Design for 100-Yr storm

1. Marine Mattress with Gabion Toe

The wave will be limited to the depth at the structure, which is determined by combination of storm surge during storm conditions, additional setup due to the breaking wave and the depth at the revetment toe.

- **Still Water Level:**

  10.2 ft MLW based on 100-yr storm - (2006 FEIR, Table 5-5)

- **Deep Water Wave Height:**

  28.8 ft interpolated for 100-yr storm - (2006 FEIR, Table 5-4)

- **Design Toe Elevation:**

  + 8.0 ft average elevation of bank toe along study area

- **Wave Setup:**

  Wave setup will be calculated according to the direct integration method (DIM) methodology

  Estimated setup = 3.9 ft - see calculation attached

- **Design Water Depth:**

  Design water depth (100-yr) at the structure's toe will be calculated as:

  10.2 ft + 3.9 ft - 8.0 ft = 6.1 ft ✓ ✓ ✓

- **Wave Height:**

  Assume breaker index of 0.78. The maximum wave height which would occur at the depth above will be:

  6.1 ft * 0.78 = 4.8 ft ✓ H_{10} = 6.1 H_{max} = 8'

  Wave peak period = 15.2 sec. ✓

- **Wave Run-up:**

  Wave run-up will be estimated using the following methods:

  ACES Estimated runup = 9.1 ft - calcs attached for the method

  Run-up on Beach= 10.3 ft (2%) & 11.2 ft (max) - calc attached

  Taw Method = 10.9 ft - calc attached for the method

  Use 11.0 ft for run-up (conservative)

- **Crest Elevation:**

Structure required crest elevation = 10.2 ft + 3.9 ft + 11.0 ft = 25.1 ft (use 25.0 ft)

1 ft sand cover will be added to bring the crest elevation to +26.0 ft MLW

Check final crest elevation even for maximum runup (11 ft):

10.2 ft + 3.9 ft + 11.2 ft = 25.3 ft (< 26 ft OK)

- **Marine Mattress Stability:**

Design guidance provided in "Triton coastal engineering with TENSAR geogrid" indicate that the minimum thickness for the marine mattress; used as an armor; should meet the following stability requirements to resist sliding and uplift

$$T_{mat,d} > \frac{H}{2.8\ s\ (S_r - 1)\ (1 - p)} \quad \textit{for downslope stability}$$

$$T_{mat,u} > \frac{H}{7\ s^{1/3}\ (S_r - 1)\ (1 - p)} \quad \textit{for upliftstability}$$

Where:

T = required mat thickness for stability

H = significant wave height = 4.8 ft (use 5 ft)

S_r = Specific gravity of the stones = 2.65 (typical value)

P = voids allowance = 0.35 (typical value)

S = slope of the structure, 1.5

RESULTS:

T_{min}= 13.3 in. for downslope stability

T_{min}= 7 in. for uplift stability

Marine Mattresses typically come in 12-, 18- and 24-in. thicknesses; therefore we will use 18-in. thick mattresses for this design

- **Scour Depth:**

As a rule of thumb, the scour depth can be estimated as equal to the incident wave height. The apron length will be 2.5 to 3.5 times the incident wave height.

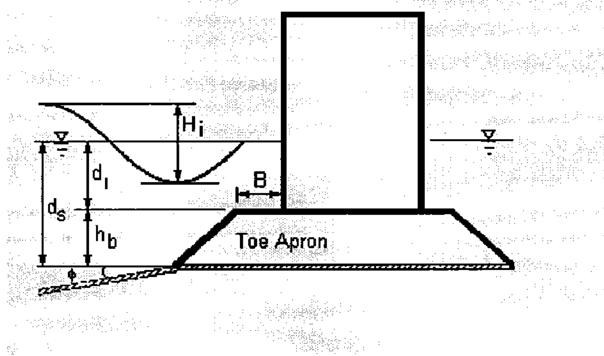
The scour depth requirements therefore will be ~ 5 ft or ~ 6 ft assuming the 100-yr storm wave occurs. Take scour depth = 6 ft ✓

