D.2.6 Wave Setup

This subsection provides guidance for the determination of wave setup—an increase in the total stillwater elevation against a barrier caused by the attenuation of waves in shallow water.

D.2.6.1 Overview

In addition to wind, waves can also affect the mean nearshore water levels during hurricanes and severe storms. This occurs as a result of the transfer of momentum from waves to the water column (see Figure D.2.6-1). Wave setup increases as the water depth near a barrier decreases and wave dissipation increases.

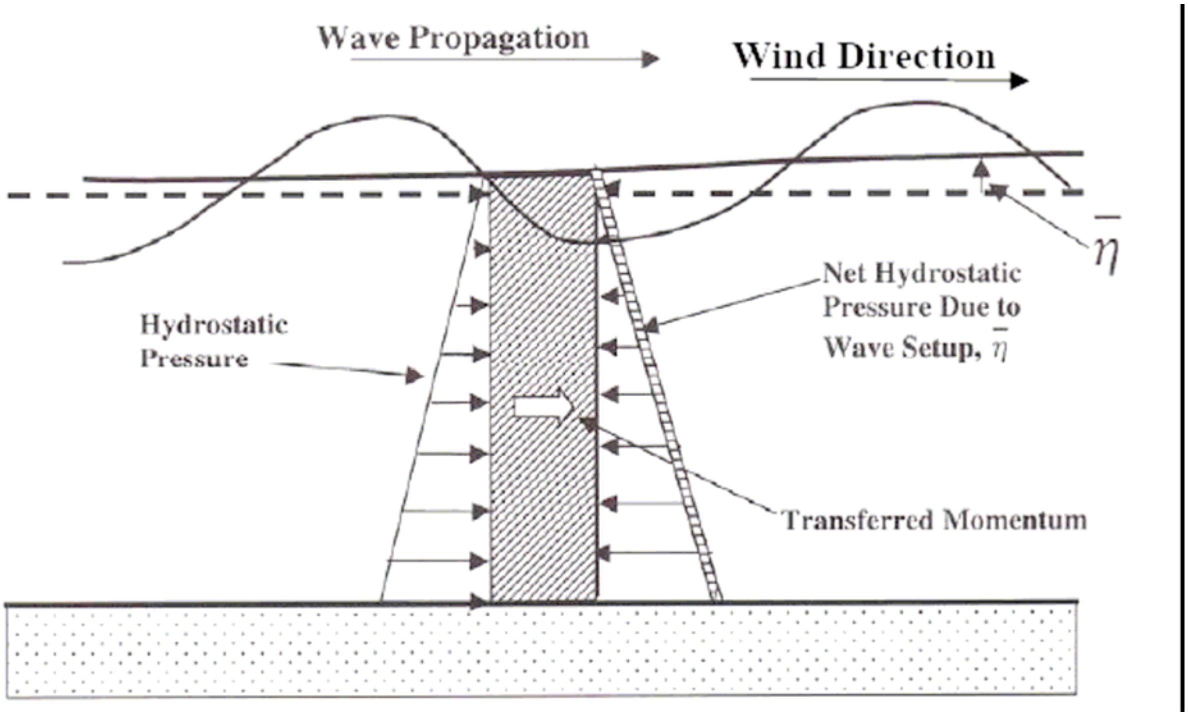

Figure D.2.6-1. Wave Setup Due to Transfer of Momentum.

Consider a train of waves approaching the shoreline. Outside of the breaker zone, a relatively small reduction in mean water level, termed a “setdown,” will occur. This setdown is small, approximately 5 percent of the breaking wave height. However, as the waves break, they transfer momentum to the water column, causing a wave “setup” that can be on the order of 10 to 20 percent of the breaking wave height. This is a “static” wave setup, which remains approximately constant as long as the storm tide and incident wave conditions remain unchanged. Although theoretical equations exist for the case of idealized static wave setup, the actual static setup value depends on a number of factors, including wave nonlinearity, wave breaking characteristics, profile slope, and wave propagation through vegetation.

However, oscillations in the wave setup will also occur in nature, and this oscillation is known as "dynamic" wave setup (see Figure D.2.6-2). These oscillations will typically occur with periods of 10 to 20 times the mean wave period. The dynamic wave setup increases with narrow frequency spectra and narrow directional spectra, both uncharacteristic of hurricane and nor'easter conditions. Therefore, the dynamic setup component is considered to be small by comparison with the static component for the Atlantic and Gulf applications, and should not be included at present in the calculations for the Atlantic and Gulf storm surges.

