Town of Marshfield, MA, Appeal to FEMA Preliminary Coastal Flood Maps

I. Introduction

This is an appeal to a portion of the Preliminary Flood Insurance Rate Maps for Plymouth County, Massachusetts, as released on May 1, 2013, and as documented by Flood Insurance Study Number 25023CV001B, and supplemented by electronic files provided to us by STARR, the consultant that prepared the study for FEMA. This appeal is being filed by the Town of Marshfield, Massachusetts, on behalf of itself, specifically for the detailed studies (VE- and AE-designated) areas near Wave Transects PL-64 and PL-66 identified in Attachment 1. Attachment 2 contains FEMA STWAVE model significant wave height contours of the 1% annual chance coastal storm. Attachment 3 shows the contouring of the Peak Wave Period of the 1% annual chance coastal storm. The FEMA Preliminary Map for the area of interest is shown in Attachment 4. These areas are included within the FEMA Preliminary panels 25023C0231K, 25023C0232K, 25023C0233K, and 25023C0234K, respectively. This appeal is focused only on the boundaries and Base Flood Elevations (BFE) for the area near Wave Transects PL-64 and PL-66, and deals only with the 1% annual chance flood as determined by detailed studies. However, these transects were done to illustrate a general principle that wave setup, which largely determines the BFE on the inland side of the outer coast, is overstated and would be lower by several feet if the incident wave height as determined by the STWAVE model were used instead of the deepwater offshore wave height of 30.65’. As explained in detail below, the wave setups as we calculated them, would result in a reduction of the inland BFE from 16-17’ to 13-15’ NAVD88 for Wave Transects PL-64 and PL-66 in the area of detailed studies compared with the BFEs calculated by FEMA through the WHAFIS program.

II. Legal Basis for Appeal

FEMA has issued a Guidance Document dated November 30, 2011, called “Criteria for Appeals of Flood Insurance Rate Maps.” In that document several different criteria are identified as valid bases for appealing Preliminary FIRMs. The basis for this appeal comes from page 7 of the Guidance Document: “Technically Incorrect BFES, Base Flood Depths, SFHA Zone Designations, or Regulatory Floodways.” Ransom applied a new hydrologic analysis in which the original methodology was applied differently (“the methodology was not applied correctly”) More specifically, the appeal is based on:

1) Use of a different incident wave height and period than used by FEMA on each of the two transects based on the examination of the significant wave height (Hs=Hmo) contours given to us by STARR as an x,y,z file as output from STARR’s STWAVE model for Plymouth County. The incident wave height and period were selected near the

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1 The modeling, calculations, reporting, and website from which Ransom downloaded data were created by STARR, the consultant for FEMA. However, since the maps are being promulgated by FEMA, the report commonly refers to FEMA as if it were the creator of the studies being challenged.

2 Ransom Consulting, Inc., is a civil and environmental engineering firm with offices in Hamilton, New Jersey; Providence, Rhode Island; Byfield, Massachusetts; Portsmouth, New Hampshire; and Portland, Maine
shore where the density of wave contours increased (suggesting breaking) and was approximately equal to one wave length out from the shore. As explained below, this methodology has been used and accepted in coastal studies in Maine that have been prepared by Ransom and accepted by FEMA.

III. Technical Basis of the Appeal

Ransom Consulting, Inc. (Ransom), prepared the technical aspects of this appeal. Elevations are all referenced to NAVD88 in feet, unless otherwise noted.

The Wave Transects that this appeal focuses on that were used in the FEMA setup, CHAMP, and runup models for the detailed studies in this area are shown on Attachment 1. Coastal flood analyses require a number of modeling calculations in a certain sequence and can become quite complicated. STARR has developed a lengthy and complex MATHCAD sheet to compute many of the intermediate modeling steps that may be required. Ransom has used STARR’s MATHCAD sheet, where appropriate, and their assumptions and inputs, where appropriate. This report points out where the Ransom inputs and methodology differ from STARR’s.

The first and most important step in the process is defining the incident significant wave height and peak period that is used to calculate wave setup and drive the CHAMP and runup models. With the exception of inside Duxbury Bay, all of the incident wave heights used by FEMA are deep offshore ocean waves calculated as the 1% annual chance offshore wave calculated from WIS station statistics. For Duxbury Bay, as an example, STARR uses a significant incident wave height for Wave Transect PL-113 of 30.67’ and for the adjacent Wave Transect PL-112 the incident wave height is 4.76’. The latter was derived from a nested grid STWAVE model carved out of a coarser grid STWAVE model that covers all of Plymouth County. For unknown reasons, then, STARR uses its STWAVE model to pick off incident wave heights for the purpose of calculating wave setup, critical wave height (WHAFIS), and wave runup inside Duxbury Harbor, but nowhere else in Plymouth County. We note that Ransom has performed a lot of STWAVE modeling on the coast of Maine as part of FEMA appeals and LOMRs to develop incident wave heights for the purpose of calculating wave setups, CHAMP inputs and runup. This approach has been discussed with Region 1 and adopted as an acceptable way to calculate incident wave heights.

Ransom has taken the x,y,z nested STWAVE significant wave height and Tp “results” files and gridded them in SURFER™ at a grid cell size of Δ10m x Δ10m and then contoured it to develop maps of wave height and of wave period and from those maps, chose incident wave heights and periods for PL-64 and PL-66 (Attachments 2 and 3). Using these data, Ransom calculated wave setup, then ran WHAFIS and then ran the appropriate runup models.

Attachment 5 is the Excel spreadsheet used to do an independent check on the open ocean wave setup for PL-64. Attachment 6 is STARR’s MATHCAD sheet for PL-64 modified by Ransom to take into account a different choice of incident wave properties. Attachment 7 is the WHAFIS intact revetment model text output. Attachment 8 is the Wave Profile from WHAFIS with the Runup added by hand to the intact revetment condition. Attachment 9 is the WHAFIS
failed revetment model text output. **Attachment 10** is the Wave Profile from WHAFIS with the Runup added by hand to the failed revetment condition.

**Attachment 11** is the Excel spreadsheet used to do an independent check on the open ocean wave setup for PL-66. **Attachment 12** is STARR’s MATHCAD sheet for PL-66, modified by Ransom for a different choice of incident wave properties. **Attachment 13** is the worksheet to develop the input for the ACES runup model for PL-66 intact revetment condition. **Attachment 14** text output for the WHAFIS model of the intact revetment condition. **Attachment 15** is the Wave Profile from WHAFIS with the Runup added by hand to the intact revetment condition for PL-66. **Attachment 16** is the WHAFIS failed revetment model text output. **Attachment 17** is the Wave Profile from WHAFIS with the Runup added by hand to the failed revetment condition for PL-66.

**Attachment 18** is Ransom’s remapping of the flood zones around PL-64 and PL-66.

The summary of results and comparison with the FEMA results are summarized in the Table in **Attachment 19**.

**Other Comments:**

Besides the major comment that STWAVE should have been used to define the incident wave height and period for setup, WHAFIS, and runup modeling, Ransom has two other comments on the new MATHCAD sheet developed by STARR. First, the decision tree for the choice of porosity reduction factor in the TAW Runup portion of the sheet does not function properly. For the porosity = 0.1 and porosity = 0.4 the reduction factors are supposed to be proportioned between the calculated value for porosity = 0.5 and no reduction (reduction factor = 1.0); however that is not the case in the sheet.

Second, the “berm” reduction factor in the TAW Runup portion of the sheet is toggled to either 1.0 or 0.6 regardless of the elevation of the berm relative to SWEL or to the width of the berm. Ransom suggests that STARR add a note asking the user to use the TAW recommended formula for calculating the berm reduction factor.

We noted late in our work that the GIS files given to us by STARR contained two separate S_FLD_HAZ_AR shape files. We worked with and modified the one we found in the “Spatial” subdirectory of the Plymouth County detailed study files. In producing **Attachment 18** we noticed that there appeared to be an AO zone missing in STARR’s shape file along Wave Transect PL-061. After searching around in the complex directory tree in the download we obtained from STARR, we found another shape file of the same name that contained AO and X zones which were missing in the file we used from the “Spatial” subdirectory. We are not proposing to modify the AO or X zones, particularly the AO zone in the vicinity of PL-061. In **Attachment 18** we have only labeled the zones that Ransom modified. Zones where Ransom did not modify the Zone type or BFE are not labeled.
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Attachments 1-19, and CD with model data sets and associated files
Transect Locations upon which appeal is Based
Marshfield, MA
Base Maps are USGS Marshfield 7.5’ quads
Grid is Mass. State Plane, Mainland, NAD83 (m)
RGG 9/30/13   131.06145

Attachment 1
Legend

FEMA Wave Transect
TRANSECT No.
- PL-064
- PL-066
- Hs Wave Height (m)

STARR Nested Grid Wave Heights upon which appeal is Based
Marshfield, MA
Base Maps are USGS Marshfield 7.5' quads
Grid is Mass. State Plane, Mainland, NAD83 (m)
RGG 9/30/13   131.06145

Attachment 2
Legend

FEMA Wave Transect
TRANSECT No.

- PL-064
- PL-066

Tp_Main Wave model
Tp, seconds

- 10.5
- 11
- 11.5

STARR Main Wave Model Peak Period upon which appeal is Based
Marshfield, MA
Base Maps are USGS Marshfield 7.5' quads
Grid is Mass. State Plane, Mainland, NAD83 (m)
RGG 9/30/13 131.06145

Attachment 3
FEMA Preliminary Coastal Floodplain Designations
Marshfield, MA
Base Maps are USGS Marshfield 7.5' quads
Grid is Mass. State Plane, Mainland, NAD83 (m)
RGG 9/30/13  131.06145
Wave Setup for Marshfield, MA, Transect PL-64 Intact

LO 642.9 ft INCIDENT WAVE LENGTH
H0 11.5 ft INCIDENT WAVE HEIGHT FROM STWAVE Model
Ho/Lo 0.0179 ft/ft DEEPWATER WAVE STEEPNESS
Hb 13.3246344 ft CALCULATE Hb USING MUNK 1949

Instructions: Insert Values into Highlighted Cells

Lo 642.9 ft INCIDENT WAVE LENGTH
H0 11.5 ft INCIDENT WAVE HEIGHT FROM STWAVE Model
Ho/Lo 0.0179 ft/ft DEEPWATER WAVE STEEPNESS
Hb 13.3246344 ft CALCULATE Hb USING MUNK 1949

Legend:

1% SWEL 10.46 NAVD88 TOP OF SLOPE
17.08286 ft of water supports the breaking wave height
therefore, -6.62286 NAVD88 BOTTOM OF SLOPE

Rise 17.08286 ft
Run 757.6355 ft
Slope 0.022548
1:ON 44.3506

Wave Setup

H'o = 11.5 feet DEEPWATER SIGNIFICANT WAVE HEIGHT
T = 11.2 sec PEAK WAVE PERIOD
m = 0.0225 ft/ft AVERAGE SLOPE OF TRANSECT
Lo = 642.9 ft DEEPWATER WAVELENGTH
H'o/Lo = 0.0179 ft/ft DEEPWATER WAVE STEEPNESS

Irabarren Number 0.1686 ft/ft
I.N. = m/sqrt(Ho/Lo)

Sigma(2) 0.5816 ft

n 1.92717316 ft TOTAL STATIC SETUP
n = 4.0*G(H)*G(T)*G(Gamma)*G(Slope)

FEMA extracted profile
Interpolation

x y delta y delta x
39.77 4.364 -19.483 -34
73.77 23.847 0 0
-708.23 -6.63762
-706.23 -6.60819

Find depth of wave breaking using 0.78Db=Hb

10.46 NAVD88 top of slope

Db 17.0828647 ft

FIND DEPTH OF WAVE BREAKING USING 0.78Db=Hb

1% SWEL 10.46 NAVD88 TOP OF SLOPE
17.08286 ft of water supports the breaking wave height
therefore, -6.62286 NAVD88 BOTTOM OF SLOPE

Rise 17.08286 ft
Run 757.6355 ft
Slope 0.022548
1:ON 44.3506

Instructions: Insert Values into Highlighted Cells

xcoord of sought for y value of elevation at Db

757.6355 calculated run

Sigma(2) = 0.3*I.N.*Ho

Graph:

-4000 -3000 -2000 -1000 0 1000 2000

-40 -30 -20 -10 0 10 20 30

757.6355 calculated run
Wave Height, Wave Period, Wave Setup, and Failed Revetment / Coastal Barrier / Steep Bluff Worksheet

1.0 Purpose/Objective

This worksheet was created to determine the unrestricted \( H_{m0} \) and \( T_p \) where \( H_{m0} \) is the energy-based significant wave height in meters and \( T_p \) is the limiting wave period, or use user input \( H_{m0} \) and \( T_p \) values from ACES or STWAVE models. This worksheet also calculates the open coast wave setup, \( \eta_{\text{open}} \), which is the increase in stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributor to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. This worksheet also evaluates the wave setup against a coastal structure, \( \eta_{\text{structure}} \). For profiles with sloping revetments, this worksheet will also perform a failed structure analysis and generate a new profile of the failed structure and calculate the wave setup on the failed revetment.

2.0 Procedure

For unrestricted fetch length analysis where no STWAVE or ACES model run was produced, an extremal analysis was performed to determine three thresholds for peak wind speeds. The threshold with the highest correlation to either the Fisher-Tippett Type 1 (Gumbel), Fisher-Tippett Type II (Frecher), or Wiebull distribution is input parameter \( U_{10} \) or the wind speed at 10m elevation (m/sec). Fetch, \( X \), was also determined for each location. An excel spreadsheet for each transect was generated to calculate the 1% annual chance stillwater elevation. These variables are input into this worksheet from external worksheets and used for calculation within this worksheet.

Calculation worksheet details:
1. Go to View> Header and Footer... and fill out ALL relevant information to worksheet
2. Enter similar information on Page 2
3. Use radio buttons to select if analysis is based on "Unrestricted Fetch Wind Speed Input", "Restricted Fetch Input From ACES (\( H_{m0}, T_p \))", or "STWAVE Input (\( H_{m0}, T_p \))"

Section 5.1 - Wave Height and Wave Period
4. Fill in value of \( U_{10} \) and list peak threshold, regression, and correlation coefficient and associated files
5. If fetch length is unrestricted, continue to section 5.1.1, otherwise, skip section 5.1.1

Section 5.1.1 - Unrestricted Wave Height and Wave Period Calculation
6. Fill in value of Fetch, X, and list associated calculation files.
7. Skip Section 5.1.2 and Section 5.1.3 if fetch length is unrestricted

**Section 5.1.2 - Restricted Wave Height and Wave Period Calculation**
8. If ACES model run was complete enter ACES program inputs including the fetch angles and fetch lengths used in the restricted analysis in ACES
9. List the .mxd file and associated information involved in the calculation of fetch lengths
10. Fill in results of $H_m^0$ and $T_p$ from the ACES analysis and any ACES output files which were saved
11. Skip section 5.1.3

**Section 5.1.3 - STWAVE Wave Height and Wave Period**
12. If STWAVE model run was complete enter the associated wave height and wave period
13. List the associated STWAVE model file

**Section 5.2 - Wave Setup**
14. Enter value for average transect slope and associated .mxd file from which average slope was calculated

**Section 5.2.1 - Open Coast Wave Setup Calculation**
15. Enter Profile variable excel file path information. Excel file should be formatted with the first row of the file having column headings. The first column within the file should have station data in ascending order. The second column within the file should have the associated station elevation in order of ascending station. All data should be in feet. This file needs to be an .xls file as Mathcad is not currently compatible with .xlsx files.
16. Enter horizontal distance from shoreline along transect which identifies the start of the coastal structure, $Toe_{sta}$, in feet
17. Enter horizontal distance from shoreline along transect which identifies the top of the coastal structure, $Top_{sta}$, in feet
18. Enter value for $SWEL$, 1% annual chance stillwater elevation in feet and name and path of associated excel file from which SWEL was calculated

**Section 5.3 - Wave Runup - TAW Method**
19. Check Slope$_{Check}$ and Iribarren$_{Check}$ variables to determine if TAW method holds for these situations
20. Use radio buttons to select runup reduction factors
21. Enter incident angle, $\beta$, if known, otherwise, assume 0

**Section 5.4 - Failed Revetment Analysis**
22. Enter approximate depth of armor layer in feet based on photographs and site inspections (ft)
23. Check value of $Toe_{location}^r$, $Mid_{location}^r$, $Quarter_{location}^r$, and $Top_{location}^r$ which should be the location in the Station array which holds the value of $Toe_{sta}$, $Mid_{sta}$, $Quarter_{sta}$, and $Top_{sta}$. If the horizontal distance from the shoreline along the transect to these locations were not measured
points in the Station array, then Toe\_location, Mid\_location, Quarter\_location, and/or Top\_location should be arrays of two values representing the indices which the value of Toe\_sta, Mid\_sta, Quarter\_sta, and/or Top\_sta are between. If none or more than two values are listed, adjust the convergence tolerance (TOL) from the Tools > Worksheet Options option in the menu bar, until two values are listed for the Toe\_location, Mid\_location, Quarter\_location, and/or Top\_location variables.

**Section 5.5 - Wave Setup on Failed Revetment**

**Section 5.6 - Wave Runup on Failed Revetment**

24. Check SlopeCheck and IribarrenCheck variables to determine if TAW method holds for these situations

25. Use radio buttons to select runup reduction factors

26. Enter incident angle, \( \beta \), if known, otherwise, assume 0

**Section 6.0 - Conclusions**

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**3.0 References/Data Sources**

Equation taken from Coastal Engineering Manual Part II (Publication date: August 1, 2008)

Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February, 2007

Guidelines and Specifications for Flood Hazard Mapping Partners [February 2007]

Coastal Engineering Manual Part VI

**4.0 Assumptions**

**Unrestricted Wave Height and Wave Period Mathcad Calculation:**

1. One of the following situations hold:
   - Wind blows, with essentially constant direction, over a fetch for sufficient time to achieve steady-state, fetch-limited values
   - Wind increases very quickly through time in an area removed from any close boundaries. Wave growth is considered duration-limited. RARE condition
   - Fully developed wave height, however, open-ocean waves rarely attain a limiting wave height for wind speeds above 50 knots of so.

2. Wave growth with fetch.

3. Wind speeds collected were taken at 10 m, to be a \( U_{10} \) measurement of wind speeds

**Open Coast Wave Setup and Wave Setup on Existing and Failed Structures Analysis**

1. Wave height, \( H_{m0} \), is the deepwater wave height and is not in water of transitional depth
2. The wave setup calculated is a "static" wave setup, during which the storm tide and incident wave conditions remain unchanged.
3. The open coast wave setup calculation does not consider wave nonlinearity, wave breaking characteristics, profile slope, or wave propagation through vegetation.
4. Dynamic wave setup component is not considered, as it is small by comparison with the static component for the locations considered.
5. Wave period, $T_p$, remains constant and independent of depth for oscillatory waves.

