

The Power of Storm Surge and Waves

Coastal Resilience Symposium

Rice University

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*Steve Fitzgerald, P.E.
Chief Engineer
Harris County Flood Control District*



www.hcfd.org

Destructive Forces

- **Wind**
 - Coastal and Inland
 - Tornadoes
- **Surge and Waves**
 - Both Induced By Wind
 - Surge Flooding
 - Surge Enables Larger Waves
 - Waves Are Destructive and Scour
- **Rain**
 - Inland Flooding



Destructive Forces

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Storm Surge

- **Storm surge is not a tsunami**
- **Storm surge alone produces flooding damage, but not much velocity**
- **Waves on top of storm surge greatly exacerbate damage – high orbital velocities and dynamic loadings**

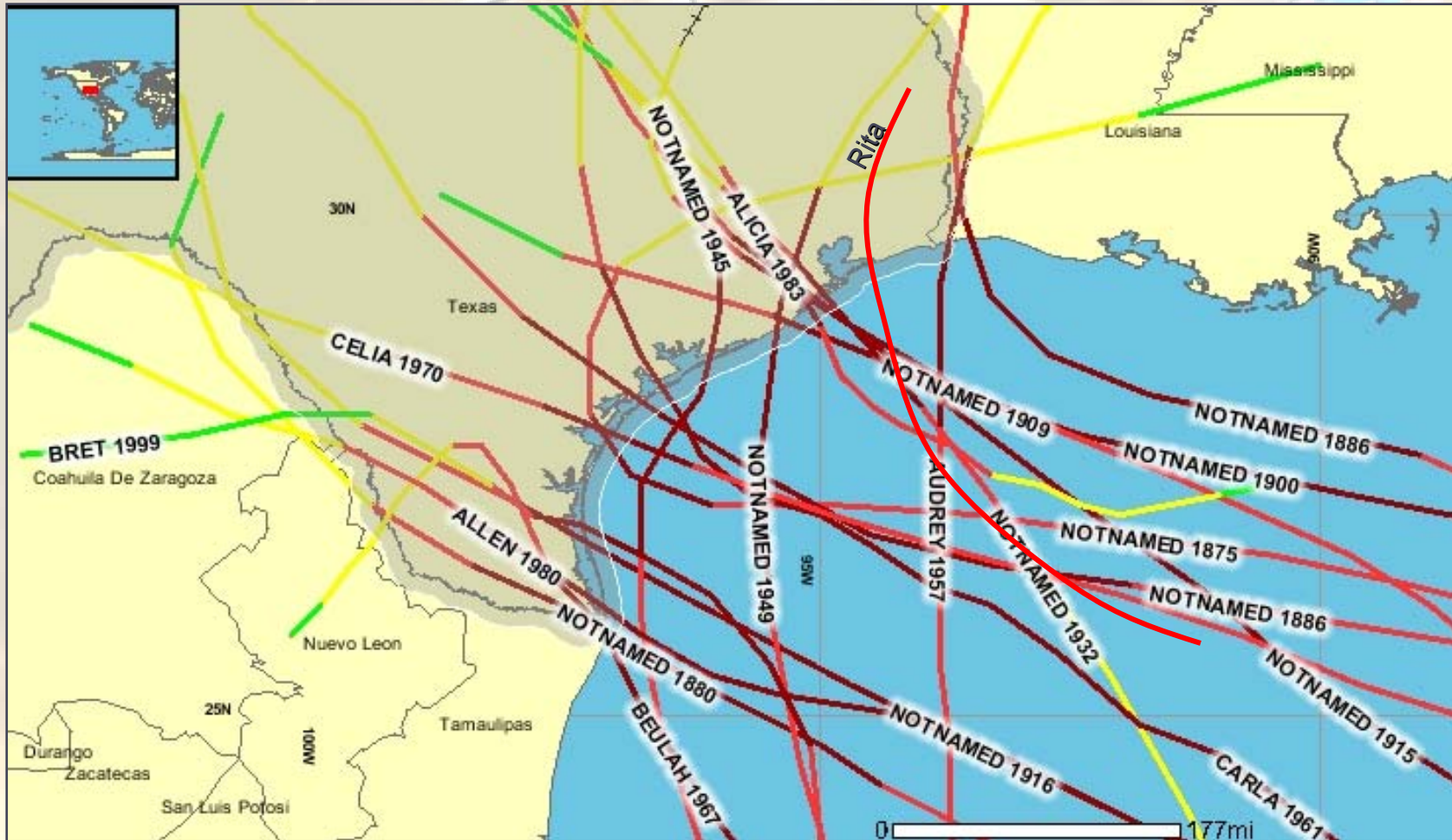


Storm Surge and Wave Variables

- **Hurricane**
 - **Wind Speed**
 - **Track**
 - **Forward Speed/Direction**
 - **Diameter (Radius)**
 - **Central Pressure**
 - **Angle of Approach**



