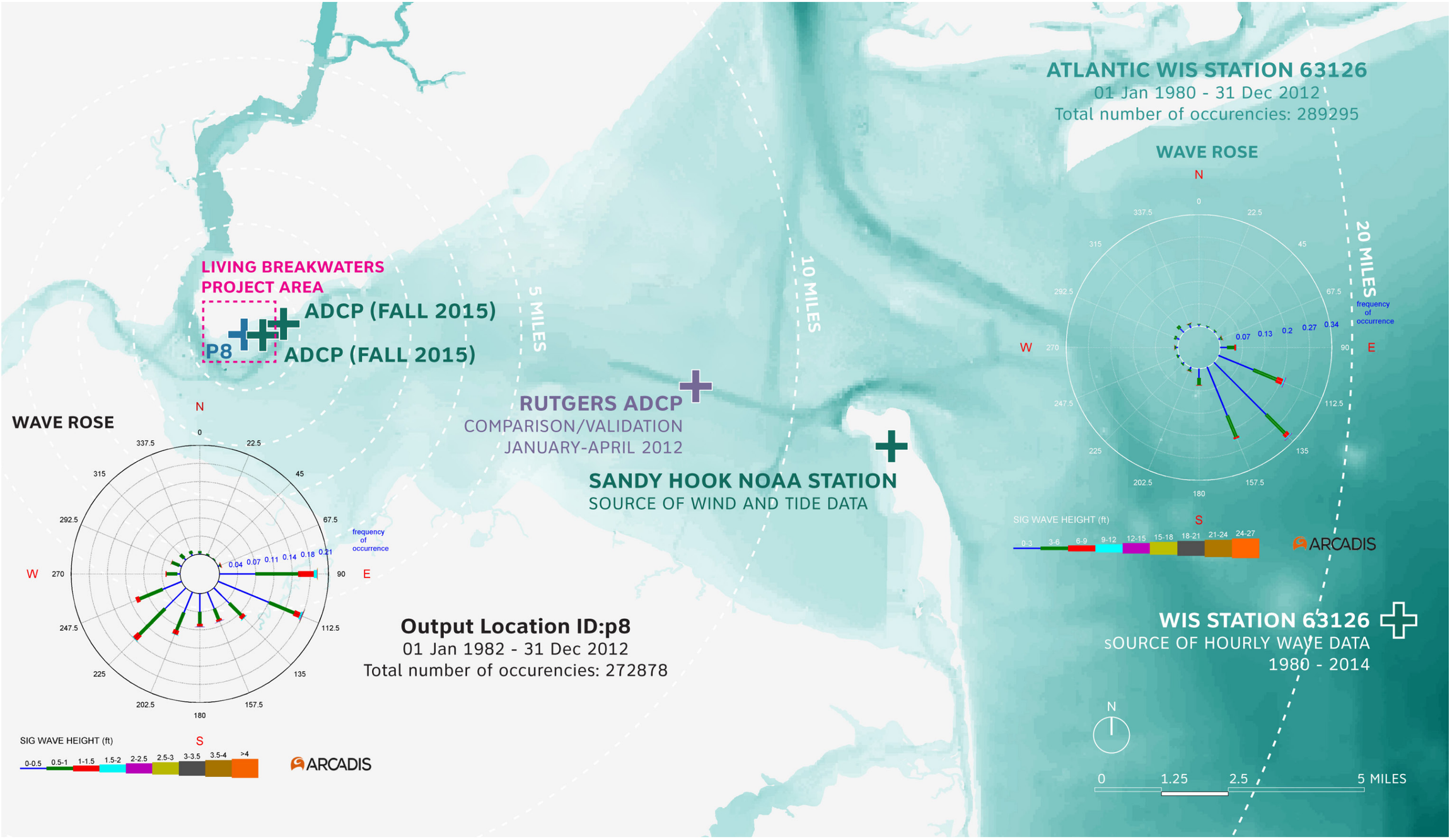
WAVES & STORM WAVES: EXISTING CONDITIONS

What do we know about the waves here?
What analysis of waves has been done?

ANALYSIS PERFORMED TO UNDERSTAND THE WAVE CONDITIONS AT TOTTENVILLE

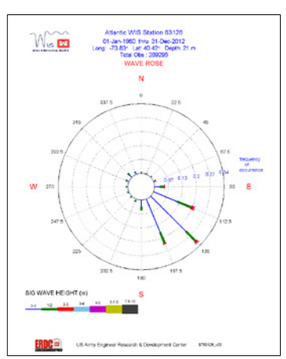
Wave transformation modeling using wave hindcast data from the USACE Wave Information Station (WIS) and SWAN model



WAVE DIRECTION IN THE PROJECT AREA

Wave transformation modeling results

Offshore Wave Data

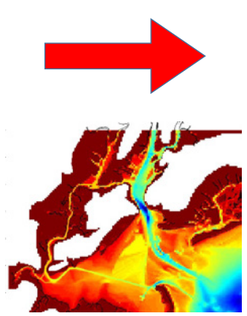


30 YEARS (1982 - 2012)

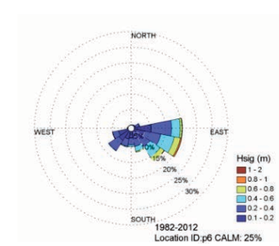
+

Winds
(locally generated waves)

Wave Transformation Model (SWAN)

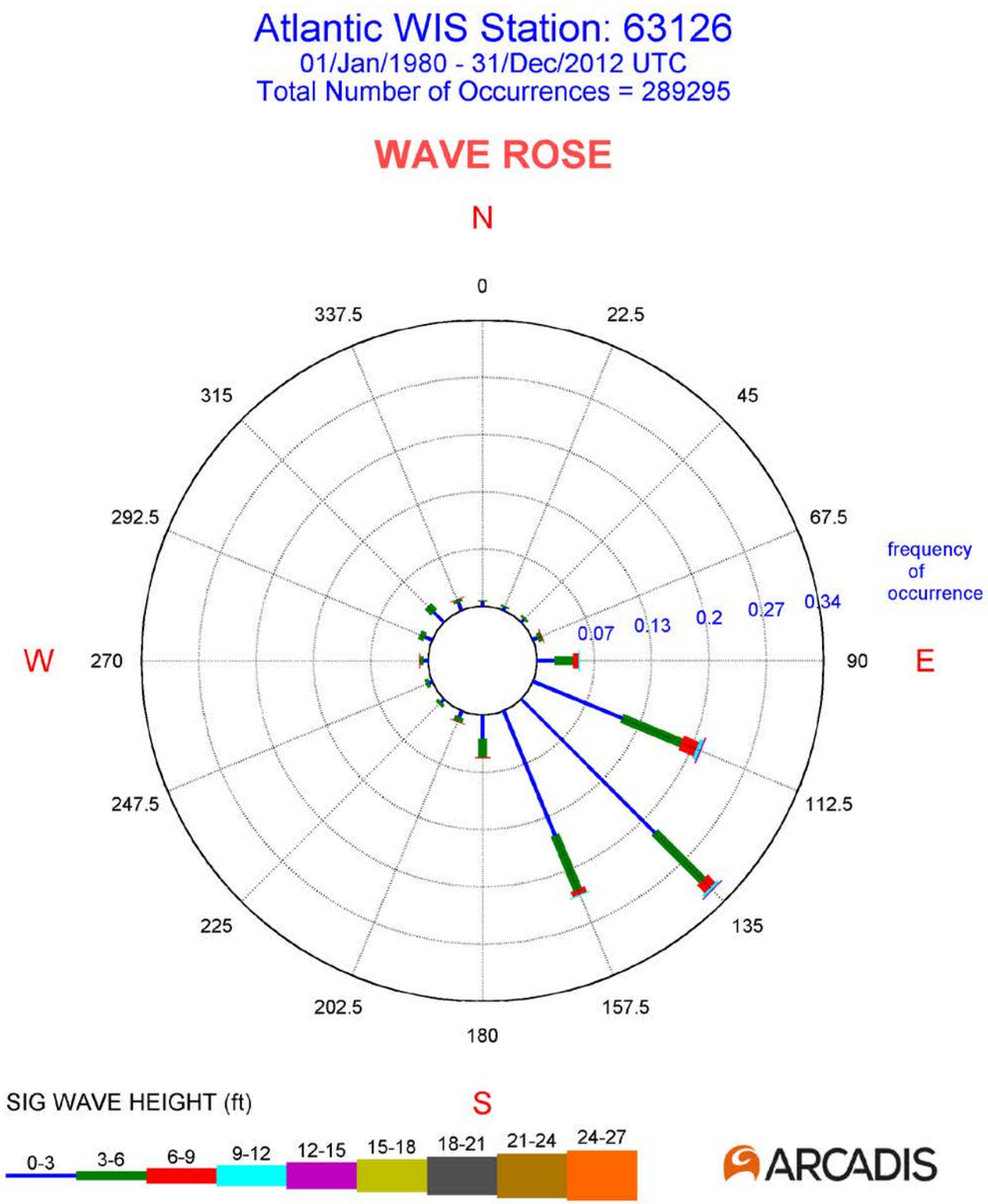


Nearshore Wave Climate



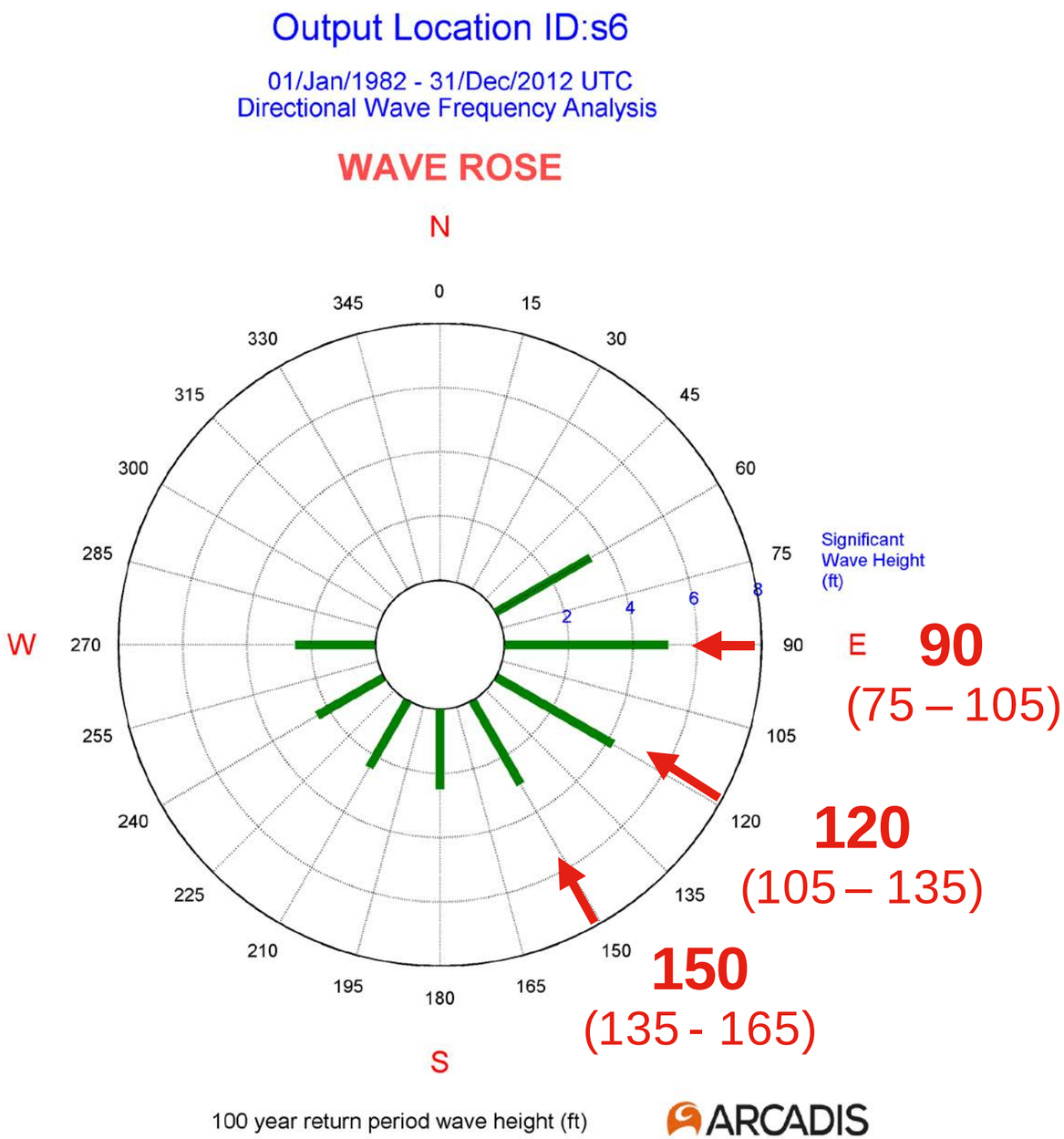
WHAT ARE THE WAVES LIKE HERE?

All waves / day to day



WHAT ARE THE WAVES LIKE HERE DURING STORM EVENTS?

During severe storm events (1% annual chance storm event)

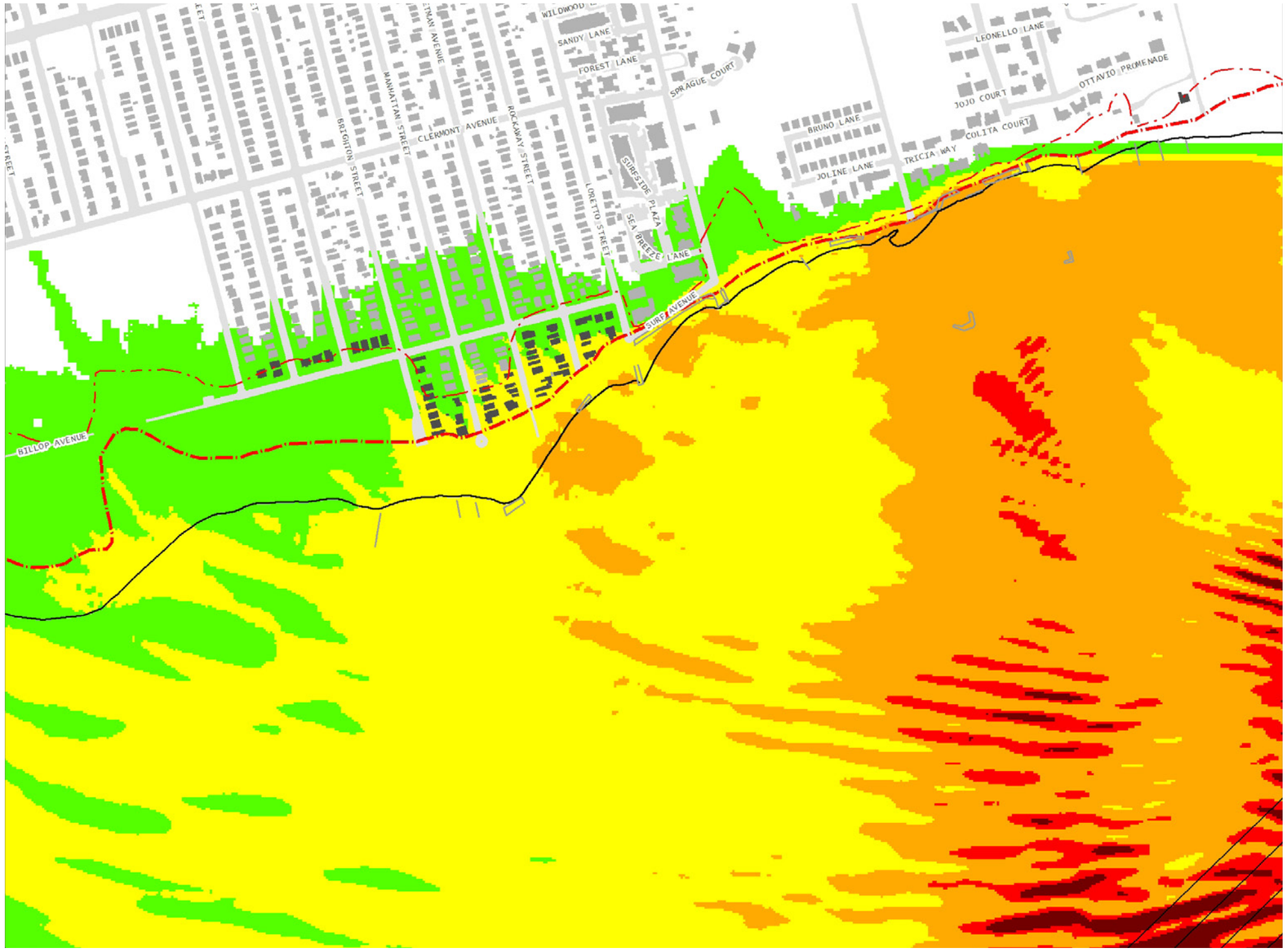


100-YEAR RETURN PERIOD (1% ANNUAL CHANCE)
WAVE HEIGHT AND PERIOD BY DIRECTION

DIRECTION (DEGREES FROM N)	WAVE HEIGHT (FT)	WAVE PERIOD (S)
90 (75 - 105)	5.3	5.0
120 (105 - 135)	4.2	4.8
150 (135 - 165)	3.0	4.0