The required apron width is between 12 ft to 17 ft - Three successive gabions will provide 15 ft width, assuming gabion basket sizes are 4 ft X 5 ft X 6 ft

OCEAN AND COASTAL CONSULTANTS

		Sheet No	3	**of**	4
Project	**Sconset Coastal Bank Stabilization**	**Job No**	210019	**Task No**	004
Subject	**Marine Mattress and Gabion Concept**	**Made By**	ADKA	**Date**	08/20/10
	100-Year Storm Design Calculations	**Checked By**	BRJO	**Date**	08/25/10

- **Gabion Stability:**



Stability of gabion units (static stability) **in accordance to methods presented in port engineering text book, Tsinker and CIRIA**

H_s= 4.8 ft (1.46 m), T=15 sec

D_{gabion}= 5 ft (1.52 m)

And slope 1:1.5 (tan α= 0.667, cos α = 0.832)

F = stability factor (6 -9) -> use 6 (more conservative)

Breaker parameter ζ_{op}=tan α /Sqrt(H_s/1.56*T^2) ~ 10.47

$(H_s)_{cr}$= 1.52 m * 6 * 10.47^-(2/3) = 1.96 m > 1.46 m - OK (Eqn. 5.27a) Tsinker

OR use Pilarczyk's eqn.

Assume F in the range of 7-9. The critical wave height:

$(H_s)_{cr}$= 1.52 m* 9*cos α /ζ^$^{(2/3)}$ = 2.38 m > 1.52 m - OK [F= 9] (Eqn. 5.27b) Tsinker

$(H_s)_{cr}$= 1.52 m* 7*cos α /ζ^$^{(2/3)}$ = 1.85 m > 1.52 m - OK [F= 9] (Eqn. 5.184) CIRIA

Stability of filling materials (Dynamic stability)

Assume F = 5 (per CIRIA)

D_f= (H_s)*sqrt(10.47) / (1.65*5)= 0.57m ~ 22" (Eqn. 5.28) Tsinker & (Eqn. 5.185) CIRIA

This method provides larger filling stone requirement.

Toe Protection requirements (ACES)

Design of toe stone will be performed using ACES (as a guidance only) to check the filling stones size inside the gabions. Scour depth (gabion height) will be added to the water depth in order to run the model (see sketch) Model output:

Required weight of individual armor = **145 lb ~ 12 in. stones**. Note that this is the requirement for toe stone as a loose rock. **THE FILLED GABIONS ARE MORE STABLE THAN LOOSE ROCK.** The motion of filling material can lead to rupture of the mesh. So for fill stone size, select a range of between 12- and 22-in. diameter stones. Use 3-in. stone to fill the voids. The size of the gabion mesh shall be less than 3 in. to prevent fill stone from escaping out of the basket.

Encounter Probability

Table 1 - Probability of achieving or exceeding the return period design wave during the design life of the project (Encounter probability)

Return Period (yr)	Time Period encounter probability (yr)					
	2	5	10	25	50	100
2	75.0%	96.9%	99.9%	100.0%	100.0%	100.0%
5	36.0%	67.2%	89.3%	99.6%	100.0%	100.0%
10	19.0%	41.0%	65.1%	92.8%	99.5%	100.0%
25	7.8%	18.5%	33.5%	64.0%	87.0%	98.3%
50	4.0%	9.6%	18.3%	39.7%	63.6%	86.7%
100	2.0%	4.9%	9.6%	22.2%	39.5%	63.4%

OPEN COAST WAVE SETUP ANALYSIS FOR NANTUCKET - MA

Wave setup is an increase in the 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 contributer to the total water level at the shoreline and must be included in the determination of coastal base flood elevations. The following methodology (Direct Integration Method [DIM]) should be used for calculating wave setup for each coastal transect.

