North Carolina Society of Surveyors

Coastal Flood Study Modeling and Mapping 101

March 18, 2017

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NCEM Floodplain Mapping Program

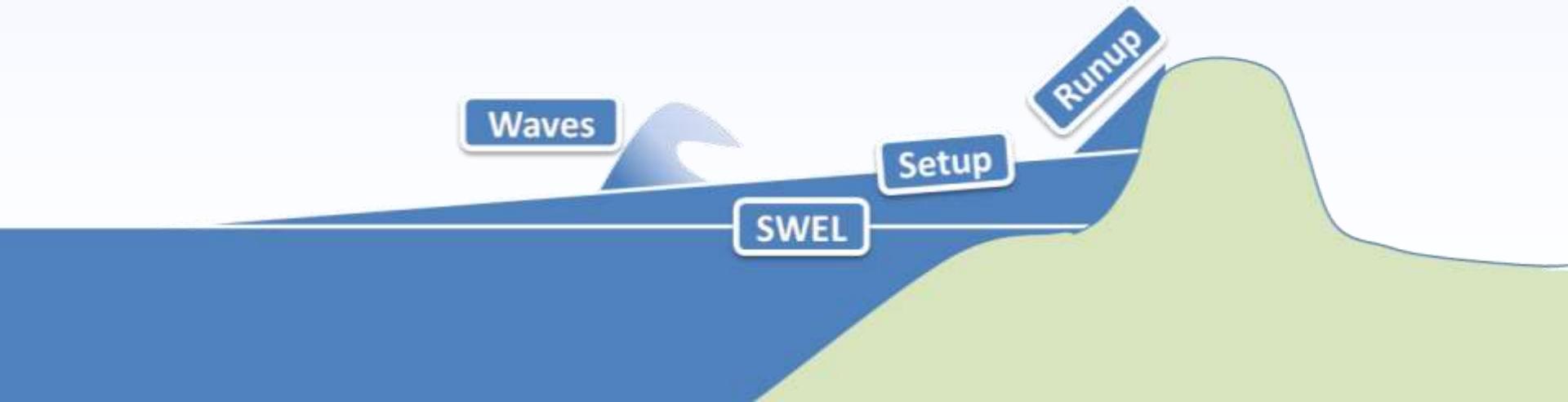
FEMA Coastal Flood Hazards

Base flood elevation (BFE) on FIRM includes 4 components:

- Storm surge stillwater elevation (SWEL)
- Wave setup
- Wave height above storm surge elevation
- Wave runup above storm surge limits

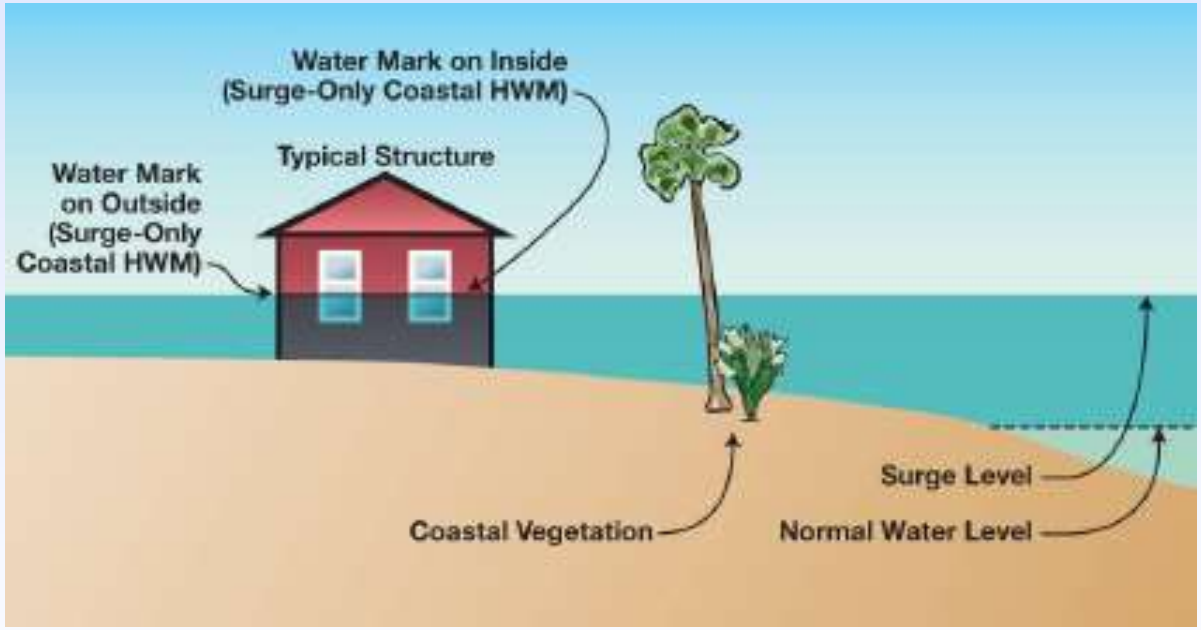
All applied to an eroded beach profile

Regulatory flood elevation includes freeboard



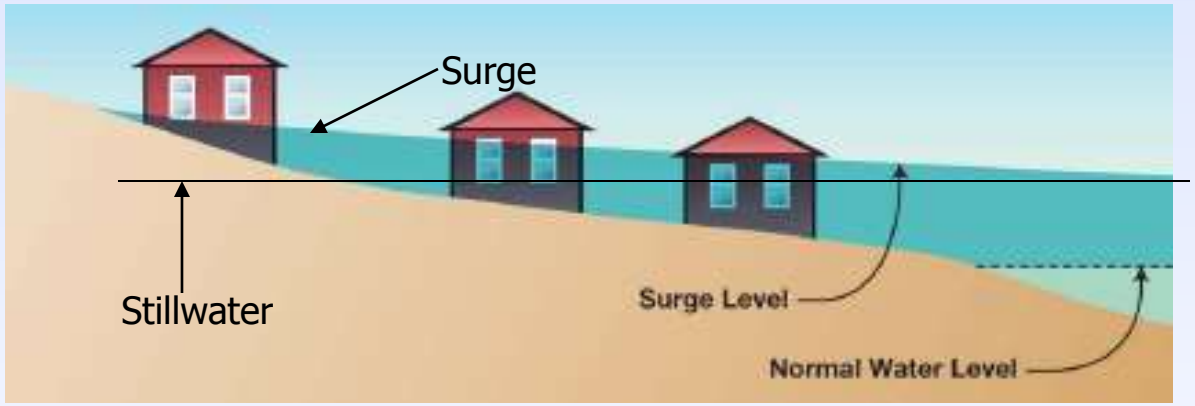
What is Still Water?

- Rise in the normal water level of a coastal body.
- The increase in sea level by the water being pushed against the shore by an approaching storm.



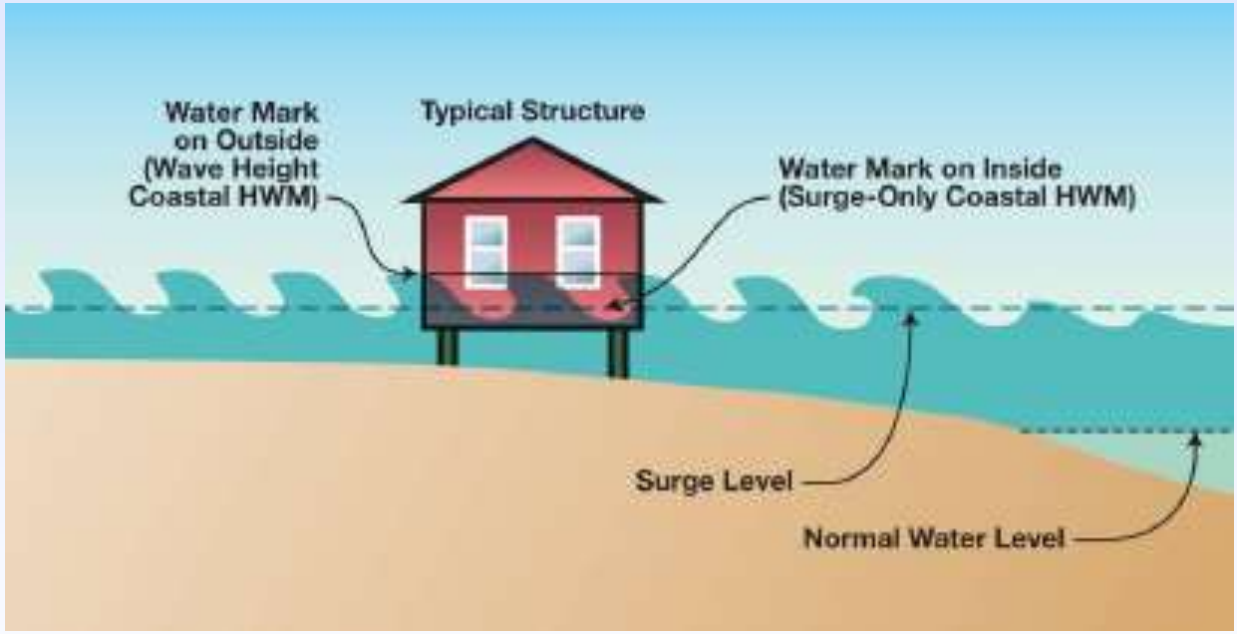
What is Storm Surge?

- Increase in stillwater elevation caused by a strong onshore wind.
- Combined effect of the increase in sea level by the water being pushed against the shore by an approaching storm and the winds pushing against the shore.