ANTICIAPTED WAVE HEIGHTS IN A 100 YEAR STORM (1% ANNUAL CHANCE EVENT)

Funwave modeling results, waves from the east



LEGEND

- SHORELINE RESTORATION
- SHORELINE STRUCTURES
- 2015 MHW LINE (2.08 NAVD88)
- V ZONE
- LIMWA
- BUILDINGS IN LIMWA
- BUILDINGS
- USACE NAVIGATION CHANNEL

WAVE HEIGHT (FT)

- < 1.5’
- 1.5’ - 3.0’
- 3.0’ - 4.5’
- 4.5’ - 5.3’
- > 5.3’

0’ 500’ 1000’ 2000’

NO ACTION

100 YR STORM : 12.9’ NAVD88

WAVE DIRECTION: EAST

Governor’s Office of Storm Recovery

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
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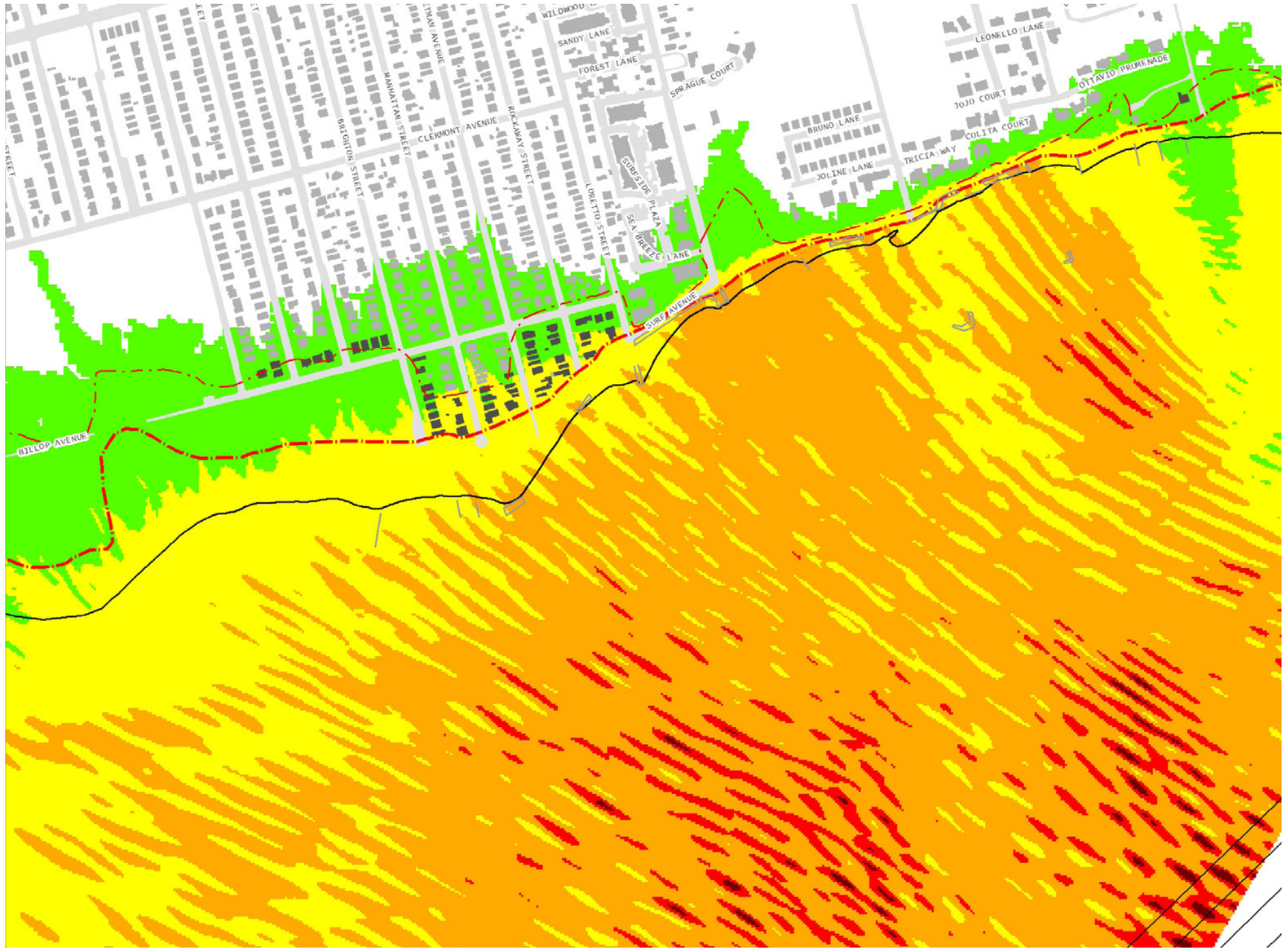
PRUDENT ENGINEERING

ANTICIAPTED WAVE HEIGHTS IN A 100 YEAR STORM (1% ANNUAL CHANCE EVENT)

Funwave modeling results, waves from the east - southeast



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- > 5.3’

0’ 500’ 1000’ 2000’

NO ACTION

100 YR STORM : 12.9’ NAVD88

WAVE DIRECTION: EAST - SOUTHEAST

Governor’s Office of Storm Recovery

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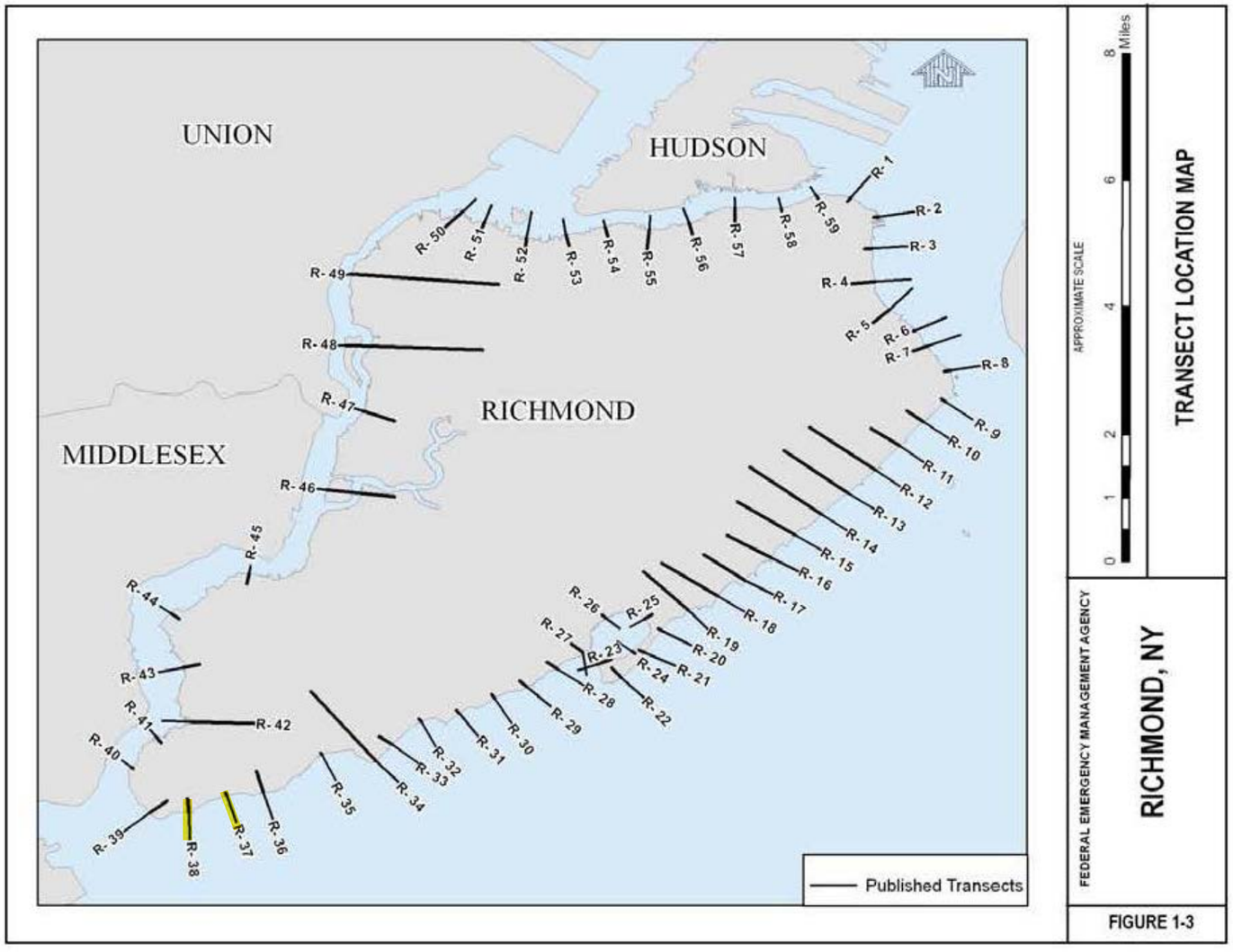
OUR ANALYSIS INDICATED SIMILAR STORM WAVE HEIGHTS TO WHAT FEMA ESTIMATES

FEMA Flood Insurance Study stillwater surge and significant wave heights



Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (ft NAVD88) Range of Stillwater Elevations[2](ft NAVD88)			
		Coordinates	Significant Wave Height (ft)	Peak Wave Period (sec)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Raritan Bay	R-36	N 40.502497 W 74.222385	6.65	5.49	8 6.9 - 8.1	11.2	12.7 12.5 - 12.7	16.2 16.1 - 16.3
Raritan Bay	R-37	N 40.501746 W 74.231526	6.17	5.27	8.1	11.3	12.8	16.3

FEMA

Preliminary:
DECEMEBER 5, 2013

FLOOD INSURANCE STUDY NUMBER
360497V000B
Version Number 1.0.0.0

FLOOD INSURANCE STUDY
FEDERAL EMERGENCY MANAGEMENT AGENCY

VOLUME 1 OF 1

CITY OF NEW YORK, NEW YORK

COMMUNITY NAME	COMMUNITY NUMBER
BRONX COUNTY	
KINGS COUNTY	
NEW YORK COUNTY	
QUEENS COUNTY	
RICHMOND COUNTY	

OUR ANALYSIS INDICATED SIMILAR STORM WAVE HEIGHTS TO WHAT FEMA ESTIMATES

FEMA FIRM map for the project area

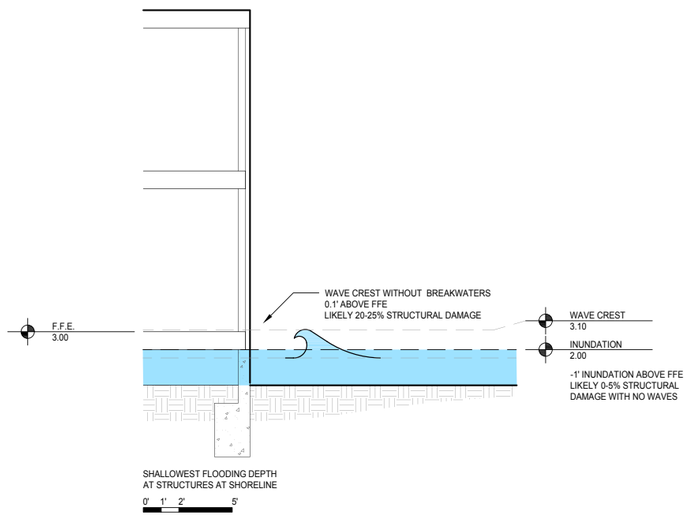
WAVES CAUSE DAMAGE
Post Hurricane Sandy destruction on Yetman Street