Texas Hurricane History

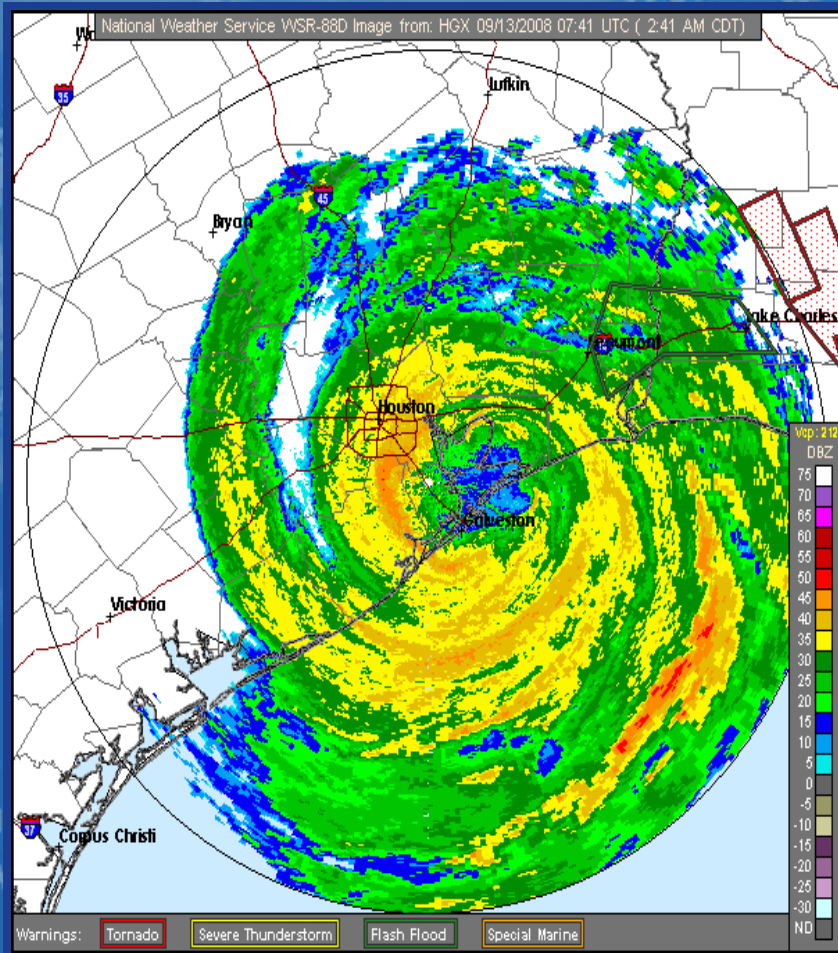


**Total of 19 Major Hurricanes Dating Back to 1851
One Every 8-9 Years – No Category 5 Landfalls**

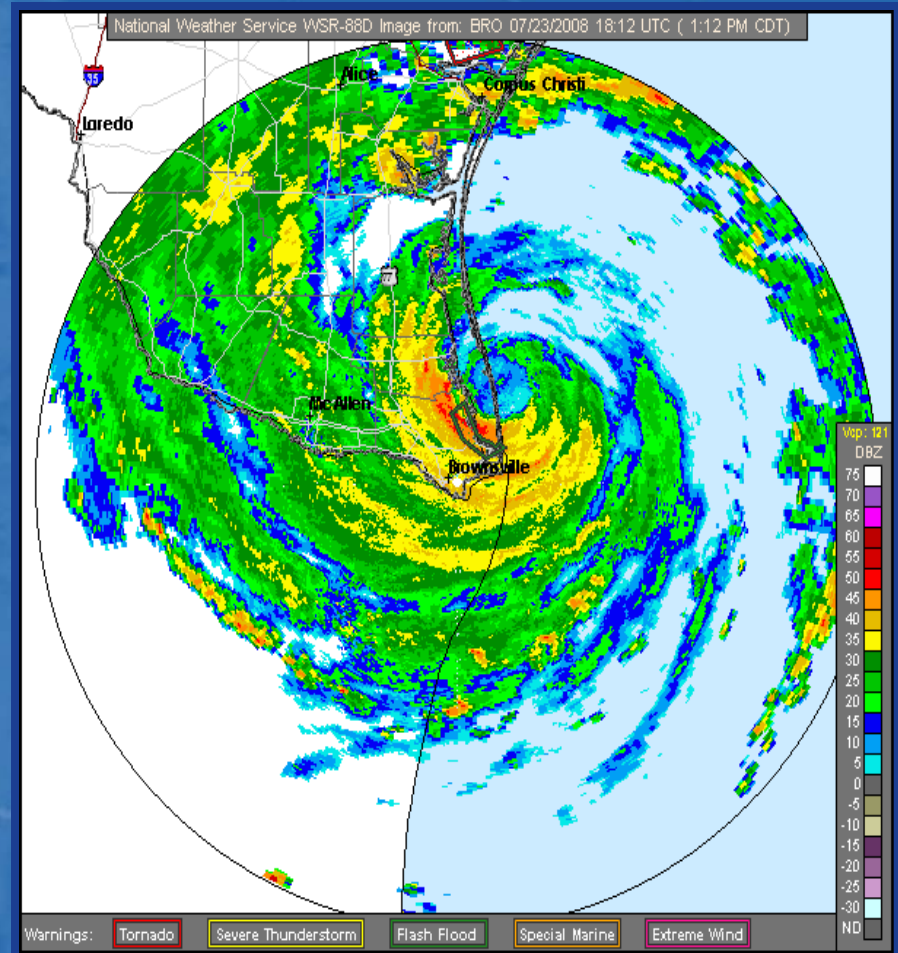


Hurricane Ike vs. Hurricane Dolly

Hurricane force winds: 125 miles
Sustained winds: 110 mph
Storm Surge: 11-17 ft



Hurricane force winds: 25 miles
Sustained winds: 100 mph
Storm Surge: 4-6 ft

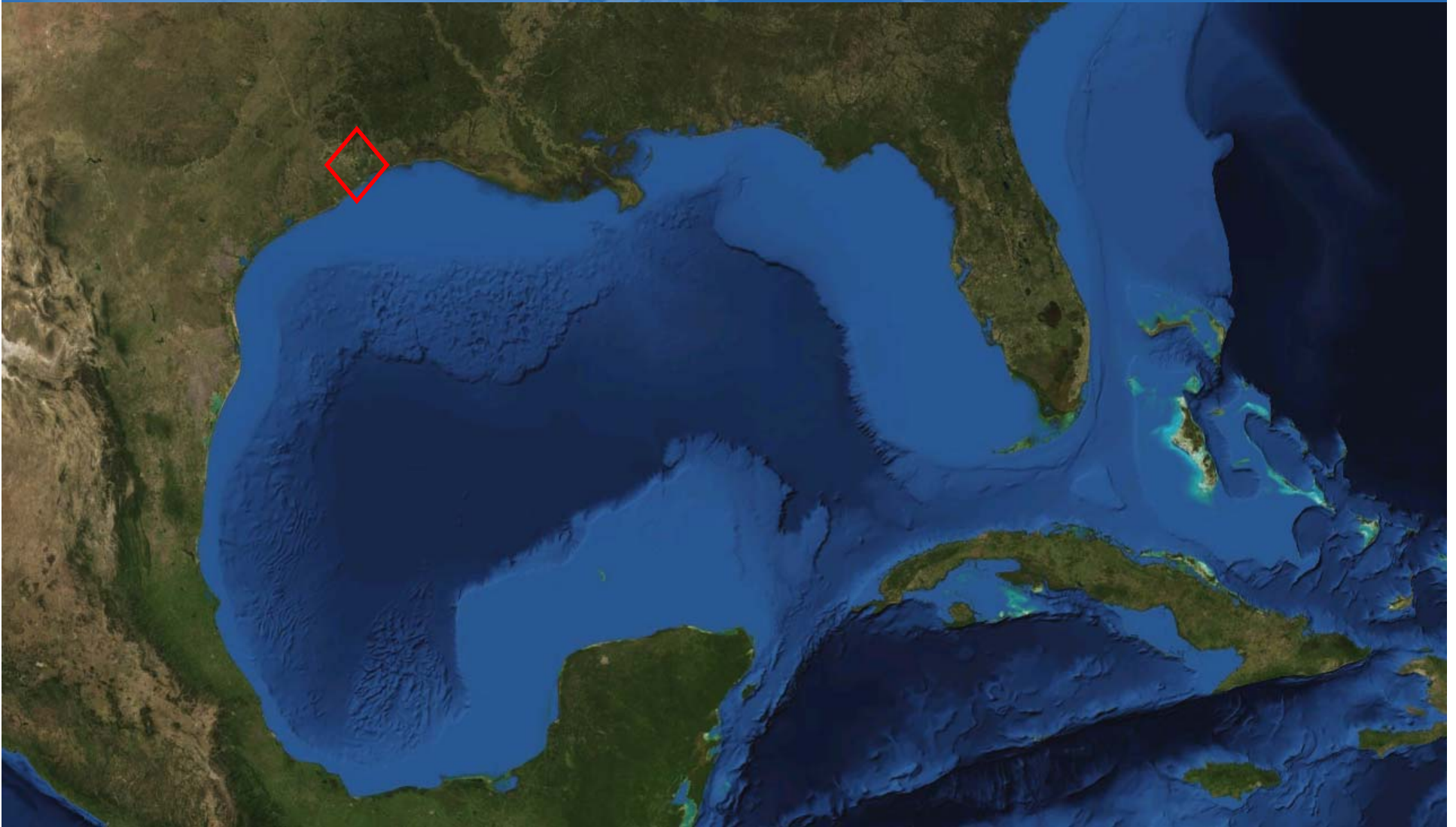


Storm Surge and Wave Variables

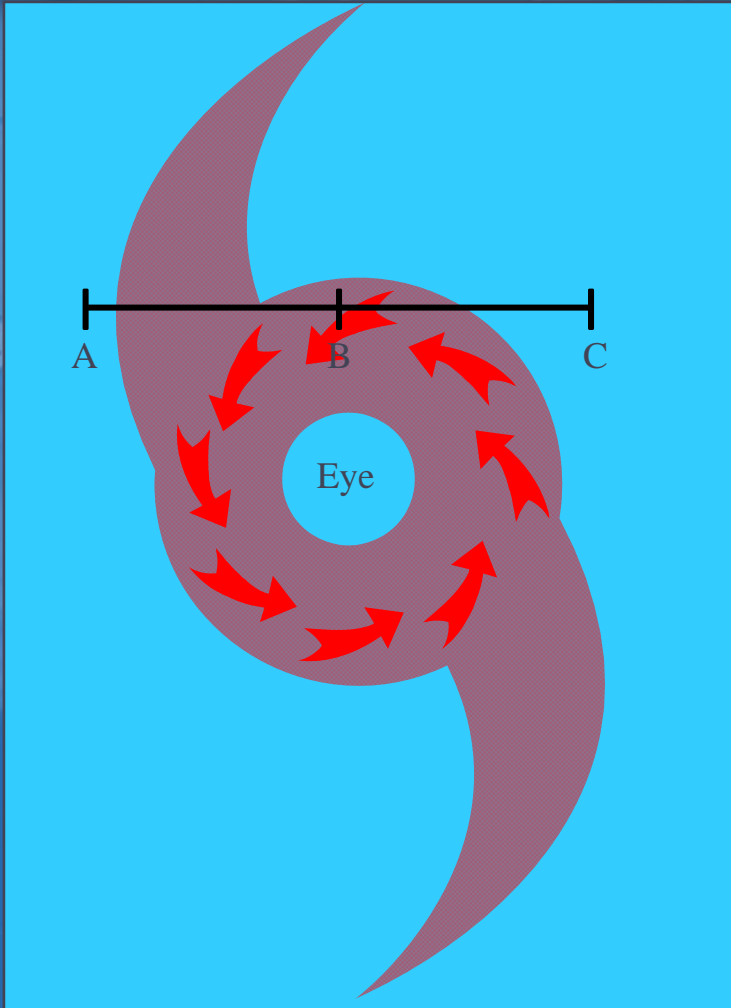
- **Offshore Water Depth**
 - Slope and depth of the sea floor (shallow water enhances surge)
- **Coastal Topography**
 - Barrier islands (speed bumps)
 - Bays enhance surge