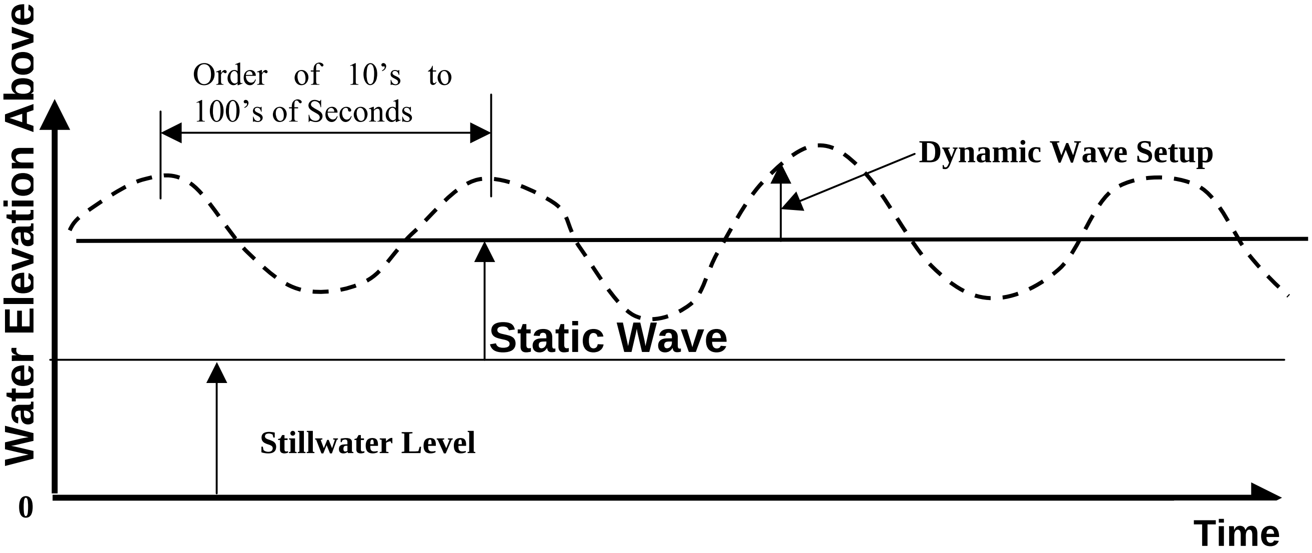

Figure D.2.6-2. Definitions of Static and Dynamic Wave Setup Components.

D.2.6.2 Wave Setup Implications for Flood Insurance Studies

Wave setup can be a significant contributor to the total water level landward of the +/- MSL shoreline and should be included in the determination of coastal BFEs. The manner in which it is included, however, is critical to the accuracy of the BFEs. There are two ways of estimating stillwater levels for use in an FIS. One involves separate calculations of storm surge and wave setup, and one computes storm surge and wave setup concurrently. Recall that the stillwater level comprised of the combination of these two components is the *mean water level* (MWL).

In the first case, wave setup must be added to the storm surge stillwater level for WHAFIS calculations (see Section 2.5), but *not* added to the storm surge stillwater level for wave runup calculations (wave runup models typically include wave setup effects in the computed wave runup heights) or for dune erosion removal/retreat (see Subsection 2.9.3.1).

In the second case, the surge and wave setup components may have to be decoupled before wave runup calculations and dune removal/retreat calculations can be made (to avoid double counting wave setup). This will require the Mapping Partner to make separate wave setup calculations, and to subtract the calculated wave setup from the combined stillwater elevation (MWL) before using RUNUP 2.0 (or most other wave runup procedures) or before estimating the frontal dune reservoir. WHAFIS calculations can proceed with the combined storm surge and wave setup stillwater level (MWL), but the wave setup value should not be input separately into WHAFIS, even if it is known.

Wave setup and its treatment in an FIS must be carefully documented by the Mapping Partner, and any questions over how to handle wave setup should be discussed with the FEMA Study Representative.

D.2.6.3 Guidelines for Estimating Static Wave Setup

There are several methods for establishing static wave setup. One method uses the results described in the USACE Shore Protection Manual (SPM), which present normalized wave setup as a function of bottom slope and the deepwater wave steepness (H_o/L_o), as shown in Figure D.2.6-3 (Note the symbol *S* for static wave setup in Figure D.2.6-3 will be replaced by $\bar{\eta}$ here). Other methods include those developed by Goda (2000) and the Direct Integration Method (DIM), an integration of the governing equations. DIM was developed in conjunction with the recent FEMA-sponsored development of the Pacific Coast *Guidelines* (FEMA 2004). The first two methods yield a computation of wave setup at the landward limit of flooding, while the latter (DIM) yields wave setup estimates at any point along a shore-normal transect.

A comparison analysis of these three methods was conducted by the Pacific *Guidelines* working group (TWG). TWG found that the DIM methodology yielded static wave setup values ranging from 60 to 100 percent larger than those from the SPM method. However, the DIM methodology values were less than 16 percent greater than those predicted by Goda. It was concluded by TWG that the DIM methodology provides a better estimate of wave setup than the SPM methodology.

The Mapping Partner should use the DIM methodology to determine static wave setup. A reduction of up to 16 percent (based on the comparison with the Goda methodology) may be applied to the DIM results if evidence[3] suggests a reduction is appropriate.

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[3] Evidence that indicates a reduction is appropriate can include measured water level data during previous severe storms affecting the study area.

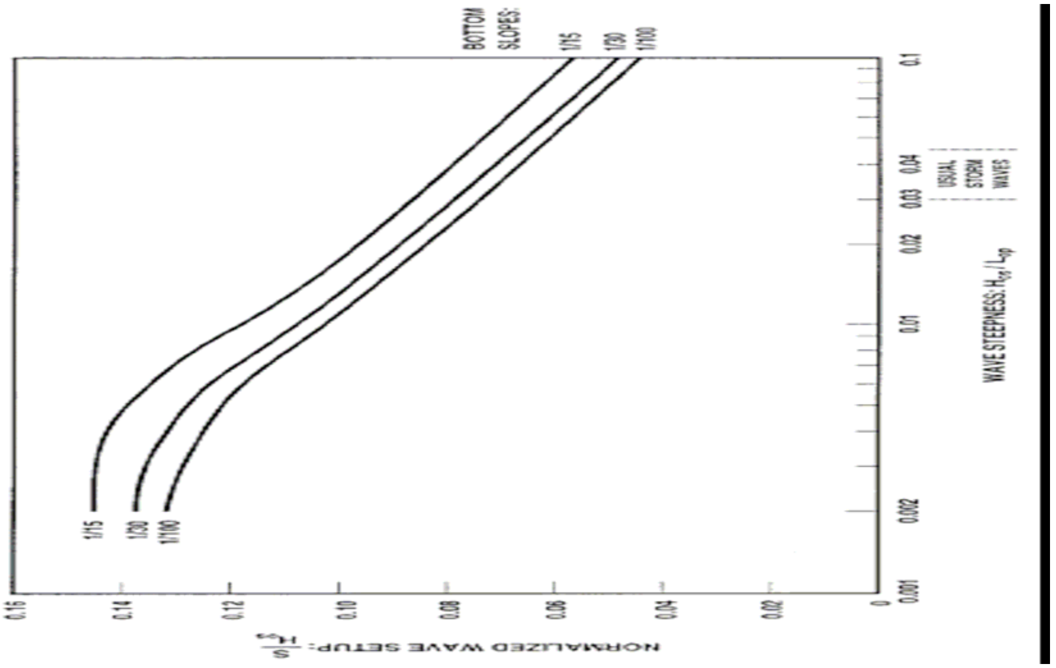

Figure D.2.6-3. Methodology for Calculating Wave Setup (from USACE SPM).

