STEVENS
INSTITUTE OF TECHNOLOGY
1870

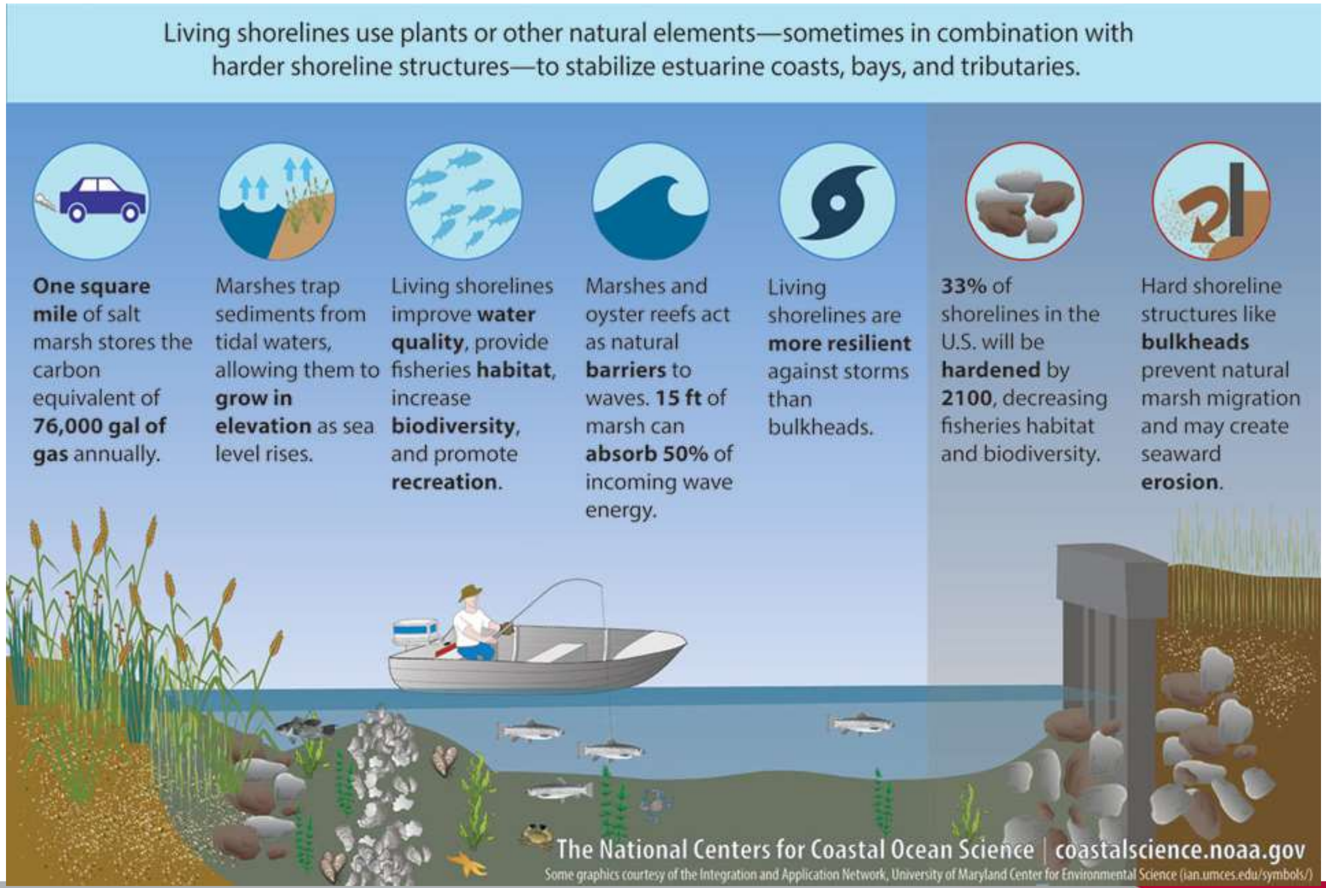
# Living Shorelines in the Decade Since Sandy

## Lessons Learned and Implications for Future Design

**Jon K. Miller, Laura Kerr, Amy Bredes**

**Katherine Gannon, and Ian Day**

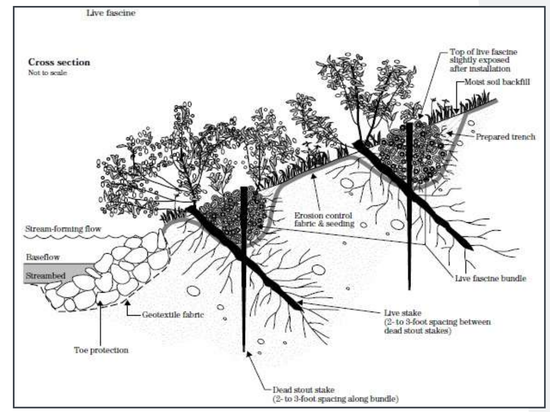
**October 26, 2022**




# What are Living Shorelines?

# What are living shorelines?

- “shoreline management practice that addresses the loss of vegetated shorelines, beaches, and habitat in the littoral zone by providing for the protection, restoration or enhancement of these habitats” (N.J.A.C. 7:7-1.5)




# What about developed shorelines?

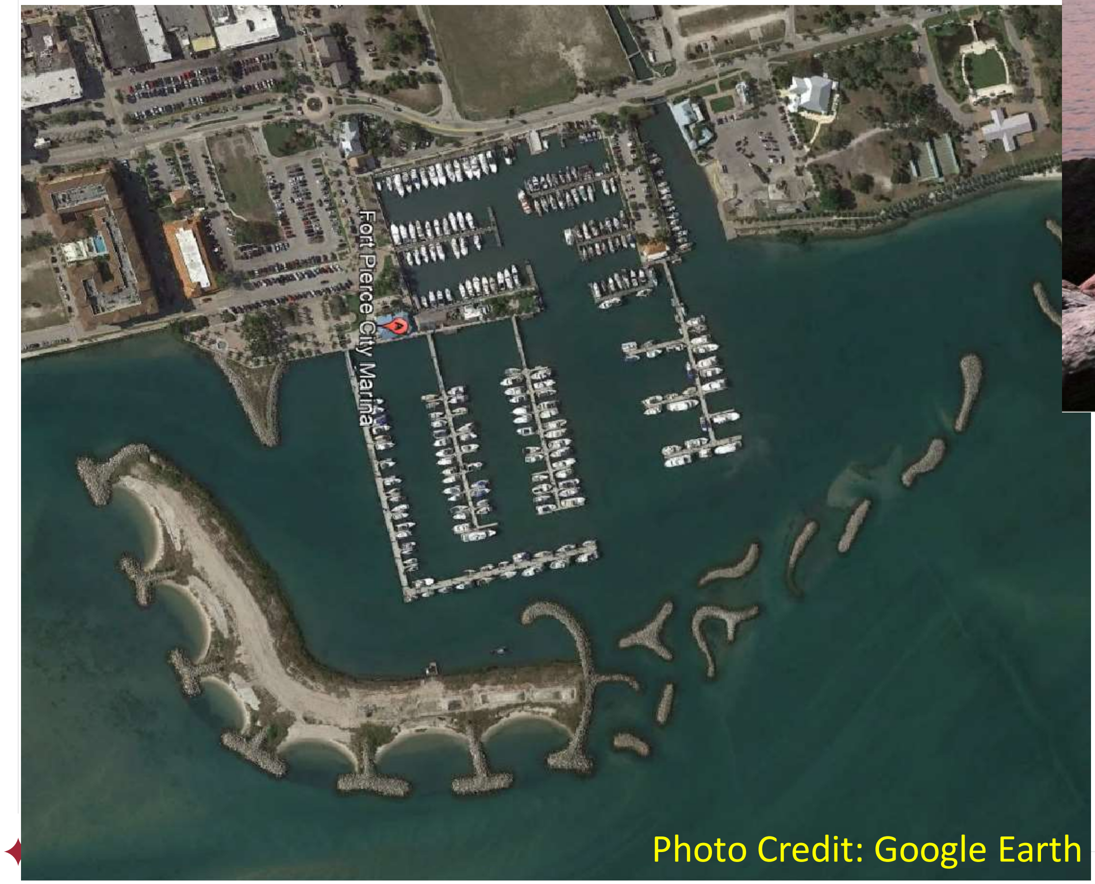


Photo Credit: Google Earth


Photo Credit: ECOncrete

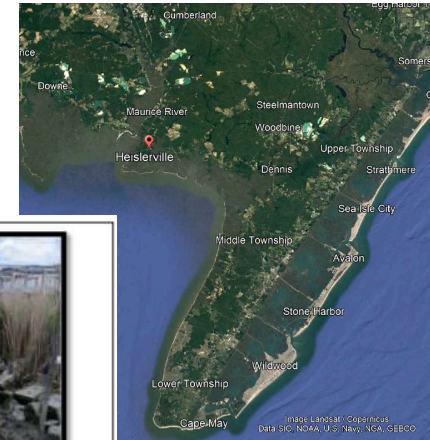
# Time Travel...

# Dark Ages

# Dark Ages

# Time Travel...

# DELSI




## Delaware Estuary Living Shorelines Initiative

- PDE/Rutgers
- Project initiated in 2008
- Maurice River
- Coir Log & Shell Bag
- Key Takeaways
  - Permitting is painful
  - Effective on moderate/low energy shorelines
  - Can survive large storms
- Project story map created in 2021

**BEFORE:** Marina in New Jersey's Heislerville Fish and Wildlife Management Area in April of 2010.

**BEFORE:** Day of installation of coconut-fiber (coir) logs and mats in New Jersey's Heislerville Fish and Wildlife Management Area in May of 2010.

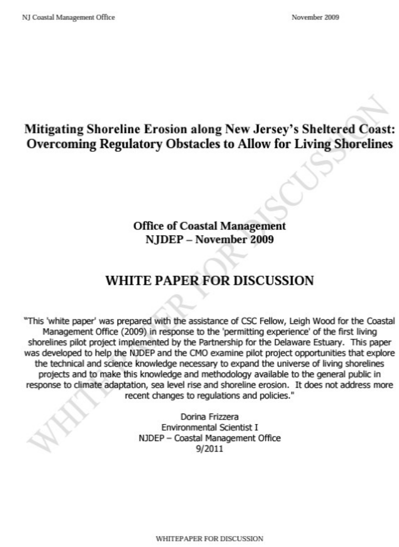
**AFTER:** One year later, June 2011, native marsh grass can be seen flourishing in the soil that has collected behind the new "living shoreline." Not only does this defend land against destructive waves, but also it serves as fish habitat during high tides.