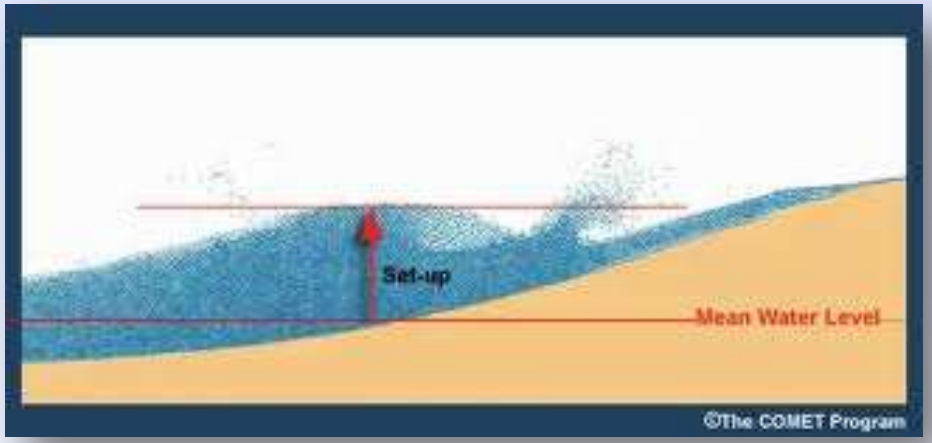
Wave Effects

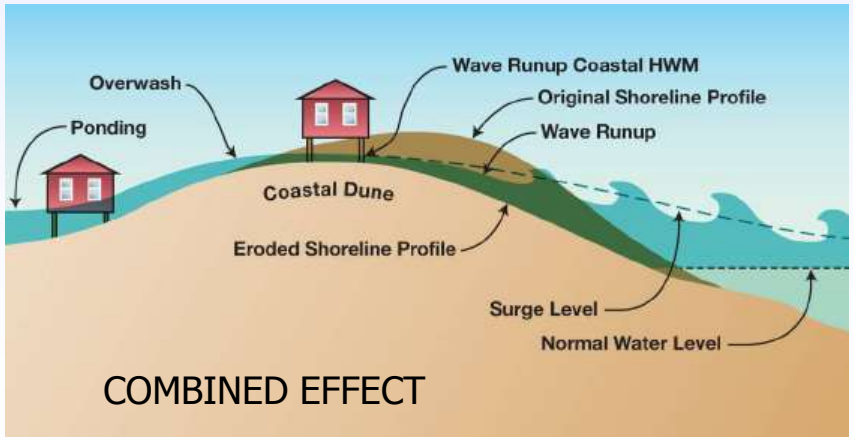
- VE Zone: Zone with velocity hazard (wave action)
- VE Flood Zone: BFEs where waves will be 3’ or higher in the 100-year event.



Wave Effects - Setup

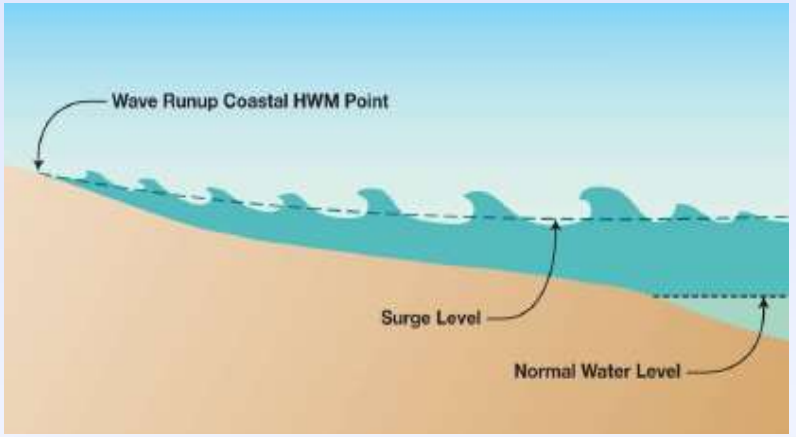
- Additional height of water due to effects of transferring wave related momentum to the surf zone.
- The height of water caused by waves coming in so quickly they pile up on each other before the water can recede.





Wave Effects - Runup

- Represents the height of water rise above the surge-only level due to water rush up from a breaking wave.
- Adds to the height of the surge and waves bringing damage to a higher elevation.



Elements of a Coastal Flood Insurance Study

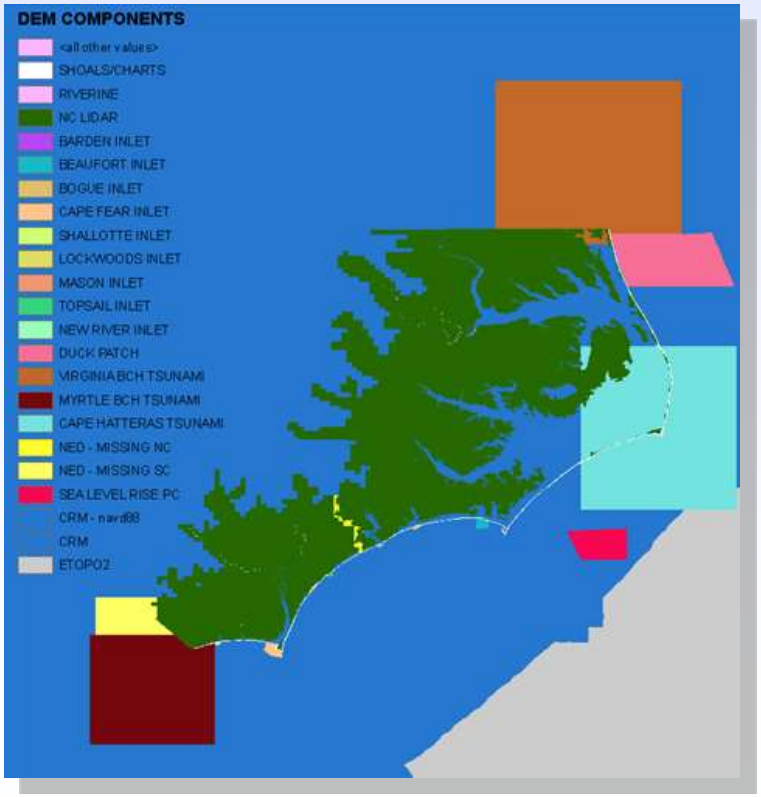
- Terrain processing (DEM/Mesh Development)
- Storm surge analysis (Stillwater elevations)
- Wave setup
- Overland wave analysis starting wave conditions
- Field reconnaissance
- Storm-induced erosion
- Overland wave height and wave run-up analyses
- Primary Frontal Dune delineation
- Floodplain boundary and flood hazard zone (VE & AE) mapping

NC Surge Study Approach

- Entire coastline restudied
  - Avoid discontinuities, maximize efficiency
- Coupled 2-D hydrodynamic and wave model
  - Surge – ADCIRC (RENCI)
  - Nearshore Waves – SWAN (RENCI)
- Combined extratropical and tropical surge
  - Joint Probability Method - Statistical method for tropical
  - Empirical Simulation Technique (EST) – Statistical method for extratropical storm

DEM Data Inventory and Assembly

- Topographic and Bathymetric Data Sources
  - Charts/Shoals
  - Riverine
  - NC LIDAR (~13%)
  - Local data Inlets
  - Duck patch
  - Three tsunami datasets (~11%)
  - NED - NC missing piece, SC wedge
  - Sea Level Rise Piece - patch on CRM
  - CRM - corrected to NAVD88 (~66%)
  - ETOPO2 (last, only with no other data)



