourse maintenance does not apply and FEMA would not request a community to make such a submission.

3. Comments from a local government and an association suggested that the proposed amendments to § 65.6 be deleted or revised due to problems of access to private property, cost, legal liability and environmental impacts. It is important to note that FEMA is not creating a new requirement for maintenance of altered or relocated watercourses by the final rule. Such a requirement has existed for many years under § 60.3(b)(7). Instead, the final rule merely establishes a procedure whereby FEMA can verify that maintenance, where appropriate, will be carried out for new watercourse alterations for which map revisions are being sought. The final rule enables FEMA to obtain documentation as to the nature of the maintenance activities to be performed, the frequency with which they will be performed, and the title of the local official who will be responsible for assuring that the maintenance activities are accomplished. If it is prohibitive for a community to maintain its altered or relocated watercourses (for whatever reason), FEMA will not credit the flood control benefit of those projects on its maps. It is up to each community to evaluate the benefit of lower BFE's and reduced Special Flood Hazard Areas versus the costs of maintaining its watercourse modifications originally intended for these purposes.

4. A local government, a State agency and two associations addressed the environmental considerations connected with maintenance of altered watercourses. Some commented that implementation policies for maintenance of altered watercourses should be developed in concert with other Federal agencies and that such policies should specify criteria which is environmentally sensitive. While FEMA agrees that there is a need for better coordination among appropriate Federal agencies in regard to environmental issues and the Federal permitting process in connection with the maintenance of altered watercourses, the final rule is not the appropriate mechanism by which to address these issues. Further, it is unlikely that situations will arise where the alteration of watercourses for flood control purposes would be permitted, but maintenance of such alterations would not. Should such situations occur, then FEMA will not revise the map to reflect the mitigating effects of the altered watercourse and, therefore, no maintenance responsibilities will be imposed.

5. A State government and an association suggested that FEMA should require communities to report periodically regarding their maintenance activities and the continued effectiveness of their altered watercourses. FEMA agrees with the concept of monitoring community compliance with this requirement and is considering modification of the Community Assistance Visit Program to include elements relative to the maintenance of altered watercourses. However, establishing a formal reporting requirement would create an unnecessary paperwork burden on NFIP communities and an unnecessary administrative burden on the Agency. Therefore, reporting requirements will not be included in the final rule.

6. The same two commentators suggested that in rapidly urbanizing areas, future development of the watershed upstream from the altered watercourse should be considered in estimating design flows and flood plain limits. They asserted that with any flood control project, there is a potential for the benefits to be partially or completely negated by upstream development which increases runoff and the 100-year flood discharge. FEMA has taken these comments under advisement. A study is presently underway to examine the feasibility of considering future development in flood risk determinations. However, certain administrative issues become immediately apparent. First is the issue of equitable charging of actuarial premium rates for flood insurance coverage when rates are based on future rather than current risk conditions. Secondly, the estimation of future development and its effects on hydrologic conditions adds an additional level of uncertainty on the regulatory data established. This data remains subject to individual rights to appeal, and therefore, must be scientifically, technically and legally defensible. While FEMA is aware of the impact of possible future urbanization on the flood risk, these significant administrative concerns may prove too complex to implement effectively. Nevertheless, communities are encouraged to address the issue of the impacts of upstream future development on the potential benefits of a flood control project and adopt more restrictive local standards as necessary.