**AFTER:** September 2011- the site remained stable after Hurricane Irene and Tropical Storm Ike.

# NJDEP

## Early Living Shorelines Initiatives

- NJDEP – Living Shorelines Whitepaper
  - November 2009
  - Set the stage for the development of a general permit
  - “The regulatory preference for permitting bulkheads and similar structures should be changed to favor more ecologically beneficial solutions.”
- Regulatory Rule Writing Workshop
  - 2010?
  - Invited experts from around the region
  - Accelerated the development of a “Living Shorelines General Permit”


NJ Coastal Management Office November 2009

**Mitigating Shoreline Erosion along New Jersey’s Sheltered Coast: Overcoming Regulatory Obstacles to Allow for Living Shorelines**

**Office of Coastal Management**
**NJDEP – November 2009**

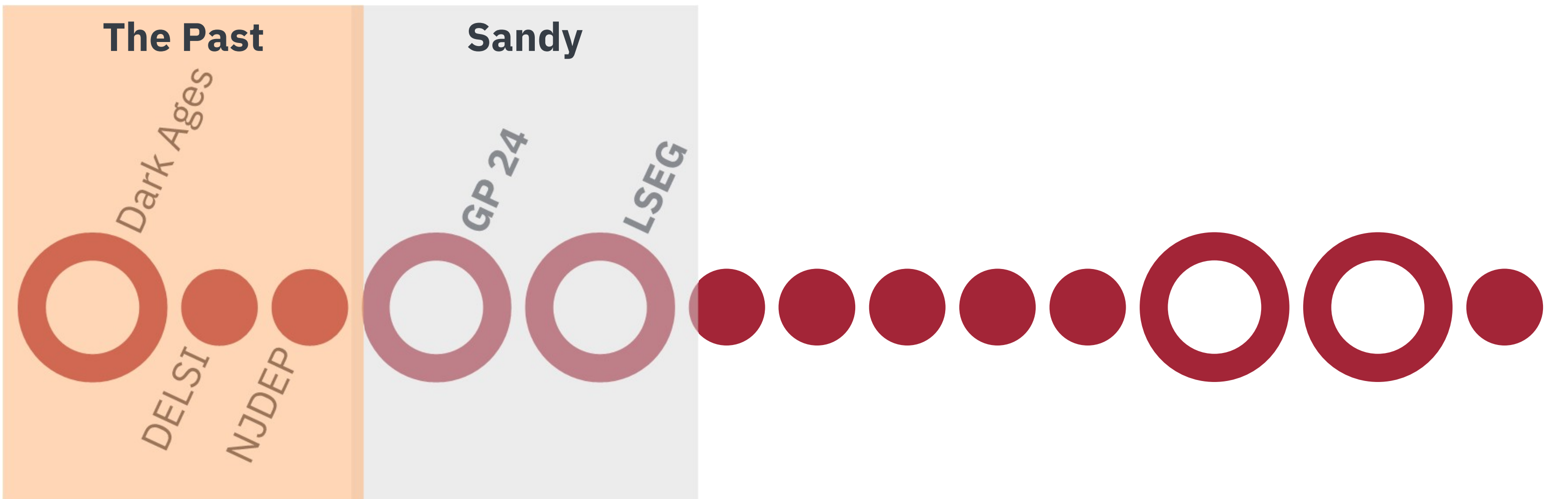
**WHITE PAPER FOR DISCUSSION**

“This 'white paper' was prepared with the assistance of CSC Fellow, Leigh Wood for the Coastal Management Office (2009) in response to the 'permitting experience' of the first living shorelines pilot project implemented by the Partnership for the Delaware Estuary. This paper was developed to help the NJDEP and the CMO examine pilot project opportunities that explore the technical and science knowledge necessary to expand the universe of living shorelines projects and to make this knowledge and methodology available to the general public in response to climate adaptation, sea level rise and shoreline erosion. It does not address more recent changes to regulations and policies."

Dorina Frizzera
Environmental Scientist I
NJDEP – Coastal Management Office
9/2011

WHITEPAPER FOR DISCUSSION

# Time Travel...

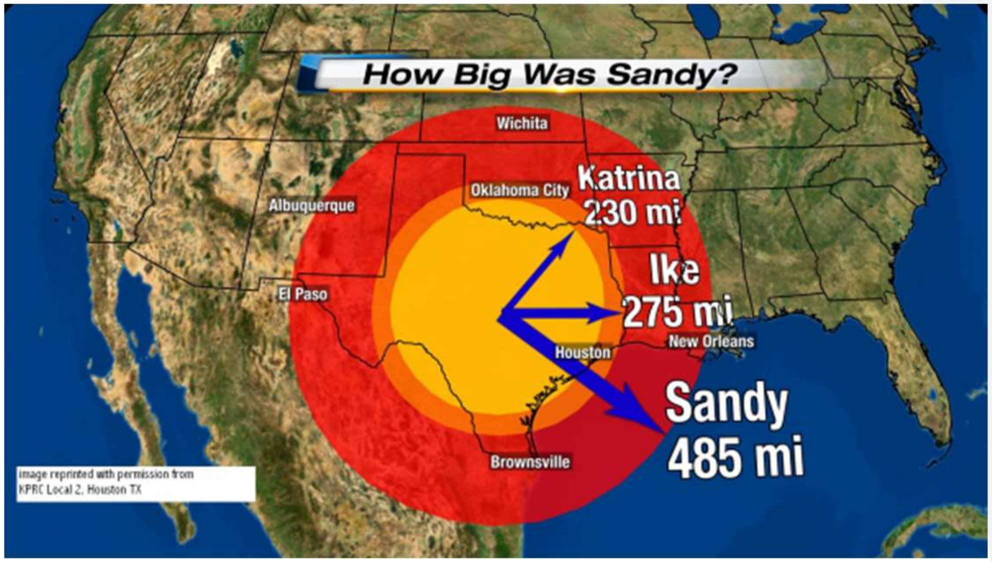


# Superstorm Sandy

# Superstorm Sandy

By the numbers…

- 92 mph winds estimated just offshore at landfall
- Hurricane Sandy broke dozens of records
  - 800 to 1,000 miles across
  - Radius of maximum winds → greater than 100 miles
  - Diameter of tropical storm-force winds at landfall: 945 miles
  - At its peak, Sandy had tropical storm-force winds that covered an area nearly 1/5$^{th}$ the size of the contiguous United States
  - 940 mb - Lowest pressure measured in the U.S. north of Cape Hatteras, NC
  - Highest storm surge in Lower Manhattan

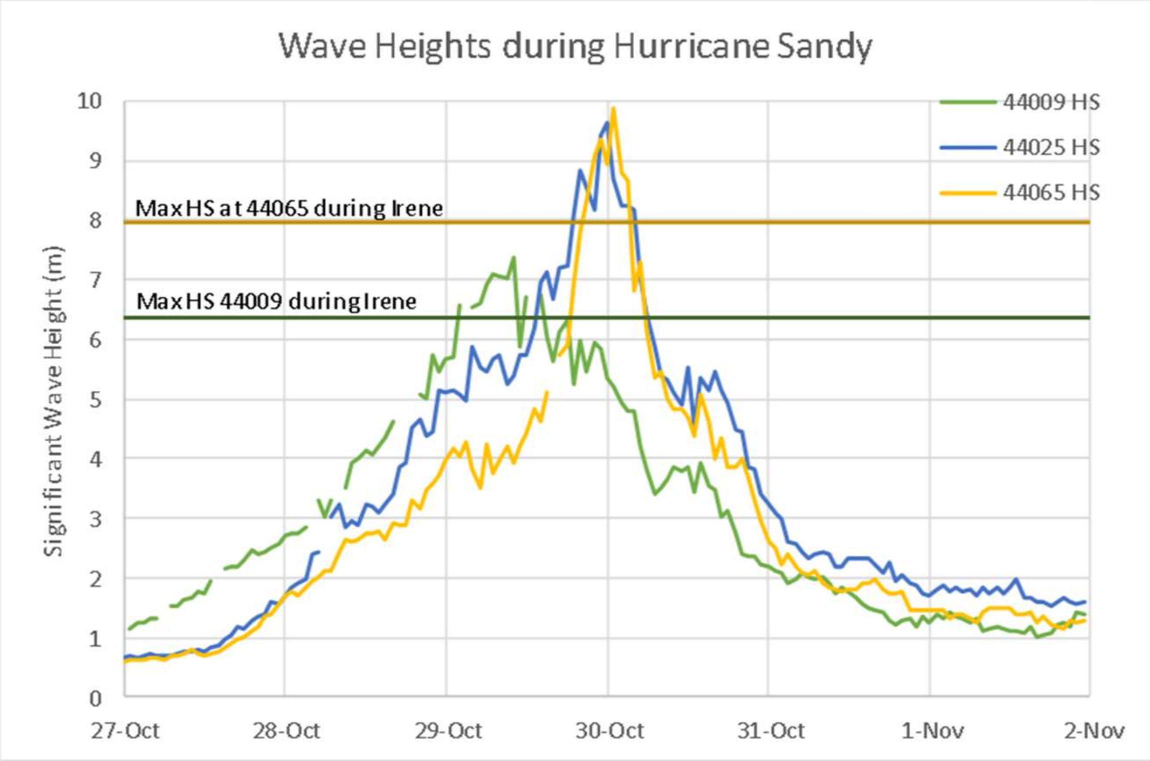



Graphic Credit: https://www.click2houston.com/weather/2012/10/31/hurricane-sandy-dwarfed-other-notable-hurricanes-in-recent-years/