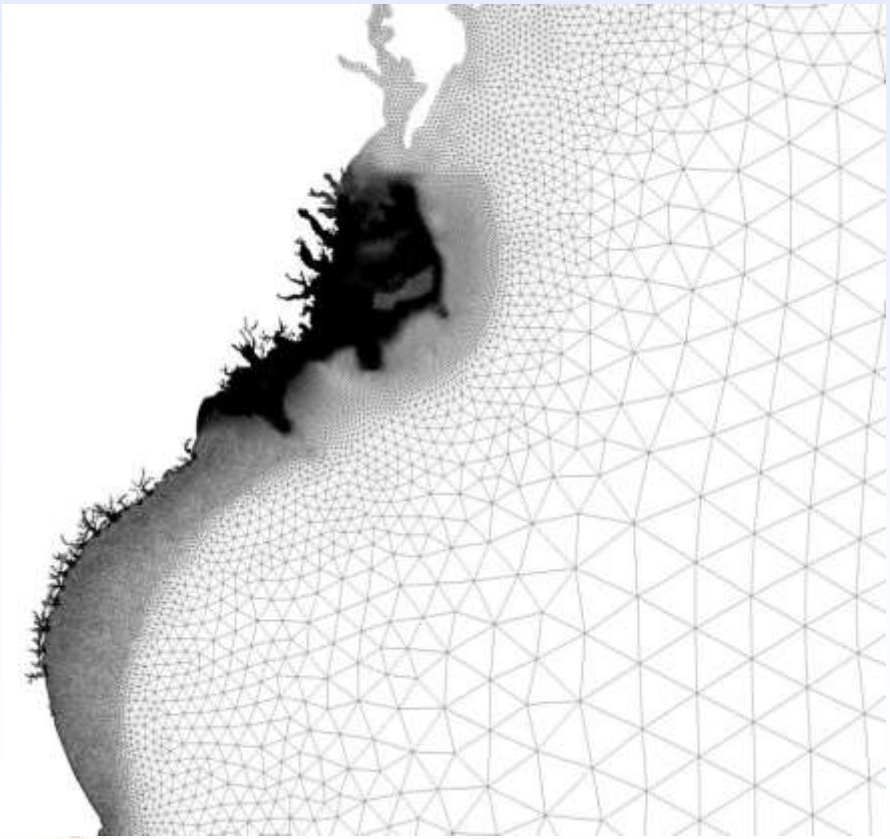
ADCIRC Model Mesh and DEM

Digital Elevation Model

- 10 m x 10 m raster

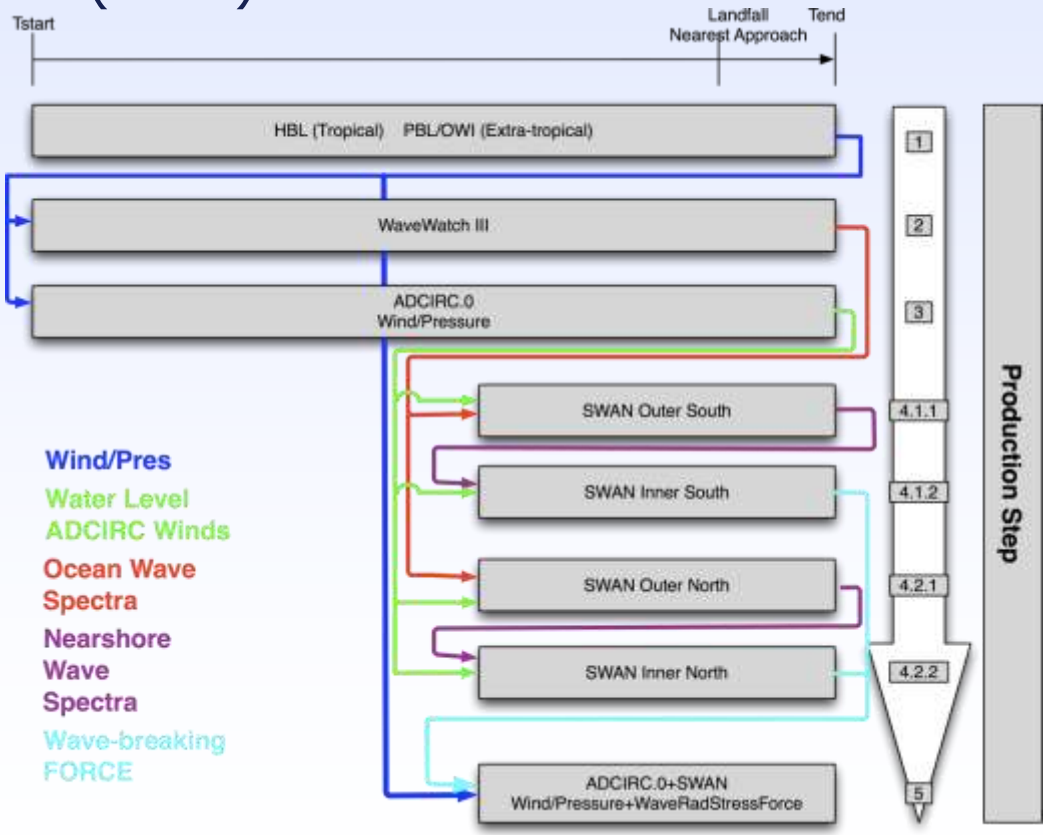
ADCIRC MESH

- Variable spacing

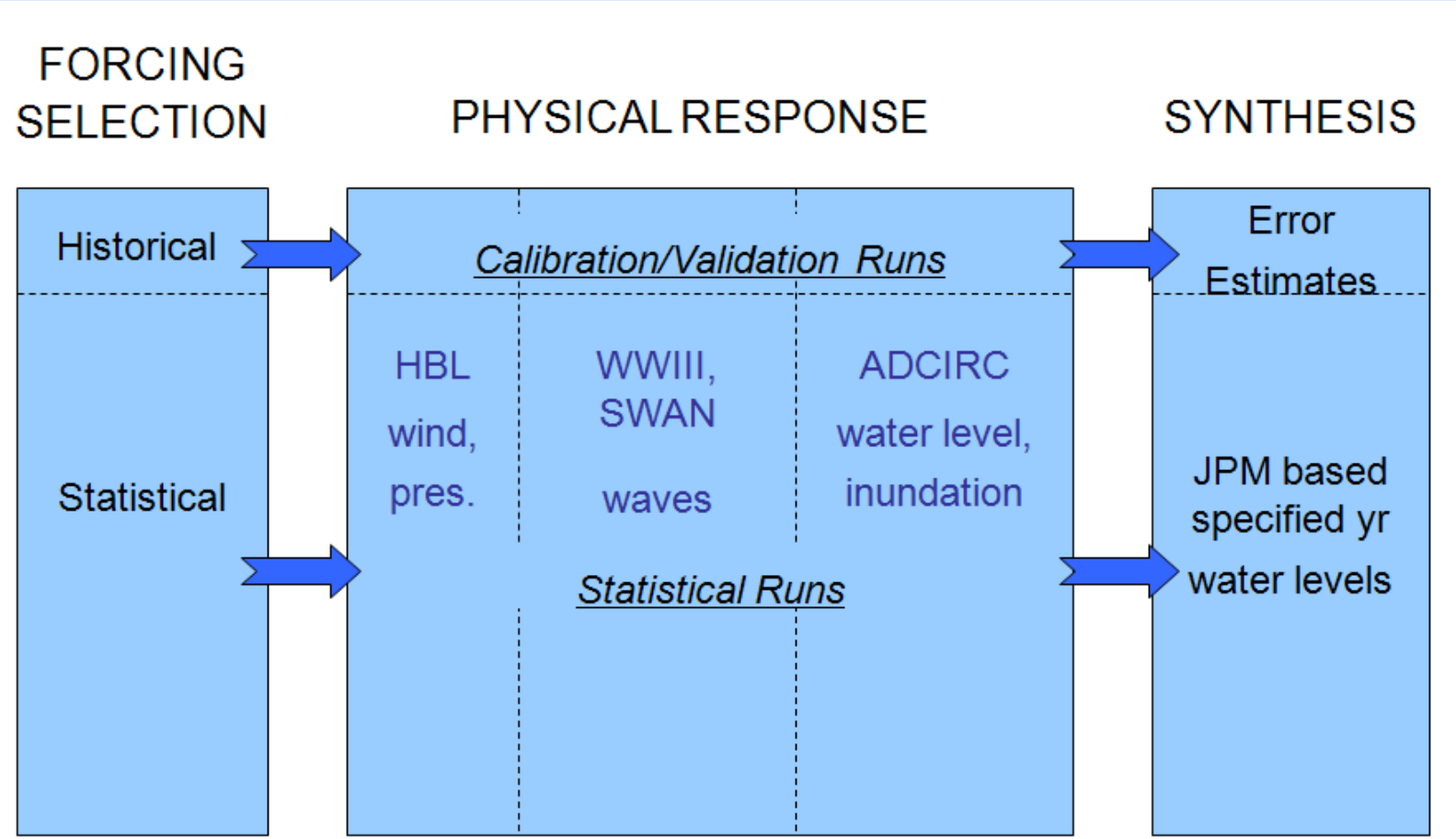


Storm Surge Modeling System

- Wind/Pressure Fields
  - Tropical - Hurricane Boundary Layer (HBL)
  - Extratropical - Planetary Boundary Layer from Ocean Weather Inc. (PBL/OWI)
- Offshore Waves - Wave Watch III (WW3)
- Near Shore Waves - SWAN
- Stillwater/Setup - ADCIRC



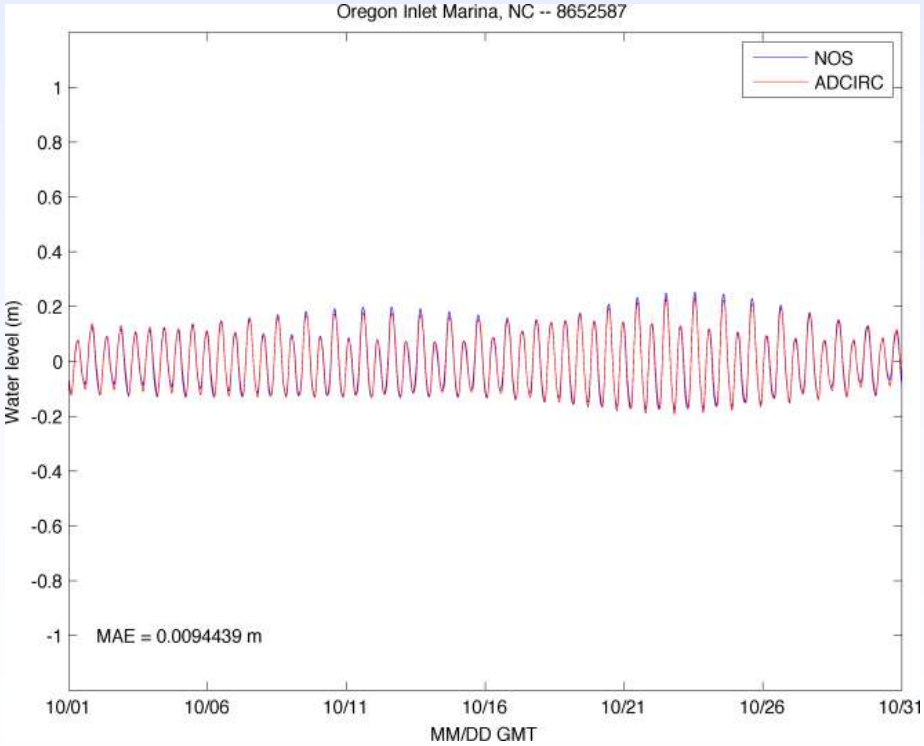
Surge Modeling Setup and Workflow

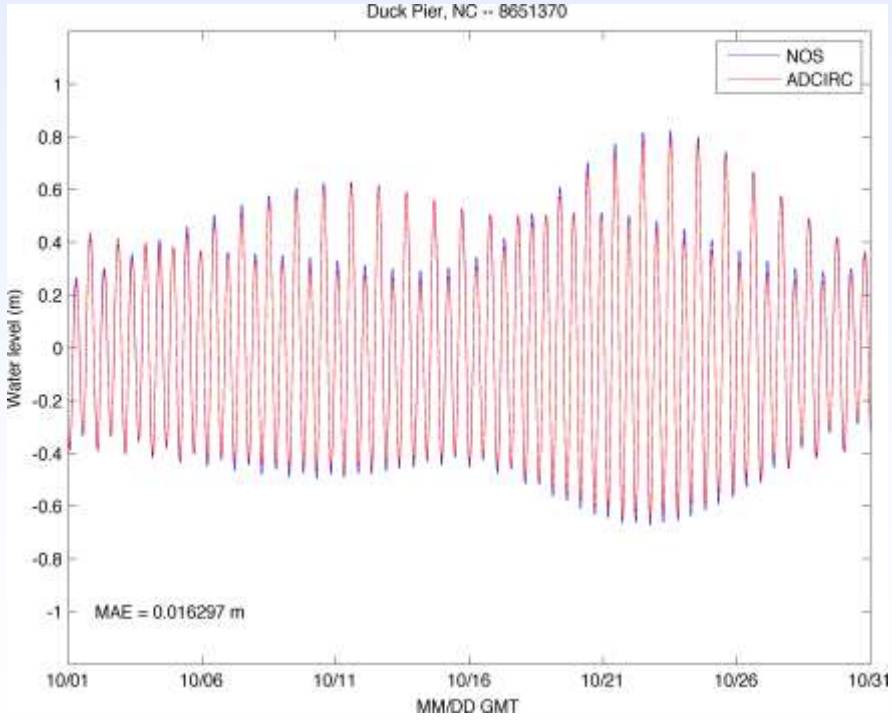


Storm Surge Model - Tidal Validation

- ADCIRC model run 120 days with tides
- Simulated tide levels compared to NOAA gages

