

SMALL BUILDING PERFORMANCE IN HURRICANE IKE ON THE BOLIVAR PENINSULA

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**NC STATE
UNIVERSITY**



Houston

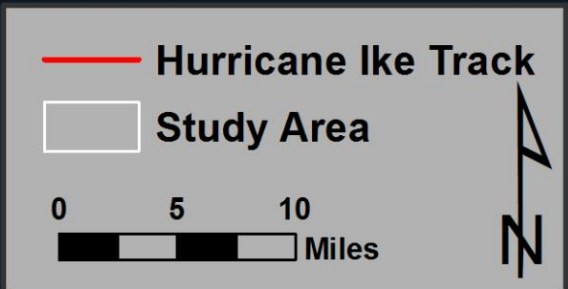
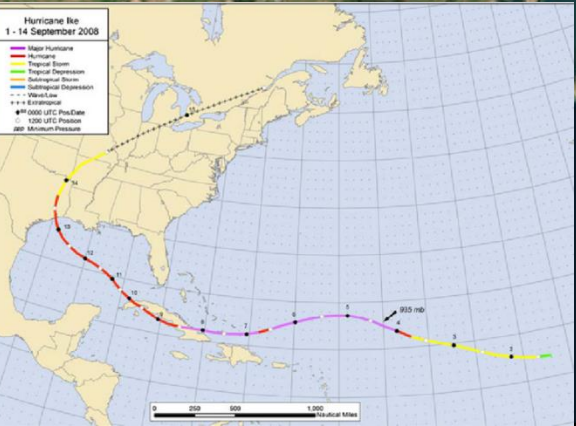
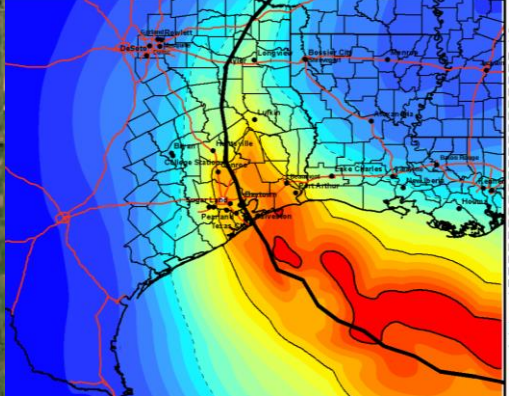
Galveston Bay

**110 mph
at Landfall**

**Bolivar
Peninsula**

Galveston

**West
Beach**

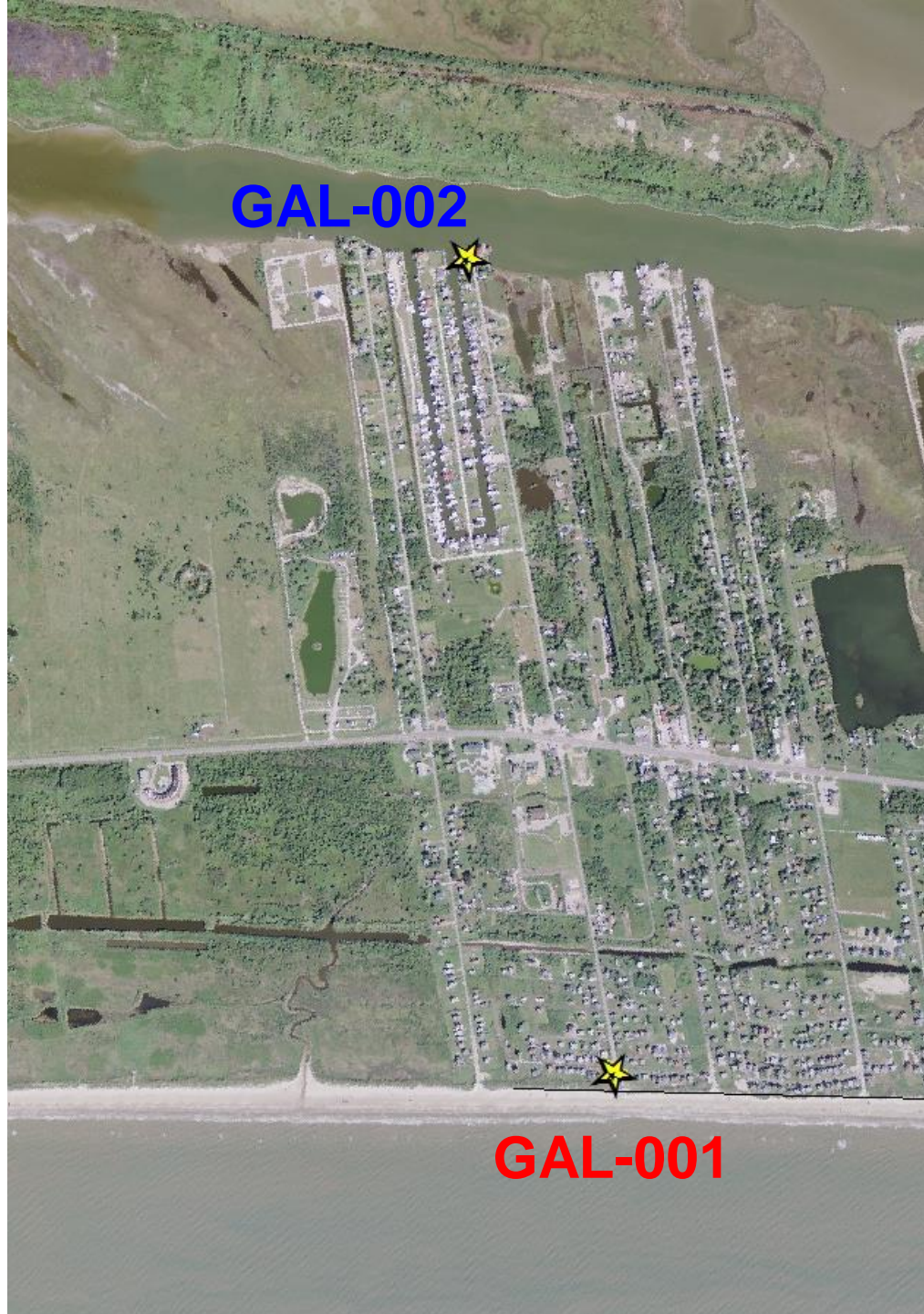
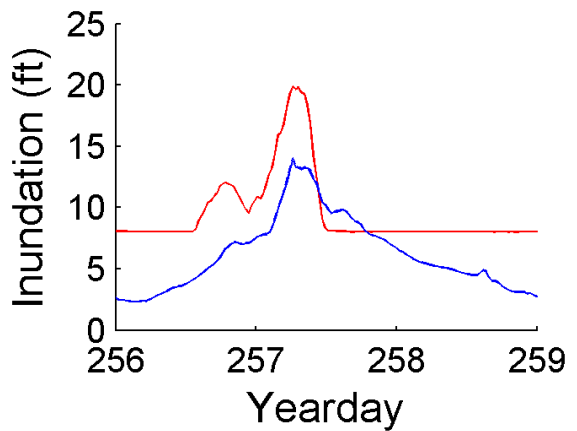
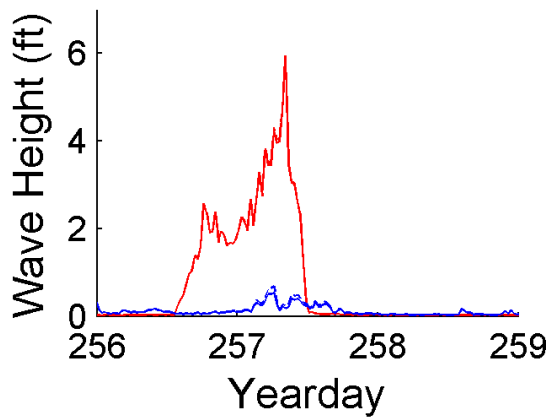
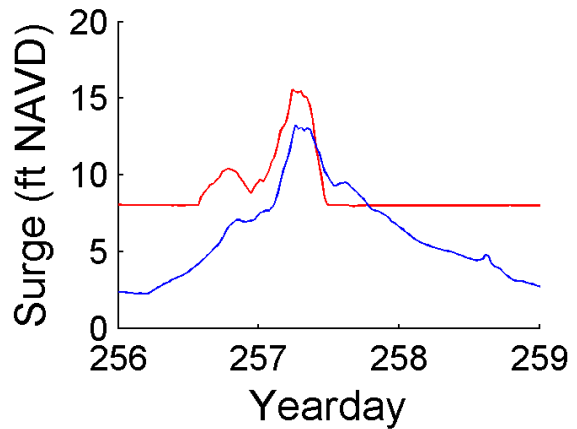