Transect: Nantucket

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$Ho := 28.8ft$ Deepwater significant wave height (estimated for 100 yr)

$S := 0.035$ Wave Steepness ($S = \frac{Ho}{Lo}$) (Recommendation:Wave Steepness = 0.035 for Extratropical storms "Northeasters" and 0.040 for Hurricanes)

$m := \frac{1}{65}$ Average slope of transect (determined from nautical chart)

STEP 2: DETERMINE DEEP WATER WAVE LENGTH (L_o)

$Lo := \frac{Ho}{S}$ Deep water wave length $Lo = 822.9\,ft$

The associated wave period is estimated for the wave steepness (After Goda Eq. 11.47)

$T := \sqrt{\frac{Ho}{5.12 \cdot S \cdot ft}} \cdot sec$ $T = 12.7\,s$

STEP 3: CALCULATE SETUP USING DIM METHOD

$$\eta := Ho \cdot 0.16 \cdot \frac{m^{0.2}}{\left(\frac{Ho}{Lo}\right)^{0.2}}$$ Equation D.2.6-1

$\eta = 3.9\,ft$ Wave Setup

REFERENCE: Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, FEMA, February 2007
Random Seas And Design of Marine Structures, Y. Goda

Project: Sconset
Group: Sconset

Case: Runup-STR marine mattress 100-Yr

Wave Runup and Overtopping on Impermeable Structures

Wave type: Monochromatic **Slope type:** Rough
Rate estimate: Runup

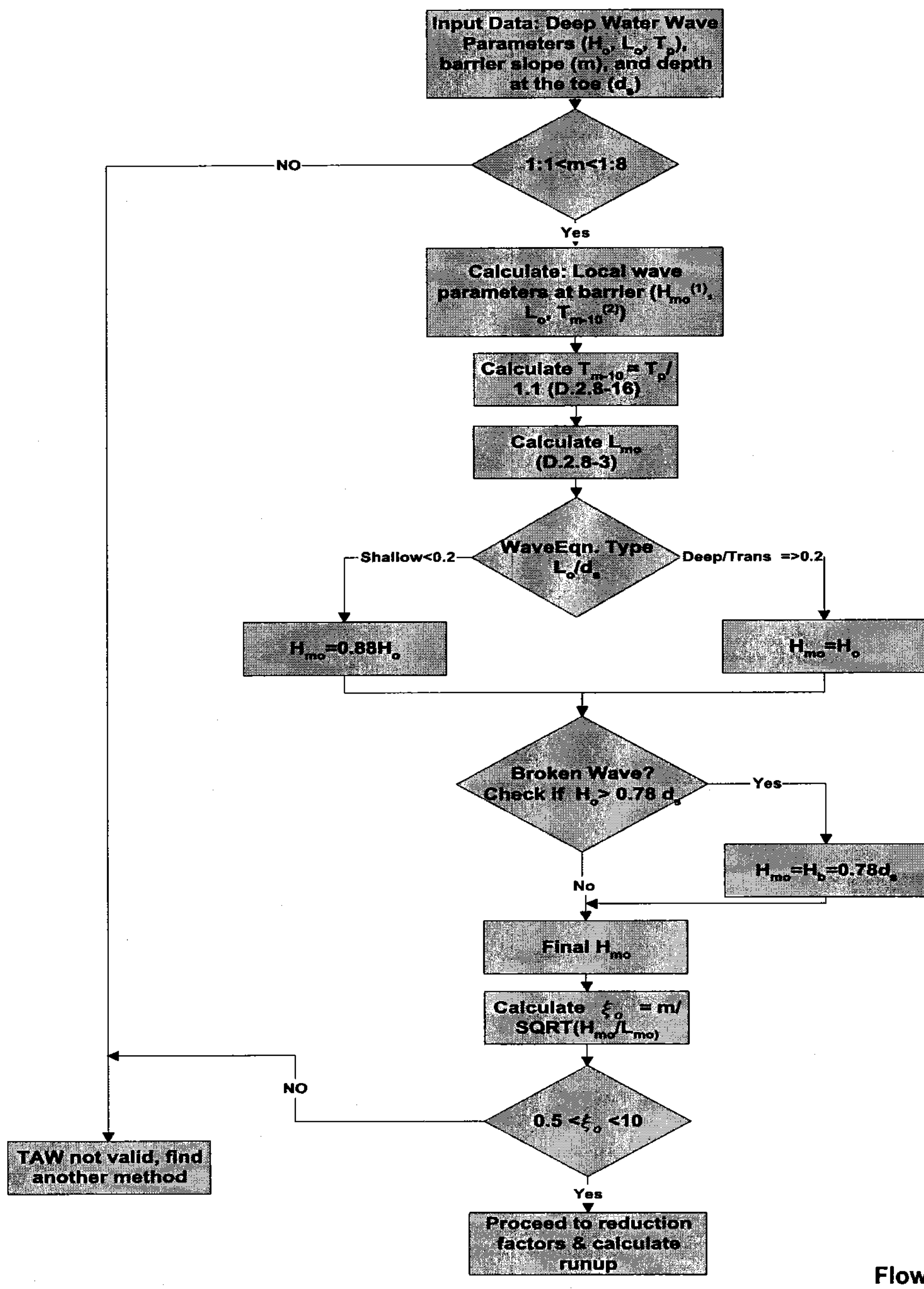
Breaking criteria:	0.780				
Incident wave ht (Hi):	4.700	ft	Wave Runup (R):	9.122	ft
Peak wave period (T):	15.200				
COTAN of nearshore slope (cot phi):	65.000		Deepwater wave (Ho):	2.797	ft
Water depth at structure toe (ds):	6.100	ft	Relative height (ds/Ho):	2.181	
COTAN of structure slope (cot theta):	1.500		Wave steepness (Ho/gT^2):	0.000	
Structure height above toe (hs):	17.000	ft			
Rough slope coefficient(a):	0.956				
Rough slope coefficient(b):	0.398				

