Connecticut Association of Flood Managers

2018 Conference

The Coastal Engineering Behind the Flood Maps

Presented by:

Azure Dee Sleicher, P.E.

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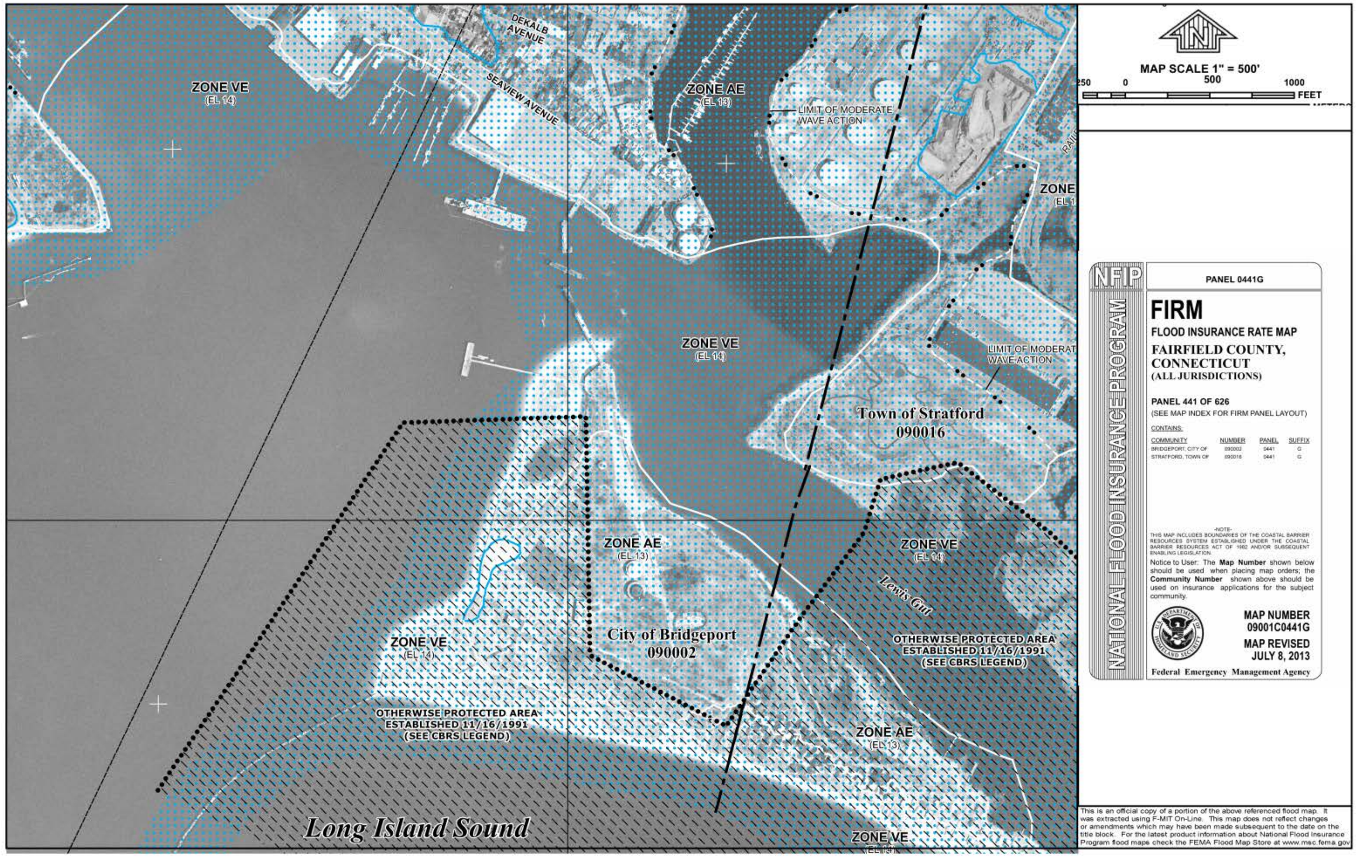
Introduction

FIRMs and Flood Zone Basics

How are BFEs Determined

- Topography
- Stillwater Elevations (SWEL)
- Wave Height
- Wave Setup
- Runup and Overtopping
- Coastal Structures
- Erosion

Letter of Map Revision Process



FIRMS and Flood Zone Basics

FIRM – Flood Insurance Rate Map: An informational map prepared by FEMA to depict the location of SFHAs and associated BFE. Easy to acquire, not revised frequently.

FIS – Flood Insurance Study: Community specific, compiled flooding and hazard data that is used to prepare Flood Insurance Rate Maps (FIRMs). Includes Riverine and Coastal analyses.

SFHA – Special Flood Hazard Area: Defines the area included within the 100-yr flood event (1% chance of occurrence in any given year).

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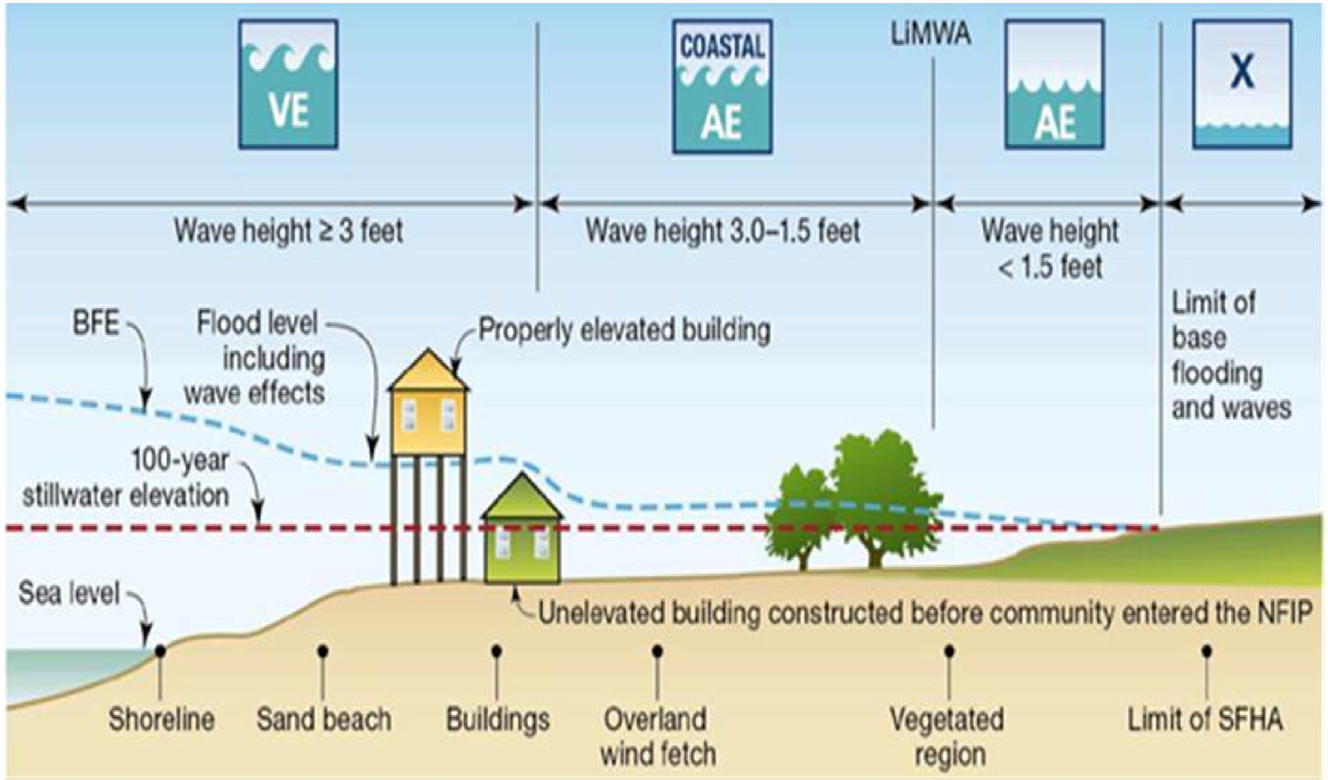
FIRMS and Flood Zone Basics

Flood Zones: Areas within the SFHA with specific connotations and requirements

- A-Zone: SFHA with wave heights less than 3’
- LiMWA/Coastal A Zone: SFHA with wave heights between 1.5’ – 3’
- V-Zone: SFHA with wave heights greater than 3’



Although FEMA does not impose requirements for the LIMWA, the CT Building Code, through reference to ASCE 24, requires V-Zone type building standards for first floor elevation and foundation type, as well as, restricts use of structural fill.

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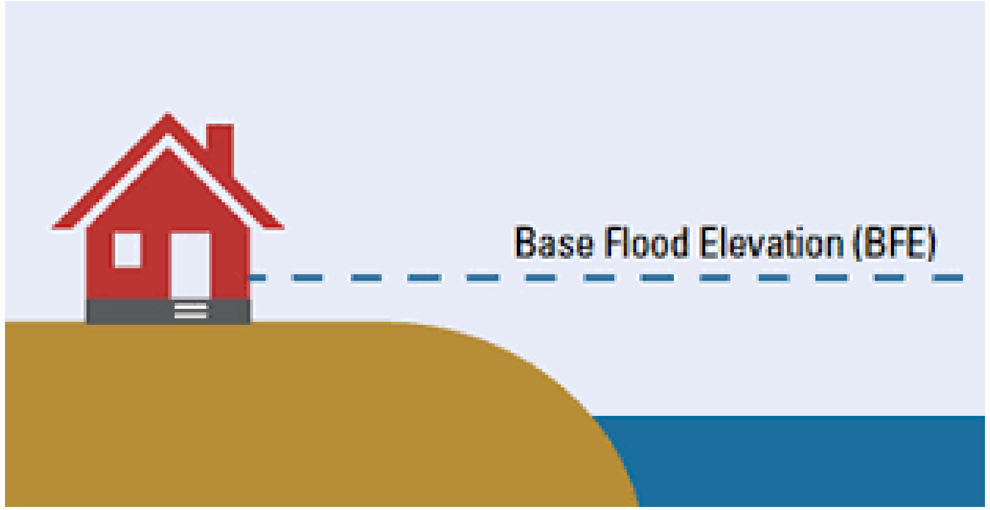
What is a BFE?

Base Flood Elevation (BFE) is the computed elevation to which floodwater is anticipated to rise during the base flood (1% annual chance occurrence storm).

The BFE can be the stillwater elevation (SWEL) in cases of inundation or the highest elevation of the wave CREST or the wave RUNUP in coastal cases.