**Wave Runup Analysis on Failed and Existing Structures - Technical Advisory Committee for Water Retaining Structures (TAW) Method**

1. The TAW method is assumed to hold for all barriers, revetments, or dunes which have a slope of 1:8 or steeper.
2. The shallow water significant wave height is assumed to be 88% of the deep water significant wave height.
3. The breaking wave height is assumed to be 78% of the water depth at the toe of the barrier, revetment, or dune.
4. The TAW method is assumed to hold for Iribarren numbers in the range of 0.5 to 10.
5. The incident wave angle is assumed to be 0 in most cases.
6. Assuming berm width is unknown, minimum and maximum berm section breakwater reduction factors were assumed for conditions when a berm does and does not exist respectively.
7. The runup values calculated are the 2% exceedence probability values.

**Failure of a Sloping Revetment**

1. Landslide of revetment has constant slope.
2. The scour depth does not include any parameters relating to sediment properties, which are expected to have some influence on the scouring process.
3. The scour at the base of the structure is equal to the depth of the armored layer.
4. The structure will collapse in place into a triangular section throughout the structure footprint, with side slopes equal to the original structure slope.
5. The landward side of the failed configuration will be half exposed and half buried.
6. The soil slope landward from the failed structure fails to a uniform 1:1.5 slope, which extends to existing grade.
7. Slope recedes back from the toe of the revetment at a 1:3 slope.

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**Wave Height, Wave Period, Wave Setup, Failed Vertical Structure Calculation Worksheet**

Modeler Name: Robert G. Gerber
Date: Sept. 18, 2013
County: Plymouth, MA
Transect Number: PL-66
Airport:
Years of Data set: ST WAVE MODEL
5.0 Calculations

List of Variables:

**Constants:**
- \( g \) - Gravitational acceleration (m/sec^2)

**Inputs:**
- \( X \) - straight line fetch distances over which the wind blows (miles)
- \( U_{10} \) - Wind speed at 10 m elevation (ft/sec)
- \( H_{m0STWAVE} \) - Deep water significant wave height input by user from STWAVE model
- \( T_{PSTWAVE} \) - Wave period input by user from STWAVE model
- \( m \) - Average slope of transect (dimensionless)
- Profile - Excel file with station (ft) and elevations (ft) of transect profile
- \( \text{Toe}_{sta} \) - Horizontal location of toe of structure relative to shoreline (ft)
- \( \text{Top}_{sta} \) - Horizontal location of top of structure relative to shoreline (ft)
- \( \text{SWEL} \) - 1% Annual Chance Stillwater Elevation (ft)
- Armor\( D \) - Depth of armor layer on a sloping revetment (ft)
- ACESInput\( \text{Ang} \) - Angle of fetches input into ACES analysis (deg)
- ACESInput\( \text{Fetch} \) - Fetch length of fetches input into ACES analysis (ft)
- \( H_{m0ACES} \) - Deepwater significant wave height from ACES analysis (ft)
- \( T_{PACES} \) - Limiting wave period from ACES analysis (sec)

**Working Variables:**
- \( C_D \) - Coefficient of drag for winds measured at 10 meters (dimensionless)
- \( u_s \) - Wind friction velocity (m/sec)
- \( L_0 \) - Deep water wave length (ft)
- \( S \) - Wave slope (dimensionless)
- \( \text{Toe}_{ele}, \text{Mid}_{ele}, \text{Quarter}_{ele}, \text{Top}_{ele} \) - Elevation of toe, midpoint, upper quarter, and top of revetment from interpolation (ft)
- Station - Array of station (ft) of existing (non-failed) profile
- Elevation - Array of elevations (ft) of existing (non-failed) profile
### Wave Height and Wave Period Calculation Worksheet

**PL-64**

**Calc By:** RGG  
**Date:** 9-30-13

**Variables:**
- **h**: Water depth from the top of the water surface against a structure to the toe of the structure (ft)
- **bh**: Dimensionless breaking wave height
- **Hb**: Breaking wave height (ft)
- **bd**: Dimensionless breaking wave depth (dimensionless)
- **Hd**: Breaking wave depth (ft)
- **R**: Wave setup relative to maximum wave setup (dimensionless)
- **ηopen**: Open coast wave setup (ft)
- **η1**: Wave setup component on a coastal structure from the water depth at the toe of a coastal structure (ft)
- **η2**: Wave setup component determined for a sloping coastal structure (ft)
- **h2**: Water depth over coastal structure when overtopping occurs (ft)
- **ηstructure**: Total wave setup on a structure or steep slope (ft)
- **Hfail**: Wave height used for analysis of failed structure equal to Hm0, or the energy-based significant wave height, Hm0, but limited to a maximum equal to the breaking wave height, Hb (ft)
- **Sm**: Maximum scour depth (ft)
- **ToeVscour**: Elevation of toe of vertical coastal structure after scour occurs (ft)
- **ηlocation**/Midlocation/Quarterlocation/Toplocation**: Index of location of bottom of vertical coastal structure or revetment, midpoint of revetment, quarter, and top of revetment within the Station array (dimensionless)
- **Offset**, Offsettoe, Offsetmid, Offsetqua, Offsettop, OffsetfailTop**: Dummy variable equal to 0 if the horizontal location of the bottom of the vertical structure, revetment toe, revetment midpoint, revetment quarter distance, revetment top is listed in the Station array, equal to 1 if the horizontal location of the bottom of the vertical structure is not listed in the station array (dimensionless)
- **Toestaloc**, Midstaloc, Quarterstaloc, Topstaloc**: Index of location of toe of vertical coastal structure or revetment, midpoint of revetment, quarter length of revetment, and top of revetment within the station array (dimensionless)
- **Stalastloc**: Index to the last element in the Station array (dimensionless)
- **failed**: Index to the last element in the Station array (dimensionless)
- **i,x,y,z,a,w**: Counter variables (dimensionless)
- **Slope**: Slope of a revetment (dimensionless)
- **Length**: Length of a revetment (ft)
- **Midpoint**, Quarter**: Midpoint and Quarter of the distance along length of revetment (ft)
Midsta, Quartersta - Distance from shoreline to midpoint and quarter distance of sloping revetment (ft)
ToeRscour - Elevation of toe of sloping revetment structure after scour occurs (ft)
end - last index of the station and elevation of the partial failure of a sloping revetment arrays

FailRevetEle - Array of elevations of partial failure of a sloping revetment (ft)
FailRevetSta - Array of station data of partial failure of a sloping revetment (ft)
SlopeRevet - Slope or revetment expressed as a decimal or percentage (dimensionless)
SlopeRevetOneOn - Slope of revetment expressed as the horizontal distance associated with an increase in one vertical foot (string)
SlopeCheck - Indicator variable associated with determining if the TAW method is applicable based on barrier slope (string)
SlopeCheck - Indicator variable associated with determining if the TAW method is applicable based on barrier slope of failed revetment (string)
DepthLimited - Indicator variable associated with determining if the wave is depth limited at the toe of the revetment or structure (string)
WaveType - Indicator variable associated with determining if water is considered to be shallow, deep, or transitional at the toe of the barrier
β - Incident wave angle (degrees)
Tm10 - Spectral wave period (sec)
Hm0Runup, Hm0Runup1 - Significant wave height adjusted if necessary for runup calculations (ft)
γr - Roughness reduction factor (dimensionless)
γb - Berm section in breakwater (dimensionless)
γp - Porosity factor (dimensionless)
γβ - Wave direction factor (dimensionless)
SlopeFAILRevet - Slope or revetment expressed as a decimal or percentage (dimensionless)
SlopeFAILRevetOneOn - Slope of revetment expressed as the horizontal distance associated with an increase in one vertical foot (string)
IribarrenCheck - Indicator variable to determine if the TAW method is applicable based on the Iribarren number (string)
FAILIribarrenCheck - Indicator variable to determine if the TAW method is applicable based on the Iribarren number for the failed revetment (string)
FailTopSta - Station of top of revetment after failure (ft)
FailTopEle - Elevation of top of revetment after failure (ft)

Output:
Hm0 - Energy-based significant wave height (ft)
### 5.1 Wave Height, $H_{m0}$, and Wave Period, $T_p$ Calculation

Definition of Variables:

$$g = 9.81 \text{ m/s}^2$$

Insert $U_{10}$, wind speed in meters per second:

These fields must be populated, but will only be used for calculations if

Select using radio buttons if input(s) is Unrestricted Fetch Length, Restricted Fetch Length, or Wave Height and Wave Period from STWAVE

- Unrestricted Fetch
- Restricted Fetch Input from ACES ($H_{m0}$, $T_p$)
- STWAVE Input ($H_{m0}$, $T_p$)
**unrestricted radio button is selected above**

Wind speed based on CHAMP model default offshore wind = 80 mph

Taken from file:

\[ U_{10} = 35.76 \text{ m/s} \]

\[ U_{10} = 117.32 \text{ ft/s} \]

5.1.1 Calculation of Unrestricted Wave Height, \( H_{m0} \), and Wave Period, \( T_p \)

Insert \( X \), fetch in miles:

\[ X = 12.84 \text{ mi} \quad X = 20663.98 \text{ m} \]

Feature Class used:

Calculate Coefficient of Drag, \( C_D \):

\[ C_D = 0.001 \left[ 1.1 + \left( 0.035 \cdot \frac{U_{10}}{s} \cdot \frac{m}{s} \right) \right] \quad C_D = 0.0024 \]

Calculate Wind Friction Velocity, \( u_s \) (m/sec):

initialize \( u_s \):

\[ u_s := 1 \text{ m/s} \]

Given

\[ C_D = \frac{u_s^2}{U_{10}^2} \]

\[ u_s := \text{Find}(u_s) \quad u_s = 1.73 \text{ m/s} \]

Calculate Wave Height, \( H_{m0} \) (m):

initialize \( H_{m0} := 0.01 \text{ m} \)

\[ X = 20663.98 \text{ m} \]

\[ u_s = 1.73 \text{ m/s} \]

\[ g = 9.81 \text{ m/s}^2 \]

Given
Calculate Wave Period, $T_p$ (sec): 

initialize $T_p$: 

$T_p := 0.01 \text{s}$ 

$X = 20663.98 \text{m}$ 

$u_s = 1.73 \text{ m/s}$ 

$g = 9.81 \text{ m/s}^2$ 

Given 

\[
\frac{g \cdot T_p}{u_s} = 0.751 \left( \frac{g \cdot X}{u_s^2} \right)^{0.5} 
\]

$T_p := \text{Find}(T_p)$ 

$T_p = 5.4 \text{s}$ 

5.1.2 Calculation of Restricted Wave Height, $H_{m0}$, and Wave Period, $T_p$ 

The calculation of restricted wave height, $H_{m0}$, and Wave Period, $T_p$, require the use of ACES software.

Input angle of fetch and fetch length as input to ACES with $0^\circ$ facing North.

Feature Class File:
Aces Output:  

These fields must be populated, but will only be used for calculations if restricted radio button is selected above  

\[ H_{m0\text{ACES}} = 9999 \text{ ft}, \quad T_{P\text{ACES}} = 9999 \text{ sec} \]  

ACES result file: _____________

5.1.3 Input Significant Wave Height (\(H_{m0}\)) and Wave Period (\(T_p\)) taken from STWAVE  

These fields must be populated, but will only be used for calculations if STWAVE Input radio button is selected above

Input the path to the STWAVE Model File: \\
\text{\textbackslash\textbackslash chifednas2\fema\Mass\Plymouth\ENGINEERING\COASTAL\GENERAL}  

\[ H_{m0\text{STWAVE}} = 3.5 \text{ m}, \quad T_{P\text{STWAVE}} = 11.2 \text{ sec} \]

RESULT:  

\[ H_{m0} = \begin{cases} 
H_{m0\text{STWAVE}} & \text{if } \text{FetchStatus} = "\text{STWAVE Input (Hmo, Tp)}" \\
H_{m0\text{ACES}} & \text{if } \text{FetchStatus} = "\text{Restricted Fetch Input from ACES (Hmo, Tp)}" \\
H_{m0} & \text{otherwise}
\end{cases} \]  

\[ H_{m0} = 11.5 \text{ ft}, \quad T_P = 11.2 \text{ sec} \]  

FetchStatus = "STWAVE Input (Hmo, Tp)"  

Based on STWAVE model Results

5.2 Wave Setup, \(\eta\), Calculation

5.2.1 Open Coast Wave Setup Analysis

Definition of Variables:

\[ \eta = \begin{cases} 
0.022548 & \text{Insert value of average transect slope based on GIS data (see Ransom spreadsheet)} \\
\end{cases} \]

Calculate Deep Water Wave Length, \(L_0\):
Wave Height and Wave Period Calculation Worksheet

PL-64

Calc By: RGG
Date: 9-30-13

\[ L_0 = \frac{gT_p^2}{2\pi} \]


Calculate Wave Slope, S:

\[ S = \frac{H_{m0}}{L_0} \]

\[ S = 0.0179 \quad S = 1.79\% \]

Calculate Static Open Coast Wave Setup:

\[ \eta_{\text{open}} = H_{m0} \left( 0.160 \frac{m}{s^{0.2}} \right) \]

\[ \eta_{\text{open}} = 1.93\text{ft} \]

Equation Source: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007 - Equation D.2.6-1

5.2.2 Wave Setup On Structures Analysis for Structures/Steep Slopes (1:8 or Steeper) which Intersect the SWEL

Figure from: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007

Definition of Variables:

Enter path and file name of .xls file containing station and elevation data for transect within the "" below:

Profile := READFILE("PL64_Sta_El.csv", "delimited", 2, 1)

Note: The Path name above corresponds to an excel file containing station and elevation data. The 1st row of the excel file
The following displays Profile data from excel worksheet identified above and lists Station and Elevation as two separate arrays and define elevation and station in feet:

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-3334.7</td>
</tr>
<tr>
<td>1</td>
<td>-3284.7</td>
</tr>
<tr>
<td>2</td>
<td>-3234.7</td>
</tr>
<tr>
<td>3</td>
<td>-3184.7</td>
</tr>
<tr>
<td>4</td>
<td>-3134.7</td>
</tr>
<tr>
<td>5</td>
<td>-3084.7</td>
</tr>
<tr>
<td>6</td>
<td>-3034.7</td>
</tr>
<tr>
<td>7</td>
<td>-2984.7</td>
</tr>
</tbody>
</table>

Array of horizontal distance from the shoreline:

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-3334.7</td>
</tr>
<tr>
<td>1</td>
<td>-3284.7</td>
</tr>
<tr>
<td>2</td>
<td>-3234.7</td>
</tr>
<tr>
<td>3</td>
<td>-3184.7</td>
</tr>
</tbody>
</table>

Array of Elevations associated with each horizontal distance from the shoreline:

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-34.65</td>
</tr>
<tr>
<td>1</td>
<td>-34.34</td>
</tr>
<tr>
<td>2</td>
<td>-34.0</td>
</tr>
<tr>
<td>3</td>
<td>-33.65</td>
</tr>
</tbody>
</table>

The following displays the profile of the
Wave Height and Wave Period Calculation Worksheet

PL-64

Calc By: RGG
Date: 9-30-13

---

**Wave Height and Wave Period Calculation**

**Crest Elev.**

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>105.07</td>
<td>119.07</td>
</tr>
</tbody>
</table>

**Elevation**

**Total Setup**

- **hT+SWEL > Crest Elev.**
- **Recalculate h2**
- **Check overtopping if occurs**

**MathCAD V14**

**Page 14**
Identify station and elevation of the toe of the structure:

\[ \text{Toesta} = 39.77 \text{ ft} \]

\[ \text{Toe}_{\text{ele}} := \text{interp}(\text{Station}, \text{Elevation}, \text{Toesta}) \]

\[ \text{Toe}_{\text{ele}} = 4.36 \text{ ft} \]

Identify station and elevation of the top of the structure:

\[ \text{Topsta} := 73.77 \text{ ft} \]

\[ \text{Top}_{\text{ele}} := \text{interp}(\text{Station}, \text{Elevation}, \text{Topsta}) \]

\[ \text{Top}_{\text{ele}} = 23.85 \text{ ft} \]

Enter 1% annual chance stillwater elevation (ft):

\[ \text{SWEL} := 10.46 \text{ ft} \]

Associated excel file for calculation of 1% annual chance stillwater elevation (SWEL): ________
Calculate Water Depth at Structure, $h$

$$h = \text{SWEL} - \text{Toele} \quad h = 6.1 \text{ ft}$$

Calculate the Breaking Wave Height, $H_b$:
Calculate the Breaking Wave Depth, $H_b$:

\[ b_h = 0.8481 \cdot S + 0.0057 \quad b_h = 0.02 \]

Estimated curve equation in Figure D.2.6-7

\[ H_b = b_h \cdot L_0 \quad H_b = 13.41 \text{ ft} \]
Wave Height and Wave Period Calculation Worksheet

PL-64

Calc By: RGG
Date: 9-30-13

Figure from: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007

bd = 1.2205 s + 0.0033  
bd = 0.03  
Estimated curve equation from Figure D.2.6-8

Hd = bd \cdot L0  
Hd = 16.16 ft

Calculate Wave Setup on a Structure, η_{structure}.
Equation based on estimated curve from Figure D.2.6-9

\[
R_W = \begin{cases} 
0.8 \left( \frac{h}{H_d} \right) + 1 & \text{if } 0 \leq \frac{h}{H_d} \leq 0.092 \\
-0.3919 \left( \frac{h}{H_d} \right) + 0.9585 & \text{if } 0.092 < \frac{h}{H_d} \leq 0.4 \\
-0.3475 \left( \frac{h}{H_d} \right) + 0.9379 & \text{if } 0.4 < \frac{h}{H_d} \leq 0.9 \\
-33.312 \left( \frac{h}{H_d} \right)^2 + 59.811 \left( \frac{h}{H_d} \right) - 26.223 & \text{if } 0.9 < \frac{h}{H_d} \leq 0.94444 \\
-9.8703 \left( \frac{h}{H_d} \right) + 9.8703 & \text{if } 0.94444 < \frac{h}{H_d} \leq 1 \\
0 & \text{otherwise}
\end{cases}
\]
5.3 Wave Runup Analysis (Using TAW Method)

Flow Chart of Process of Calculating Wave Runup:

\[ R = 0.81 \quad \frac{h}{H_d} = 0.38 \]

\[ \eta_1 = R \cdot \eta_{open} \quad \eta_1 = 1.56 \text{ ft} \quad \eta_2 = 0.15 (h + \eta_1) \quad \eta_2 = 1.15 \text{ ft} \]

\[ \eta_{Structure} := \eta_1 + \eta_2 \quad \eta_{Structure} = 2.71 \text{ ft} \]

Check Overtopping if Coastal Structure Exists:

Overtopped := "Yes" if \((\eta_{Structure} + \text{SWEL}) > \text{Topele}\)

Overtopped := "No" otherwise

\[ h_2 := \begin{cases} \eta_{Structure} + \text{SWEL} - \text{Topele} & \text{if Overtopped = "Yes"} \\ 0 & \text{otherwise} \end{cases} \]

