U.S. Department of Homeland Security
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FEMA

MEMORANDUM FOR: Mitigation Division Directors
Regions I, II, III, IV and VI

FROM: Doug Bellomo, P.E., Acting Chief

SUBJECT: Procedure Memorandum No. 47 – Guidance for the Determination of the 0.2-Percent-Annual-Chance Wave Envelope along the Atlantic Ocean and Gulf of Mexico Coasts

EFFECTIVE DATE: September 6, 2007

Background: In 2003 the Department of Homeland Security's Federal Emergency Management Agency (FEMA) commissioned a project to update the guidance for analyzing and mapping coastal flood hazards for the Pacific Ocean, Atlantic Ocean, Gulf of Mexico, and the Great Lakes coasts. The Pacific coast update, *Final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States*, was prepared and issued in November 2004. Subsequently, the Atlantic and Gulf of Mexico update, *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Final Draft*, was issued February 2007. The Great Lakes update is in progress. The scopes of the updates for the Atlantic, Gulf, and Great Lakes coasts were limited to reviewing existing methodologies, outlining process improvements, and clarifying Appendix D: Guidance for Coastal Flooding Analyses and Mapping of the current *Guidelines and Specifications for Flood Hazard Mapping Partners*, dated April 2003.

Issue: As part of a Flood Insurance Study (FIS), Mapping Partners may be required to calculated the 0.2-percent-annual-chance flood elevation and delineate the area above the 1-percent-annual-chance (base) flood that is inundated by the 0.2-percent-annual-chance flood. This area is mapped as shaded Zone X on the Flood Insurance Rate Map (FIRM). Present mapping procedures do not include guidance for calculation of the 0.2-percent-annual-chance wave envelope, that is, the superelevation of flood levels above the stillwater level due to wave effects.

Because of the recent catastrophic hurricanes that affected several Gulf Coast States, FEMA has identified a need in some coastal areas for 0.2-percent-annual-chance flood elevations that include wave effects. At present, FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners* does not require a determination of the

0.2-percent-annual-chance flood elevation with wave effects. However, Regional Offices in coordination with State and local officials may choose to include these analyses during the preparation of an FIS to assist communities in their floodplain management with issues related to the 0.2-percent-annual-chance flood level including the siting and construction of critical infrastructures such as hospitals and emergency operations centers.

Action Taken: The guidelines in the attached technical memorandum titled "Guidance for the Determination of the 0.2-Percent-Annual-Chance Wave Envelope along the Atlantic Ocean and Gulf of Mexico Coasts" should be followed for the computation of the 0.2-percent-annual-chance flood elevation including wave effects when deemed necessary by the Regional Office in coordination with State and local officials.

It should be noted that the guidance presented herein was developed to produce a 0.2-percent-annual-chance wave envelope profile for the purpose of determining the 0.2-percent-annual-chance flood elevation including wave effects. These elevations can be reflected on flood profiles in the FIS; however, they can not be reflected on the FIRM. The 0.2-percent-annual-chance flood boundaries on the FIRM will continue to be mapped as shaded Zone X based on the guidance found in **Appendix D: Guidance for Coastal Flooding Analyses and Mapping** of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*.

Attachment Technical Memorandum—Guidance for the Determination of the 0.2-Percent-Annual-Chance Wave Profile along the Atlantic Ocean and Gulf of Mexico Coasts

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TECHNICAL MEMORANDUM FOR:

FEMA Regional Division Directors, Regions I-IV and VI

FROM: Doug Bellomo, Acting Chief Risk Analysis Branch

SUBJECT: Guidance for the Determination of the 0.2-Percent-Annual-Chance Wave Envelope along the Atlantic Ocean and Gulf of Mexico Coasts

Introduction

As part of a Flood Insurance Study (FIS), Mapping Partners may be required to calculated the 0.2-percent-annual-chance flood elevation and delineate the area above the 1-percent-annual-chance (base) flood that is inundated by the 0.2-percent-annual-chance flood. This area is mapped as shaded Zone X on the Flood Insurance Rate Map (FIRM). Present mapping procedures do not include guidance for calculation of the 0.2-percentannual-chance wave envelope, that is, the superelevation of flood levels above the stillwater level due to wave effects.

The Federal Emergency Management Agency (FEMA) assembled a Technical Working Group (TWG) to define guidance for procedures to compute the 0.2-percent-annualchance wave envelope. The guidance presented herein is largely based on that provided in the *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update* (hereafter referred to as *A & G Update*) for the determination of the 1.0-percent-annual-chance (base) flood with modified procedures for the calculation of certain components (wave height, wind speed, dune reservoir area, etc.).

The TWG determined that the 0.2-percent-annual-chance flood elevation depends primarily on 1) incident water level and wave conditions, and 2) the expected erosion or modification of the study area topography (including coastal dunes, structures and levees) during the modeled flood conditions. These factors are also the basis for the 1-percent-annual-chance flood elevation computations.

The TWG also concluded that the general procedures outlined in *A & G Update* for calculating the base flood elevation can be used to calculate the 0.2-percent-annual-chance flood elevation, provided certain modifications and additions are made to those procedures. All Section references in this memorandum refer to *A & G Update* unless otherwise specified.