BOLIVAR PENINSULA



Hurricane Ike UNIQUE DATASET

- Surge and wave gages
- >100-year design conditions
- Freeboard above required Base
Flood Elevation common
- Floor elevations surveyed
- Community scale



PRIOR POST-STORM ELEVATION STUDIES

25 houses H. Katrina FEMA MAT

- Floor joist failure documented

81 houses H. Opal FEMA HAZUS

- Coastal A-zone/Limit of Moderate Wave Area (LIMWA) identified

This study: H. Ike Three phases

4337 buildings

2,813 failures

19 Partial Wave Damage

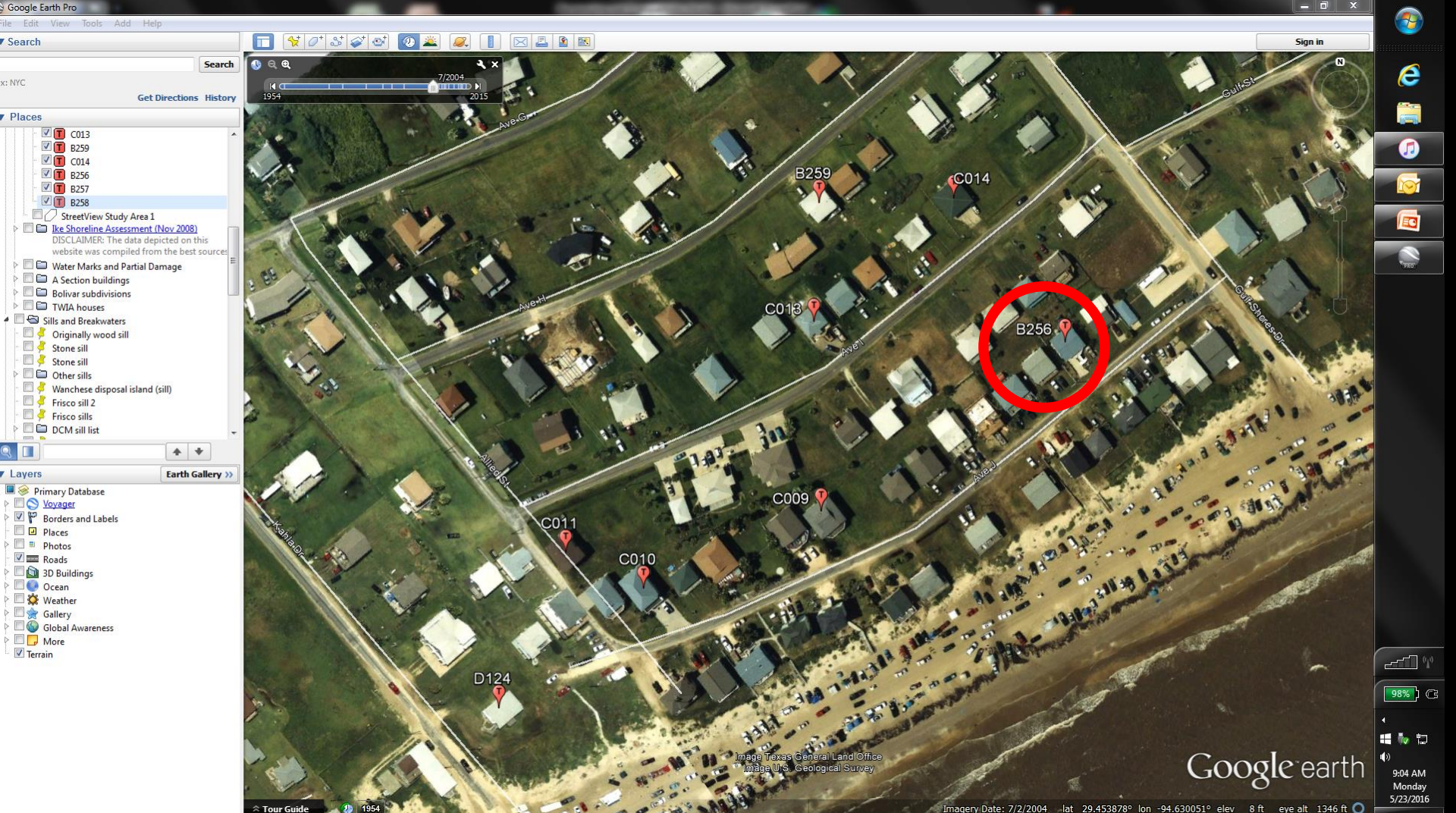
USGS, Notre Dame, UNC-W, NCSU & NC Floodmapping











Google IT!