Project: Sconset
Group: Sconset

Case: Runup Beach 1:65 - 100 yr		
Irregular Wave Runup on Smooth Slope Linear E		
Deepwater significant wave height:	28.80	ft
Peak energy wave period:	15.20	
Cotangent of beach slope:	65.00	
Maximum wave runup:	11.22	ft
Runup exceeded by 2% of runups:	10.34	ft
Average of highest 1/10 of runups:	9.45	ft
Average of highest 1/3 of runups	7.85	ft
Average wave runup:	5.12	ft

WAVE RUNUP ON BARRIERS ANALYSIS (TAW METHOD)

Wave runup is the uprush of water from wave action on a shore barrier intercepting still water level. The presence of coastal structures/steep slopes is not unusual. The structures could be overtopped or non overtopped.The following methodology (TAW) should be used for calculating wave runup on barriers.



Flowchart for TAW method to calculate runup on barrier

To use: *edit values highlighted in* green

Transcect: Sconset

STEP 1: PROVIDE WAVE PARAMETERS AND AVERAGE NEARSHORE SLOPE FOR TRANSECT

$d_s := 6.1ft$ Depth at structure/slope toe. (Calculate as: SWEL-ELEVATION OF TOE)

indicate the available information **(T or S)**

○ Deep Water Wave Steepness $S := 0.035$ Deep water wave steepness ($S = \frac{H_o}{L_o}$) (Wave Steepness = 0.035 for Extratropical storms "Northeasters" and 0.040 for Hurricanes)

◉ Peak Wave Period $T_p := 15.2sec$ Peak wave period

$H_o := 28.8ft$ Deep water significant wave height in feet (estimated for 100-Yr storm)

$C := 23.5ft$ Crest of the structure/slope Elevation in feet

$SWEL := 10.2\,ft$ Still water elevation in feet (NAVD)

$m := \frac{1}{1.5}$ Barrier slope

$$L_o := \begin{cases} \frac{H_o}{S} & \text{if } WS1 = 1 \\ \frac{g \cdot T_p^2}{2\pi} & \text{if } WS1 = 2 \\ 0 & \text{otherwise} \end{cases}$$

Deep Water Wave Length based on wave steepness input

Deep Water Wave Length based on peak wave period input

$$S := \begin{cases} S & \text{if } WS1 = 1 \\ \frac{H_o}{L_o} & \text{if } WS1 = 2 \\ 0 & \text{otherwise} \end{cases}$$

$$T_p := \begin{cases} \sqrt{\frac{L_o}{5.12 \cdot ft}} \cdot sec & \text{if } WS1 = 1 \\ T_p & \text{if } WS1 = 2 \\ 0 & \text{otherwise} \end{cases}$$