This technical memorandum provides guidance for the computation of the 0.2-percentannual-chance flood elevation with consideration to the following nine coastal flooding components:

1 Water Levels (Storm Surge and Astronomical Tide)
2 Wave Generation and Wave Transformation
3 Wave Setup
4 Dune Erosion
5 Coastal Armoring Structures
6 Coastal Levees
7 Wave Runup and Overtopping
8 Overland Waves
9 Plotting Wave Envelope Profile

The guidance for each of the nine issues above is distinguished between two categories of coastal studies:

1 Where results of 0.2-percent-annual-chance storm surge analyses are available and can serve as the input to wave analyses—the “Existing FIS” approach, and

2 Where results of 0.2-percent-annual-chance storm surge analyses are not available and, therefore, new storm surge and wave analyses are both required—the “New Study” approach.

While the following guidance has not yet been tested, it is considered the most appropriate approach to define the 0.2-percent-annual-chance wave envelope for the Atlantic Ocean and the Gulf of Mexico. However, those calculating the 0.2-percent-annual-chance wave envelope should recognize that the uncertainties associated with 0.2-percent-annual-chance water-level and wave calculations will be higher than those associated with the base flood water-level and wave calculations. Thus, a careful review of historical data and selection of appropriate statistical and analysis techniques are essential to calculate the 0.2-percent-annual-chance wave envelope.

The calculation of 0.2-percent-annual-chance wave effects in sheltered waters is not fully addressed in this technical memorandum. However, the guidance for 1-percent-annualchance wave effects contained in the applicable sections of *A & G Update* will assist Mapping Partners to develop appropriate methodologies. Mapping Partners shall confer with the FEMA Study Representative before conducting a 0.2-percent-annual-chance flood analysis with wave effects for sheltered waters.

Computer programs developed by FEMA to calculate the 1-percent-annual-chance wave envelope, the Wave Height Analysis for Flood Insurance Studies (WHAFIS) program Version 3.0 and the Coastal Hazard Analysis and Mapping Program (CHAMP), have been modified to allow for the computation of the 0.2-percent-annual-chance wave envelope.

ISSUE 1: Water Levels (Storm Surge and Astronomical Tide)

The methods used to determine 0.2-percent-annual-chance stillwater elevations (SWELs) on the Gulf of Mexico and the Atlantic Ocean will differ on the basis of coastal location in two general ways. First, a region's coastal flooding may be dominated by hurricanes (Gulf and Atlantic Southeast), northeasters (New England), or a mixture of the two (Central Atlantic). Second, locations may be characterized as either open coast sites or sheltered water sites.

Location is also an important consideration in a more local sense. Lower reaches of tidal rivers are subject to flooding from both coastal sources and riverine runoff. Where both processes are important, the appropriate water levels are composites of the two. Simplified procedures for determining the composite 1-percent-annual-chance level assuming physical independence are presented in Section D.2.4.5.4.

Recommended Procedures: The procedures included in Sections D.2.3 and D.2.4 for flood frequency analysis and the calculation of 1-percent-annual- chance SWELs are also recommended for use at the 0.2-percent-annual-chance level. Differences between the analyses of the two frequencies will depend principally on the length and quality of the historical record and on how the Mapping Partner can use available statistical and analysis tools to overcome or mitigate deficiencies in the record.

The procedures included in Section D.2.4.5.4 for the combined coastal and riverine 1-percent-annual-chance flood level calculations are also recommended for use at the 0.2-percent-annual-chance level. However, in order to accomplish this, both coastal and riverine stage-frequency information will be required at recurrence intervals beyond 500 years. The Mapping Partner may derive an approximation to the necessary distributions by extrapolating curves available from the published riverine and coastal studies. This may be done by plotting elevations vs. the logarithm of frequency and then fitting an extension to the upper portion of the curves, or by fitting an analytical frequency distribution to the established levels and extending it to higher levels.

The Mapping Partner should critically review the results to ensure that they are reasonable. In particular, local physical factors may distort the shape of the frequency curve, invalidating a simple extrapolation. This might be the case, for example, if the floodwaters are contained within well-defined waterways (rivers, bays, etc.) at 1-percent-annual-chance levels but spread overland at higher levels, thereby causing the recurrence curve to flatten. In any case, the Mapping Partner shall confer with the FEMA Study Representative to obtain approval for the proposed combined coastal and riverine 0.2-percent-annual-chance water levels.

Existing FIS In most cases, the 0.2-percent-annual-chance SWEL is provided in the text of the effective FIS report. If a Mapping Partner must determine the 0.2-percent-annual-chance wave effects but the existing FIS does not list the 0.2-percent-annual-chance SWEL in the report text, then the original study materials must be found, and the Mapping Partner must determine the slope of the stage-recurrence frequency curve in some manner approved by the FEMA Study Representative. The Mapping Partner must then extrapolate from the 1-percent-annual-chance level to the 0.2-percent-annual-chance level, or perform a new historical analysis including the 0.2-percent-annual-chance level if adequate data is available. If the original study materials are not available, a new storm surge study will need to be undertaken.