BFE sets the criteria for floor elevation and other structural design and siting requirements



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Critical Data Needs to Determine BFEs

Topography

Transect Location

Stillwater Elevation (SWEL)

Wave Heights

Wave Setup, Runup & Overtopping

Coastal Structures

Erosion

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Topography

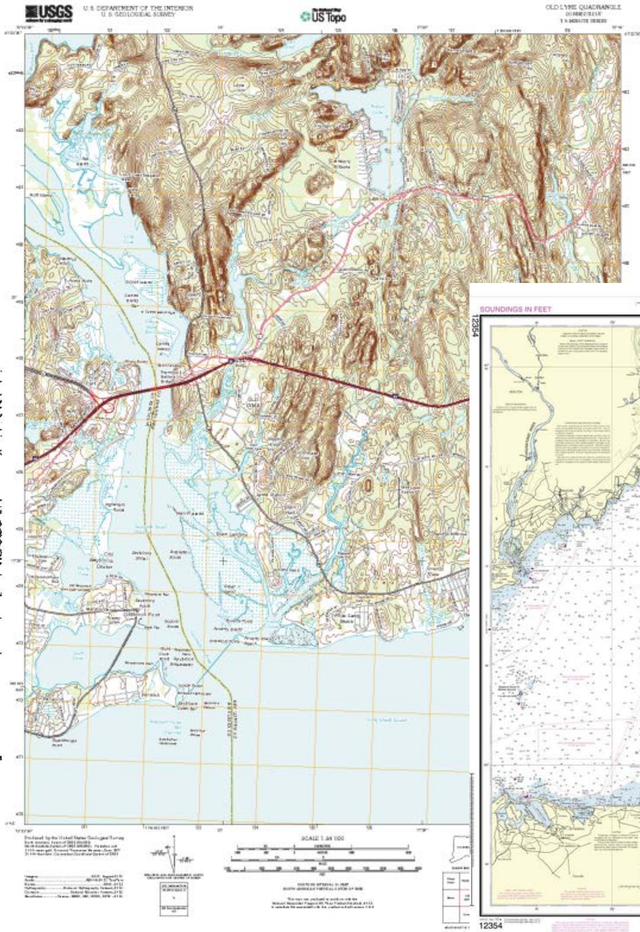
Airborne LiDAR (Light Detection and Ranging)

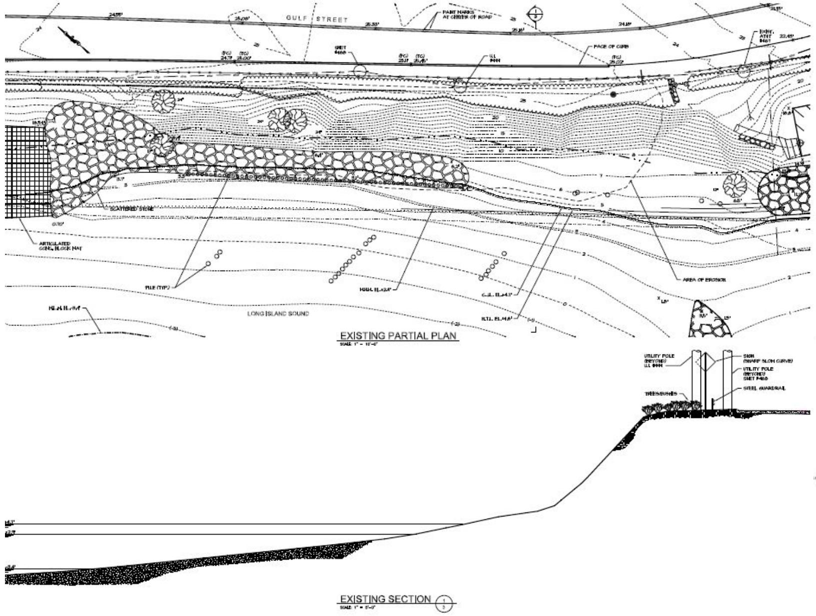
Aerial Topographic Surveys

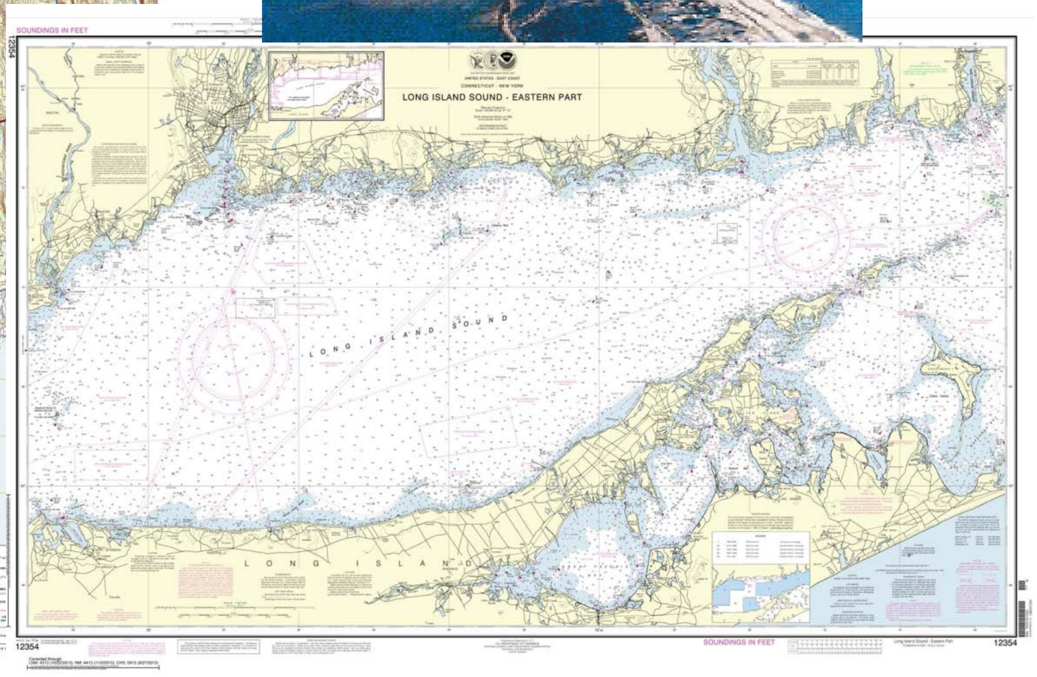
NOAA Data

USGS Maps

Physical Survey







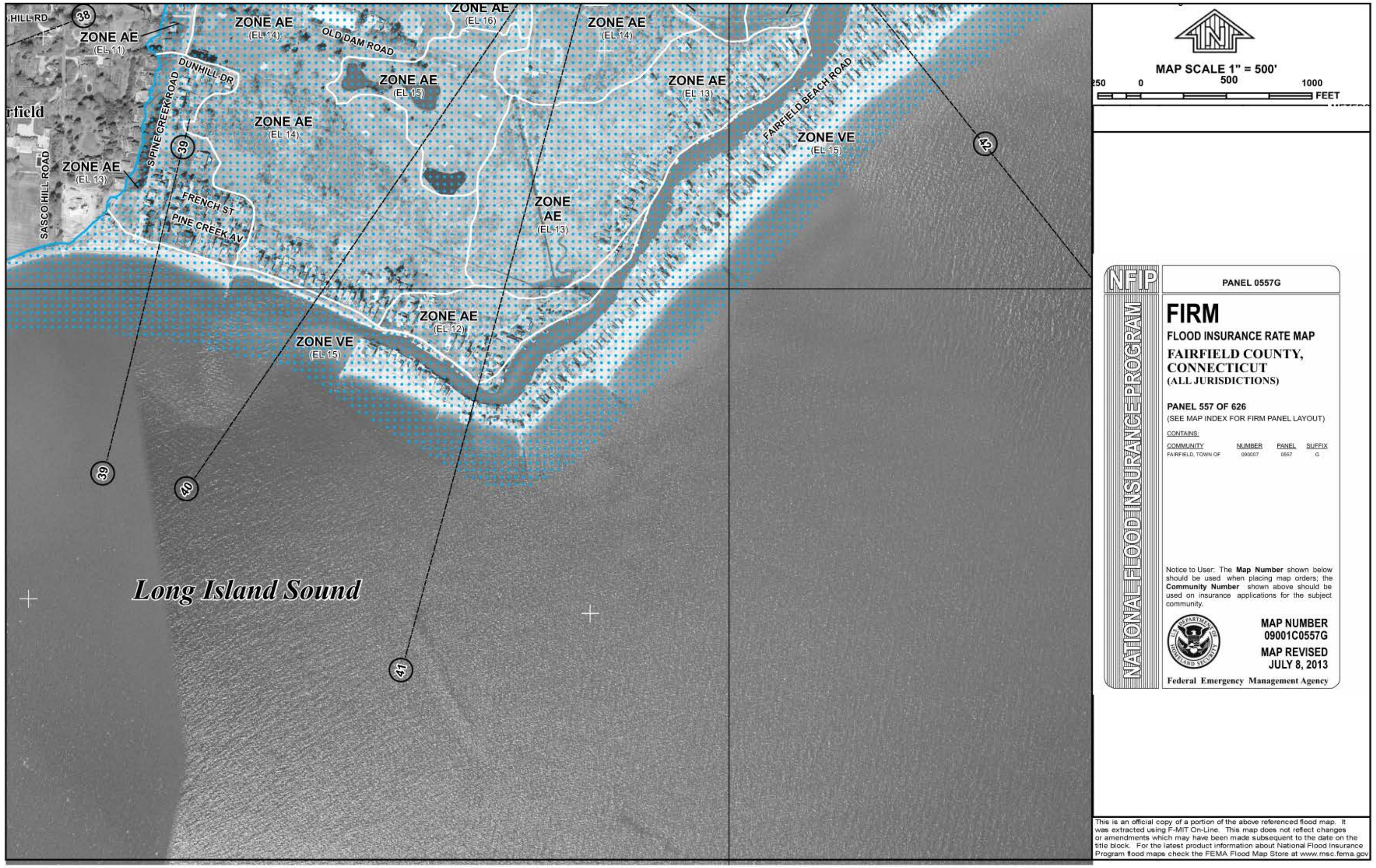
Transect Location

Transects location determined by:

- Topography
- Bathymetry
- Shoreline orientation
- Land cover data
- Shoreline typology (beach, dune, structure, bluff, etc.)