Street View in
Google Earth
Google Maps
c. Notre Dame

9/2008
1954 2015

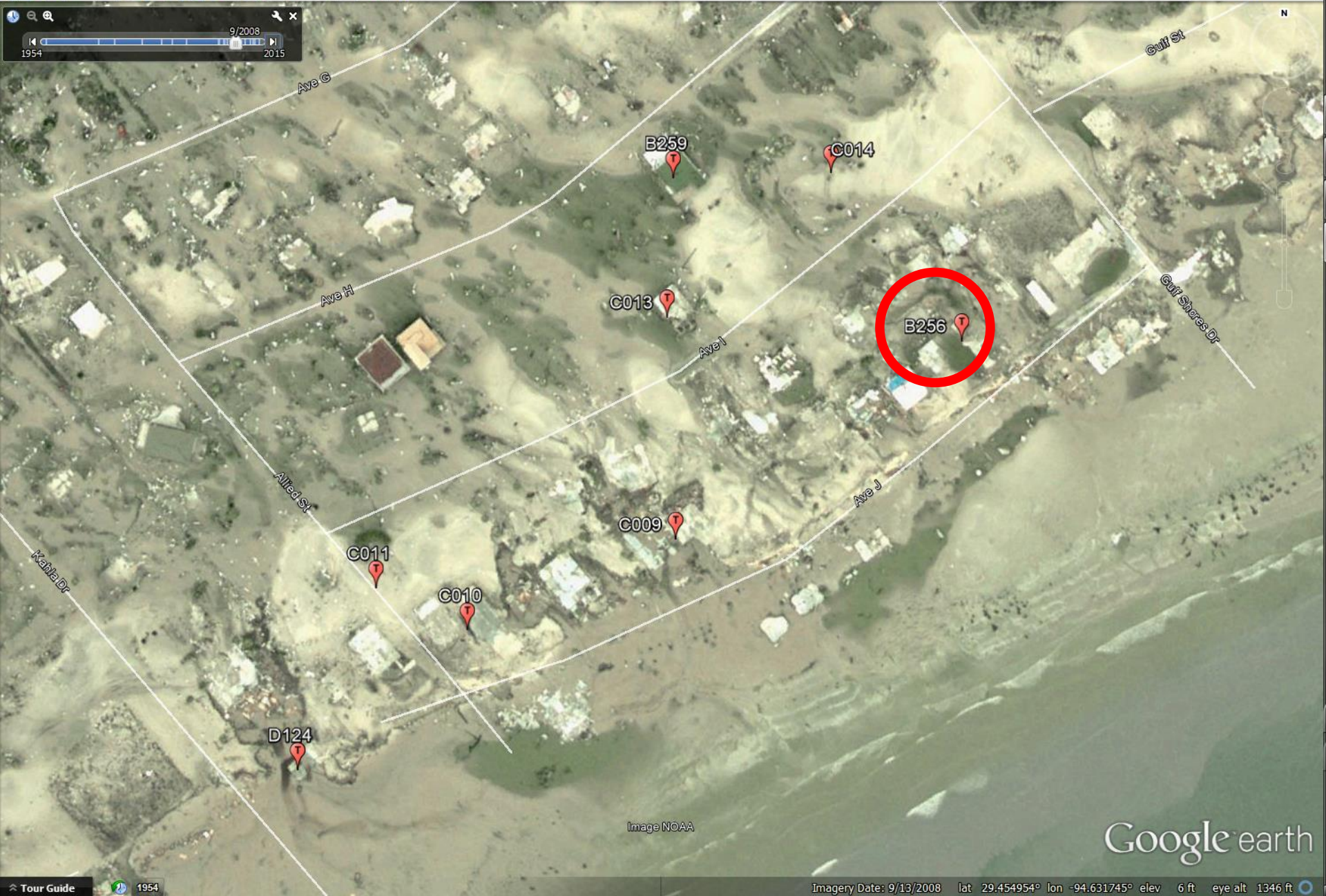


Image NOAA

Google earth



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Imagery Date: 3/2013 lat 29.454678° lon -94.629033° elev 82 ft eye alt 14 ft