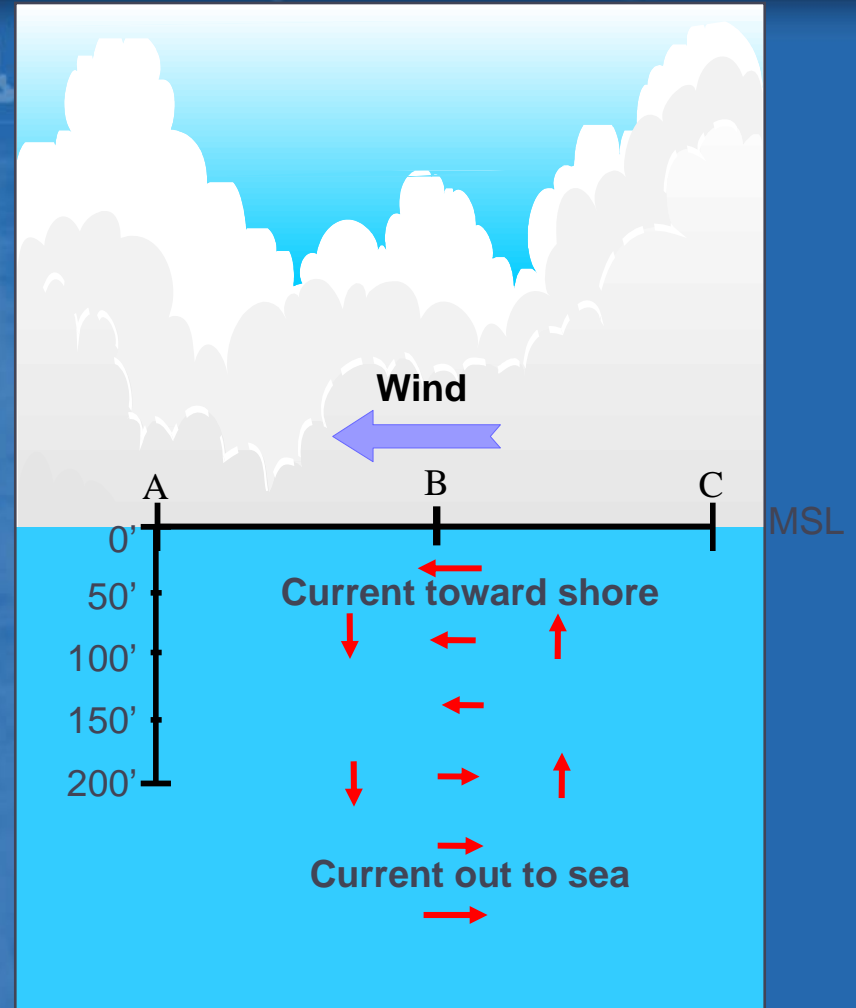
Bathymetry



Deep Water

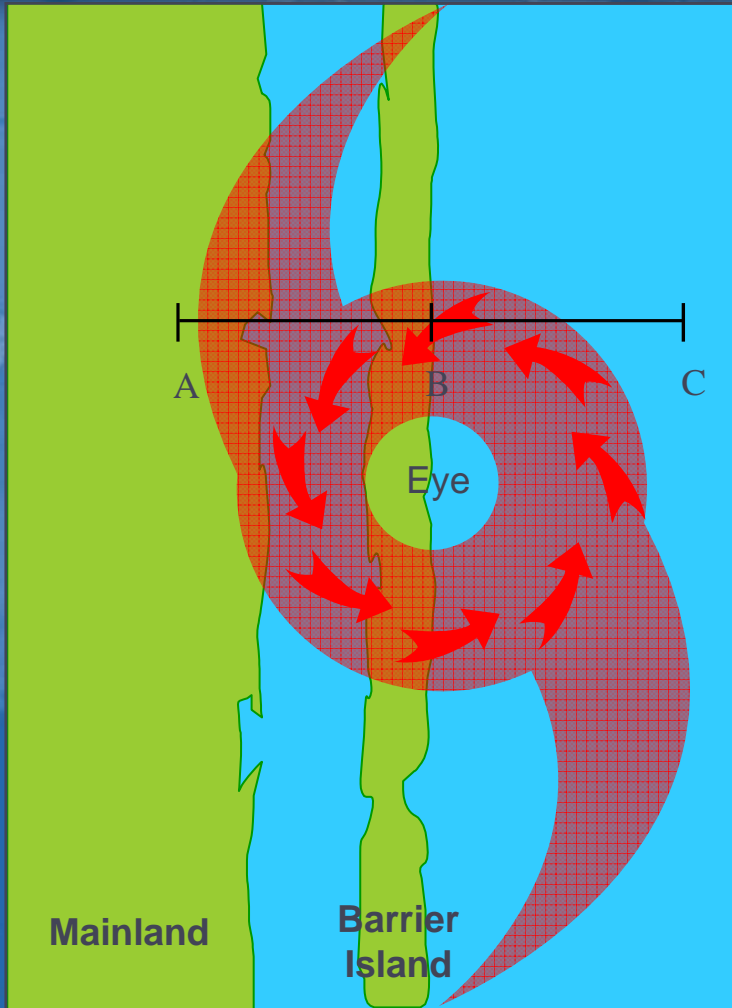


Top View of Sea Surface

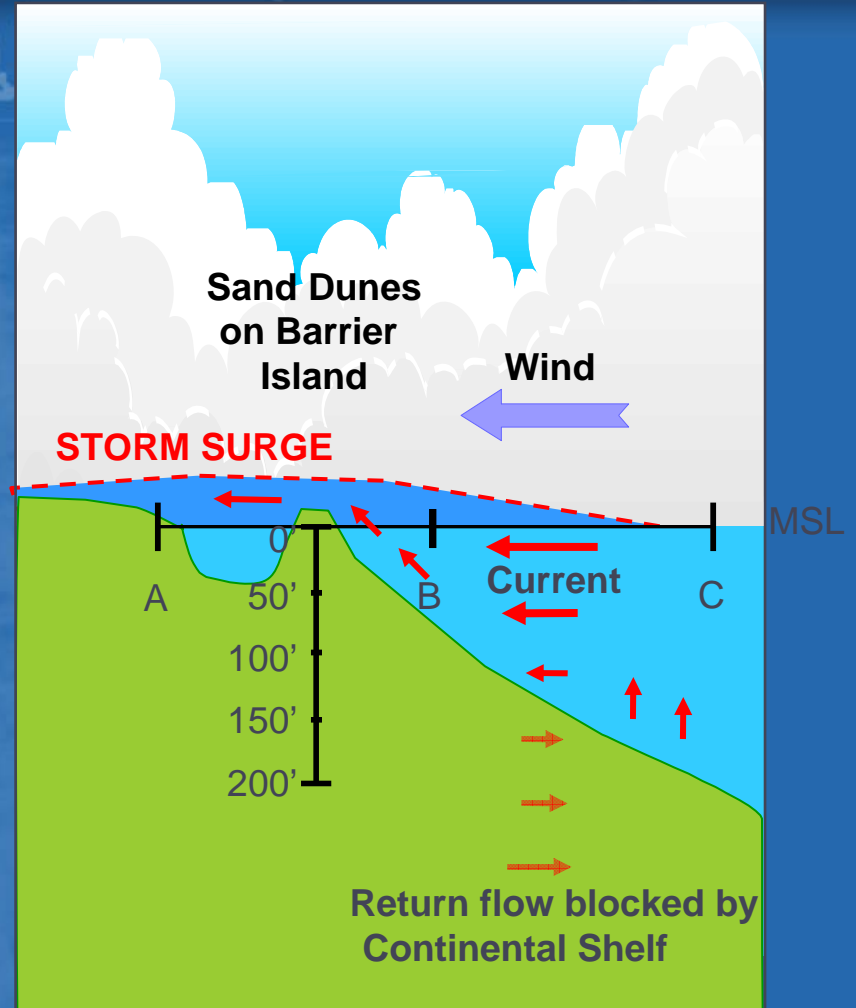


Side View

Landfall

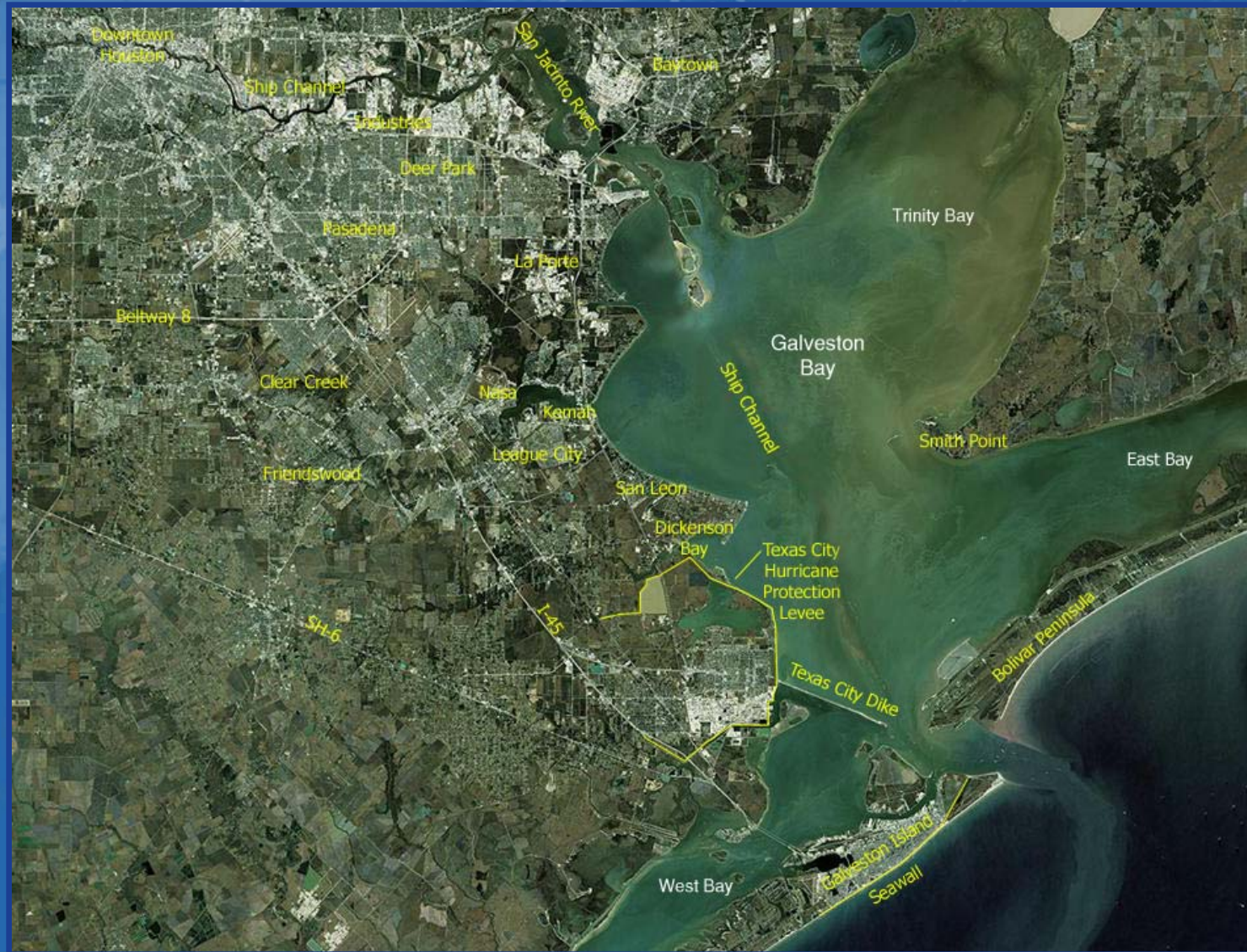


Top View of Sea Surface and Land



Side View

Galveston Bay & Barrier Islands



Basin: Ell Galveston Bay (2002) <g12>