$S = 0.024$

$L_o = 1 \times 10^3\,ft$

$T_p = 15.2\,sec$

STEP 2: CALCULATE WAVE PARAMETERS AT BARRIER LOCATION

Check if broken wave

$$\text{BrokenWave} := \begin{cases} \text{"Broken"} & \text{if } H_o \geq 0.78 \cdot d_s \\ \text{"Not Broken"} & \text{if } H_o < 0.78 \cdot d_s \\ \text{"Undetermined"} & \text{otherwise} \end{cases}$$

H_b will be taken

BrokenWave = "Broken"

$$\text{WaveType} := \begin{cases} \text{"Shallow""} & \text{if } \frac{d_s}{L_o} < 0.2 \\ \text{"Transitional"} & \text{if } 0.2 \leq \frac{d_s}{L_o} < 0.5 \\ \text{"Deep"} & \text{if } \left(\frac{d_s}{L_o}\right) \geq 0.5 \end{cases}$$

WaveType = "Shallow""

$$H_{mo} := \begin{cases} H_o & \text{if WaveType = "Deep"} \\ H_o & \text{if WaveType = "Transitional"} \\ .88 \cdot H_o & \text{if WaveType = "Shallow""} \\ \text{"NONE"} & \text{otherwise} \end{cases}$$

Deep Water

Shallow Water

$H_{mo} = 25.3\,\text{ft}$

$$H_{mo} := \begin{cases} d_s \cdot 0.78 & \text{if BrokenWave = "Broken"} \\ H_{mo} & \text{if BrokenWave = "Not Broken"} \\ 0 & \text{otherwise} \end{cases}$$

H_b will be taken

H_{mo} will be taken

in case error

$H_{mo} = 4.76\,\text{ft}$

$$T_{m10} := \frac{T_p}{1.1} \qquad \text{(D.2.8-16)}$$

$T_{m10} = 13.8\,\text{s}$

$$L_{mo} := \left(\frac{g}{2 \cdot \pi}\right) \cdot T_{m10}^{\ 2} \qquad \text{(after D.2.8-3)}$$

$L_{mo} = 977.7\,\text{ft}$

Iribarren number, ξ_o

$$\xi_{om} := \frac{m}{\sqrt{\frac{H_{mo}}{L_{mo}}}}$$

$\xi_{om} = 9.56$

Check TAW method for Validity

TAW method will be valid if:

* $0.5< \xi_{om} <8\text{–}10$

* 1:1<Barrier Slope<1:8

$$\text{TAW\_Validity} := \begin{cases} \text{"Valid"} & \text{if } (0.5 < \xi_{om} < 10) \wedge (0.1 \le m \le 1) \\ \text{"Not valid, Seek Another Method"} & \text{otherwise} \end{cases}$$

continue

TAW_Validity = "Valid"

STEP 3: CALCULATE REDUCTION FACTORS

In accordance to Table D.2.8-5

Roughness Reduction Factor, γ_r

- (•) Smooth concrete, asphalt, and smooth block revetment
- ( ) 1 Layer of Rock with Diameter, D. Hs/D=1 to 3
- ( ) 2 or more layers of rock Hs/D=1.5 to 6
- ( ) Quadratic Blocks