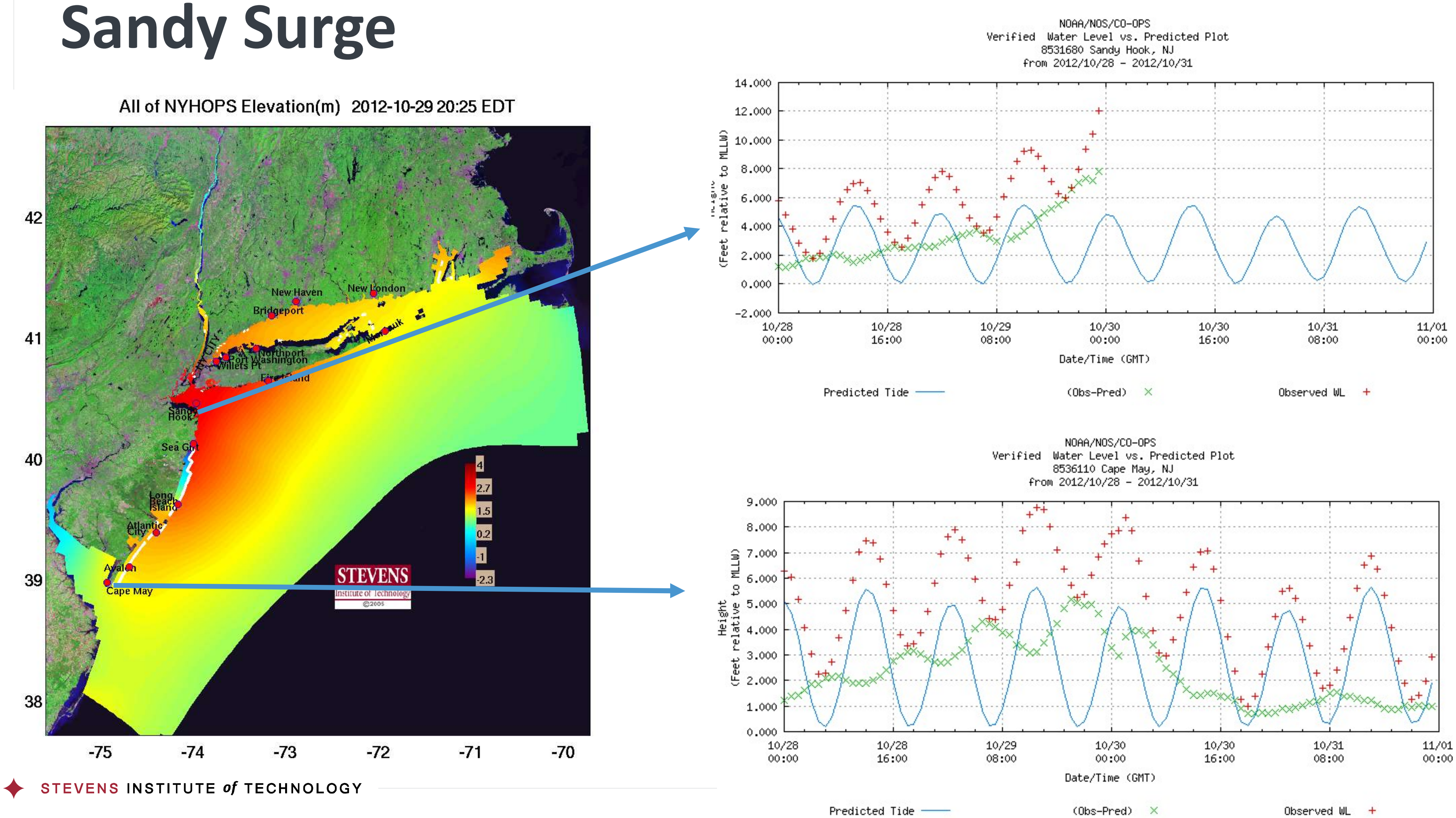
# Superstorm Sandy

## By the numbers…

- NWS determined that wave heights at two buoys were the highest recorded
- Offshore, wave heights in excess of 12' covered an estimated area of 1.4 million square miles
  - or roughly ½ half the contiguous US
  - or area of ocean with a diameter of 1,500 miles
- Maximum significant wave height:
  - Highest - 33.1' east of Cape Hatteras
  - 2nd highest - 32.5' at the Entrance to New York Harbor

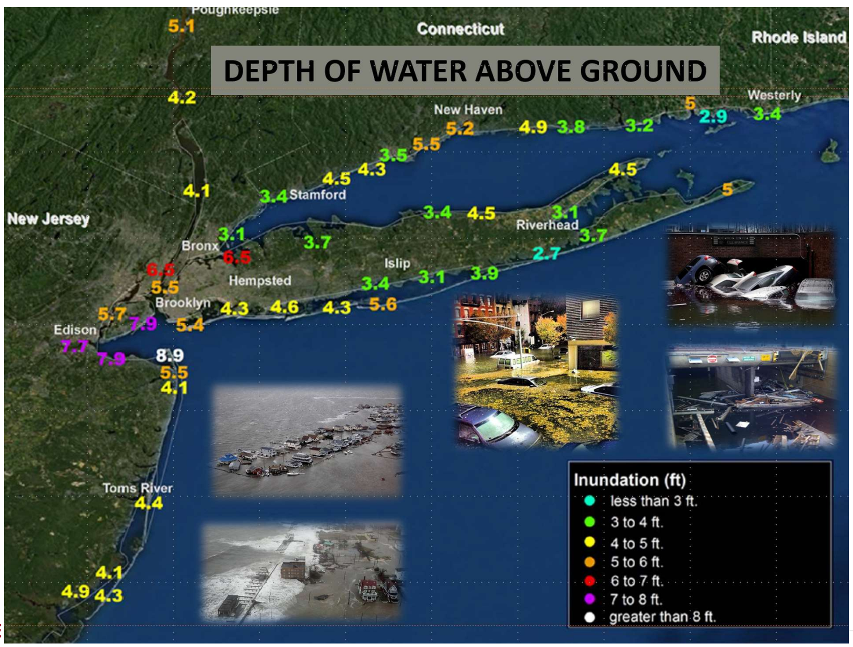


# Sandy Surge

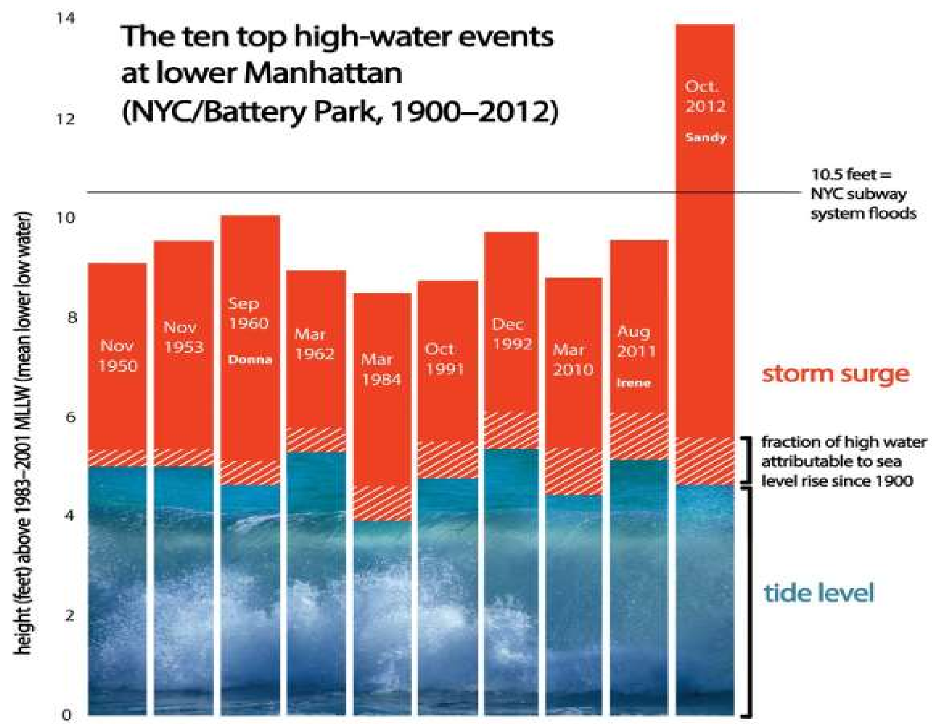

All of NYHOPS Elevation(m) 2012-10-29 20:25 EDT
42
41
40
39
38
-75
-74
-73
-72
-71
-70
New Haven
New London
Bridgeport
Northport
Port Washington
Willets Pt
Sandy Hook
Sea Girt
Long Beach Island
Atlantic City
Avalon
Cape May
4
2.7
1.5
0.2
-1
-2.3
STEVENS
Institute of Technology
©2005
NOAA/NOS/CO-OPS
Verified Water Level vs. Predicted Plot
8531680 Sandy Hook, NJ
from 2012/10/28 - 2012/10/31
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
(Feet relative to MLLW)
10/28 00:00
10/28 16:00
10/29 08:00
10/30 00:00
10/30 16:00
10/31 08:00
11/01 00:00
Date/Time (GMT)
Predicted Tide
(Obs-Pred)
Observed WL
NOAA/NOS/CO-OPS
Verified Water Level vs. Predicted Plot
8536110 Cape May, NJ
from 2012/10/28 - 2012/10/31
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
Height
(Feet relative to MLLW)
10/28 00:00
10/28 16:00
10/29 08:00
10/30 00:00
10/30 16:00
10/31 08:00
11/01 00:00
Date/Time (GMT)
Predicted Tide
(Obs-Pred)
Observed WL

# Inundation levels

- Monmouth and Middlesex Counties 4-9 ft
- Union and Hudson Counties 3-7 ft
- Essex and Bergen Counties 2-4 ft
- Ocean County 3-5 ft
- Atlantic, Burlington, and Cape May Counties 2-4 ft




(Graphic Credit: USACE)



