

The State of the Art and Science of Coastal Engineering

LIVING BREAKWATERS - Designing for Resiliency

Geosyntec 
consultants

Paul Tschirky, PhD, PEng, D.CE

Geosyntec Consultants

SCAPE

Pippa Brashear

SCAPE Landscape Architecture DPC



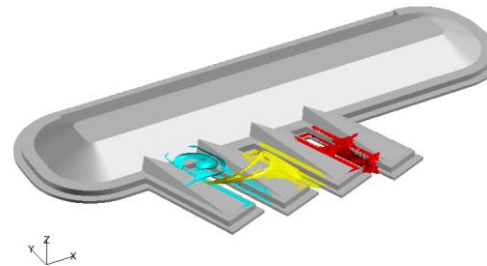
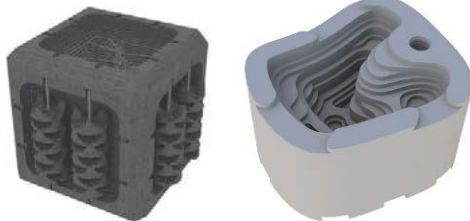
Ido Sella, PhD

SeArc Ecological Marine Consulting

COWI

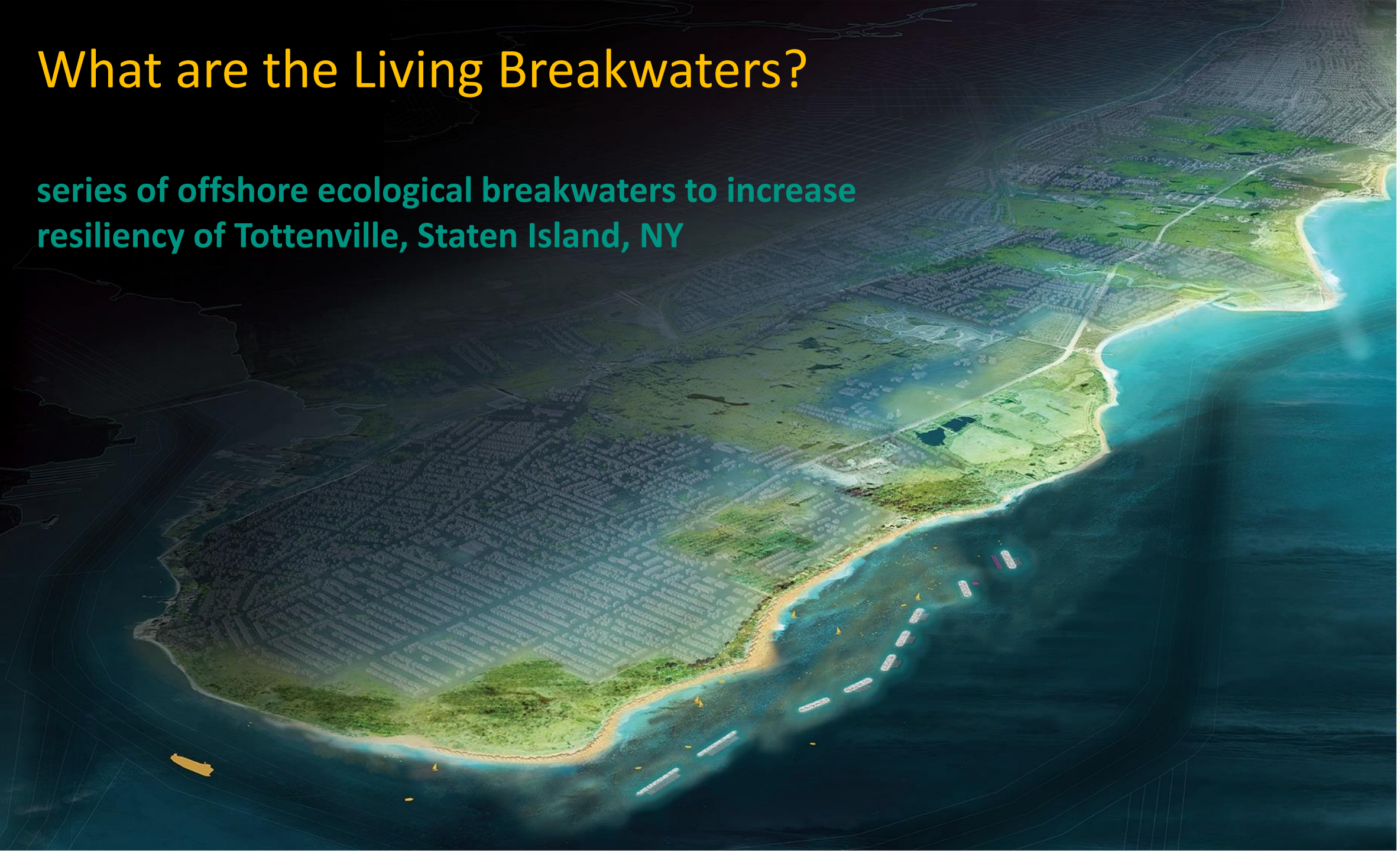
Todd Manson, PE

COWI



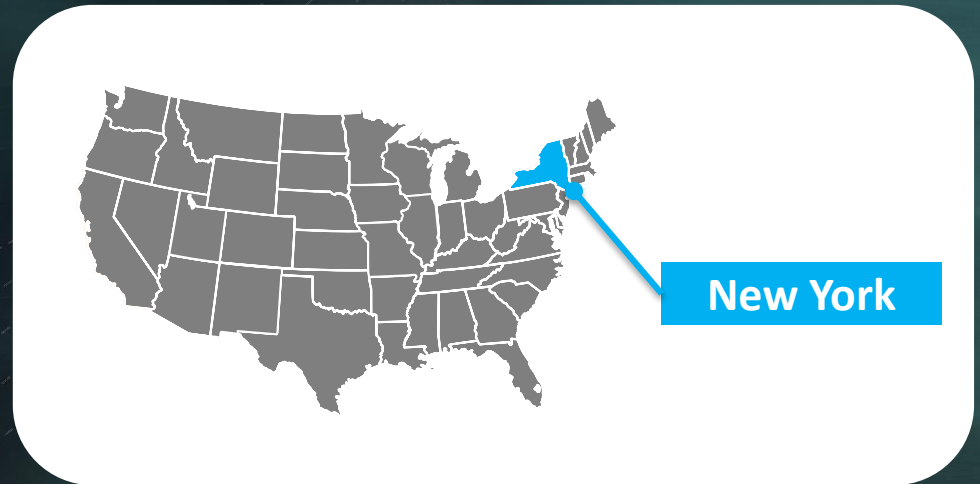
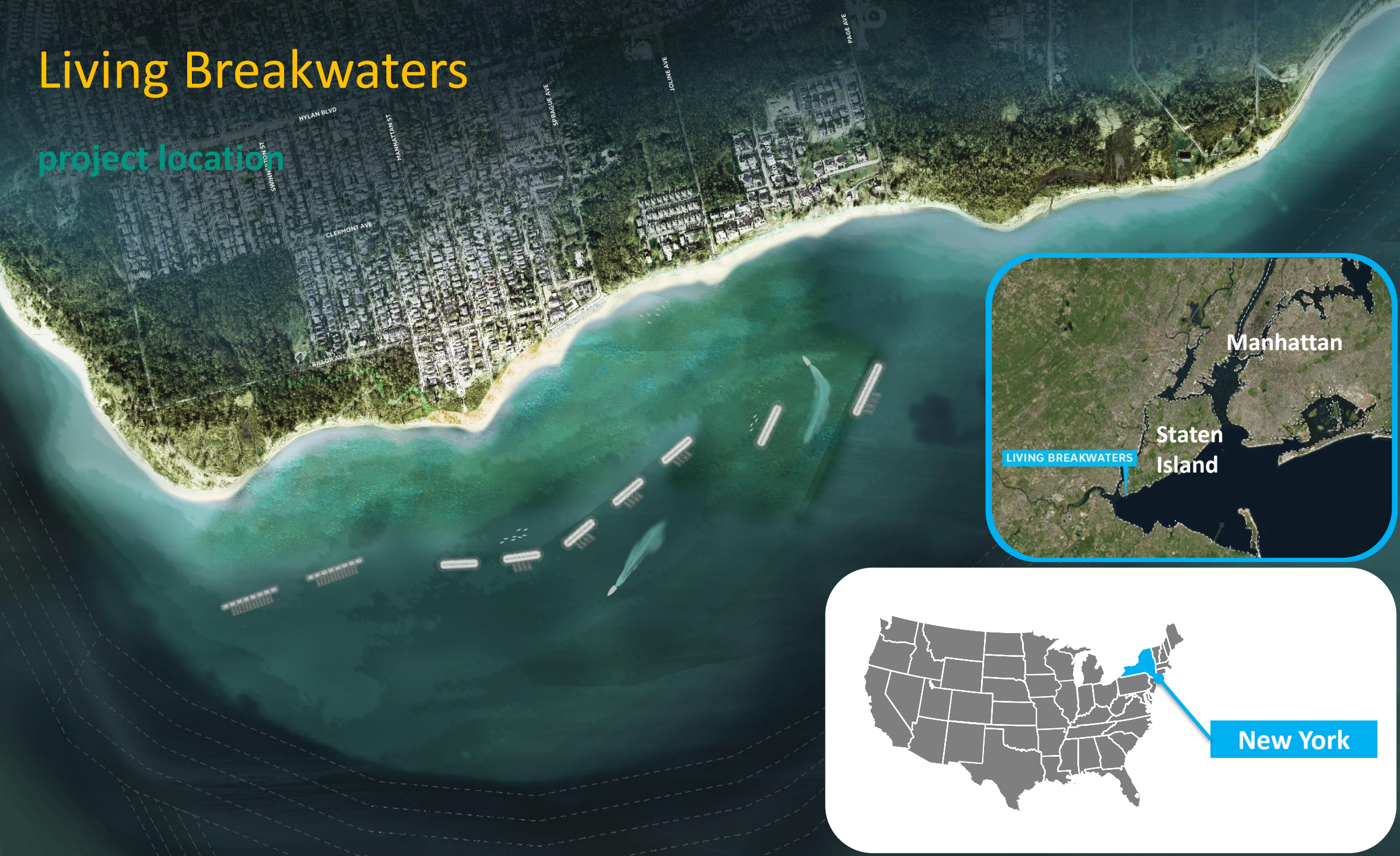
What are the Living Breakwaters?