refer to CEM for accurate values

Wave Direction Factor, γ_β

$\gamma_{\beta d} := 0$ 0° for normally incident wave

- (•) Short-Crested Wave default
- ( ) Long-Crested Wave

Berm Section in Breakwater, γ_b

- (•) No Berm default
- ( ) Berm

Porosity Factor, γ_p

- ( ) P=0.1
- ( ) P=0.4
- (•) P=0.5 default
- ( ) P=0.6

other than defaults, refer to CEM for accurate values

Table D.2.8-5. Summary of γ Runup Reduction Factors

Runup Reduction Factor	Characteristic/Condition	Value of γ for Runup	
Roughness Reduction Factor, γ_r	Smooth Concrete, Asphalt, and Smooth Block Revetment	$\gamma_r = 1.0$	(D.2.8-10)
	1 Layer of Rock With Diameter, D. $H_s / D = 1$ to 3.	$\gamma_r = 0.55$ to 0.60	
	2 or More Layers of Rock. $H_s / D = 1.5$ to 6.	$\gamma_r = 0.5$ to 0.55	
	Quadratic Blocks	$\gamma_r = 0.70$ to 0.95. See Table V-5-3 in CEM for greater detail	
Berm Section in Breakwater, γ_b, B = Berm Width, $\left(\frac{\pi d_h}{x}\right)$ in radians	Berm Present in Structure Cross section. See Figure D.4.5-8 for Definitions of B, L_{berm} and Other Parameters	$\gamma_b = 1 - \frac{B}{2L_{berm}}\left[1+\cos\left(\frac{\pi d_h}{x}\right)\right], 0.6 < \gamma_B < 1.0$ $x = \begin{cases} R \text{ if } \frac{-R}{H_{mo}} \le \frac{d_h}{H_{mo}} \le 0 \\ 2H_{mo} \text{ if } 0 \le \frac{d_h}{H_{mo}} \le 2 \end{cases}$ Minimum and maximum values of $\gamma_b = 0.6$ and 1.0, respectively	(D.2.8-11)
Wave Direction Factor, γ_β, β is in degrees and = 0° for normally incident waves	Long-Crested Waves	$\gamma_\beta = \begin{cases} 1.0, 0 < \lvert\beta\rvert < 10^o \\ \cos(\lvert\beta\rvert - 10^o), 10^o < \lvert\beta\rvert < 63^o \\ 0.63, \lvert\beta\rvert > 63^o \end{cases}$	(D.2.8-12)
	Short-Crested Waves	$1 - 0.0022\lvert\beta\rvert, \lvert\beta\rvert \le 80^o$ $1 - 0.0022\lvert 80\rvert, \lvert\beta\rvert \ge 80^o$	(D.2.8-13)
Porosity Factor, γ_P	Permeable Structure Core	$\gamma_P = 1.0$, $\xi_{om} < 3.3$; $\gamma_P = \frac{2.0}{1.17(\xi_{om})^{0.46}}$, $\xi_{om} >$ 3.3 and porosity = 0.5. for smaller porosities, proportion γ_P according to porosity . See Figure D.2.8-7 for definition of porosity	(D.2.8-14)

Based on the seleced parameters, the reduction factors are summarized as follows:

Edit factors below if desired, otherwise leave as is:

Roughness Reduction Factor=	$\gamma_r = 1$	$\gamma_r = \gamma_r$
Berm Section=	$\gamma_b = 1$	$\gamma_b = \gamma_b$
Wave Direction Factor=	$\gamma_\beta = 1$	$\gamma_\beta = \gamma_\beta$
Porosity Factor=	$\gamma_p = 0.61$	$\gamma_p = \gamma_p$

STEP 4: CALCULATE RUNUP

$$R := \begin{cases} H_{mo}\cdot\left(1.77\cdot\gamma_r\cdot\gamma_b\cdot\gamma_\beta\cdot\gamma_p\cdot\xi_{om}\right) & \text{if } 0.5 \le \gamma_b\cdot\xi_{om} < 1.8 \\ H_{mo}\cdot\left[\gamma_r\cdot\gamma_b\cdot\gamma_\beta\cdot\gamma_p\cdot\left(4.3 - \frac{1.6}{\sqrt{\xi_{om}}}\right)\right] & \text{if } 1.8 \le \gamma_b\cdot\xi_{om} \\ 0 & \text{otherwise} \end{cases}$$