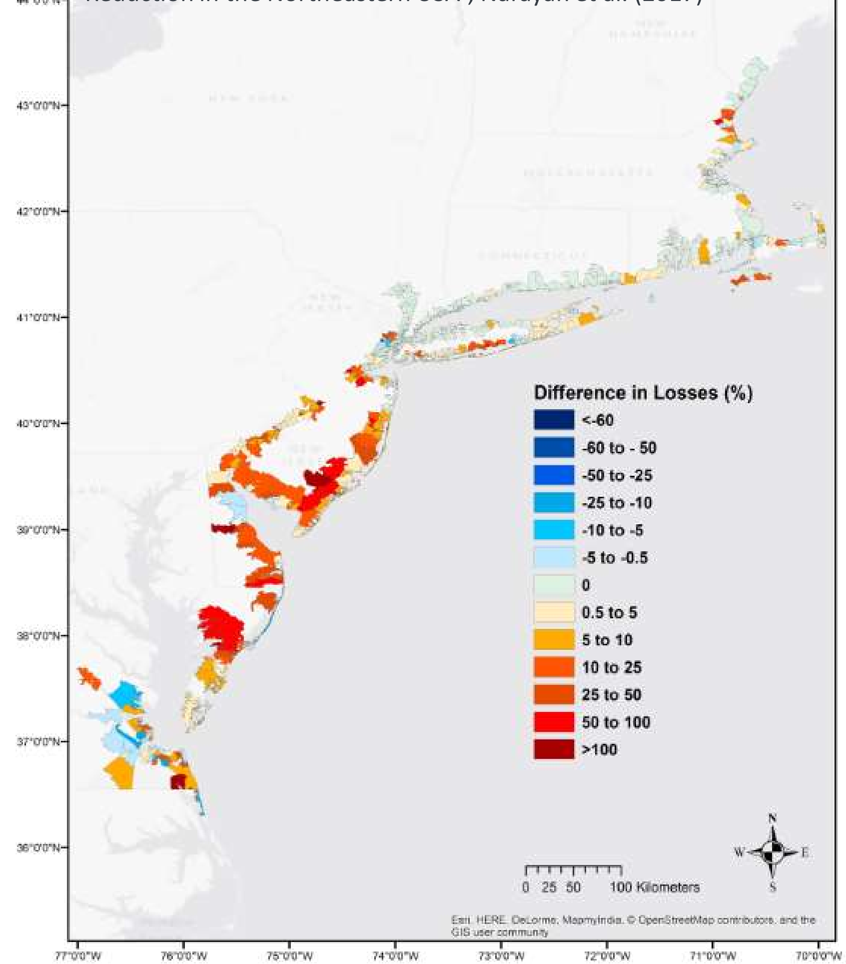

(Graphic Credit: USACE)

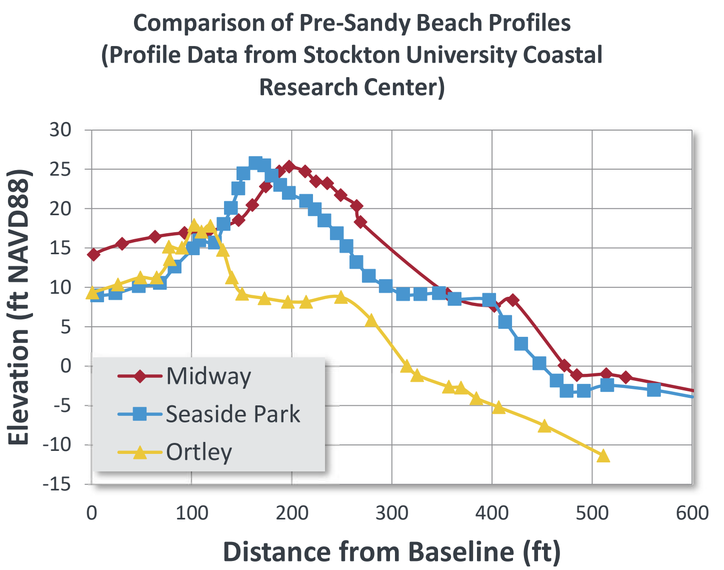
# Sandy

NNBF shown to reduce damage

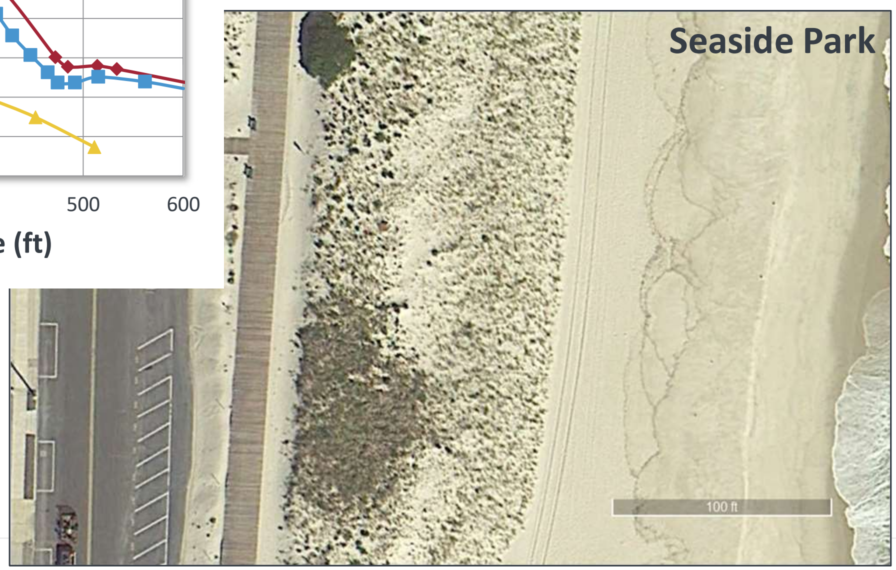
- NRC advocates consider the **full spectrum of options** available
- USACE calls for integrated approach to risk management that draws from the **full array of available measures**
- “The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA”, Narayan et al. (2017)
    - Wetlands avoided $625 million in direct flood damage during Sandy
    - 16% average reduction in annual flood losses by Salt Marshes

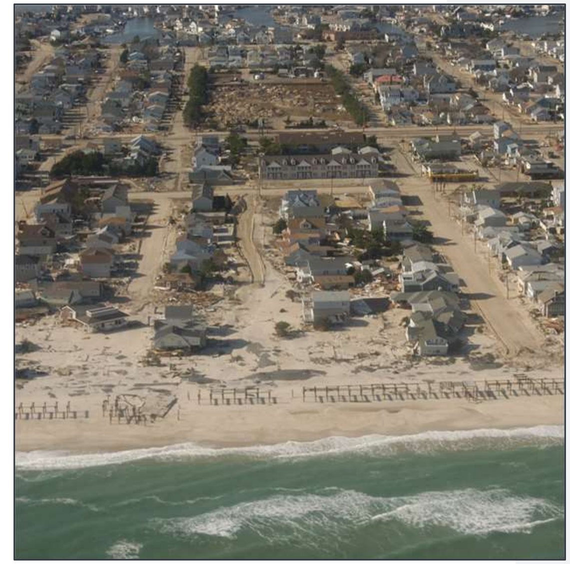
Graphic credit: “The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA”, Narayan et al. (2017)

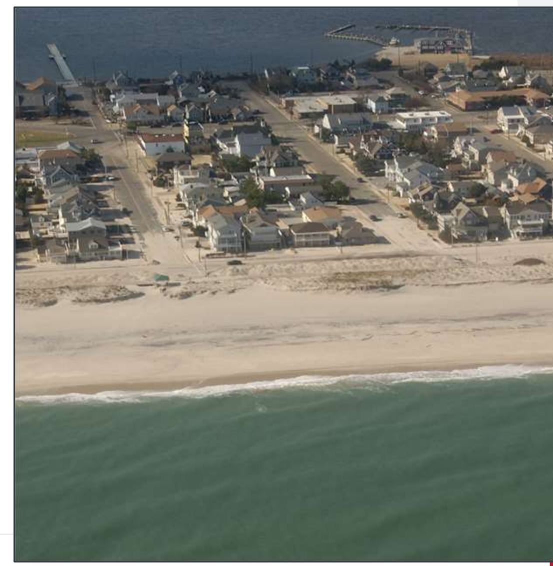



Comparison of Pre-Sandy Beach Profiles
(Profile Data from Stockton University Coastal Research Center)
Elevation (ft NAVD88)
30
25
20
15
10
5
0
-5
-10
-15
0
100
200
300
400
500
600
Distance from Baseline (ft)
Midway
Seaside Park
Ortley


Ortley Beach
149
100 ft


Seaside Park
100 ft





# GP 24

## NJ Living Shoreline General Permit

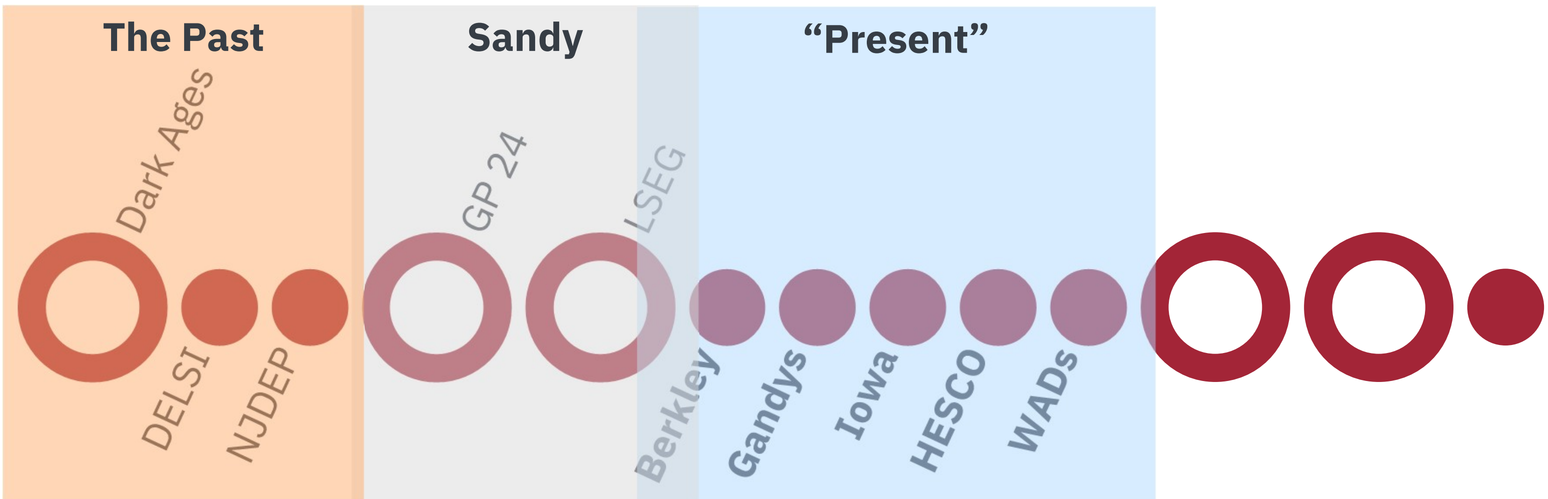
- Originally released in 2013 as GP 29
- Projects must have the endorsement of a “sponsor” with experience designing and implementing living shorelines projects.
- Projects must have a reasonable likelihood of success unless they are constructed as a research project with a university partner.
- The project area below the mean high-water line must be one acre or less unless the applicant is a county, State or Federal agency that demonstrates the necessity of a larger project.
- Projects must minimize disturbance to special areas as defined in N.J.A.C. 7:7-9, unless the proposed activities are deemed sufficiently environmentally beneficial as to outweigh the negative environmental impacts of reduction.
- Projects intended to restore an existing shoreline must limit fill to the footprint of the shoreline shown on the applicable Tidelands Map, except for structural components intended to reduce wave energy.