series of offshore ecological breakwaters to increase resiliency of Tottenville, Staten Island, NY



Living Breakwaters

project location



Designing for Resilience

“resilience” not just rebuilding

**REBUILD
BY
DESIGN**



**Governor's Office of
Storm Recovery**



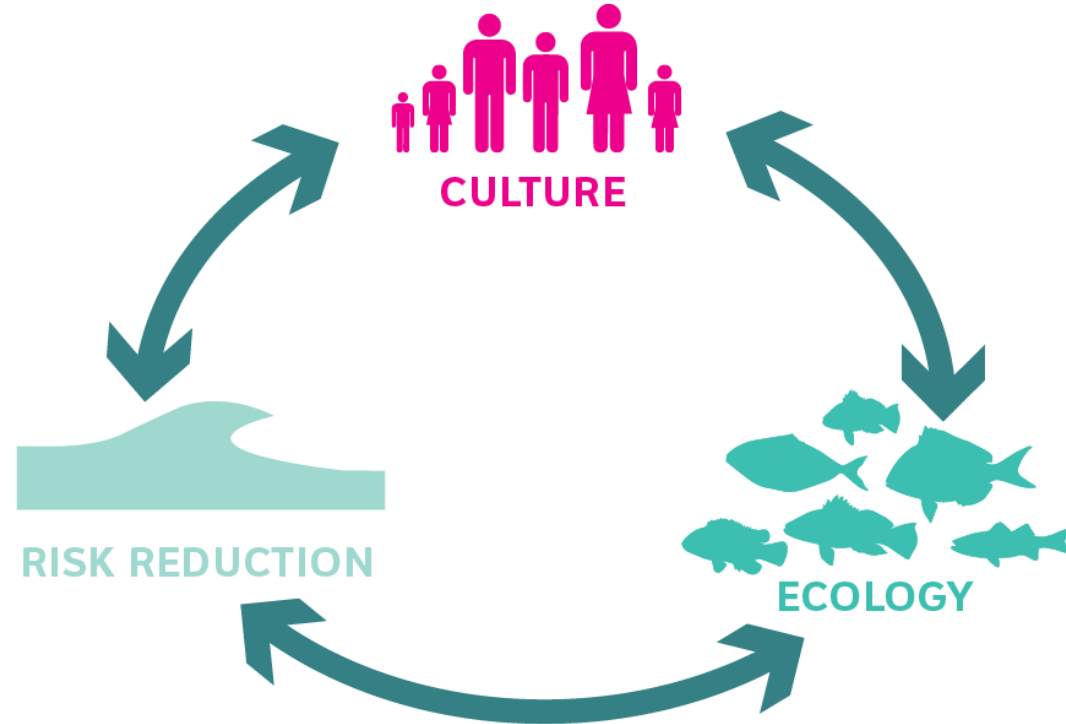
Designing for Resilience

design + ecology + engineering

Resiliency - the ability of a natural or built system to recover from an extreme load or event.

REQUIRES:

- **Multidisciplinary Collaboration**
- **Multilayered Solutions**

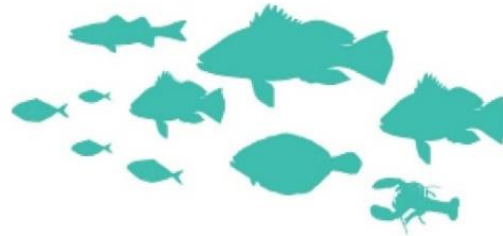


Designing for Resilience



RISK REDUCTION

- **ATTENUATE STORM WAVES**
- **REDUCE OR REVERSE LONG TERM EROSION**
- **REDUCE EVENT-BASED EROSION**



ECOLOGICAL ENHANCEMENT

- **CREATE HABITAT**
- **INCREASE BIODIVERSITY**
- **IMPROVE ECOSYSTEM HEALTH**



SOCIAL RESILIENCY

- **IMPROVE ACCESS TO THE SHORELINE & NEARSHORE WATERS**
- **RAISE AWARENESS OF RISK**
- **ENCOURAGE STEWARDSHIP**



Modeling and Design Integration

modeling design components

SYSTEM LAYOUT:

- shoreline retention or growth / reduced erosion
- wave attenuation

BREAKWATER STRUCTURE:

- wave and current conditions at the breakwaters
- stability of various rock sizes
- stability of unique design elements (crenelated crests, reef ridges)
- scour potential at breakwater toe

ECOLOGICAL:

- sedimentation, flow patterns, velocities in and around the breakwater and reef streets
- placement of treatments



Modeling and Design Integration

modeling approach and models

APPROACH:

Model simple to complex -- to allow testing of multiple concepts early and refine details later (this also fostered collaboration and innovation)

Concept --- Design --- Test --- Analyze --- Iterate

MODELS:

- Waves (SWAN, REFDIF, Funwave)
- Shoreline change (GENESIS)
- Sediment movement (Delft3D)
- Water quality changes / tidal flushing (Delft3D)
- Detailed flows and sediment movement for ecological design (Flow3D)
- Structural stability (Physical)
- Confirmation and wave attenuation (Physical)



Risk Reduction



RISK REDUCTION

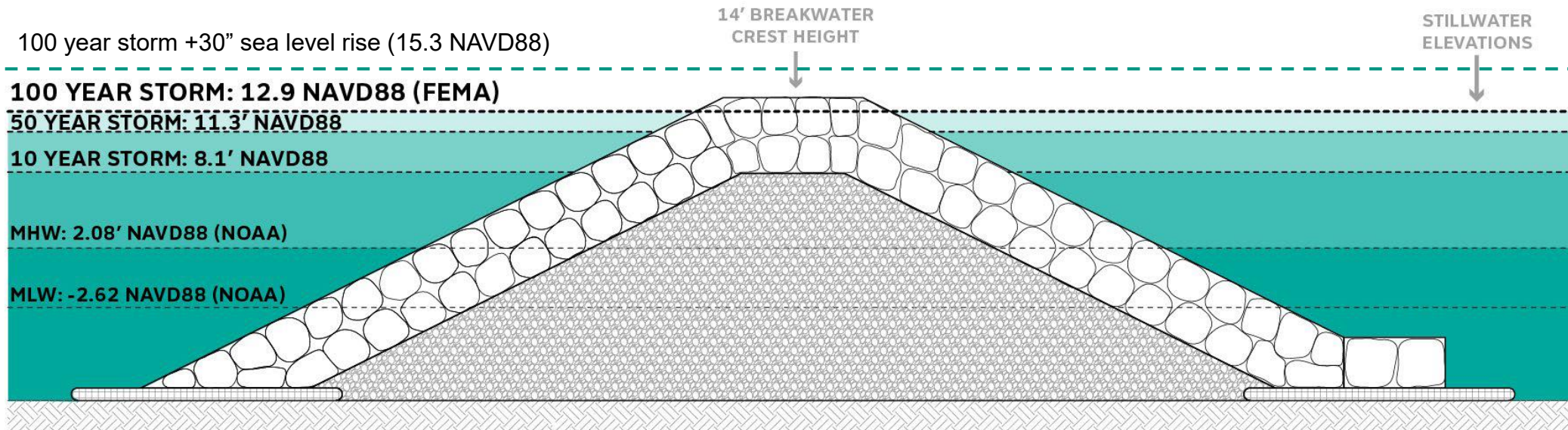
- **ATTENUATE STORM WAVES**
- **REDUCE OR REVERSE LONG TERM EROSION**
- **REDUCE EVENT-BASED EROSION**



Hydrodynamic Conditions

driving forces

- **Storm surge** – 12.9 ft NAVD88 (1% annual chance)
- **Sea level rise** – 30" (medium projection for 2080, high projection for 2050)
- **Storm waves** – 5.3 ft, 5 s (Hsig, 1% annual chance event)
- **Normal tidal range** ~5 ft