Total Final Wave Runup

→ $R = 10.9\,ft$

Check Overtopping

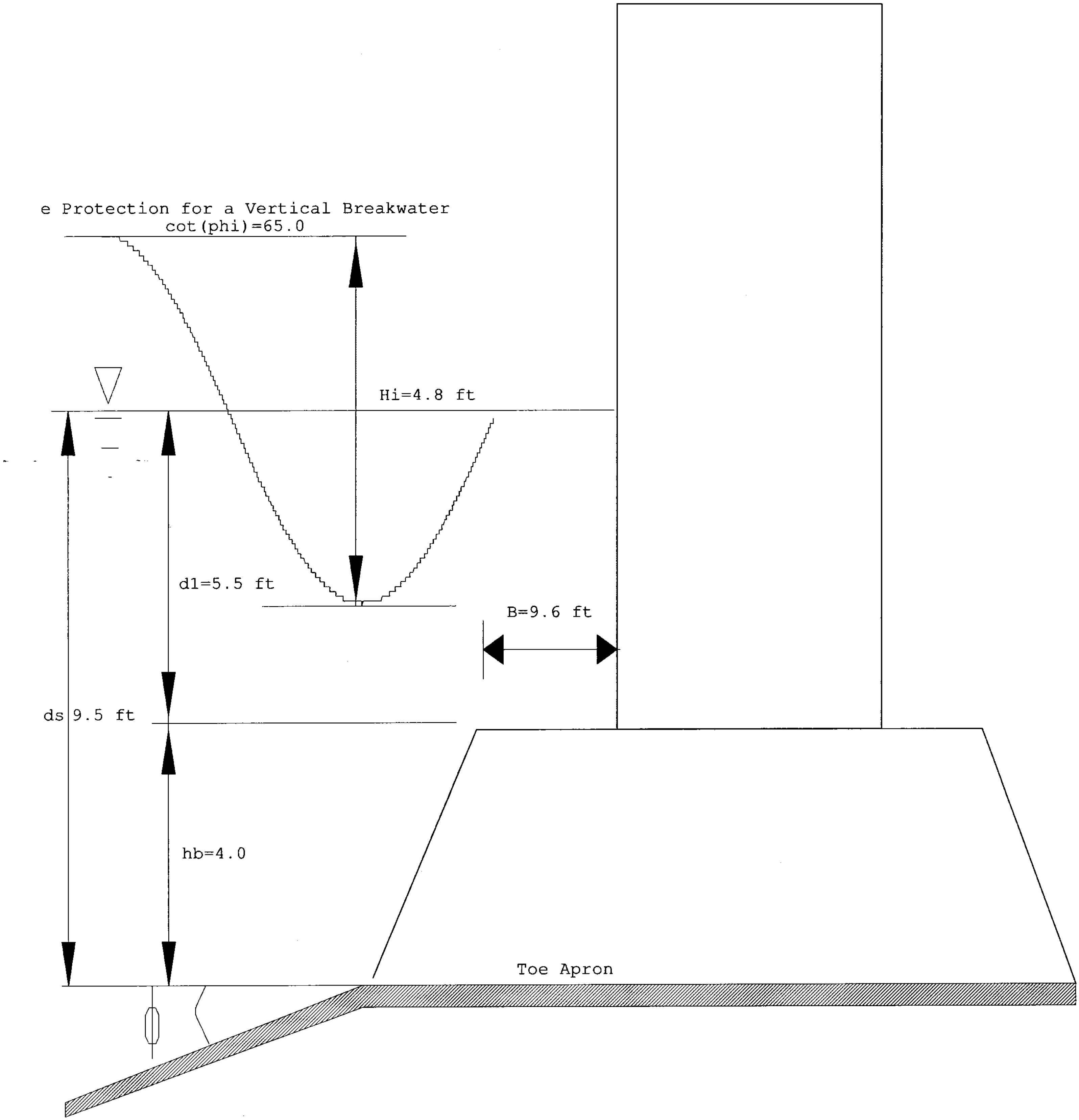
$$\text{OVERTOPPED} := \begin{cases} \text{"YES"} & \text{if } (R + SWEL) > C \\ \text{"NO"} & \text{otherwise} \end{cases}$$

OVERTOPPED = "NO"