New Study In hurricane-dominated regions, new studies performed using a Joint Probability Method (JPM) statistical analysis should, inherently, provide estimates at the 0.2-percent-annual-chance level. However, the Mapping Partner shall take care to choose the JPM storm parameters (especially the pressure deficit) in such a way as to include an adequate representation of strong storms. For new hurricane studies that adopt an Empirical Simulation Technique (EST) approach, particular attention must be given to the historical storm sample. Some regions may not have experienced sufficiently strong storms within recent history (for which high-quality storm data is available) to provide confidence that the EST training set represents the 0.2-percent-annual-chance hazard. If an EST approach is considered at the 0.2-percent-annual-chance level, the Mapping Partner shall confer with the FEMA Study Representative and shall consider enhancements to the EST approach, including the specification of hypothetical storms.

For new studies in northeaster-dominated regions, a historical approach involving either tide gage analysis or EST simulations may be approved by the FEMA Study Representative. Procedures that have been used to determine the 1-percent-annual-chance levels in past FEMA studies for these areas may be adopted for the new study. However, the Mapping Partner must consider the reliability of 0.2-percent-annual-chance estimates based upon short records. To obtain estimates at the 1-percent-annual-chance level, at least 30 years of data is commonly recommended; this suggests that to achieve similar reliability at the 0.2-perenct-annual-chance level, the analyst would require about 150 years of data. Even where long records are available, the question of stationarity must be considered (owing especially to the alteration of basin characteristics over time). The Mapping Partner might also consider using regionalization methods (e.g., Hosking & Wallis, 1997) in an effort to improve estimates of the higher moments of empirically based distributions.

For new studies in regions where both hurricanes and northeasters are important, the Mapping Partner shall determine flood statistics for both mechanisms, separately and independently, and shall construct the composite stage-recurrence curve by simply adding the corresponding rates of occurrence for fixed elevations.

ISSUE 2: Wave Generation and Wave Transformation

Wave generation and transformation data associated with the 0.2-percent-annual-chance flood are required for two reasons: 1) to estimate incident wave characteristics for subsequent wave height and runup calculations, and 2) to quantify the wave setup in the nearshore zone and over flooded land.

Recommended Procedures: The procedures included in Section D.2.5 at the 1-percentannual-chance level are also recommended for use at the 0.2-percent-annual-chance level.

Existing FIS When existing studies will be updated to include 0.2-percent-annual-chance wave effects, and when the assumed coincidence between peak water levels and peak wave conditions is appropriate (e.g., open coast shoreline subject to hurricane and/or northeaster conditions, and some sheltered waters), the extrapolation of existing deep-water wave data can be used to estimate the deep-water wave heights at the 0.2-percent-annual-chance level. For example, wave height hindcast data from the

U.S. Army Corps of Engineers (USACE) *Coastal and Hydraulics Laboratory Wave Information Studies* (WIS) and from other sources are typically available for the 10-, 5-, and 2-percent-annual-chance. These data can be extrapolated, although the Mapping Partner must ensure that the extrapolation results are reasonable. Wave period extrapolations may also be possible; however, if wave period data are not available or if the wave period extrapolation is unsuitable, wave periods (which may be necessary for later wave runup calculations) can be approximated by the relationship

$$T = 2.\sqrt{H_s}\, H_s$$

in which T is the 0.2-percent-annual-chance wave period, in seconds, associated with the 0.2-percent-annual-chance significant wave height, H_s, in feet.

New Study New studies in areas governed by hurricanes and/or northeasters conducted with two-dimensional wave models, or other FEMA-approved wave models, will consider the effects of wave generation and transformation. These applications will generate waves and transform them from deep water to the nearshore and over the flooded area for each storm in the JPM or EST methodologies. The Mapping Partner must ensure that the wave characteristics calculated by the model are saved at the intersections of the 0.2-percent-annual-chance wave envelope calculation transects and the +/- mean sea level (MSL) shoreline.

ISSUE 3: Wave Setup

There are two ways of estimating mean water levels (SWEL plus setup) for use in an FIS. One involves separate calculations of storm surge and wave setup, while the other computes surge and setup concurrently. In the first case, wave setup must be added to the storm surge SWEL for wave height calculations in WHAFIS. In the second case, the surge and wave setup components may have to be decoupled before wave runup calculations and dune erosion calculations can be made.

Recommended Procedures: The procedures included in Section D.2.6 for base flood wave setup calculations are also recommended for use at the 0.2-percent-annual-chance level.

Existing FIS Two common scenarios occur when existing studies are updated to include the wave setup associated with 0.2-percent-annual-chance flooding: 1) the existing FIS contains wave setup estimates at the 1-percent-annual-chance level and water-level estimates at the 1- and 0.2-percent-annual-chance levels or 2) the existing FIS contains water-level estimates but no wave setup estimates.

In the first scenario, one way to estimate the wave setup associated with the 0.2-percent-annual-chance flood is to scale it from the 1-percent-annual-chance setup value by using the ratio of the 0.2-percent-annual-chance SWEL divided by the 1-percent-annual-chance SWEL (without setup).[1] For example, if the 1- and 0.2-percent-annual-chance SWELs are 10.0 and 12.5 feet, respectively, and if the 1-percent-annual-chance wave setup is 2.0 feet, the estimated 0.2-percent-annual-chance wave setup will be 2.5 feet [(12.5 feet/10.0 feet) x (2.0 feet)]. Note that existing FISs typically list wave setup values at the +/-MSL shoreline only, so the 0.2-percent-annual-chance wave setup calculation will also apply at the shoreline.