Driving Forces

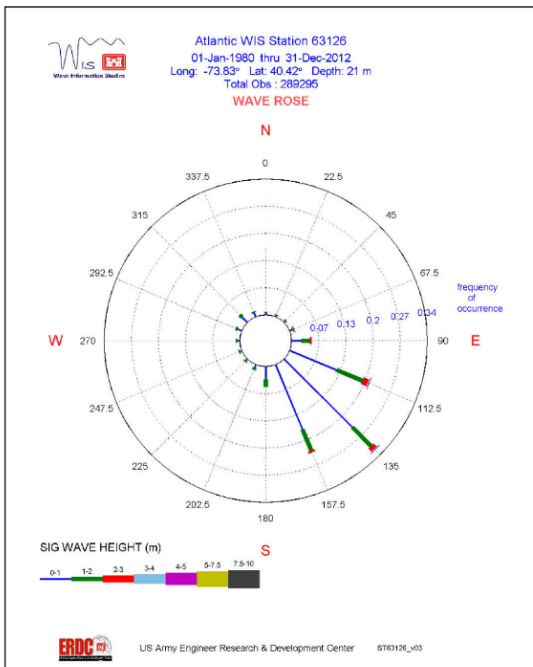
waves




Modeling

Understanding the wave climate

Offshore Wave Data

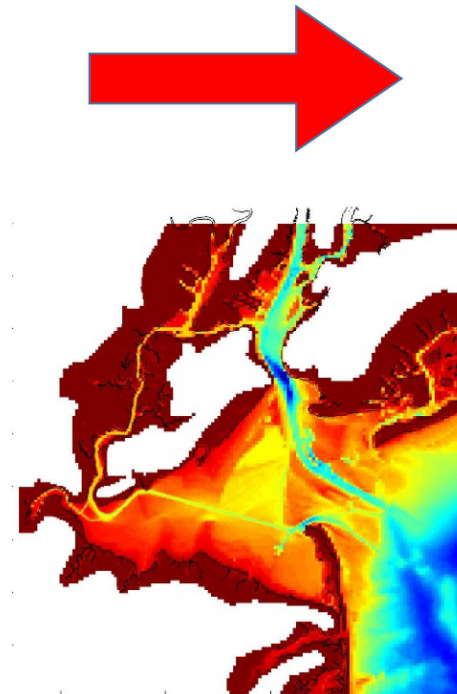


+ 
Winds
(locally generated waves)

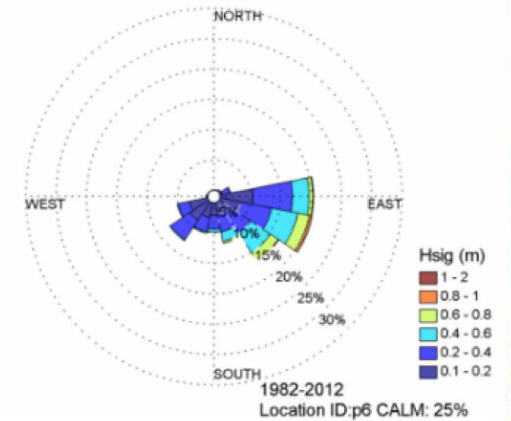
developing input data sets

- wave transformation modeling
- 30 years of hourly data

Wave Transformation Model (SWAN)

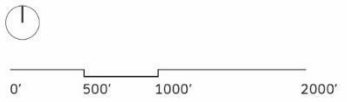


Nearshore Wave Climate



- 1978 MHW LINE
- 2015 MHW LINE
- CURRENT MLW LINE
- HISTORIC SHORELINE EROSION
- HISTORIC SHORELINE ACCRETION
- VE ZONE LINE
- LIMWA LINE
- SHORELINE STRUCTURES
- STRUCTURES WITHIN RISK ZONES

DATA SOURCES:
 PREDOMINANT WAVE DIRECTION DEVELOPED BY ARCADIS USING WAVE TRANSFORMATION MODELING FROM NEARBY WIS STATION
 2015 MHW LINE AND SHORELINE STRUCTURES SURVEYED BY NYACK, SUPPLEMENTED WITH 2014 LIDAR AND HISTORIC AERIAL IMAGERY
 CHANNEL EDGE: BASED ON COORDINATES PROVIDED BY USACE (JOHN BELDIN-QUINONES) ON 2/25/2015
 CONTOUR BATHYMETRY GENERATED BY HILL



VULNERABLE STRUCTURES AND INFRASTRUCTURE EXPOSED TO STORM WAVE ACTION IN THE 1% ANNUAL CHANCE STORM

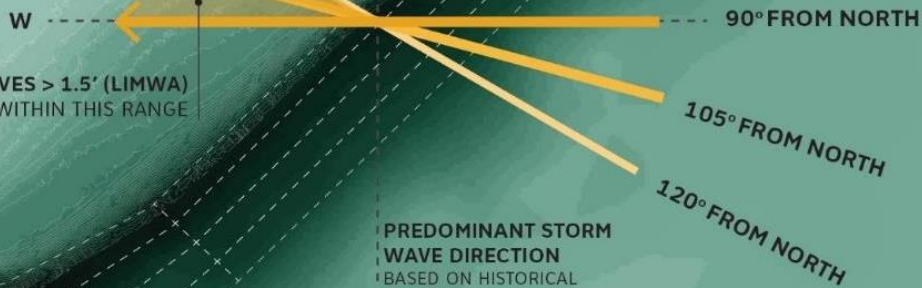
FEMA V ZONE WAVES > 3.0'

LIMIT OF MODERATE WAVE ACTION (LIMWA) WAVES > 1.5'

100% OF WAVES > 3' (V ZONE)
 48.5% OF WAVES > 1.5' (LIMWA)
 FALL WITHIN THIS RANGE

17% OF WAVES > 1.5' (LIMWA)
 FALL WITHIN THIS RANGE

PREDOMINANT STORM WAVE DIRECTION
 BASED ON HISTORICAL WAVE DATA (1980-2014)



FEDERAL NAVIGATION CHANNEL

FEDERAL NAVIGATION CHANNEL



Modeling

shoreline change
(erosion reduction)

Tested 15+ different layouts.

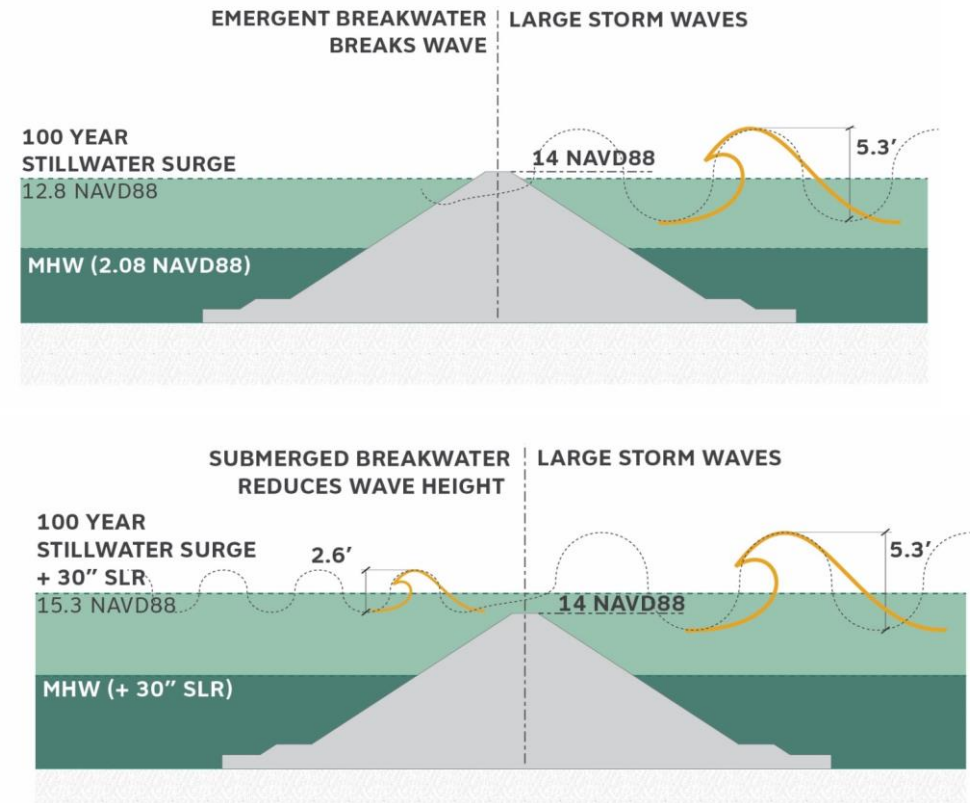
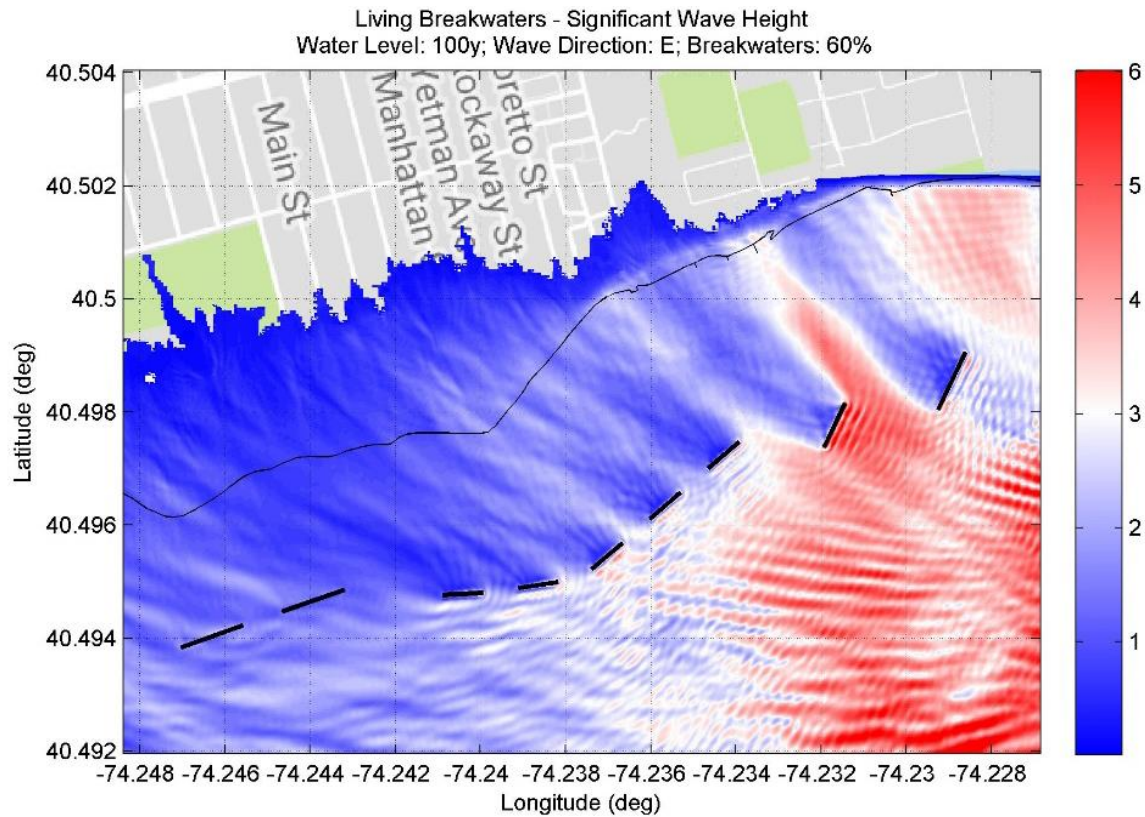
Modeled changes after 20 years.