Equation D.2.6-12 for \( \eta_2 \) from Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update

\[ \eta_2 = \begin{cases} 0.15 (h + \eta_1) \left[ 1 - \left( \frac{h_2}{h} \right)^2 \right] & \text{if Overtopped = "Yes"} \\ \eta_2 & \text{otherwise} \end{cases} \]

\[ \eta_{Structure} := \eta_1 + \eta_2 \quad \eta_{Structure} = 2.71 \text{ ft} \]

Total Setup against a coastal structure without considering overtopping

Overtopped = "No"

Total Setup with a coastal structure

5.3 Wave Runup Analysis (Using TAW Method)
Checking Slope of Revetment to determine if it is between 1:1 and 1:8:

\[ \text{Slope}_{\text{Rev}} = \frac{(\text{Tople} - \text{Toele})}{(\text{Topsta} - \text{Toesta})} \]
\[ \text{Slope}_{\text{Rev}} = 57.3\% \]

\[ \text{Slope}_{\text{Rev,oneon}} = \frac{1}{\text{Slope}_{\text{Rev}}} \]
\[ \text{Slope}_{\text{Rev,oneon}} = 1.75 \]
SlopeCheck := "TAW Method of Runup Calculation Applies" if \(0 < \text{SlopeRevetOneOn} \leq 8\) 
"TAW Method Does Not Apply, Switch to Runup-2.0" otherwise

SlopeCheck = "TAW Method of Runup Calculation Applies"

Check if Wave is Depth Limited at the Toe of the Revetment / Barrier:

DepthLimited := "Limited" if \(H_{m0} \geq 0.78h\)
"Not Limited" otherwise

If wave is depth limited, \(H_b\) will be used rather than \(H_{m0}\)

DepthLimited = "Limited"

Determine Wave Type:

WaveType := "Shallow" if \(\frac{h}{L_0} < 2\)
"Transitional" if \(0.2 \leq \frac{h}{L_0} < 0.5\)
"Deep" otherwise

WaveType = "Shallow"

Determine Significant Wave Height Depending on Wave Type and DepthLimited Condition:

\(H_{m0 runup 1} := \begin{cases} 0.88 \cdot H_{m0} & \text{if WaveType = "Shallow"} \\ H_{m0} & \text{otherwise} \end{cases}\)

\(H_{m0 runup 1} = 10.12\) ft

\(H_{m0 runup} := \begin{cases} 0.78 \cdot h & \text{if DepthLimited = "Limited"} \\ H_{m0 runup 1} & \text{otherwise} \end{cases}\)

\(H_{m0 runup} \approx 4.75\) ft
Calculate the Spectral Wave Period, $T_{m10}$

$$T_{m10} := \frac{T_p}{1.1}$$  \hspace{1cm} \text{Equation D.2.8-16}  \hspace{1cm} T_{m10} = 10.18 \text{s}$$

Calculate the Wave Length Associated with the Spectral Wave Period, $L_{m0}$:

$$L_{m0} := \frac{g T_{m10}^2}{2 \pi}$$  \hspace{1cm} \text{Equation D.2.8-3}  \hspace{1cm} L_{m0} = 530.86 \text{ft}$$

Calculate the Iribarren Number, $\xi_{om}$:

$$\xi_{om} := \frac{\text{Slope Revet}}{\sqrt{\frac{H_{m0runup}}{L_{m0}}}}$$  \hspace{1cm} \xi_{om} = 6.05$$

Check TAW Method for Validity based on Iribarren Number:

$$\text{IribarrenCheck} := \begin{cases} 
"TAW method is Valid" & \text{if } 0.5 < \xi_{om} < 10 \\
"TAW method is NOT valid for this Iribarren value. Please seek alternative method." & \text{otherwise}
\end{cases}$$

$$\text{IribarrenCheck} = "TAW method is Valid"$$

Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:
Table D.2.8-5. Summary of Runup Reduction Factors

<table>
<thead>
<tr>
<th>Runup Reduction Factor</th>
<th>Characteristic/Condition</th>
<th>Value of $\gamma$ for Runup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness Reduction Factor, $\gamma_r$</td>
<td>Smooth Concrete, Asphalt, and Smooth Block Revetment</td>
<td>$\gamma_r = 1.0$</td>
</tr>
<tr>
<td></td>
<td>1 Layer of Rock With Diameter, D.</td>
<td>$\gamma_r = 0.55$ to 0.60</td>
</tr>
<tr>
<td></td>
<td>$H_s / D = 1$ to 3.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 or More Layers of Rock $H_s / D = 1.5$ to 6.</td>
<td>$\gamma_r = 0.5$ to 0.55</td>
</tr>
<tr>
<td></td>
<td>Quadratic Blocks</td>
<td>$\gamma_r = 0.70$ to 0.95. See Table V-3-3 in CEM for greater detail</td>
</tr>
<tr>
<td>Berm Section in Breakwater, $\gamma_b$</td>
<td>$B$ = Berm Width, $\frac{\pi d_h}{X}$ in radians.</td>
<td>$\gamma_b = \frac{B}{2L_{berm}} \left[ 1 + \cos \left( \frac{\pi d_h}{X} \right) \right]$, $0.6 &lt; \gamma_b &lt; 1.0$</td>
</tr>
<tr>
<td></td>
<td>Berm Present in Structure Cross section. See Figure D.4.5-8 for Definitions of $B$, $L_{berm}$ and Other Parameters</td>
<td>$x = \begin{cases} R \text{ if } \frac{R}{H_{mo}} \leq \frac{d_h}{H_{mo}} \leq 0 \ 2H_{mo} \text{ if } 0 \leq \frac{d_h}{H_{mo}} \leq 2 \end{cases}$ (D.2.8-11)</td>
</tr>
<tr>
<td></td>
<td>Minimum and maximum values of $\gamma_b = 0.6$ and $1.0$, respectively</td>
<td></td>
</tr>
<tr>
<td>Wave Direction Factor, $\gamma_\phi$, $\phi$ is in degrees and $= 0^\circ$ for normally incident waves</td>
<td>Long-Crested Waves ($1.0.0 &lt;</td>
<td>\phi</td>
</tr>
<tr>
<td></td>
<td>Short-Crested Waves ($1 - 0.0022</td>
<td>\phi</td>
</tr>
<tr>
<td>Porosity Factor, $\gamma_p$</td>
<td>Permeable Structure Core</td>
<td>$\gamma_p = 1.0$, if $\phi_{mo} &lt; 3.3$, $\gamma_p = 1.17(\phi_{mo})^{0.66}$, $\phi_{mo} \geq 3.3$ and porosity $= 0.5$. for smaller porosities, proportion $\gamma_p$ according to porosity. See Figure D.2.8-7 for definition of porosity (D.2.8-14)</td>
</tr>
</tbody>
</table>
Select Roughness Reduction Factor, $\gamma_r$:  
- Smooth Concrete, Asphalt, and Smooth Block Revetment  
- 1 Layer of Rock with Diameter, $D$, where $H_s/D = 1$ to $3$  
- 2 or More Layers of Rock where $H_s/D = 1.5$ to $6$  
- Quadratic Blocks

Default Value - 1 layer of rock with diameter $H_s/D = 1$ to $3$

\[
\gamma_r = \begin{cases} 
\gamma_{r} & \text{if } \gamma_r \geq 0.53 \\
"Please Select Radio Button" & \text{otherwise}
\end{cases}
\]

Select Berm Section in Breakwater, $\gamma_b$:  
- Berm Present  
- No Berm Present

Default Value - No Berm

\[
\gamma_b = \begin{cases} 
\gamma_{b} & \text{if } \gamma_b > 0.5 \\
"Please Select Radio Button" & \text{otherwise}
\end{cases}
\]

Select Wave Direction Factor, $\gamma_\beta$:  
- $\beta = 0$  
- $0^\circ$ for normally incident wave

Default Value - Short Crested Wave with normally incident wave

\[
\gamma_\beta = \begin{cases} 
1 - 0.0022 |\beta| & \text{if } 0 \leq |\beta| < 80 \land \gamma_\beta = 1 \\
1 - 0.0022 |80| & \text{if } (|\beta| \geq 80) \land \gamma_\beta = 1 \\
1 & \text{if } 0 \leq |\beta| < 10 \land \gamma_\beta = 2 \\
\cos\left(\left(\frac{\pi}{180}\right) - 10\right) & \text{if } (10 \leq |\beta| < 63 \land \gamma_\beta = 2) \\
0.63 & \text{if } |\beta| \geq 63 \land \gamma_\beta = 2 \\
"Please Select Radio Button" & \text{otherwise}
\end{cases}
\]

$\gamma_\beta = 1$
Wave Height and Wave Period Calculation Worksheet

Select Porosity Factor, $\gamma_p$:

- 0.1
- 0.4
- 0.5
- 0.6

Default Porosity = 0.5

Summary of Reduction Factors:

- $\gamma_p = 0.75$
- $\gamma_b = 1$
- $\gamma_r = 0.58$

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P:\2013\131.06126\Scituate, MA\Scituate\Coastal\1090002\Plymouth\Plymouth_Coastal_PMR\Offshore_Wave_Models\Mathcad\Simulations\Production_Runs\Wave_Model\Ransom PL64_HmoTp_Setup_Runup_REVETMENT.xmcdz
Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:

\[ R_{2\%} = \begin{cases} 
H_{m0}r_{\text{runup}} & \text{if } 0.5 \leq \gamma_b \cdot \xi_{\text{om}} < 1.8 \\
H_{m0}r_{\text{runup}} \left[ \gamma_r \cdot \gamma_b \cdot \gamma_p \left( 4.3 - \frac{1.6}{\sqrt{\xi_{\text{om}}}} \right) \right] & \text{if } 1.8 \leq \gamma_b \cdot \xi_{\text{om}} \\
0 & \text{otherwise}
\end{cases} \]

\[ R_{2\%} = \begin{cases} 
"TAW Not Valid" & \text{if } \text{SlopeCheck} = "\text{TAW Method Does Not Apply, Switch to Runup-2.0}" \\
"TAW Not Valid" & \text{if } \text{IribarrenCheck} = "\text{TAW method is NOT valid for this Irbarren value. Please seek alternative method.}" \\
R_{2\%} & \text{otherwise}
\end{cases} \]

\[ R_{2\%} = 7.51 \text{ ft} \]

Check for Overtopping:

\[ \text{OVERTOPPED}_{\text{Runup}} := \begin{cases} 
"Overtopped... Please consider 3 foot rule" & \text{if } \left( R_{2\%} + \text{SWEL} \right) > \text{Topele} \\
"NO Overtopping" & \text{otherwise}
\end{cases} \]

\[ \text{OVERTOPPED}_{\text{Runup}} = "\text{NO Overtopping}" \]

5.4 Failed Revetment Structure Analysis

\[ \text{ArmorD} = 4 \text{ ft} \]

Insert Depth of Armor layer in Feet

Calculate Slope of the Revetment:
Calculate the Midpoint of the Revetment:

\[ \text{Slope} = \frac{(\text{Top}_{\text{ele}} - \text{Top}_{\text{ele}})}{(\text{Top}_{\text{sta}} - \text{Top}_{\text{sta}})} \]

\[ \text{Slope} = 0.57 \]

\[ \text{Length} = \sqrt{(\text{Top}_{\text{sta}} - \text{Toe}_{\text{sta}})^2 + (\text{Top}_{\text{ele}} - \text{Toe}_{\text{ele}})^2} \]

\[ \text{Length} = 39.19 \text{ ft} \]

\[ \text{Midpoint} = \frac{\text{Length}}{2} \]

\[ \text{Midpoint} = 19.59 \text{ ft} \]

Determine the Distance from the Shoreline to the Midpoint of the Revetment:

\[ \text{Mid}_{\text{sta}} = \left[ \left( \frac{\text{Midpoint}}{\text{Length}} \right) \times (\text{Top}_{\text{sta}} - \text{Toe}_{\text{sta}}) \right] + \text{Toe}_{\text{sta}} \]

\[ \text{Mid}_{\text{sta}} = 56.77 \text{ ft} \]

Determine the Elevation of the Midpoint of the Revetment:

\[ \text{Mid}_{\text{ele}} := \text{interp} (\text{Station}, \text{Elevation}, \text{Mid}_{\text{sta}}) \]

\[ \text{Mid}_{\text{ele}} = 14.11 \text{ ft} \]

Calculate the Upper Quarter of the Revetment:

\[ \text{Quarter} := \frac{\text{Length} \times 3}{4} \]

\[ \text{Quarter} = 29.39 \text{ ft} \]

Determine the Distance from the Shoreline to the Upper Quadrant of the Revetment:

\[ \text{Quarter}_{\text{sta}} = \left[ \left( \frac{\text{Quarter}}{\text{Length}} \right) \times (\text{Top}_{\text{sta}} - \text{Toe}_{\text{sta}}) \right] + \text{Toe}_{\text{sta}} \]

\[ \text{Quarter}_{\text{sta}} = 65.27 \text{ ft} \]

Determine the Elevation of the Upper Quadrant of the Revetment:

\[ \text{Quarter}_{\text{ele}} := \text{interp} (\text{Station}, \text{Elevation}, \text{Quarter}_{\text{sta}}) \]

\[ \text{Quarter}_{\text{ele}} = 18.98 \text{ ft} \]

Calculate Scour at the Toe of the Revetment:
Wave Height and Wave Period Calculation Worksheet

Adjusting the Existing Profile:

The following calculations determine the index values in the array Station which identify the toe, midpoint, upper quadrant, and top of the revetment. If the value of Toelocation, Midlocation, Quarterlocation, or Toplocation exists within the Station array, then only one value should appear for Toelocation. If two values appear, then the station location is between two points in the Station array. If more than two value appears, adjust the TOL, convergence tolerance, in Tools > Worksheet Options... to be lower until only 2 values appear for Toelocation, Midlocation, Quarterlocation, and Toplocation.

Offsettoe, Offsetmid, Offsetqua, and Offsettop are equal to 0 if the horizontal distance from the shoreline to the bottom of the vertical structure already exists in the station array, otherwise, offset is set to 1. If no data point exists to represent the station of these locations, a data point is created in the FailSta array, which is the array of horizontal distances from the shoreline along the transect which is used to generate a profile of the failed structures.

ToeRscour := Toele - ArmorD

ToeRscour = 0.36 ft

Determine if station of the toe of the revetment is within the Station array and if not, add a data point.
Toelocation := match(Toesta, Station)  
Toelocation = (225)  
Toelocation0 = 225  
Toesta = 39.77 ft

Offsettoe :=  
0 if Station(Toelocation0) = Toesta  
1 otherwise 

Offsettoe = 0

Determine if station of the midpoint of the revetment is within the Station array and if not, add a data point

Midlocation := match(Midsta, Station)  
Midlocation := (225)  
Midlocation0 = 225  
Midsta = 56.77 ft

Offsetmid :=  
0 if Station(Midlocation0) = Midsta  
1 otherwise 

Offsetmid = 1

Determine if station of the upper quadrant of the revetment is within the Station array and if not, add a data point

Quarterlocation := match(Quartersta, Station)  
Quarterlocation := (225)  
Quarterlocation0 = 225  
Quartersta = 65.27 ft

Offsetqua :=  
0 if Station(Quarterlocation0) = Quartersta  
1 otherwise 

Offsetqua = 0
Offset\text{qua} = 1

\begin{align*}
\text{QuarterStaloc} &= \begin{cases} 
\text{Quarterlocation}_0 + \text{Offset}_\text{toe} + \text{Offset}_\text{mid} + \text{Offset}_\text{qua} & \text{if } \text{QuarterSta} \geq \text{Station} \\
\text{Quarterlocation}_0 + \text{Offset}_\text{toe} + \text{Offset}_\text{mid} & \text{otherwise}
\end{cases} \\
\text{QuarterStaloc} &= 227 \\
\text{FailRevetSta}_{\text{QuarterStaloc}} &= \text{QuarterSta}
\end{align*}

Determine if station of the top of the revetment is within the Station array and if not, add a data point

\begin{align*}
\text{Toplocation} &= \text{match}(\text{Topsta}, \text{Station}) \\
\text{Toplocation} &= (226) \\
\text{Toplocation}_0 &= 226 \\
\text{Topsta} &= 73.77 \text{ ft}
\end{align*}

\begin{align*}
\text{Offset}_\text{top} &= \begin{cases} 
0 & \text{if } \text{Station}(\text{Toplocation}_0) = \text{Topsta} \\
1 & \text{otherwise}
\end{cases} \\
\text{Offset}_\text{top} &= 0
\end{align*}

\begin{align*}
\text{TopStaloc} &= \begin{cases} 
\text{Toplocation}_0 + \text{Offset}_\text{toe} + \text{Offset}_\text{mid} + \text{Offset}_\text{qua} + \text{Offset}_\text{top} & \text{if } \text{Topsta} \geq \text{Station} \\
\text{Toplocation}_0 + \text{Offset}_\text{toe} + \text{Offset}_\text{mid} + \text{Offset}_\text{qua} & \text{otherwise}
\end{cases} \\
\text{TopStaloc} &= 228 \\
\text{FailRevetSta}_{\text{TopStaloc}} &= \text{Topsta}
\end{align*}

Sets the station of the failed profile to be equal to the existing profile station from the shore to the toe of the revetment

\begin{align*}
i &= \text{Toe}_{\text{location}}_0 \\
\text{FailRevetSta}_i &= \text{Station}_i \\
\text{FailRevetSta}_{\text{ToeStaloc}} &= \text{Toesta}
\end{align*}

Sets the station of the failed profile to be equal to the existing profile station from the toe of the revetment to the midpoint of the revetment, offsetting if a data point was added to represent the toe of the revetment
x := \begin{cases} (\text{ToeStaloc} + 1) \cdot (\text{MidStaloc} - 1) & \text{if } (\text{ToeStaloc} + 1) \leq (\text{MidStaloc} - 1) \\ \text{ToeStaloc} & \text{otherwise} \end{cases}

\text{FailRevetSta}_x := \begin{cases} \text{Station}_{x-\text{Offset}_{\text{Toe}}} & \text{if } x \neq \text{ToeStaloc} \\ \text{ToeSta} & \text{otherwise} \end{cases}

\text{FailRevetSta}_{\text{MidStaloc}} := \text{MidSta}

Sets the station of the failed profile to be equal to the existing profile station from the midpoint of the revetment to the upper quadrant of the revetment, offsetting values if a data point was added to represent the midpoint of the revetment.

y := \begin{cases} (\text{MidStaloc} + 1) \cdot (\text{QuarterStaloc} - 1) & \text{if } (\text{MidStaloc} + 1) \leq (\text{QuarterStaloc} - 1) \\ \text{MidStaloc} & \text{otherwise} \end{cases}

\text{FailRevetSta}_y := \begin{cases} \text{Station}_{y-\text{Offset}_{\text{Toe}}-\text{Offset}_{\text{mid}}} & \text{if } y \neq \text{MidStaloc} \\ \text{MidSta} & \text{otherwise} \end{cases}