In the second scenario, where the existing FIS contains no wave setup estimates, it is recommended that the 0.2-percent-annual-chance wave setup be determined using the 0.2-percent-annual-chance deep-water wave conditions and either the USACE's *Shore Protection Manual* (SPM) method (see *A & G Update*, Figure D.2.6-3) or the Direct Integration Method (see *A & G Update*, Equation D.2.6-1).

New Study Where new hurricane storm surge and wave modeling are conducted with two-dimensional models, the effects of wave setup are included in the mean water levels computed by the models for the entire region, extending from deep water to the limits of flooding, for each synthetic storm analyzed. These models typically include the effects of wave damping and reduced wave setup growth rate due to vegetation and buildings.[2] The models may or may not provide output that allows specific values of wave setup to be broken out across the domain.

- Where wave setup values are broken out, the Mapping Partner should identify wave setup values near the intersections of the +/- MSL shoreline and the 0.2-percent-annual-chance analysis transects, and use those values in subsequent dune erosion, wave height, and wave runup calculations, as required by *A & G Update*.

[1] Other methods to scale or calculate the 0.2-percent-annual-chance wave setup may be appropriate in some cases. The Mapping Partner shall consult with the FEMA Study Representative to obtain approval for methods used to calculate the 0.2-percent-annual-chance wave setup using information from the FIS. [2] At present, the effects of vegetation and buildings are included through defining approximate Manning "n" values, although the relationships governing these types of interactions differ in form.

• Where wave setup values cannot be broken out from model results, the following approach is recommended:

- The Mapping Partner should determine the 0.2-percent-annual-chance mean water level (including storm surge and wave setup) at each shoreline location of interest through a plotting procedure.
- Once the 0.2-percent-annual-chance mean water levels along the shoreline are known, the Mapping Partner should search through the model outputs and select the individual storm that produced the approximate 0.2-percent-annual-chance mean water level at each location of interest.
- The Mapping Partner should use the "Existing FIS" wave setup calculation procedures (SPM or Direct Integration Method, see above) and parameters associated with each identified storm to calculate the 0.2-percent-annual-chance wave setup values at the shoreline. These values can be subtracted from the mean water levels at the shoreline to separate the 0.2-percent-annual-chance storm surge and the wave setup.

Where new northeaster storm surge and wave modeling are conducted with two-dimensional models, the effects of wave setup will likely be included in the output mean water levels. If JPM is used, the northeaster wave setup calculations should be similar to those used for new hurricane studies. If EST is used, it is recommended that WIS or other hindcast wave data are used to determine the 0.2-percent-annual-chance deep-water wave conditions, followed by the "Existing FIS" wave setup calculation procedures at the shoreline.

ISSUE 4: Dune Erosion

Section D.2.9 describes methods to evaluate beaches, dunes, and bluffs subject to storminduced erosion during the base flood and provides procedures to determine post-storm profiles for use in subsequent wave height, runup, and/or overtopping analyses. Section

D.2.9.3.1 states that on open coasts, sandy dunes must have a dune reservoir of 540 $feet^2$ or greater above the base flood SWEL to remain a barrier to flooding on the coastal transect. Dunes with inadequate reservoirs will be removed from the coastal transect and replaced with a 1-on-50 slope that starts from the dune toe.

The 540-$foot^2$ dune reservoir criterion was established in a study that examined pre- and post-storm profiles for 38 storms that affected Dutch and U.S. coasts (FEMA, 1989). In that study, the median erosion volume above the SWEL was plotted against the recurrence interval for each event (see Figure 1). A best-fit line for these data shows that an erosion volume of 20 $yards^3$ (or 540 $feet^2$ per foot of alongshore distance) corresponds to the base flood event. Hallermeier and Rhodes (1988) determined that the equation of the best-fit line is:

$$\text{Median erosion } (ft^3/ft) = 85.6 * (\text{Recurrence Interval in years})^{0.4}$$