Modeling

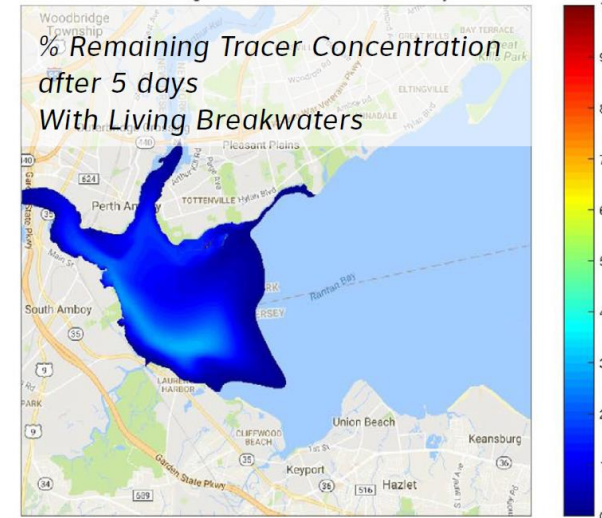
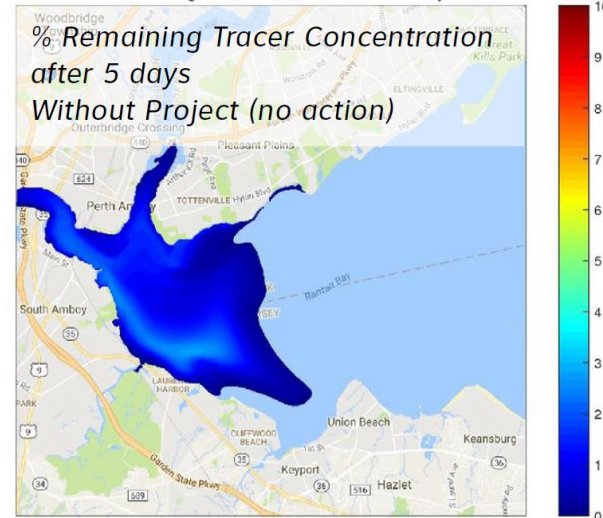
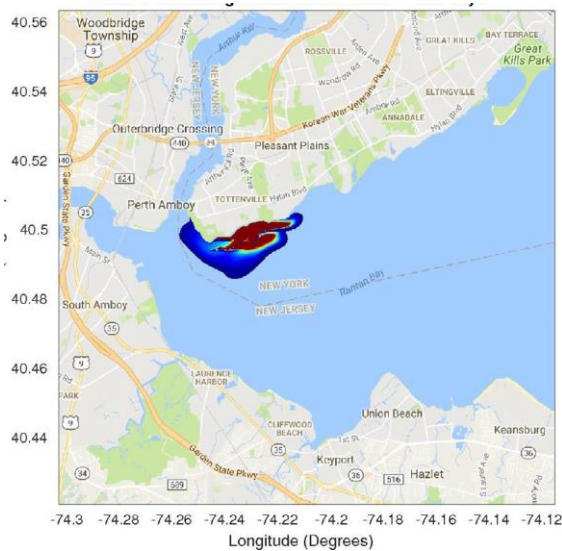
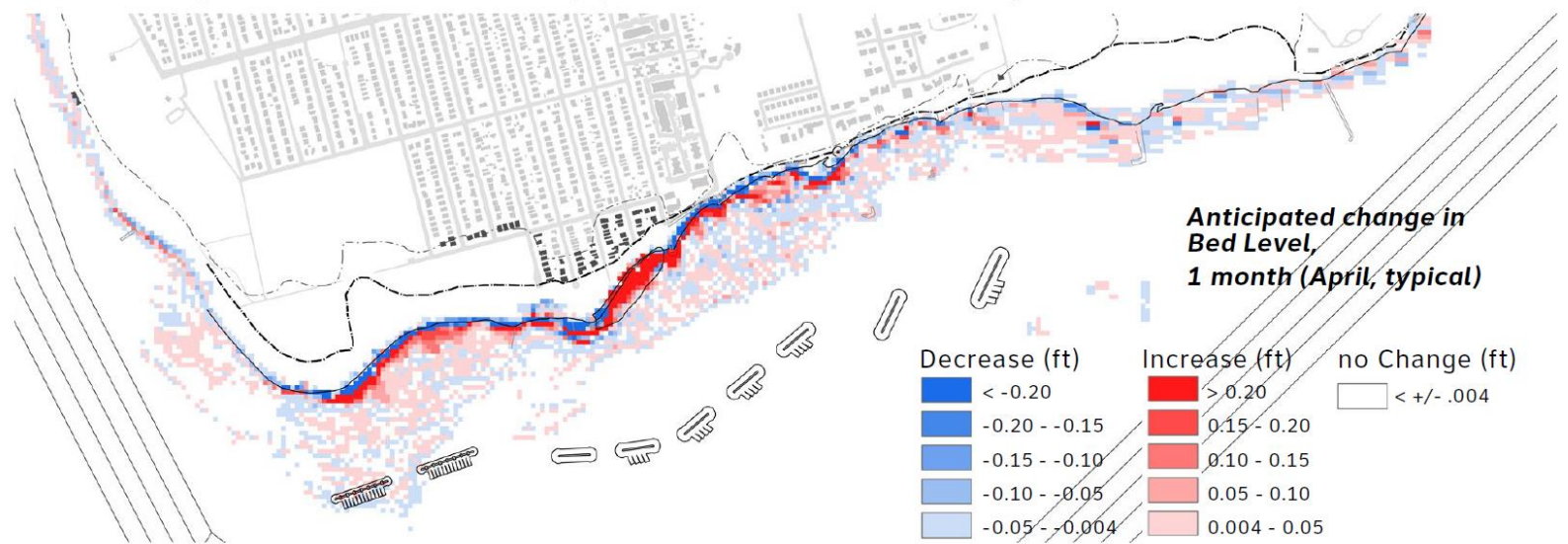
wave attenuation

- risk reduction
- reduce waves particularly along shoreline where vulnerable infrastructure and buildings are located in high energy wave zones

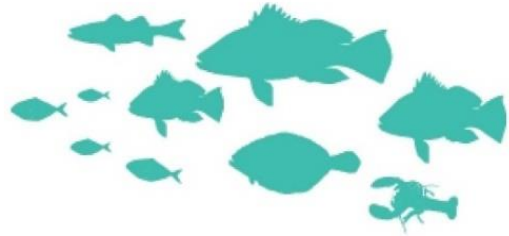


Modeling to Confirm Details

sediment motion,
tidal flushing
(water quality)