PRE-IKE LIDAR ELEVATION

© 2013 Google

Google earth

STRUCTURES

Survived = 1,505

Destroyed = 2,813

Wave Damage = 19

Bolivar Peninsula

Structures

- Destroyed
- ▲ Wave Damage
- Survived

— Shoreline

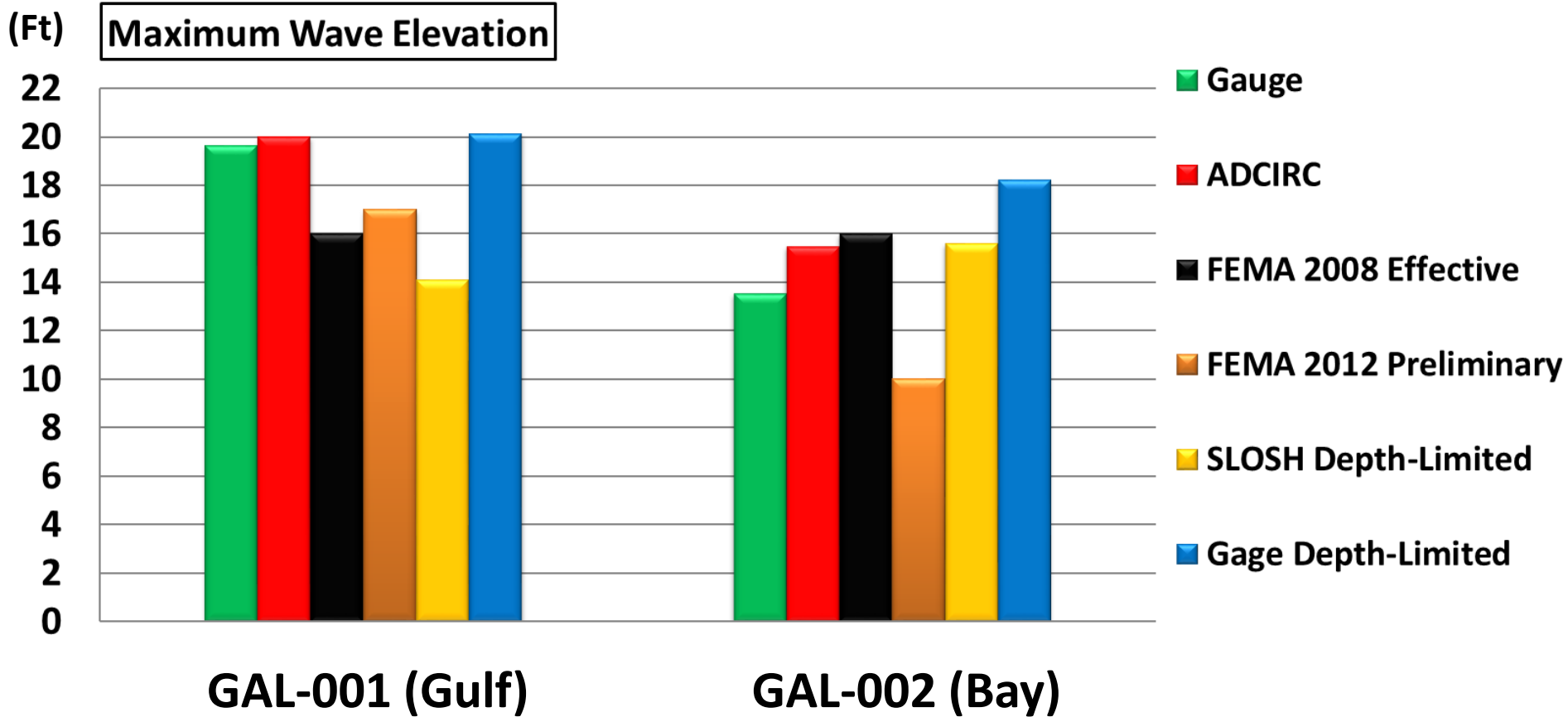
— Eastern Cross Shoreline

⊕ Surge Gauges

0 2.5 5 Miles

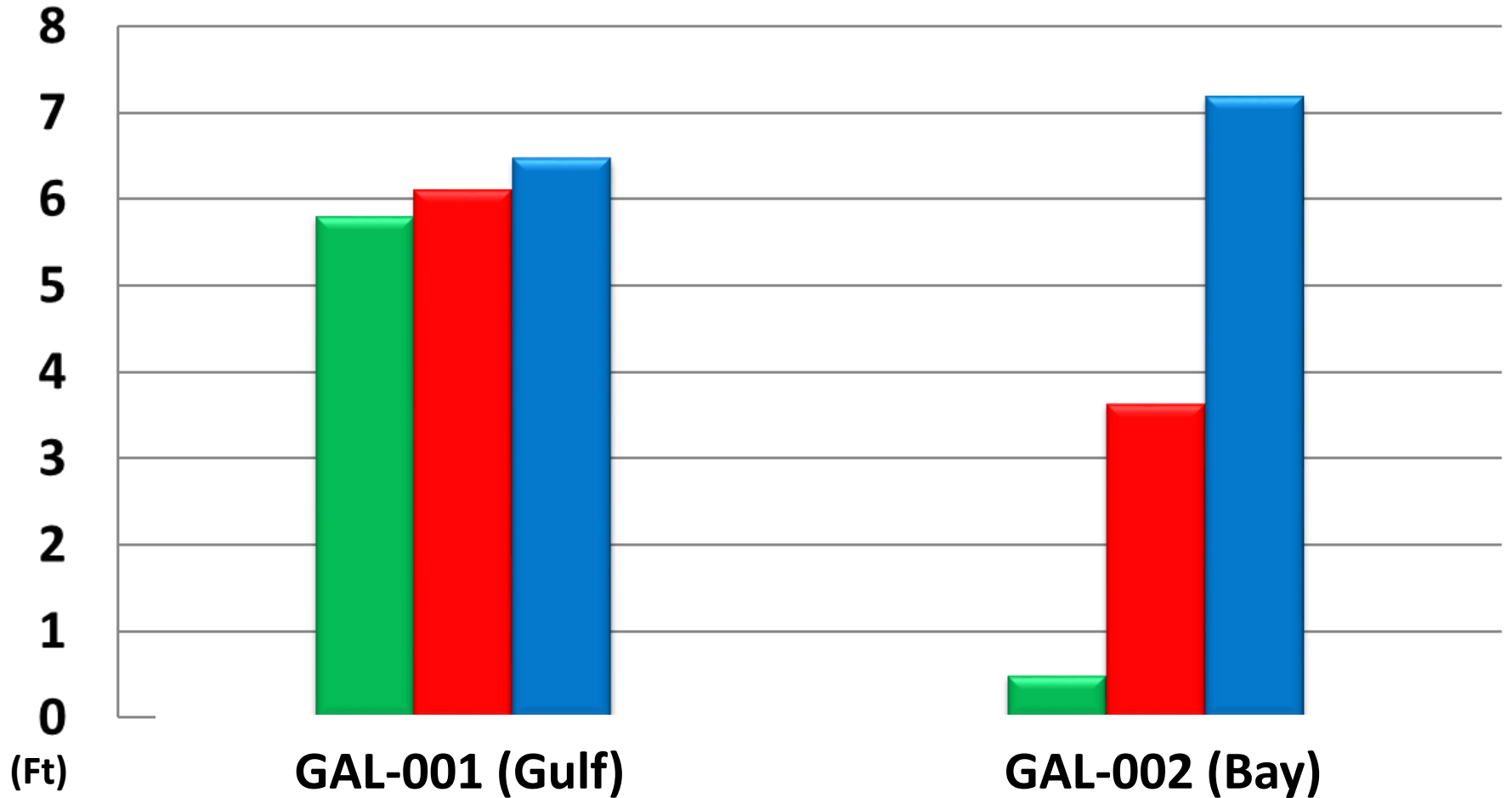


Maximum Wave Elevation



Maximum Wave Height

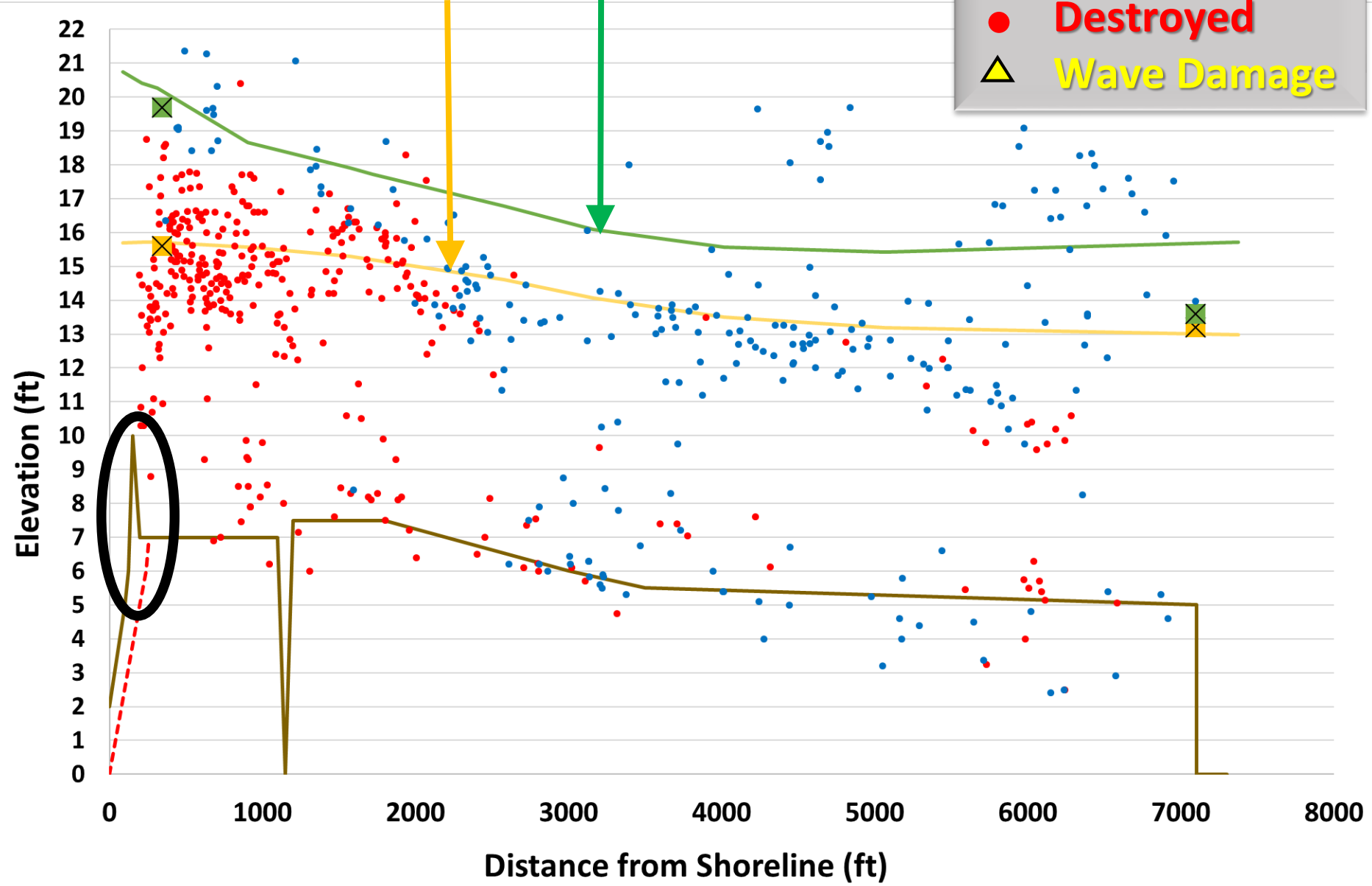
-  GAUGE
-  ADCIRC
-  GAUGE DEPTH-LIMITED