The DIM methodology can be written as follows for the static wave setup ($\bar{\eta}$) which allows direct calculation of the effect of profile slope (*m*) and deepwater wave steepness (H_o/L_o).

$$\bar{\eta}/H_o' = 0.160\frac{m^{0.2}}{(H_o'/L_o)^{0.2}} \qquad \text{(D.2.6-1)}$$

Note that the SPM and Goda methods provide the wave setup at the landward limit of flooding, thus, in some cases a method might be required to determine the wave setup value at the normal (+/- MSL) shoreline for later transect applications. It is recommended that the Mapping Partner proportion the maximum wave setup as determined by the SPM or Goda method to determine the approximate wave setup at the normal shoreline. Denoting the wave setup at the shoreline as $\overline{\eta_o}$ and the maximum setup as $\overline{\eta_{\max}}$, $\overline{\eta_o}$ can be approximated as

$$\overline{\eta_o} = \left[1 - \frac{3\kappa^2}{8}\frac{1}{\left(1+\frac{3\kappa^2}{8}\right)}\right]\overline{\eta_{\max}} \qquad \text{(D.2.6-2a)}$$

which simplifies to

$$\overline{\eta_0} = \left[\frac{8}{\left(8+3\kappa^2\right)}\right]\overline{\eta_{\max}} \qquad \text{(D.2.6-2b)}$$

where κ is the ratio of breaking wave height to breaking water depth. For the case of significant wave height and non-vegetated slopes, typical values of κ range from 0.4 to 0.6.[4] These values result in

$$\overline{\eta_o} = 0.88 \text{ to } 0.94\ \overline{\eta_{\max}} \approx 0.9\ \overline{\eta_{\max}} \tag{D.2.6-2c}$$

Procedures for calculating wave setup on an open coast will be presented, followed by cases of setup on levees, which entail modifications to the open coast method. As seen in Equation (D.2.6-1), wave setup calculations require a reference wave height. In this case, the effective deepwater significant wave height is H'_o.

D.2.6.3.1 Wave Setup on an Open Coast

D.2.6.3.1.1 Determining a Reference Deepwater Significant Wave Height

Estimation of the static wave setup requires an estimate of the deepwater significant wave height, which can be calculated or determined from hindcast data (such as that provided by the USACE Coastal and Hydraulics Laboratory WIS or other sources). WIS modeling stations are located continuously along the Atlantic and Gulf coasts.

Because there are two primary statistical approaches for estimating storm surge elevations (JPM and EST), two approaches are recommended to determine a reference deepwater wave height. The JPM methodology requires the development of synthetic storms in accordance with the historical database. For hurricanes, this involves calculating storm surges and waves based on a large number of synthetic storms. For nor'easters, the database may be better suited to the EST method or the use of a wave hindcast method based on the windfields used to generate the storm surge.

D.2.6.3.1.2 JPM—Wave Setup Due to Hurricanes

The SPM provides recommendations for calculating the deepwater wave characteristics associated with a hurricane. These methods included two equations, one for the maximum significant wave height and one for the associated wave period. In addition, a graph was provided that represents the nondimensional distribution of significant deepwater wave heights in a hurricane. Each of these is discussed below.

The wave characteristics (significant height and associated period) are presented in the SPM in terms of the hurricane parameters in both English and metric systems. The equations below are presented for the English system. The parameters are:

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[4] The values of κ cited here assume wave setup is due to wave breaking only (i.e., no reduction in wave setup due to vegetation – see Sec. D.2.6.3.4.1) and waves are passing over a sloping surface without significant changes in slope. If the ground surface along the transect changes slope suddenly (e.g., a bluff or levee landward of a marsh) then the Mapping Partner may consider breaking the wave setup analysis into segments and calculating a different κ for each segment.

- Central pressure deficit: Δp in inches of mercury
- Forward translational speed of hurricane: V_F in knots
- Radius to maximum winds: R in nautical miles
- Maximum sustained windspeed at 33 feet above the sea surface: U_R in knots
- Coefficient depending on hurricane speed: α (dimensionless)
- Coriolis parameter: f (dimensionless)

where the Coriolis parameter, f, is given by

$$f = 0.524 \sin \phi \tag{D.2.6-3}$$

and ϕ is the latitude at the location of interest

The equations for maximum significant wave height and associated period are:

$$H'_{o,\max} = 16.5 e^{\frac{R\Delta p}{100}} \left[1 + \frac{0.208 \alpha V_F}{\sqrt{U_R}} \right] \tag{D.2.6-4}$$

and

$$T_s = 8.6 e^{\frac{R\Delta p}{200}} \left[1 + \frac{0.104 \alpha V_F}{\sqrt{U_R}} \right] \tag{D.2.6-5}$$

where

$$U_{\max} = 0.868\left(73\sqrt{\Delta p} - 0.575Rf\right) \tag{D.2.6-6}$$

The parameter U_R, is expressed in terms of U_{max} as:

$$U_R = 0.865U_{\max} + 0.5V_F \tag{D.2.6-7}$$

The value of the parameter α is recommended as unity (one) for slowly translating hurricanes, and this value is recommended for use here.

Figure D.2.6-4 presents the relationship for nondimensional significant wave height as a function of nondimensional distances relative to the hurricane center. The distances are made nondimensional by the hurricane radius to maximum winds (R).