Ecological Enhancement



ECOLOGICAL ENHANCEMENT

- **CREATE HABITAT**
- **INCREASE BIODIVERSITY**
- **IMPROVE ECOSYSTEM HEALTH**



Ecological Enhancement

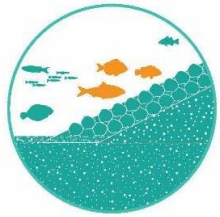
target species groups



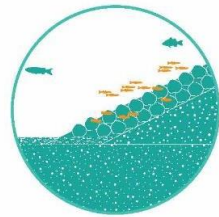
HABITAT FORMING
SPECIES



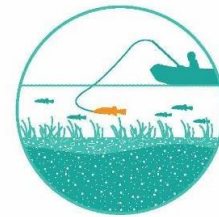
MOTILE BENTHIC
INVERTEBRATES



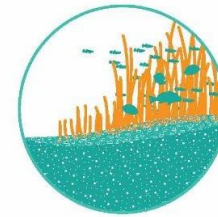
STRUCTURE
ORIENTED REEF
FISH



STRUCTURE
ORIENTED FORAGE
FISH



TRANSIENT
RECREATIONAL AND
COMMERCIAL FISHERY



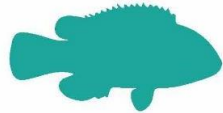
VEGETATION



EASTERN OYSTER
CRASSOSTREA VIRGINICA



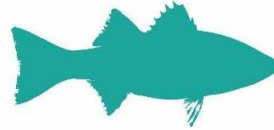
BLUE CRAB
CALLINECTES SAPIDUS



TAUTOG
TAUTOGA ONITIS



ATLANTIC MENHADEN
BREVOORTIA TYRANNUS



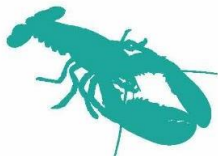
ATLANTIC STRIPED BASS
MORONE SAXATILIS



EELGRASS
ZOSTERA MARINA



BLUE MUSSEL
MYTILUS EDULIS



AMERICAN LOBSTER
HOMARUS AMERICANUS



BLACK SEA BASS
CENTROPRISTIS STRIATA



ATLANTIC SILVERSIDES
MENIDIA MENIDIA



BLUEFISH
POMATOMUS SALTATRIX



HARD CLAM
MERCENARIA MERCENARIA



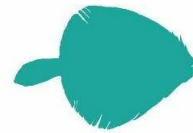
HORSESHOE CRAB
LIMULUS POLYPHEMUS



CUNNER
TAUTOGOLABRUS ADSPERSUS



BAY ANCHOVY
ANCHOA MITCHILLI

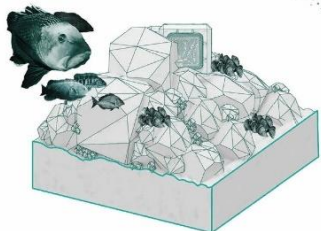
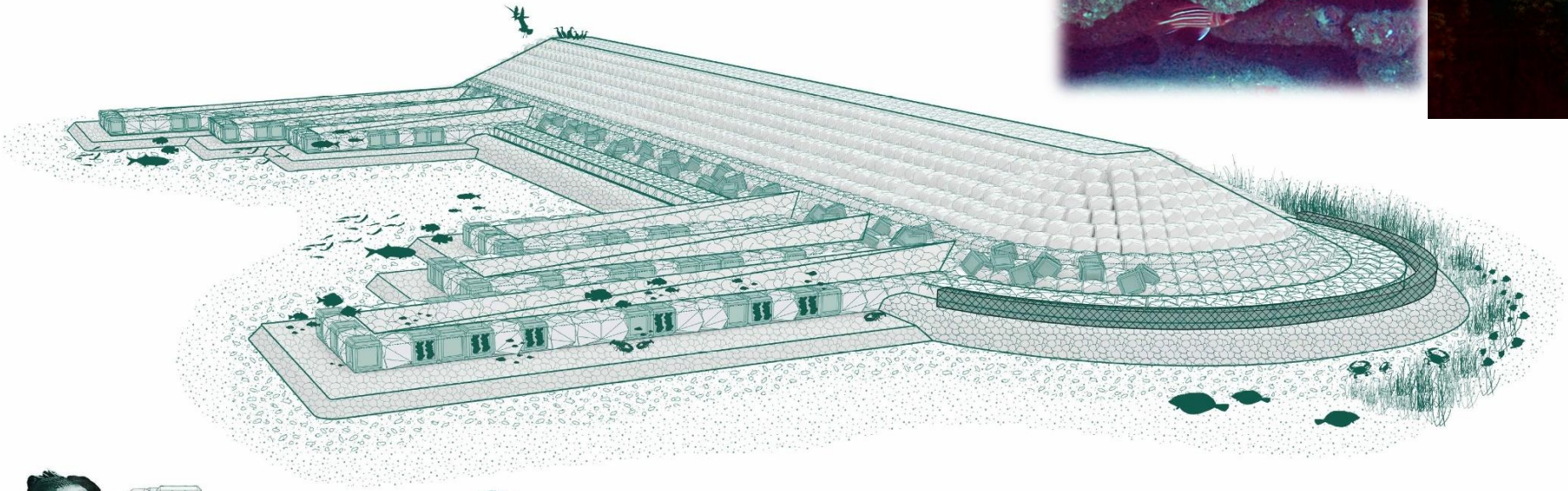
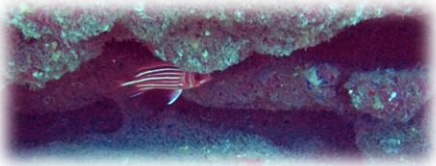


WINDOWPANE
SCOPHTHALMUS AQUOSUS

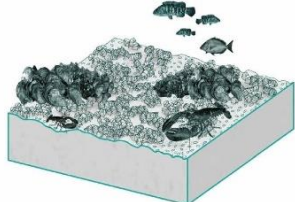


Ecological Design

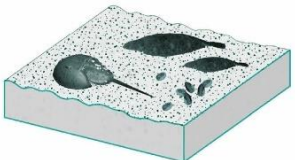
ecology thrives in complexity



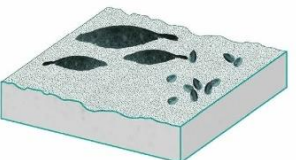
HARD BOTTOM OR HARD/ROCKY
Greater than 64 mm (2.5")



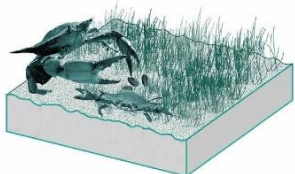
LARGE GRAIN
64 mm (2.5") to 2mm (.07")



SMALL GRAIN
2mm (.07") to .063mm (.002")



FINE GRAIN
Less than .063mm (.002")



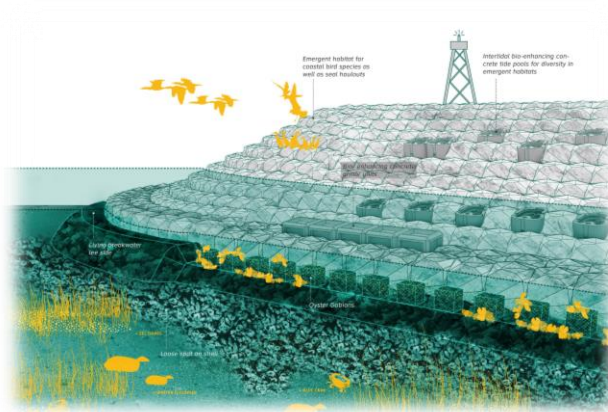
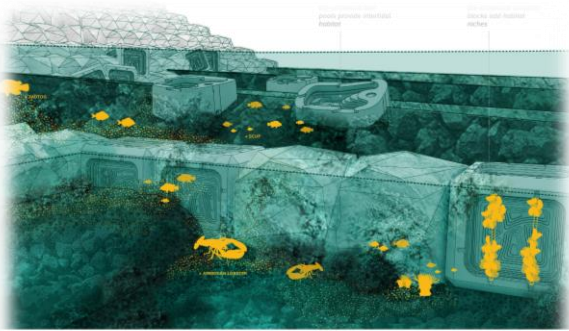
VEGETATION
Small to fine grain