\text{FailRevetSta}_{\text{QuarterStaloc}} := \text{QuarterSta}

Sets the station of the failed profile to be equal to the existing profile station from the upper quadrant of the revetment to the top of the revetment, offsetting values if a data point was added to represent the upper quadrant of the revetment.

z := \begin{cases} (\text{QuarterStaloc} + 1) \cdot (\text{TopStaloc} - 1) & \text{if } (\text{QuarterStaloc} + 1) \leq (\text{TopStaloc} - 1) \\ \text{QuarterStaloc} & \text{otherwise} \end{cases}
FailRevetSta_z := Station_{\text{z}} - \text{Offset}_{\text{toe}} - \text{Offset}_{\text{mid}} - \text{Offset}_{\text{qua}}\quad \text{if}\quad z = \text{QuarterStaloc}\\
\text{QuarterStaloc}\quad \text{otherwise}

FailRevetSta_{\text{TopStaloc}} := \text{TopSta}

Sets the station of the failed profile to be equal to the existing profile station from the top of the revetment to the end of the transect, offsetting values to compensate for any added data points

\text{end} := \text{last}(\text{Station}) + \text{Offset}_{\text{toe}} + \text{Offset}_{\text{mid}} + \text{Offset}_{\text{qua}} + \text{Offset}_{\text{top}}\quad \text{end} = 1005\\
\text{w} := \left(\text{TopStaloc} + 1\right)_{\text{end}}\\
\text{FailRevetSta}_w := \text{Station}_w - \text{Offset}_{\text{toe}} - \text{Offset}_{\text{mid}} - \text{Offset}_{\text{qua}} - \text{Offset}_{\text{top}}

Sets the elevation of the failed profile to be equal to the existing profile from the shore to the toe of the revetment and then slopes towards the shoreline at a 3h:1v slope from the toe of the revetment

\text{FailRevetEle}_i := \text{Elevation}_i\\
\text{FailRevetEle}_i := \left[\text{TopSta} - \text{FailRevetSta}_i\left(\frac{1}{3}\right) + \text{ToeRscour}\right]_{\text{if}}\left[\text{TopSta} - \text{FailRevetSta}_i\left(\frac{1}{3}\right) + \text{ToeRscour}\right]_{\leq \text{Elevation}_i}

break\quad \text{otherwise}

Sets the elevation at the toe of the revetment to the elevation after failure

\text{FailRevetEle}_{\text{ToeStaloc}} := \text{ToeRscour}

Sets the elevation of the failed revetment from the toe to the midpoint of the revetment based on armor depth if points exist between the toe and midpoint of the revetment

\text{FailRevetEle}_x := \text{Elevation}_x - \text{Offset}_{\text{toe}} - \text{ArmorD}\quad \text{if}\quad x = \text{ToeStaloc}\\
\text{ToeRscour}\quad \text{otherwise}
Sets the elevation of the middle of the revetment

\[ \text{ FailRevetEleMidStaloc} := (\text{Midele} - \text{ArmorD}) \]

Sets the elevation of the failed revetment from the midpoint to the upper quadrant of the revetment assuming a constant slope equal to the slope of the original revetment, only sloping downwards instead.

\[
\text{FailRevetEle}_y := \begin{cases} 
(\text{Station}_y - \text{Offsettoe} - \text{Offsetmid} - \text{Midsta}) \cdot (\text{Slope} - 1) + (\text{Midele} - \text{ArmorD}) & \text{if } y \neq \text{MidStaloc} \\
((\text{Midele} - \text{ArmorD})) & \text{otherwise}
\end{cases}
\]

Sets the elevation of the upper quadrant of the revetment

\[ \text{FailRevetEleQuarterStaloc} := (\text{Quartersta} - \text{Midsta}) \cdot (\text{Slope} - 1) + (\text{Midele} - \text{ArmorD}) \]

Sets the elevation of the failed revetment from the upper quadrant to the top of the failed revetment assuming a constant slope of 1v:1.5h until it reaches the existing elevation, or the top of the revetment.

\[ j := (\text{QuarterStaloc} + 1) \text{ end} \]

\[
\text{FailRevetEle}_j := \begin{cases} 
\text{FailRevetStaj} - \text{Quartersta} & \left( \frac{1}{1.5} \right) + \text{FailRevetEleQuarterStaloc} & \text{if } \left( \text{FailRevetStaj} - \text{Quartersta} \right) \left( \frac{1}{1.5} \right) + \text{FailRevetEleQuarterStaloc} \leq \text{Elevation} \\
b \text{break} & \text{otherwise}
\end{cases}
\]

failed := last(\text{FailRevetEle})

\[ \text{failed} = 230 \]

Finds the intersection point of failed profile and intact profile:

\[ \text{Station}_{\text{failed}} - \text{Offsettoe} - \text{Offsetmid} - \text{Offsetqua} + 1 = 95.77 \text{ ft} \]

\[ \text{Station}_{\text{failed}} - \text{Offsettoe} - \text{Offsetmid} - \text{Offsetqua} = 81.77 \text{ ft} \]
Landslope := \frac{Elevation_{\text{failed}} - Offset_{\text{toe}} - Offset_{\text{mid}} - Offset_{\text{qua}} + 1}{Station_{\text{failed}} - Offset_{\text{toe}} - Offset_{\text{mid}} - Offset_{\text{qua}} + 1}

Landslope = -0

Given

\begin{align*}
Elevation_{\text{failed}} - Offset_{\text{toe}} - Offset_{\text{mid}} - Offset_{\text{qua}} + 1 &= Station_{\text{failed}} - Offset_{\text{toe}} - Offset_{\text{mid}} - Offset_{\text{qua}} + 1 \\
\text{Landslope} &= \text{bland} \end{align*}

\text{bland} := \text{Find}(\text{bland}) = 24.41 \text{ ft}

Failed\text{slope} := \frac{1}{1.5}

Given

\begin{align*}
\text{FailRevetEle}_{\text{failed}} &= \text{FailRevetSta}_{\text{failed}} - \text{Failed\text{slope}} + \text{b}_{\text{failed}} \\
\text{b}_{\text{failed}} &= \text{Find}(\text{b}_{\text{failed}}) = -38.28 \text{ ft} \\
\text{X} &= \text{Find}(\text{X}) = 93.56 \text{ ft}
\end{align*}

Given

\begin{align*}
\text{X} - \text{Failed\text{slope}} + \text{b}_{\text{failed}} &= \text{X} - \text{Landslope} + \text{b}_{\text{land}} \\
\text{Y} &= \text{X} - \text{Failed\text{slope}} + \text{b}_{\text{failed}} = 24.09 \text{ ft}
\end{align*}

\begin{align*}
\text{FailTopSta} &= \text{X} & \text{FailTopSta} &= 93.56 \text{ ft} \\
\text{FailTopEle} &= \text{Y} & \text{FailTopEle} &= 24.09 \text{ ft}
\end{align*}
5.5 Wave Setup, $\eta$, Calculation on Failed Revetment
The following displays the failed profile of the transect:
Calculate Water Depth at Failed Structure, h

\[ h = \text{SWEL} - \text{ToeScour} \]
\[ h = 10.1\text{ ft} \]

\[ H_b = b_h L_0 \quad H_b = 13.41\text{ ft} \]
\[ H_d = b_d L_0 \quad H_d = 16.16\text{ ft} \]

Calculate Wave Setup on a Failed Structure, \( h_{\text{structure}} \):

\[ \eta = 0.15(h_1 + h_2 \left(1 - \frac{h_2}{h_1}\right)^2) \]
Wave Height and Wave Period Calculation Worksheet

PL-64

Calc By:__RGG__________
Date:____9-30-13_________

\[ R = \begin{cases} 
-0.8 \left( \frac{h}{H_d} \right) + 1 & \text{if } \frac{h}{H_d} \leq 0.092 \\
-0.3919 \left( \frac{h}{H_d} \right) + 0.9585 & \text{if } 0.092 < \frac{h}{H_d} \leq 0.4 \\
-0.3475 \left( \frac{h}{H_d} \right) + 0.9379 & \text{if } 0.4 < \frac{h}{H_d} \leq 0.9 \\
-33.312 \left( \frac{h}{H_d} \right)^2 + 59.811 \left( \frac{h}{H_d} \right) - 26.223 & \text{if } 0.9 < \frac{h}{H_d} \leq 0.94444 \\
-9.8703 \left( \frac{h}{H_d} \right) + 9.8703 & \text{if } 0.94444 < \frac{h}{H_d} \leq 1 \\
0 & \text{otherwise}
\end{cases} \]

Equation based on estimated curve from Figure D.2.6-9

Figure from: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007

\[ R = 0.72 \]

\[ \eta_1 = 1.39 \text{ ft} \]

\[ \eta_2 = 0.15 (h + \eta_1) \]

\[ \eta_2 = 1.72 \text{ ft} \]

Total Setup against a coastal structure without considering overtopping

Check Overtopping if Coastal Structure Exists:

\[ \text{Overtopped} = \begin{cases} 
\text{"Yes"} & \text{if } (\eta_{\text{FailedStructure}} + \text{SWEL}) > \text{FailTopEle} \\
\text{"No"} & \text{otherwise}
\end{cases} \]

Overtopped = "No"
\[ h_2 := \begin{cases} \eta_{\text{FailedStructure}} + \text{SWEL} - \text{Topele} & \text{if Overtopped = "Yes"} \\ 0 & \text{otherwise} \end{cases} \]

Equation D.2.6-12 for \( \eta_2 \) from Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update

\[ \eta_2 := \begin{cases} 0.15(h + \eta_1) \left[ 1 - \left( \frac{h_2}{h} \right)^2 \right] & \text{if Overtopped = "Yes"} \\ \eta_2 & \text{otherwise} \end{cases} \]

\( \eta_{\text{FailedStructure}} = \eta_1 + \eta_2 \)

Total Setup with a failed coastal structure

\( \eta_{\text{FailedStructure}} = 3.11 \)
5.6 Wave Runup Analysis (Using TAW Method) on a Failed Revetment

Flow Chart of Process of Calculating Wave Runup:

- **Input Data:** Deep Water Wave Parameters ($H_o$, $L_o$, $T_p$), barrier slope (m), and depth at the toe ($d_s$)
- **Step 1:**
  - If $1.1 < m < 1.8$, follow next step.
  - Otherwise, proceed to TAW not valid, find another method.

- **Step 2:**
  - Calculate Local wave parameters at barrier ($H_{mo}^{(1)}$, $L_{mo}^{(1)}$, $T_{mo}^{(1)}$)
  - Calculate $T_{mo}^{(1)} = T_p / 1.1$ (D.2.8-16)
  - Calculate $L_{mo}^{(1)}$ (D.2.8-3)

- **Step 3:**
  - Wave Eqn. Type
  - If $L_o/d_s < 0.2$, proceed to reduce factors & calculate runup.
  - If $L_o/d_s > 0.2$, check if $H_o > 0.78 d_s$.

- **Step 4:**
  - If $H_o > 0.78 d_s$, $H_{mo} = 0.88 H_o$
  - If $H_o < 0.78 d_s$, $H_{mo} = H_o$

- **Step 5:**
  - Calculate $\text{TAW not valid, find another method}$ if $0.5 < x_o < 10$.
  - Calculate $x_o = mL_o / \text{SQRT}(H_{mo}^{(1)}H_{mo}^{(2)})$

- **Step 6:**
  - Proceed to reduction factors & calculate runup.
Checking Slope of Revetment to determine if it is between 1:0 and 1:8:

\[
Slope_{FAILRevet} := \frac{(FailTopEle - ToeRscour)}{(FailTopSta - ToeSta)}
\]

\[
Slope_{FAILRevet} = 44.12\%
\]

\[
Slope_{FAILRevetOneOn} := \frac{1}{Slope_{FAILRevet}}
\]

\[
Slope_{FAILRevetOneOn} = 2.27
\]

\[
FAILSlopeCheck := \begin{cases} 
&TAW Method of Runup Calculation Applies \quad \text{if } 0 < \text{SlopeRevetOneOn} \leq 8 \\
&TAW Method Does Not Apply, Switch to Runup-2.0 \quad \text{otherwise}
\end{cases}
\]

If wave is depth limited at the Toe of the Revetment / Barrier:

\[
\text{DepthLimited} := \begin{cases} 
&\text{Limited} \quad \text{if } H_m0 \geq 0.78 \cdot h \\
&\text{Not Limited} \quad \text{otherwise}
\end{cases}
\]

If wave is depth limited, \( H_b \) will be used rather than \( H_m0 \)

\[
\text{DepthLimited} = \text{Limited}
\]

Determine Wave Type:

\[
\text{WaveType} := \begin{cases} 
&\text{Shallow} \quad \text{if } \frac{h}{L_0} < 2 \\
&\text{Transitional} \quad \text{if } 0.2 \leq \frac{h}{L_0} < 0.5 \\
&\text{Deep} \quad \text{otherwise}
\end{cases}
\]

\[
\text{WaveType} = \text{Shallow}
\]
Determine Significant Wave Height Depending on WaveType and DepthLimited Condition:

\[ H_{m0runupFAIL1} = \begin{cases} 
0.88H_{m0} & \text{if WaveType = "Shallow"} \\
H_{m0} & \text{otherwise}
\end{cases} \]

\[ H_{m0runupFAIL1} = 10.12 \text{ ft} \]

\[ H_{m0runupFAIL} = \begin{cases} 
0.78H_{m0} & \text{if DepthLimited = "Limited"} \\
H_{m0runupFAIL1} & \text{otherwise}
\end{cases} \]

\[ H_{m0runupFAIL} = 7.87 \text{ ft} \]

Calculate the Iribarren Number, \( \xi_{om} \):

\[ \xi_{om} = \frac{\text{SlopeFAILRevet}}{\sqrt{\frac{H_{m0runupFAIL}}{L_{m0}}}} \]

\[ \xi_{om} = 3.62 \]

Check TAW Method for Validity based on Iribarren Number:

\[ \text{FAILIribarrenCheck} = \begin{cases} 
"TAW method is Valid" & \text{if } 0.5 < \xi_{om} < 10 \\
"TAW method is NOT valid for this Irbarren value. Please seek alternative method." & \text{otherwise}
\end{cases} \]

\[ \text{FAILIribarrenCheck} = "TAW method is Valid" \]

Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:

Select Roughness Reduction Factor, \( \gamma_{\xi} \): Default - 1 layer of rock with diameter, \( d \), where \( H_s/d = 1 \) to 3
Wave Height and Wave Period Calculation Worksheet

PL-64

Calc By: RGG
Date: 9-30-13

Smooth Concrete, Asphalt, and Smooth Block Revetment

1 Layer of Rock with Diameter, D, where $H_s/D = 1$ to $3$

2 or More Layers of Rock where $H_s/D = 1.5$ to $6$

Quadratic Blocks

Select Berm Section in Breakwater, $\gamma_b$:

- Berm Present
- No Berm Present

Select Wave Direction Factor, $\gamma_\beta$:

- Short-Crested Wave
- Long-Crested Wave

Select Porosity Factor, $\gamma_P$:

- Porosity = 0.1
- Porosity = 0.4
- Porosity = 0.5
- Porosity = 0.6

Porosity = 0.5

$\gamma_r = \frac{\gamma_r}{\gamma}$ if $\gamma_r \geq 0.53$

"Please Select Radio Button" otherwise

$\gamma_r = 0.58$

$\gamma_b = 0.6$

Default - Short crested with beta = 0

$\gamma_\beta = \begin{cases} 
(1 - 0.0022 |\beta|) & \text{if } |\beta| \leq 80 \land \gamma_\beta = 1 \\
(1 - 0.0022 |80|) & \text{if } (|\beta| > 80) \land \gamma_\beta = 1 \\
1 & \text{if } 0 \leq |\beta| < 10 \land \gamma_\beta = 2 \\
\cos \left((|\beta| - 10) \left(\frac{\pi}{180}\right)\right) & \text{if } (10 < |\beta| < 63 \land \gamma_\beta = 2) \\
0.63 & \text{if } |\beta| > 63 \land \gamma_\beta = 2 \\
\end{cases}$

"Please Select Radio Button" otherwise

$\gamma_p = 0.95$

$\gamma_p = \begin{cases} 
1 & \text{if } (\text{Porosity} = 0.5) \land \xi_{om} \leq 3.3 \\
\left(\frac{2}{1.17 \xi_{om} 0.46}\right) & \text{if } (\text{Porosity} = 0.5) \land \xi_{om} > 3.3 \\
0.5 & \text{otherwise} \\
\end{cases}$
Summary of Reduction Factors:

\[
\begin{align*}
\gamma_p &= 0.95 \\
\gamma_\beta &= 1 \\
\gamma_b &= 0.6 \\
\gamma_r &= 0.58
\end{align*}
\]

Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:

\[
R_{FAIL2\%} = \begin{cases} 
H_{m0runup} \left( 1.77 \gamma_r \gamma_b \gamma_\beta \gamma_p \xi_{om} \right) & \text{if } 0.5 \leq \gamma_b \xi_{om} < 1.8 \\
H_{m0runup} \left[ \gamma_r \gamma_b \gamma_\beta \gamma_p \left( 4.3 - \frac{1.6}{\xi_{om}} \right) \right] & \text{if } 1.8 \leq \gamma_b \xi_{om} \\
0 & \text{otherwise}
\end{cases}
\]

\[
R_{FAIL2\%} = \begin{cases} 
\text{"TAW Not Valid"} & \text{if } \text{FAILSlopeCheck} = \text{"TAW Method Does Not Apply, Switch to Runup-2.0"} \\
\text{"TAW Not Valid"} & \text{if } \text{FAILIrbarrenCheck} = \text{"TAW method is NOT vaild for this Irbarren value. Please seek alternative method."} \\
R_{FAIL2\%} & \text{otherwise}
\end{cases}
\]

\[R_{FAIL2\%} = 5.41 \text{ ft}\]

Check for Overtopping:

\[
\text{OVERTOPPEDFAILRunup} = \begin{cases} 
\text{"Overtopped... Please consider 3 foot rule"} & \text{if } \left( R_{FAIL2\%} + \text{SWEL} \right) > \text{FailTopEle} \\
\text{"NO Overtopping"} & \text{otherwise}
\end{cases}
\]

\[\text{OVERTOPPEDFAILRunup} = \text{"NO Overtopping"}\]
6.0 Conclusions/Results

Wave Height, $H_{m0}$
$H_{m0} = 11.5 \text{ ft}$

Wave Period, $T_p$
$T_p = 11.2 \text{ s}$

Wave Setup on an open coast, $\eta_{\text{open}}$
$\eta_{\text{open}} = 1.93 \text{ ft}$

Wave Setup on a revetment, $\eta_{\text{Structure}}$
$\eta_{\text{Structure}} = 2.71 \text{ ft}$

Wave Runup on a revetment, $R_{2\%}$
$R_{2\%} = 7.51 \text{ ft}$

Failed Structure Profile:

Wave Setup on a Failed Structure, $\eta_{\text{Failed}}$
$\eta_{\text{Failed}} = 3.11 \text{ ft}$