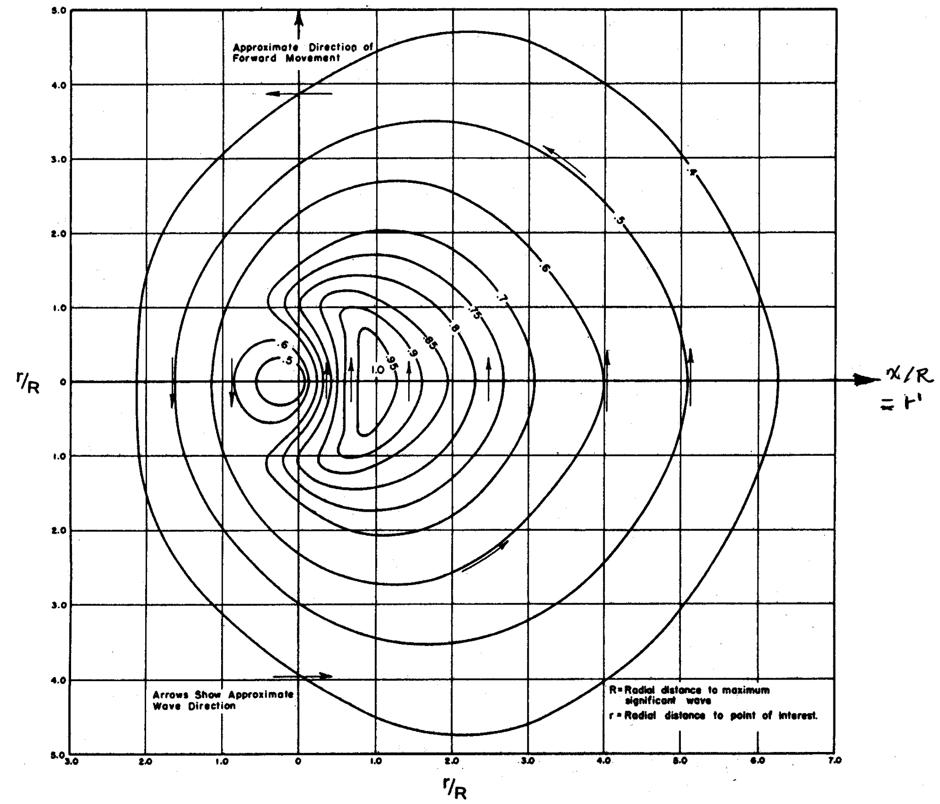

Figure D.2.6-4. SPM Relationship for Wave Heights Relative to Their Maximum in a Hurricane (USACE).

As shown in Figure D.2.6-4, the SPM model predicts waves that propagate in approximately the same direction as the local winds. For these purposes, wave height distributions are presented for two distances offshore, and it is recommended that the applied distribution be prorated by the actual distance of the hurricane center from the shoreline. The two distributions are presented in Figure D.2.6-5, along with the SPM distribution. The deviations from the SPM model are based on the recognition that waves diffract and disperse in advance of a hurricane. The two distributions are associated with the following positions: (1) distances of more than 4 radii from the shoreline, and (2) at the shoreline. Specifically, the recommended relevant deepwater wave heights at shore are:

Hurricane Center More Than 4 Radii (R) From the Shoreline

$$H_o / H_{o,\max} = 0.40 + 0.20\cos^2\left[\frac{\pi}{2}\left(\frac{r'-2}{12}\right)\right], \ -10 < r' < 14$$

$$H_o / H_{o,\max} = 0.40, \ r' < -10, \ r' > 14 \qquad \text{(D.2.6-8)}$$

Hurricane Center at the Shoreline

$$\begin{aligned}
H_o / H_{o,\max} &= 0.3, \quad r' < -3.0 \\
H_o / H_{o,\max} &= 0.3 + 0.233(r'+3), \quad -3.0 < r' < 0 \\
H_o / H_{o,\max} &= 1.0, \quad 0 < r' < 1.0 \\
H_o / H_{o,\max} &= 1.0 - 0.10(r'-1), \quad 1 < r' < 8 \\
H_o / H_{o,\max} &= 0.3, \quad r' > 6
\end{aligned} \qquad \text{(D.2.6-9)}$$

and $r' = x / R$.

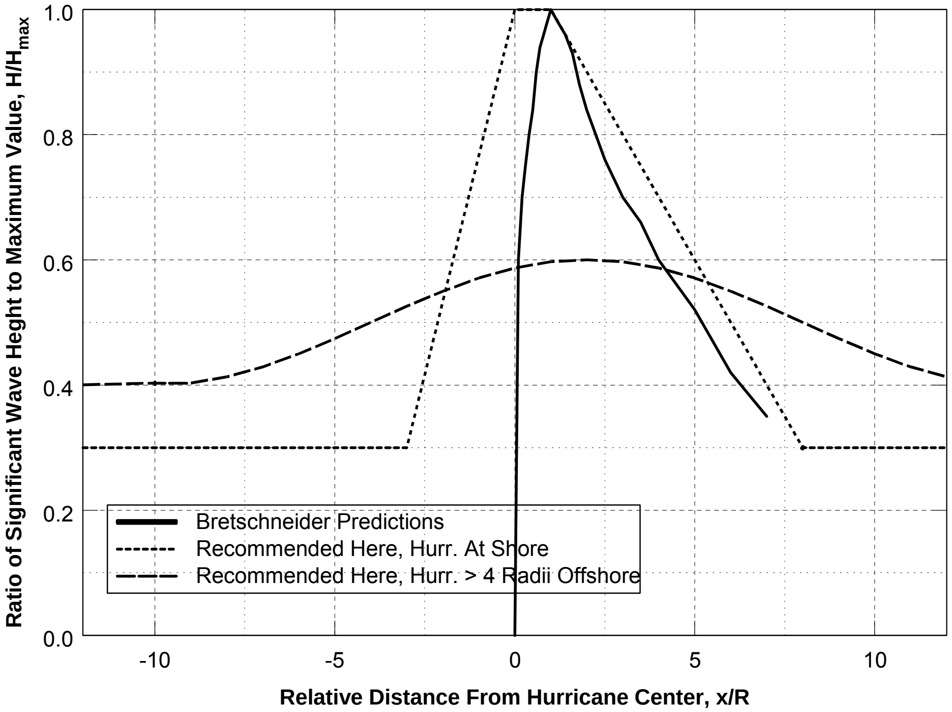

Figure D.2.6-5. Recommended Relative Wave Height Along a Line Perpendicular to Hurricane Translation Direction