Storm: Dir mv: Cat 4: 15 mph



Harris

Houston ★

Chambers

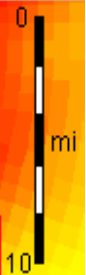
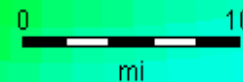
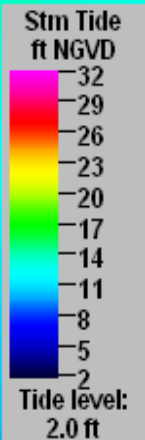
GALVESTON BAY

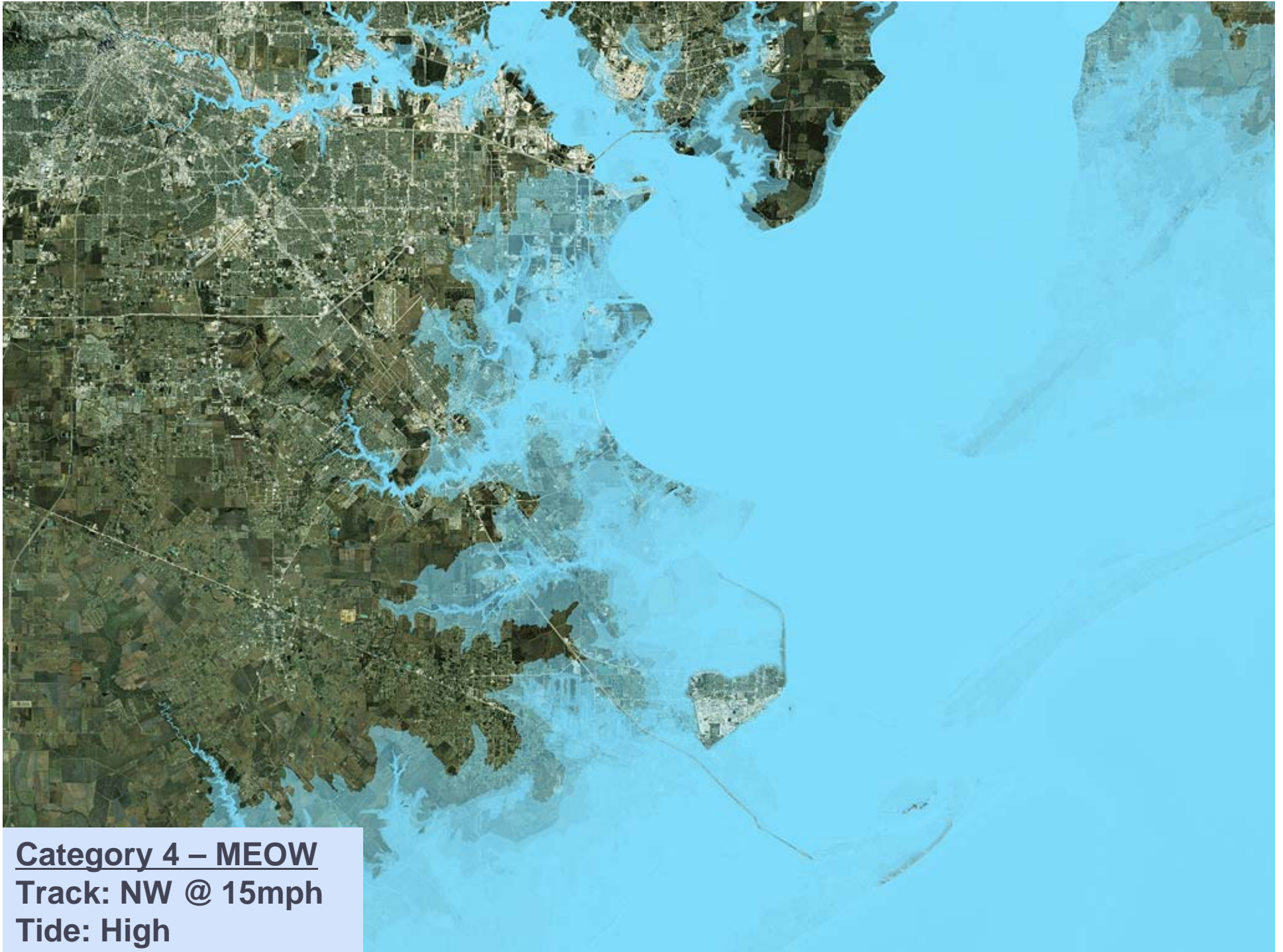
Galveston

Galveston

Galveston Island

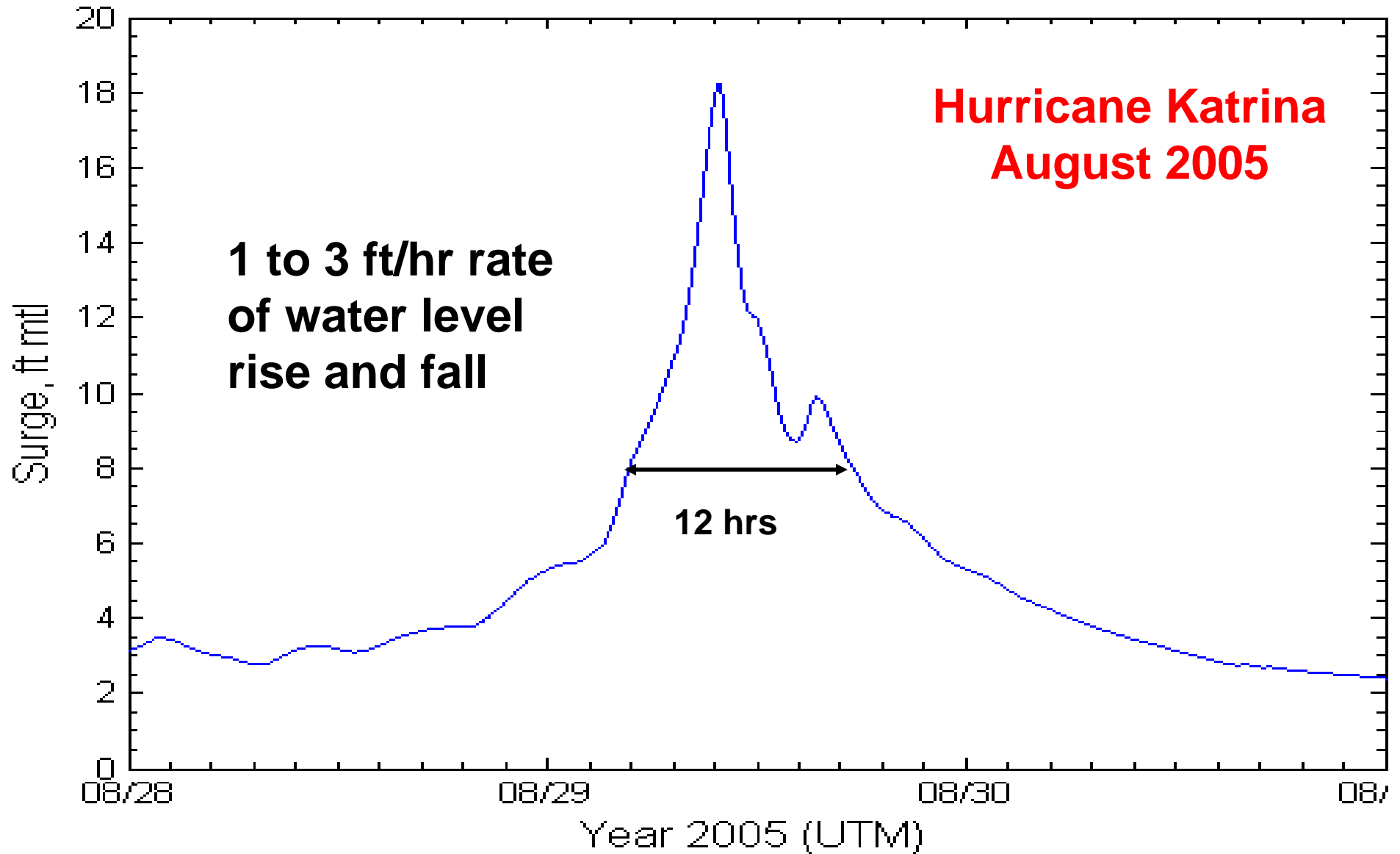
- Category 4 – MEOU
- Track: NW @ 15mph
- Tide: High