STRUCTURES

- Survived
- Destroyed
- △ Wave Damage

ADCIRC
Surge & Wave Elevation



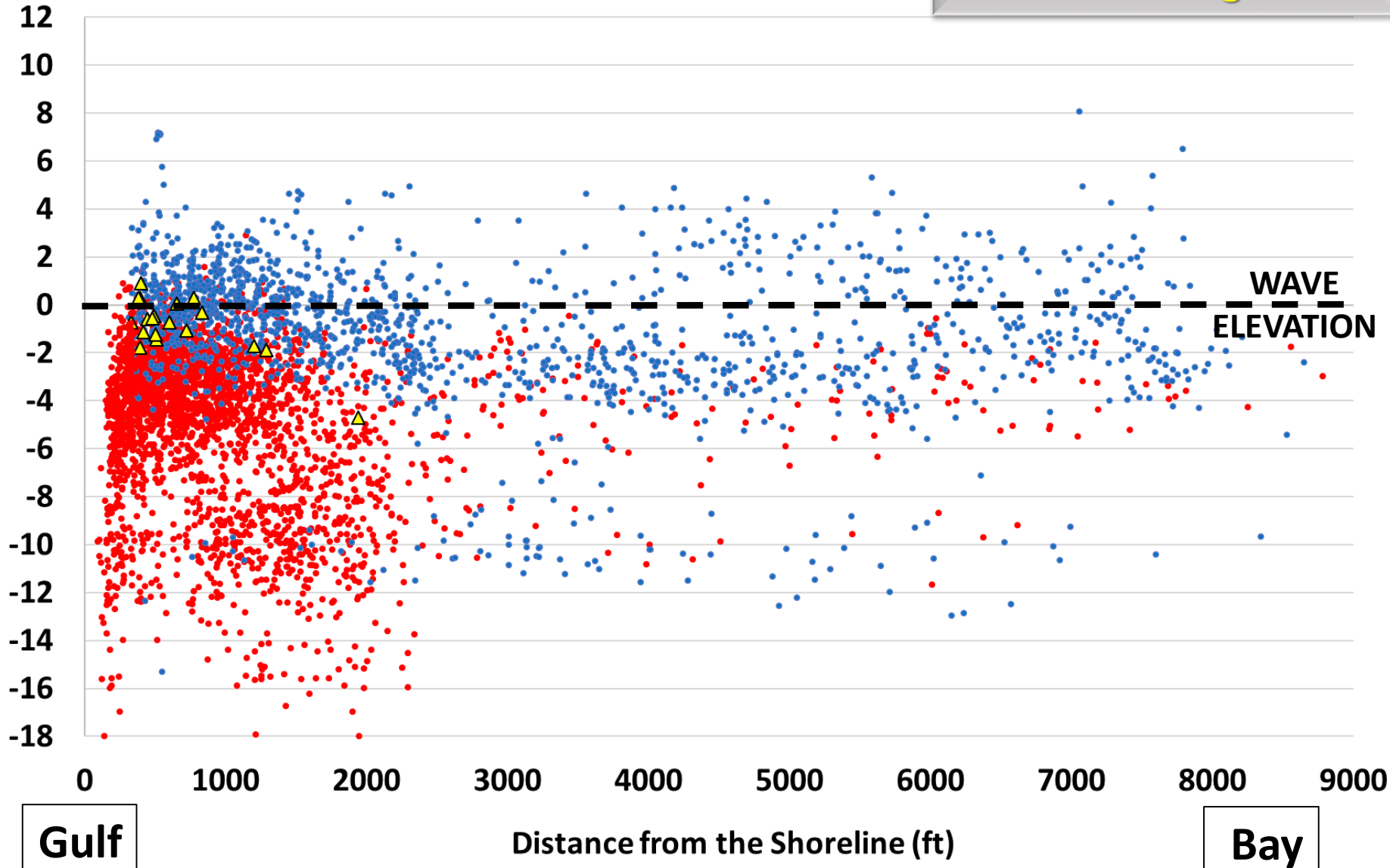
Cross-Shore Lowest Floor Elevation Relative to ADCIRC Wave Elevation