Source: Craig Warga /New York Daily News

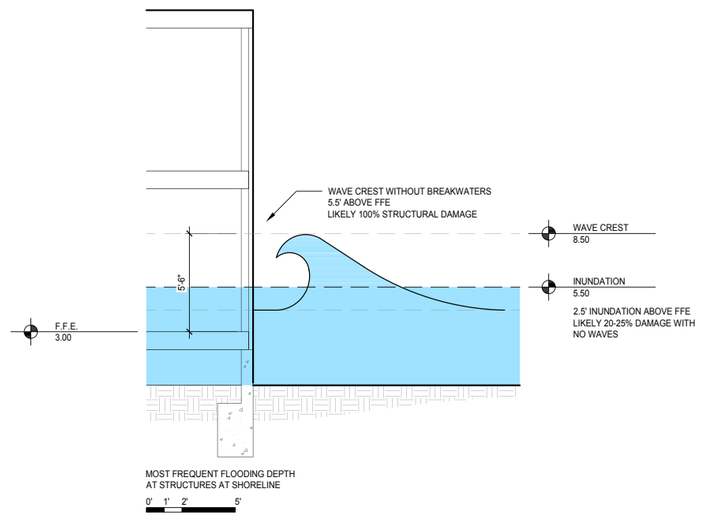
Source: (screen shot) RealEstate SI NY

SURGE + WAVES CAUSE MORE DAMAGE THAN SURGE ALONE

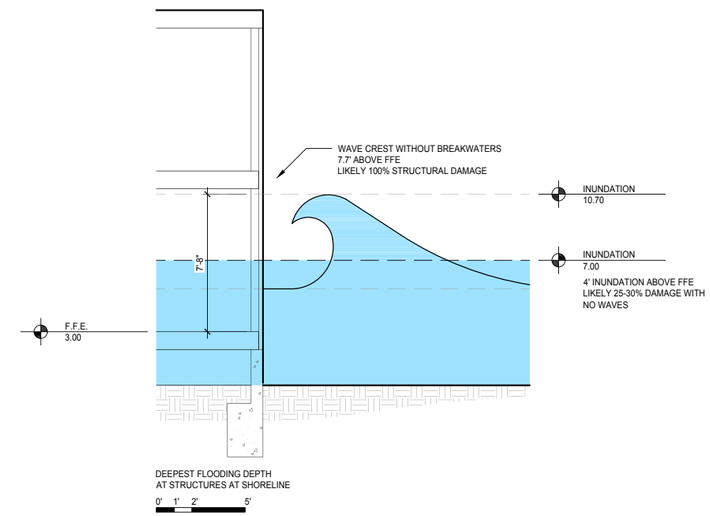
2′ OF WATER

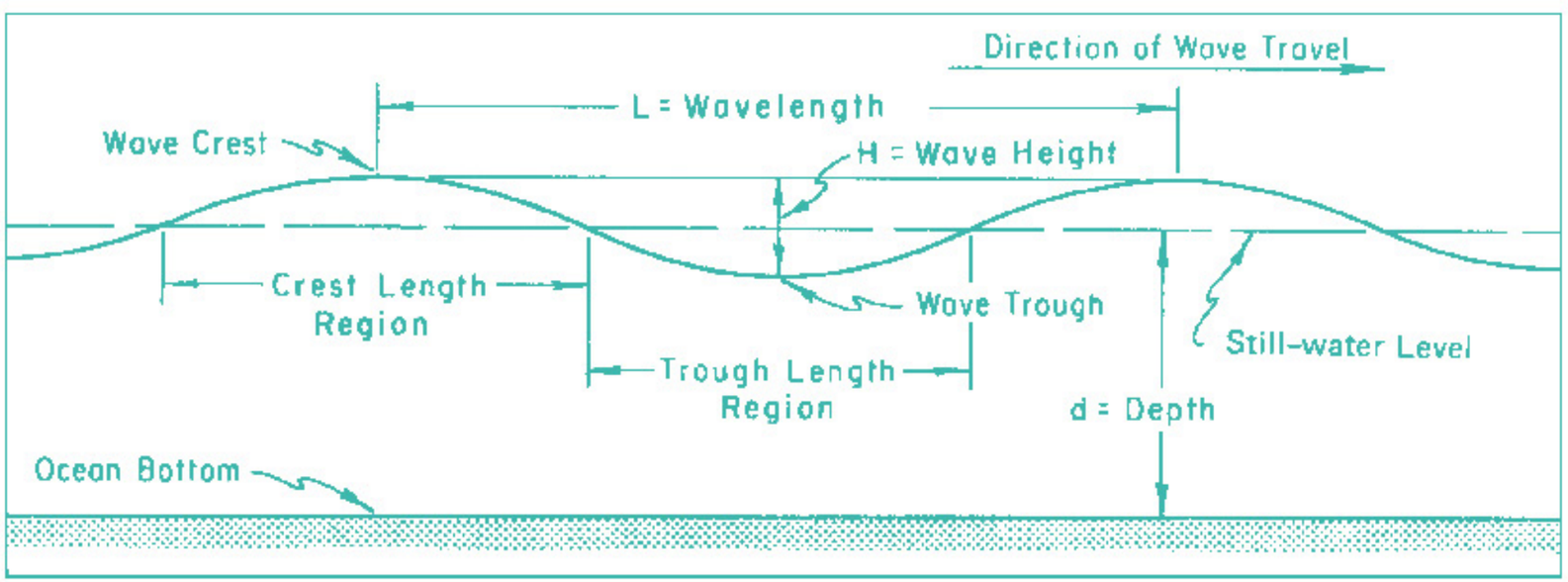


5.5′ OF WATER



7′ OF WATER





Note: Depth-limited wave height assumed to be ___ x water depth

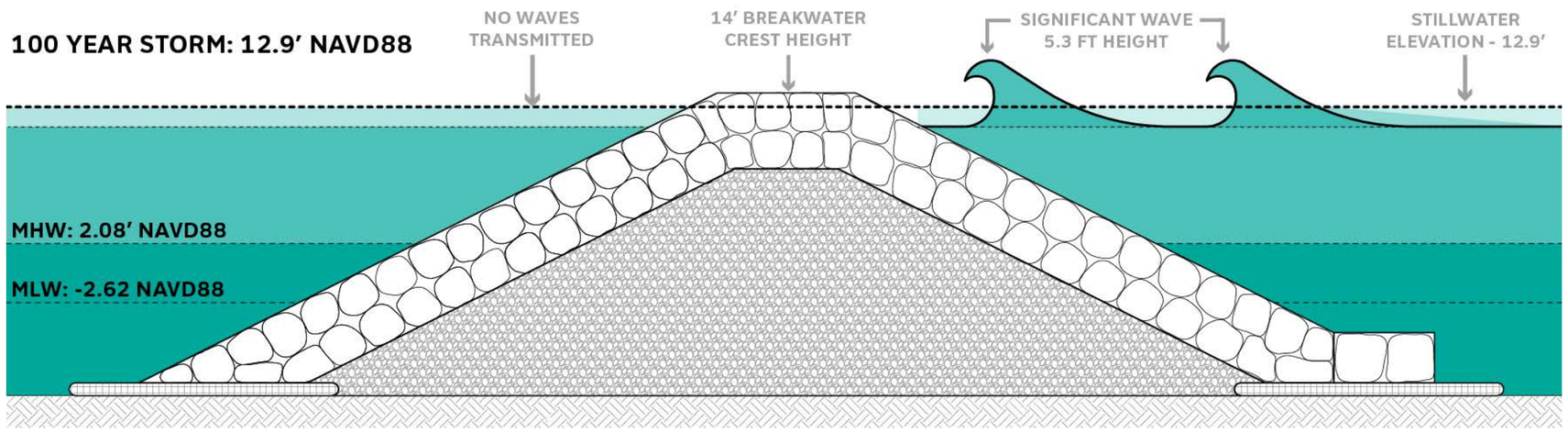
Data Source for damage functions related to water levels and wave heights: US Army Corps of Engineers. North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk - Physical Depth Damage Function Summary Report (January, 2015)

HOW BREAKWATERS ATTENUATE WAVES

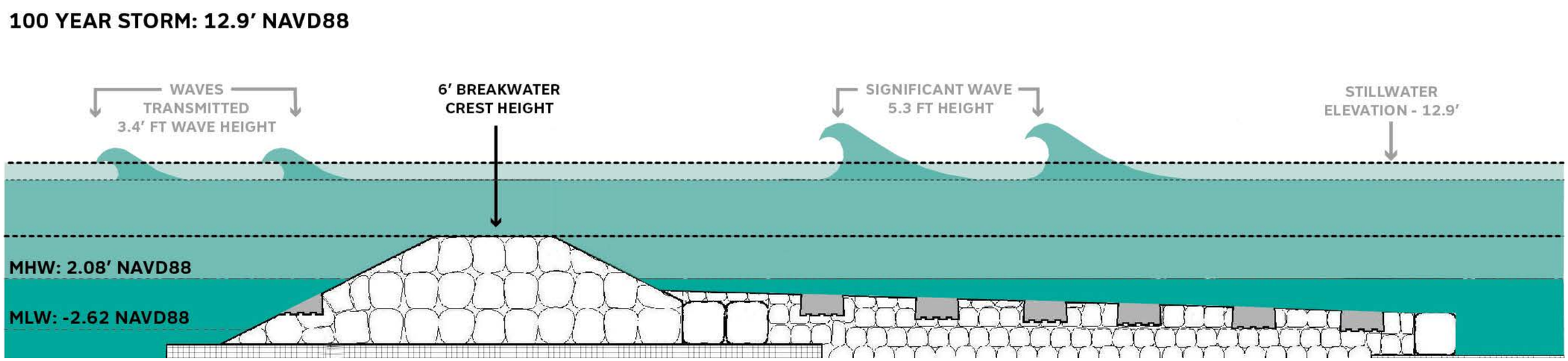
How do breakwaters reduce storm waves?
How will the Living Breakwaters change wave conditions at the site?

HOW BREAKWATERS ATTENUATE WAVES: CROSS SECTION & CREST HEIGHT

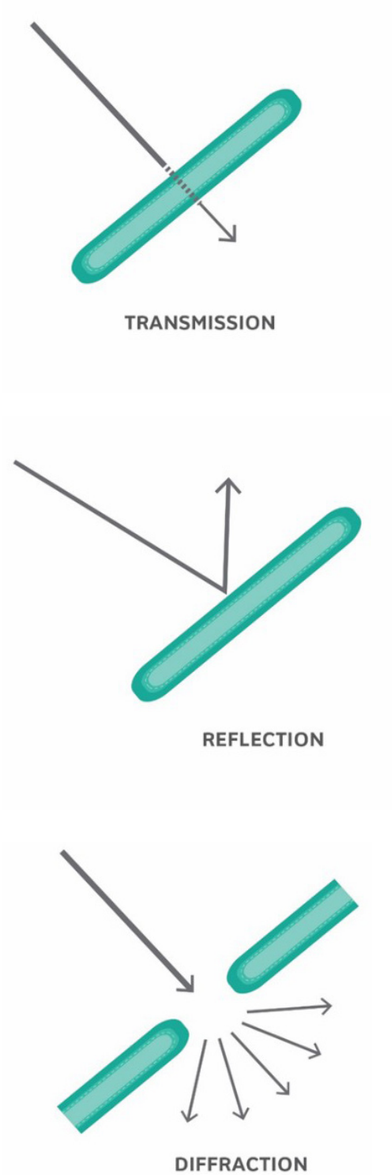
High-Crested Breakwaters

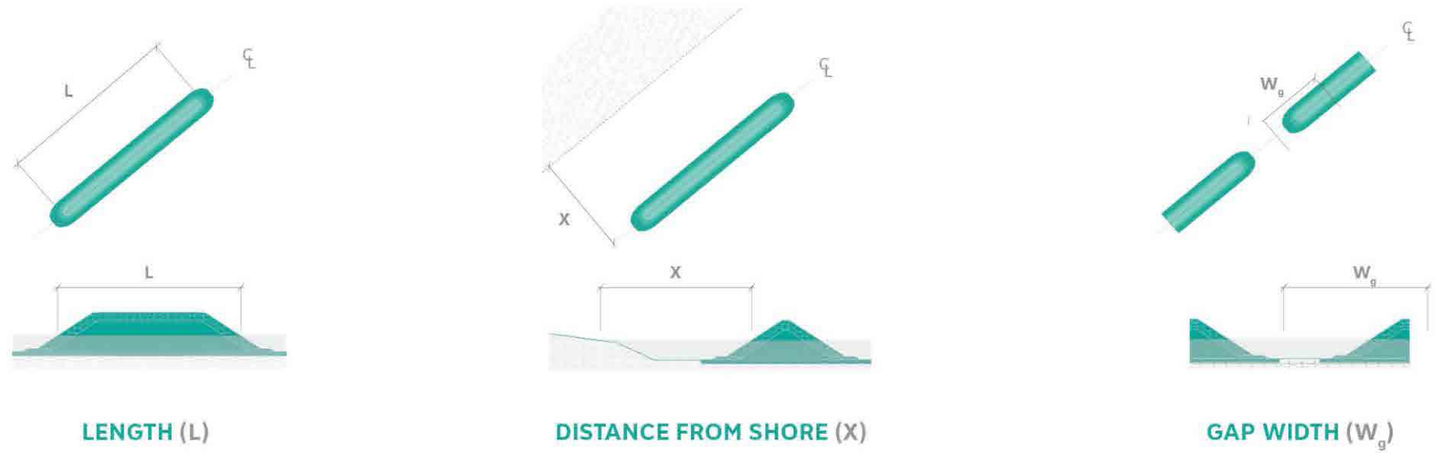


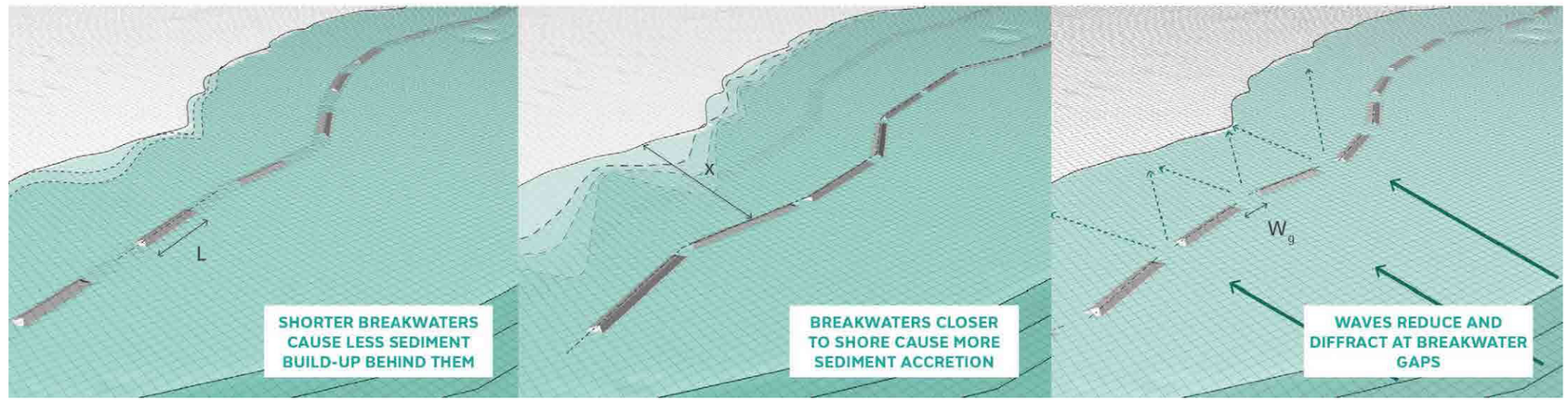
Low-Crested Breakwaters



HOW BREAKWATERS ATTENUATE WAVES

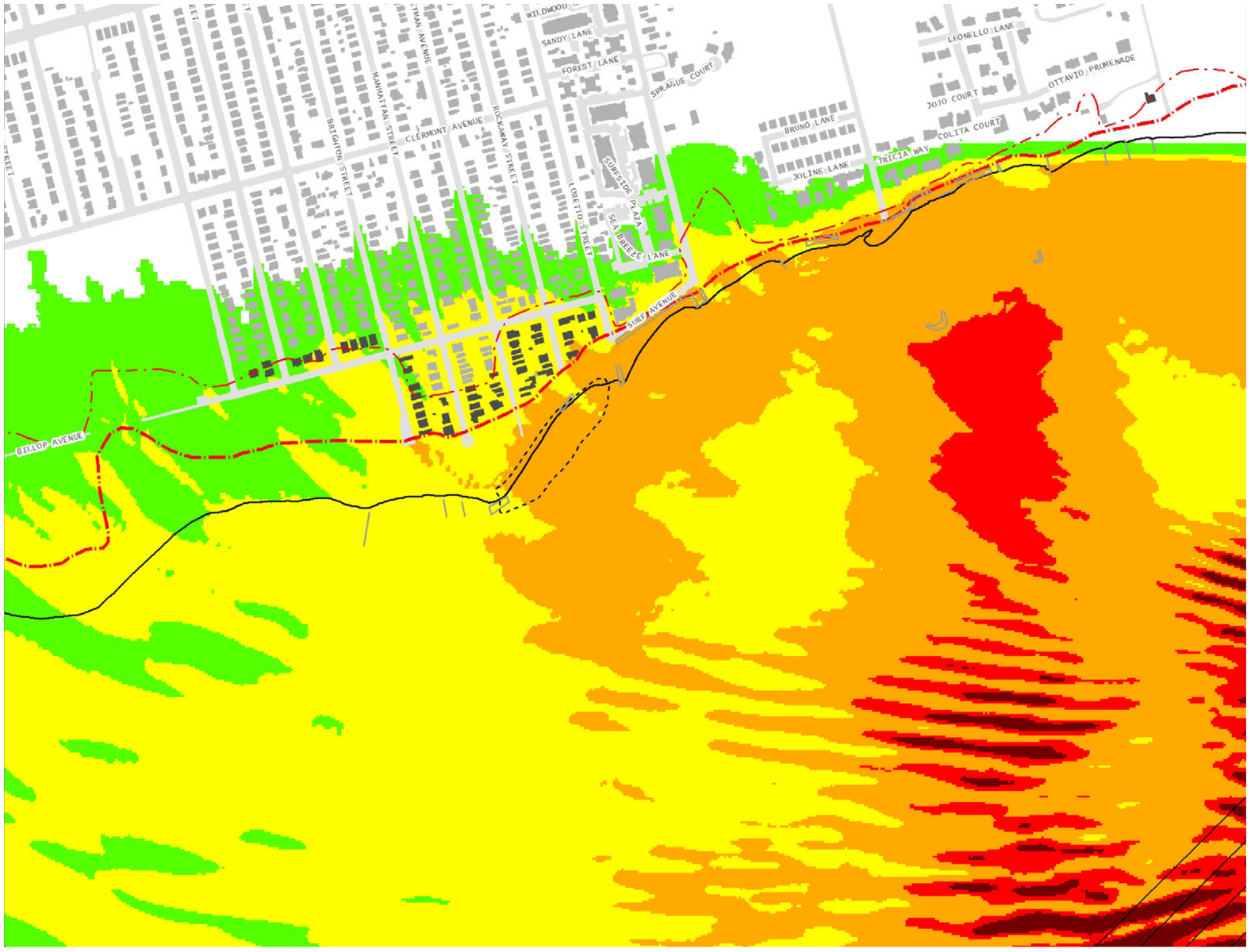






STORM WAVES FROM THE EAST WITHOUT BREAKWATERS (FUNWAVE RESULTS)