Wave Runup on a Failed Structure, $R_{\text{FAIL2\%}}$
$R_{\text{FAIL2\%}} = 5.41 \text{ ft}$
OVERTOPPEDFAILRunup = "NO Overtopping"

Top of Failed Revetment Station and Elevation:

\[
\text{FailTopSta} = 93.56\text{ft} \\
\text{FailTopEle} = 24.09\text{ft}
\]

\[
\text{FailSta} = \text{FailRevetSta} - 1\text{ft} \\
\text{FailEle} = \text{FailRevetEle} - 1\text{ft}
\]

NOTES:
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Transect PL-064
Marshfield, Massachusetts

WHAFIS Analysis on Intact Profile
September 30, 2013

Legend
- 1% SWEL
- ADJTRANS_PNT
- ADJTRANS_LN
- LANDWARD_TOE
- EROSION_LN
- PEAK
- TOE
- WHAFIS_SW
- WHAFIS_CREST
- WHAFIS_STEPS

Zone VE
Zone AE
Zone AO
Zone X
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<td>200</td>
</tr>
<tr>
<td>48.99</td>
<td>18.50</td>
<td>V30 EL=19</td>
<td>200</td>
</tr>
<tr>
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<td>17.50</td>
<td>V30 EL=18</td>
<td>200</td>
</tr>
<tr>
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<td>16.50</td>
<td>V30 EL=17</td>
<td>200</td>
</tr>
<tr>
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<td>15.67</td>
<td>V30 EL=16</td>
<td>200</td>
</tr>
<tr>
<td>74.95</td>
<td>14.50</td>
<td>A24 EL=15</td>
<td>140</td>
</tr>
<tr>
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<td>13.58</td>
<td>A24 EL=14</td>
<td>140</td>
</tr>
<tr>
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<td>15.77</td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
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<td>15.77</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>226.00</td>
<td>15.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>246.00</td>
<td>15.77</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Transect PL-064
Marshfield, Massachusetts

WHAFIS Analysis on Failed Profile
September 30, 2013
Wave Setup for Scituate, MA, Transect PL-66 Intact

**Wave Setup**

\[ H' = 13.3 \text{ feet} \]  
\[ T = 11.5 \text{ sec} \]  
\[ m = 0.0358 \text{ ft/ft} \]  
\[ Lo = 677.8 \text{ ft} \]  
\[ H' / Lo = 0.0196 \text{ ft/ft} \]  
\[ \text{Irabarren Number} = 0.2553 \text{ ft/ft} \]  
\[ \text{Sigma}(2) = 1.0187 \text{ ft} \]  
\[ \text{Setup} = 2.3994184 \text{ ft} \]  
\[ n = 2.3994184 \text{ ft} \]  
\[ \text{Total Static Setup} = \text{Total Static Setup} \]

---

**Incident Wave Length**

\[ L_0 = 677.8 \text{ ft} \]  
**Incident Wave Height from STWAVE Model**

\[ H_0 = 13.3 \text{ ft} \]  
**Deepwater Wave Length**

\[ Lo = \left( \frac{gT^2}{2\pi} \right) \]  
**Deepwater Significant Wave Height**

\[ H' = 13.3 \text{ ft} \]  
**Peak Wave Period**

\[ T = 11.5 \text{ sec} \]  
**Average Slope of Transect**

\[ m = 0.0358 \text{ ft/ft} \]  
**Deepwater Wave Wavelength**

\[ Lo = \left( \frac{gT^2}{2\pi} \right) \]  
**Deepwater Wave Steepness**

\[ H'/Lo = 0.0196 \text{ ft/ft} \]  
**Irabarren Number**

\[ \text{Irabarren Number} = 0.2553 \text{ ft/ft} \]  
**Sigma(2)**

\[ \Sigma(2) = 1.0187 \text{ ft} \]  
**Setup**

\[ 2.3994184 \text{ ft} \]  
**Total Static Setup**

\[ n = 2.3994184 \text{ ft} \]  

---

**Incident Wave Height**

\[ H_0 = 13.3 \text{ ft} \]  
**Wetted Width**

\[ W = \text{Wetted Width} \]  
**Wave Setup**

\[ H' = 13.3 \text{ feet} \]  
\[ T = 11.5 \text{ sec} \]  
\[ m = 0.0358 \text{ ft/ft} \]  
\[ Lo = 677.8 \text{ ft} \]  
\[ H'/Lo = 0.0196 \text{ ft/ft} \]  
**Irabarren Number**

\[ \text{Irabarren Number} = 0.2553 \text{ ft/ft} \]  
**Sigma(2)**

\[ \Sigma(2) = 1.0187 \text{ ft} \]  
**Setup**

\[ 2.3994184 \text{ ft} \]  
**Total Static Setup**

\[ n = 2.3994184 \text{ ft} \]  

---

**Instructions:** Insert Values into Highlighted Cells

---

**FEMA extracted profile**

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>delta x</th>
<th>delta y</th>
</tr>
</thead>
<tbody>
<tr>
<td>105.07</td>
<td>10.3</td>
<td>-14</td>
<td>-8.936</td>
</tr>
<tr>
<td>119.07</td>
<td>19.236</td>
<td>105.3207</td>
<td>xcoord of sought for y value of SWEL</td>
</tr>
<tr>
<td>-430.93</td>
<td>-8.70659</td>
<td>-430.309</td>
<td>xcoord of sought for y value of elevation at Db</td>
</tr>
<tr>
<td>-428.93</td>
<td>-8.67412</td>
<td>-430.309</td>
<td>xcoord of sought for y value of elevation at Db</td>
</tr>
</tbody>
</table>

---

**Topography**

- **Rise:** 19.15651 ft
- **Run:** 535.6297 ft
- **Slope:** 0.035764
- **1:ON:** 27.96071

---

**FEMA extracted profile**

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>delta x</th>
<th>delta y</th>
</tr>
</thead>
<tbody>
<tr>
<td>105.07</td>
<td>10.3</td>
<td>-14</td>
<td>-8.936</td>
</tr>
<tr>
<td>119.07</td>
<td>19.236</td>
<td>105.3207</td>
<td>xcoord of sought for y value of SWEL</td>
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<tr>
<td>-430.93</td>
<td>-8.70659</td>
<td>-430.309</td>
<td>xcoord of sought for y value of elevation at Db</td>
</tr>
<tr>
<td>-428.93</td>
<td>-8.67412</td>
<td>-430.309</td>
<td>xcoord of sought for y value of elevation at Db</td>
</tr>
</tbody>
</table>

---

**Profile Calculations**

- **Calculate Db**
  
  \[ -8.70659 \]  
  \[ -8.67412 \]  
  \[ -0.032 \]  
  \[ -430.309 \]  
  \[ -430.309 \]  

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071

---

**Wave Setup**

- **H' = 13.3 feet**
- **T = 11.5 sec**
- **m = 0.0358 ft/ft**
- **Lo = 677.8 ft**
- **H'/Lo = 0.0196 ft/ft**
- **Irabarren Number = 0.2553 ft/ft**
- **Sigma(2) = 1.0187 ft**
- **Setup = 2.3994184 ft**
- **n = 2.3994184 ft**

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071

---

**Earthwork Calculations**

- **Topography**
  
  - **Rise:** 19.15651 ft
  - **Run:** 535.6297 ft
  - **Slope:** 0.035764
  - **1:ON:** 27.96071
Wave Height, Wave Period, Wave Setup, and Failed Revetment / Coastal Barrier / Steep Bluff Worksheet

1.0 Purpose/Objective

This worksheet was created to determine the unrestricted \( H_{m0} \) and \( T_p \) where \( H_{m0} \) is the energy-based significant wave height in meters and \( T_p \) is the limiting wave period, or use user input \( H_{m0} \) and \( T_p \) values from ACES or STWAVE models. This worksheet also calculates the open coast wave setup, \( \eta_{open} \), which is the increase in stillwater elevation against a barrier caused by the attenuation of waves in shallow water. Wave setup is based upon wave breaking characteristics and profile slope. Wave setup can be a significant contributor to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. This worksheet also evaluates the wave setup against a coastal structure, \( \eta_{structure} \). For profiles with sloping revetments, this worksheet will also perform a failed structure analysis and generate a new profile of the failed structure and calculate the wave setup on the failed revetment.

2.0 Procedure

For unrestricted fetch length analysis where no STWAVE or ACES model run was produced, an extremal analysis was performed to determine three thresholds for peak wind speeds. The threshold with the highest correlation to either the Fisher-Tippett Type 1 (Gumbel), Fisher-Tippett Type II (Frecher), or Wiebull distribution is input parameter \( U_{10} \), or the wind speed at 10m elevation (m/sec). Fetch, \( X \), was also determined for each location. An excel spreadsheet for each transect was generated to calculate the 1% annual chance stillwater elevation. These variables are input into this worksheet from external worksheets and used for calculation within this worksheet.

Calculation worksheet details:
1. Go to View> Header and Footer... and fill out ALL relevant information to worksheet
2. Enter similar information on Page 2
3. Use radio buttons to select if analysis is based on "Unrestricted Fetch Wind Speed Input", "Restricted Fetch Input From ACES (\( H_{m0}, T_p \))", or "STWAVE Input (\( H_{m0}, T_p \))"

Section 5.1 - Wave Height and Wave Period

4. Fill in value of \( U_{10} \) and list peak threshold, regression, and correlation coefficient and associated files
5. If fetch length is unrestricted, continue to section 5.1.1, otherwise, skip section 5.1.1

Section 5.1.1 - Unrestricted Wave Height and Wave Period Calculation
6. Fill in value of Fetch, X, and list associated calculation files.
7. Skip Section 5.1.2 and Section 5.1.3 if fetch length is unrestricted

**Section 5.1.2 - Restricted Wave Height and Wave Period Calculation**
8. If ACES model run was complete enter ACES program inputs including the fetch angles and fetch lengths used in the restricted analysis in ACES
9. List the .mxd file and associated information involved in the calculation of fetch lengths
10. Fill in results of Hm0 and Tp from the ACES analysis and any ACES output files which were saved
11. Skip section 5.1.3

**Section 5.1.3 - STWAVE Wave Height and Wave Period**
12. If STWAVE model run was complete enter the associated wave height and wave period
13. List the associated STWAVE model file

**Section 5.2 - Wave Setup**

**Section 5.2.1 - Open Coast Wave Setup Calculation**
14. Enter value for average transect slope and associated .mxd file from which average slope was calculated

**Section 5.2.2 - Wave Setup on a Revetment Calculation**
15. Enter Profile variable excel file path information. Excel file should be formatted with the first row of the file having column headings. The first column within the file should have station data in ascending order. The second column within the file should have the associated station elevation in order of ascending station. All data should be in feet. This file needs to be an .xls file as Mathcad is not currently compatible with .xlsx files.
16. Enter horizontal distance from shoreline along transect which identifies the start of the coastal structure, Toestar, in feet
17. Enter horizontal distance from shoreline along transect which identifies the top of the coastal structure, Topstar, in feet
18. Enter value for SWEL, 1% annual chance stillwater elevation in feet and name and path of associated excel file from which SWEL was calculated

**Section 5.3 - Wave Runup - TAW Method**
19. Check SlopeCheck and IribarrenCheck variables to determine if TAW method holds for these situations
20. Use radio buttons to select runup reduction factors
21. Enter incident angle, \( \beta \), if known, otherwise, assume 0

**Section 5.4 - Failed Revetment Analysis**
22. Enter approximate depth of armor layer in feet based on photographs and site inspections (ft)
23. Check value of Toestar, Midstar, Quarterstar, and Topstar which should be the location in the Station array which holds the value of Toe, Mid, Quarter, and Top. If the horizontal distance from the shoreline along the transect to these locations were not measured
3.0 References/Data Sources

Equation taken from Coastal Engineering Manual Part II (Publication date: August 1, 2008)
Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February, 2007
Guidelines and Specifications for Flood Hazard Mapping Partners [February 2007]
Coastal Engineering Manual Part VI

4.0 Assumptions

Unrestricted Wave Height and Wave Period Mathcad Calculation:
1. One of the following situations hold:
   - Wind blows, with essentially constant direction, over a fetch for sufficient time to achieve steady-state, fetch-limited values
   - Wind increases very quickly through time in an area removed from any close boundaries. Wave growth is considered duration-limited.
     RARE condition
   - Fully developed wave height, however, open-ocean waves rarely attain a limiting wave height for wind speeds above 50 knots of so.
2. Wave growth with fetch.
3. Wind speeds collected were taken at 10 m, to be a U_{10} measurement of wind speeds

Open Coast Wave Setup and Wave Setup on Existing and Failed Structures Analysis
1. Wave height, H_{m0}^p is the deepwater wave height and is not in water of transitional depth
2. The wave setup calculated is a "static" wave setup, during which the storm tide and incident wave conditions remain unchanged.

3. The open coast wave setup calculation does not consider wave nonlinearity, wave breaking characteristics, profile slope, or wave propagation through vegetation.

4. Dynamic wave setup component is not considered, as it is small by comparison with the static component for the locations considered.

5. Wave period, $T_P$, remains constant and independent of depth for oscillatory waves.

**Wave Runup Analysis on Failed and Existing Structures - Technical Advisory Committee for Water Retaining Structures (TAW) Method**

1. The TAW method is assumed to hold for all barriers, revetments, or dunes which have a slope of 1:8 or steeper.
2. The shallow water significant wave height is assumed to be 88% of the deep water significant wave height.
3. The breaking wave height is assumed to be 78% of the water depth at the toe of the barrier, revetment, or dune.
4. The TAW method is assumed to hold for Iribarren numbers in the range of 0.5 to 10.
5. The incident wave angle is assumed to be 0 in most cases.
6. Assuming berm width is unknown, minimum and maximum berm section breakwater reduction factors were assumed for conditions when a berm does and does not exist respectively.
7. The runup values calculated are the 2% exceedance probability values.

**Failure of a Sloping Revetment**

1. Landslide of revetment has constant slope.
2. The scour depth does not include any parameters relating to sediment properties, which are expected to have some influence on the scouring process.
3. The scour at the base of the structure is equal to the depth of the armored layer.
4. The structure will collapse in place into a triangular section throughout the structure footprint, with side slopes equal to the original structure slope.
5. The landward side of the failed configuration will be half exposed and half buried.
6. The soil slope landward from the failed structure fails to a uniform 1:1.5 slope, which extends to existing grade.
7. Slope recedes back from the toe of the revetment at a 1:3 slope.

---

**Wave Height, Wave Period, Wave Setup, Failed Vertical Structure Calculation Worksheet**

Modeler Name: Robert G. Gerber
Date: Sept. 18, 2013
County: Plymouth, MA
Transect Number: PL-66
Airport:
Years of Data set: ST WAVE MODEL
5.0 Calculations

List of Variables:

Constants:
- \( g \) - Gravitational acceleration (m/\text{sec}^2)

Inputs:
- \( X \) - straight line fetch distances over which the wind blows (miles)
- \( U_{10} \) - Wind speed at 10 m elevation (ft/sec)
- \( H_{m0\text{STWAVE}} \) - Deep water significant wave height input by user from STWAVE model
- \( T_{P\text{STWAVE}} \) - Wave period input by user from STWAVE model
- \( m \) - Average slope of transect (dimensionless)
- Profile - Excel file with station (ft) and elevations (ft) of transect profile
- \( \text{Toe}_{sta} \) - Horizontal location of toe of structure relative to shoreline (ft)
- \( \text{Top}_{sta} \) - Horizontal location of top of structure relative to shoreline (ft)
- \( \text{SWEL} \) - 1\% Annual Chance Stillwater Elevation (ft)
- \( \text{Armor} \) - Depth of armor layer on a sloping revetment (ft)
- \( \text{ACESInputAng} \) - Angle of fetches input into ACES analysis (deg)
- \( \text{ACESInputFetch} \) - Fetch length of fetches input into ACES analysis (ft)
- \( H_{m0\text{ACES}} \) - Deepwater significant wave height from ACES analysis (ft)
- \( T_{P\text{ACES}} \) - Limiting wave period from ACES analysis (sec)

Working Variables:
- \( C_D \) - Coefficient of drag for winds measured at 10 meters (dimensionless)
- \( u_s \) - Wind friction velocity (m/sec)
- \( L_0 \) - Deep water wave length (ft)
- \( S \) - Wave slope (dimensionless)
- \( \text{Toe}_{ele}, \text{Mid}_{ele}, \text{Quarter}_{ele}, \text{Top}_{ele} \) - Elevation of toe, midpoint, upper quarter, and top of revetment from interpolation (ft)
- Station - Array of station (ft) of existing (non-failed) profile
- Elevation - Array of elevations (ft) of existing (non-failed) profile
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h )</td>
<td>Water depth from the top of the water surface against a structure to the toe of the structure (ft)</td>
</tr>
<tr>
<td>( b_h )</td>
<td>Dimensionless breaking wave height</td>
</tr>
<tr>
<td>( H_b )</td>
<td>Breaking wave height (ft)</td>
</tr>
<tr>
<td>( b_d )</td>
<td>Dimensionless breaking wave depth (dimensionless)</td>
</tr>
<tr>
<td>( H_d )</td>
<td>Breaking wave depth (ft)</td>
</tr>
<tr>
<td>( R )</td>
<td>Wave setup relative to maximum wave setup (dimensionless)</td>
</tr>
<tr>
<td>( n_{\text{open}} )</td>
<td>Open coast wave setup (ft)</td>
</tr>
<tr>
<td>( n_1 )</td>
<td>Wave setup component on a coastal structure from the water depth at the toe of a coastal structure (ft)</td>
</tr>
<tr>
<td>( n_2 )</td>
<td>Wave setup component determined for a sloping coastal structure (ft)</td>
</tr>
<tr>
<td>( h_2 )</td>
<td>Water depth over coastal structure when overtopping occurs (ft)</td>
</tr>
<tr>
<td>( n_{\text{structure}} )</td>
<td>Total wave setup on a structure or steep slope (ft)</td>
</tr>
<tr>
<td>( H_{\text{fail}} )</td>
<td>Wave height used for analysis of failed structure equal to ( H_{m0} ), or the energy-based significant wave height, ( H_{m0} ), but limited to a maximum equal to the breaking wave height, ( H_b ) (ft)</td>
</tr>
<tr>
<td>( S_m )</td>
<td>Maximum scour depth (ft)</td>
</tr>
<tr>
<td>( \eta_{\text{scour}} )</td>
<td>Elevation of toe of vertical coastal structure after scour occurs (ft)</td>
</tr>
<tr>
<td>( n_{\text{location}} ), ( n_{\text{midlocation}} ), ( n_{\text{Quarterlocation}} ), ( n_{\text{Toplocation}} )</td>
<td>Index of location of bottom of vertical coastal structure or revetment, midpoint of revetment, quarter, and top of revetment within the station array (dimensionless)</td>
</tr>
<tr>
<td>( \text{Offset}, \text{offset}<em>{\text{toe}}, \text{offset}</em>{\text{mid}}, \text{offset}<em>{\text{qua}}, \text{offset}</em>{\text{top}}, \text{offset}_{\text{failTop}} )</td>
<td>Dummy variable equal to 0 if the horizontal location of the bottom of the vertical structure, revetment toe, revetment midpoint, revetment quarter distance, revetment top is listed in the Station array, equal to 1 if the horizontal location of the bottom of the vertical structure is not listed in the station array (dimensionless)</td>
</tr>
<tr>
<td>( n_{\text{staloc}}, n_{\text{midstaloc}}, n_{\text{Quarterstaloc}}, n_{\text{Topstaloc}} )</td>
<td>Index of location of toe of vertical coastal structure or revetment, midpoint of revetment, quarter length of revetment, and top of revetment within the station array (dimensionless)</td>
</tr>
<tr>
<td>( n_{\text{lastloc}} )</td>
<td>Index to the last element in the Station array (dimensionless)</td>
</tr>
<tr>
<td>( n_{\text{failed}} )</td>
<td>Index to the last element in the Station array (dimensionless)</td>
</tr>
<tr>
<td>( i, x, y, z, a, w )</td>
<td>Counter variables (dimensionless)</td>
</tr>
<tr>
<td>( \text{Slope} )</td>
<td>Slope of a revetment (dimensionless)</td>
</tr>
<tr>
<td>( \text{Length} )</td>
<td>Length of a revetment (ft)</td>
</tr>
<tr>
<td>( \text{Midpoint}, \text{Quarter} )</td>
<td>Midpoint and Quarter of the distance along length of revetment (ft)</td>
</tr>
</tbody>
</table>
### Wave Height and Wave Period Calculation Worksheet