# NJ Living Shorelines Engineering Guidelines

Developed by Stevens for NJDEP

- Released in 2013; revised in 2015 & 2022
- Objectives
  - Provide guidance to engineers and regulators on the engineering components of living shorelines
  - Ensure consistency with GP 24 (N.J.A.C. 7:7-6.24)
  - Reduce the number of failures due to poor engineering/construction
  - Intended to be a living document
- Approach
  - Identify factors relevant to living shoreline design
  - Describe approaches for determining those parameters
  - Provide guidance on alternative selection
  - Provide example applications of those parameters to design

# Time Travel...



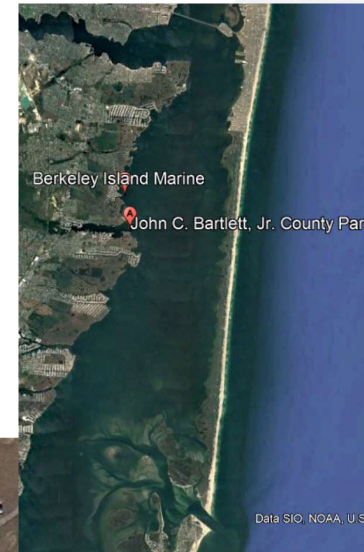
The Past
Sandy
"Present"
Dark Ages
DELSI
NJDEP
GP 24
LSEG
Berkley
Gandys
Iowa
HESCO
WADs

# Berkeley Island

- Site characteristics:
  - Erosion Rate: 1-3 ft/yr
  - Estimate Wave Heights: 0.5-1.5 ft
  - Tidal Range: < 0.5 ft
  - Beach type: Marsh
  - Region: Barnegat Bay

- Original design: segmented rock sill
- Final design: linear stone/bulkhead sill

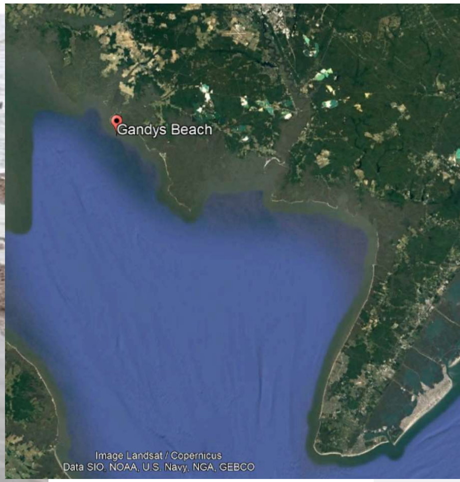


# Berkeley Island

# Gandys Beach

- Site characteristics:
  - Erosion Rate: 4-8 ft/yr
  - Estimate Wave Heights: 0.5 – 3 ft
  - Tidal Range: >6 ft
  - Beach type: Marsh and sand
  - Region: Delaware Bay
- Design: Oyster Castle Breakwater
  - Complex
  - Mostly submerged (60-80%)




# Iowa Court

- Site characteristics:
  - Erosion Rate: 2-10 ft/yr
  - Estimate Wave Heights: 1-4ft
  - Tidal Range: ~ 3 ft
  - Beach type: Marsh
  - Region: Barnegat Bay
- Design: Sill with bulkhead spine & fill
  - No water behind sill except during storms

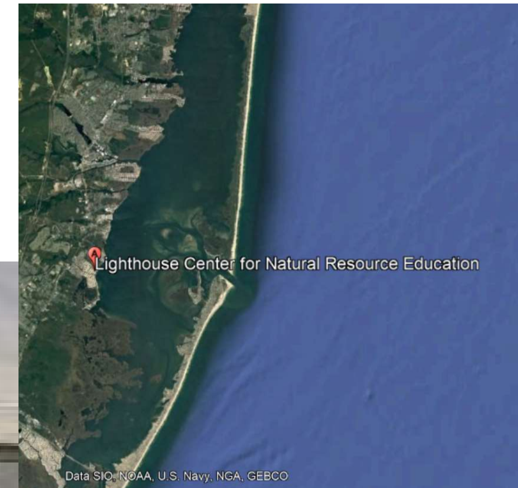
# Iowa Court


# Forked River Beach

- Site characteristics:
  - Erosion Rate: 2-8 ft/yr
  - Estimate Wave Heights: 0.5-3ft
  - Tide Range: < 0.5ft
  - Beach type: Sandy
  - Region: Barnegat Bay
- Design: HESCO basket breakwater
  - Varied angles and gaps
  - Rock interior with shell veneer

# Lighthouse Center

- Site characteristics:
    - Erosion Rate: 1-4 ft/yr
    - Estimate Wave Heights: 0.5-2 ft
    - Tide Range: ~0.5 ft
    - Beach type: Marsh
    - Region: Barnegat Bay
- Design: WAD sill/breakwater
    - Emergent



# Money Island Shoreline Restoration

(Slide courtesy NJDEP Bureau of Coastal Engineering)

- Description: 1st in the nation effort utilizing FEMA HMGP funds for shoreline/habitat restoration
- Goal: Create horseshoe crab spawning and red knot foraging habitat
- Date Completed: 2022
- Total Cost: $957k (Shoreline Restoration ONLY)
- Cost Share: 100% FEMA

FEMA

# Money Island Shoreline Restoration

(Slide courtesy NJDEP Bureau of Coastal Engineering)

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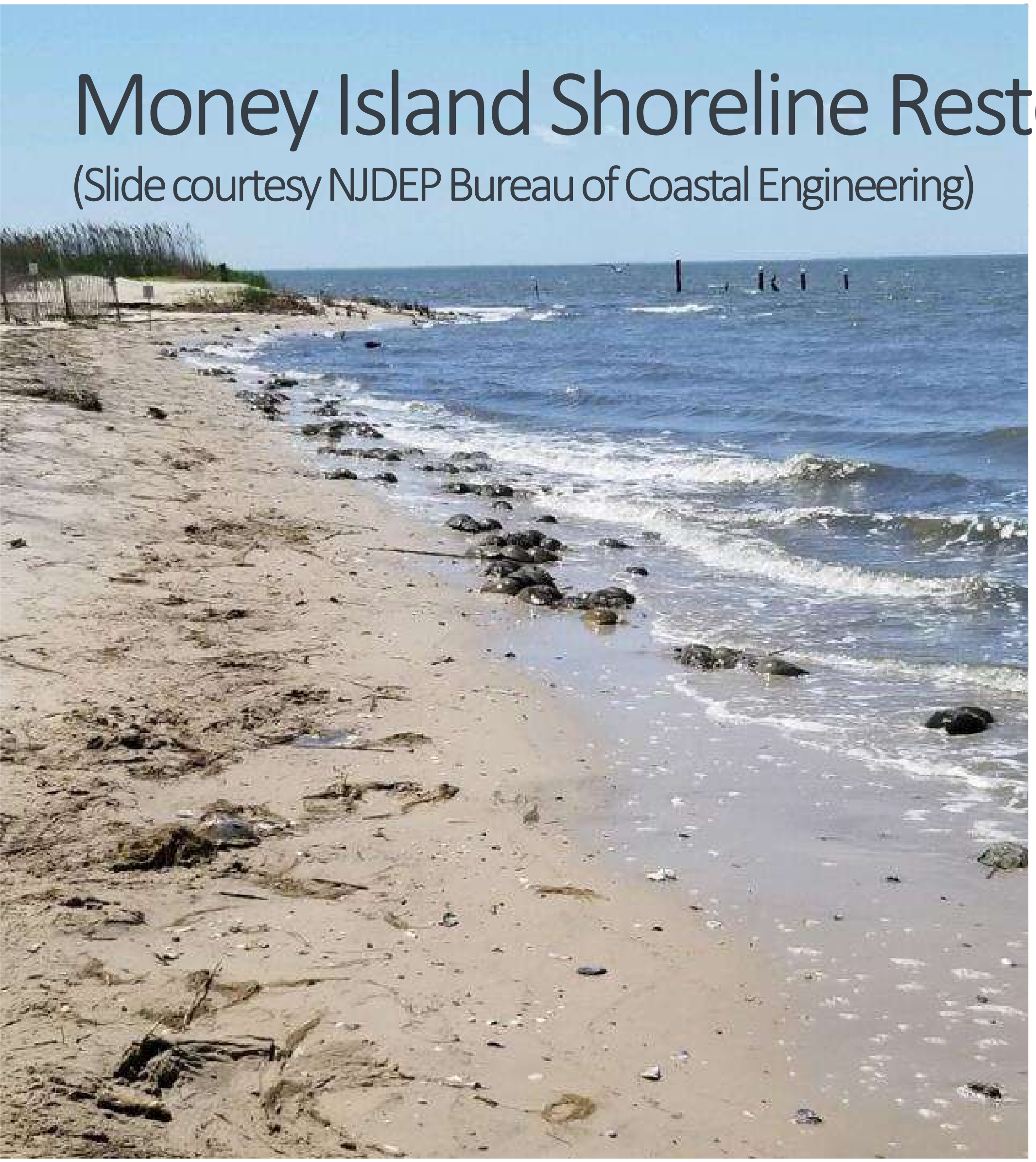