1% annual chance storm + 30” SLR, waves from the east, current conditions



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0’ 500’ 1000’ 2000’

NO ACTION

100 YR STORM + 30” SLR : 15.4 NAVD88

WAVE DIRECTION: EAST

Governor’s Office of Storm Recovery

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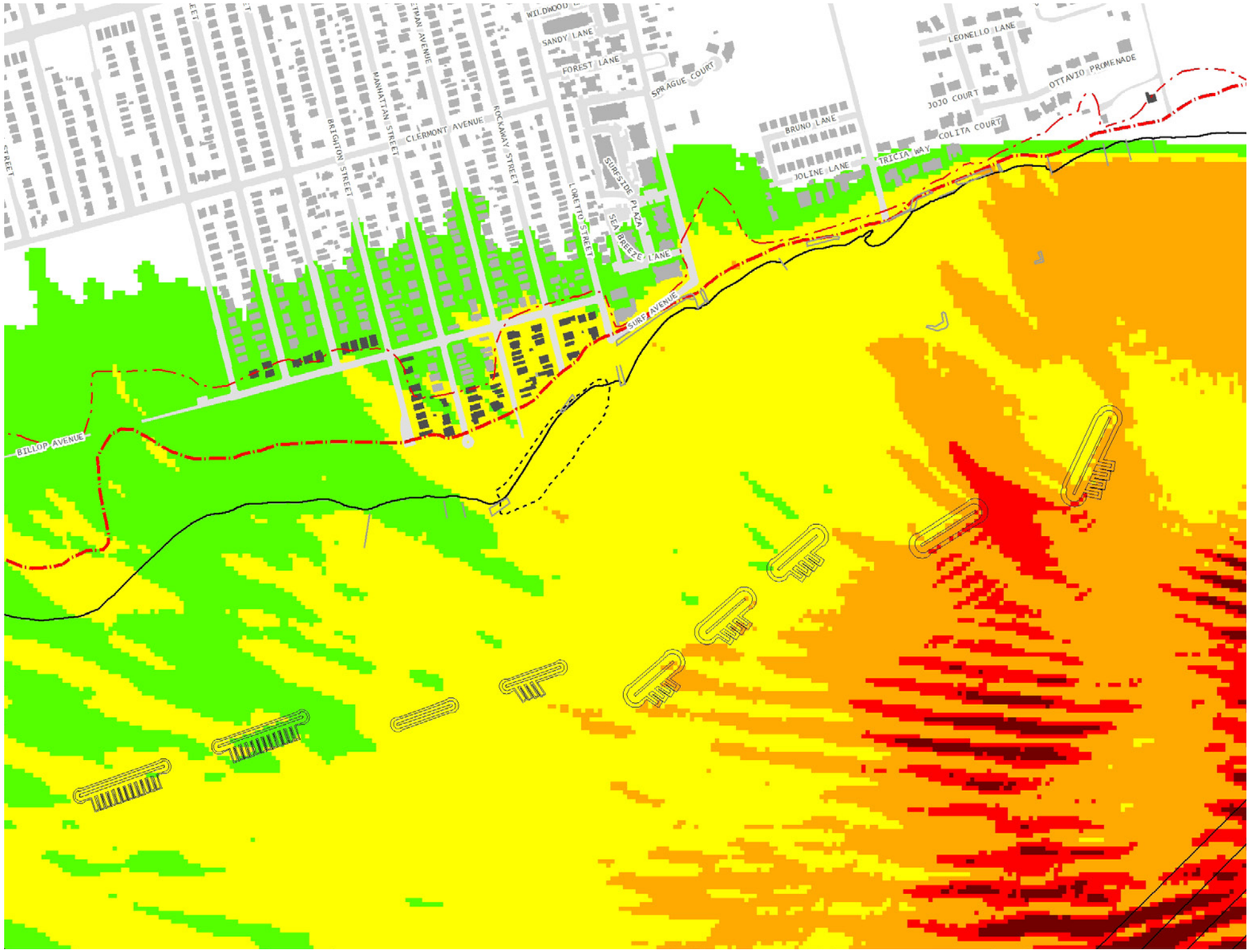
PRUDENT ENGINEERING

STORM WAVES FROM THE EAST WITH BREAKWATERS (FUNWAVE RESULTS)

1% annual chance storm + 30” SLR, waves from the east, with project



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0’ 500’ 1000’ 2000’

SCENARIO 63

100 YR STORM + 30” SLR : 15.4 NAVD88

WAVE DIRECTION: EAST

Governor’s Office of Storm Recovery

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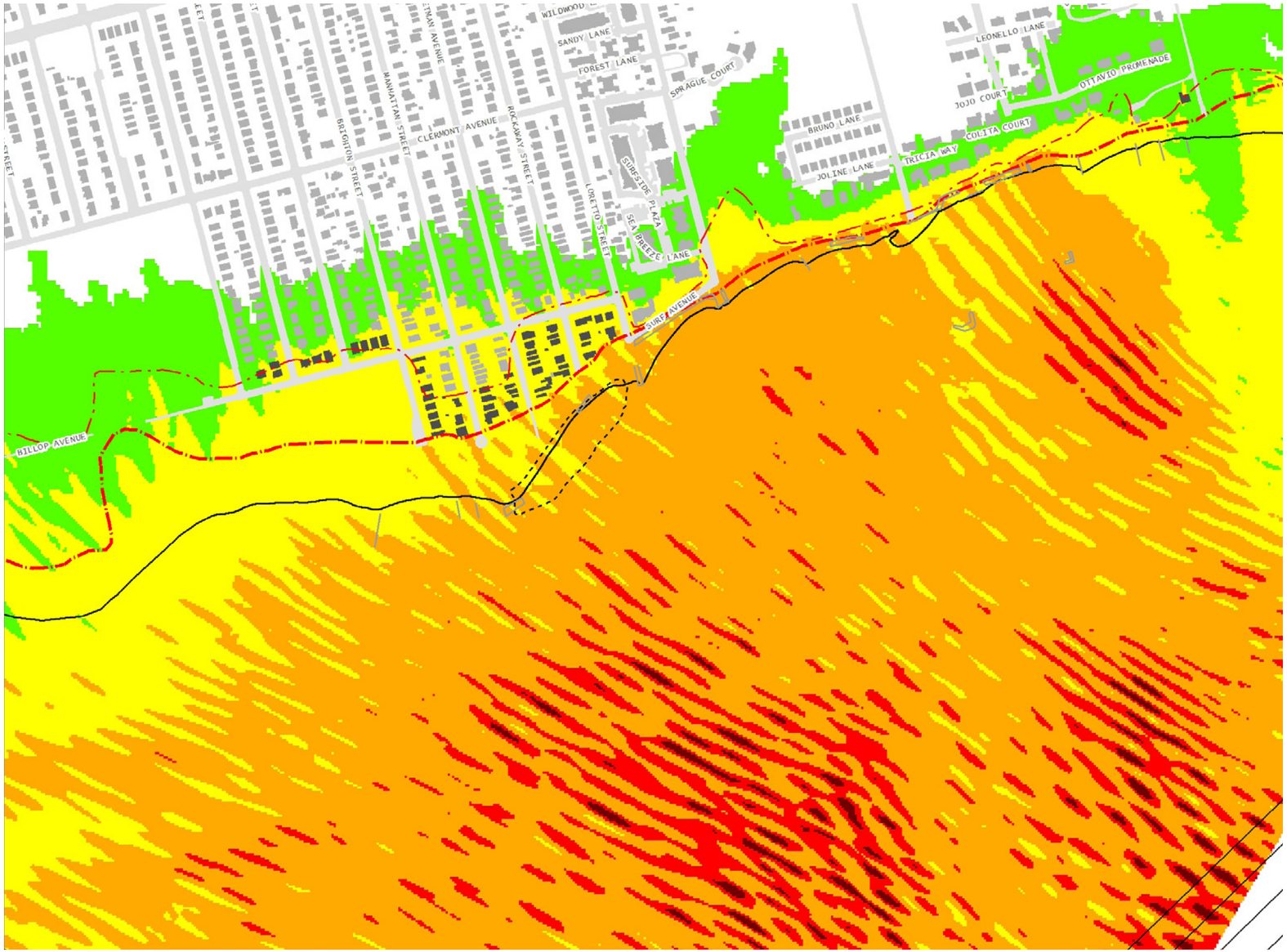
STORM WAVES FROM THE ESE WITHOUT BREAKWATERS (FUNWAVE RESULTS)

1% annual chance storm + 30” SLR, waves from the east-south-east, current conditions



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0’ 500’ 1000’ 2000’

NO ACTION

100 YR STORM + 30” SLR : 15.4 NAVD88

WAVE DIRECTION: EAST - SOUTHEAST

Governor’s Office of Storm Recovery

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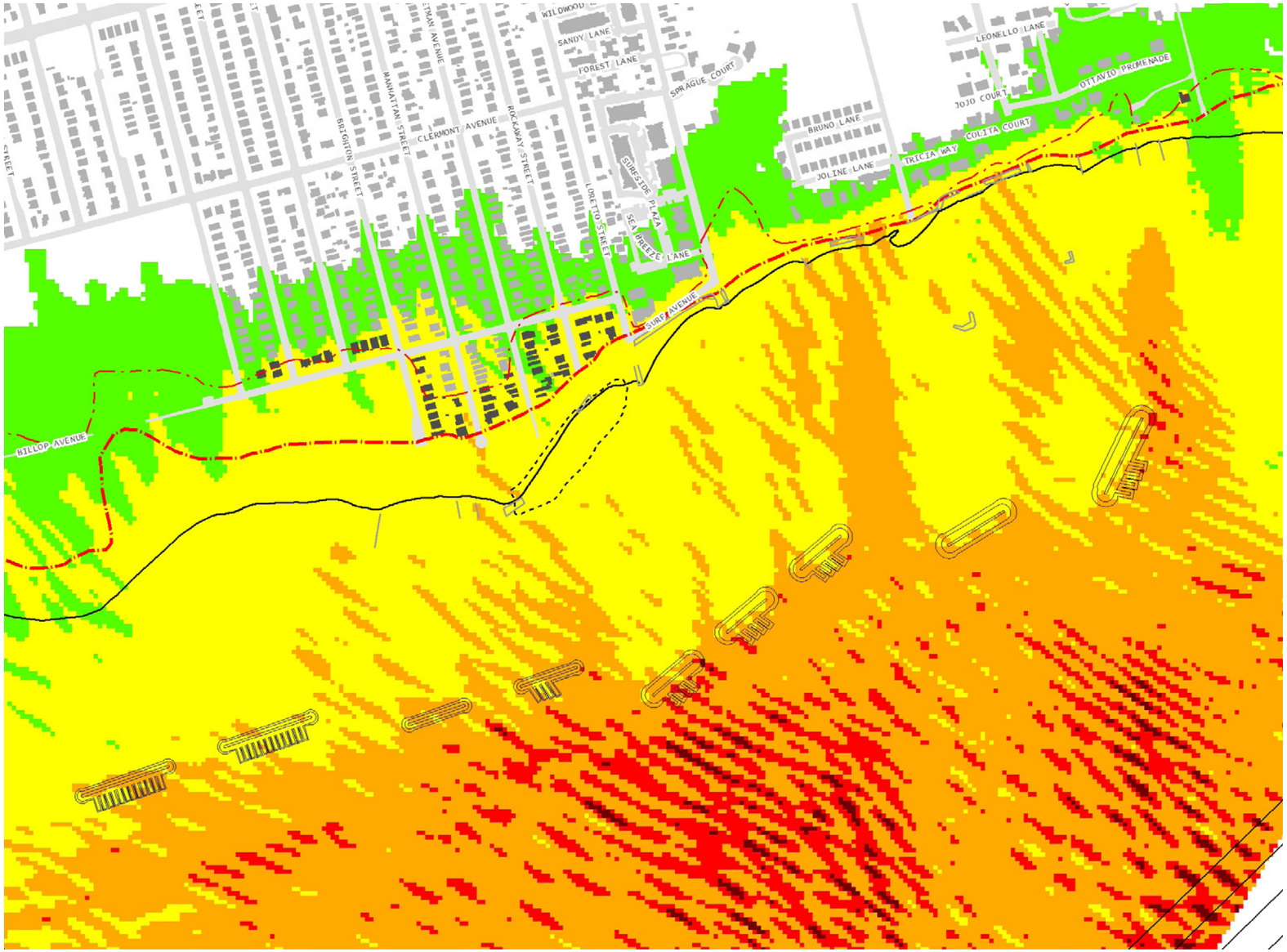
1% annual chance storm + 30” SLR, waves from the east-south-east, with project



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EROSION & SHORELINE CHANGE: HISTORIC AND PROJECTED CONDITIONS

How has the shoreline changed over time?
Is erosion a concern?
What is causing erosion?

HISTORIC SHORELINE CHANGE: 1978 TO SPRING 2012

1978 MHW LINE

2012 MHW LINE (PRE-SANDY)

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED BEACH FILL

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
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

0' 500' 1000' 2000'

THE SHORELINE IN 1978

THE SHORELINE IN 1996

HISTORIC SHORELINE CHANGE: SPRING TO FALL 2012 (BEFORE AND AFTER SANDY)

SPRING 2012 MHW (PRE-SANDY)

FALL 2012 MHW (POST-SANDY)

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

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CONTOUR BATHYMETRY GENERATED BY HILL

0′ 500′ 1000′ 2000′

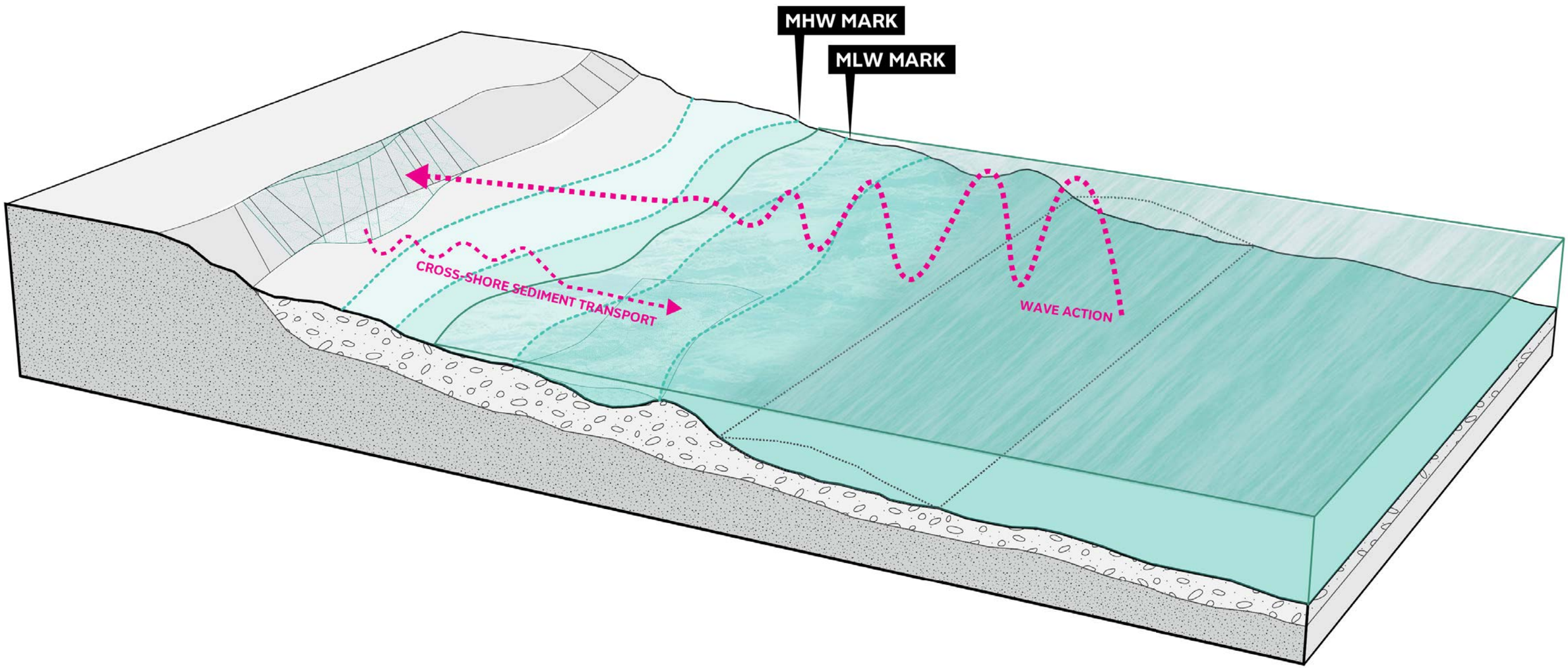
THE SHORELINE IN SPRING 2012 (PRE SANDY)