**Client:** Town of Marshfield  
**County:** Plymouth, MA  
**Transect Number:** PL-66  
**Calc By:** RGG  
**Date:** 9-23-13

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Midsta</td>
<td>Quartersta</td>
</tr>
<tr>
<td>ToeRscour</td>
<td></td>
</tr>
<tr>
<td>end</td>
<td></td>
</tr>
</tbody>
</table>

- FailRevetEle - Array of elevations of partial failure of a sloping revetment (ft)
- FailRevetSta - Array of station data of partial failure of a sloping revetment (ft)
- SlopeRevet |  | - Slope or revetment expressed as a decimal or percentage (dimensionless) |
- SlopeRevetOneOn |  | - Slope of revetment expressed as the horizontal distance associated with an increase in one vertical foot (string) |
- SlopeCheck |  | - Indicator variable associated with determining if the TAW method is applicable based on barrier slope (string) |
- SlopeCheck |  | - Indicator variable associated with determining if the TAW method is applicable based on barrier slope of failed revetment (string) |
- DepthLimited |  | - Indicator variable associated with determining if the wave is depth limited at the toe of the revetment or structure (string) |
- WaveType |  | - Indicator variable associated with determining if water is considered to be shallow, deep, or transitional at the toe of the barrier |
- $\beta$ |  | - Incident wave angle (degrees) |
- $T_{m10}$ |  | - Spectral wave period (sec) |
- $H_{m0\text{Runup}}, H_{m0\text{Runup1}}$ |  | - Significant wave height adjusted if necessary for runup calculations (ft) |
- $\gamma_r$ |  | - Roughness reduction factor (dimensionless) |
- $\gamma_b$ |  | - Berm section in breakwater (dimensionless) |
- $\gamma_p$ |  | - Porosity factor (dimensionless) |
- $\gamma_\beta$ |  | - Wave direction factor (dimensionless) |
- SlopeFAILRevet |  | - Slope or revetment expressed as a decimal or percentage (dimensionless) |
- SlopeFAILRevetOneOn |  | - Slope of revetment expressed as the horizontal distance associated with an increase in one vertical foot (string) |
- IribarrenCheck |  | - Indicator variable to determine if the TAW method is applicable based on the Iribarren number (string) |
- FAILIribarrenCheck |  | - Indicator variable to determine if the TAW method is applicable based on the Iribarren number for the failed revetment (string) |
- FailTopSta |  | - Station of top of revetment after failure (ft) |
- FailTopEle |  | - Elevation of top of revetment after failure (ft) |

**Output:**

- $H_{m0}$ |  | - Energy-based significant wave height (ft) |
Wave Height and Wave Period Calculation Worksheet

**5.1 Wave Height, \( H_{m0} \), and Wave Period, \( T_p \) Calculation**

**Definition of Variables:**

\[
g = \frac{9.81 \text{ m}}{\text{s}^2}
\]

Insert \( U_{10} \), wind speed in meters per second:

*These fields must be populated, but will only be used for calculations if*
unrestricted radio button is selected above

Wind speed based on CHAMP model default offshore wind = 80 mph

Taken from file:

\[ U_{10} = 35.76 \text{ m/s} \]

\[ U_{10} = 117.32 \text{ m/s} \]

5.1.1 Calculation of Unrestricted Wave Height, \( H_{m0} \), and Wave Period, \( T_p \)

Insert X, fetch in miles:

\[ x = 12.84 \text{ m} \]

\[ x = 20663.98 \text{ m} \]

Feature Class used:

Calculate Coefficient of Drag, \( C_D \):

\[ C_D = 0.001 \left[ 1.1 + \left( 0.035 \cdot \frac{U_{10}}{x} \right) \right] \]

\[ C_D = 0.0024 \]

Calculate Wind Friction Velocity, \( u_s \) (m/sec):

\[ u_s = 1 \text{ m/s} \]

Given\n
\[ C_D = \frac{u_s^2}{U_{10}^2} \]

\[ u_s = \text{Find}(u_s) \]

\[ u_s = 1.73 \text{ m/s} \]

Calculate Wave Height, \( H_{m0} \) (m):

\[ H_{m0} = 0.01 \text{ m} \]

\[ x = 20663.98 \text{ m} \]

\[ u_s = 1.73 \text{ m/s} \]

\[ g = 9.81 \text{ m/s}^2 \]

Given
Calculate Wave Period, $T_p$ (sec):

initialize $T_p$:

\[
t_p := 0.01 \text{s}
\]

\[
x = 20663.98 \text{m} \quad u_s = 1.73 \frac{\text{m}}{\text{s}} \quad g = 9.81 \frac{\text{m}}{\text{s}^2}
\]

Given

\[
\frac{g \cdot T_p}{u_s^2} = 0.751 \left( \frac{g \cdot x}{u_s^2} \right)^{\frac{1}{3}}
\]

\[
T_p := \text{Find}(T_p) \quad T_p = 5.4 \text{s}
\]

5.1.2 Calculation of Restricted Wave Height, $H_{m0}$, and Wave Period, $T_p$

The calculation of restricted wave height, $H_{m0}$, and Wave Period, $T_p$, require the use of ACES software.

Input angle of fetch and fetch length as input to ACES with 0° facing North.

Feature Class File:
Aces
Output:

\( H_m^{ACES} = 9.999 \text{ ft} \) \hspace{1cm} \( T_P^{ACES} = 9.999 \text{ sec} \)

These fields must be populated, but will only be used for calculations if restricted radio button is selected above

ACES result file: ____________

5.1.3 Input Significant Wave Height (\( H_m^0 \)) and Wave Period (\( T_P \)) taken from STWAVE

\( H_m^{STWAVE} = 9.327 \text{ m} \) \hspace{1cm} \( T_P^{STWAVE} = 13.58 \text{ sec} \)

These fields must be populated, but will only be used for calculations if STWAVE Input radio button is selected above

Input the path to the STWAVE Model File:
\( \text{\textbackslash chifednas2\fema\Mass\Plymouth\ENGINEERING\COASTAL\GENERAL} \)

RESULT:

\( H_m^0 = 13.3 \text{ ft} \) \hspace{1cm} \( T_P = 11.5 \text{ sec} \)

Based on STWAVE model Results

5.2 Wave Setup, \( \eta \), Calculation

5.2.1 Open Coast Wave Setup Analysis

Definition of Variables:

\( m = 0.03576 \)

Insert value of average transect slope based on GIS data

Calculate Deep Water Wave Length, \( L_d^0 \):

\( L_d^0 \)
Wave Height and Wave Period Calculation Worksheet

**L₀ = \( \frac{g \cdot T_p^2}{2 \pi} \)**  \[ L₀ = 677.21 \text{ ft} \]


Calculate Wave Slope, S:

\[ S = \frac{H_{m0}}{L₀} \]

\[ S = 0.0196 \quad S = 1.96\% \]

Calculate Static Open Coast Wave Setup:

\[ \eta_{\text{open}} := H_{m0} \cdot \left( \frac{m}{s} \right)^{0.2} \]

\[ \eta_{\text{open}} = 2.4 \text{ ft} \]

Equation Source: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007 - Equation D.2.6-1

5.2.2 Wave Setup On Structures Analysis for Structures/Steep Slopes (1:8 or Steeper) which Intersect the SWEL

---

**Definition of Variables:**

Enter path and file name of .xls file containing station and elevation data for transect within the "" below:

```
Profile := READFILE("PL66_Sta_El.csv", "delimited", 2, 1)
```

Note: The Path name above corresponds to an excel file containing station and elevation data. The 1st row of the excel file
should contain column headings. The 1st column in the spreadsheet should contain the Station (ft) starting at station 0 and listed in ascending order. Column B, or the 2nd column, should contain elevation data (ft) corresponding with the associated station listed in Column A, or column 1, in ascending order by station. THIS FILE NEEDS TO BE AN .XLS FILE!!!

MATHCAD WILL NOT SUPPORT 2007 VERSION OF EXCEL.

The following displays Profile data from excel worksheet identified above and lists Station and Elevation as two separate arrays and define elevation and station in feet:

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-6436.06</td>
</tr>
<tr>
<td>1</td>
<td>-6386.06</td>
</tr>
<tr>
<td>2</td>
<td>-6336.06</td>
</tr>
<tr>
<td>3</td>
<td>-6286.06</td>
</tr>
<tr>
<td>4</td>
<td>-6236.06</td>
</tr>
<tr>
<td>5</td>
<td>-6186.06</td>
</tr>
<tr>
<td>6</td>
<td>-6136.06</td>
</tr>
<tr>
<td>7</td>
<td>-6086.06</td>
</tr>
</tbody>
</table>

The following displays the profile of the
**Wave Height and Wave Period Calculation Worksheet**

**Calc By:** RGG  
**Date:** 9-23-13

---

**Total Setup**

\[ h_T = h_1 + h_2 \]

**Check overtopping if occurs**

- **Yes**
  - **Recalculate** \( h_2 \)
  - **Calculate setup height over the structure**
    \[ h_2 = h_1 + \text{SWEL} - \text{Crest Elev} \]
    
  - **No**

- **No**
  - **Total Setup**
    \[ h_T = h_1 + h_2 \]

---

**MathCAD V14**

Saved 9/30/2013 2:34 PM

P:/20131311.06126/Scituate, MA/Scituate/Coastal/1090002/Plymouth/Plymouth_Coastal_PMR/Offshore_Wave_Models/Mathcad/Simulations/Production_Runs/Wave_Model/Ransom PL66

_HmoTp_Setup_Runup_failed_REVETMENT - Copy.xmcd_
Identify station and elevation of the toe of the structure:

\[ \text{Toe}_{\text{sta}} = 105.07 \text{ ft} \]

Input value representing coastal structure's bottom station (Toe_{\text{sta}})

\[ \text{Toe}_{\text{ele}} := \text{interp(Station, Elevation, Toe}_{\text{sta}}) \]

\[ \text{Toe}_{\text{ele}} = 10.3 \text{ ft} \]

Identify station and elevation of the top of the structure:

\[ \text{Top}_{\text{sta}} = 119.07 \text{ ft} \]

Input value representing coastal structure's top station (Top_{\text{sta}})

\[ \text{Top}_{\text{ele}} := \text{interp(Station, Elevation, Top}_{\text{sta}}) \]

\[ \text{Top}_{\text{ele}} = 19.24 \text{ ft} \]

Enter 1% annual chance stillwater elevation (ft):

\[ \text{SWEL} := 10.46 \text{ ft} \]

Associated excel file for calculation of 1% annual chance stillwater elevation (SWEL):
Calculate Water Depth at Structure, \( h \)

\[
h := \text{SWEL} - \text{Toe ele} \quad h = 0.16 \text{ ft}
\]

Calculate the Breaking Wave Height, \( H_b \):
Calculate the Breaking Wave Depth, $H_d$:

Estimated curve equation in Figure D.2.6-7

$$bh = 0.8481 \cdot s + 0.0057 \quad bh = 0.02$$

$$H_b := bh \cdot L_0 \quad H_b = 15.14 \text{ ft}$$

Figure from: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007
Wave Height and Wave Period Calculation Worksheet

Calc By: __RGG__________  Date: ____9-23-13_________

Figure from: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007

\[
\begin{align*}
\text{bd} &= 1.2205 \times s + 0.0033 \quad \text{bd} = 0.03 \\
\text{Hd} &= \text{bd} \times L_0 \quad \text{Hd} = 18.47 \text{ ft}
\end{align*}
\]

Estimated curve equation from Figure D.2.6-8

Calculate Wave Setup on a Structure, \( n_{\text{structure}} \):  

Figure from: Atlantic Ocean and
Equation based on estimated curve from Figure D.2.6-9

\[
\frac{R_w}{H} = \begin{cases} 
0.8 \left( \frac{h}{H_d} \right) + 1 & \text{if } \left( \frac{h}{H_d} \right) \leq 0.092 \\
-0.3919 \left( \frac{h}{H_d} \right) + 0.9585 & \text{if } 0.092 < \left( \frac{h}{H_d} \right) \leq 0.4 \\
-0.3475 \left( \frac{h}{H_d} \right) + 0.9379 & \text{if } 0.4 < \left( \frac{h}{H_d} \right) \leq 0.9 \\
-33.312 \left( \frac{h}{H_d} \right)^2 + 59.811 \left( \frac{h}{H_d} \right) - 26.223 & \text{if } 0.9 < \left( \frac{h}{H_d} \right) \leq 0.94444 \\
-9.8703 \left( \frac{h}{H_d} \right) + 9.8703 & \text{if } 0.94444 < \left( \frac{h}{H_d} \right) \leq 1 \\
0 & \text{otherwise}
\end{cases}
\]
\[ R = 0.99 \quad \frac{h}{H_d} = 0.01 \]

\[ \eta_1 = R \eta_{\text{open}} \quad \eta_1 = 2.38\text{ ft} \quad \eta_2 = 0.15(h + \eta_1) \quad \eta_2 = 0.38\text{ ft} \]

\[ \eta_{\text{Structure}} := \eta_1 + \eta_2 \quad \eta_{\text{Structure}} = 2.76\text{ ft} \]

**Check Overtopping if Coastal Structure Exists:**

Overtopped :=

"Yes" if \((\eta_{\text{Structure}} + \text{SWEL}) > \text{Topele}\)

"No" otherwise

\[ h_2 := \begin{cases} (\eta_{\text{Structure}} + \text{SWEL} - \text{Topele}) & \text{if Overtopped = "Yes"} \\ 0 & \text{otherwise} \end{cases} \]

**Total Setup against a coastal structure without considering overtopping**

Overtopped = "No"

Equation D.2.6-12 for \( \eta_2 \) from Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update

\[ \eta_2 = 0.15(h + \eta_1) \cdot \left[ 1 - \left( \frac{h_2}{h} \right)^2 \right] \quad \text{if Overtopped = "Yes"} \]

\[ \eta_{\text{Structure}} := \eta_1 + \eta_2 \quad \eta_{\text{Structure}} = 2.76\text{ ft} \]

**5.3 Wave Runup Analysis (Using TAW Method)**

Flow Chart of Process of Calculating Wave Runup:
Checking Slope of Revetment to determine if it is between 1:1 and 1:8:

\[
\text{Slope}_{\text{Revet}} := \frac{(\text{Top} \text{ele} - \text{Toe} \text{ele})}{(\text{Top} \text{sta} - \text{Toe} \text{sta})}
\]

\[
\text{Slope}_{\text{Revet}} = 63.83 \%
\]

\[
\text{Slope}_{\text{RevetOneOn}} := \frac{1}{\text{Slope}_{\text{Revet}}}
\]

\[
\text{Slope}_{\text{RevetOneOn}} = 1.57
\]
SlopeCheck := "TAW Method of Runup Calculation Applies" if 0 < SlopeRevetOneOn \leq 8
   "TAW Method Does Not Apply, Switch to Runup-2.0" otherwise

SlopeCheck = "TAW Method of Runup Calculation Applies"

Check if Wave is Depth Limited at the Toe of the Revetment / Barrier:

DepthLimited := "Limited" if \( H_m0 \geq 0.78 \cdot h \)
   "Not Limited" otherwise

If wave is depth limited, \( H_b \) will be used rather than \( H_m0 \)

DepthLimited = "Limited"

Determine Wave Type:

WaveType := "Shallow" if \( \frac{h}{L_0} < 2 \)
   "Transitional" if \( 0.2 \leq \frac{h}{L_0} < 0.5 \)
   "Deep" otherwise

WaveType = "Shallow"

Determine Significant Wave Height Depending on Wave Type and DepthLimited Condition:

\[ H_m0runup1 := \begin{cases} 0.88 \cdot H_m0 & \text{if } \text{WaveType = "Shallow"} \\ H_m0 & \text{otherwise} \end{cases} \]

\( H_m0runup1 = 11.7 \text{ ft} \)

\[ H_m0runup := \begin{cases} 0.78 \cdot h & \text{if } \text{DepthLimited = "Limited"} \\ H_m0runup1 & \text{otherwise} \end{cases} \]

\( H_m0runup = 0.12 \text{ ft} \)
Calculate the Spectral Wave Period, $T_{m10}$

$$T_{m10} = \frac{T_p}{1.1} \quad \text{Equation D.2.8-16} \quad T_{m10} = 10.45\text{s}$$

Calculate the Wave Length Associated with the Spectral Wave Period, $L_{m0}$:

$$L_{m0} = \frac{g T_{m10}^2}{2 \pi} \quad \text{Equation D.2.8-3} \quad L_{m0} = 559.68\text{ft}$$

Calculate the Iribarren Number, $\xi_{om}$:

$$\xi_{om} = \sqrt{\frac{\text{Slope}_{Revet}}{\frac{H_{m0}}{L_{m0}}}} \quad \xi_{om} = 42.74$$

Check TAW Method for Validity based on Iribarren Number:

$$\text{IribarrenCheck} := \begin{cases} \text{"TAW method is Valid"} & \text{if} \quad 0.5 < \xi_{om} < 10 \\ \text{"TAW method is NOT valid for this Iribarren value. Please seek alternative method."} & \text{otherwise} \end{cases}$$

$$\text{IribarrenCheck} = \text{"TAW method is NOT valid for this Iribarren value. Please seek alternative method."}$$

Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:
### Table D.2.8-6. Summary of Runup Reduction Factors