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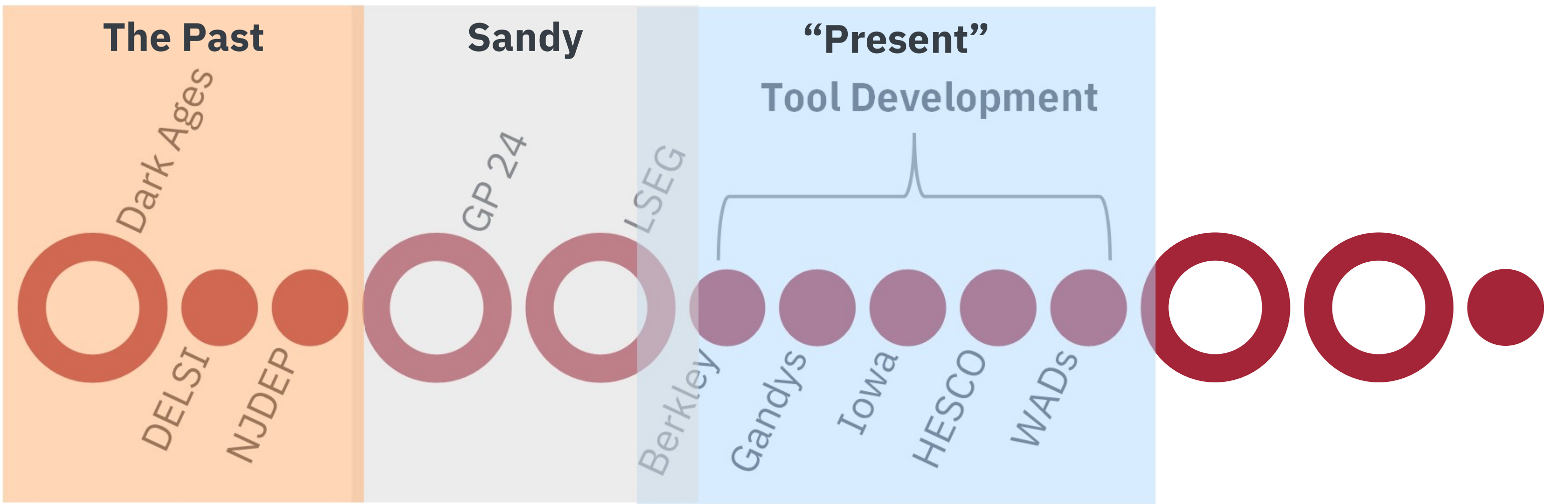

The Past
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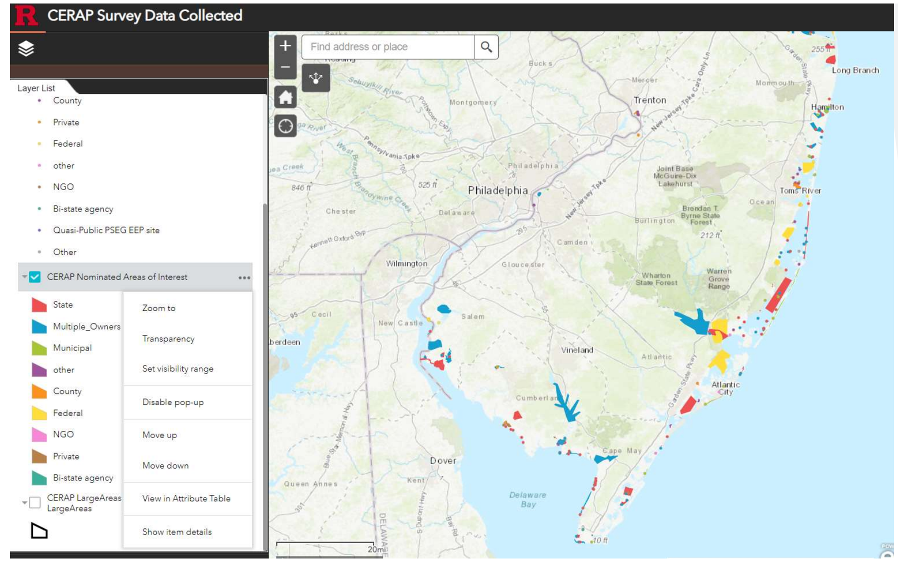
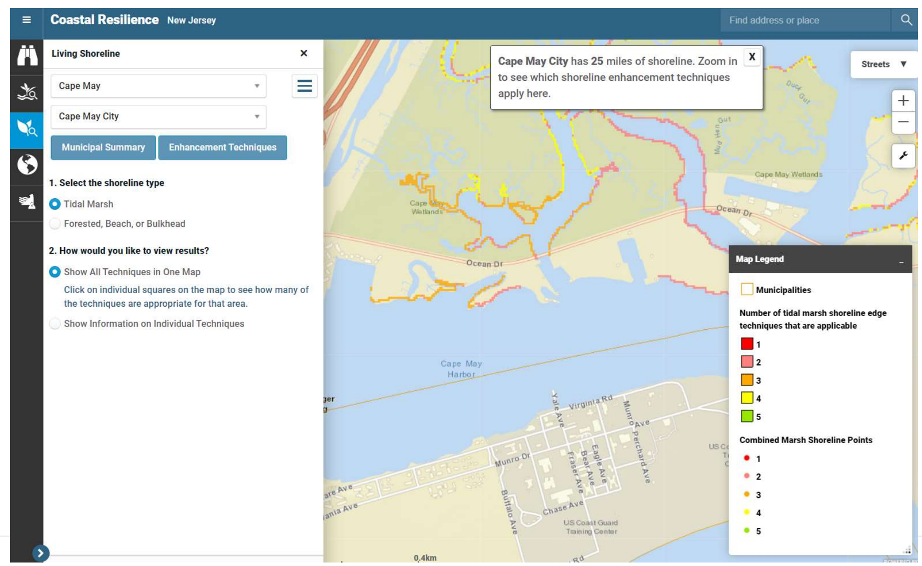
# Tool Development

## Incomplete list

- Living Shorelines Engineering Guidelines (2022 Update Soon) – Stevens
- Restoration Explorer – TNC
- Wetland Assessment Tool for Condition and Health (WATCH) - PDE
- New Jersey Coastal Ecological Restoration and Adaptation Plan (CERAP) – Rutgers/NJDEP
- Mid-Atlantic Coastal Wetlands Assessment (MACWA) - Multiple
- A Community Resource Guide for Planning Living Shoreline Projects New Jersey – Multiple
- A Framework for Developing Monitoring Plans for Coastal Restoration and Living Shorelines Projects in New Jersey – TNC
- Building Ecological Solutions to Coastal Community Hazards – NWF
- Ecoshorelines on Developed Coasts Guidance and Best Practices – Stevens



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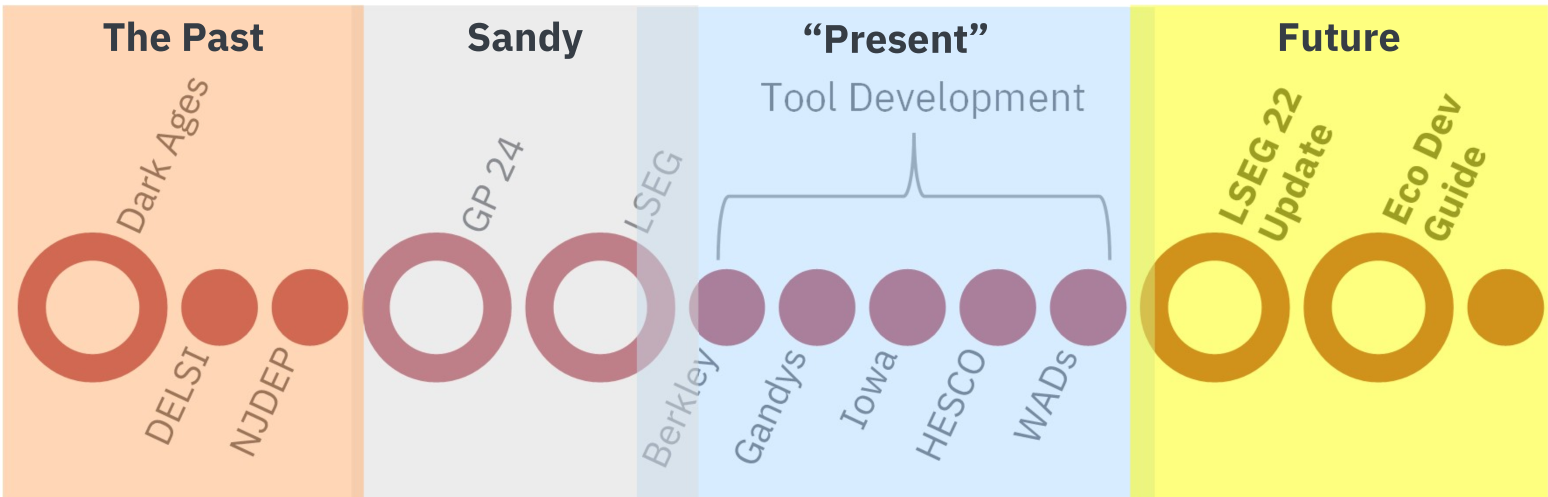

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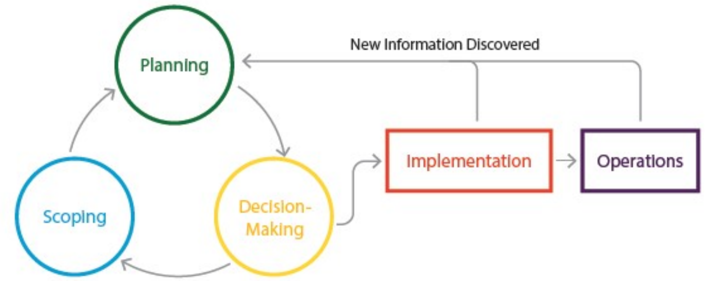
HESCO
WADs
LSEG 22 Update
Eco Dev Guide