THE SHORELINE IN FALL 2012 (POST SANDY)

THE SHORELINE TODAY

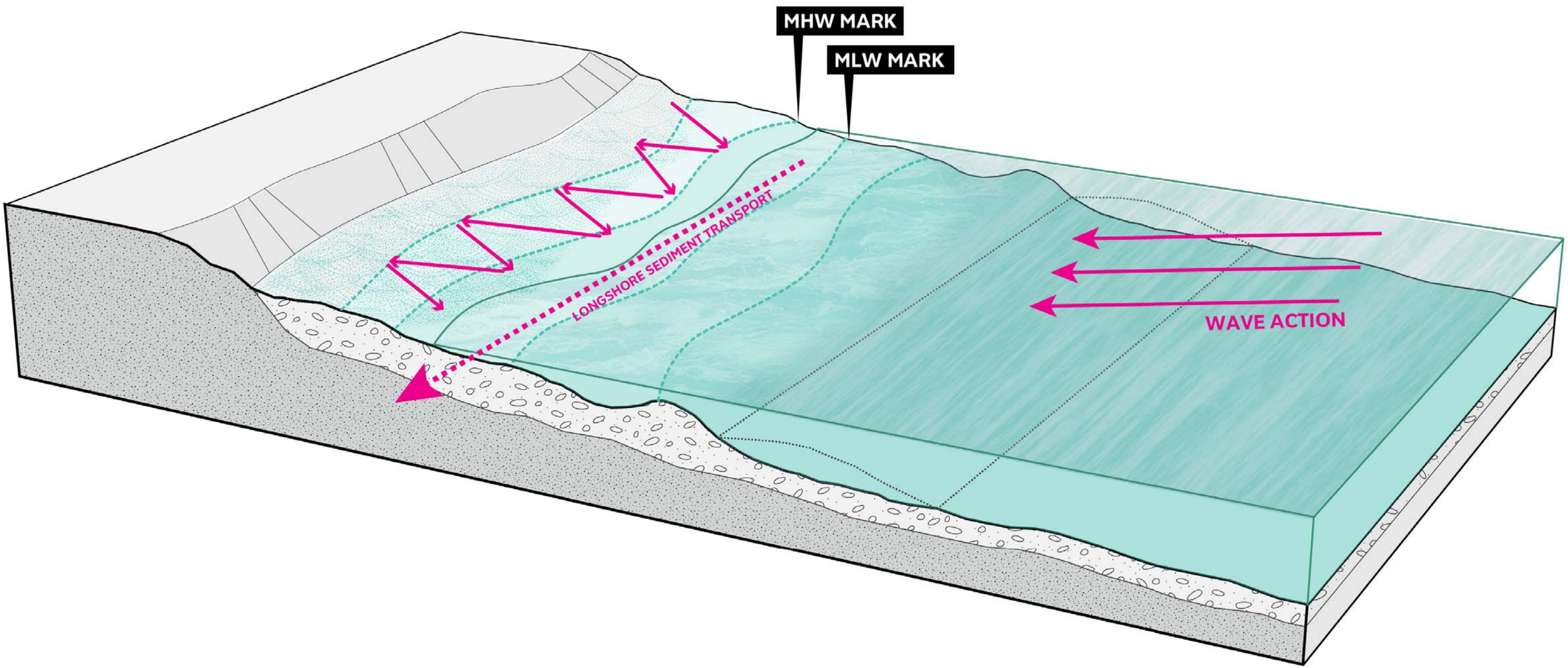
THE SHORELINE TODAY

HOW LONG-TERM EROSION WORKS
Cross-shore sediment transport



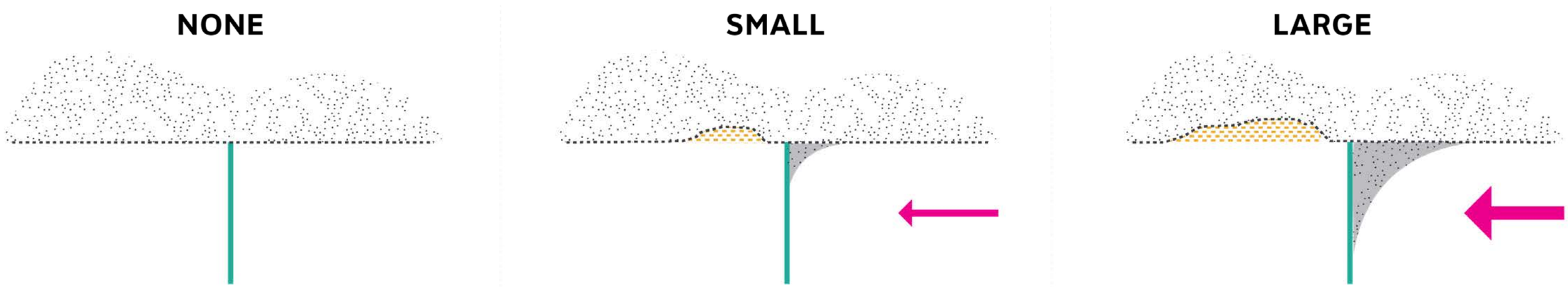
HOW LONG-TERM EROSION WORKS

Longshore sediment transport



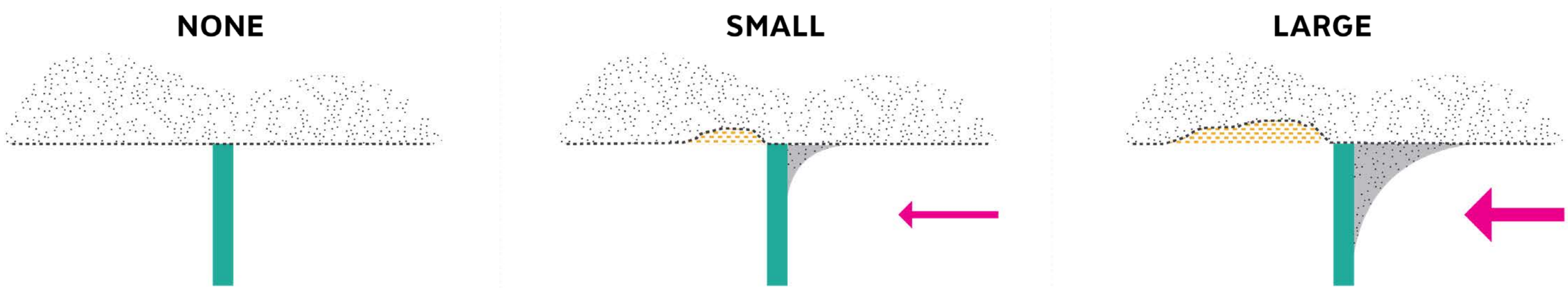
WHAT CONTRIBUTES TO EROSION

Longshore sediment transport - Perth Amboy, NJ



WHAT CONTRIBUTES TO EROSION

Longshore sediment transport - Fairfield Beach, CN

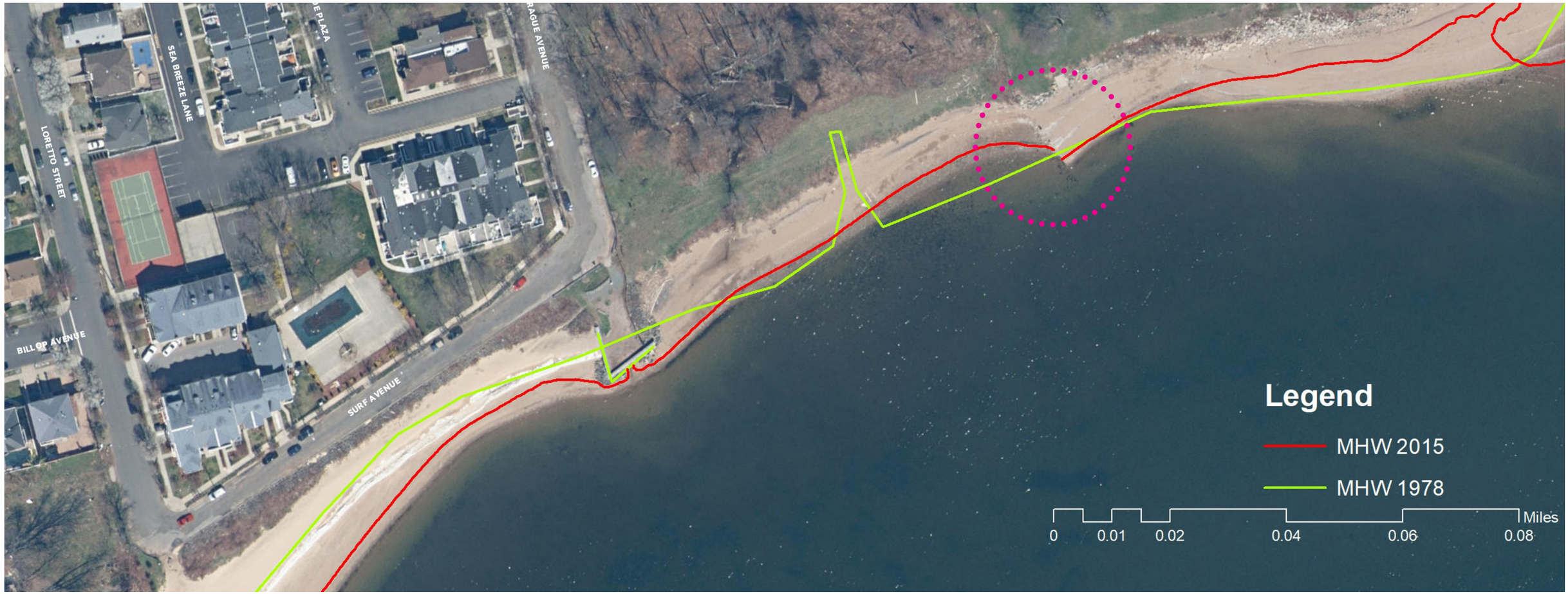


SHORELINE STRUCTURES CAN INFLUENCE SHORELINE CHANGE AND EXACERBATE DOWN-DRIFT EROSION

Longshore sediment transport - at Loretto St. outfall

CONT.

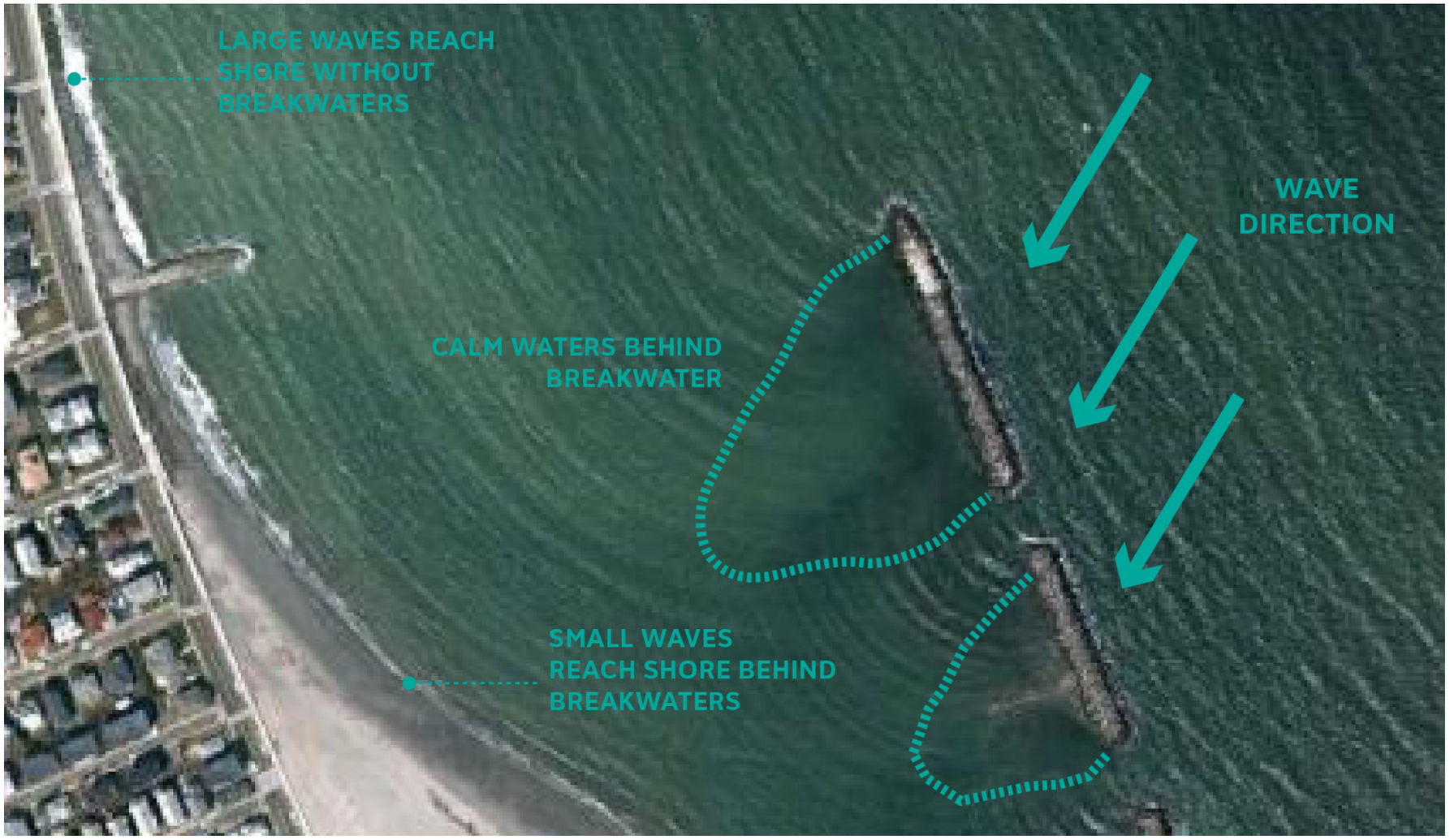
Longshore sediment transport - at Joline Lane Groin