Specific wave height analysis performed along each transect

BFEs interpolated between transects based on contour data



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Stillwater Elevation (SWEL)

Available in FIS for 10, 50, 100 and 500-yr recurrence intervals

SWEL accounts for storm surge from:

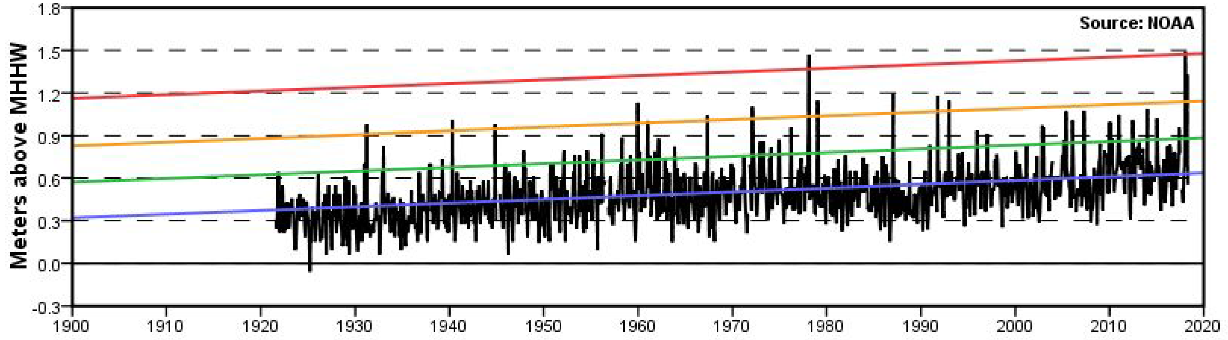
- Offshore wind
- Barometric pressure

The 100-yr recurrence interval is used for BFEs

SWELs are typically determined through statistical analyses of available tide gauge data

ADCIRC modeling being used in current updates

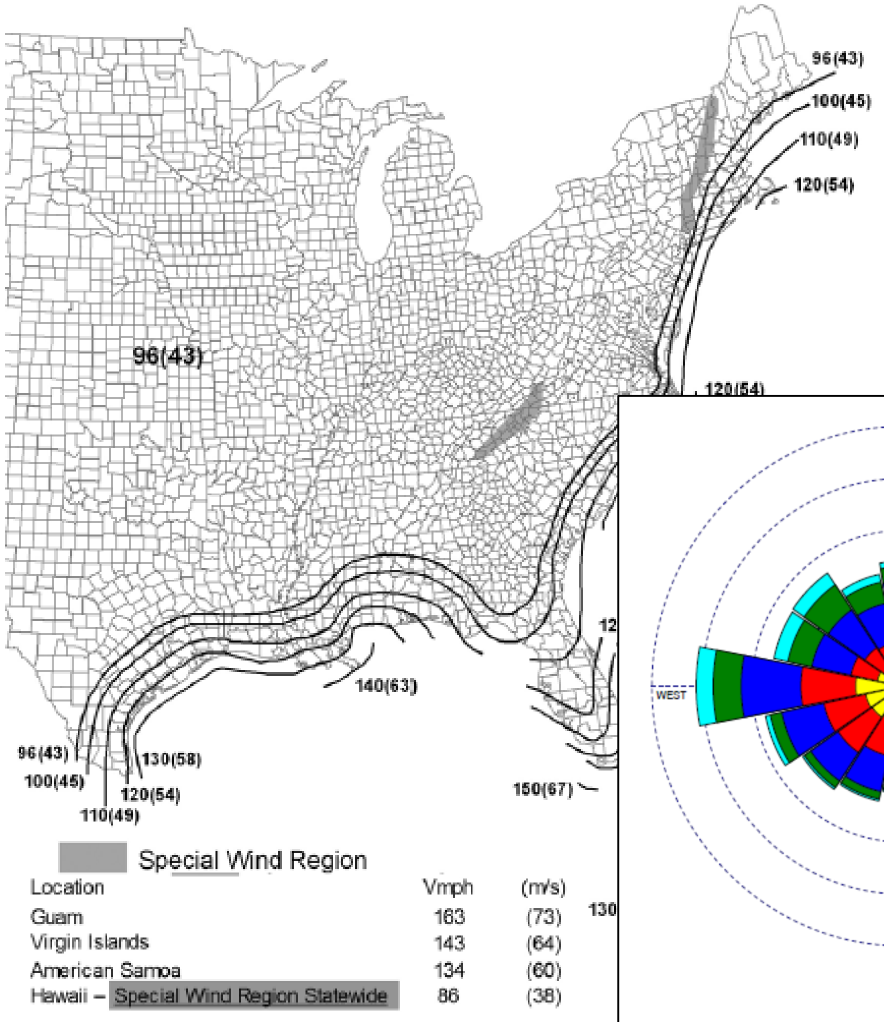
	Threshold Value	No. of Data Records	Analysis Method	Correlation	Statistically Predicted Tide Level			
					10 (yr)	50 (yr)	100 (yr)	500 (yr)
Peaks over threshold (hourly data)	12.0	282	Fisher-Tippett type I (Gumbel)	0.875	13.5	13.9	14.1	14.6
			Fisher-Tippett type II (Frechet)	0.974	13.8	15.2	16.1	18.8
			Weibull	0.990	13.9	14.8	15.3	16.3
	12.1	206	Fisher-Tippett type I (Gumbel)	0.865	13.5	14.0	14.2	14.7
			Fisher-Tippett type II (Frechet)	0.969	13.8	15.1	15.9	18.6
			Weibull	0.989	13.9	14.9	15.3	16.4
	12.3	107	Fisher-Tippett type I (Gumbel)	0.880	13.7	14.3	14.5	15.1
			Fisher-Tippett type II (Frechet)	0.963	13.8	14.9	15.4	17.0
			Weibull	0.987	13.9	15.0	15.5	16.7
	12.5	53	Fisher-Tippett type I (Gumbel)	0.915	13.9	14.5	14.8	15.5
			Fisher-Tippett type II (Frechet)	0.966	13.9	14.9	15.5	17.1
			Weibull	0.981	14.0	14.8	15.2	16.1
	12.8	23	Fisher-Tippett type I (Gumbel)	0.960	14.0	14.7	15.0	15.7
			Fisher-Tippett type II (Frechet)	0.976	14.0	14.8	15.2	16.3
			Weibull	0.974	14.0	14.9	15.3	16.3
Peaks over threshold (daily data)	12.0		Fisher-Tippett type I (Gumbel)	0.871	13.2	13.5	13.7	14.0
			Fisher-Tippett type II (Frechet)	0.970	13.4	14.2	14.7	16.0
			Weibull	0.979	13.5	14.2	14.6	15.4
	12.1		Fisher-Tippett type I (Gumbel)	0.855	13.2	13.6	13.8	14.1
			Fisher-Tippett type II (Frechet)	0.962	13.5	14.5	15.1	17.2
			Weibull	0.976	13.5	14.3	14.6	15.4
	12.3		Fisher-Tippett type I (Gumbel)	0.860	13.4	13.8	14.0	14.5
			Fisher-Tippett type II (Frechet)	0.944	13.5	14.3	14.7	16.0
			Weibull	0.969	13.6	14.4	14.8	15.8
	12.5		Fisher-Tippett type I (Gumbel)	0.864	13.5	14.0	14.3	14.8
			Fisher-Tippett type II (Frechet)	0.925	13.5	14.3	14.7	16.0
			Weibull	0.946	13.6	14.5	14.9	16.0
			Fisher-Tippett type	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



Wave Height Determination

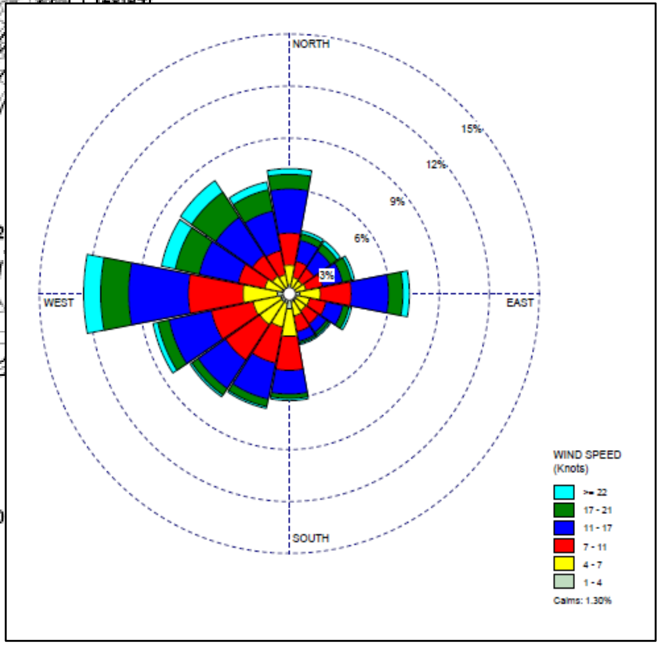
Based on:

- Fetch
  - Distance over which wind blows to form wave
- Wind Speed
  - ASCE/Building Code Wind Maps
  - Statistical analysis of airport observations



Location	Vmph	(m/s)
Guam	163	(73)
Virgin Islands	143	(64)
American Samoa	134	(60)
Hawaii – Special Wind Region Statewide	86	(38)