With the maximum significant wave height and associated period known along a line perpendicular to the hurricane translation direction, the wave height at any location can be determined from the approximate graphical relationship in Figure D.2.6-5 or Equations (D.2.6-8) and (D.2.6-9), which present local significant deepwater wave height relative to the global maximum deepwater significant wave height. The recommended wave period at all locations is that given by Equation (D.2.6-5).

With the effective deepwater wave height and period, the effective profile slope (m) can be based on the average slope out to the breaking depth, which may be approximated by H'_o, and the static wave setup calculated by Equation (D.2.6-1). This completes the recommendations for applying the JPM to calculate wave setup for hurricanes on an open coast.

D.2.6.3.1.3 EST - Wave Setup Due to Nor'easters

As noted, the database for nor'easters may be better suited for applying the EST method. In this case, it is appropriate to determine a field of reference deepwater wave heights based on hindcasts using the windfield applied to calculate wind surge. The Mapping Partner may consider both 1-D and 2-D methodologies for calculating wave characteristics.

The method for determining a deepwater wave height in cases where the EST method is used to calculate wind surges differs only slightly from that of the JPM method. The difference is that historical storms, rather than synthetic storms, are used in the EST methodology. The general approach is to estimate the necessary parameters Δp, R, $V_{F,}$ *ect* for each of the historical storms and then to apply the procedures presented for the JPM method to calculate static wave setup.

The forward velocity (V_F) is determined from the path characteristics used in the simulation, so only the central pressure deficit (Δp) and the radius to maximum winds (R) need to be determined. The subsections below describe one approach to determine these variables. The Mapping Partner may evaluate other approaches.

D.2.6.3.1.3 Radius to Maximum Winds (*R*)

It is recommended that the radius to maximum winds (R) be determined from inspecting the historical windfield.

D.2.6.3.1.4 Central Pressure Deficit (*Δp*)

The central pressure deficit (Δp) can be related approximately to the maximum wind (U_{max}) in the windfield used in Equation (D.2.6-6), which is provided below in a different form:

$$\Delta p = 1.88x10^{-4}\left(\frac{U_{\max}}{0.868}+0.575Rf\right)^2 \tag{D.2.6-10}$$

With the above-referenced definitions and knowledge of the track of the hurricane, it is possible to apply the procedures described earlier for the JPM approach.

D.2.6.3.2 Wave Setup On a Coastal Structure

The following subsections address the case of wave setup on a coastal structure that could be overtopped. Figure D.2.6-6 presents the case of a nonovertopped levee.

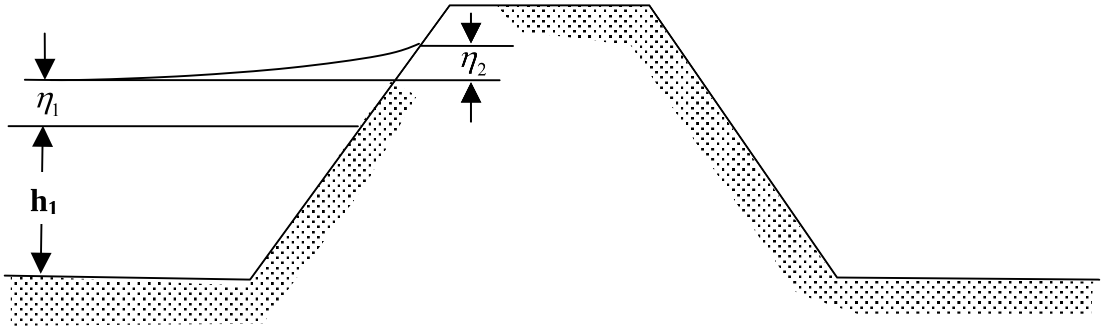

Figure D.2.6-6. Definition Sketch for Nonovertopped Levee

Because of the steep slopes associated with coastal structures such as levees, seawalls, and revetments, the wave setup is greater over this portion of the profile and must be treated separately. Referring to Figure 4, the setup must be considered in two components. The first setup component (η_1) is the water depth, h_1, determined at the toe of the levee, and the second setup component (η_2) is determined for the sloping structure. In order to quantify η_1, the breaking wave height and depth must be determined.

D.2.6.3.2.1 Determining the Breaking Wave Height and Water Depth

It can be shown that the nondimensional breaking wave height (H_o/L_o) is a function of the deepwater wave steepness (H'_o/L_o), as shown in Figure D.2.6-7.