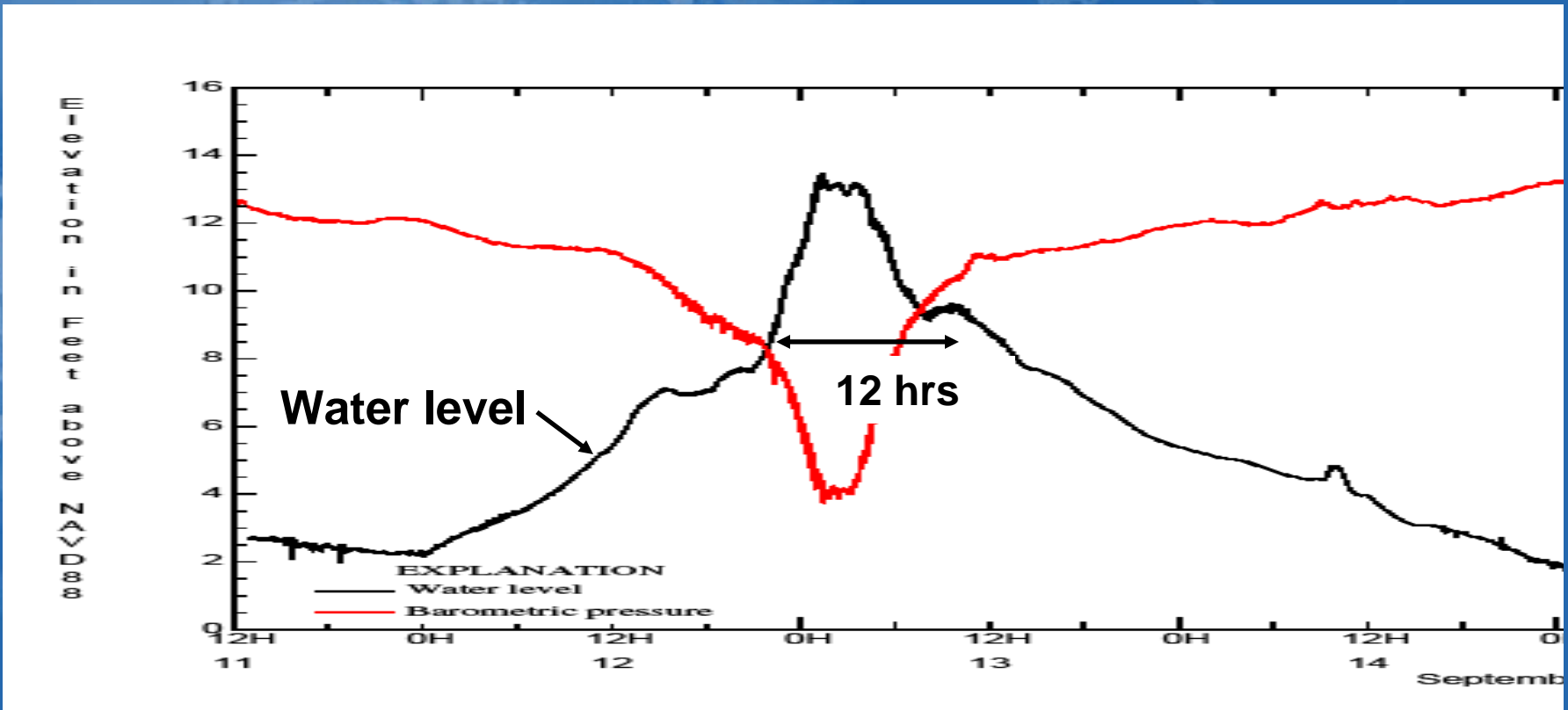


Category 4 – MEOW
Track: NW @ 15mph
Tide: High

Rising Storm Surge Level



Storm Surge Level



Hurricane Ike Bolivar Peninsula

Friday Morning - Storm Surge Onset



Storm Surge Saturday Afternoon: Clear Creek



Storm Surge Saturday Morning: Clear Creek



Ike Storm Surge Elevations

- **3rd highest surge on Galveston Island**
 - **1915: 11.10**
 - **1900: 10.87**
 - **Carla: 9.30**
 - **Alicia: 6.85**
- **10-14 feet Galveston Island –10.65 (Est)**
- **15-17 feet on Bolivar**
- **12-14 feet W side of Bay**



**HURRICANE HIGH WATER DATA
PREPARED BY CHURCH HISTORIAN
LT. COLONEL VERNON BENNETT**

FEET M.S.L.