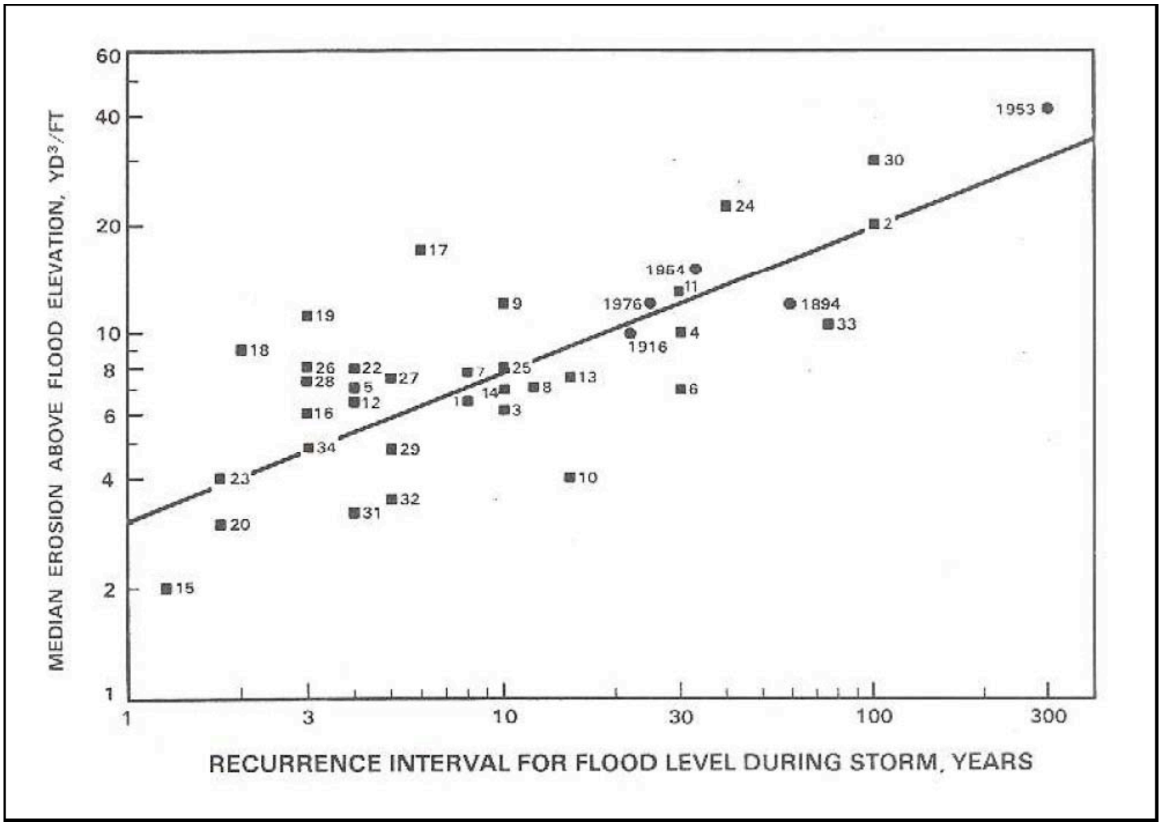


Figure 1. Median erosion volume above flood level recorded in 38 storm events.

Recommended Procedures: Based on the equation above, Mapping Partners shall use 1,030 feet^2 as the dune reservoir required to prevent dune removal during the 0.2-percent-annual-chance flood along Atlantic Ocean and Gulf of Mexico open coasts, whether for an "Existing FIS" or a "New Study" approach. The Mapping Partner must ensure that the wave setup contribution is not included in the 0.2-percent-annual-chance stillwater level before the dune reservoir is calculated. Mapping Partners should use the dune retreat and removal profile geometries provided in Section D.2.9.3 in conjunction with this 1,030-foot^2 dune reservoir criterion.

For coastal reaches that are considered sheltered waters, mixed-sediment systems, or erodible bluffs, the Mapping Partner shall use historical data to estimate a reasonable eroded profile for the 0.2-percent-annual-chance conditions, and shall propose it to the FEMA Study Representative. This approach is analogous to the guidance provided in Sections D.2.9.3.2 through D.2.9.3.4 for determining the 1-percent-annual-chance eroded profiles in such settings.

ISSUE 5: Coastal Armoring Structures

Current guidelines for evaluating coastal structures that protect against the base flood are provided in Section D.2.10. Specific guidelines for evaluating and certifying coastal armoring structures (e.g., seawalls and revetments) are provided in Section D.2.10.2. Structural stability must be evaluated, in order to determine whether the topographic profiles used to determine wave effects inland of the shoreline should include the structure or whether the transect should be modified to represent structural failure.

Recommended Procedures: Coastal structures respond to the forces and conditions to which they are subject, without regard to the return frequency of those forces and conditions. Therefore, Mapping Partners should evaluate coastal structures for the 0.2-percent-annual-chance flood by using the procedures described in Section D.2.10 for the base flood. They should take care to use frequency-appropriate water levels and wave conditions.

Existing FIS For existing studies where coastal structures have been certified at the base flood level, the Mapping Partner shall not assume that the certification also applies for the 0.2-percent-annual-chance flood level. A separate evaluation is required to determine whether or not the coastal structure can be certified against the 0.2-percent-annual-chance flood conditions. However, it may not be feasible to perform a detailed evaluation of every coastal structure according to Section D.2.10.1, because of data limitations. In this case, the Mapping Partner may either assume structure failure or perform the erosion and wave analyses for both the intact and the failed structure transect profiles[3]. If the latter approach is taken, the more conservative (higher) flood elevations shall be used by the Mapping Partner to depict the 0.2-percent-annual-chance wave envelope profile.

New Study For a new study, coastal structures shall be evaluated to determine whether they will survive 1-and 0.2-percent-annual-chance flooding, starting with the 0.2-percent-annual-chance-flood evaluation. If a coastal structure is evaluated and consequently certified to withstand the 0.2-percent-annual-chance flood, the Mapping Partner may consider the structure able to withstand the 1-percent-annual-chance flood, without further analysis.

In both the “Existing FIS” and the “New Study” procedures, structures that cannot withstand the forces associated with 0.2-percent-annual-chance flooding may still mitigate wave hazards by breaking waves that pass over the structures’ failed profiles. The Mapping Partner should review suggested failed structure profiles in Section

D.2.10.3 for use with 0.2-percent-annual-chance flood structure failures.