rocky --- varying grain sizes --- vegetation



Ecological Design

reef streets

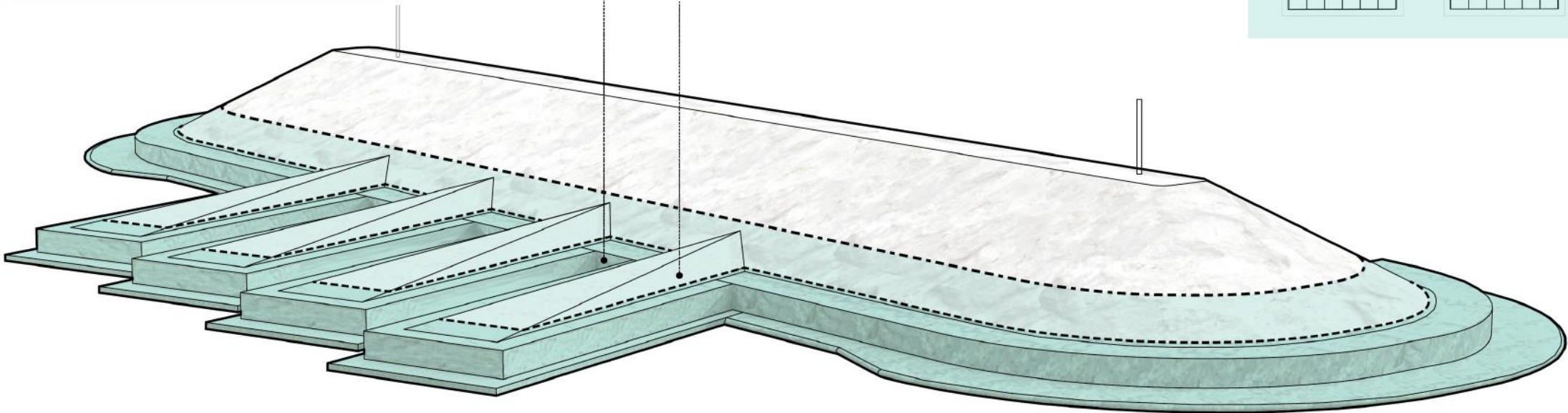


BREAKWATER REEF STREET

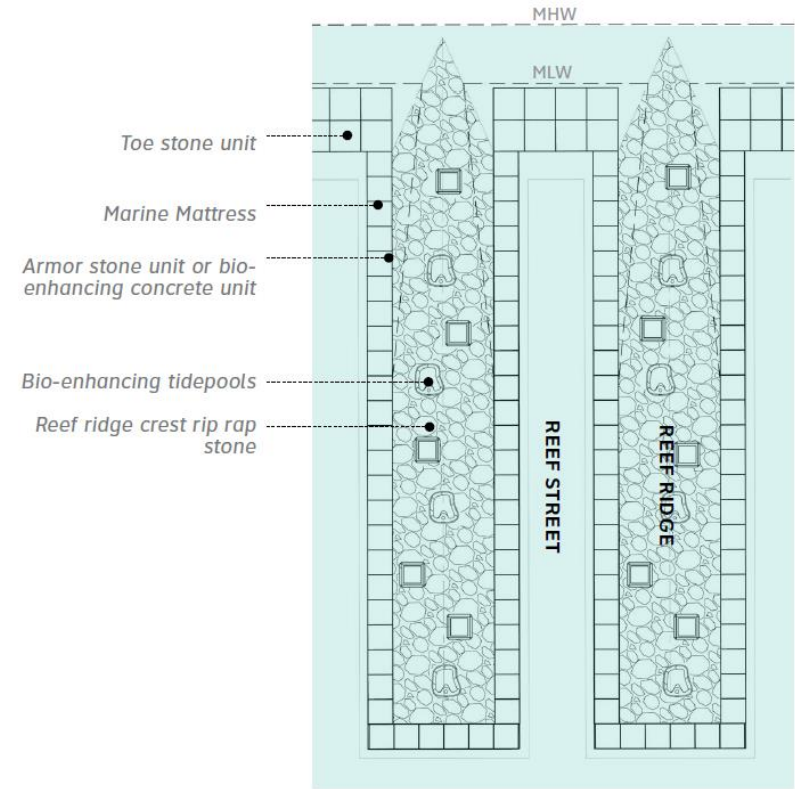
The Space between reef ridges

BREAKWATER REEF RIDGE

Rocky protrusion from main breakwater



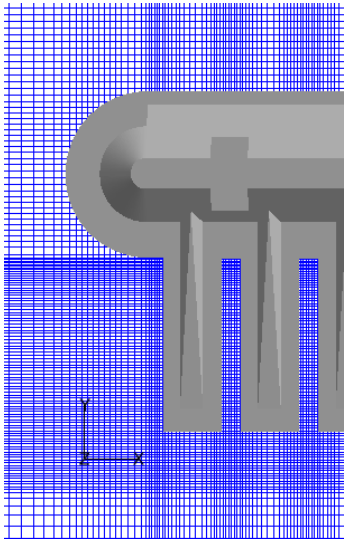
MAIN BREAKWATER SEGMENT



Detailed modeling

testing ecological elements

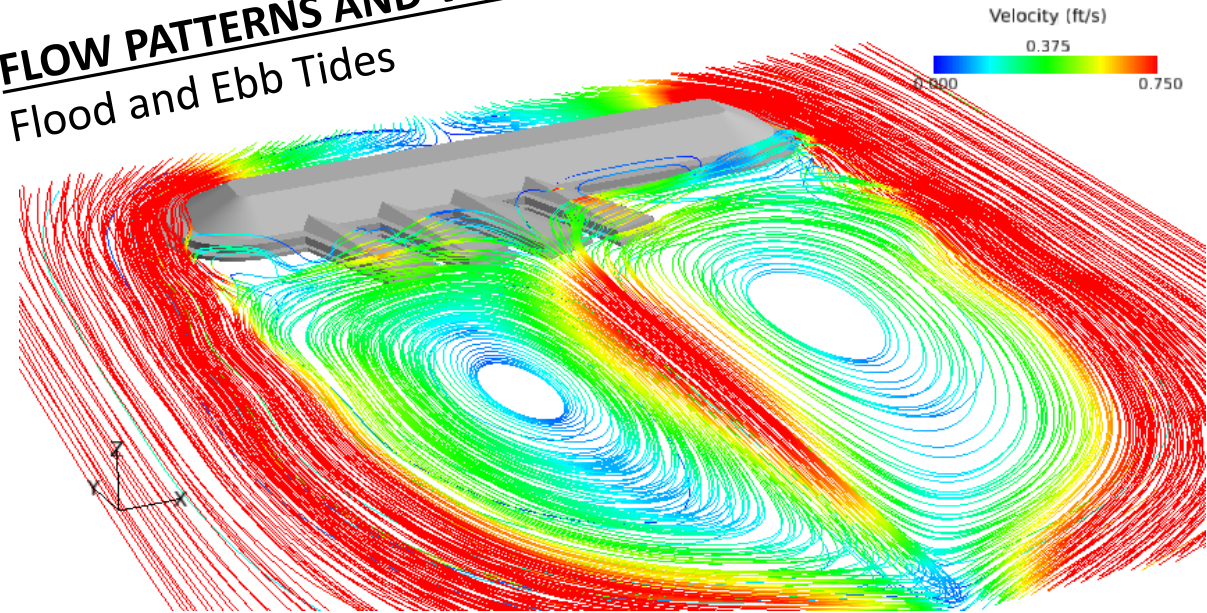
3D CFD model



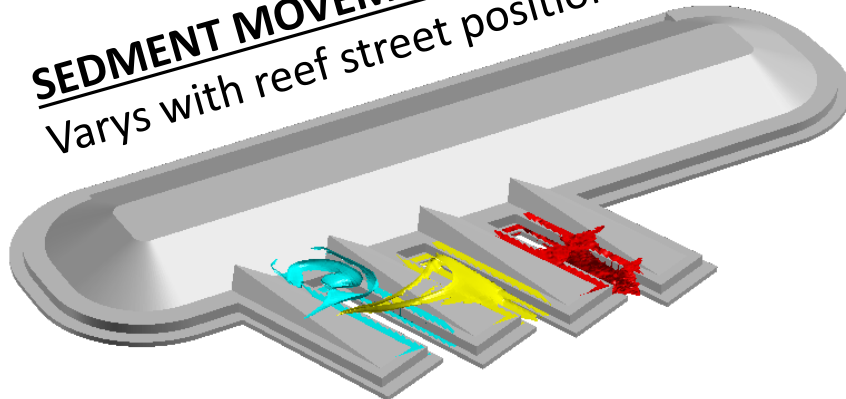
GRID

Range from
0.25 to 2.5 ft
> 2.5M cells

FLOW PATTERNS AND VELOCITIES Flood and Ebb Tides



SEDIMENT MOVEMENT Varys with reef street position



Ecological Units

bio-enhancing concrete armor units and tide pools

- function structurally as **armor stone**
- promotes the recruitment of marine plants and animals through science based **chemical composition** (eliminating and replacing certain negative elements within the concrete mix) and **physical design** (providing complex micro-surfaces)