Station	RMSE, cm	Adjusted RMSE, cm	Adjustment, min
Duck Pier	2.0	1.9	2
Oregon Inlet	1.1	1.0	6
Beaufort	1.9	1.4	4
Wilmington	4.8	3.5	10
Wrightsville	1.6	1.6	0
Southport	2.2	2.2	0
Sunset Beach	2.7	2.6	-2





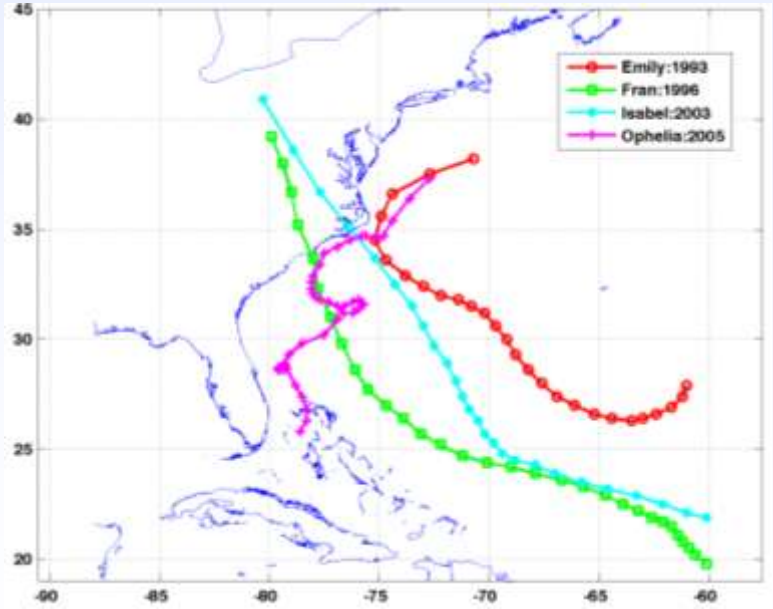
Storm Selection - Validation Storms

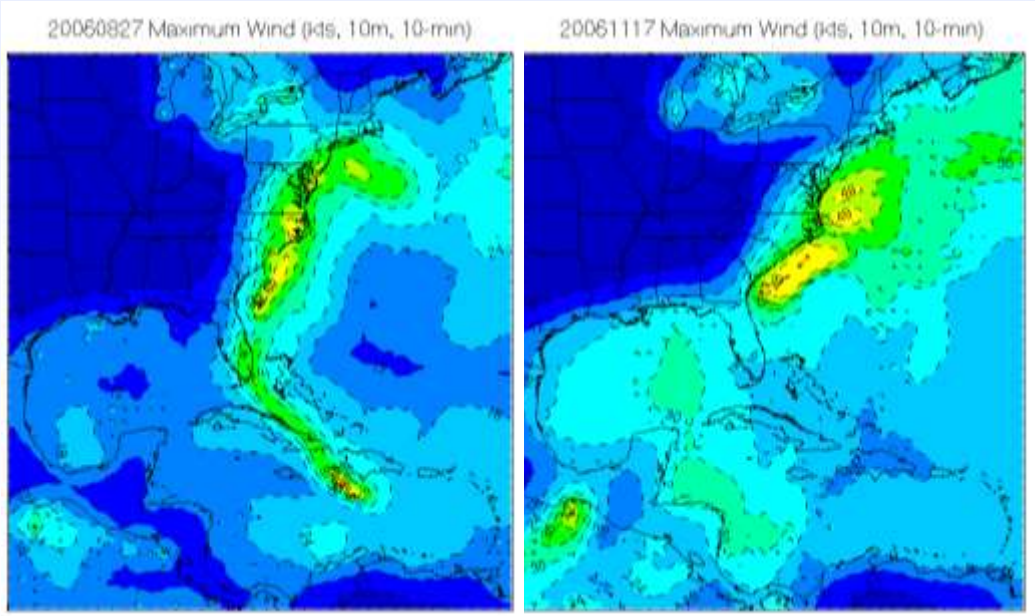
Four tropical storms:

- Emily (1993)
- Fran (1996)
- Isabel (2003)
- Ophelia (2005)

Two extratropical storms:

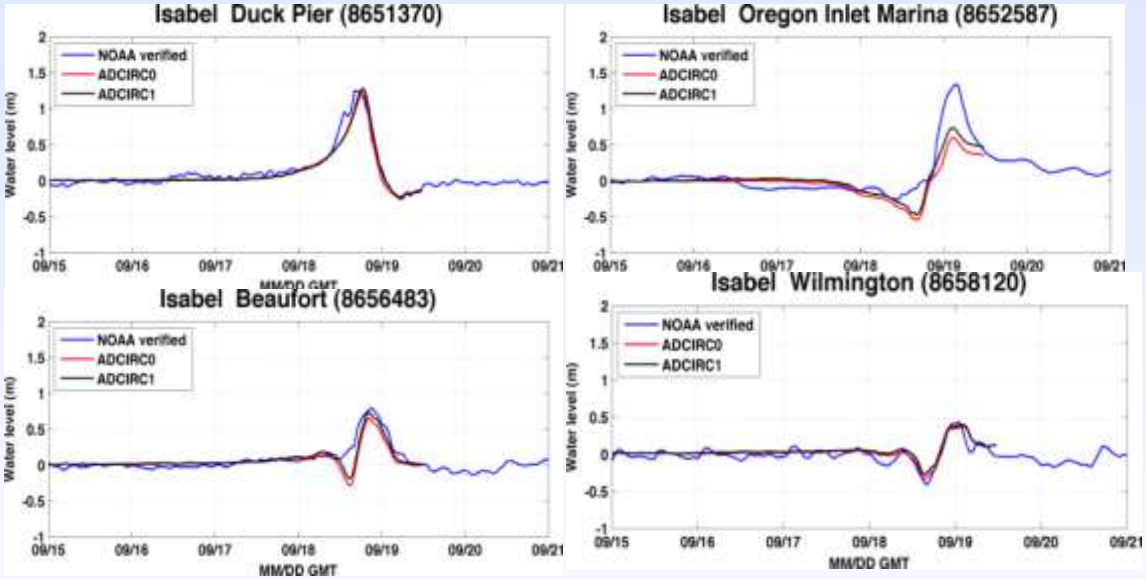
- 2006 Thanksgiving storm
- 2006 Decayed extratropical storm Ernesto

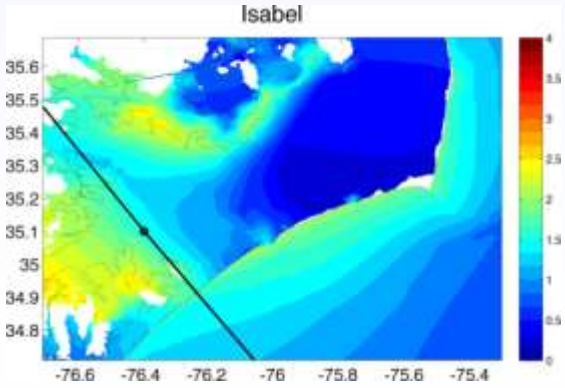




Storm Surge Model Validation Runs

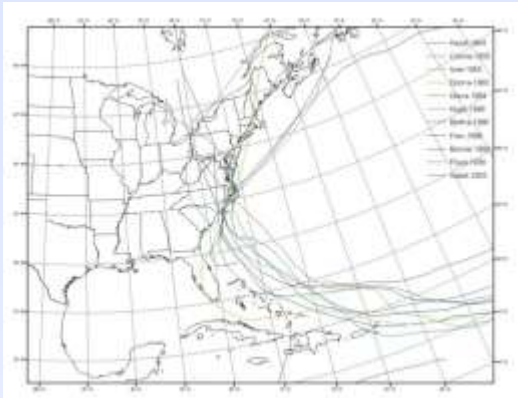
- Tropical and extratropical validation storms run through surge modeling system (HBL/PBL, WW3, SWAN and ADCIRC)
- Results compared to coastal gages and historical high water marks



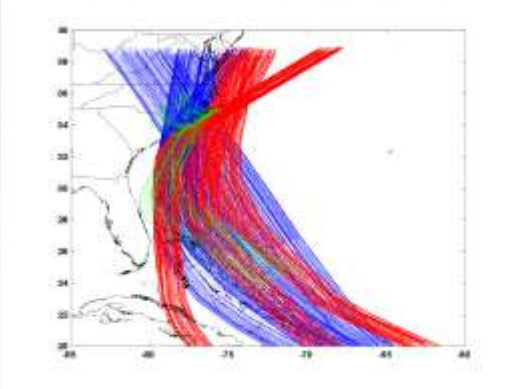


Storm Surge Model Statistical Run Storms

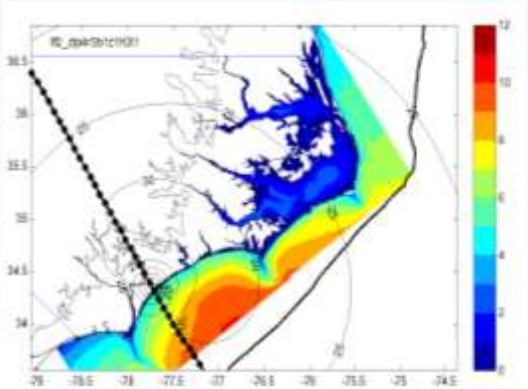
- Tropical Synthetic Storms
  - Historical Tropical Storms - After 1940 – Storms with a central pressure less than 980 mb that impacted NC and SC
  - 24 historic tropical storms were considered representative of NC climatology (Central pressure, forward speed and heading, wind speed and direction, and radius of maximum winds)
  - Tropical events are modeled through synthetic tracks generated using hurricane parameters developed from historical storms
  - 675 tropical synthetic tracks were developed from the combination of the above parameters
- 22 Extratropical Historical Storms (Northeasters)
  - Extratropical use historical storms