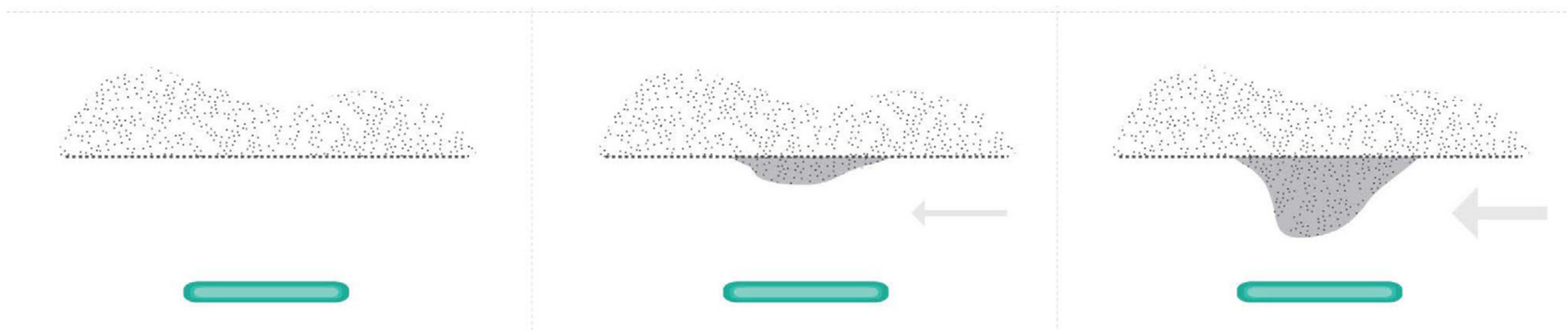


HOW BREAKWATERS REDUCE EROSION AND BUILD BEACHES

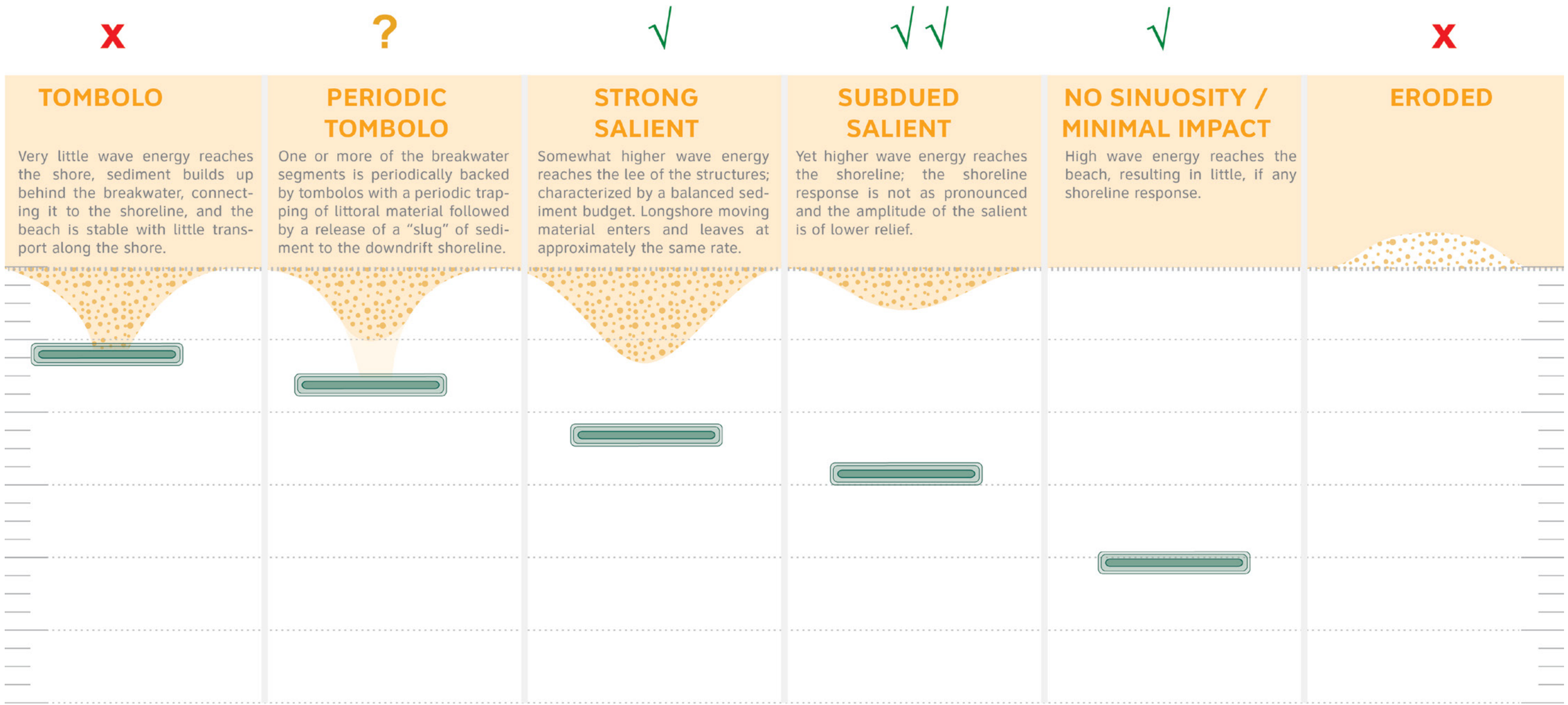
How do breakwaters effect shoreline change?
How do they build beaches?
How will the Living Breakwaters change beach width over time?

HOW BREAKWATERS TRAP SEDIMENT AND REDUCE EROSION

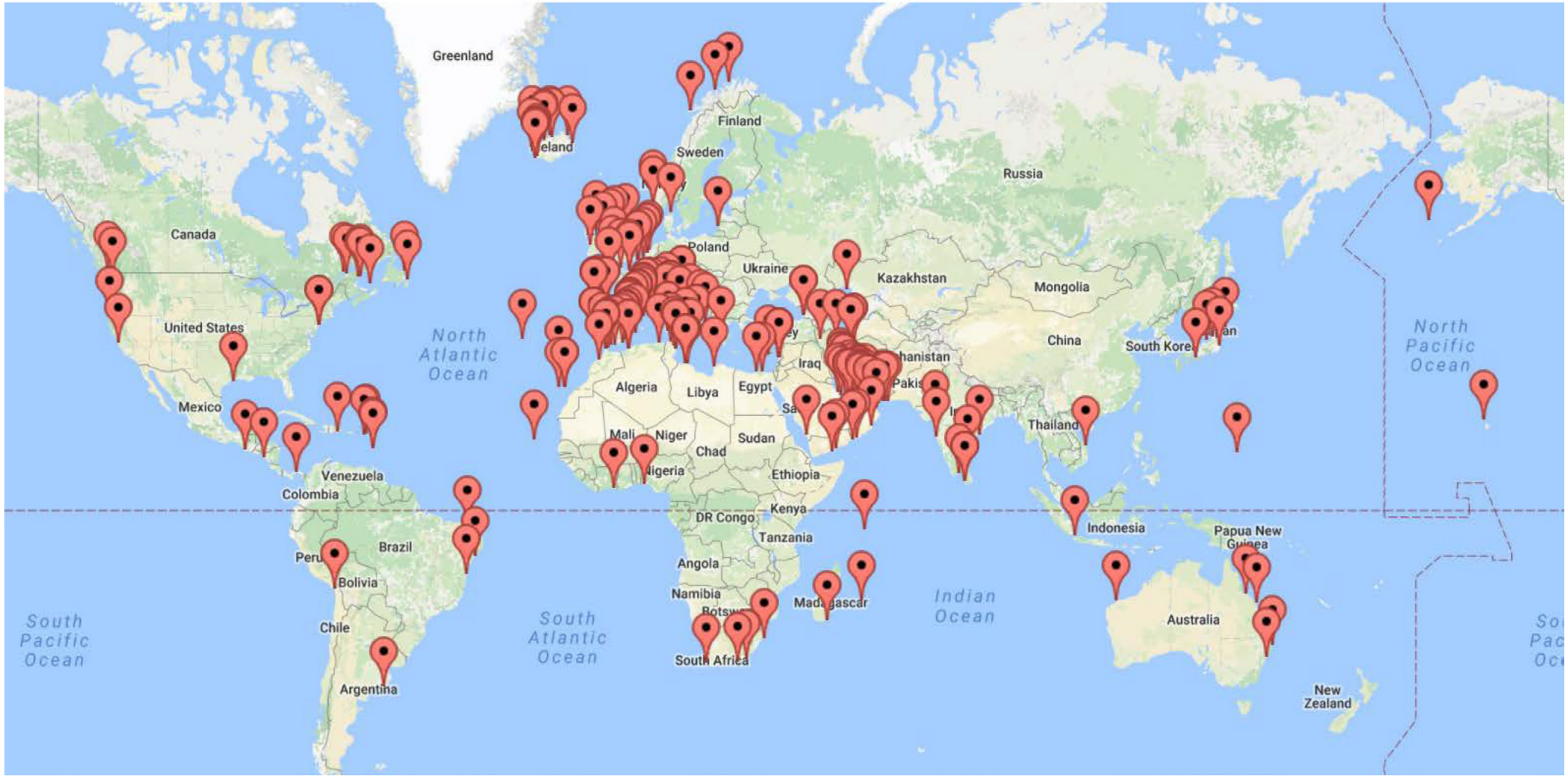




SHORELINE RESPONSES TO BREAKWATERS



Breakwaters around the world

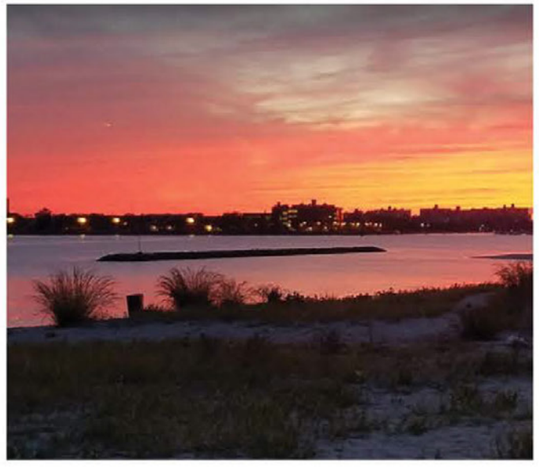


Source: International Breakwater Directory

Breakwaters in the U.S.

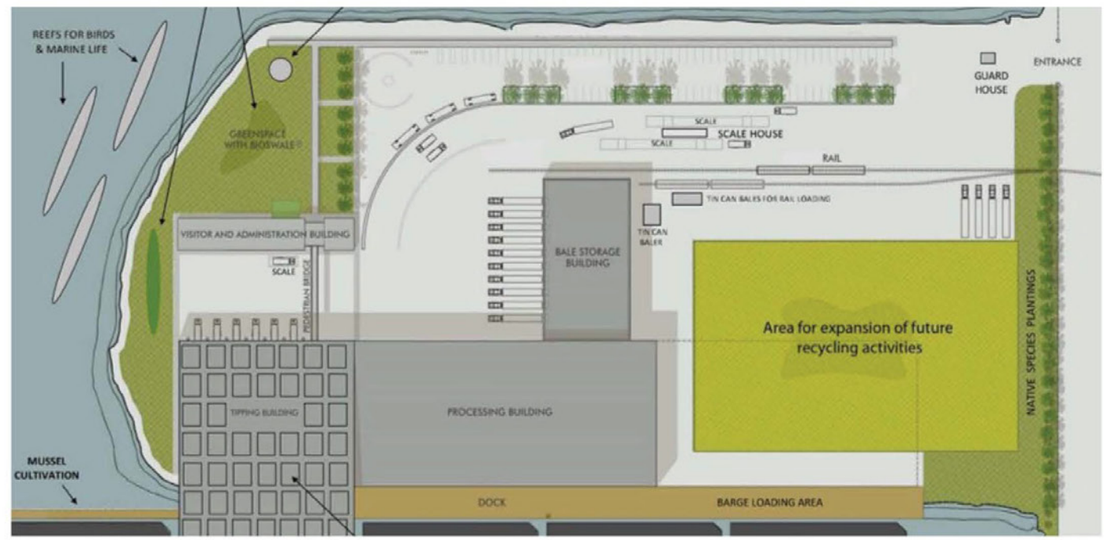
Source: International Breakwater Directory

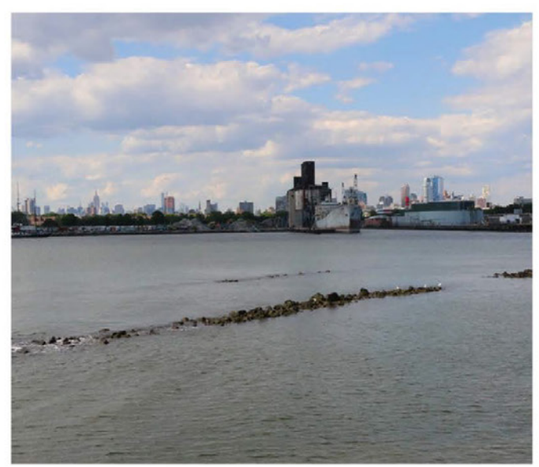
Breakwaters in New York Harbor: Plumb Beach, Brooklyn, 2013