BIO-ENHANCING CONCRETE UNITS



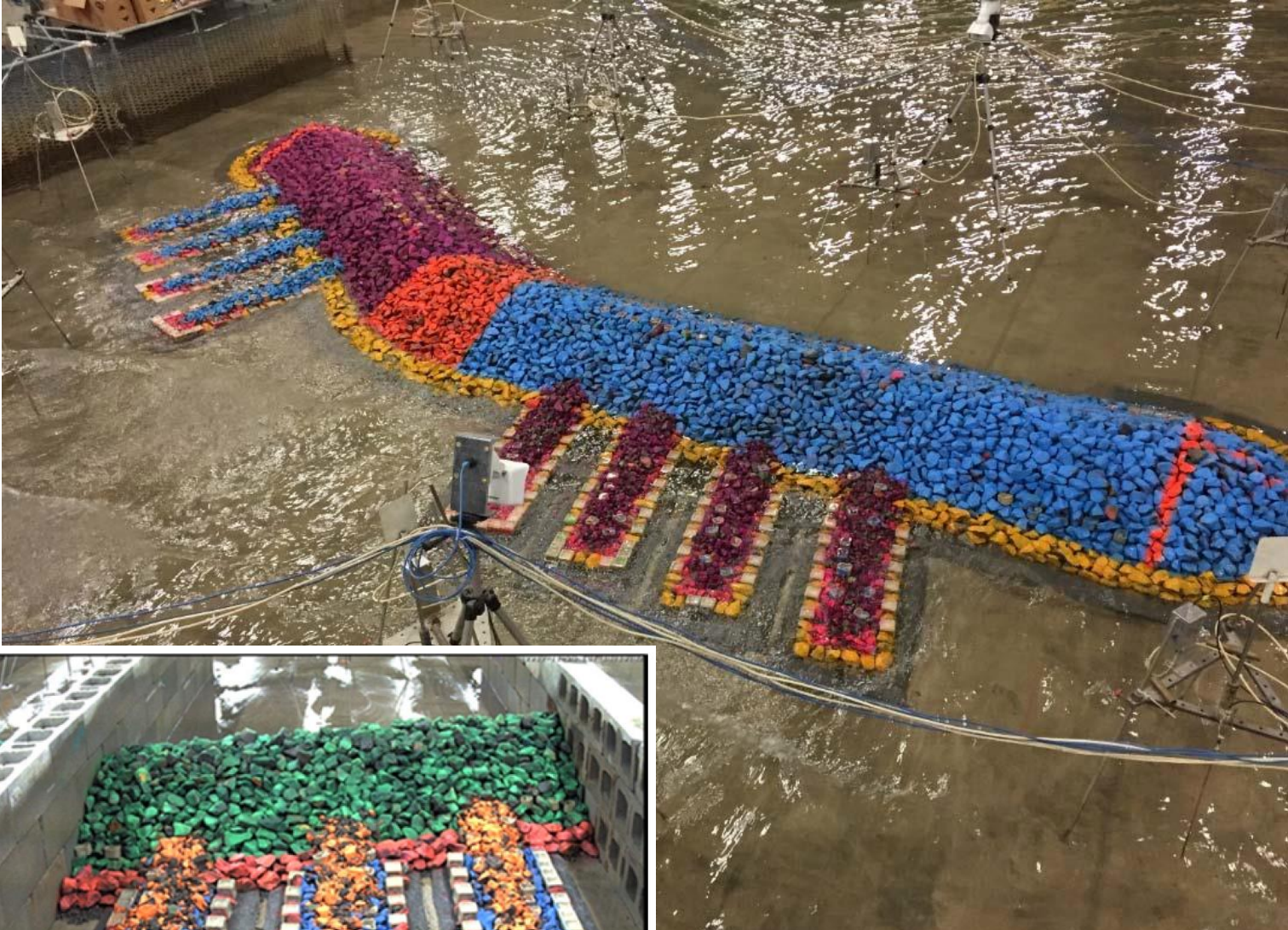
TIDE POOL UNITS



Physical Modeling

testing unique features

Reverse armor on reef ridges



Before Testing

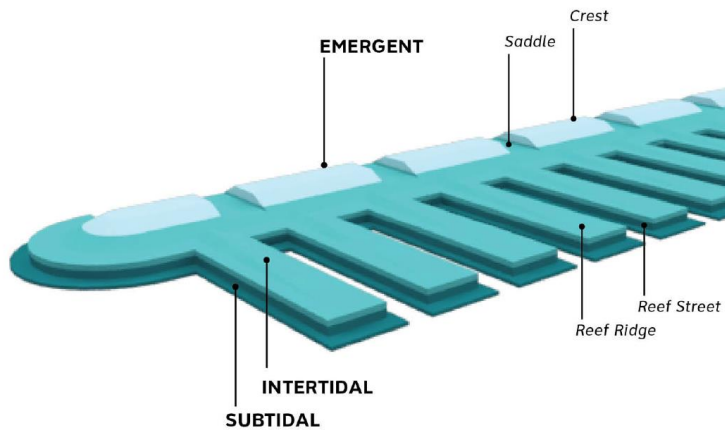


Cumulative Damage after Testing



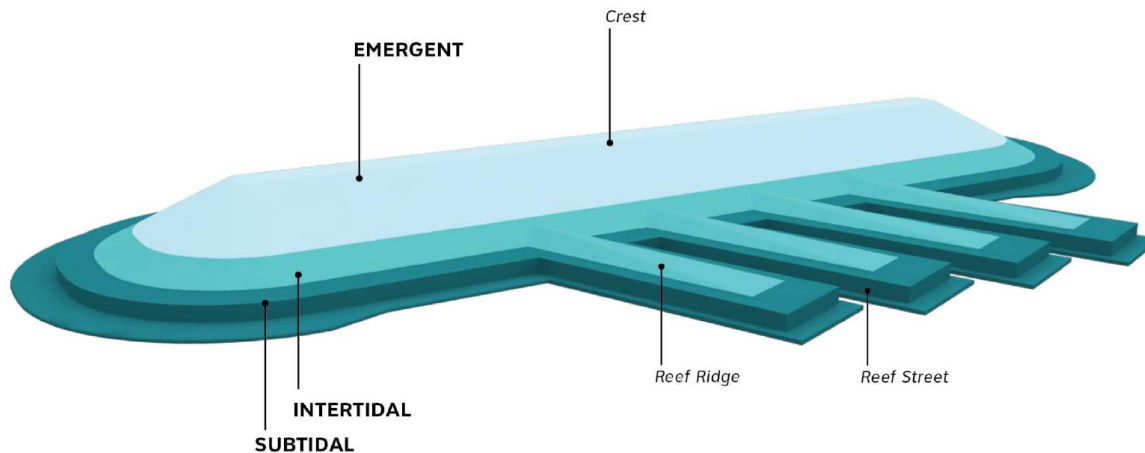
Design Layout

shoreline retention, wave attenuation,
varied breakwater types, ecology



Type A

- low crested (+5 NAVD)
- crenelated crest



Type B

+14 NAVD

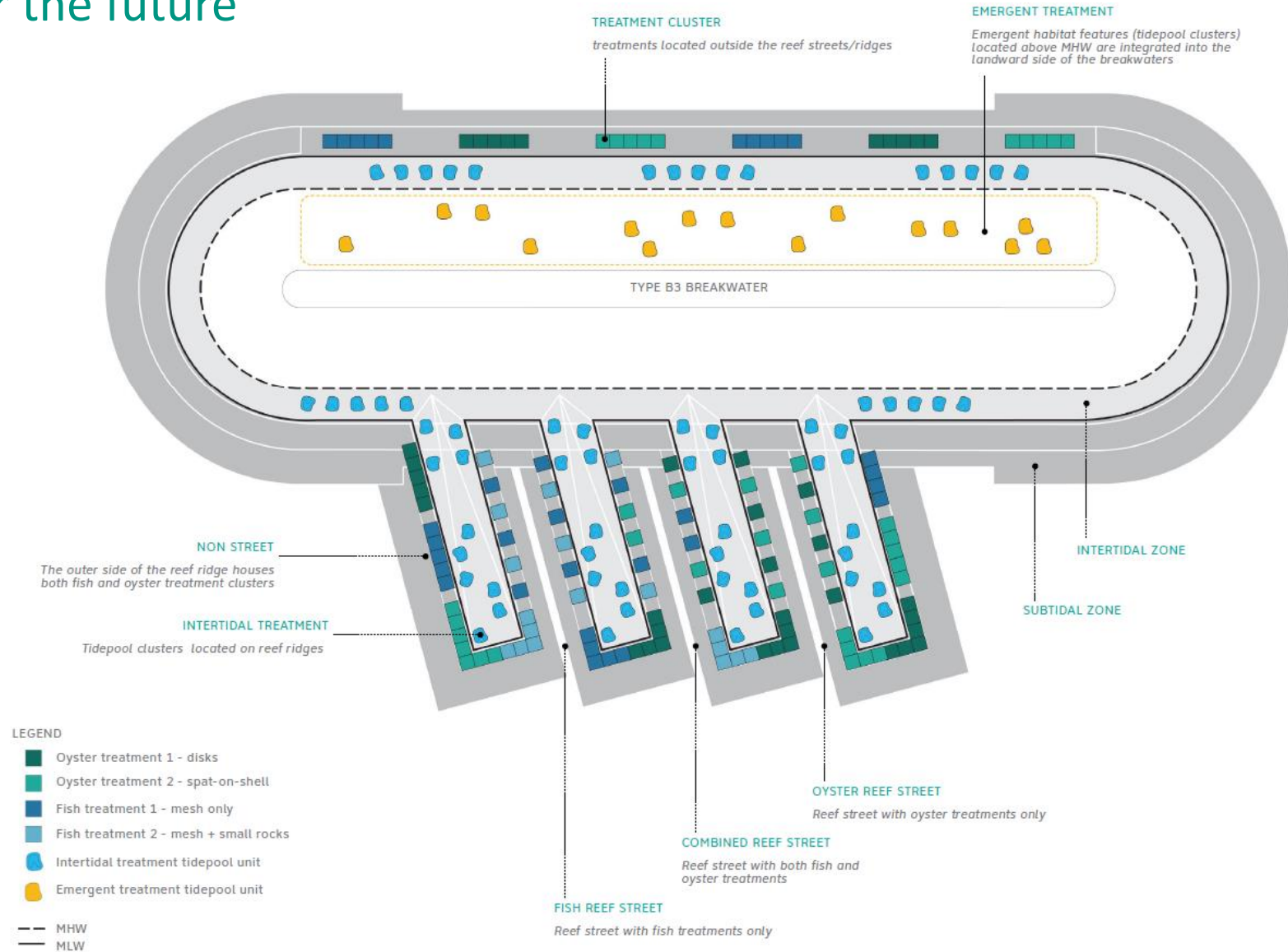
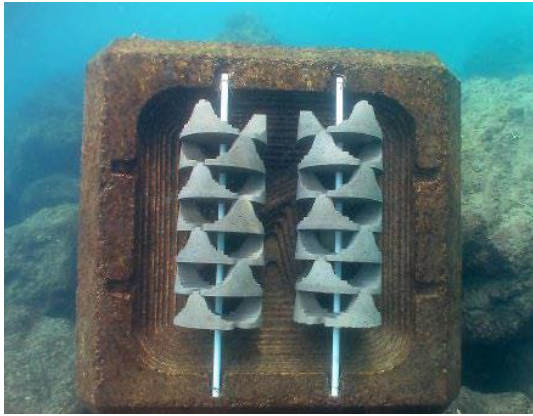
Type C