Representative Storms



Tropical Storm Tracks



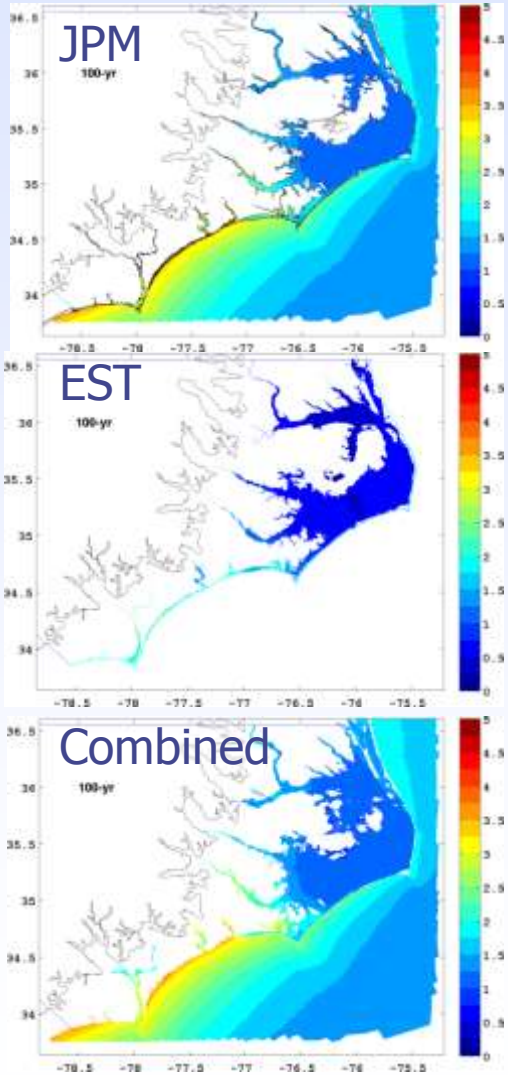
Statistical Run Water Levels

Statistical Surge Model Runs

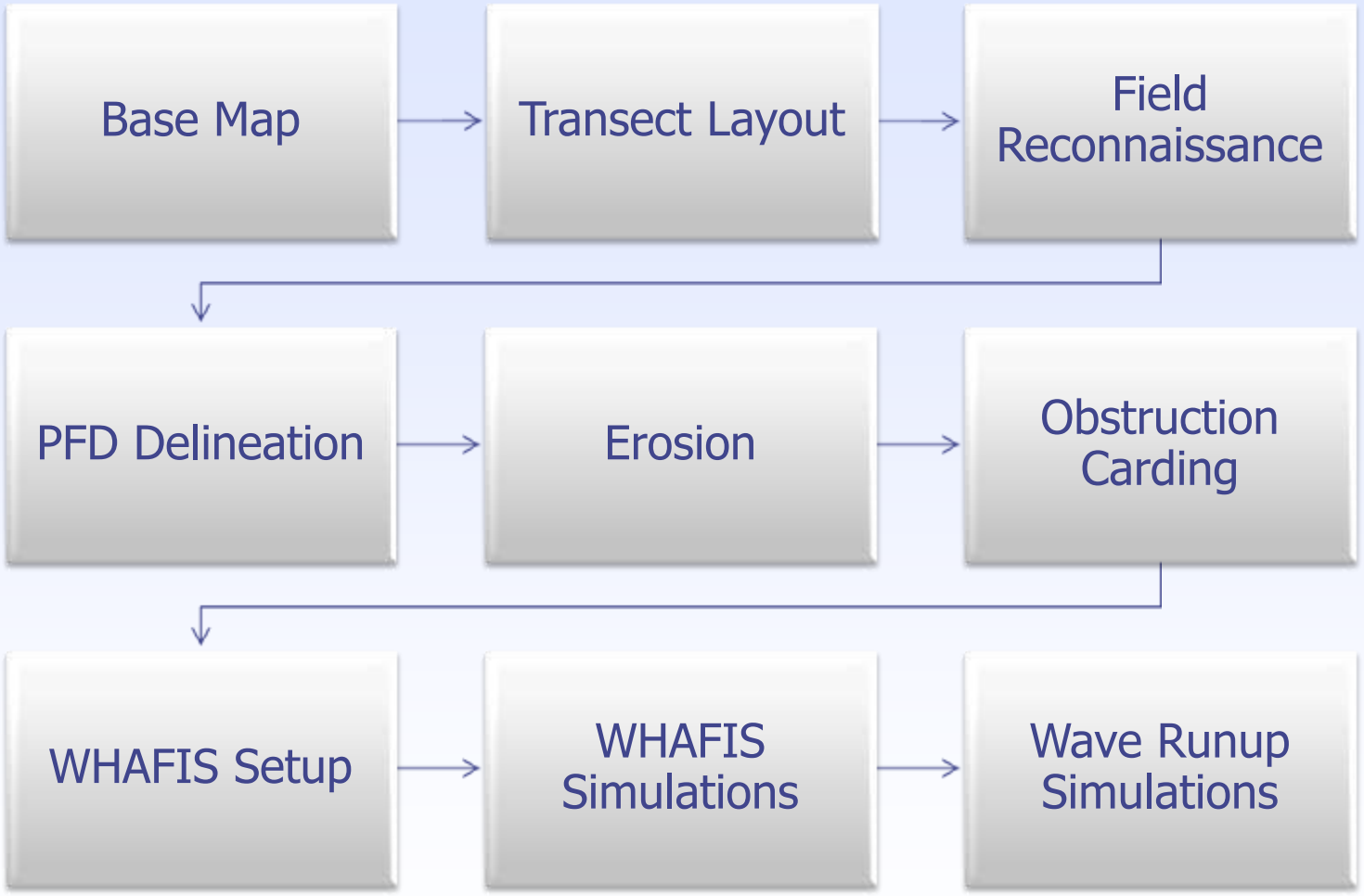
- 675 tropical and 22 extratropical storm run through the surge model system (HBL/OWI, WW3, SWAN and ADCIRC)
- Wind/Pressure Models – HBL and PBL/OWI
  - Wind and Pressure Fields for WW3 and ADCIRC
- Offshore Wave Model - WW3 output is provided to nearshore SWAN model
- Nearshore Wave Model (SWAN)
  - Wave breaking force (ADCIRC – Wave Setup)
  - Wave height, direction and period (Overland Wave Analysis)
- Stillwater Level and Setup – ADCIRC Model
  - Stillwater only values for all storms
    - Input for Initial SWAN Run
  - Stillwater plus setup values for all storms
    - Wave breaking component from SWAN

Surge Water Level Statistical Methods

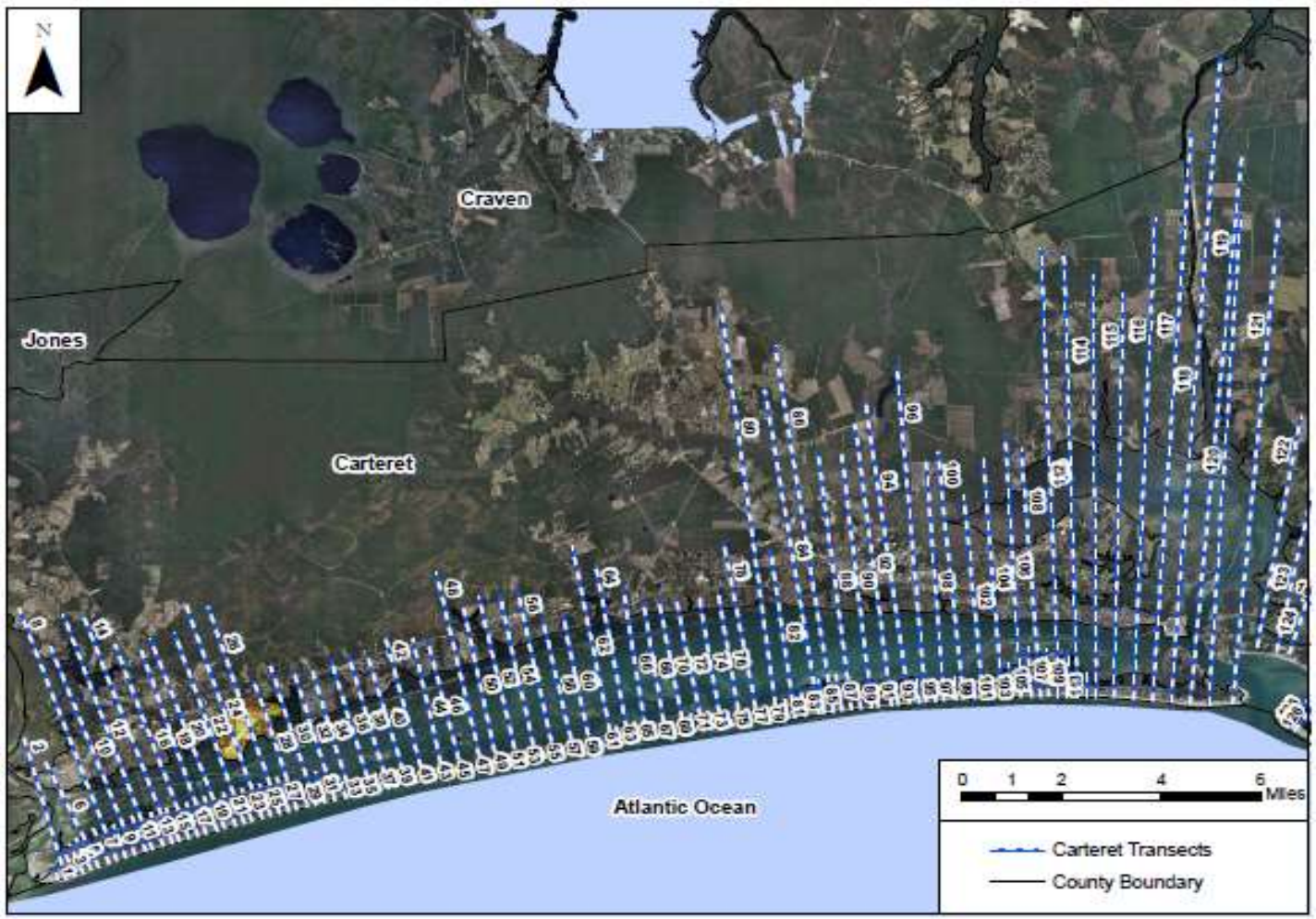
- Tides are statistically computed and incorporated into Statistical Surge Model results
- Surge water level probabilities computed from ADCIRC statistical runs using:
  - Joint Probability Method (JPM) – Tropical Storms
  - Empirical Simulation Technique (EST) – Extratropical Storms
- JPM and EST surge water levels statistically combined