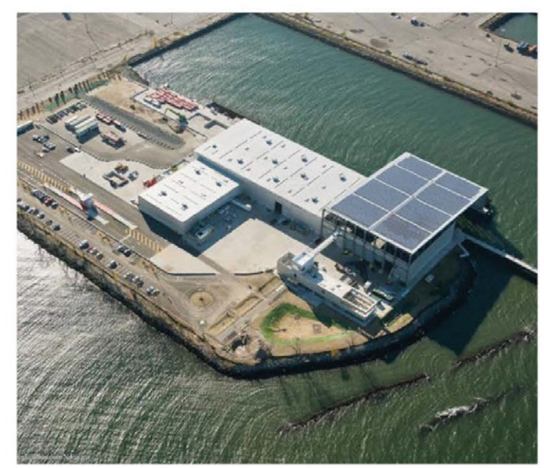


BREAKWATERS - CASE STUDIES

Sims Breakwaters, Sunset Park, Brooklyn, 2013





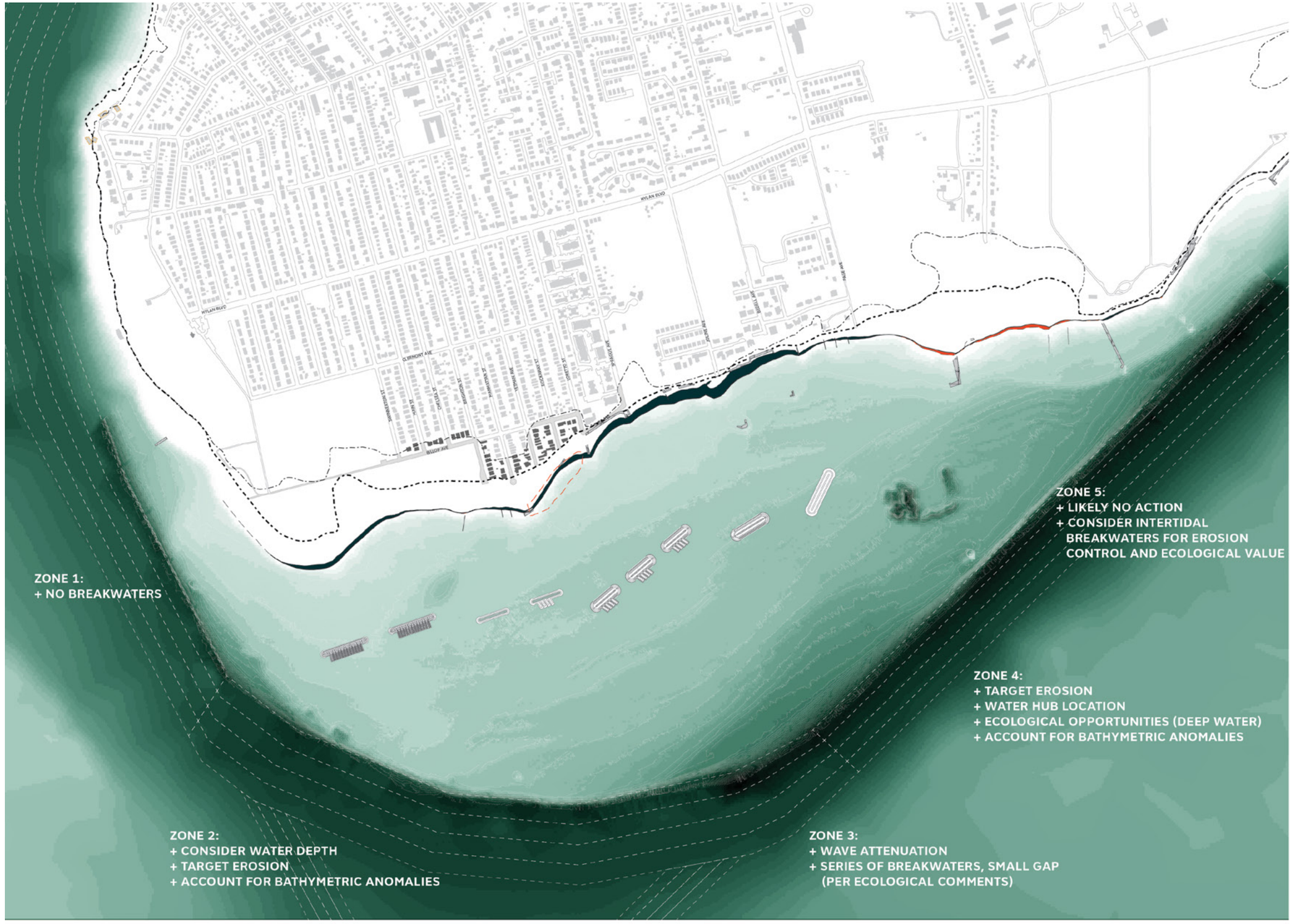


Breakwaters on the East Coast: Winthrop Beach, MA, 1935

Breakwaters in the Great Lakes: Presque Isle, Lake Erie, PA, 1992

HOW THE LIVING BREAKWATERS WILL LIKELY INFLUENCE SHORELINE CHANGE OVER THE NEXT 20 YEAR

GENESIS shoreline change model results, 2015 shoreline + 20 years



MODELED 2035 SHORELINE

MHW SPRING 2015

OBSERVED BEACH GROWTH

OBSERVED EROSION

SHORELINE STRUCTURES

BREAKWATER FOOTPRINT

PROPOSED SHORELINE RESTORATION

DATA SOURCES:
2035 MHW MODELED BY ARCADIS USING GENESIS
2012 MHW LINES BY ARCADIS USING ORTHOIMAGERY
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

0' 500' 1000' 2000'

HOW THE SHORELINE IS LIKELY TO CHANGE OVER THE NEXT 20 YEARS WITHOUT THE PROJECT

GENESIS shoreline change model results, 2015 shoreline + 20 years

MODELED 2035 SHORELINE

MHW SPRING 2015

OBSERVED BEACH GROWTH

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0' 500' 1000' 2000'

HOW THE LIVING BREAKWATERS WILL LIKELY INFLUENCE SHORELINE CHANGE OVER THE NEXT 20 YEAR

GENESIS shoreline change accretion rates at 60% design

60% Design Scenario - Shoreline Change at +5 Years

60% Design Scenario - Shoreline Change at +10 Years

60% Design Scenario - Shoreline Change at +15 Years

60% Design Scenario - Shoreline Change at +20 Years

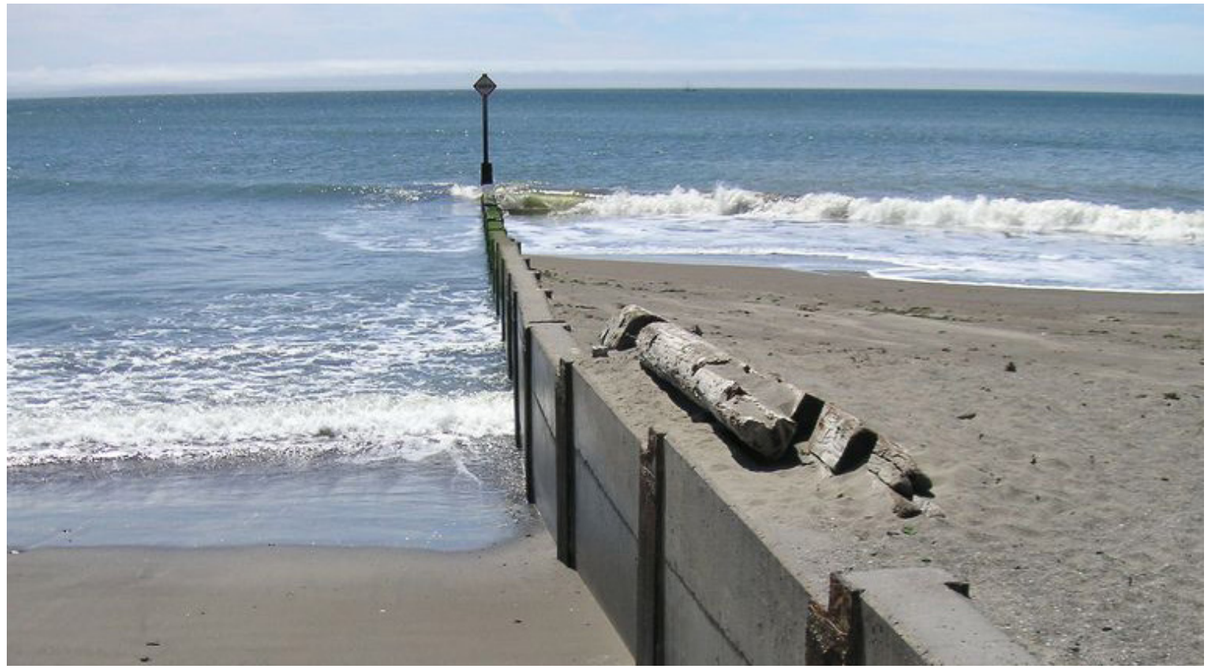
WHY NOT GROINS?

Why not groins & beach fill?

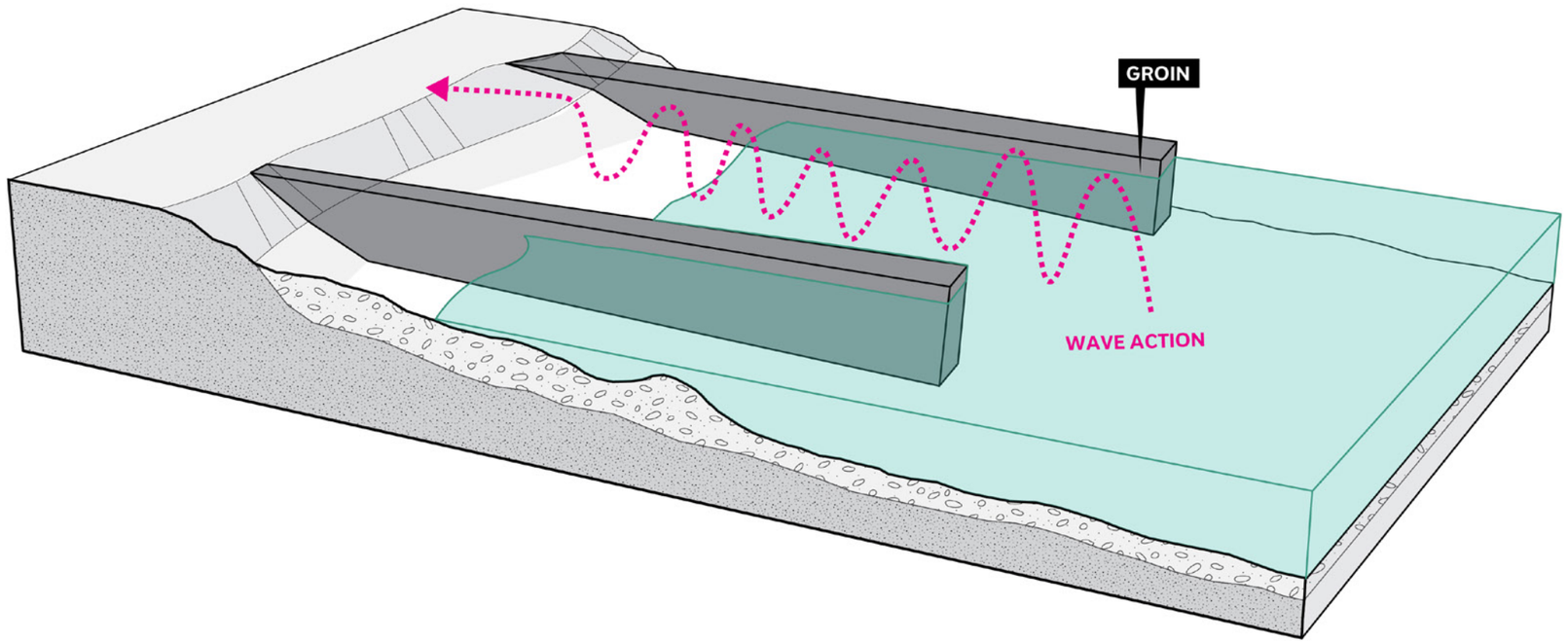
HOW GROINS AFFECT THE SHORELINE
Willoughby Spit, VA

HOW BREAKWATERS AFFECT THE SHORELINE
Willoughby Spit, VA

WHAT IS A GROIN?