ISSUE 6: Coastal Levees

Section D.2.10.3.4 contains guidance for evaluating coastal levees against base flood conditions. Levees that cannot withstand those forces and conditions (and thus cannot be certified) are to be “removed” from the analysis transect. This removal may take the form of a complete physical levee failure, with the exclusion of all cross-sectional topography, in which case both stillwater flooding and unattenuated waves penetrate

[3] Note that the failed structure scenario will almost always result in the more conservative flood hazard estimate. The exception is where wave runup on an intact structure may reach a higher elevation than wave effects in the vicinity of the failed structure.

behind the levee, or a partial failure of the levee, with remnant cross-sectional topography, in which case stillwater flooding and attenuated waves (or no waves) will penetrate landward of the levee.

Recommended Procedures:

Coastal levees shall be evaluated against 0.2-percent-annual-chance flood conditions using the procedures in Section D.2.10.3.4, taking care to use frequency-appropriate water levels and wave conditions.

Existing FIS For existing studies where levees have been certified at the base flood level, the Mapping Partner shall not assume that the certification also applies for the 0.2-percent-annual-chance flood level. A separate evaluation is required to determine whether or not the levee can be certified against the 0.2-percent-annual-chance flood conditions.

New Study For new studies, levee evaluation and certification at both the 1- and the 0.2-percent-annual-chance levels will be required.

In general, Mapping Partners are not the certifying agency; thus, Mapping Partners will generally rely on the evaluations and certifications of others. However, in cases where 0.2-percent-annual-chance flood certification is not achieved, the Mapping Partner must determine the configuration of the removed or failed levee cross section and the degree to which waves and stillwater flooding will penetrate behind the levee.

For cases where levees are not certified against 0.2-percent-annual-chance flood conditions, the Mapping Partner should, where possible, use historical data to guide determination of the failed levee cross sections. The analysis of wave penetration and stillwater flooding should follow the guidance in Section D.2.10.3.4.1.

ISSUE 7: Wave Runup and Overtopping

Section D.2.8 contains procedures for calculating wave runup and overtopping on beaches and barriers for the base flood. This guidance calls for calculating the 2-percent runup[4], rather than the mean runup called for by earlier versions of the *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix D. Simplified calculation and mapping procedures are included for cases where the runup exceeds a barrier crest. Specific overtopping calculation methods and mapping guidance are provided.

[4] Current policy for the NFIP is to define the wave runup elevation as the value exceeded by 2 percent of the runup events. This runup elevation is a short-term statistic associated with a group of waves or a particular storm. It is a standard definition of runup, commonly denoted as $R_{2\%}$. This 2 percent is different from the 1-percent-annual-chance or 0.2-percent-annual-chance conditions that are associated with long-term extreme value statistics. The 0.2-percent condition has a 0.2-percent annual probability of occurrence, which corresponds approximately to the 500-year condition, while the runup statistic corresponds to a 2-percent exceedance occurrence in several hours of waves.

- The Mapping Partner will use incident stillwater and wave conditions associated with the 0.2-percent-annual-chance flood. These conditions must be consistent with those used for other 0.2-percent-annual-chance analyses (e.g., wave setup, dune erosion, and wave runup).

Section D.2.8.1.2 contains guidance for the use of the RUNUP 2.0 computer program, which yields a mean runup height, and for scaling the results to obtain the 2-percent runup height. A & G Update also contains guidance for the use of runup procedures contained in the SPM (for vertical walls), the USACE Coastal Engineering Manual (CEM) and the Technical Advisory Committee for Water Retaining Structures (TAW), as well as advanced wave models (e.g., Boussinesq).

Recommended Procedures: The wave runup and overtopping procedures included in Section D.2.8.1 for the base flood are also recommended for use with the 0.2-percent-annual-chance flood. In order to use these procedures, incident wave conditions associated with the 0.2-percent-annual-chance flood must be calculated. These incident wave conditions must be consistent with those used for wave setup and other parameter estimates at the 0.2-percent-annual-chance level.

<u>Existing FIS</u> Where a Mapping Partner is supplementing an existing FIS and not updating storm surge levels, 0.2-percent-annual-chance wave runup and overtopping calculations shall be made along the previous FIS transects where possible, but new intermediate transects may be added.

<u>New Study</u> For studies requiring new storm surge calculations, the Mapping Partner shall calculate wave runup and overtopping at the 0.2-percent-annual-chance level along each transect used to compute base flood effects.

ISSUE 8: Overland Waves

The propagation of overland waves with the storm surge is one of the critical components that establish the base flood elevations for the National Flood Insurance Program. Existing guidance for the one-dimensional analysis accounts for wave height decay caused by obstructions from buildings and vegetation and for wave growth across unobstructed open water and inland bay fetches. Section D.2.7 contains procedures recommended for analyzing overland waves associated with the base flood, including a description of FEMA's wave height model, WHAFIS 3.0.