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

Project: Sconset
Group: A

Case: 100 Yr Toe Protection Design		
Incident wave height:	4.800	ft
Wave Period:	15.200	sec
Water depth at structure toe:	9.500	ft
Breaking criteria:	0.780	
Cotangent of nearshore slope:	65.000	
Coefficient of passive Earth pressure:	1.000	
Depth of sheet pile penetration below mudline:	0.000	ft
Height of toe protection layer above mudline:	4.000	
Unit weight of rock:	165.000	lb/ft³
Width of toe apron:	9.600	ft
Weight of individual armor:	146.880	lb
Depth of water at top of toe protection layer:	5.500	ft


e Protection for a Vertical Breakwater
cot(phi)=65.0
Hi=4.8 ft
d1=5.5 ft
B=9.6 ft
ds 9.5 ft
hb=4.0
Toe Apron

Tensar Earth Technologies, Inc.
5883 Glenridge Drive, Suite 200
Atlanta, GA 30328

Tensar®

Anchoring Calculations for TRITON MATTRESS
For slope protection, *November 2004*

A. FACTORS MUST BE CONSIDERED

The following factors must be considered when deciding what anchoring materials will perform best:

1. Degree of slope
2. Length of slope
3. External loads
4. Angle of friction of the fill material and the slope soil (only the smaller of the two will be used)
5. Unit weight of the material used as fill
6. Height of Triton Mattress
7. Presence of a geomembrane on the slope
8. Presence of submerged conditions (Submerged Conditions Sheet)
9. Presence of waves when the Triton Mattress is used as amor (see Section E).

B. NET SLIDING FORCE (NSF) - INPUT REQUIRED

1. Before selecting an anchoring method, it is first necessary to calculate the net sliding force (NSF).
2. If the NSF is negative, then the friction force between the Triton Mattress and the slope is sufficient to hold the system.

The height of slope (H_s) =	16.5	ft.
Inclination of slope (β) =	33.69	degrees
Length of inclined slope (L_s) =	29.75	ft.
Height of Triton Mattress (h_m) =	18	in.
Unit weight of cover soil (γ_f) =	115	pcf
Unit weight of soil (γ_s) =	120	pcf
External live loads (q) =	30	psf (Ignore contribution to resisting force)
Lowest internal friction of soil / geomembrane (ϕ) =	30	degrees (see Ref. Table)
Internal friction of soil (ϕ_s) =	34	degrees
Coefficient of interaction, geogrid / soil (q) =	0.9	(assumes Anchor Trench depth of 2' or less)
Runout length (R_o) =	4.5	ft.

Driving Force (F_d)=	**3258.57**	pound per foot measured parallel to top of slope (lb/ft).
Frictional Resistance Force (F_{fr}) =	**2465.27**	lb/ft
Runout Resistance Force (F_{ro}) =	**448.17**	lb/ft
Anchor Trench Resistance Force (F_{at}) =	**1974.41**	lb/ft
NSF =	**-1629.28**	lb/ft
Compensate Force =	**0.00**	lb/ft, Additional force required for listed factor of safety (FS) = 1.5

C. ANCHOR TRENCH

1. The following equation can be used to calculate the required length and height of the trench to resist the sliding force.

Factor of Safety = 1.5

if ℓ_{at} (ft) = 4.5
then d_{at} (ft)= 3.0

if d_{at} (ft)= 3
then ℓ_{at} (ft)= 4.5

if over-ride, FS = 1.5

D. STAKES

1. Use steel reinforcing bars bent into a "candy cane" shape called J-hooks are the preferred type of stake.
2. The length of the stake should be three times the mattress height.

Section Width (w) =	6	
NSF Load =	0	lbs. for the "w" foot wide panel.
Stake pull-out / shear capacity =	70	lbs.
Use>>	**0**	**J-hooks per w-foot width**

E TRITON MATTRESS THICKNESS (USED AS ARMOR)

1. Thickness calculations are based on equations 24 and 25 of Olsen White paper on Triton mattresses ("Thick" tab).

Wave Height (H) =	5	ft.
Specific Gravity of Stone within Mattress (S) =	2.65	
Stone Void Allowance (p) =	0.35	
Slope of Structure (s) =	1.5	(Horizontal component for sH:1V)

***Triton Mattress Thickness ($T_{mat,d}$)=**	**13.32**	inches, for downslope stability
***Triton Mattress Thickness ($T_{mat,u}$)=**	**6.98**	inches, for uplift stability

Dwg