Figure CC-4 *(Continued)*



Wave Height Determination

Restricted Fetch Analysis

Statistical Analysis of Buoy Data

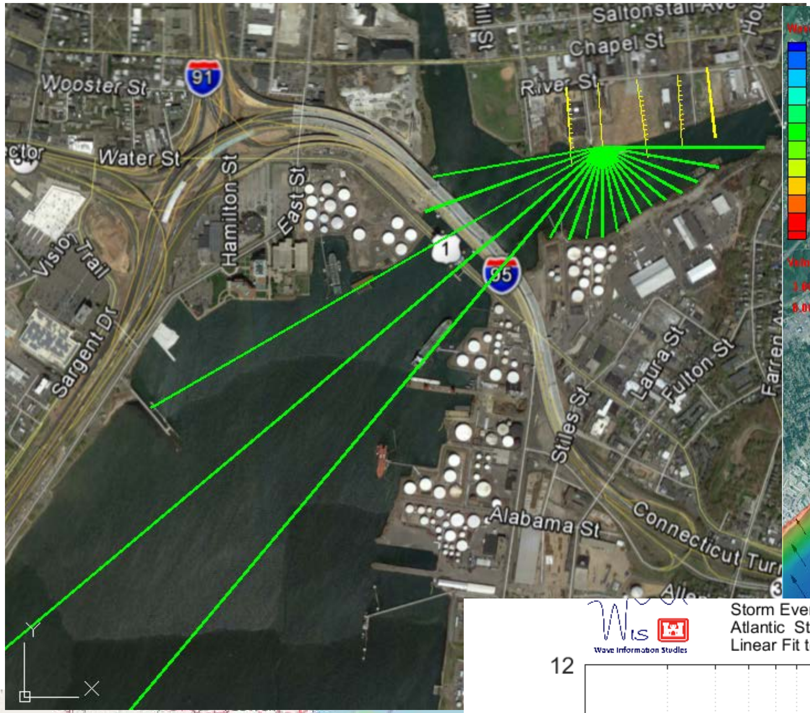
Numerical Modeling

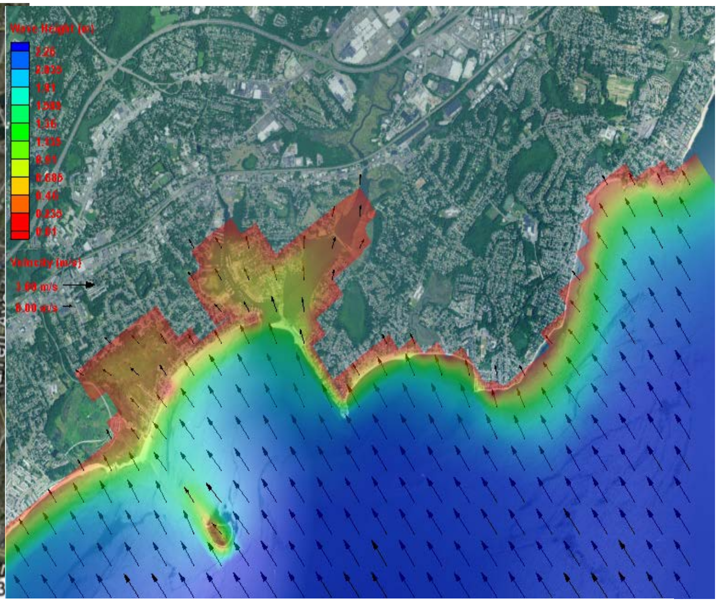
- ADCIRC/SWAN
- MIKE21
- STWAVE

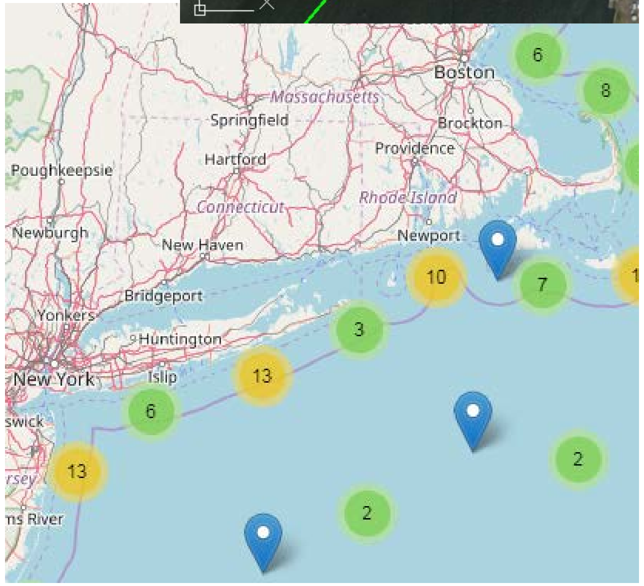
Obtain:

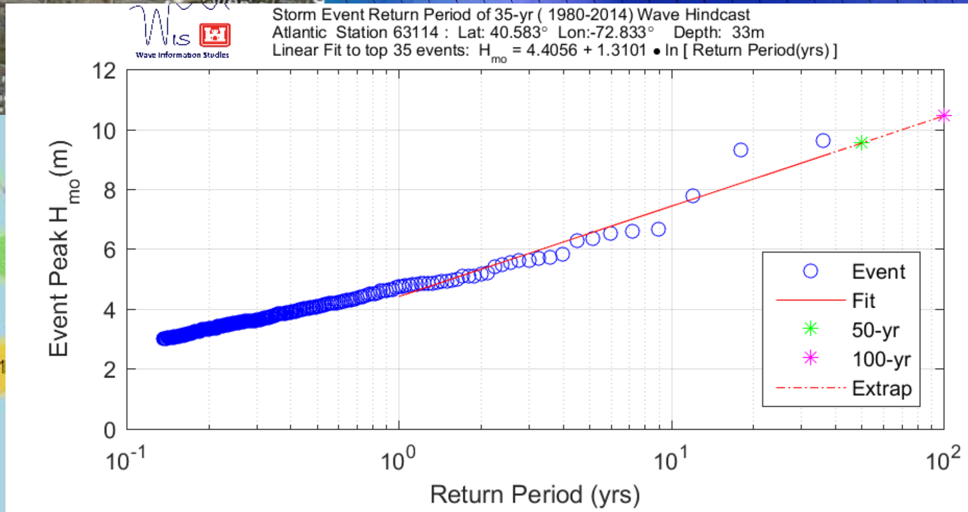
Significant Wave Height, Hs

Wave Period, Tp









Top 10 events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}	Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}
1	2012/10/29 23:00	9.62	15.65	124.0	6	1991/08/19 16:00	6.50	15.38	152.0
2	1985/09/27 16:00	9.31	15.24	167.0	7	2010/03/14 01:00	6.35	12.38	117.0
3	2011/08/28 11:00	7.76	14.46	160.0	8	1993/03/14 15:00	6.26	15.30	173.0
4	2009/11/14 01:00	6.65	14.57	117.0	9	2007/11/03 21:00	5.81	15.20	140.0
5	1992/12/11 15:00	6.58	12.17	113.0	10	1996/07/13 20:00	5.73	11.57	171.0

An event is defined as any period when $H_{mo} > 3.00$m θ_{mean} is direction that waves are arriving from

US Army Engineer Research & Development Center   ST63114_v03

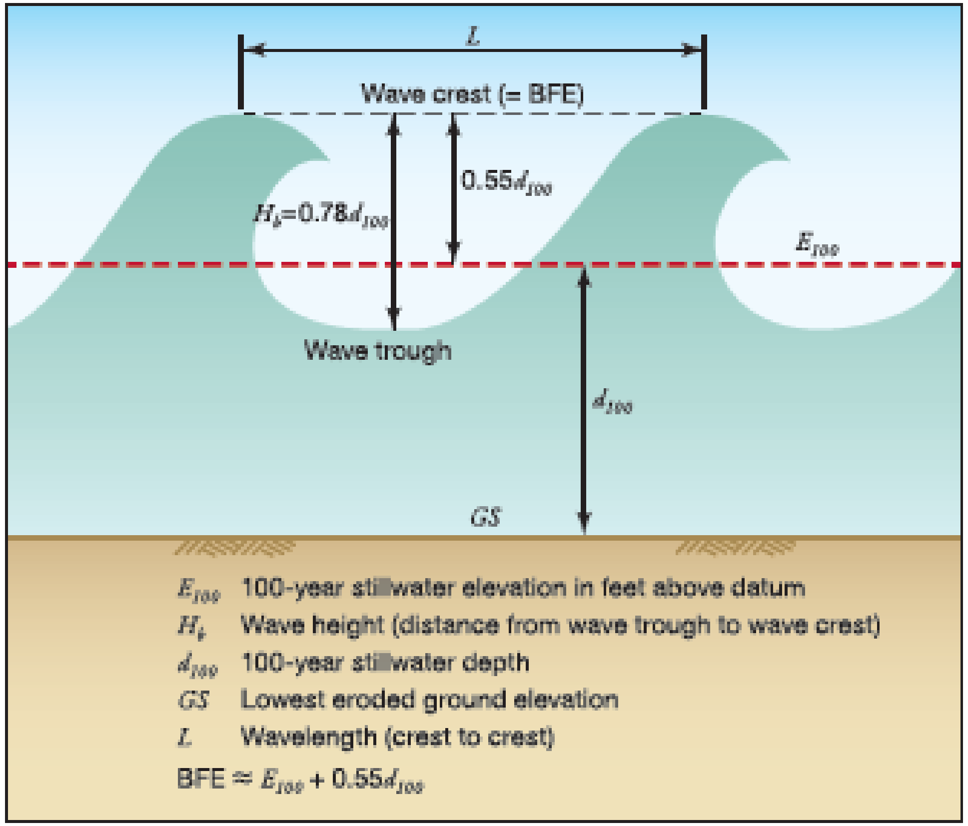
Wave Heights – Transformed (Shallow Water)