<table>
<thead>
<tr>
<th>Runup Reduction Factor</th>
<th>Characteristic/Condition</th>
<th>Value of ( \gamma_r ) for Runup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness Reduction Factor, ( \gamma_r )</td>
<td>Smooth Concrete, Asphalt, and Smooth Block Revetment</td>
<td>( \gamma_r = 1.0 )</td>
</tr>
<tr>
<td></td>
<td>1 Layer of Rock With Diameter, ( D ), ( H_i / D = 1 ) to 3.</td>
<td>( \gamma_r = 0.55 ) to 0.60</td>
</tr>
<tr>
<td></td>
<td>2 or More Layers of Rock, ( H_i / D = 1.5 ) to 6.</td>
<td>( \gamma_r = 0.5 ) to 0.55</td>
</tr>
<tr>
<td></td>
<td>Quadratic Blocks</td>
<td>( \gamma_r = 0.70 ) to 0.95. See Table V-3-3 in CEM for greater detail</td>
</tr>
<tr>
<td>Berm Section in Breakwater, ( \gamma_b ), ( B = ) Berm Width, ( (\pi d_b / x) ) in radians</td>
<td>Berm Present in Structure Cross section. See Figure D.4.5-8 for Definitions of ( B ), ( L_{bern} ) and Other Parameters</td>
<td>[ \gamma_b = 1 - \frac{B}{2L_{bern}} \left[ 1 + \cos \left( \frac{\pi d_b}{x} \right) \right], 0.6 &lt; \gamma_b &lt; 1.0 ] ( x = \begin{cases} R &amp; \text{if } \frac{R}{H_{no}} \leq \frac{d_b}{H_{no}} \ 2 \frac{H_{no}}{H_{no}} &amp; \text{if } 0 \leq \frac{d_b}{H_{no}} \leq 2 \end{cases} ) ( \text{Minimum and maximum values of } \gamma_b = 0.6 \text{ and } 1.0, \text{ respectively} )</td>
</tr>
</tbody>
</table>
| Wave Direction Factor, \( \gamma_\theta \), \( \beta \) is in degrees and \( 0^\circ \) for normally incident waves | Long-Crested Waves | \[ \gamma_\theta = \begin{cases} 1.0 & 0^\circ < |\beta| < 10^\circ \\ \cos (|\beta| - 10^\circ) & 10^\circ < |\beta| < 63^\circ \\ 0.63 & |\beta| \geq 63^\circ \end{cases} \] (D.2.8-12)
|                       | Short-Crested Waves                                                                    | \( 1 - 0.0022 |\beta|, |\beta| \leq 80^\circ \\ 1 - 0.002280^\circ, |\beta| \geq 80^\circ \) (D.2.8-13)|
| Porosity Factor, \( \gamma_r \) | Permeable Structure Core                                                              | \( \gamma_r = 1.0, \phi_{\text{om}} < 3.3; \phi_{\text{om}} = 2.0 \left( \phi_{\text{om}} \right)^{0.54}, \phi_{\text{om}} > 3.3 \) and porosity = 0.5. for smaller porosities, proportion \( \gamma_r \) according to porosity. See Figure D.2.8-7 for definition of porosity (D.2.8-14)
Select Roughness Reduction Factor, $\gamma_r$:

$$\gamma_r := \begin{cases} \gamma_r & \text{if } \gamma_r \geq 0.53 \\ "Please Select Radio Button" & \text{otherwise} \end{cases}$$

Default Value - 1 layer of rock with diameter $H_s/D = 1$ to $3$

Select Berm Section in Breakwater, $\gamma_b$:

$$\gamma_b := \begin{cases} \gamma_b & \text{if } \gamma_b > 0.5 \\ "Please Select Radio Button" & \text{otherwise} \end{cases}$$

Default Value - No Berm

Select Wave Direction Factor, $\gamma_\beta$:

$$\gamma_\beta := \begin{cases} (1 - 0.0022|\beta|) & \text{if } |\beta| \leq 80 \land \gamma_\beta = 1 \\ (1 - 0.0022|80|) & \text{if } (|\beta| > 80) \land \gamma_\beta = 1 \\ 1 & \text{if } 0 \leq |\beta| < 10 \land \gamma_\beta = 2 \\ \cos\left(\left|\beta - 10\right| \cdot \frac{\pi}{180}\right) & \text{if } (10 < |\beta| < 63) \land \gamma_\beta = 2 \\ 0.63 & \text{if } |\beta| > 63 \land \gamma_\beta = 2 \\ "Please Select Radio Button" & \text{otherwise} \end{cases}$$

Default Value - Short Crested Wave with normally incident wave
Select Porosity Factor, $\gamma_p$:

Default Porosity = 0.5

Summary of Reduction Factors:

$\gamma_p = 0.3$
$\gamma_\beta = 1$
$\gamma_b = 1$
$\gamma_r = 0.58$

Figure VI-5-11. Notational permeability coefficients (van der Meer 1988)

Default Value -

$P=0.5$

$\gamma_p = 0.3$

$P=0.4$

$P=0.5$

$P=0.6$
Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:

\[
R_{2\%} = \begin{cases} 
  H_{m0runup} \left( 1.77 \cdot \gamma_r \cdot \gamma_b \cdot \gamma_p \cdot \xi_{om} \right) & \text{if } 0.5 \leq \gamma_b \cdot \xi_{om} < 1.8 \\
  H_{m0runup} \left( \gamma_r \cdot \gamma_b \cdot \gamma_p \left( 4.3 - \frac{1.6}{\sqrt{\xi_{om}}} \right) \right) & \text{if } 1.8 \leq \gamma_b \cdot \xi_{om} \\
  0 & \text{otherwise}
\end{cases}
\]

\[
R_{2\%} = \begin{cases} 
  "TAW Not Valid" & \text{if } \text{SlopeCheck} = "TAW Method Does Not Apply, Switch to Runup-2.0" \\
  "TAW Not Valid" & \text{if } \text{IribarrenCheck} = "TAW method is NOT vaild for this Iribarren value. Please seek alternative method." \\
  R_{2\%} & \text{otherwise}
\end{cases}
\]

\[
R_{2\%} = "TAW Not Valid"
\]

Check for Overtopping:

\[
\text{OVERTOPPED}_{\text{Runup}} = \begin{cases} 
  "Overtopped... Please consider 3 foot rule" & \text{if } \left( R_{2\%} + \text{SWEL} \right) > \text{Topele} \\
  "NO Overtopping" & \text{otherwise}
\end{cases}
\]

\[
\text{OVERTOPPED}_{\text{Runup}} = 1
\]

5.4 Failed Revetment Structure Analysis

\[
\text{Armor} = 4.0
\]

Insert Depth of Armor layer in Feet

Calculate Slope of the Revetment:
Slope := (Topele - Toeole) / (Topsta - Toesta)
Slope = 0.64

Calculate the Midpoint of the Revetment:

Length := \sqrt{(Topsta - Toesta)^2 + (Topele - Toeole)^2} 
Length = 16.61 ft

Midpoint := Length / 2
Midpoint = 8.3 ft

Determine the Distance from the Shoreline to the Midpoint of the Revetment:

Midsta := \left( \frac{Midpoint}{Length} \right) (Topsta - Toesta) + Toesta
Midsta = 112.07 ft

Determine the Elevation of the Midpoint of the Revetment:

Midele := interp(Station, Elevation, Midsta)
Midele = 14.77 ft

Calculate the Upper Quarter of the Revetment:

Quarter := \frac{Length \cdot 3}{4}
Quarter = 12.46 ft

Determine the Distance from the Shoreline to the Upper Quadrant of the Revetment:

Quartersta := \left( \frac{Quarter}{Length} \right) (Topsta - Toesta) + Toesta
Quartersta = 115.57 ft

Determine the Elevation of the Upper Quadrant of the Revetment:

Quarterele := interp(Station, Elevation, Quartersta)
Quarterele = 17 ft

Calculate Scour at the Toe of the Revetment:
Adjusting the Existing Profile:

The following calculations determine the index values in the array Station which identify the toe, midpoint, upper quadrant, and top of the revetment. If the value of Toe_{location}, Mid_{location}, Quarter_{location}, or Top_{location} exists within the Station array, then only one value should appear for Toe location. If two values appear, then the station location is between two points in the Station array. If more than two value appears, adjust the TOL, convergence tolerance, in Tools > Worksheet Options... to be lower until only 2 values appear for Toelocation, Mid_{location}, Quarter_{location}, and Top_{location}.

Offset_{toe}, Offset_{mid}, Offset_{qua}, and Offset_{top} are equal to 0 if the horizontal distance from the shoreline to the bottom of the vertical structure already exists in the station array, otherwise, offset is set to 1. If no data point exists to represent the station of these locations, a data point is created in the FailSta array, which is the array of horizontal distances from the shoreline along the transect which is used to generate a profile of the failed structures.

Determine if station of the toe of the revetment is within the Station array and if not, add a data point.
Toelocation := match(Toesta, Station)

Toelocation = (286)  

Toelocation0 = 286  

Toesta = 105.07 ft

Offsettoe := 0 if Station(Toelocation0) = Toesta
1 otherwise

Offsettoe = 0

Determine if station of the midpoint of the revetment is within the Station array and if not, add a data point

Midlocation := match(Midsta, Station)

Midlocation = (286 287)

Midlocation0 = 286

Midsta = 112.07 ft

Offsetmid := 0 if Station(Midlocation0) = Midsta
1 otherwise

Offsetmid = 1

MidStaloc := Midlocation0 + Offsettoe + Offsetmid if Midsta ≥ Station(Midlocation0)

MidStaloc = 286

Determine if station of the upper quadrant of the revetment is within the Station array and if not, add a data point

Quarterlocation := match(Quartersta, Station)

Quarterlocation = (286 287)

Quarterlocation0 = 286

Quartersta = 115.57 ft

Offsetqua := 0 if Station(Quarterlocation0) = Quartersta
1 otherwise

Offsetqua = 0
Offsetqua = 1

QuarterStaloc := \begin{align*}
&\text{Quarterolocation}_0 + \text{Offsettoe} + \text{Offsetmid} + \text{Offsetqua} \quad \text{if} \quad \text{Quartersta} \geq \text{Station} \\
&\text{Quarterolocation}_0 + \text{Offsettoe} + \text{Offsetmid} \quad \text{otherwise}
\end{align*}

QuarterStaloc = 288

FailRevetStaQuarterStaloc := \text{Quartersta}

Determine if station of the top of the revetment is within the Station array and if not, add a data point

Toplocation := \text{match}(\text{Topsta}, \text{Station})

Toplocation = 287

Toplocation0 = 287

Topsta = 119.07 ft

Offsettop := \begin{align*}
&0 \quad \text{if} \quad \text{Station}(\text{Toplocation}_0) = \text{Topsta} \\
&1 \quad \text{otherwise}
\end{align*}

Offsettop = 0

TopStaloc := \begin{align*}
&\text{Toplocation}_0 + \text{Offsettoe} + \text{Offsetmid} + \text{Offsetqua} + \text{Offsettop} \quad \text{if} \quad \text{Topsta} \geq \text{Station} \\
&\text{Toplocation}_0 + \text{Offsettoe} + \text{Offsetmid} + \text{Offsetqua} \quad \text{otherwise}
\end{align*}

TopStaloc = 289

FailRevetStaTopStaloc := \text{Topsta}

Sets the station of the failed profile to be equal to the existing profile station from the shore to the toe of the revetment

\begin{align*}
i &:= \text{Toelocation}_0 \\
&0
\end{align*}

FailRevetSta_i := \text{Station}_i

FailRevetStaToeStaloc := \text{Toesta}

Sets the station of the failed profile to be equal to the existing profile station from the toe of the revetment to the midpoint of the revetment, offsetting if a data point was added to represent the toe of the revetment
\[ x := \begin{cases} 
(\text{ToeStaloc} + 1) - (\text{MidStaloc} - 1) \\
\text{ToeStaloc} & \text{if } (\text{ToeStaloc} + 1) \leq (\text{MidStaloc} - 1) \\
\text{otherwise} 
\end{cases} \]

\[ \text{FailRevetSta}_x := \begin{cases} 
\text{Station}_{x-\text{OffsetToe}} & \text{if } x \neq \text{ToeStaloc} \\
\text{Toesta} & \text{otherwise} 
\end{cases} \]

\[ \text{FailRevetSta}_{\text{MidStaloc}} := \text{Midsta} \]

Sets the station of the failed profile to be equal to the existing profile station from the midpoint of the revetment to the upper quadrant of the revetment, offsetting values if a data point was added to represent the midpoint of the revetment.

\[ y := \begin{cases} 
(\text{MidStaloc} + 1) - (\text{QuarterStaloc} - 1) \\
\text{MidStaloc} & \text{if } (\text{MidStaloc} + 1) \leq (\text{QuarterStaloc} - 1) \\
\text{otherwise} 
\end{cases} \]

\[ \text{FailRevetSta}_y := \begin{cases} 
\text{Station}_{y-\text{OffsetToe}-\text{Offsetmid}} & \text{if } y \neq \text{MidStaloc} \\
\text{Midsta} & \text{otherwise} 
\end{cases} \]

\[ \text{FailRevetSta}_{\text{QuarterStaloc}} := \text{Quartersta} \]

Sets the station of the failed profile to be equal to the existing profile station from the upper quadrant of the revetment to the top of the revetment, offsetting values if a data point was added to represent the upper quadrant of the revetment.

\[ z := \begin{cases} 
(\text{QuarterStaloc} + 1) - (\text{TopStaloc} - 1) \\
\text{QuarterStaloc} & \text{if } (\text{QuarterStaloc} + 1) \leq (\text{TopStaloc} - 1) \\
\text{otherwise} 
\end{cases} \]
FailRevetSta\_z := Station\_z - Offset\_toe - Offset\_mid - Offset\_qua if \( z = \text{QuarterStaloc} \)
QuarterSta otherwise

FailRevetSta\_TopStaloc := Top\_sta

Sets the station of the failed profile to be equal to the existing profile station from the top of the revetment to the end of the transect, offsetting values to compensate for any added data points

\[
\text{end} := \text{last(Station)} + \text{Offset\_toe} + \text{Offset\_mid} + \text{Offset\_qua} + \text{Offset\_top} \quad \text{end} = 1678
\]

\[
w := (\text{TopStaloc} + 1), \quad \text{end}
\]

\[
\text{FailRevetSta}_w := \text{Station}_w - \text{Offset\_toe} - \text{Offset\_mid} - \text{Offset\_qua} - \text{Offset\_top}
\]

Sets the elevation of the failed profile to be equal to the existing profile from the shore to the toe of the revetment and then slopes towards the shoreline at a 3h:1v slope from the toe of the revetment

\[
\text{FailRevetEle}_i := \text{Elevation}_i
\]

\[
\text{FailRevetEle}_i := \left[ \left( \frac{1}{3} \right) \left( \text{Toesta} - \text{FailRevetSta}_i \right) + \text{ToeRscour} \right] \quad \text{if} \quad \left( \frac{1}{3} \left( \text{Toesta} - \text{FailRevetSta}_i \right) + \text{ToeRscour} \right) \leq \text{Elevation}_i
\]
break otherwise

Sets the elevation at the toe of the revetment to the elevation after failure

\[
\text{FailRevetEleToeStaloc} := \text{ToeRscour}
\]

Sets the elevation of the failed revetment from the toe to the midpoint of the revetment based on armor depth if points exist between the toe and midpoint of the revetment

\[
\text{FailRevetEle}_x := \left( \frac{1}{x - \text{Offset\_toe}} - \text{ArmorD} \right) \quad \text{if} \quad x = \text{ToeStaloc}
\]
\[
\text{ToeRscour} \quad \text{otherwise}
\]
Sets the elevation of the middle of the revetment:
\[
\text{FailRevetEleMidStaloc} := (\text{Mid ele} - \text{ArmorD})
\]

Sets the elevation of the failed revetment from the midpoint to the upper quadrant of the revetment assuming a constant slope equal to the slope of the original revetment, only sloping downwards instead:
\[
\text{FailRevetEle}_{y} := \begin{cases} 
(\text{Station}_{y} - \text{Offset toe} - \text{Offset mid} - \text{Mid sta}) \cdot (\text{Slope} - 1) + (\text{Mid ele} - \text{ArmorD}) & \text{if } y \neq \text{Mid Staloc} \\
((\text{Mid ele} - \text{ArmorD})) & \text{otherwise}
\end{cases}
\]

Sets the elevation of the upper quadrant of the revetment:
\[
\text{FailRevetEleQuarterStaloc} := (\text{Quarter sta} - \text{Mid sta}) \cdot (\text{Slope} - 1) + (\text{Mid ele} - \text{ArmorD})
\]

Sets the elevation of the failed revetment from the upper quadrant to the top of the failed revetment assuming a constant slope of 1v:1.5h until it reaches the existing elevation, or the top of the revetment.
\[
\text{FailRevetEle}_{j} := \begin{cases} 
(\text{FailRevetStaj} - \text{Quarter sta}) \left( \frac{1}{1.5} \right) + \text{FailRevetEleQuarterStaloc} & \text{if } \left(\text{FailRevetStaj} - \text{Quarter sta}\right) \left( \frac{1}{1.5} \right) + \text{FailRevetEleQuarterStaloc} \leq \text{Elevation} \\
\text{break} & \text{otherwise}
\end{cases}
\]

\[
\text{Station}_{\text{failed} - \text{Offset toe} - \text{Offset mid} - \text{Offset qua} + 1} = 133.07 \text{ ft} \\
\text{Station}_{\text{failed} - \text{Offset toe} - \text{Offset mid} - \text{Offset qua}} = 119.07 \text{ ft}
\]

Finds the intersection point of failed profile and intact profile:
\[
\text{bland} := 0 \\
\text{bfailed} := 0
\]
\[
\text{Land} = 0.02
\]

Given

\[
\text{Elevation} = \frac{\text{Station} - \text{Offset} - \text{Land} + \text{Bland}}{\text{Failed} + \text{Offset} + \text{Land} + \text{Bland}}
\]

\[
\text{Bland} = \text{Find}(\text{Bland}) = 21.49 \text{ ft}
\]

\[
\text{Failed} = \frac{1}{1.5}
\]

Given

\[
\text{FailRevetEle} = \text{FailRevetSta} - \text{Failed} + \text{Bland}
\]

\[
\text{Bland} = \text{Find}(\text{Bland}) = -68.51 \text{ ft}
\]

Given

\[
\text{X} = \text{Find}(X) = 131.28 \text{ ft}
\]

\[
\text{Y} = \text{X} - \text{Failed} + 19 \text{ ft}
\]

\[
\text{FailTopSo} + \text{Failed} = 131.28 \text{ ft}
\]

\[
\text{FailTopEle} = \text{Y} = 19 \text{ ft}
\]
5.5 Wave Setup, $\eta$, Calculation on Failed Revetment
The following displays the failed profile of the transect:
Calculate Water Depth at Failed Structure, h

\[ h = \text{SWEL} - \text{Toe Scour} \quad h = 4.16 \text{ ft} \]

\[ h_b = b_h \cdot L_0 \quad H_b = 15.14 \text{ ft} \quad H_d = b_d \cdot L_0 \quad H_d = 18.47 \text{ ft} \]