Recommended Procedures: With a few exceptions, the same general procedures used to calculate the 1-percent-annual-chance wave envelope will be used to calculate the 0.2-percent-annual-chance wave envelope. The exceptions are described below:

- WHAFIS and CHAMP (see Section D.2.7.3) have been modified to provide for the calculation of 0.2-percent-annual-chance wave heights in addition to base flood wave height calculations. The only difference between the two regimes is in the wind speeds. Wind speeds associated with 0.2-percent-annual-chance flooding for overwater and inland fetches were determined to be as follows: the default OF line wind speed was changed from 80 miles per hour (mph), for 1percent-annual-chance analysis, to 100 mph, for 0.2-percent-annual-chance analysis. The default IF line and VH line wind speeds were changed from 60 mph, for 1-percent-annual-chance analysis, to 75 mph, for 0.2-percent-annualchance analysis. The changes represent a 25-percent increase in wind speeds. This increase was determined after reviewing 1- and 0.2-percent-annual-chance wind speeds at 23 coastal locations, as reported by Simiu, et al. (1979). The ratios of the 1- and 0.2-percent-annual-chance wind speeds varied from approximately 1.1 to 1.4 at these stations, with an average of approximately 1.25. Section D.2.7.3 indicates that the Mapping Partner should treat elevated buildings as open space during the 1-percent-annual-chance analysis. However, it is quite likely that some portions of elevated buildings will be lower than the 0.2-percentannual-chance mean water level or wave profile. In such cases, the Mapping Partner shall determine which elevated buildings will have their lowest floor or other obstructions beneath the 0.2-percent-annual-chance mean water level and which will likely have their lowest floor or other obstructions beneath an estimated 0.2-percent-annual-chance wave profile. The Mapping Partner shall consider the type of construction in each case (e.g., elevated light-frame single family or elevated fully-engineered mid- or high-rise) and decide whether the buildings are likely to survive 0.2-percent-annual-chance flood conditions. If the buildings are unlikely to survive, the Mapping Partner shall ignore the buildings and code them as 100-percent open space on the BU card. If the buildings are likely to survive but may present obstructions beneath the 0.2-percent-annualchance stillwater or wave level, the Mapping Partner shall determine a percentage of open space for BU coding that accounts for these obstructions.

Existing FIS Where a Mapping Partner is supplementing an existing FIS and not updating storm surge levels, 0.2-percent-annual-chance overland wave propagation calculations shall be made along the previous FIS transects where possible, but new intermediate transects may be added.

New Study For FISs requiring new storm surge calculations, the Mapping Partner shall calculate overland wave propagation at the 0.2-percent-annual-chance level along each transect used to compute base flood effects.