# NJ Living Shorelines Engineering Guidelines

2022 Update

- Adopts simplified IGNNBF terminology (design phases)
- Scoping Phase is added – Tools
- Adaptive management discussion is added
- Research gap appendix added
- Design parameters, conditions, and ranges updated
- Joint-planted revetment and reef ball specific sections have been removed
    - Alternative substrates addressed under living reef section
    - Vegetation addressed in developed coast document




| | Marsh Sill | Breakwater | Living Reef |
|---|---|---|---|
| **System Characteristics** | | | |
| Erosion History | ***Low-Med*** | ***Med-High*** | ***Low-Med*** |
| Sea Level Rise | Low-Mod | Mod-High | Low-Mod |
| Tidal Range | ***Low-High*** | Low-High | ***Low-Mod*** |
| **Hydrodynamic Characteristics** | | | |
| Wind Waves | ***Low-Mod*** | ***Mod-High*** | ***Low-Mod*** |
| Wakes | ***Low-Mod*** | ***Mod-High*** | ***Low-Mod*** |
| Currents | Low-Mod | Low-High | Low-Mod |
| Ice | ***Low*** | Low-High | ***Low*** |
| Storm Water Level | Low | ***Mod-High*** | Low |
| **Terrestrial Characteristics** | | | |
| Upland Slope | Mild-Mod | Mod-Steep | Mild-Mod |
| Shoreline Slope | ***Mild-Mod*** | ***Mild-Steep*** | ***Mild-Mod*** |
| Width | ***Mod-High*** | ***Mod-High*** | ***Mod-High*** |
| Nearshore Slope | ***Mild-Mod*** | ***Mild-Mod*** | ***Mild-Mod*** |
| Offshore Depth | Shallow-Mod | Mod-Deep | Shallow-Mod |
| Soil Bearing | Mod-High | ***High*** | Low-Mod |
| **Ecological Characteristics** | | | |
| Water Quality | Poor-Good | Poor-Good | ***Good*** |
| Soil Type | ***Any*** | Any | Any |
| Sunlight Exposure | ***Mod-High*** | Low-High | ***Mod-High*** |

# Scoping Level Analysis

Replaces “Level 0”

- TNC Restoration Explorer
- PDE WATCH tool
- CERAP

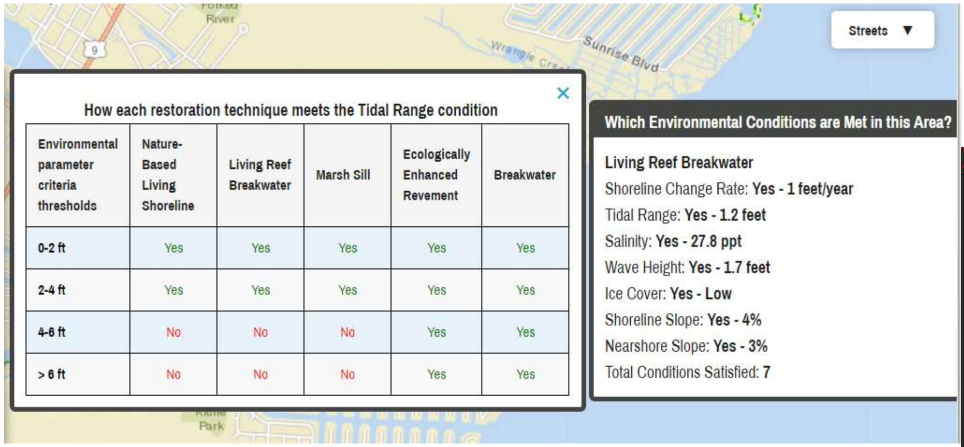

Wetland Assessment Tool for Condition & Health (WATCH) v 2.0

A user’s guide for operating WATCH v 2.0 including definitions, data input, interpreting outcomes, and training scenarios

Partnership for the DELAWARE ESTUARY

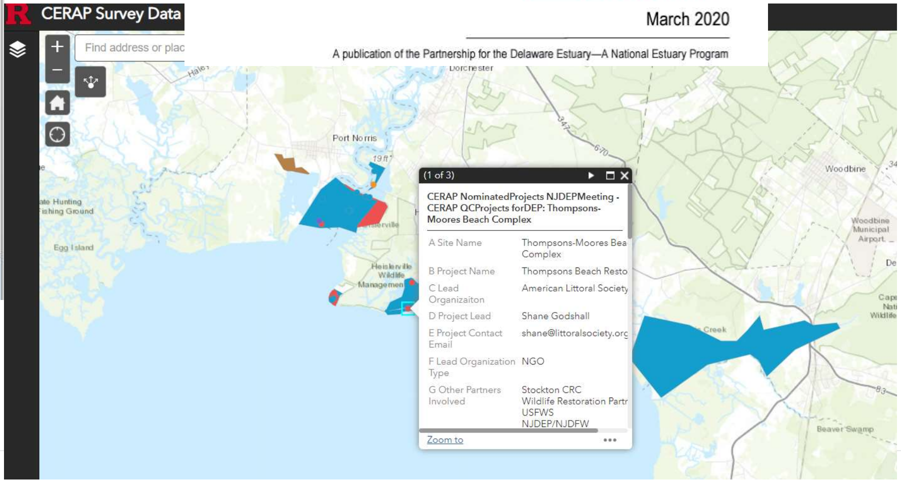
March 2020

A publication of the Partnership for the Delaware Estuary—A National Estuary Program


How each restoration technique meets the Tidal Range condition

| Environmental parameter criteria thresholds | Nature-Based Living Shoreline | Living Reef Breakwater | Marsh Sill | Ecologically Enhanced Revement | Breakwater |
|---|---|---|---|---|---|
| 0-2 ft | Yes | Yes | Yes | Yes | Yes |
| 2-4 ft | Yes | Yes | Yes | Yes | Yes |
| 4-6 ft | No | No | No | Yes | Yes |
| > 6 ft | No | No | No | Yes | Yes |





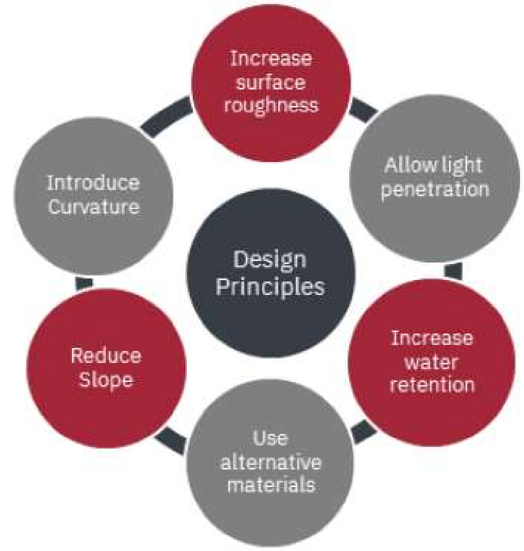
# Additional Considerations

- Adaptive management
  - prevents overbuilding at the design phase
  - reduces upfront costs by allowing management of unknowns over time
  - provides flexibility to adjust project goals over time as the needs of the site change
  - **But** requires project monitoring and an open regulatory environment
- Beneficial reuse
  - Consideration of 1977 tidelands line (N.J.A.C. 7:7-6.24)
  - Consideration of existing sediment size requirements (N.J.A.C. 7E-4.8)
  - Coarser sediments typically placed along the edge with finer sediment placed on the interior/platform

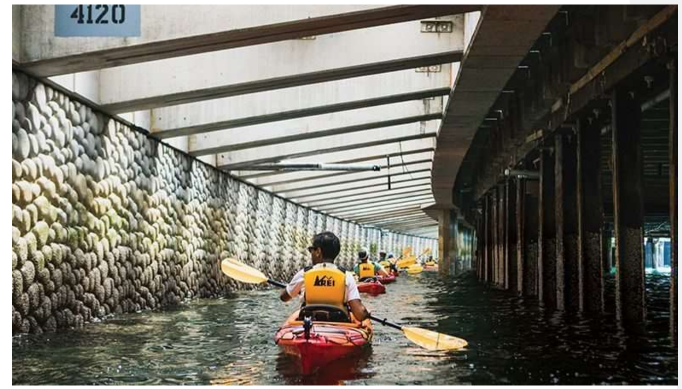
# Ecoshorelines on Developed Coasts

Guidance and Best Practices

- Sister document to NJ LSEG
- Review of Existing Guidance
    - Waterfront Edge Design Guidelines (Waterfront Alliance)
    - International Guidelines on Natural and Nature Based Features for Flood Mitigation (USACE)
- Case Studies
    - Harlem River, NY
    - Sherman Creek, NY
    - Brooklyn Bridge Park, NY
    - Seattle Seawall, WA
    - Lardners Point, PA
    - San Diego, CA




| | WEDG | IGNNBF | Harlem River | Sherman Creek | Brooklyn Bridge | Seattle Seawall | Lardners Point | San Diego |
|---|---|---|---|---|---|---|---|---|
| Preserve Natural Areas | ■ | ■ | | ■ | | | ■ | |
| Increased Surface Roughness | ■ | | ■ | | ■ | ■ | | ■ |
| Alternative Materials | ■ | ■ | ■ | ■ | ■ | | | ■ |
| Reduce Slope | ■ | | ■ | | ■ | ■ | ■ | ■ |
| Increase Sinuosity | ■ | | ■ | | | | ■ | |
| Allow Light Penetration | ■ | | | | ■ | ■ | | |
| Increase Water Retention | ■ | | ■ | | ■ | ■ | | ■ |
| Resilience/Adaptability | ■ | ■ | ■ | | ■ | ■ | | |
| Monitoring and Assessment | ■ | ■ | | ■ | ■ | ■ | ■ | ■ |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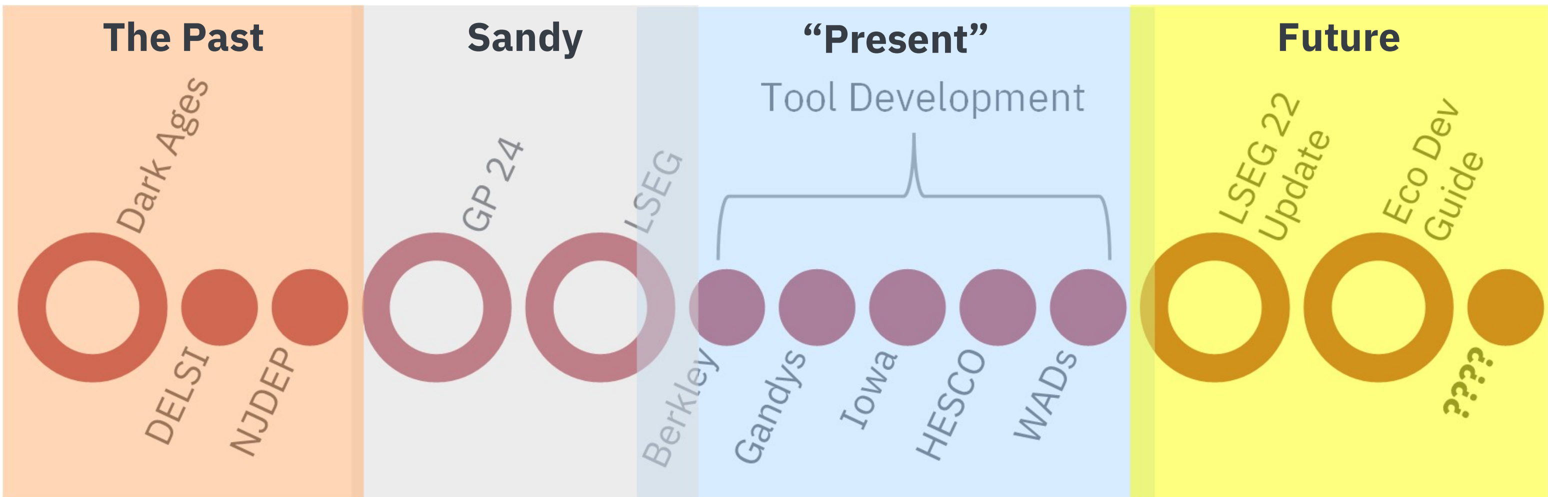
Increase surface roughness
Allow light penetration
Increase water retention
Use alternative materials
Reduce Slope
Introduce Curvature
Design Principles