Overland Wave Hazard Modeling Process

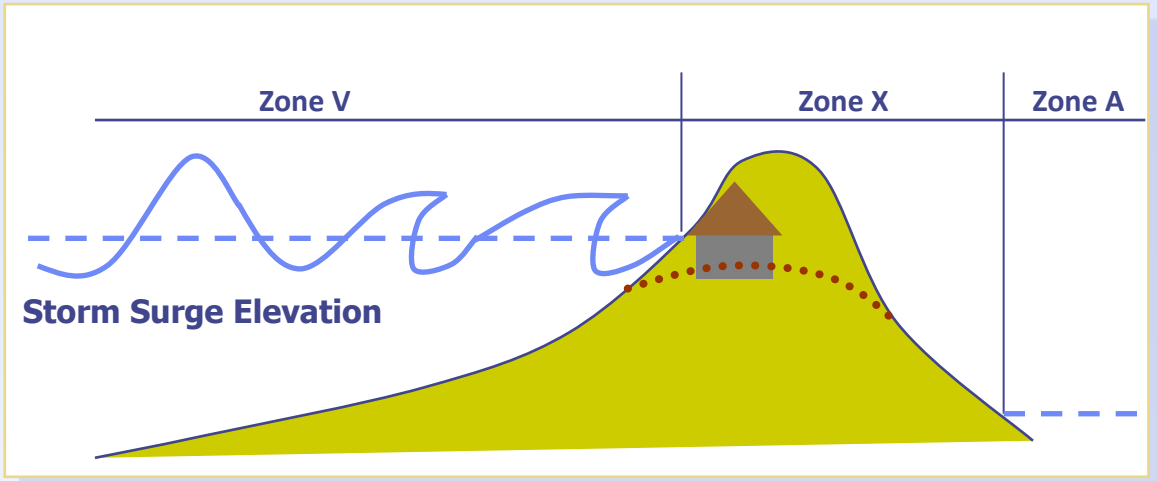


Transect Layout

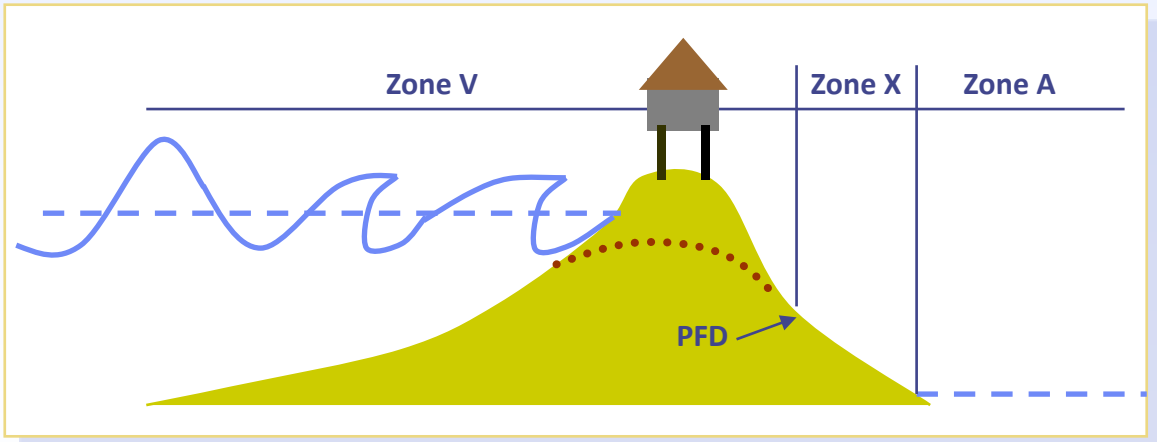


Primary Frontal Dune (PFD) Delineation

- Prior to 1989, dunes were designated outside the V Zone allowing for degradation of dune through construction or other purposes, thereby reducing initial line of natural protection and increasing flood hazards.



- After 1989, dunes were designated to be included in V Zone.
  - Reflects potential for erosion and wave impacts.
  - Preserve protection afforded by dunes and reduce flood hazards associated with man-made alterations of dunes.



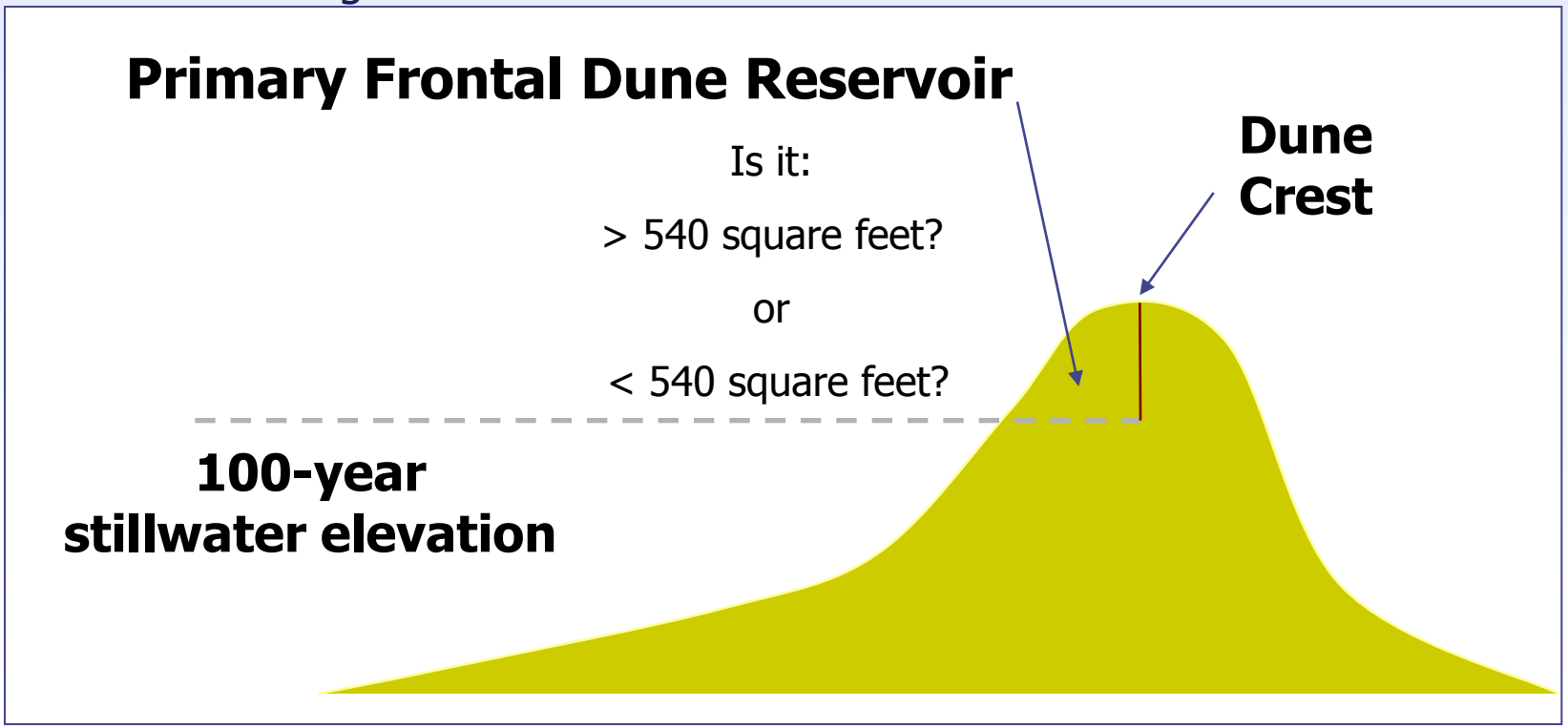
PFD Delineation

Definition in NFIP regulations:

- "Continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms."

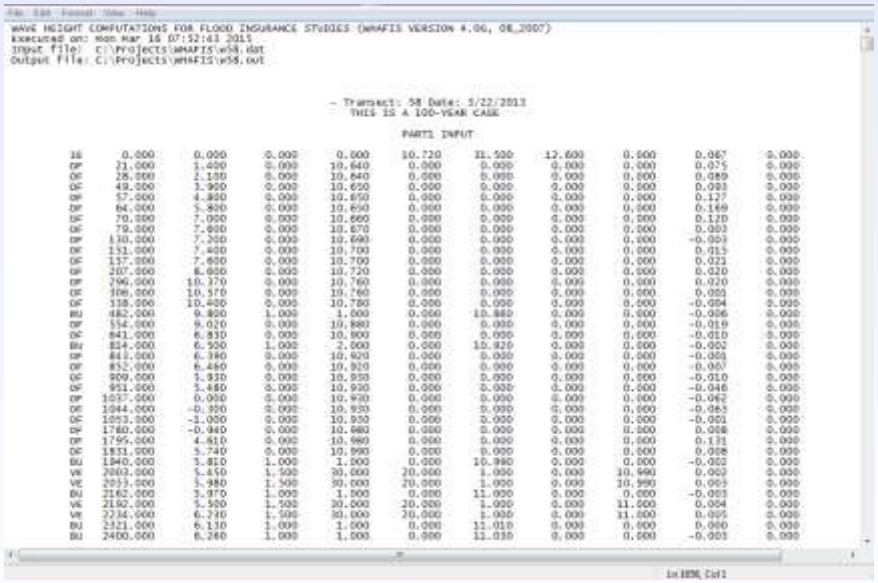
Storm Induced Erosion

- Eroded overland wave transect generated based 540 square foot rule (FEMA Guidelines and Specifications and 44 CFR 65.11).
- Determines if a dune will be modeled as fully or partially removed during the regulatory flood event.
- Established vegetative cover.