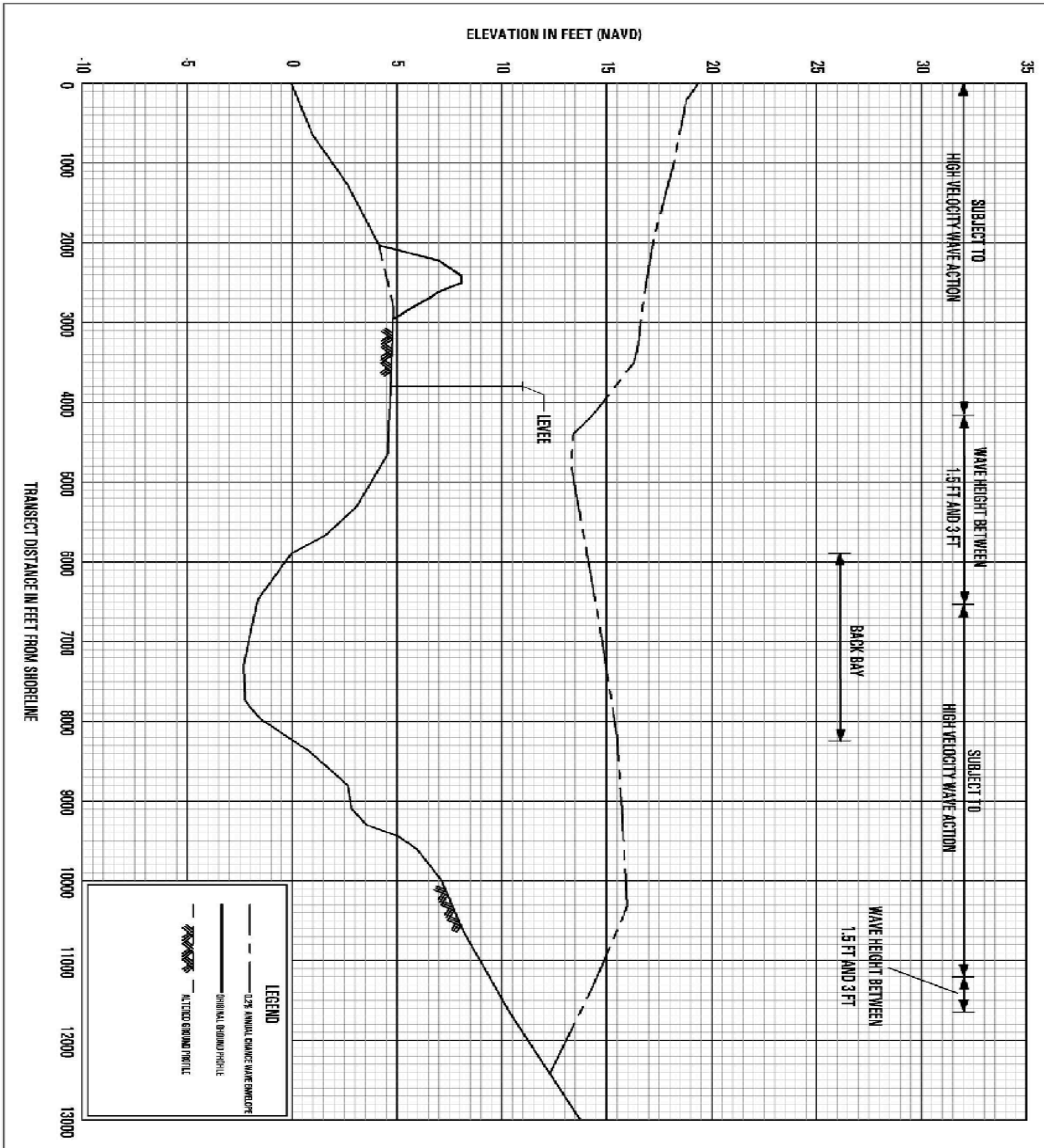
ISSUE 9: Plotting Wave Envelope Profile

Section D.2.11 contains procedures for combining and merging various 1-percent-annual-chance stillwater and wave effects along the analysis transects.

Recommended Procedures: Unless a different product is specified by the FEMA Study Representative, the Mapping Partner shall produce a 0.2-percent-annual-chance wave profile for each analysis transect, for both "Existing FIS" and "New Study" approaches. The profiles shall include the following items (see example in Figure 2):

- The ground profile used to determine the composite 0.2-percent-annual-chance wave envelope (i.e., the eroded profile with certified structures intact and/or the profile after the failure of any coastal structures or levees);
- Those portions of the original ground profile, including coastal structures and levees, that were eroded or removed during the analysis;
- The 0.2-percent-annual-chance wave envelope; (In no case, however, shall the Mapping Partner produce a 0.2-percent-annual-chance wave envelope that falls below the wave envelope from the 1-percent-annual-chance analysis. In areas where the 0.2-percent-annual-chance wave envelope might fall below the 1-percent-annual-chance wave envelope, the Mapping Partner shall plot the 1-percent-annual-chance wave envelope instead of the 0.2-percent-annual-chance wave envelope.)
- A delineation of those regions along the transect where damaging waves are calculated. These areas shall be identified as "Subject to High Velocity Wave Action" or "Wave Height between 1.5 feet and 3 feet." The first identifier will be used where wave heights during the 0.2-percent-annual-chance flood equal or exceed 3.0 feet, where the wave runup depth during the 0.2-percent-annualchance flood equals or exceeds 3.0 feet, where the wave overtopping rate during the 0.2-percent-annual-chance flood equals or exceeds 1 cfs/foot, or where a primary frontal dune (see Section D.2.9.3.1) has been established by the base flood analysis.

Figure 2 shows a theoretical wave envelope for a hypothetical transect extending 13000 feet inland from the open ocean. The transect crosses a barrier island with a large dune and levee and a shallow back bay before extending over the mainland. The solid black line shows the original topography of the transect. The dashed line represents the topography that was used in the wave analysis. The dune was found insufficient in size to be considered an effective barrier to the 0.2-percent-annual-chance flood surge and associated wave action and was therefore eroded. From inspection it is clear that the dune is not an effective barrier to the 0.2-percent-annual-chance flood since the dune would be fully submerged by the 0.2-percent-annual-chance stillwater elevation, the elevation at which the wave envelope intersects with the ground profile for transects not subject to wave runup. From inspection it is also clear that the levee cannot be certified for the 0.2-percent-annual-chance flood since it, too, would be submerged. However, the sharp decrease in wave height elevations in the vicinity of the levee indicates that the levee was modeled as only partially failed and that the remnant structure was sufficient in size to induce wave decay. Over the Back Bay, where wind blows across an unobstructed fetch, the wave height increases until the land reaches a sufficient elevation to cause the waves to be depth limited. The labels along the top of the profile indicate the stretches of the transect subject to high velocity wave action and wave heights between 1.5 and 3 feet.



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FEDERAL EMERGENCY MANAGEMENT AGENCY

FLOODED COUNTY, USA

AND INCORPORATED AREAS

0.2% ANNUAL CHANCE WAVE ENVELOPE

TRANSECT 1

REFERENCES

Federal Emergency Management Agency. 1988. *Basis of Erosion Assessment Procedures for Coastal Flood Insurance Studies*. Washington, D.C. November.

Federal Emergency Management Agency. 2003. *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping*. Washington, D.C.

Federal Emergency Management Agency. 2004. *Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States*. Washington, D.C.

Federal Emergency Management Agency. 2006. *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update*. Washington, D.C.

Hallermeier, R.J. and Rhodes, P.E. 1988. Generic treatment of dune erosion for 100-year event. *Proceedings, 21st International Conference on Coastal Engineering*, ASCE, New York, p.1197-1211.

Hosking, J.R.M. and Wallis, J.R. 1997. *Regional Frequency Analysis: An Approach based on L-Moments*. Cambridge University Press, Cambridge, UK.

Simiu, E., Changery, J., and Filliben, J.J. 1979. "Extreme Wind Speeds at 129 Stations in the Contiguous United States," NBS Building Science Series 118. National Bureau of Standards. Washington, DC.