# Time Travel…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Iowa
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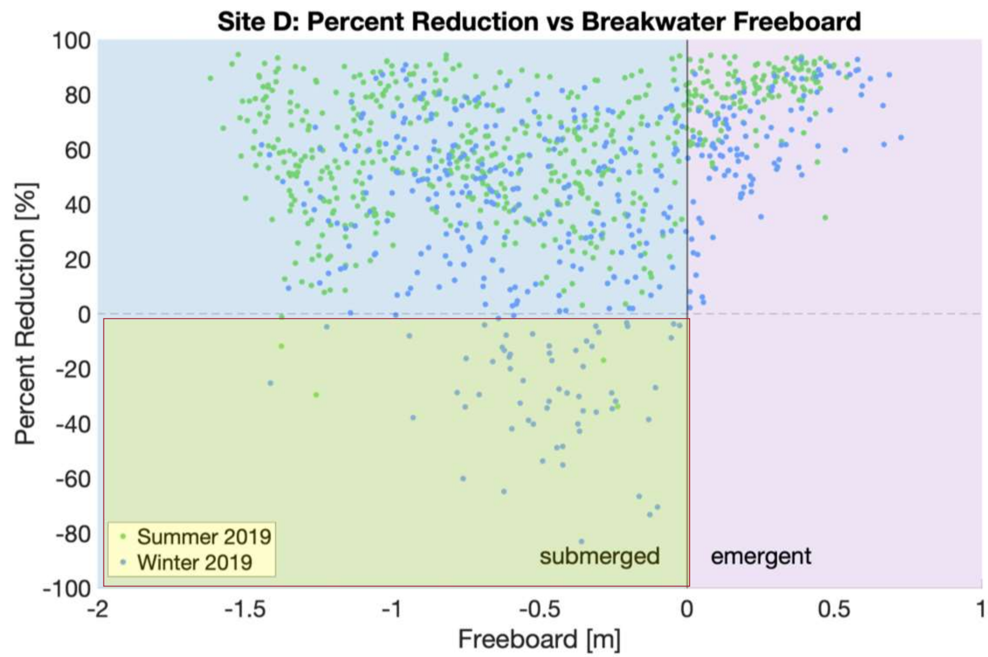
WADs
LSEG 22
Update
Eco Dev
Guide
????

# Problem

## Climate Change

- Sea level rise
- More frequent and intense storms
- Feedbacks
  - Deeper water → larger waves
  - “Modification” of wave attenuation associated with natural and engineered features
  - Potential loss of habitat/natural wave attenuation

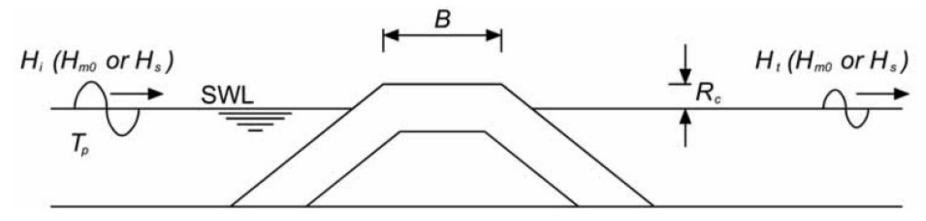


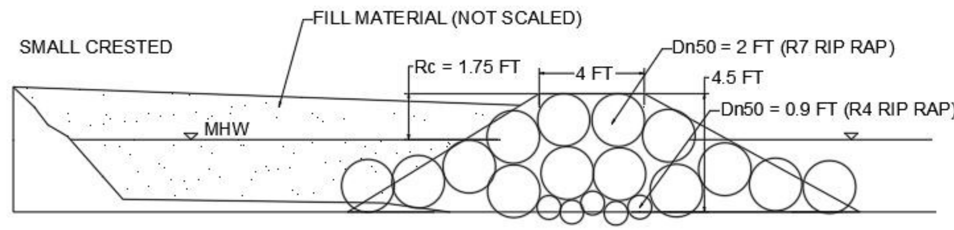
# Potential Solutions

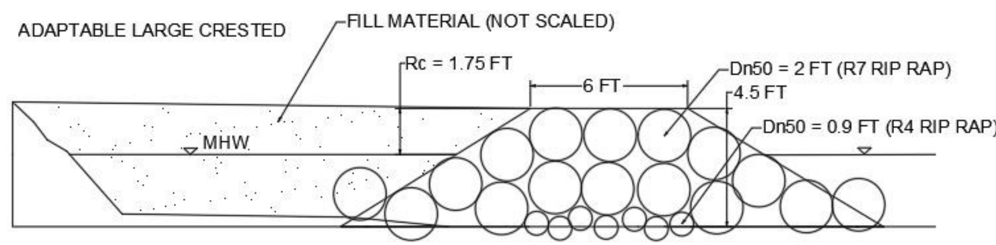
*Wider Adaptable Structures*

- Wave attenuation is a function of relative crest height and structure width
- Solution 1 - build taller structures
  - results in initially overbuilt structures that are more costly, unnatural, and that often provide less in terms of ecosystem services
- Solution 2 – build wider structures
  - provides similar wave attenuation as taller structures, more closely mimic natural reef systems, and can be adapted by adding additional layer(s) of stone
  - Difficult to permit (currently)

$$C_t = H_t / H_i = \sqrt{E_t / E_i}$$



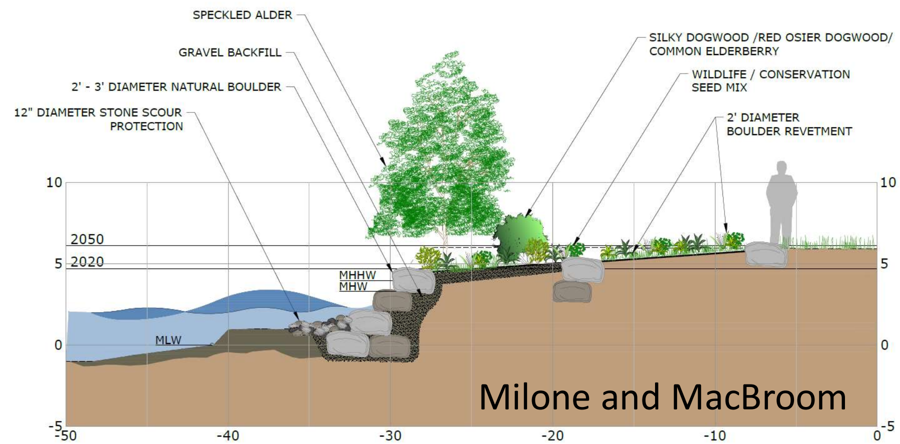



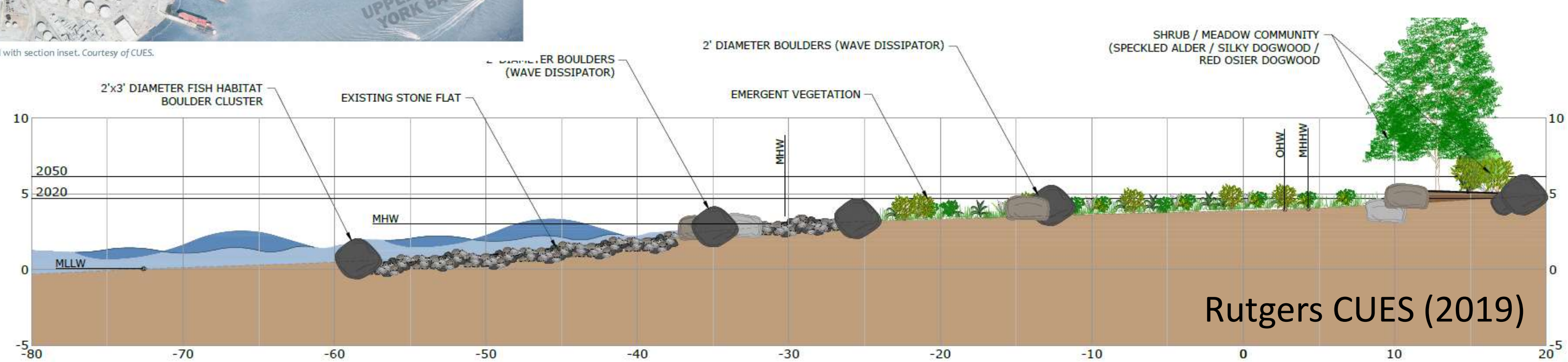
# Potential Solutions

## Adaptive Designs

- Plan for active and inactive structures and transitions


Figure 2. Plan view of the proposed Links Island with section inset. Courtesy of CUES.



# Summary

We've come a long way, but the journey continues

- ***Past***
  - DELSI & NJDEP whitepaper
- ***Sandy***
  - General Permit 24 & LSEG
- ***"Present"***
  - Tools & Projects – dozens
- ***Future***
  - Updated "traditional" design guidance
  - New guidance for developed shorelines
  - Challenges

- ***Challenges***
  - Document/learn from constructed projects
  - Continue to evaluate permitting process
    - Wider structures?
    - Adaptive management?
  - Improve Design Guidance
    - Traditional and developed shorelines
    - Consider wave power
  - Resilient Design
    - Climate and other
    - Adaptive management
    - Habitat transitions

# Questions?

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