1915 HURRICANE + 11.10

1900 HURRICANE + 10.87

CHURCH FLOOR ELV. + 9.87

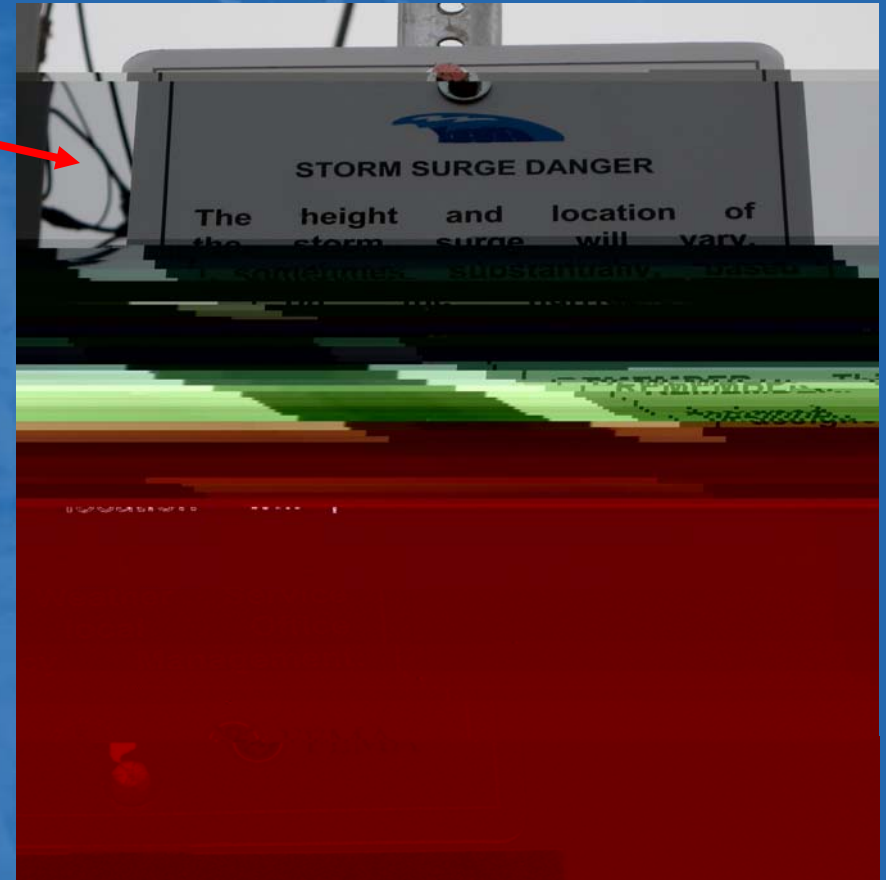
1961 HURRICANE CARLA + 9.30

EDU. BLDG. FLOOR ELV. + 9.10

1983 HURRICANE ALICIA + 6.85



Storm Surge Signage

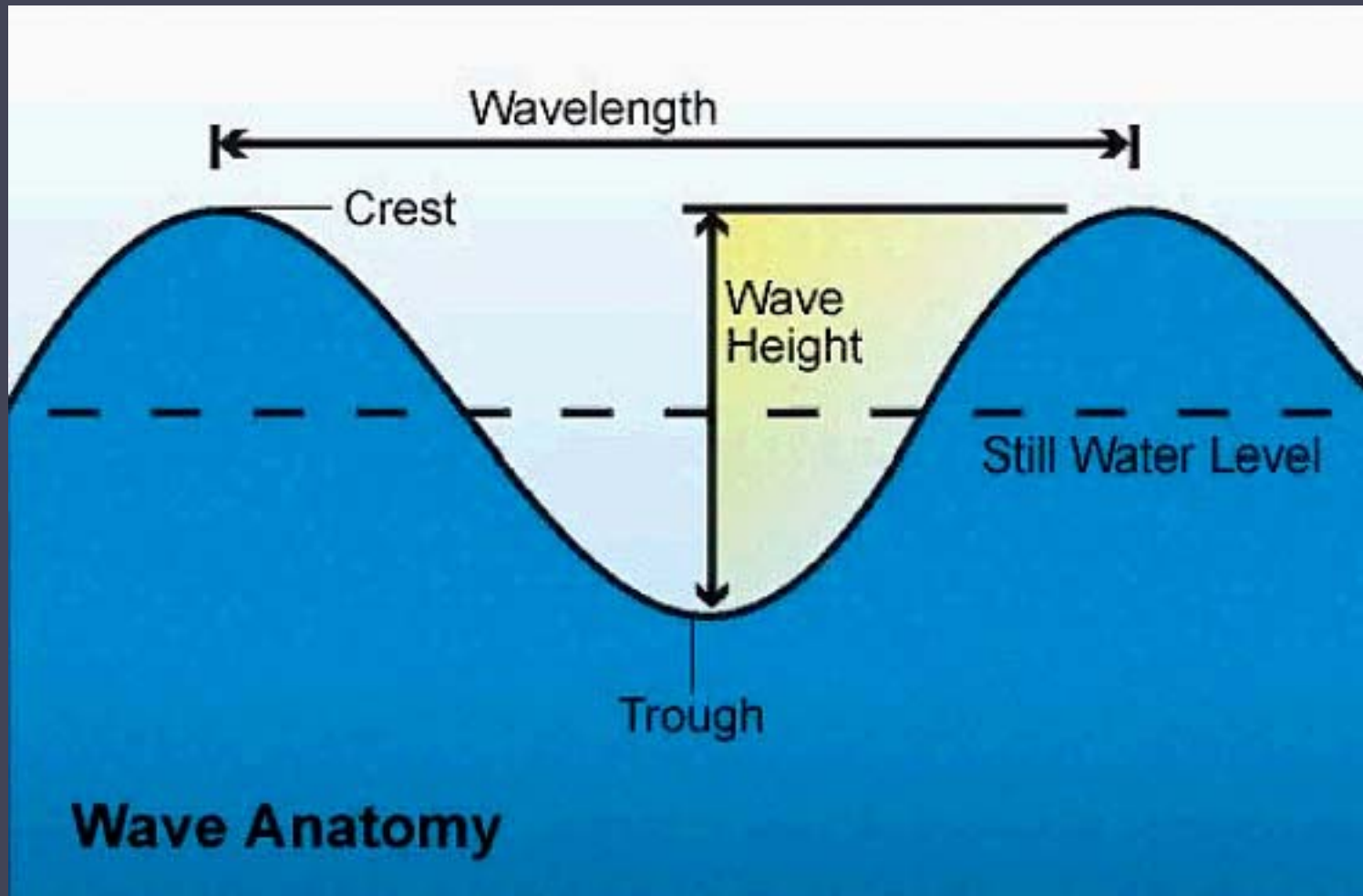


**Bay Area Blvd. at
Horsepen Creek**

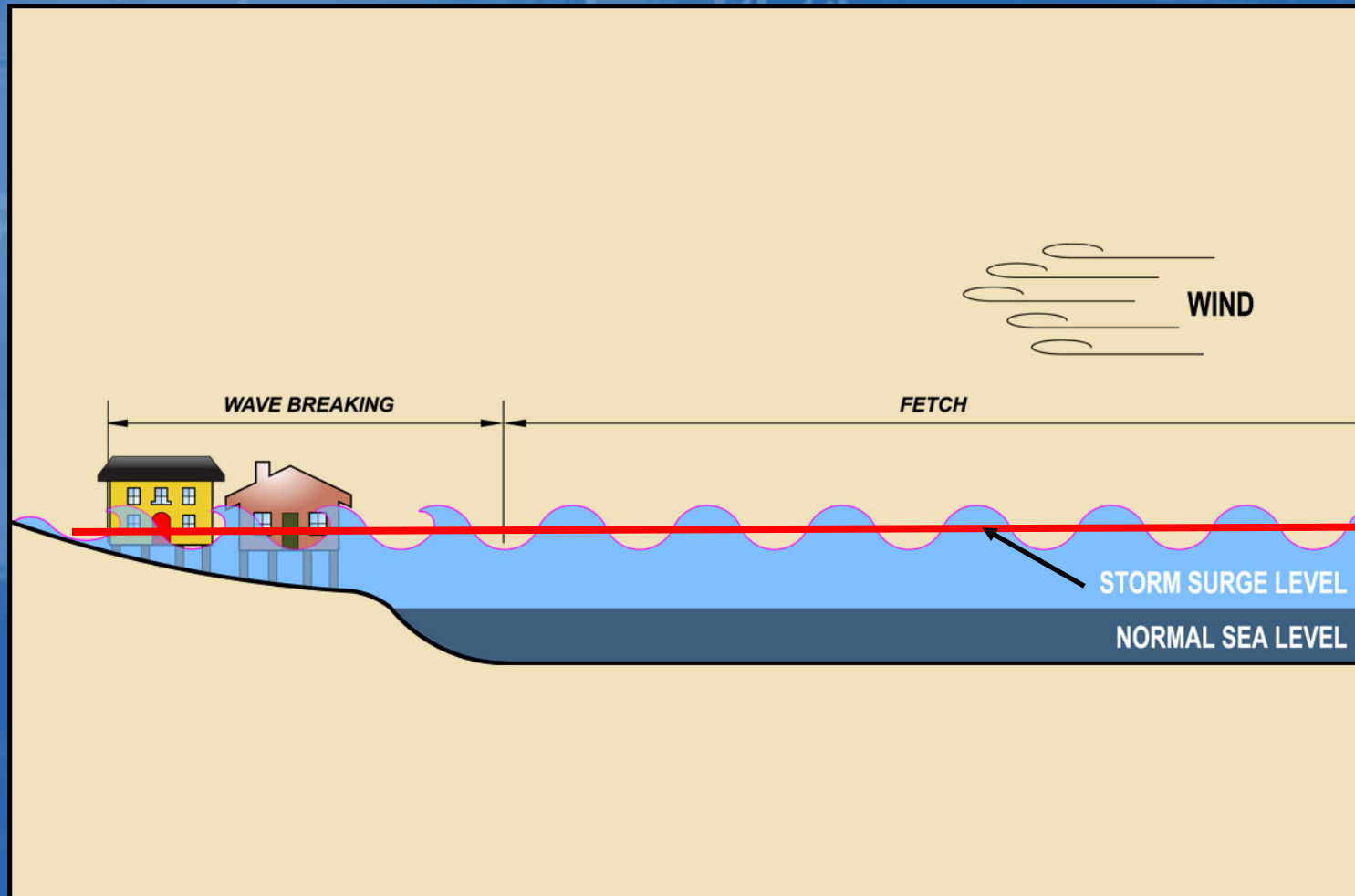
Waves

- **Complex wind and hydro dynamics**
- **Waves increase water level - runup**
- **Waves are destructive – pound like a hammer**