Deep water wave is transformed as it approaches shore due to friction

Wave “breaks” when depth is 0.78 of the wave height

- Hb = 0.78 d
  - Hb = Breaking Wave Height
  - d = Water Depth

<u>±3.8’ of water depth required for 3’ wave height</u>



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CHAMP

Coastal Hazard Analysis Modeling Program

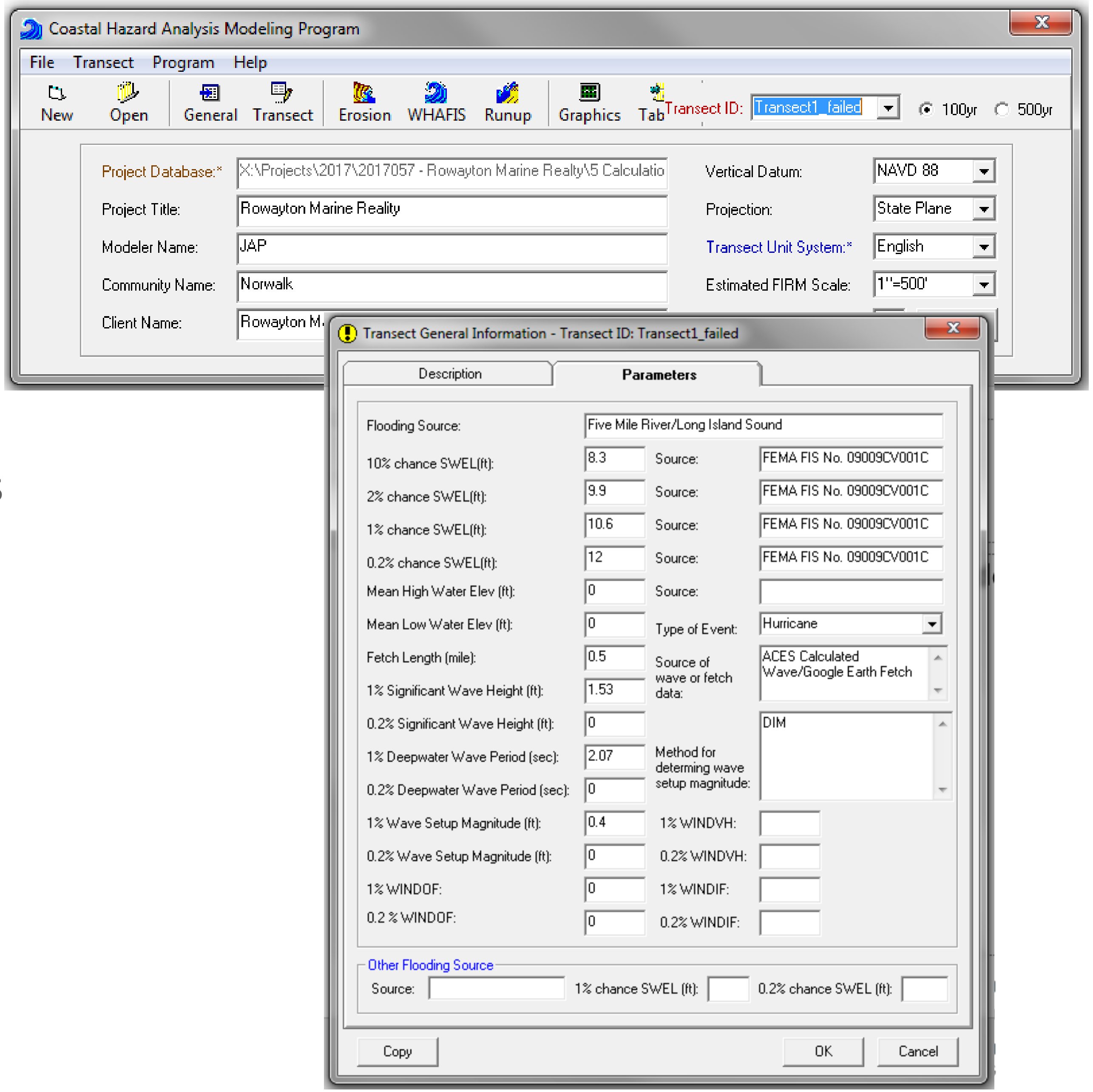
Developed by FEMA for Flood Insurance Studies (FIS)

Primary used for determining BFEs

Capable of computing wave crest elevations within Wave Height Analysis for Flood Insurance Studies (WHAFIS) and runup elevations within Runup 2.0

Required inputs include:

- SWEL
- Fetch Length
- 1% Significant Wave Height & Period
- Wave Setup
- Topography along a Transect



CHAMP – WHAFIS Output

PART2: CONTROLLING WAVE HEIGHTS, SPECTRAL PEAK WAVE PERIOD, AND WAVE CREST ELEVATIONS

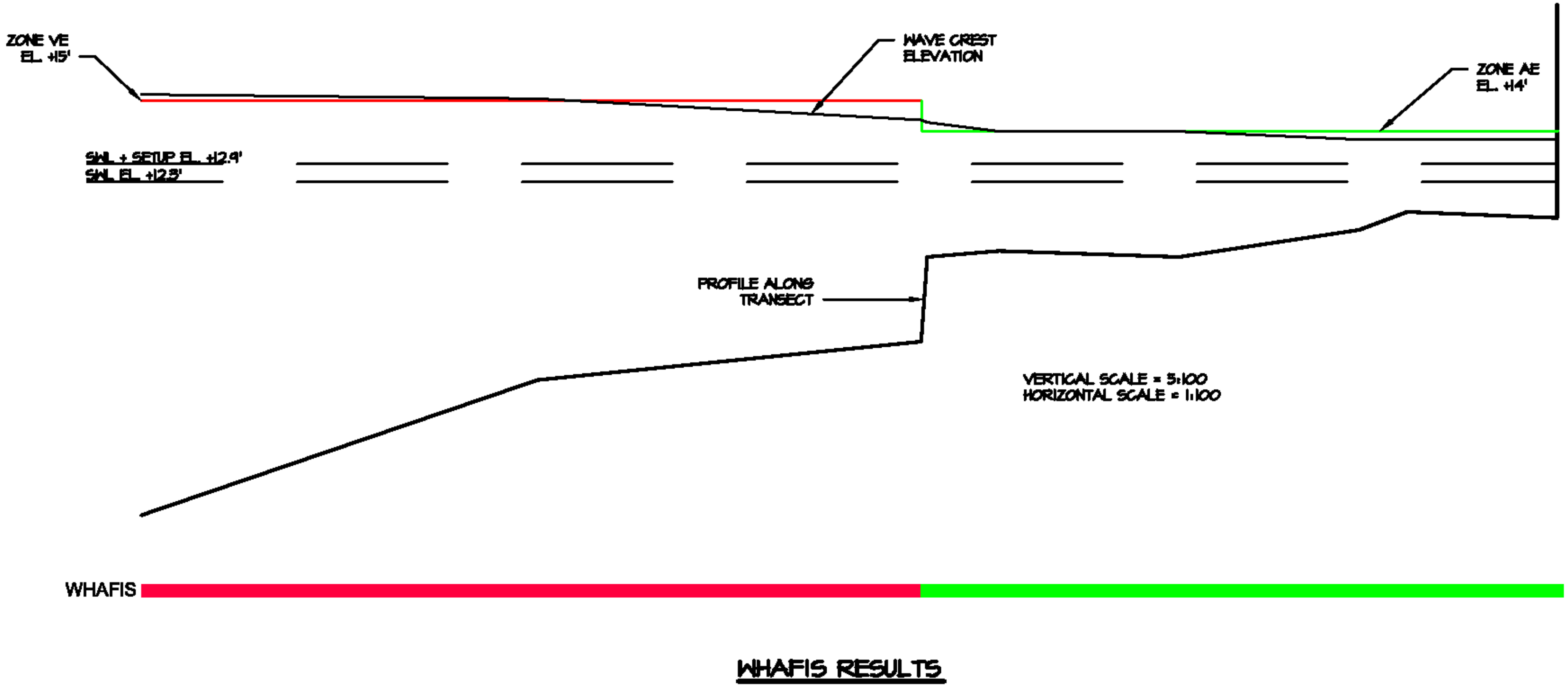
LOCATION	CONTROLLING WAVE HEIGHT	SPECTRAL PEAK WAVE PERIOD	WAVE CREST ELEVATION
-23.00	9.45	12.70	19.01
.00	7.95	12.70	17.97
101.25	5.92	12.70	16.54
202.50	3.86	12.70	15.10
225.00	3.40	12.70	14.78
317.00	1.55	12.70	13.49
319.00	.01	12.70	12.41
590.00	.00	.00	12.40
650.00	.23	.57	12.52
700.00	.35	.69	12.57
800.00	.54	.86	12.63

Controlling wave height. The transition between greater than 3 ft. to less than 3 ft. is the transition between Zones VE and AE.

Base Flood Elevation (BFE)

Station location along transect

WHAFIS Results



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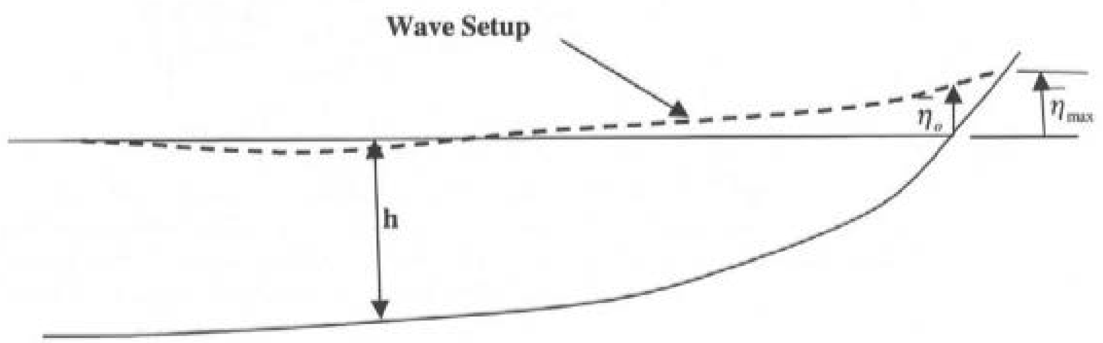
Wave Setup

An increase in the SWEL against a barrier (dunes, bluff or structure) caused by breaking waves.

It's the super-elevation of water surface due to waves propagating to the shore.

Setup is added to the SWEL in determination of overland wave transformation (WHAFIS) but not to wave runup or dune erosion calculations.

Wave setup can be a significant contributor to total water level; anywhere from a few inches to several feet.