Overland Wave Height Analysis

- WHAFIS 4.0 (Wave Height Analysis for Flood Insurance Study)
- Input parameters:
  - Stillwater and wave setup (Combined JPM/EST Statistical Water Levels)
  - Depth Limited Wave Height (SWAN)
  - Wave Period (SWAN)
  - Obstruction Cards – Land use, vegetation, dunes and buildings



Land Use Data

WHAFIS Card

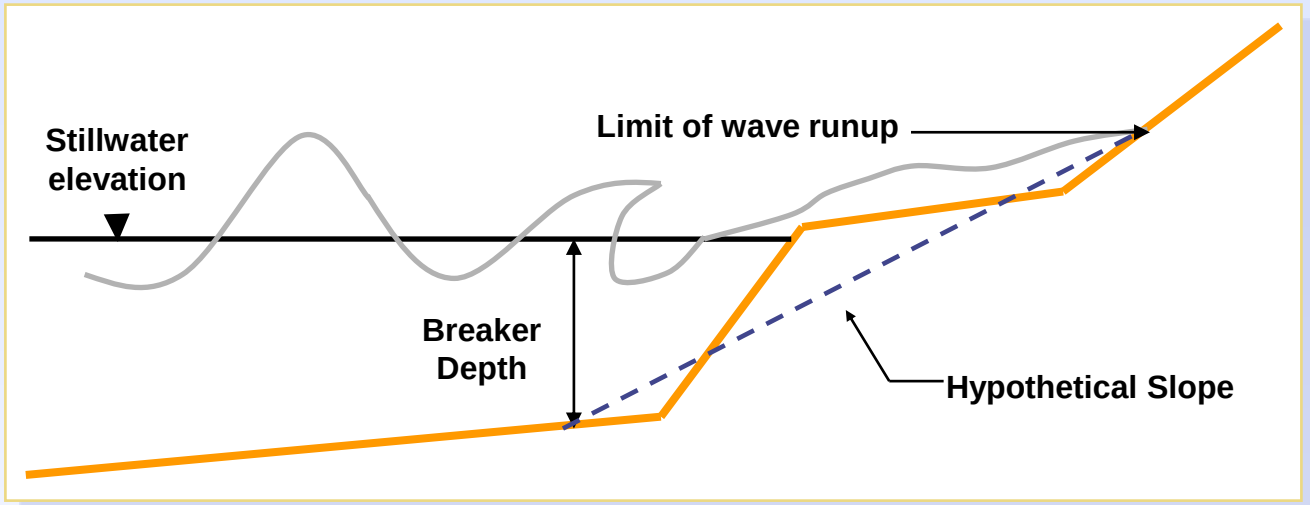
- Fetch - OF or IF
- Buildings - BU
- Vegetation – VE and VH

Input parameters

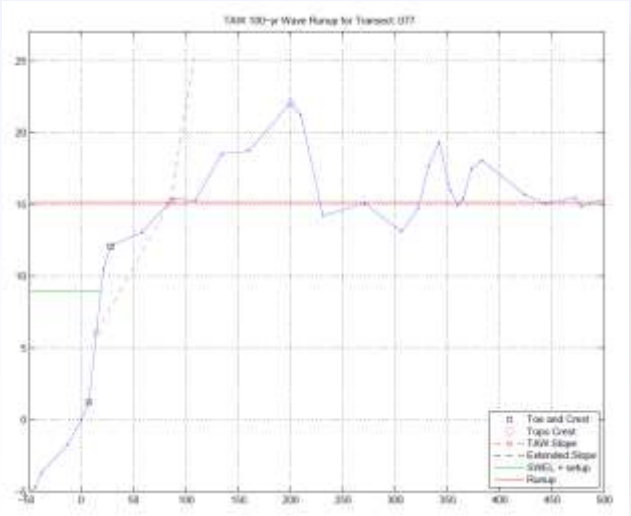
- Type of Trees
- Type of Marsh
- Density of buildings

Wave RUNUP

- Runup 2.0 – Beach and Dunes



- Vertical structures and steep topography
  - Technical Advisory Committee for Water Retaining Structures (TAW)
  - US Army Corps of Engineers Shore Protection Manual (SPM)



Coastal/Riverine Combined Probability

- Applied where riverine detailed studies overlap with coastal surge
- Results in slightly higher water level on maps

TC = 1 / [1/TR + 1/TS]

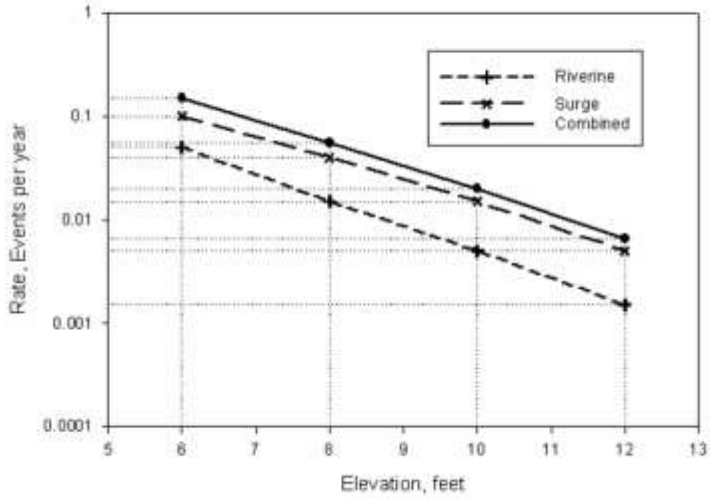
Where:

TC = Recurrence interval of the combined riverine and coastal event

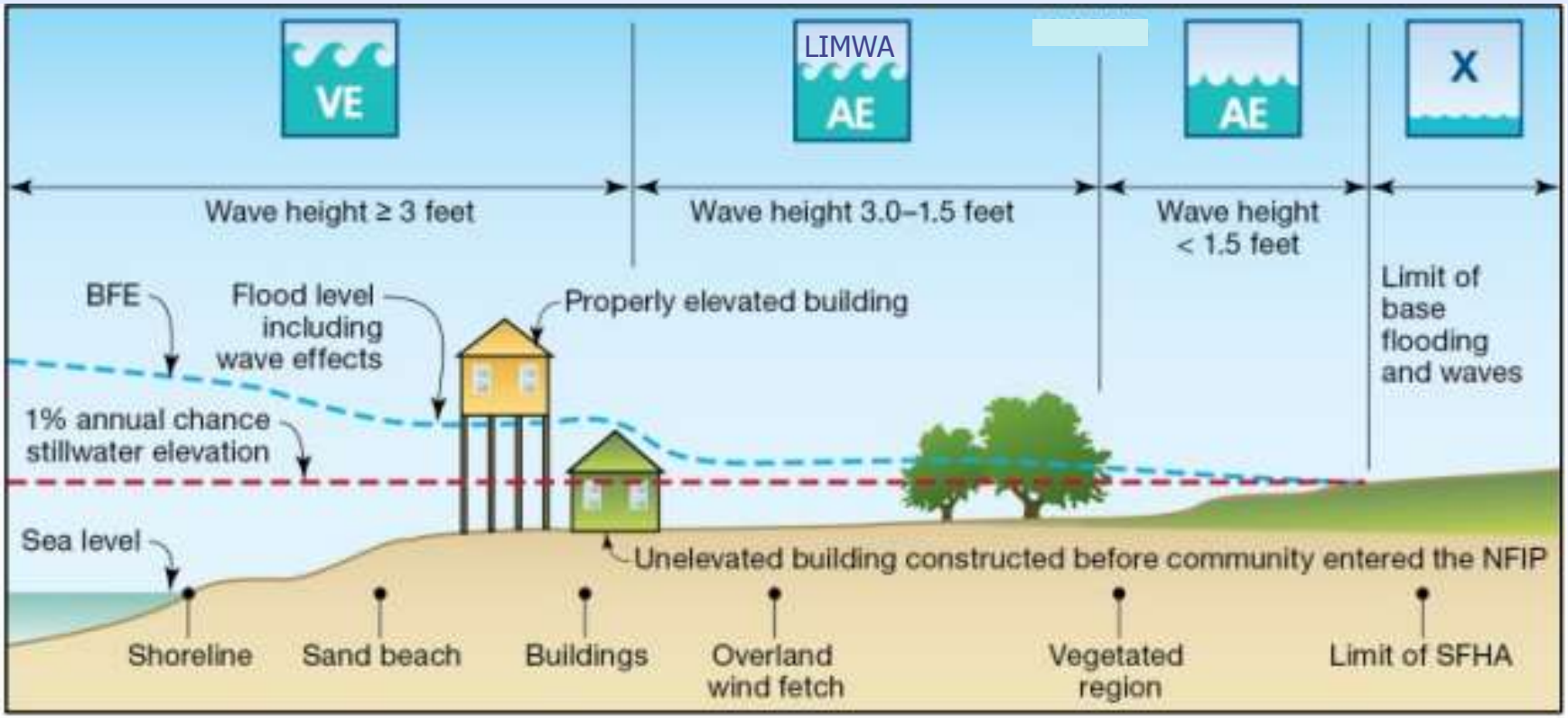
TR = Recurrence interval of the riverine event

TS = Recurrence interval of the coastal event

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



Coastal Flood Zone Designations



Coastal Flood Zone Designations

VE: coastal high hazard zone, waves >3ft, catastrophic structural damages expected
- Common at open coast shoreline, bay shoreline, open water areas
- Can regenerate inland in low-lying or over-water areas
- Extended to PFD by default

AE: subject to inundation by 1% flood, BFE shown, waves present
- Representative of most of coastal floodplain

LiMWA: Limit of Moderate Wave Action, delineates extent of waves >1.5ft, moderate structural damages expected
- Bisects AE Zone
- Several instances may occur across floodplain