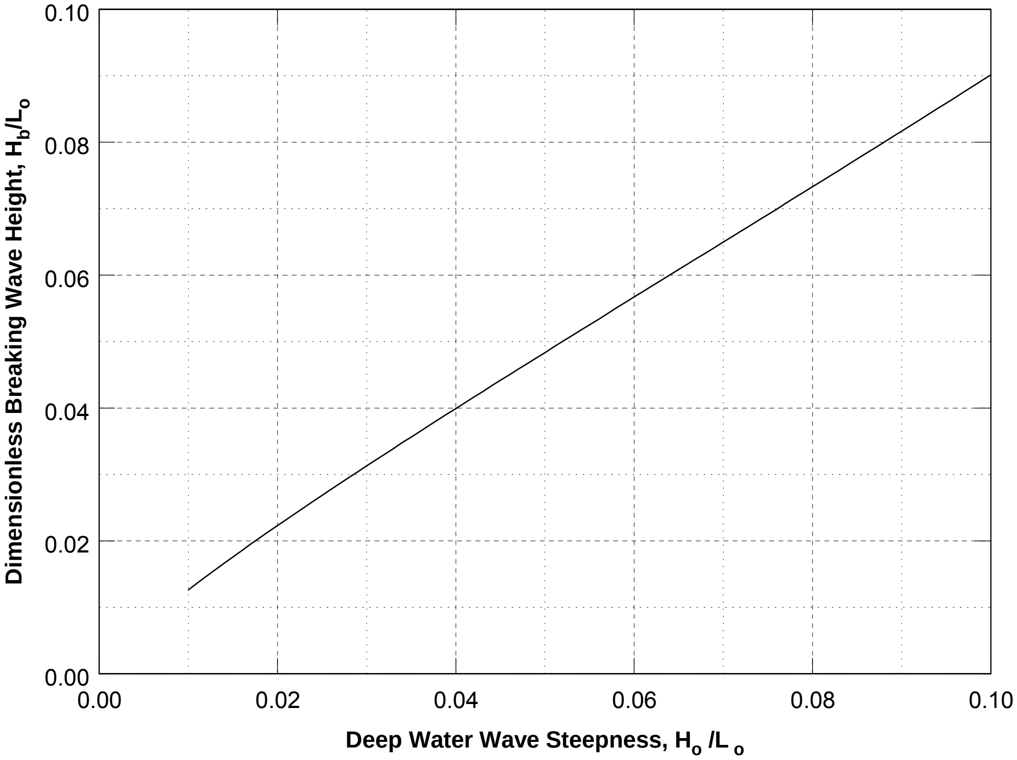

Figure D.2.6-7. Dimensionless Breaking Wave Height vs. Deepwater Wave Steepness

The nondimensional breaking wave height and depth associated with the maximum local waves are based on the deepwater wave steepness (H'_o/L_o), where L_o=5.127^2 in the English system of units being used here. The breaking wave height differs from the deepwater wave height by ±10 percent at most, over the range plotted in Figure D.2.6-7. Figure D.2.6-8 presents the dimensionless breaking water depth (h_o/L_o), which will be useful later.

D.2.6.3.2.2 Nonovertopped Structure

The wave setup at depth $h_1$is determined by referring to Figure D.2.6-9, which presents the proportion of wave setup that would occur in any depth proportional to the breaking depth (the latter determined from Figure D.2.6-8). The value of η_2 is determined as

$$\eta_2 = 0.15(h_1 + \eta_1) \tag{D.2.6-11}$$

and the total wave setup is $\eta_T = \eta_1 + \eta_2$.

Later examples will illustrate the application of these methods.

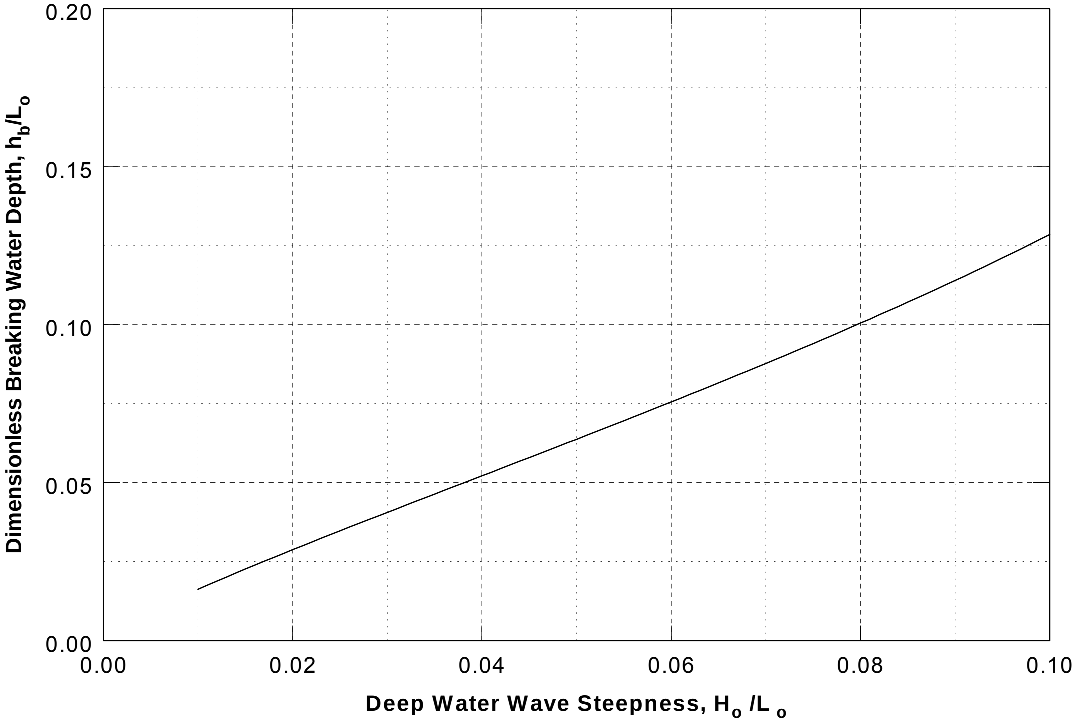

Figure D.2.6-8. Dimensionless Breaking Water Depth vs. Deepwater Wave Steepness.