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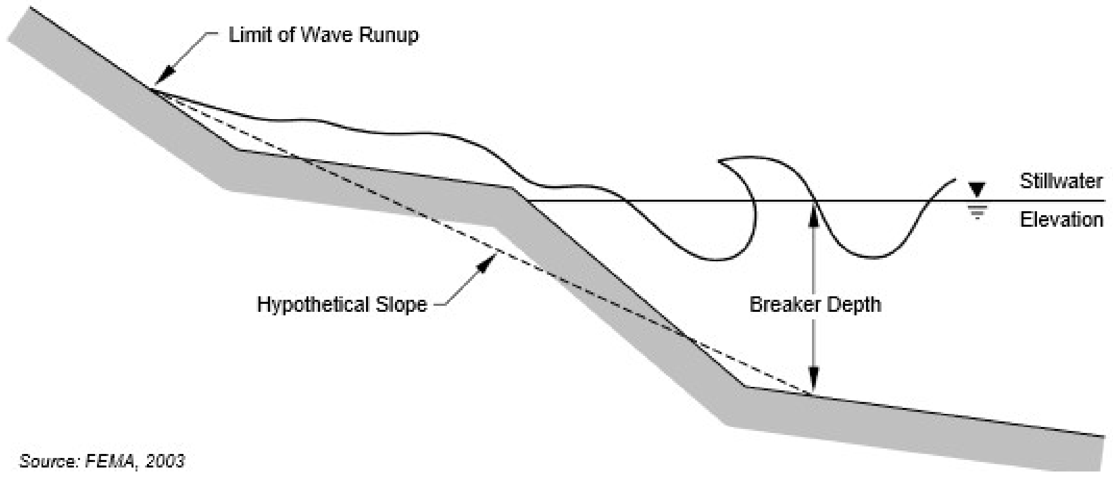
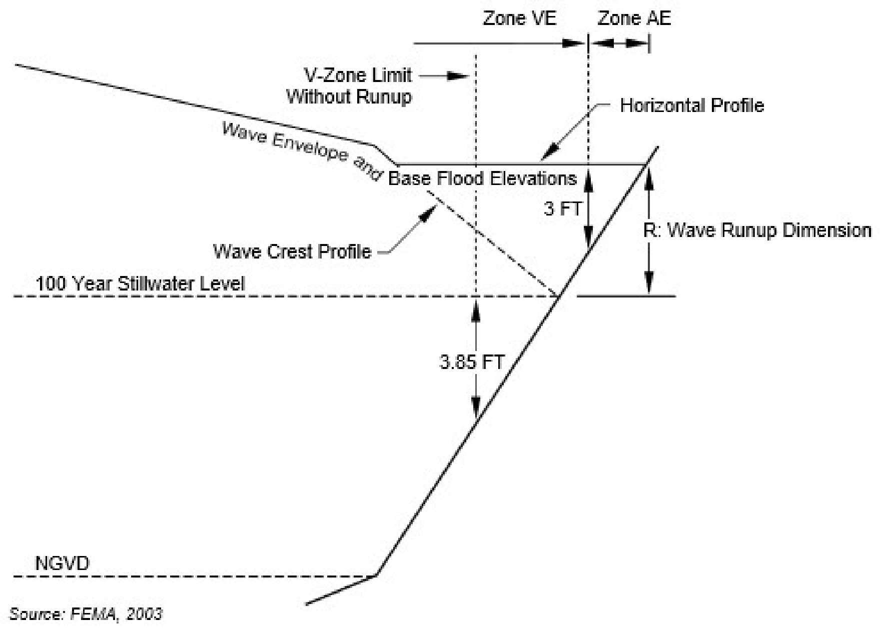
Wave Runup

Wave Runup - Vertical height above surge elevation that water will rush due to waves. Significant factor on bluffs, dunes, and manmade structures.

Several approved methods based on shoreline condition (sandy beach) or structure type and slope.





Wave Overtopping

Wave Overtopping – Occurs when the elevation of wave runup exceeds the crest height of the barrier, bluff or dune.

Table D-7. Suggestions for Interpretation of Mean Wave Overtopping Rates

$\overline{Q}$16 Order of Magnitude	Flood Hazard Zone Behind Barrier
<0.0001 cfs/ft	Zone X
0.0001-0.01 cfs/ft	Zone AO (1 ft depth)
0.01-0.1 cfs/ft	Zone AO (2 ft depth)
0.1-1.0 cfs/ft	Zone AO (3 ft depth)
>1.0 cfs/ft*	30-ft width⁺ of Zone VE (elevation 3 ft above barrier crest), landward Zone AO (3 ft depth)

*With estimated $\overline{Q}$17 much greater than 1 cfs/ft, removal of barrier from transect representation may be appropriate.

⁺Appropriate inland extent of velocity hazards should take into account structure width, incident wave period or wavelength, and other factors.

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Coastal Structures

Structures can impact the location of flood zones and elevation of BFEs

- Examples:
  - Seawalls
  - Bulkheads
  - Revetments
  - Dunes
  - Vegetated Slopes




Coastal Structures

Any structure considered in the modeling of BFEs must be designed or certified to resist the 100-yr event

- Certification of existing structures can be difficult without information regarding:
  - Original design
  - Material properties
  - Soil characteristics

If structure cannot resist 100-yr event then it must be "failed" and modeled based on a modified slope.

The BFE will be mapped to the more conservative case of structure "intact" or "failed."

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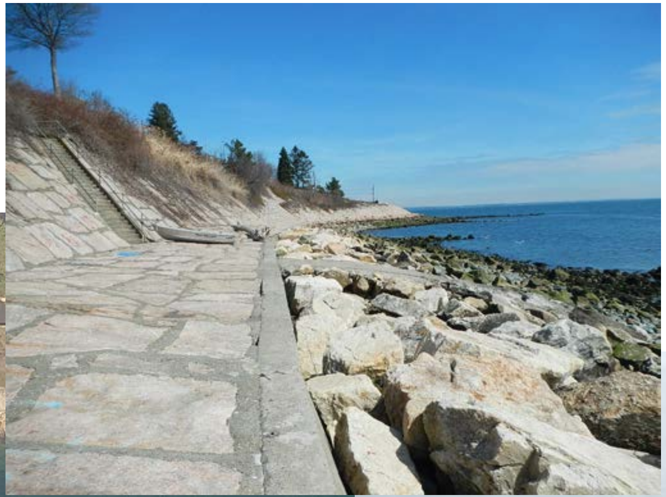
Coastal Structures

Can be very effective when properly designed

However….unintended consequences must be considered

- Runup
- Overtopping
- Scour



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Erosion

Pre-Storm

Post-Storm

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Erosion

- Why is this so critical for flood hazard mapping?

Loss of soil on beach

Deeper water at same location

Higher Wave

Higher BFE

Erosion

Coastal dunes shall be reviewed to determine if there is 540 sf/ft of volume available

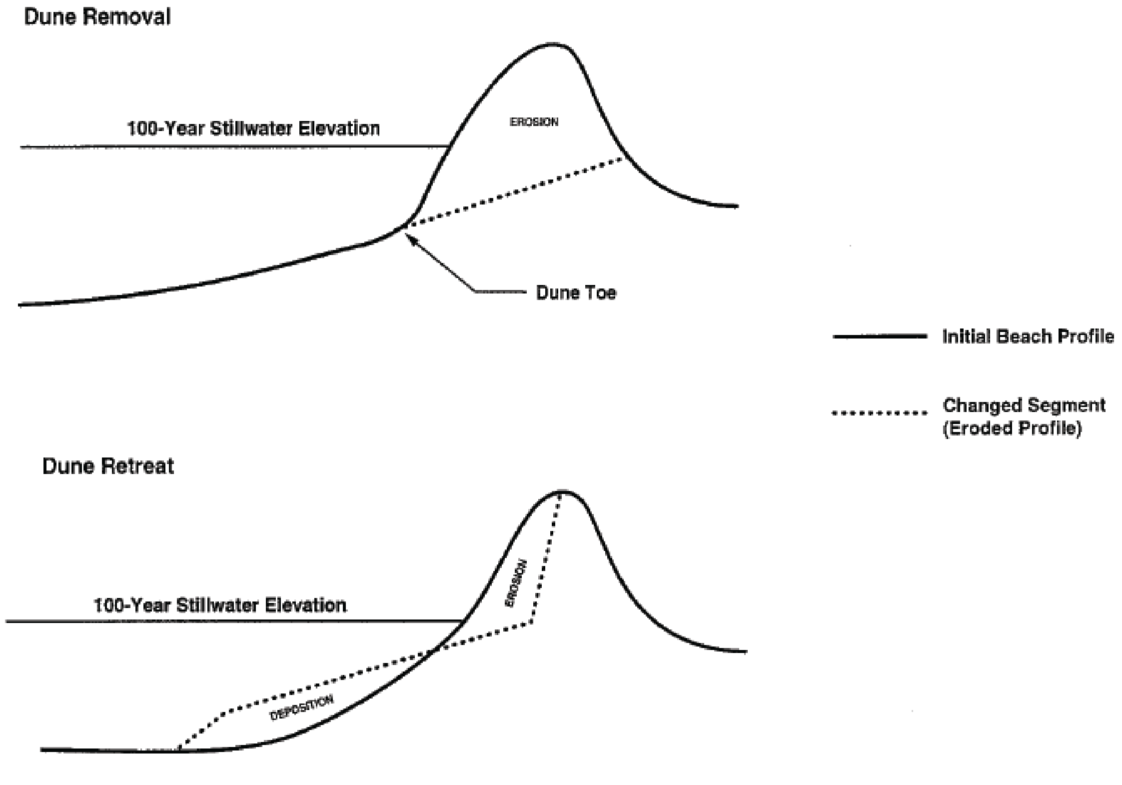

Figure D-5. Schematic Cases of Eroded Dune Geometries with Planar Slopes

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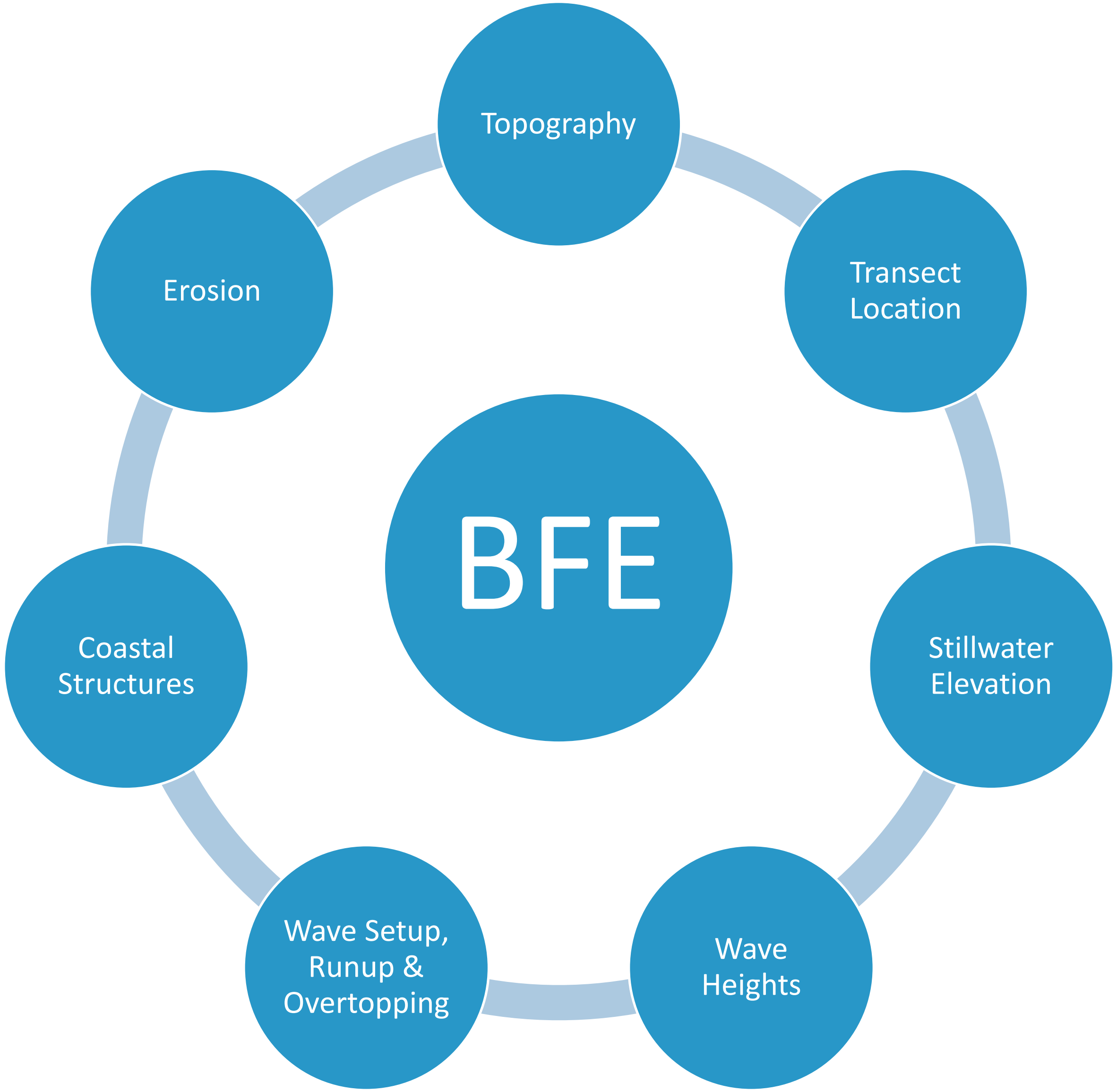
Summary of Coastal Modeling