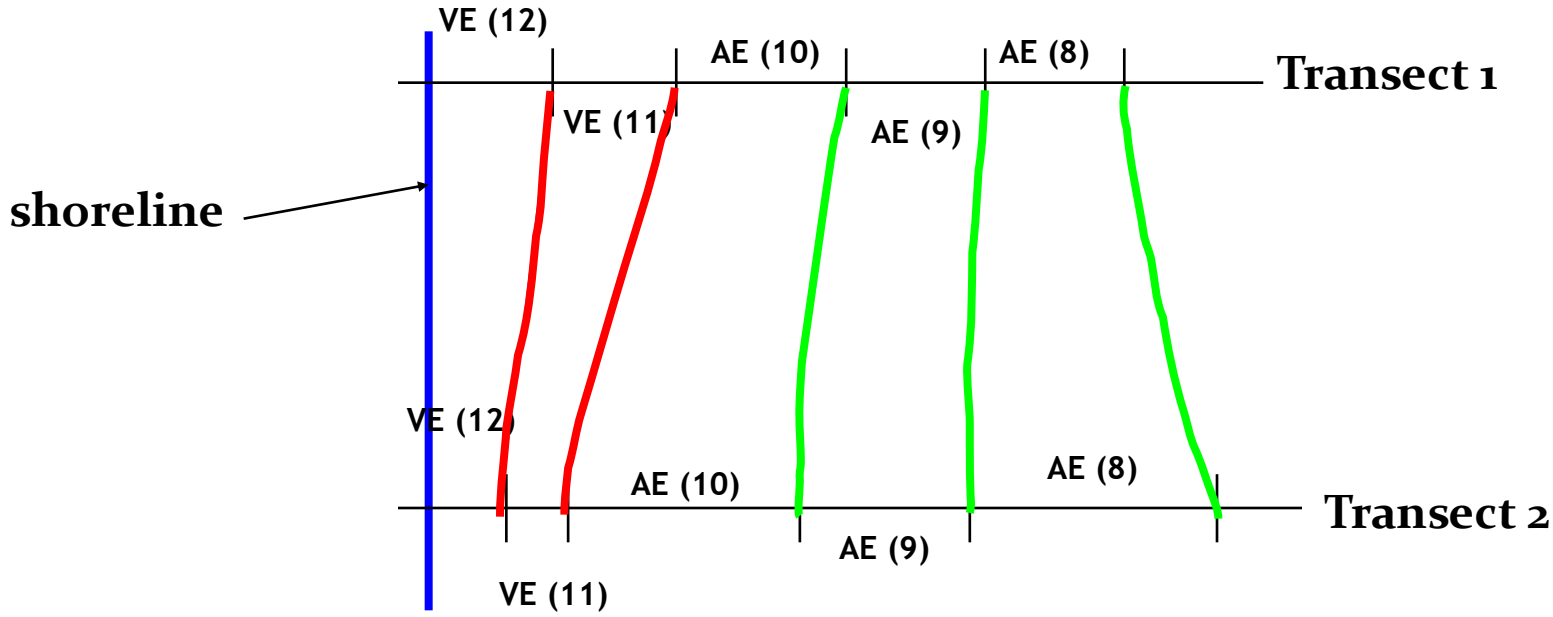
AO: subject to inundation by 1% flood, shallow flooding - sheet flow (susceptible to scour/erosion), *1% water depths shown*
- Typical on the backside of dunes (overtopping)

AH: subject to inundation by 1% flood, shallow flooding – ponding, *BFE's are provided*

Mapping of Coastal Flood Zones

Flood hazard zones are interpolated between the transects

- Topography
- Obstructions – parking and vertical structures



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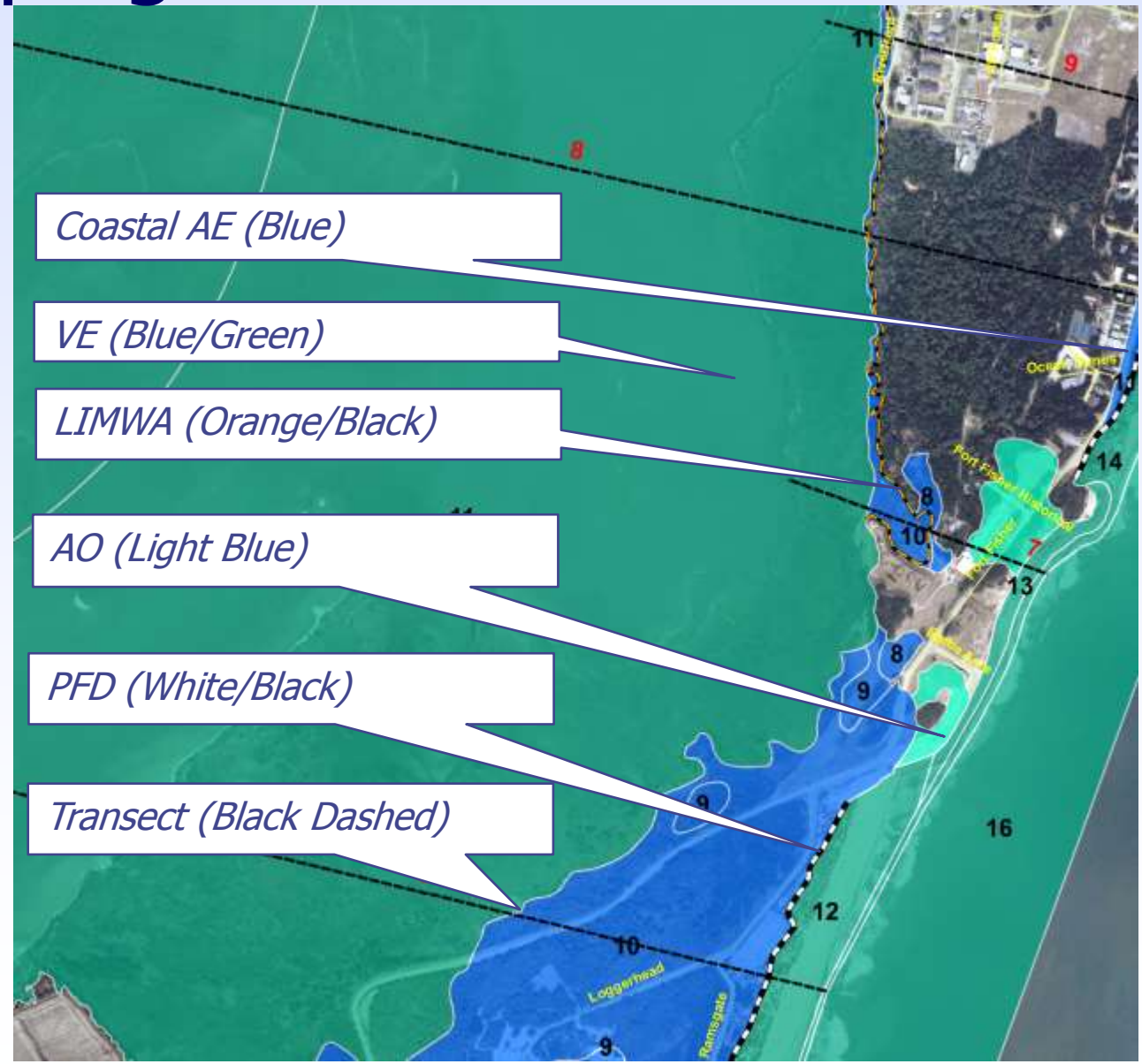

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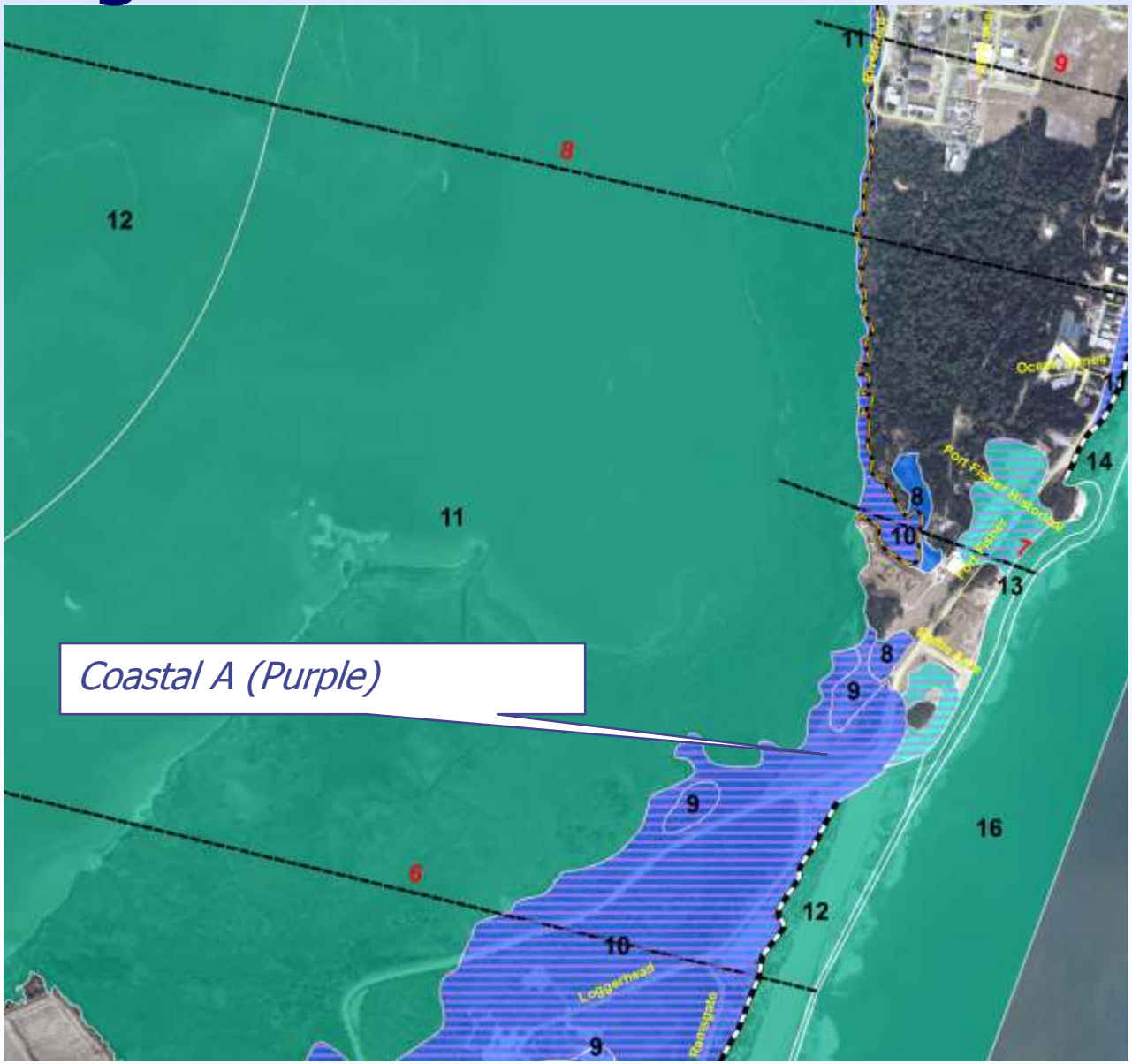

QUESTIONS?