- deeper water
- less intertidal reef area



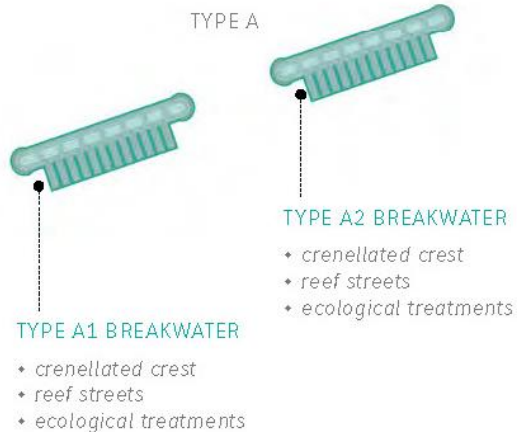
Ecological Treatment Layouts

habitat now, science for the future



Ecological Treatment Layouts

habitat now, science for the future



CONTROL SEGMENT
Segment receives no ecological treatments for monitoring purposes



TYPE B2 BREAKWATER

- reef streets

TYPE B

TYPE B3 BREAKWATER

- reef streets
- ecological treatments

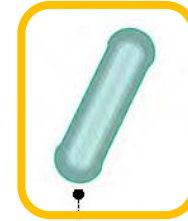
TYPE B4 BREAKWATER

- reef streets
- ecological treatments

TYPE B5 BREAKWATER

- reef streets
- ecological treatments

partial control



TYPE C1 BREAKWATER

- ecological treatments

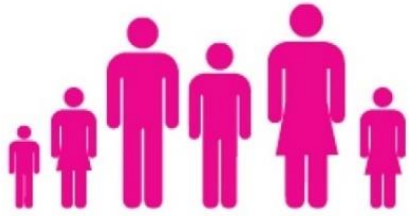
TYPE C

TYPE C1 BREAKWATER

- reef streets
- ecological treatments
- intertidal berm



Social Resilience



SOCIAL RESILIENCY

- **IMPROVE ACCESS TO THE SHORELINE & NEARSHORE WATERS**
- **RAISE AWARENESS OF RISK**
- **ENCOURAGE STEWARDSHIP**



Social Resilience

experience, education, stewardship

Programming and education are a critical part of the Living Breakwaters social resiliency project objectives, encouraging residents and visitors to engage with the shoreline and near-shore waters, learn about resiliency initiatives and ecological restoration activities, and become stewards of the harbor.

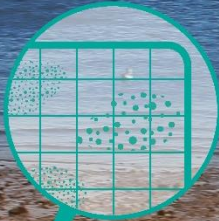


PERMANENT MONITORING STATION



VISUAL INSPECTION OF BREAKWATERS AFTER STORM

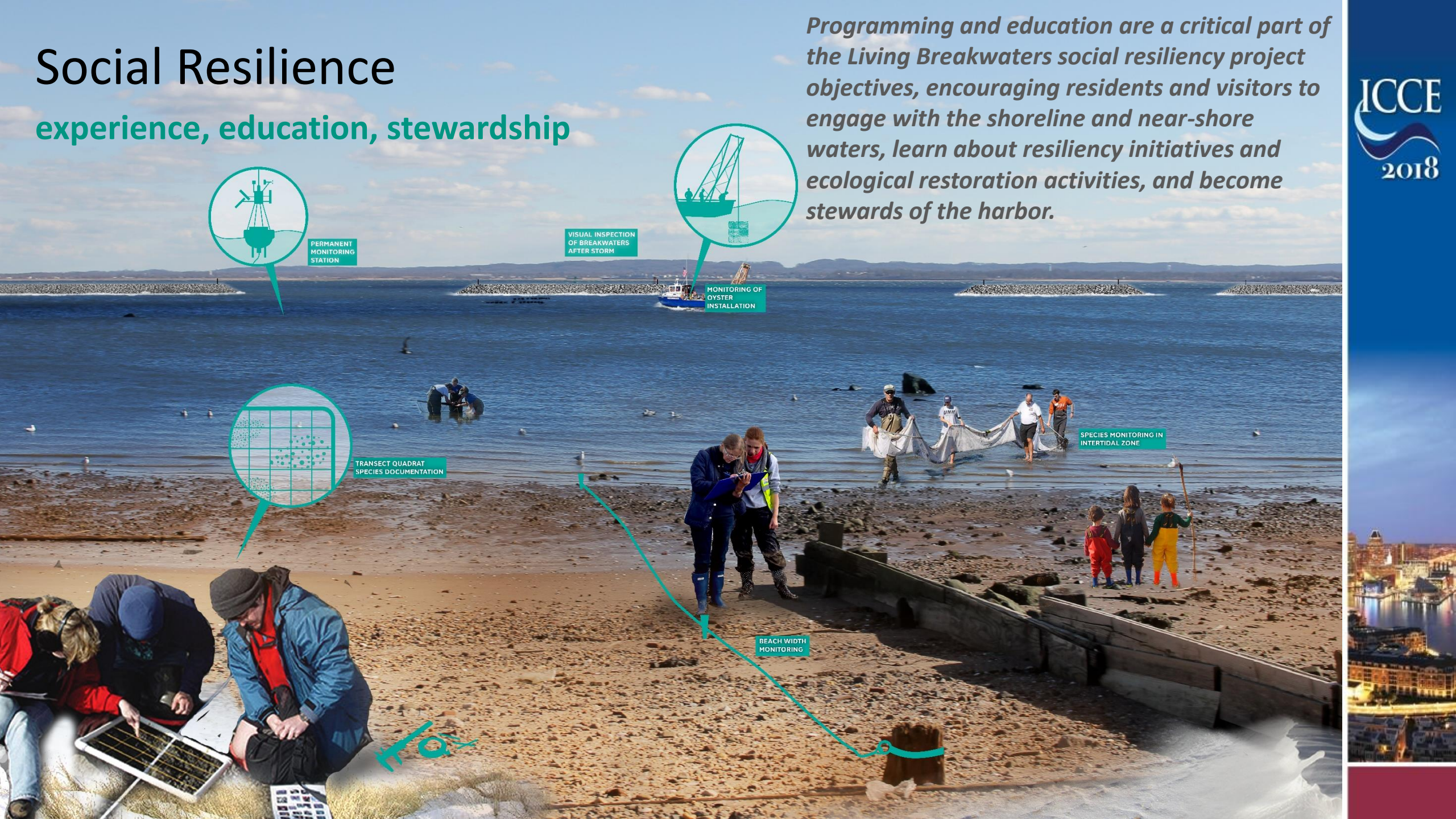
MONITORING OF OYSTER INSTALLATION



TRANSECT QUADRAT SPECIES DOCUMENTATION

SPECIES MONITORING IN INTERTIDAL ZONE

BEACH WIDTH MONITORING





Open House- January 25, 2017 - PS 6, Tottenville



Clean Ocean Action Staten Island Student Summit - October 25, 2017



Staten Island Children Museum - September 24, 2016



Submerge Festival, Hudson River Park - September 16, 2017



EDUCATION & OUTREACH



Governor's Office of Storm Recovery

SCAPE TEAM



Open House - January 25, 2017 - PS 6, Tottenville



Species and habitat ID with SCAPE



Seining with BOP



Guided Class Visits



ICCE
2018

EDUCATION & OUTREACH



Governor's Office of Storm Recovery

SCAPE TEAM

Thank You!



Governor's Office of Storm Recovery



Living Breakwaters Design Team

SCAPE



ICCE
2018



Questions



Paul Tschirky (ptschirky@geosyntec.com)

Pippa Brashear (pippa@scapestudio.com)