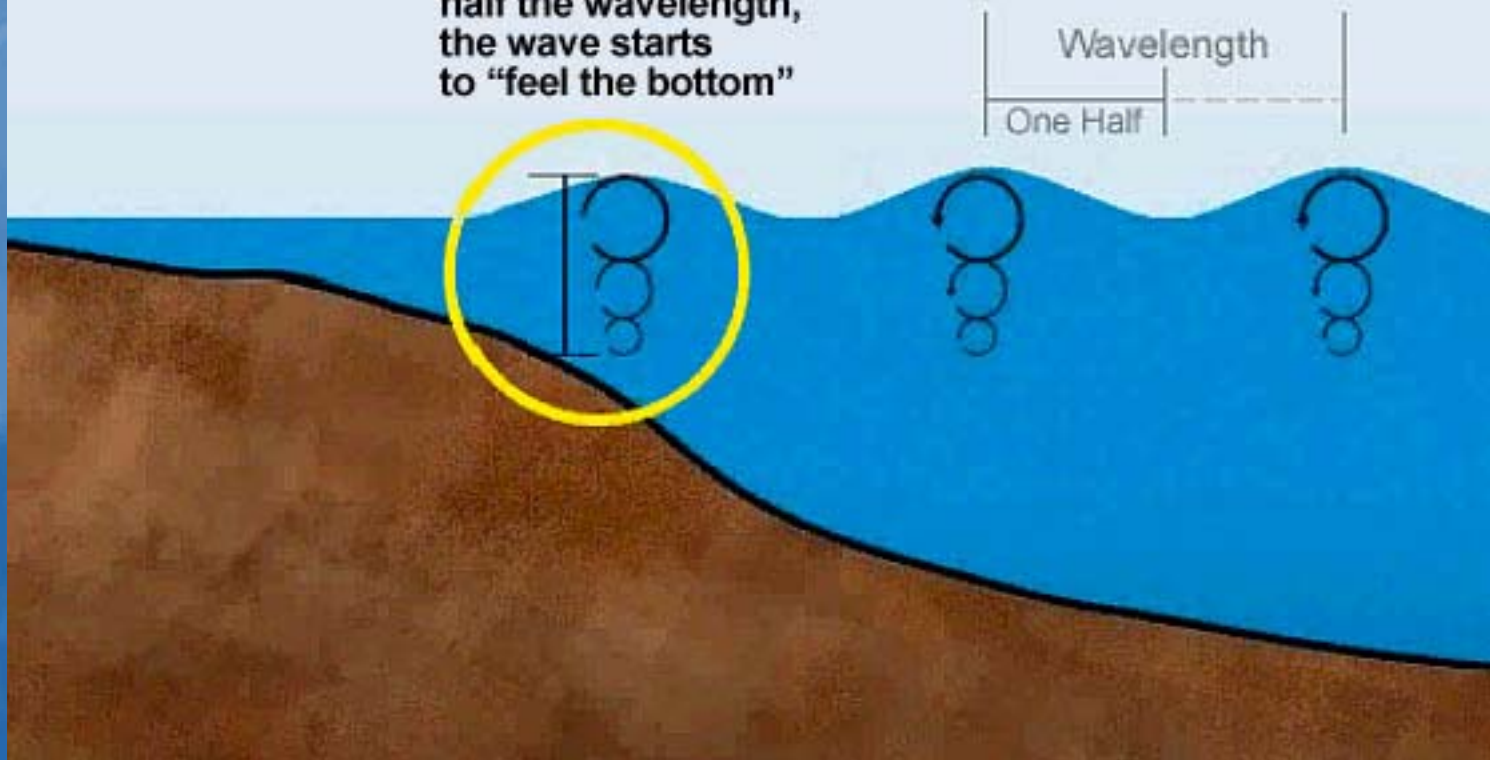


Storm Surge and Wave Action

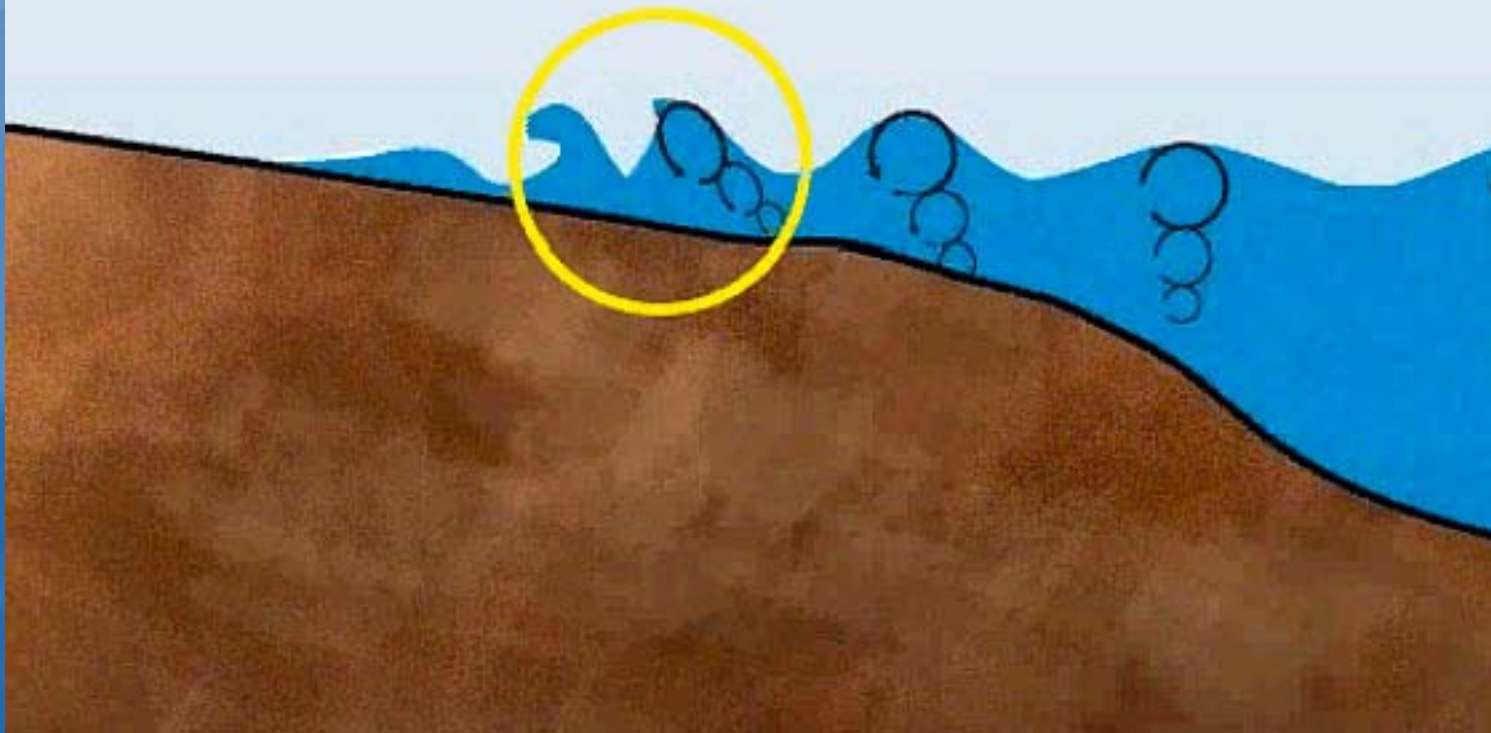


Waves in Shallow Water

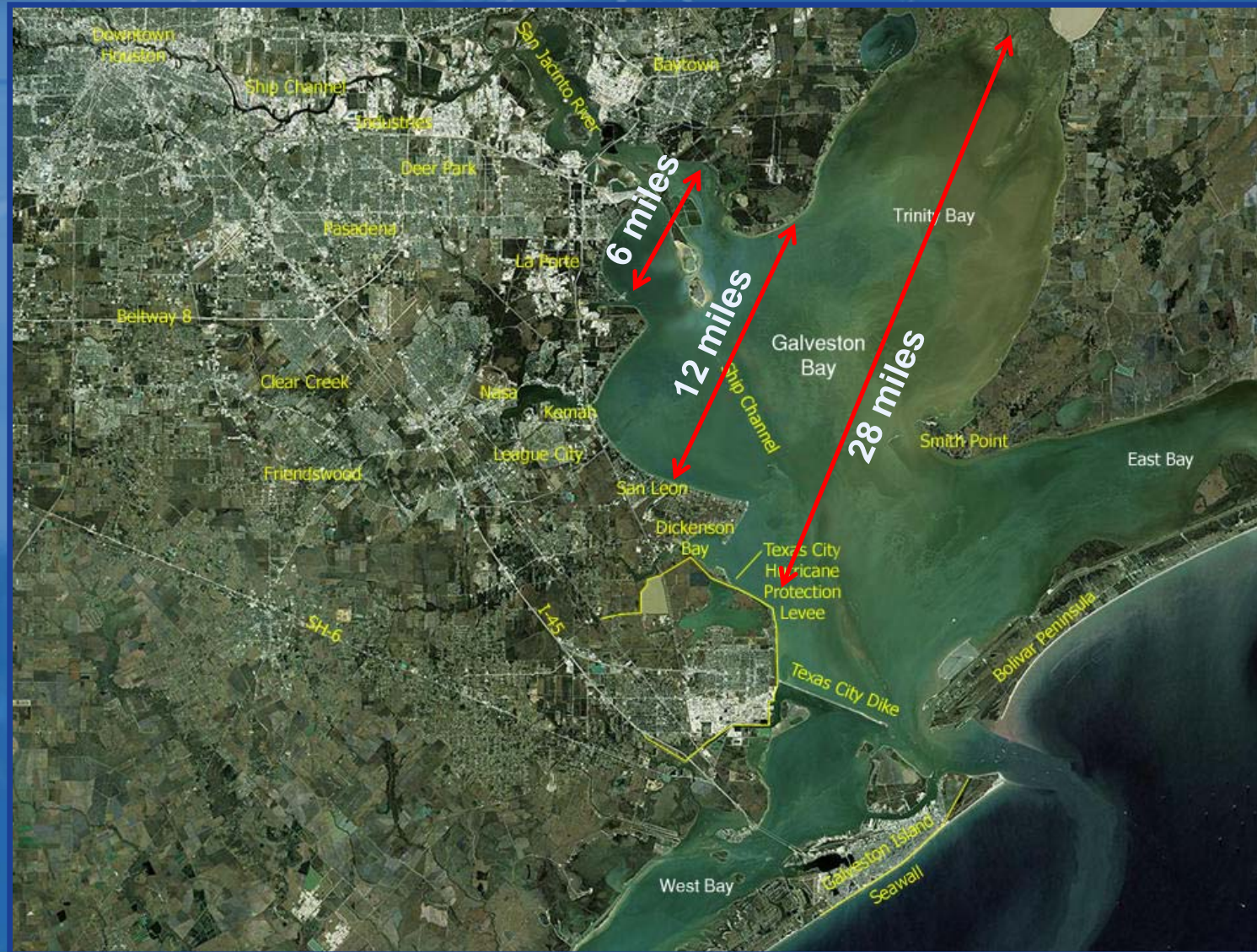
At a depth of half the wavelength, the wave starts to "feel the bottom"