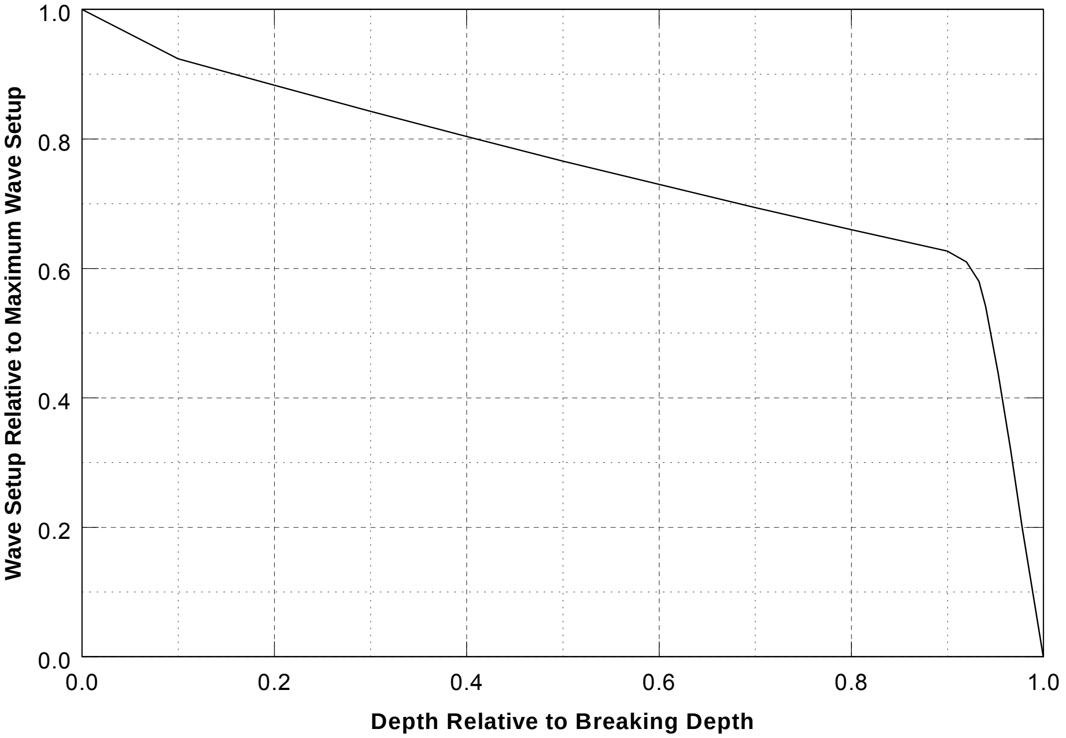

Figure D.2.6-9. Proportion of Maximum Wave Setup that Has Occurred vs. a Proportion of the Breaking Depth.

D.2.6.3.2.3 Overtopped Structure

For overtopped structures, the water depth (including the calculated storm surge) on top of the structure is denoted h_2. The recommended additional wave setup (η_2) for overtopped structures is:

$$\eta_2 = 0.15(h_1 + \eta_1)\left[1 - \left(\frac{h_2}{h_1}\right)^2\right] \qquad \text{(D.2.6-12)}$$

and, as before, $\eta_T = \eta_1 + \eta_2$.

D.2.6.3.3 Examples Illustrating Application of the Methodology

The following three examples illustrate the application of the methodology. The hurricane parameters are presented in Table D.2.6-1. For each of the examples, we will calculate the wave setup at three locations: $x/R = r' = -1.5, 1.0, 4.0$. For all three examples, we consider a location where the latitude is 30° and the effective profile slope is 0.01.

Table D.2.6-1 Hurricane Characteristics Considered in Examples

Example	Situation	Δp (in Hg)	R (n mi)	V_F (knots)	Hurricane Location Relative to Shoreline
1	Wave Setup on an Open Coast	2.5	40	12.0	At Shoreline
2	Wave Setup on a Nonovertopped Structure	3.0	20	14.0	40 n mi Seaward
3	Wave Setup on an Overtopped Structure	3.0	20	14.0	40 n mi Seaward

D.2.6.3.3.1 Example 1: Wave Setup On An Open Coast

For this case, the maximum significant deepwater wave height and period are determined from Equations (D.2.6-2) and (D.2.6-3) as: $H_{o,max}$= 56.0 ft and T_s = 15.9 sec.

For values of r' = -1.5, 1.0, and 4.0, the corresponding ratios of wave heights to the maximum are Equation (D.2.6-8): $H_o/H_{o,max}$ = 0.65, 1.0, and 0.70. Thus, the associated wave heights are 36.4 feet, 56.0 feet, and 39.2 feet, respectively. As noted, the appropriate period is determined from Equation 3 and the deepwater wave length, $L_o = 5.12T^2$ = 1,294 ft.

The wave setup values at the three shoreline locations of interest are determined from Equation (D.2.6-1) for the relevant deepwater wave steepnesses and a representative profile slope of 0.01, and are as presented in Table D.2.6-2.

Table D.2.6-2 Wave Characteristics and Setup at Three Locations for Example 1

Value of $r'(=x/R)$	H_o (ft)	$\bar{\eta}$ (ft)
-1.5	36.4	4.7
1.0	56.0	6.7
4.0	39.2	5.0

D.2.6.3.3.2 Example 2: Wave Setup at a Nonovertopped Structure

For this example, we consider that the water depth at the structure toe is 6 feet and that the structure is not overtopped. For hurricane conditions, the maximum wave height and its associated period are 38.3 feet and 13.2 seconds. The deepwater wave length is

L_o =5.12 T^2 = 892 feet. The breaking relative water depth is determined approximately from Figure 4 as h_o/L_o = 0.052. Thus the breaking depth is 46.4 feet. The ratio of h_l/h_b = 0.129, and Figure D.2.6-9 shows that approximately 91 percent of the maximum wave setup that would have occurred on an open coast has occurred at this water depth of 6 feet. Because the hurricane center is located at two times the radius to maximum winds from the shoreline, the wave height is determined as a prorated value of the two recommended relationships in Figure D.2.6-5 and Equations (D.2.6-8) and (D.2.6-9). The ratios of wave height to maximum wave height for the three longshore distances relative to the center of the hurricane are $H_o/H_{o,max}$ = 0.61, 0.80, and 0.65.