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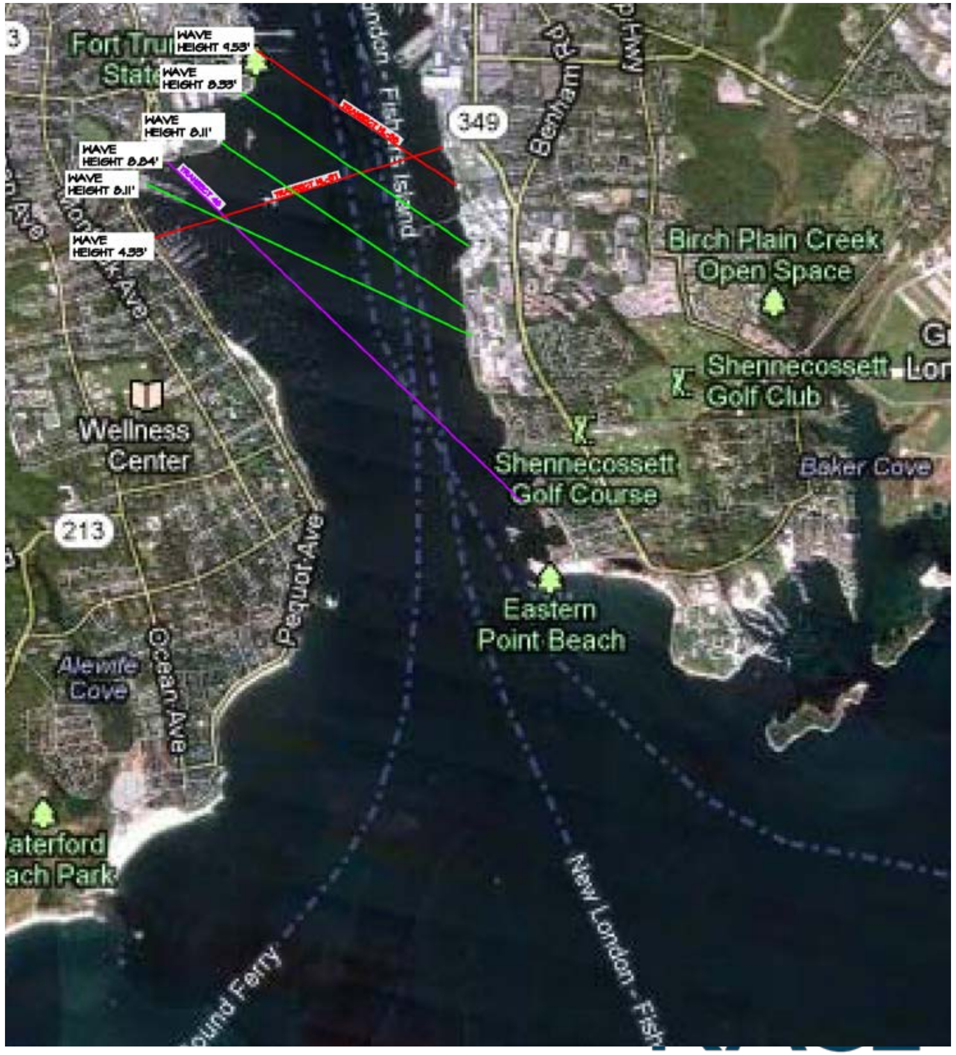
How Accurate are the FIRMs

Mapping performed on a Community wide basis

Subject to interpretation and interpolation

Selection of study transect locations and site specific topography can dramatically impact mapping



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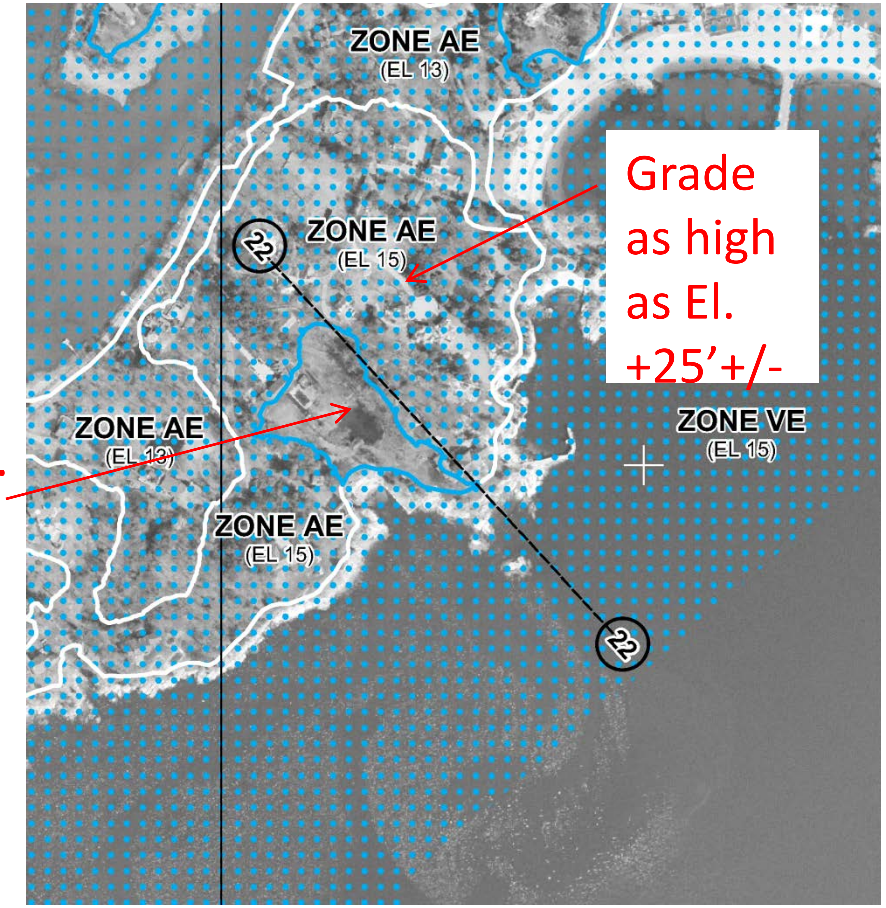
How Accurate are the FIRMs

Accuracy of LIDAR topography different than on a site specific basis

Grade as low as El. +7'+/-



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Letter of Map Revision (LOMR) Process

FEMA acknowledges limitations in its mapping processes

Allows an owner/community to revise the maps on a variety of grounds:

- Quality of topography/bathymetry used in models
- Validation of models using historical flood events
- Selection of flood events modeled
- Parameters used in models
- Methods of combing water levels from individual simulations
- Overland wave hazard modeling

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Letter of Map Revision (LOMR) Process

Used in situations where structures or modeling differences result in changes in BFE and/or location of the boundaries of the SFHA

Significantly more complicated process than a LOMA

Examples of applicable situations for LOMR

- Existing structure, able to withstand forces associated with 100-yr event is not modeled in FEMA analysis
- Interpolation between FEMA transect is not appropriate due to site conditions

Requires:

- Site specific topography
- Site specific analysis and coastal modeling

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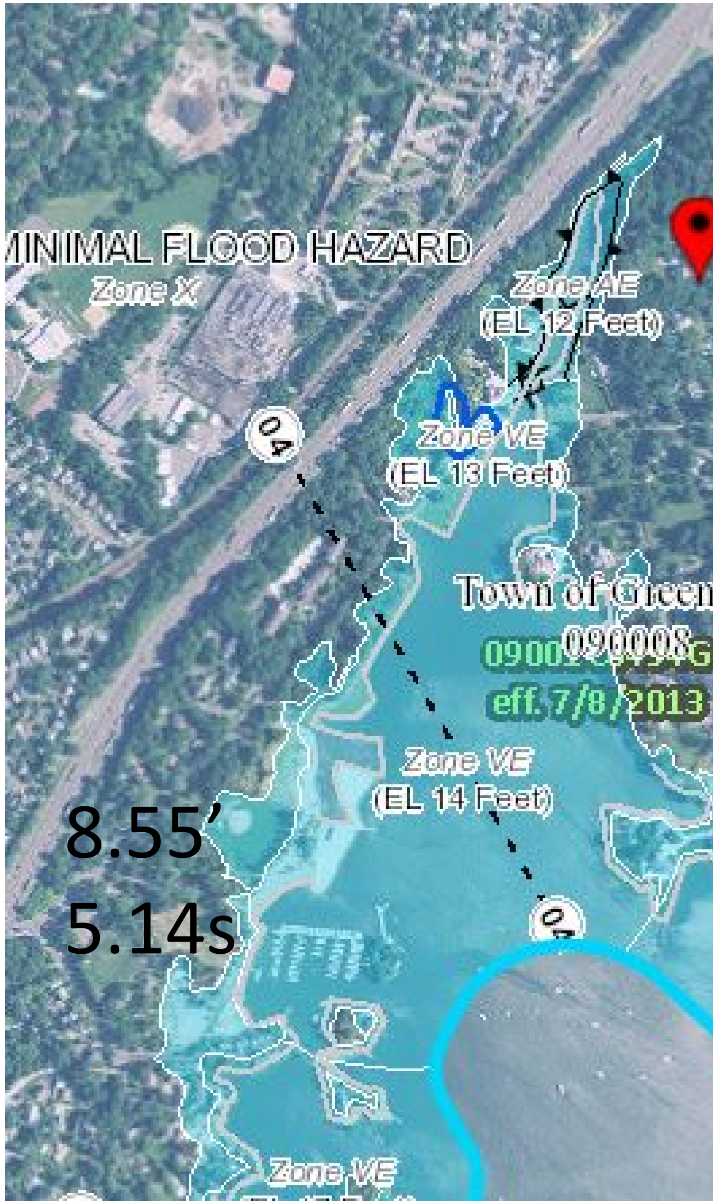
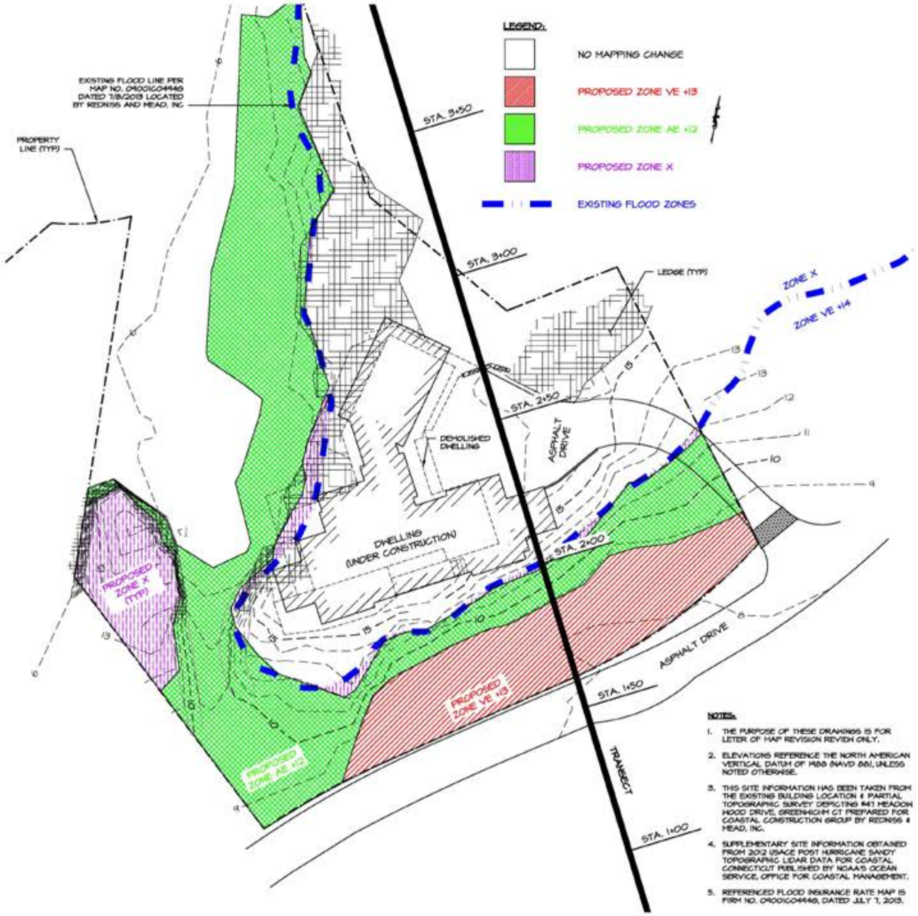
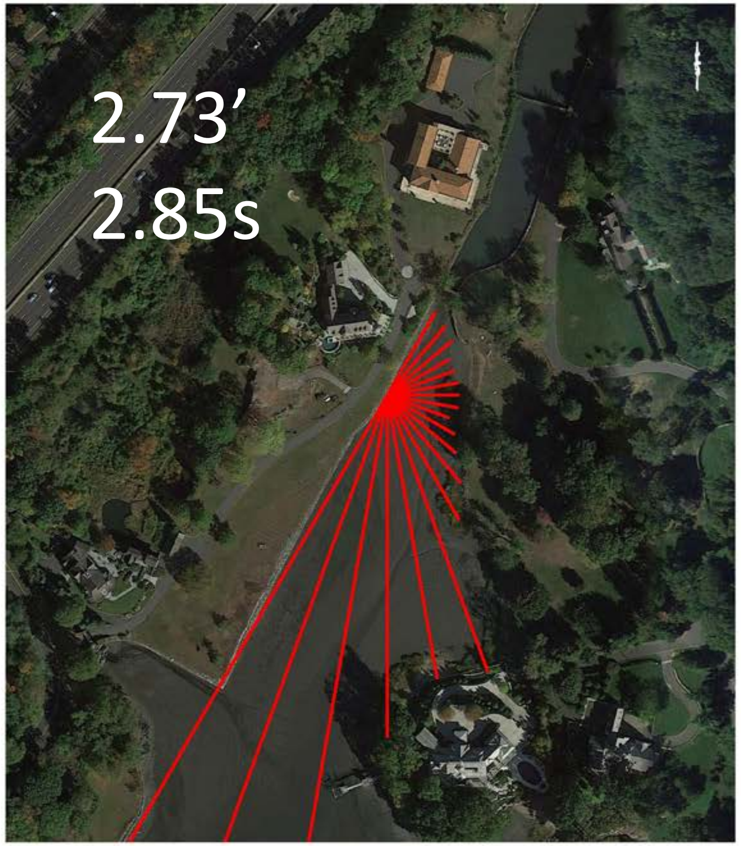
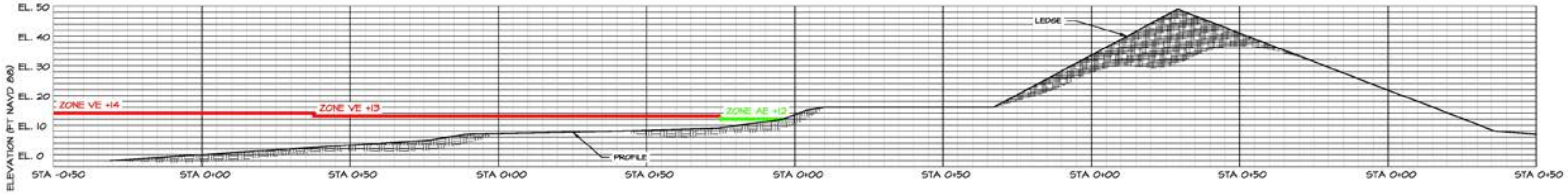




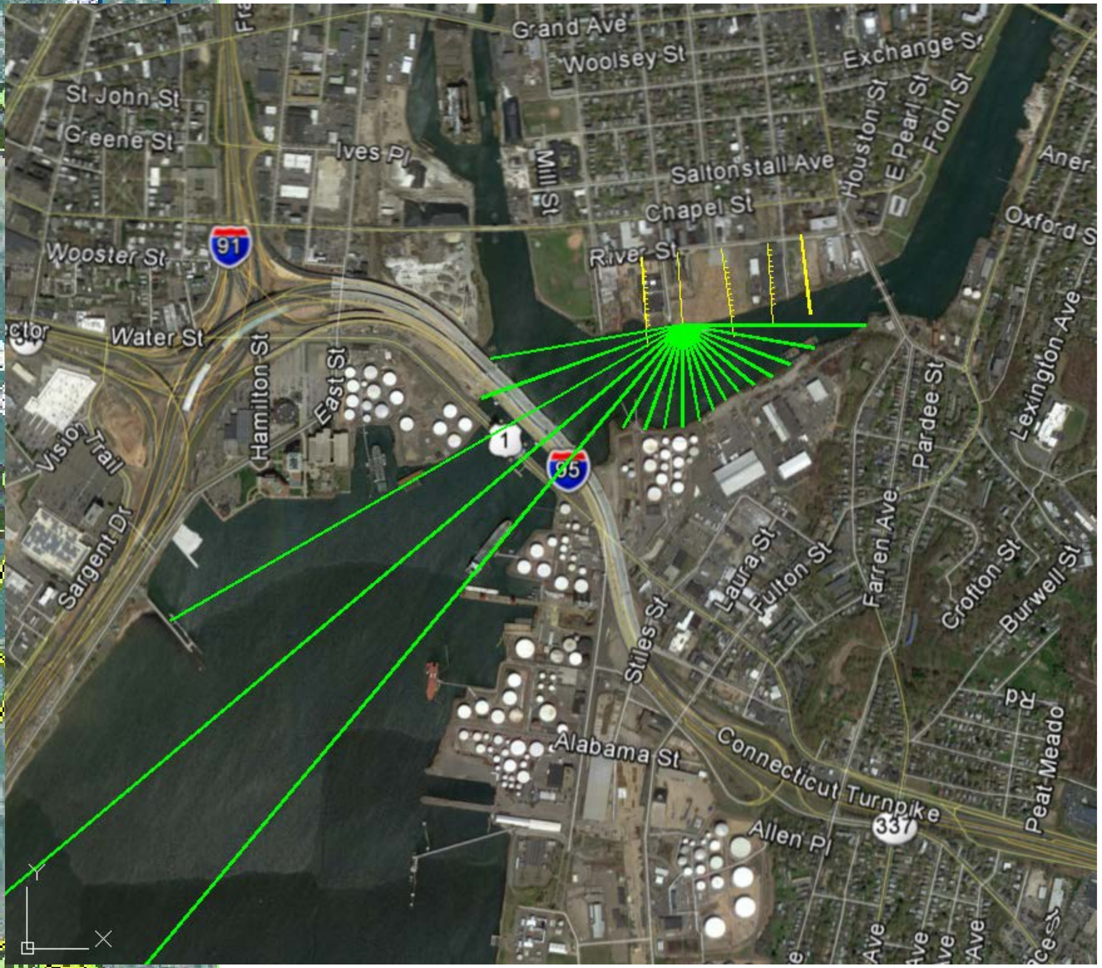


PROPOSED FLOOD ZONE MODIFICATIONS
SCALE: 1" = 20'-0"

FETCH RADIAL DIAGRAM
SCALE: 1" = 1000'-0"



COMPUTED BFE ALONG TRANSECT
SCALE: 1" = 10'-0"



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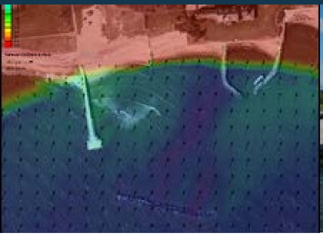
Thank you,
any questions?





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