Waves in Shallow Water

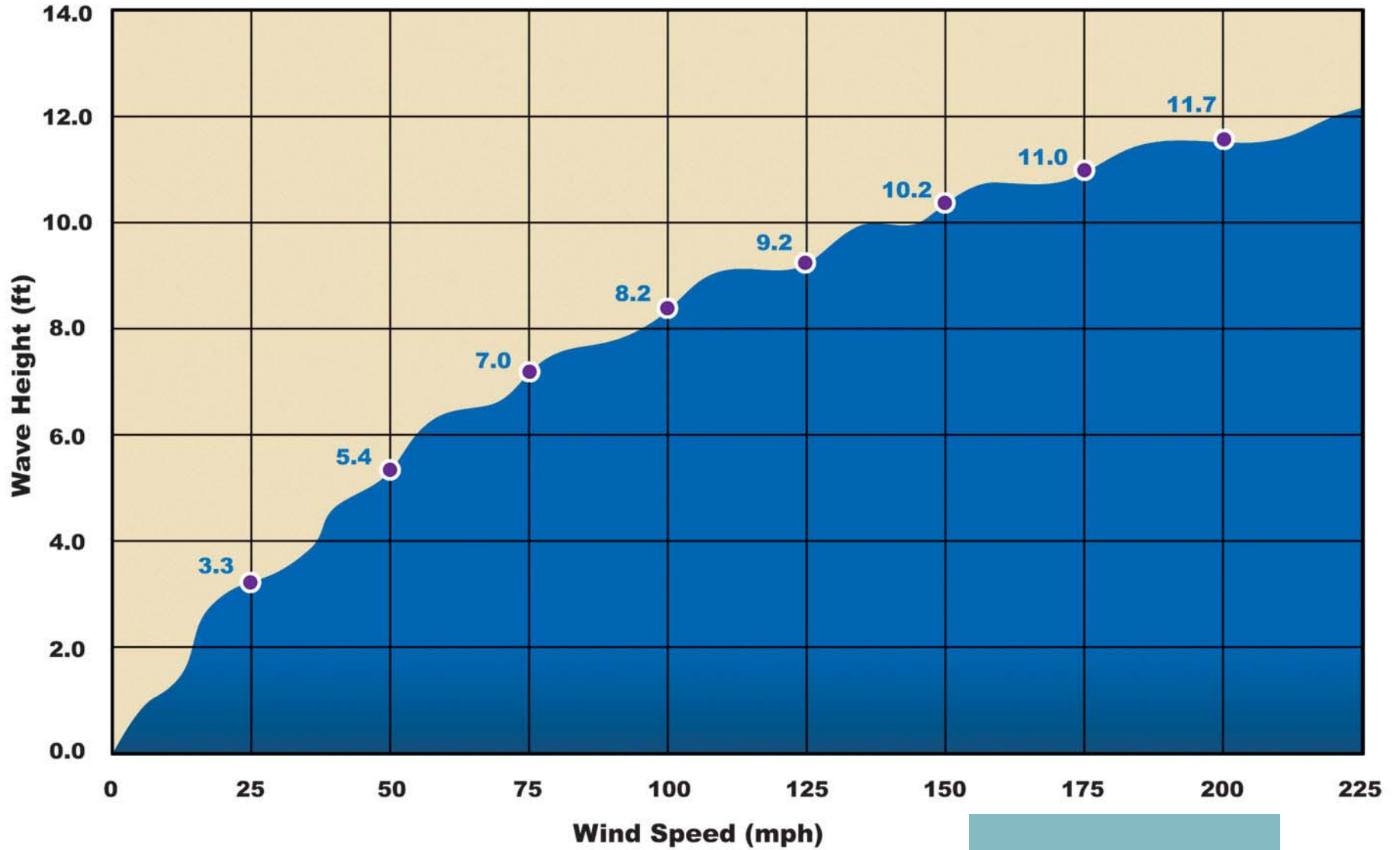


Wind Fetch Distances



Existing Conditions Wave Height vs. Wind Speed

25 - Foot Depth



Texas City Levee Debris Line



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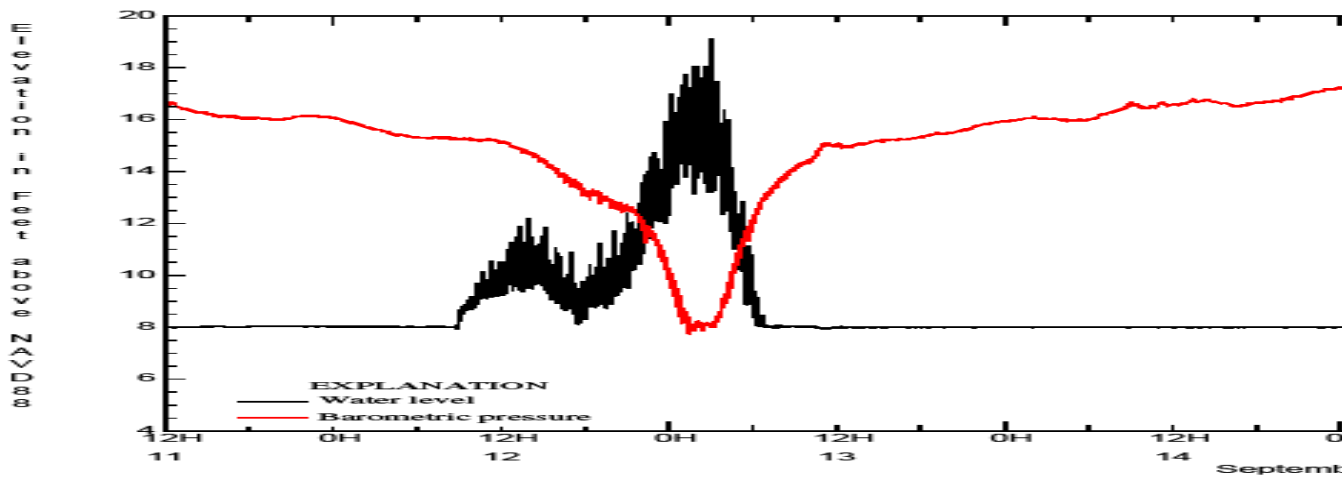
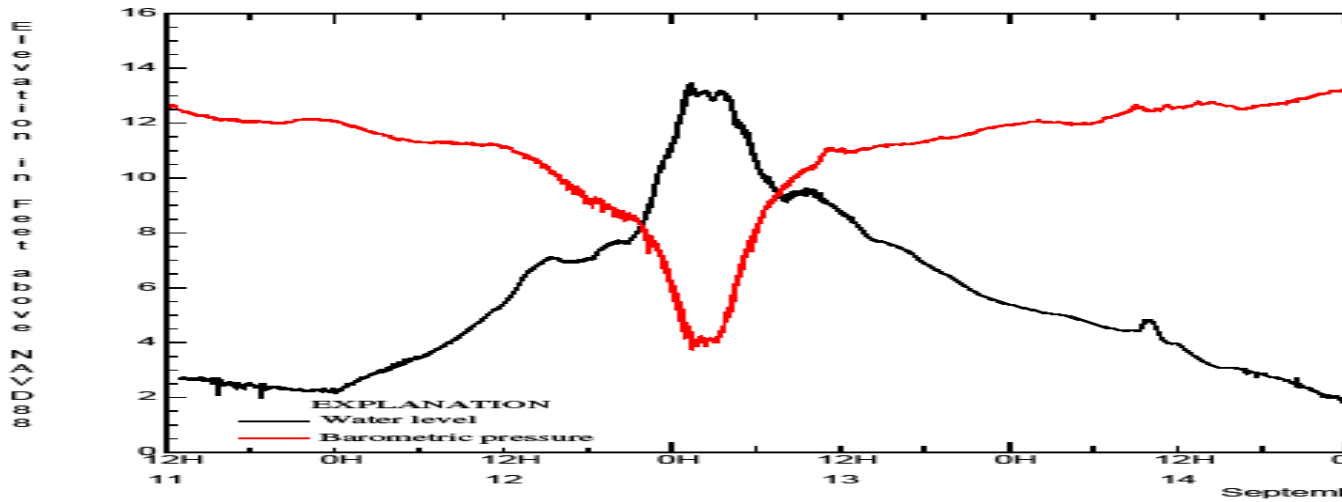
Ike - Bolivar Peninsula

Back Side

Gulf Side



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Friday Morning - Storm Surge Onset







Gulfport, MS (19ft EL....9-10ft surge EL)



Bolivar Peninsula

September 9, 2008



September 9, 2008



September 15, 2008



September 15, 2008



Bolivar - Wave Damage



West Galveston Island



Kemah



Katrina Surge and Wave Damage



Final Thoughts

- **Don't underestimate the power of storm surge and waves**
- **Evaluate effect of storm surge and waves on structural and non-structural alternatives, and vice versa**
- **Nature bats last**



Holly Beach, LA - Before Hurricane Rita



By Arthur Belala / courtesy USACE



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Holly Beach, LA - After Hurricane Rita



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