Calculate Wave Setup on a Failed Structure, \( \eta_{\text{structure}} \):

Total Setup

\[ h_T = h_1 + h_2 \]

Check overtopping if occurs

Recalculate \( h_2 \)

\( h_2 = h_T + \text{SWEL} - \text{Crest Elev} \)

\( h_2 = 0.15(h_T + h_2(f_1 - (h_T / h_2)^2)) \)

Total Setup

\[ h_T = h_1 + h_2 \]
Wave Height and Wave Period Calculation Worksheet

Figure from: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Feb 2007

\[ R = 0.87 \]

\[ \eta_1 = R \cdot \eta_{\text{open}} \quad \eta_1 = 2.09 \text{ ft} \]

\[ \eta_2 = 0.15 (h + \eta_1) \quad \eta_2 = 0.94 \text{ ft} \]

\[ \eta_{\text{FailedStructure}} = \eta_1 + \eta_2 \quad \eta_{\text{FailedStructure}} = 3.02 \text{ ft} \]

Equation based on estimated curve from Figure D.2.6-9

\[ \begin{align*}
R &= \begin{cases} 
-0.8 \left( \frac{h}{H_d} \right) + 1 & \text{if } \frac{h}{H_d} \leq 0.092 \\
-0.3919 \left( \frac{h}{H_d} \right) + 0.9585 & \text{if } 0.092 < \frac{h}{H_d} \leq 0.4 \\
-0.3475 \left( \frac{h}{H_d} \right) + 0.9379 & \text{if } 0.4 < \frac{h}{H_d} \leq 0.9 \\
-33.312 \left( \frac{h}{H_d} \right)^2 + 59.811 \left( \frac{h}{H_d} \right) - 26.223 & \text{if } 0.9 < \frac{h}{H_d} \leq 0.94444 \\
-9.8703 \left( \frac{h}{H_d} \right) + 9.8703 & \text{if } 0.94444 < \frac{h}{H_d} \leq 1 \\
0 & \text{otherwise}
\end{cases}
\]

Total Setup against a coastal structure without considering overtopping

Check Overtopping if Coastal Structure Exists:

\[ \text{Overtopped} = \begin{cases} 
"Yes" & \text{if } (\eta_{\text{FailedStructure}} + \text{SWEL}) > \text{FailTopEle} \\
"No" & \text{otherwise}
\end{cases} \]

\[ \frac{h}{H_d} = 0.23 \]
\[ h_2 := \begin{cases} 
\eta_{\text{FailedStructure}} + \text{SWEL} - \text{Topo} & \text{if Overtopped = "Yes"} \\
0 & \text{otherwise}
\end{cases} \]

Equation D.2.6-12 for \( \eta_2 \) from Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update

\[ \eta_2 := \begin{cases} 
0.15 (h + \eta_1) \left[ 1 - \left( \frac{h_2}{h} \right)^2 \right] & \text{if Overtopped = "Yes"} \\
\eta_2 & \text{otherwise}
\end{cases} \]

\[ \eta_{\text{FailedStructure}} = \eta_1 + \eta_2 \quad \eta_{\text{FailedStructure}} = 3.02 \text{ ft} \]

Total Setup with a failed coastal structure
5.6 Wave Runup Analysis (Using TAW Method) on a Failed Revetment

Flow Chart of Process of Calculating Wave Runup:

1. **Input Data:** Deep Water Wave Parameters ($H_o$, $L_o$, $T_p$), barrier slope ($m$), and depth at the toe ($d_s$)

2. **Calculate Local wave parameters at barrier ($H_{m0}$, $L_m$, $T_{m-10}$)**

3. **Calculate $T_{m-10} = T_p / 1.1$ (D.2.8-16)**

4. **Calculate $L_m$ (D.2.8-3)**

5. **Wave Eqn. Type**
   - $L_o/d_s$ ≤ 0.2
   - Shallow
   - $L_o/d_s$ > 0.2

6. **Calculate $H_{m0} = 0.88H_o$**

7. **Broken Wave?**
   - Check if $H_o > 0.78d_s$
   - Yes
   - $H_{m0} = H_o = 0.78d_s$
   - No

8. **Final $H_{m0}$**

9. **Calculate $x_o = m/\sqrt{H_{m0}/d_m}$**

10. **$0.5 < x_o < 10$**
    - Yes
    - Proceed to reduction factors & calculate runup
    - No

11. **TAW not valid, find another method**
Checking Slope of Revetment to determine if it is between 1:0 and 1:8:

\[
\text{FAILSlopeCheck} = \begin{cases} 
\text{"TAW Method of Runup Calculation Applies"} & \text{if } 0 < \text{SlopeRevetOneOn} \leq 8 \\
\text{"TAW Method Does Not Apply, Switch to Runup-2.0"} & \text{otherwise}
\end{cases}
\]

If wave is depth limited at the toe of the revetment / barrier:

\[
\text{DepthLimited} = \begin{cases} 
\text{"Limited"} & \text{if } H_{m0} \geq 0.78 \cdot h \\
\text{"Not Limited"} & \text{otherwise}
\end{cases}
\]

If wave is depth limited, \( H_b \) will be used rather than \( H_{m0} \).

Determine Wave Type:

\[
\text{WaveType} = \begin{cases} 
\text{"Shallow"} & \text{if } \frac{h}{L_0} < 2 \\
\text{"Transitional"} & \text{if } 0.2 \leq \frac{h}{L_0} < 0.5 \\
\text{"Deep"} & \text{otherwise}
\end{cases}
\]

\text{WaveType} = \text{"Shallow"}
Determine Significant Wave Height Depending on WaveType and DepthLimited Condition:

\[ H_{m0runupFAIL1} = \begin{cases} 0.88 \cdot H_{m0} & \text{if WaveType = "Shallow"} \\ H_{m0} & \text{otherwise} \end{cases} \]

\[ H_{m0runupFAIL} = \begin{cases} 0.78 \cdot H_{m0} & \text{if DepthLimited = "Limited"} \\ H_{m0runupFAIL1} & \text{otherwise} \end{cases} \]

\[ H_{m0runupFAIL1} = 11.7 \text{ ft} \]

\[ H_{m0runupFAIL} = 3.24 \text{ ft} \]

Calculate the Iribarren Number, \( \xi_{om} \):

\[ \xi_{om} = \frac{\text{SlopeFAILRevet}}{\sqrt{\frac{H_{m0runupFAIL}}{L_{m0}}}} \]

\[ \xi_{om} = 6.37 \]

Check TAW Method for Validity based on Iribarren Number:

\[ \text{FAILIribarrenCheck} = \begin{cases} "TAW method is Valid" & \text{if } 0.5 < \xi_{om} < 10 \\ "TAW method is NOT valid for this Irbarren value. Please seek alternative method." & \text{otherwise} \end{cases} \]

Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:

Select Roughness Reduction Factor, \( \gamma_\zeta \):

Default - 1 layer of rock with diameter, d, where \( H_s/d = 1 \) to 3
Wave Height and Wave Period Calculation Worksheet

Calc By: RGG
Date: 9-23-13

Select Berm Section in Breakwater, γ_b:

\[ \gamma_b = \begin{cases} 
\gamma_b & \text{if } \gamma_b > 0.5 \\
\text{"Please Select Radio Button"} & \text{otherwise}
\end{cases} \]

γ_b = 0.6

Select Wave Direction Factor, γ_β:

\[ \gamma_\beta = \begin{cases} 
(1 - 0.0022 |\beta|) & \text{if } |\beta| \leq 80 \land \gamma_\beta = 1 \\
(1 - 0.0022 |80|) & \text{if } (|\beta| > 80) \land \gamma_\beta = 1 \\
1 & \text{if } 0 \leq |\beta| < 10 \land \gamma_\beta = 2 \\
\cos \left( (|\beta| - 10) \left( \frac{\pi}{180} \right) \right) & \text{if } (10 < |\beta| < 63 \land \gamma_\beta = 2) \\
0.63 & \text{if } |\beta| > 63 \land \gamma_\beta = 2 \\
\text{"Please Select Radio Button"} & \text{otherwise}
\end{cases} \]

γ_β = 1

Select Porosity Factor, γ_p:

\[ \gamma_p = \begin{cases} 
1 & \text{if } \left( \text{Porosity} = 0.5 \right) \land \xi_{om} \leq 3.3 \\
\left( \frac{2}{1.17 \xi_{om} 0.46} \right) & \text{if } \left( \text{Porosity} = 0.5 \right) \land \xi_{om} > 3.3 \\
0.5 & \text{otherwise}
\end{cases} \]

γ_p = 0.73

Default Porosity = 0.5
Summary of Reduction Factors:

\[ \gamma_p = 0.73 \]

\[ \gamma_b = 1 \]

\[ \gamma_b = 0.6 \]

\[ \gamma_r = 0.58 \]

Calculate Runup Reduction Factors in Accordance with Table D.2.8-5 of Guidelines and Specifications for Flood Hazard Mapping:

\[
R_{FAIL2\%} = \begin{cases} 
H_{m0runup} \left( 1.77 \gamma_r \gamma_b \gamma_p \xi_{om} \right) & \text{if } 0.5 \leq \gamma_b \xi_{om} < 1.8 \\
H_{m0runup} \left[ \gamma_r \gamma_b \gamma_p \left( 4.3 - \frac{1.6}{\xi_{om}} \right) \right] & \text{if } 1.8 \leq \gamma_b \xi_{om}
\end{cases}
\]

\[
R_{FAIL2\%} = \begin{cases} 
"TAW Not Valid" & \text{if } \text{FAILSlopeCheck} = "TAW Method Does Not Apply, Switch to Runup-2.0" \\
"TAW Not Valid" & \text{if } \text{FAILIrbarrenCheck} = "TAW method is NOT valid for this Irbarren value. Please seek alternative method." \\
R_{FAIL2\%} & \text{otherwise}
\end{cases}
\]

\[ R_{FAIL2\%} = 0.12 \text{ft} \]

Check for Overtopping:

\[
\text{OVERTOPPEDFAILRunup} = \begin{cases} 
"Overtopped... Please consider 3 foot rule" & \text{if } \left( R_{FAIL2\%} + \text{SWEL} \right) > \text{FailTopEle} \\
"NO Overtopping" & \text{otherwise}
\end{cases}
\]

\[ \text{OVERTOPPEDFAILRunup} = "NO Overtopping" \]
6.0 Conclusions/Results

Wave Height, $H_{m0}$

$H_{m0} = 13.3$ ft

FetchStatus = "STWAVE Input (Hmo, Tp)"

Wave Period, $T_p$

$T_p = 11.5$ s

FetchStatus = "STWAVE Input (Hmo, Tp)"

Wave Setup on an open coast, $\eta_{open}$

$\eta_{open} = 2.4$ ft

Wave Setup on a revetment, $\eta_{Structure}$

$\eta_{Structure} = 2.76$ ft

Wave Runup on a revetment, $R_{2\%}$

$R_{2\%} = "TAW Not Valid"$

Runup result from ACES for intact = 0.6'

2% Runup Elevation from Runup2 intact = 3.3'

Failed Structure Profile:

Wave Setup on a Failed Structure, $\eta$

$\eta_{FailedStructure} = 3.02$ ft
Wave Runup on a Failed Structure, $R_{FAIL2\%}$

$R_{FAIL2\%} = 0.12\text{ft}$

OVERTOPPEDFAILRunup = "NO Overtopping"

Top of Failed Revetment Station and Elevation:

$\text{FailTopSta} = 131.28\text{ft}$

$\text{FailTopEle} = 19\text{ft}$

$\text{FailSta} := \text{FailRevetSta} - 1\text{ft}$

$\text{FailEle} := \text{FailRevetEle} - 1\text{ft}$

NOTES:
Input Parameters for ACES Runup - Intertidal Assessment

PL-66

Based on Penny Decision Tree

$SWEL = 10.46 \quad H_m = 13.3 \quad TP = 11.5 \quad$ from $5^{th}$ WAVE

$\text{transit slope} = 0.03576 \quad \text{wave slope} = 0.0196$ (Chow's)

Stage:

$T_{\text{Stage}} = 10.1 \quad T_{\text{ele}} = 10.3 \quad \Rightarrow \text{well matched}

\begin{align*}
\text{Top} & = 9.1 \quad \text{top plan} = 10.2 \quad \Rightarrow 8.9^o \\
\text{Total Step} \text{ on Structure} & = 2.76^o
\end{align*}

$\text{Stage} > 1:8 \quad \text{and Stage} < 1:1 \quad \text{and $\text{Stage} > 10$}

\Rightarrow \text{ACES}

\text{Mean wave height} = 0.626 \times H_m = 8.33'

\text{Mean } T = 0.85 \times 11.5 = 9.78 \text{ sec}

\text{Foreshore slope} = 0.1 \text{ or cut 10}

\begin{align*}
\frac{d_s}{H_o} & = 0.66 \\ H_o & = 8.33 \\ d_s & = 0.192
\end{align*}

\text{From ACES} \quad \text{Runup} = 0.27'

2% Runup $= 2.2 \times 0.27' = 0.59'$

$R_{2\% \text{ Runup}} = 10.46 + 0.59' = 11.05'$
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<thead>
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ZONE TERMINATED AT END OF TRANSECT

PART 7 POSTSCRIPT NOTES
Wave Transect PL-66 Ransom WHAFIS Output, Failed Profile

PART4 LOCATION OF SURGE CHANGES

<table>
<thead>
<tr>
<th>STATION</th>
<th>10-YEAR SURGE</th>
<th>100-YEAR SURGE</th>
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<tbody>
<tr>
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<td>NO SURGE CHANGES IN THIS TRANSECT</td>
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PART5 LOCATION OF V ZONES

<table>
<thead>
<tr>
<th>STATION OF GUTTER</th>
<th>LOCATION OF ZONE</th>
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<tbody>
<tr>
<td>105.82</td>
<td>WINDWARD</td>
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PART6 NUMBERED A ZONES AND V ZONES

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<thead>
<tr>
<th>STATION OF GUTTER</th>
<th>ELEVATION</th>
<th>ZONE DESIGNATION</th>
<th>FHF</th>
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<tr>
<td>0.00</td>
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<td></td>
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<td>V30 EL=20</td>
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<td>V30 EL=19</td>
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<td>32.61</td>
<td>18.50</td>
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<td>V30 EL=18</td>
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<td>Value 2</td>
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<td>17</td>
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<td>A24</td>
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<td>A24</td>
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<td>A24</td>
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<td>1259.43</td>
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<tr>
<td>2135.35</td>
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5364.00      13.52
5414.00      14.14
5464.00      13.80
5514.00      13.22
      A24  EL=14     140
5643.11      13.50
      A24  EL=13     140
6252.79      13.50
      A24  EL=14     140
11904.86     13.50
      A24  EL=13     140
12664.00     13.22

ZONE TERMINATED AT END OF TRANSECT

PART 7    POSTSCRIPT NOTES
Note: The only zones redefined by Ransom are the labeled zones.
### Comparison of Ransom and STARR Engineering Calculations for Wave Transects PL-64 and PL-66

<table>
<thead>
<tr>
<th>TRANSECT ID</th>
<th>Open / Restricted</th>
<th>Fetch Length (mi)</th>
<th>Wind Speed (m/s)</th>
<th>SWEL</th>
<th>Wave Height</th>
<th>Wave Period</th>
<th>Wave Length</th>
<th>H_b</th>
<th>d_b</th>
<th>Toe / Breaking Wave Height Elevation</th>
<th>Top / SWEL Elevation</th>
<th>Toe Station</th>
<th>Top / SWEL Station</th>
<th>Average Transect SLOPE, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL-64</td>
<td>Open</td>
<td>35.76</td>
<td>10.46</td>
<td>10.65</td>
<td>31.09621</td>
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<td>581.2664</td>
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<td>0.014516</td>
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<tr>
<td>Ransom PL64</td>
<td>Open</td>
<td>35.76</td>
<td>10.46</td>
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<td>10.46</td>
<td>11.2</td>
<td>642.3</td>
<td>13.32</td>
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<td>11.5</td>
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</table>
# Comparison of Ransom and STARR Engineering Calculations for Wave Transects PL-64 and PL-66

<table>
<thead>
<tr>
<th>TRANSECT ID</th>
<th>Average Beach Slope</th>
<th>Wave Setup</th>
<th>Wave Runup</th>
<th>Structure Arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:ON</td>
<td>Open, (h_{\text{open}}) (ft)</td>
<td>With Structure (h_{\text{structure}}) (ft)</td>
<td>Total Water Level</td>
</tr>
<tr>
<td>PL-64</td>
<td>68.89003</td>
<td>0.207211</td>
<td>4.826003824</td>
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<tr>
<td>Ransom PL64</td>
<td>44.35</td>
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<tr>
<td>PL-66</td>
<td>53.03029</td>
<td>0.102549</td>
<td>9.751434034</td>
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<td>Ransom PL66</td>
<td>27.96</td>
<td>0.1025</td>
<td>9.75</td>
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</table>
## Comparison of Ransom and STARR Engineering Calculations for Wave Transects PL-64 and PL-66

<table>
<thead>
<tr>
<th>TRANSECT ID</th>
<th>Toe Station (ft)</th>
<th>Top Station (ft)</th>
<th>Armor Depth (ft)</th>
<th>Failed Structure Top Station (ft)</th>
<th>Failed Structure Top Elevation (ft)</th>
<th>hFailedStructure (ft)</th>
<th>Runup 2% (ft)</th>
<th>Method</th>
<th>Overtopped?</th>
<th>SURVEY</th>
<th>SWEL/T WEL</th>
<th>STRUCTURE</th>
<th>FAILURE</th>
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</thead>
<tbody>
<tr>
<td>PL-64</td>
<td>39.77</td>
<td>73.77</td>
<td>4</td>
<td>93.56</td>
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<td>5.31</td>
<td>5.55</td>
<td>TAW</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Ransom PL64</td>
<td>39.77</td>
<td>73.77</td>
<td>4</td>
<td>93.56</td>
<td>24.09</td>
<td>10.1</td>
<td>5.41</td>
<td>TAW</td>
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<td>119.07</td>
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<td>Yes</td>
<td>No</td>
<td>No</td>
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<td>119.07</td>
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<td>19</td>
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<td>0.12</td>
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</table>

### Notes on Analysis

Failed Structure Analysis
### Comparison of Ransom and STARR Engineering Calculations for Wave Transects PL-64 and PL-66

<table>
<thead>
<tr>
<th>TRANSECT ID</th>
<th>EROSION</th>
<th>RUNUP INTACT</th>
<th>RUNUP FAILED</th>
<th>WHAFIS INTACT</th>
<th>WHAFIS FAILED</th>
<th>General Notes</th>
<th>Run-Up Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL-64</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Ransom PL64</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>PL-66</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Failed the structure using a lower toe station.</td>
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<tr>
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<td>No</td>
<td>No</td>
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</tbody>
</table>

**Notes:**
- No
- Yes