The total wave setup values if the structure were not present are shown in Column 3 of Table D.2.6-3. These values are reduced by a factor of 0.91 and tabulated in Column 4. Finally, the wave setup (η_2) as the waves propagate up on the structure is determined from Equation (D.2.6-11) and is presented in Column 5. The total wave setup at the structure (η_T), which is the sum of Columns 4 and 5, is shown in Column 6 in Table D.2.6-3.

Table D.2.6-3 Wave Characteristics and Setup at Three Locations for Example 2

Value of $r'(=x/R)$	H_o (ft)	$\bar{\eta}_{\max}$ (ft)	$\bar{\eta}_1$ (ft)	$\bar{\eta}_2$ (ft)	$\bar{\eta}_T$ (ft)
-1.5	23.4	3.1	2.8	1.3	4.1
1.0	30.6	3.8	3.5	1.4	4.9
4.0	24.9	3.2	3.0	1.4	4.4

D.2.6.3.3.3 Example 3: Wave Setup at an Overtopped Structure

For this example, we consider that the water depth at the structure toe is 6 feet, as in Example 2; however, the structure is overtopped and has a crest elevation of 4 feet, relative to the adjacent ground. Because the hurricane conditions for Examples 2 and 3 are the same, the wave heights and periods are the same: 38.3 feet and 13.2 seconds. The setup on the structure is reduced in accordance with Equation (D.2.6-11), which reduces the additional setup values (η_2) as tabulated in Column 5 of Table D.2.6-4. In this case, the overtopping only reduces the total wave setup by approximately 3 percent. The total wave setup values are presented in Column 6 of Table 4.

Table D.2.6-4 Wave Characteristics and Setup at Three Locations for Example 3

Value of $r'(=x/R)$	H_o (ft)	$\overline{\eta}_{\max}$ (ft)	$\overline{\eta}_1$ (ft)	$\overline{\eta}_2$ (ft)	$\overline{\eta}_T$ (ft)
-1.5	23.4	3.1	2.8	1.2	4.0
1.0	30.6	3.8	3.5	1.2	4.7
4.0	24.9	3.2	3.0	1.2	4.2

D.2.6.3.4 Wave Setup—Special Cases

D.2.6.3.4.1 Vegetation and Bottom Friction Effects

The methodology above represents approaches to calculating static wave setup on an open coast and on coastal levees (nonovertopped and overtopped). The methods do not account for wave setup effects caused by nonlinear waves or wave energy losses caused by bottom friction or waves propagating through vegetation. If the Mapping Partner deems these effects to be significant, Dean and Bender (2006) should be consulted. As an interim, simplified approach, results from Dean and Bender (2006) show that the incremental wave setup associated with wave energy dissipation through vegetated areas or over dissipative bottoms can be approximated as one-third of the wave setup that would occur if the energy dissipation were caused by wave breaking. Thus, depending on the height and density of vegetation, or the nature of the dissipative bottom, the Mapping Partner may reduce the otherwise calculated wave setup by up to two-thirds.

As a preliminary rule of thumb for the vegetation case, if extensive, dense stands of vegetation extend near or above the base flood wave crest elevation, the two-thirds reduction might be appropriate; if extensive, dense stands of vegetation extend to the approximate base flood mean water elevation, a one-third reduction might be appropriate; if extensive, dense vegetation does not extend above the mid-depth of mean water level, no reduction for vegetation should be used.

D.2.6.3.4.2 Wave Setup across Barriers Islands and Large Bays

There may be instances where wave setup calculations along a specific transect are complicated by the topography along the transect and possibly by 2-dimensional effects. For example:

- Case 1: storm surge and waves propagate over a low-lying or eroded barrier island, across a small bay, and onto the mainland
- Case 2: storm surge and waves propagate over a barrier island, and across a large bay or sound that separates the offshore barrier from the mainland

If, in the first case, storm surge inundates the entire barrier island or a large portion of the island, waves will pass over the island, possibly regenerate across the bay and propagate onto the mainland. Wave setup in this case will rise as the overtopped barrier is approached, then will remain roughly constant across the bay, and will increase again as the waves break on the mainland. The wave setup on the mainland may be higher than it would have been on a non-overtopped portion of the barrier, due to wave regeneration across the bay.

If, in the first case, only a small portion of the barrier is overtopped by surge and waves, wave setup calculations along a transect through the overtopped section may overstate the wave setup on the mainland. The wave setup that passes across the overtopped section may be drained laterally into regions of the bay where no wave setup crosses the island. Two-dimensional effects should be considered in this case.

The second case (large bay) may be similar to the partially overtopped barrier case, where two-dimensional effects come into play. The volume of water that is required to “fill” the potential wave setup across the large bay can be approximated as the average bay width times the bay length times the average wave setup height. This volume must be supplied by flow across the barrier or by other means (e.g., rainfall across the bay and freshwater discharge into the bay) or the wave setup height will not be realized across the entire bay. The Mapping Partner should evaluate the various factors that may limit wave setup in this case, including the fraction of the barrier that is overtopped, the bay dimensions, the duration of the storm surge hydrograph above the barrier elevation, rainfall and freshwater discharge, etc. If sufficient water is not available to “fill” the potential wave setup, the Mapping Partner should examine 2-dimensional effects across the bay and estimate wave setup along the mainland shoreline accordingly. Final wave setup calculations on the mainland will then be made.

D.2.6.3.4.3 Decay of Wave Setup across Flooded Lands

Some previous Flood Insurance Studies have been completed using the assumption that wave setup will decay in the inland direction at some prescribed rate (e.g., one foot of wave setup decay per 1,000 ft of inland flooding, or all wave setup will decay across the barrier island width, etc.). These rules of thumb should not be used. Absent the types of 2-dimensional effects described in the previous section, wave setup at the inland limit of flooding will be equal to or greater than the wave setup at the +/- MSL shoreline