STRUCTURES = 4337

● Survived = 1505

● Destroyed = 2813

▲ Wave Damage = 19

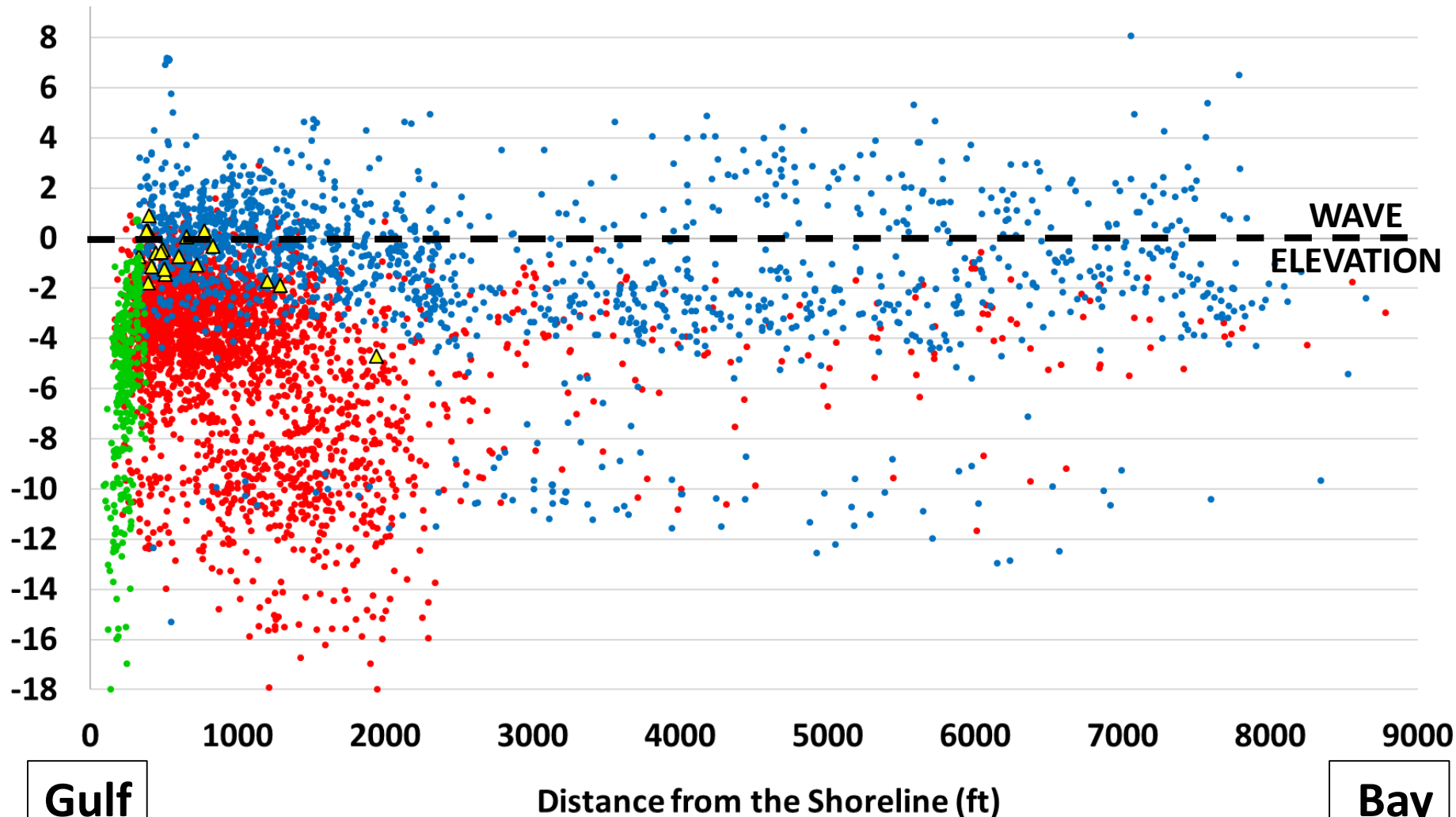


Potential Erosion Failures

Cross-Shore
Lowest Floor Elevation Relative to
ADCIRC Wave Elevation

STRUCTURES

- Survived
- Destroyed
- ▲ Wave Damage
- Erosion Failure? = 303



Wave Failures

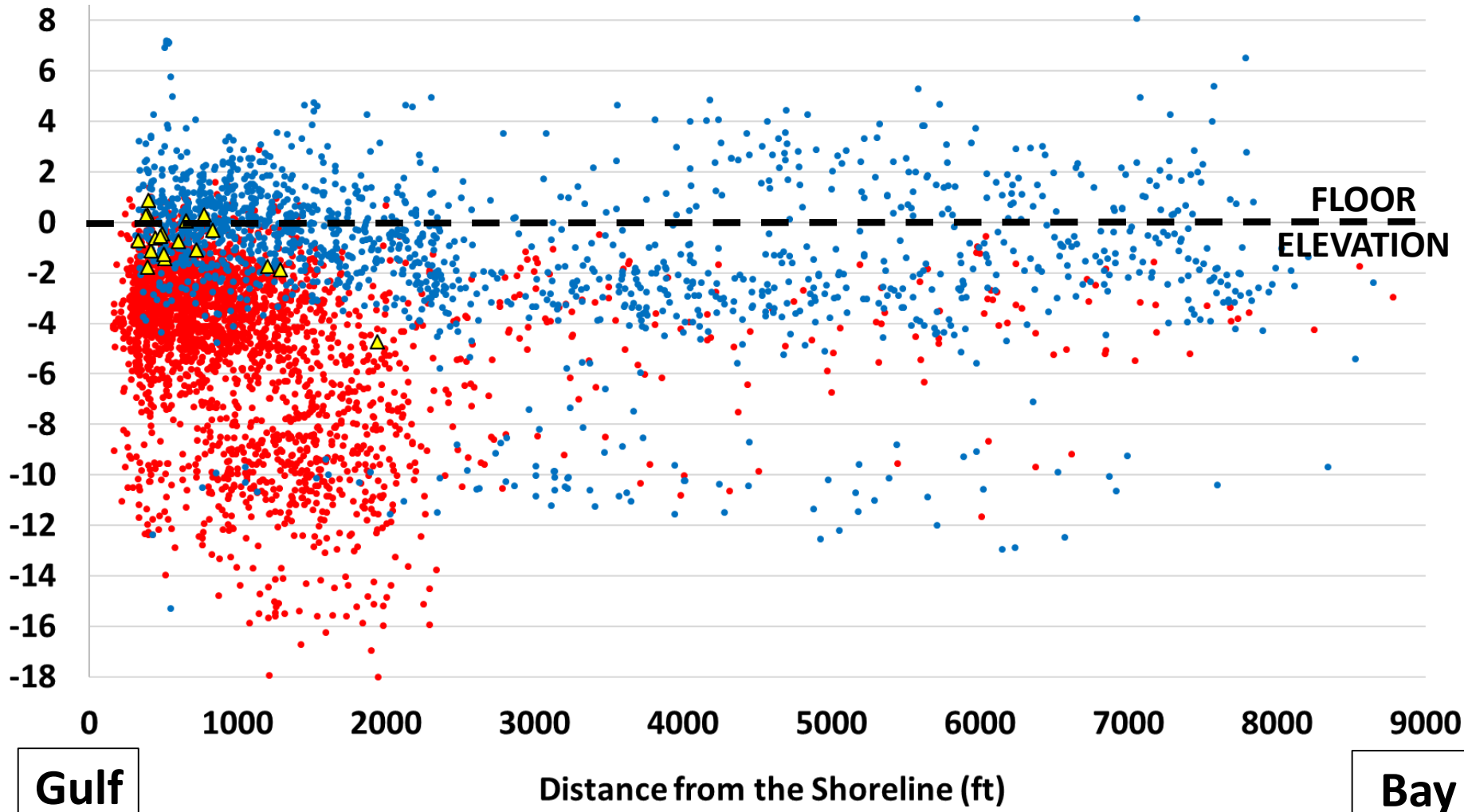
Cross-Shore
Lowest Floor Elevation Relative to
ADCIRC Wave Elevation

STRUCTURES = 4337

● Survived = 1505

● Destroyed = 2510

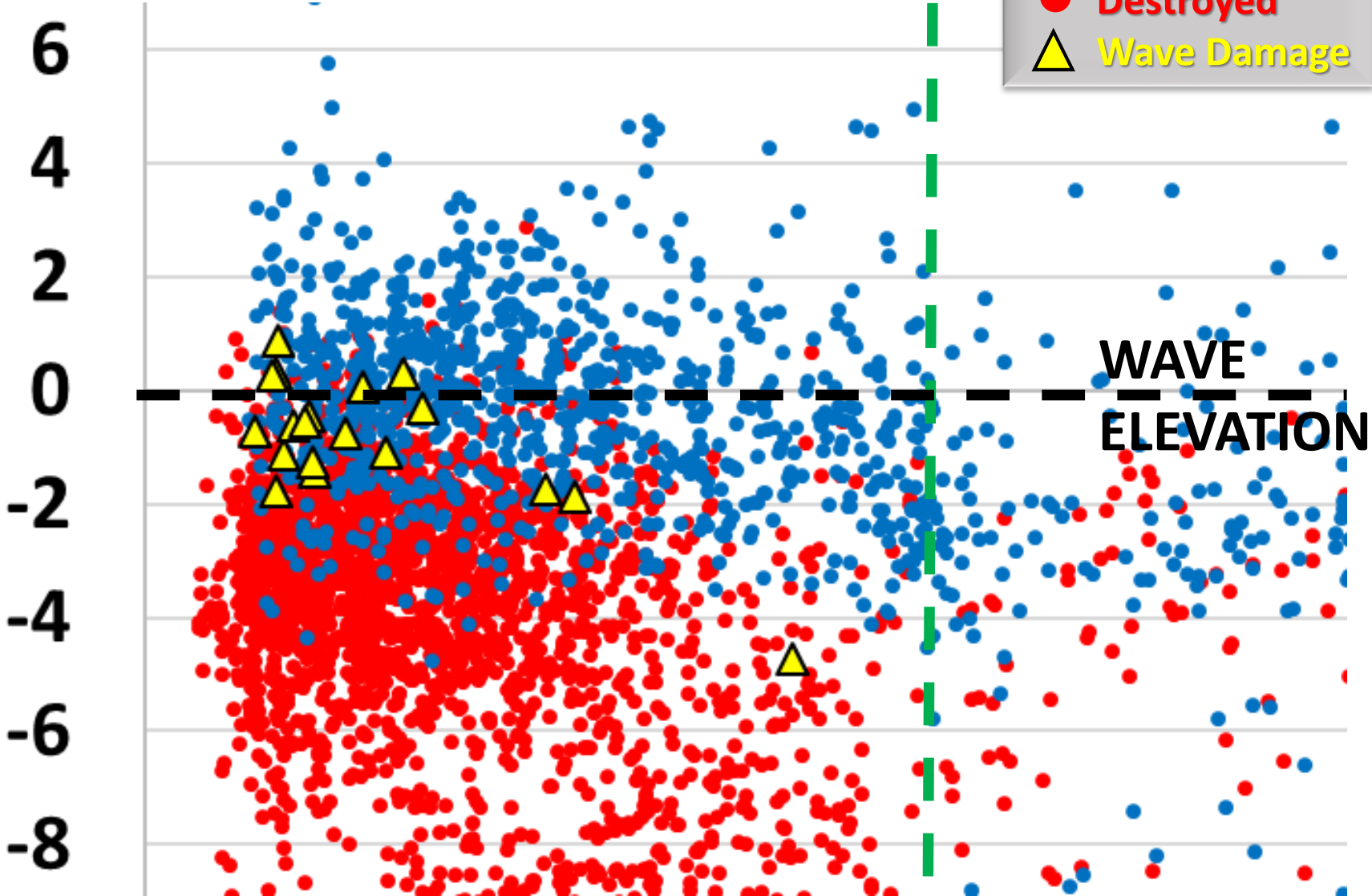
▲ Wave Damage = 19



Cross Shore Lowest Floor Elevation Relative to ADCIRC Wave Elevation

STRUCTURES

- Survived
- Destroyed
- ▲ Wave Damage



Gulf 0

2350 feet

Bay>>

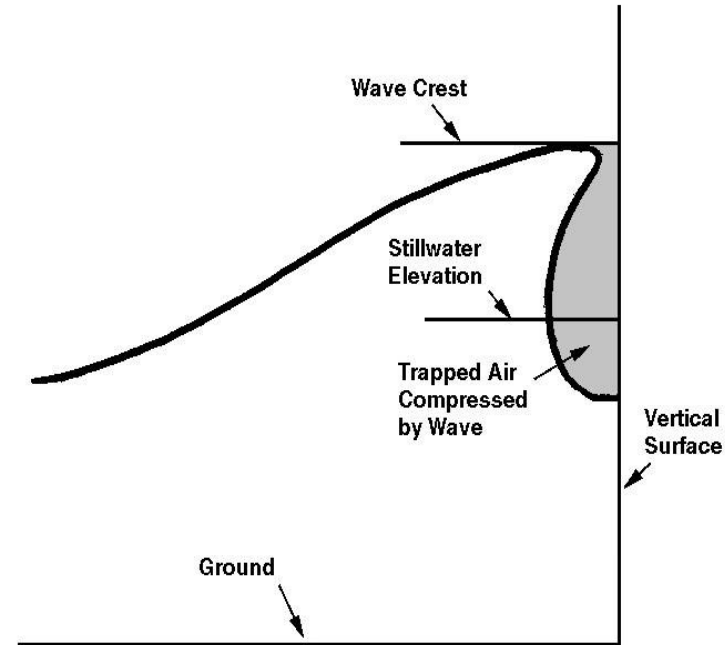
Breakaway Walls

WALLS DESIGNED
FOR 125 MPH WINDS

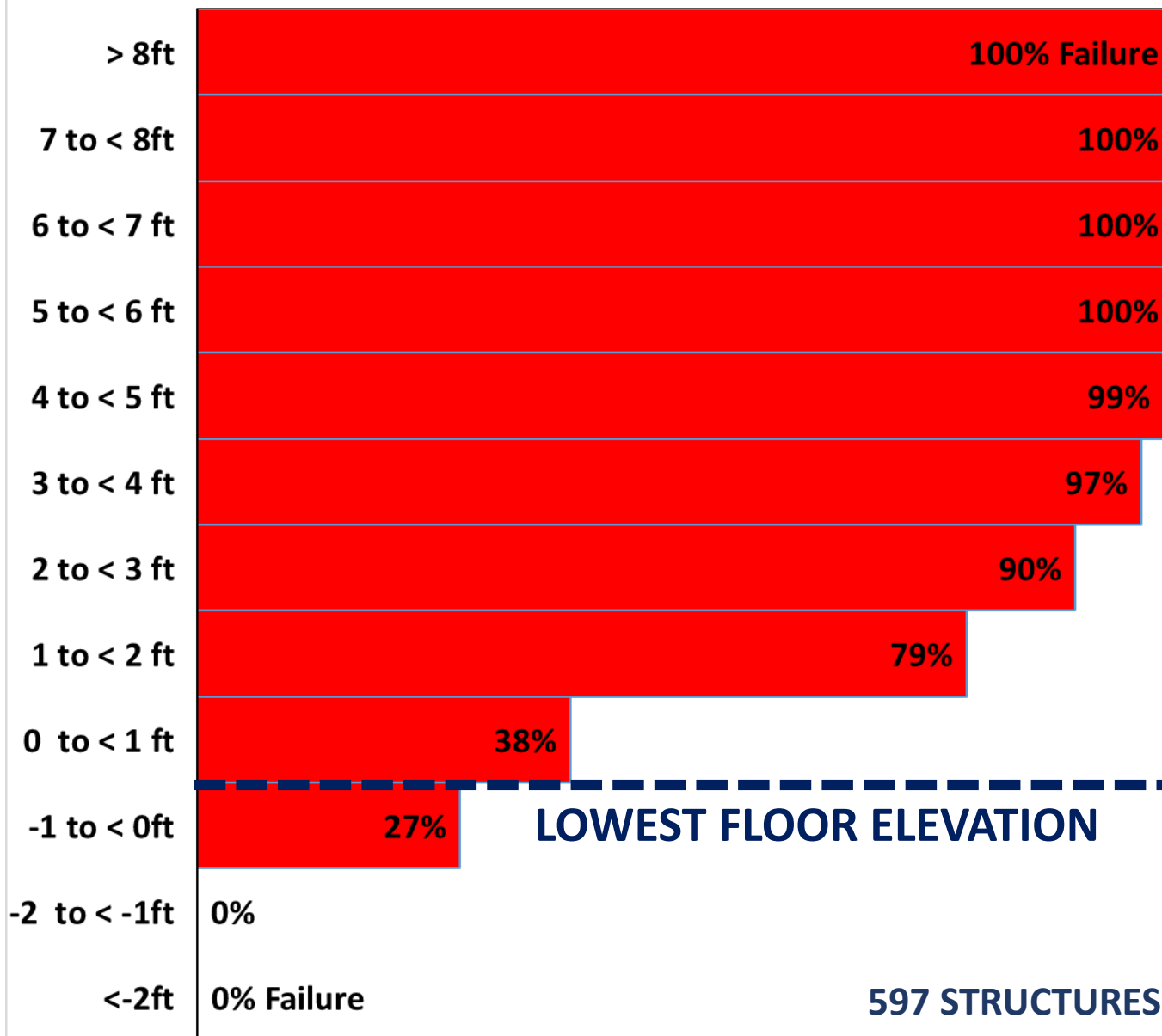
FAILED in

~1.5-ft WAVES

FEMA Limit of Moderate Wave Action
(LiMWA) or Coastal A-Zone

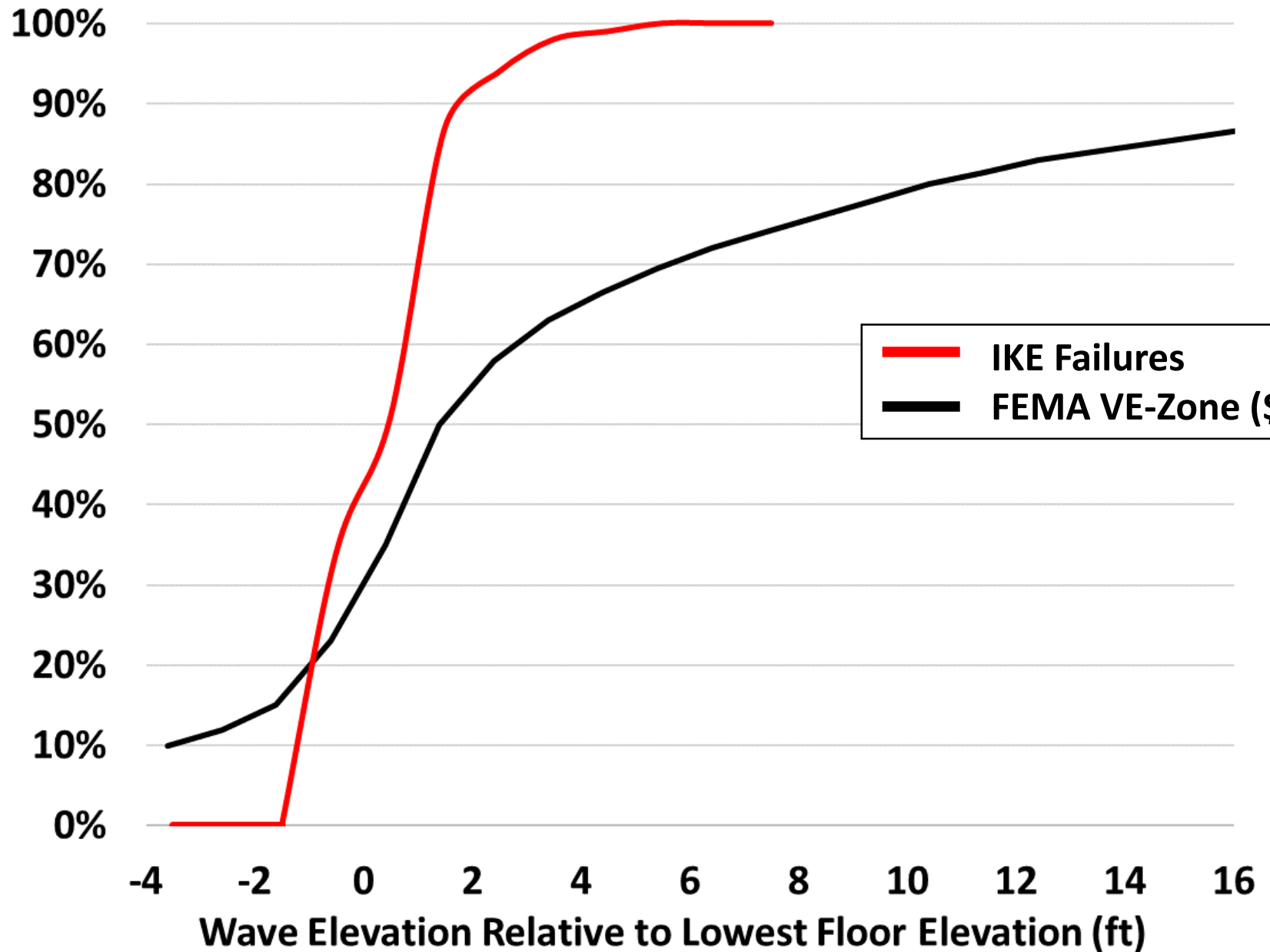






**Risk of Failure Relative to Peak Wave Elevation above
Lowest Floor Elevation (LFE): $\leq 500'$ from Shoreline for ADCIRC**

Building Damage Variability with Flood Depth



CONCLUSIONS

Where breaking wave elevation known:

- **Depth/damage begins at bottom of floor joists**
- **Failure ~100% at 5' higher**

CONCLUSIONS

- Wave models reasonable over flooded land ~500' from Gulf
- >2350' from Gulf
 - Breaking wave height $< 1.5'$?
 - Transformed to non-breaking wave?

FUTURE WORK

- **Link database to NFIP flood claims**
- **Survey why owners chose to build above minimum base flood elevation**
- **Full-scale wave tank testing on floor and wall systems**

QUESTIONS?