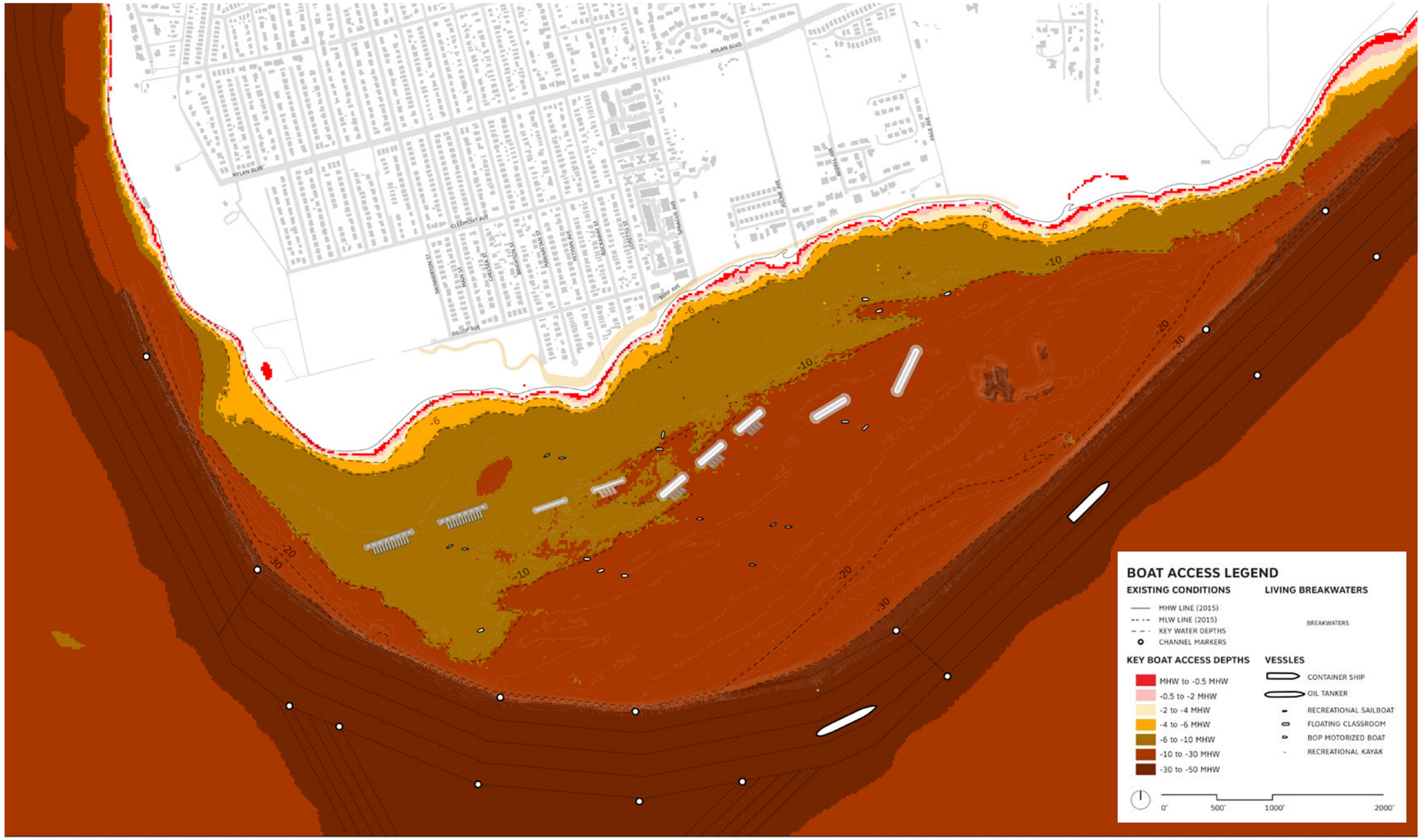


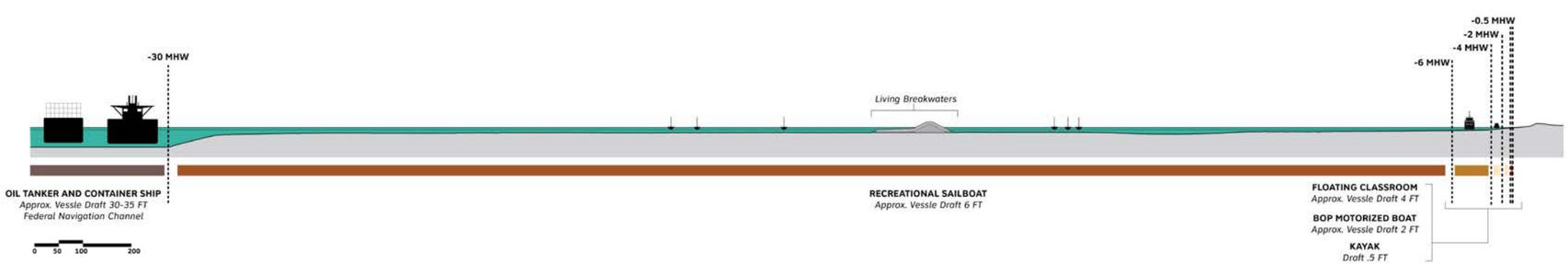
HOW GROINS INTERACT WITH WAVES

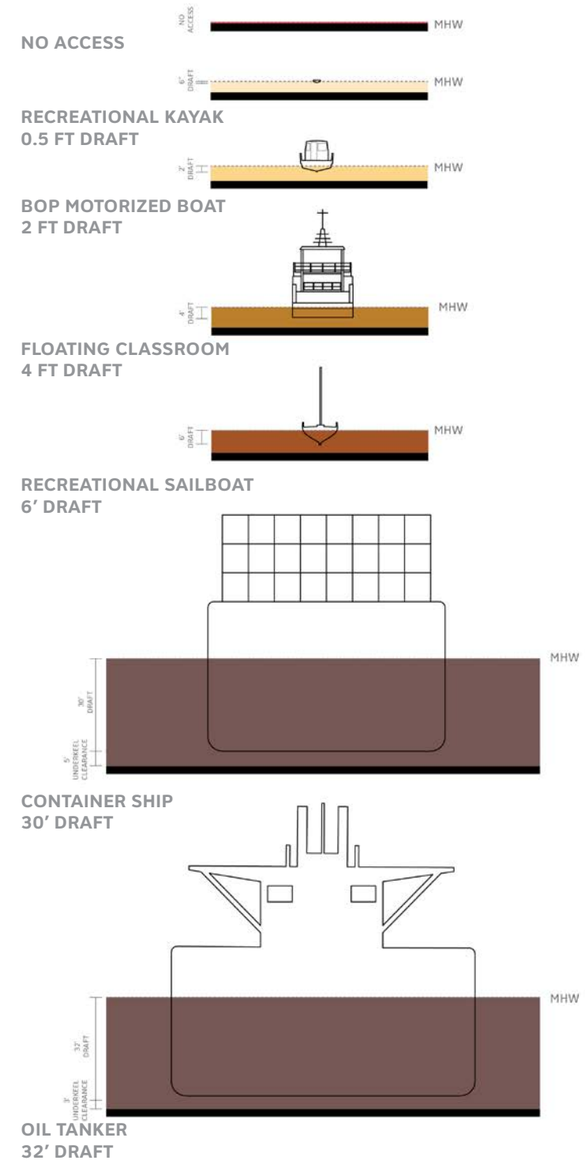


NAVIGATION CONSIDERATIONS

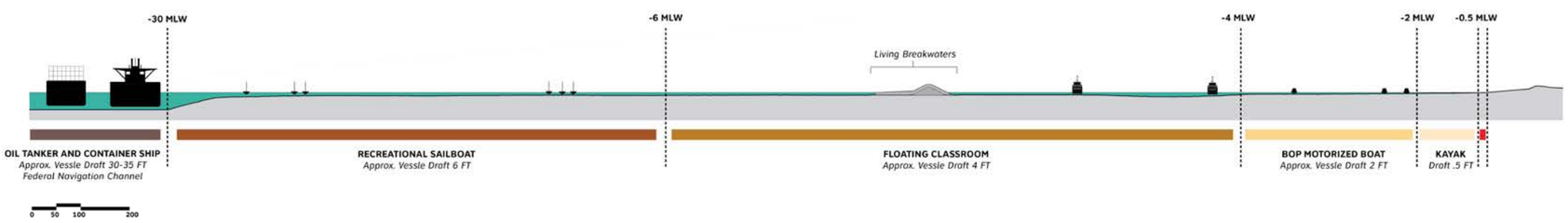
PROJECT SITE VESSEL DRAFTS AT MHW

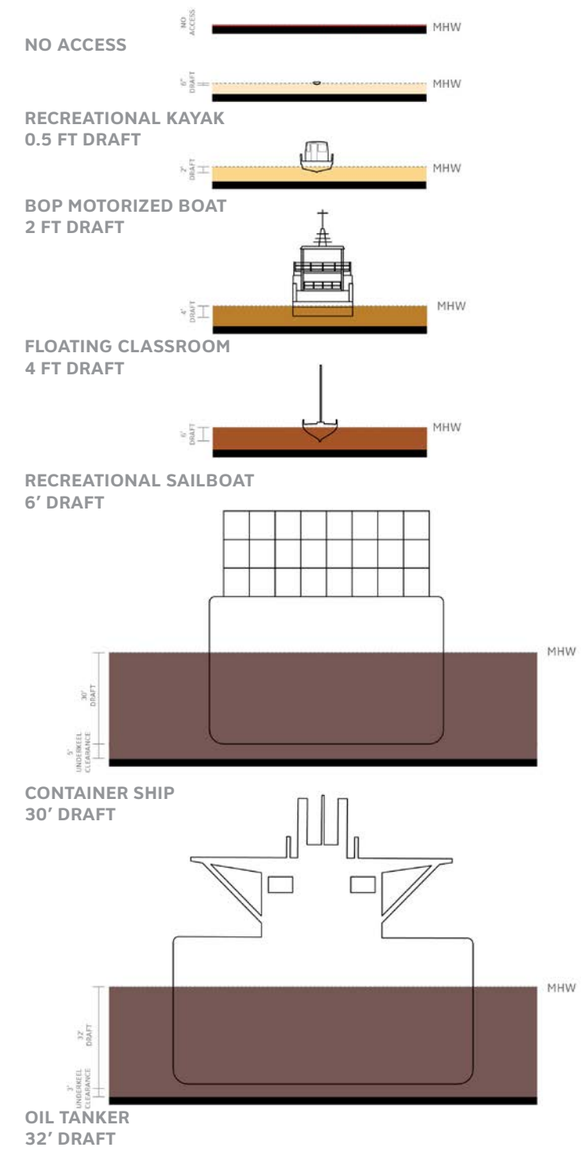




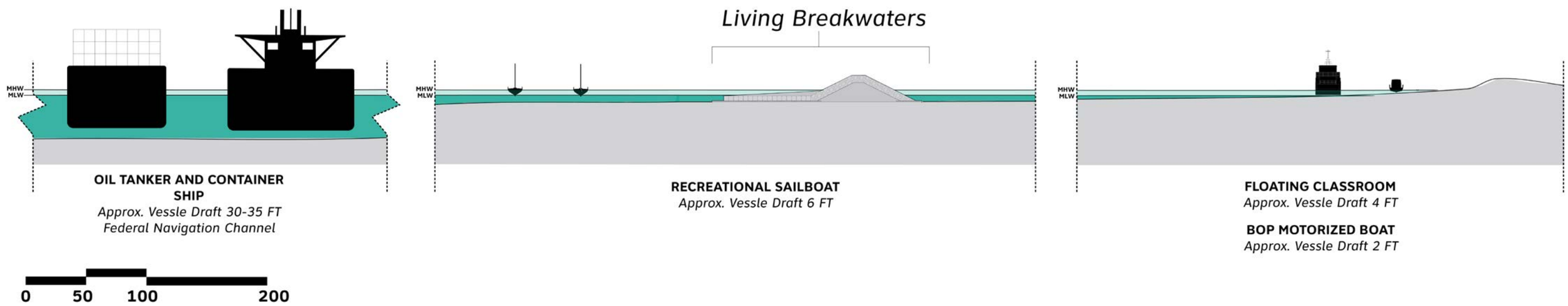


PROJECT SITE VESSEL DRAFTS AT MLW

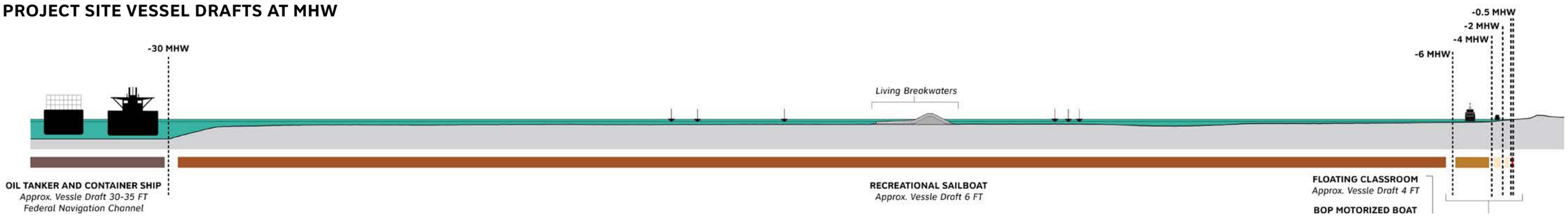




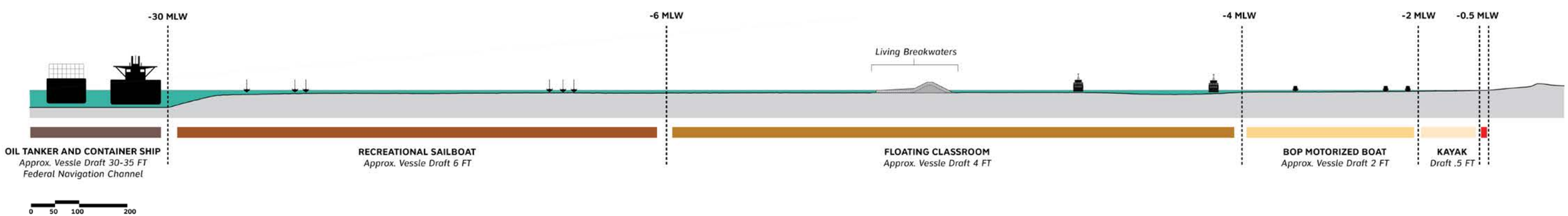
PROJECT SITE VESSEL DRAFTS



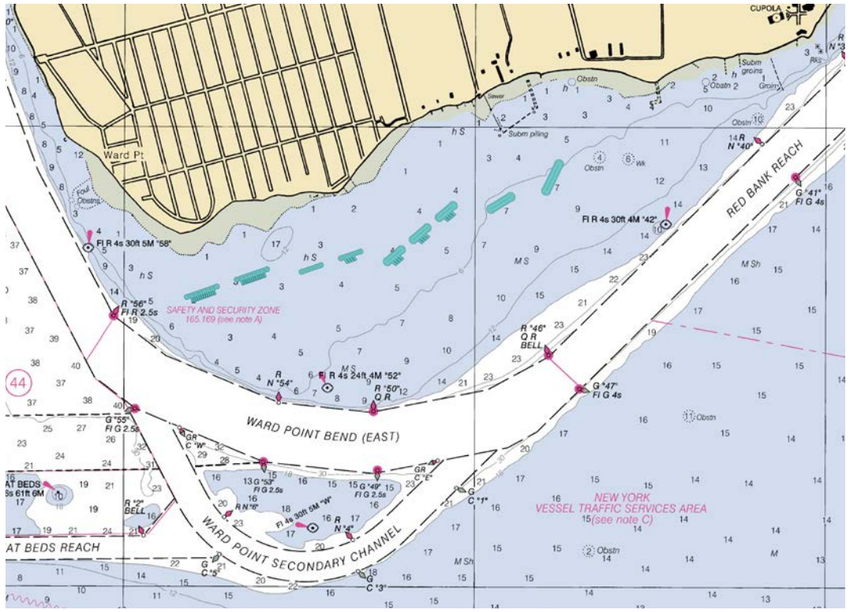
PROJECT SITE VESSEL DRAFTS AT MHW



PROJECT SITE VESSEL DRAFTS AT MLW

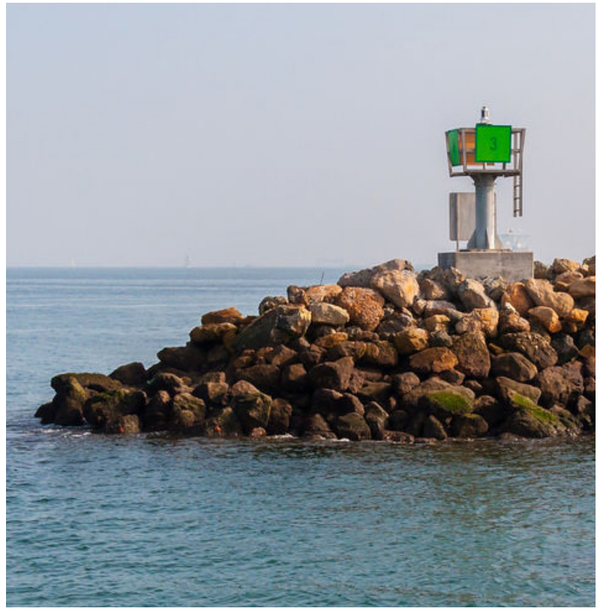


LIVING BREAKWATERS NAVIGATION AID & NAVIGATION SAFETY



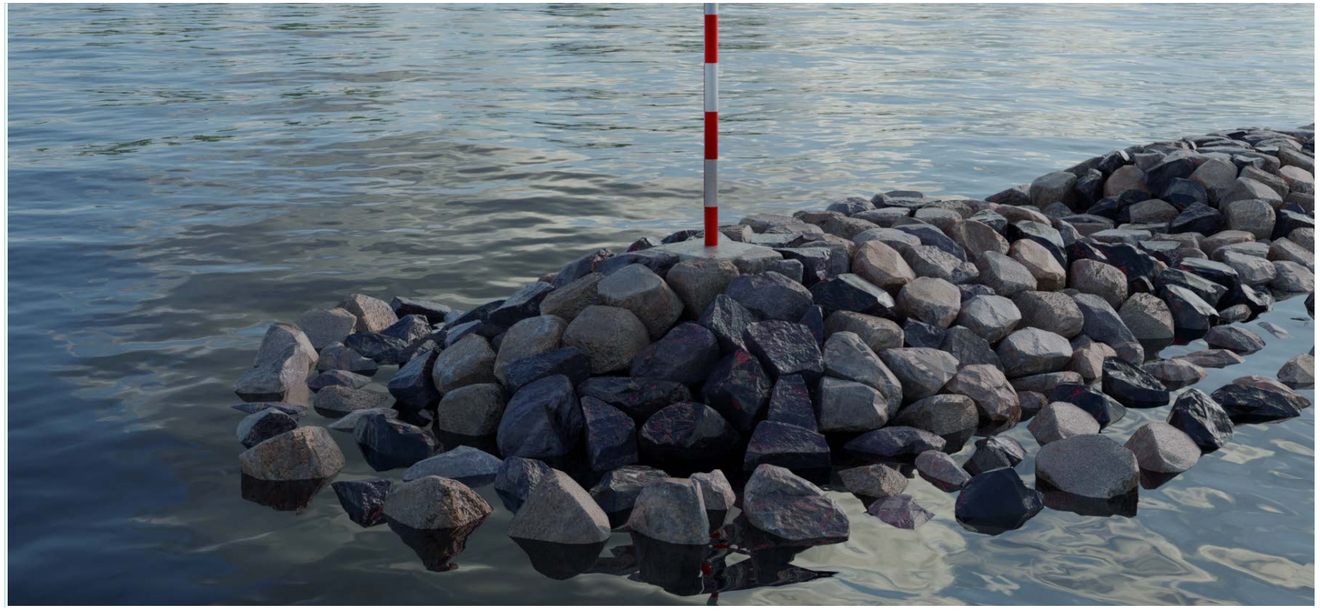
Existing Project Vicinity Navigation Aids

Provencetown Harbor Breakwater, Massachusetts



Long Beach Breakwater, California

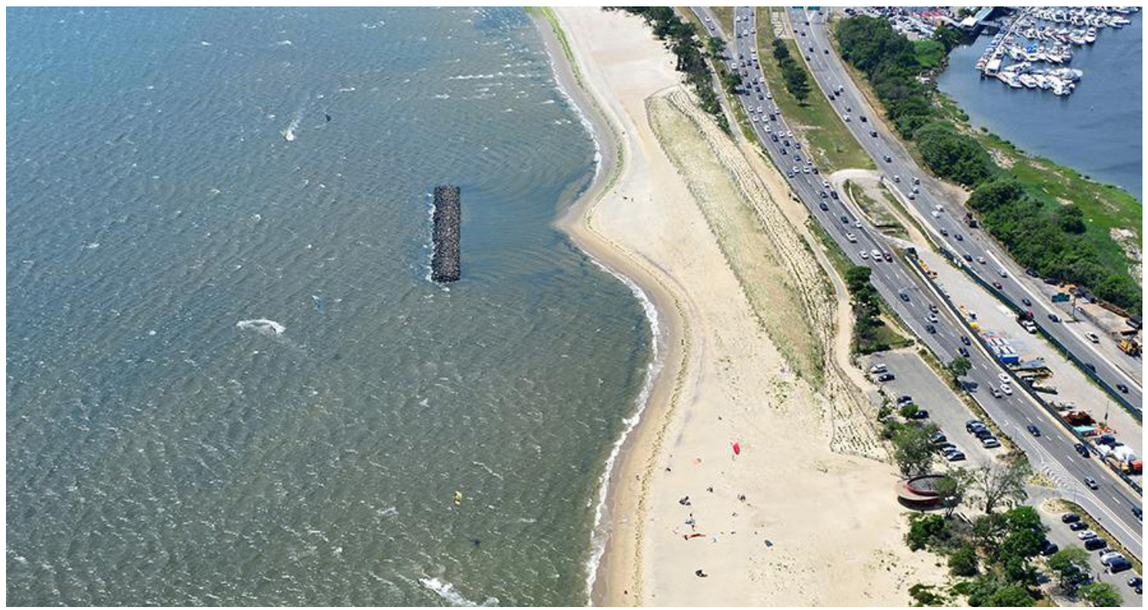
Living Breakwater Type A Navigation Aid Visualization

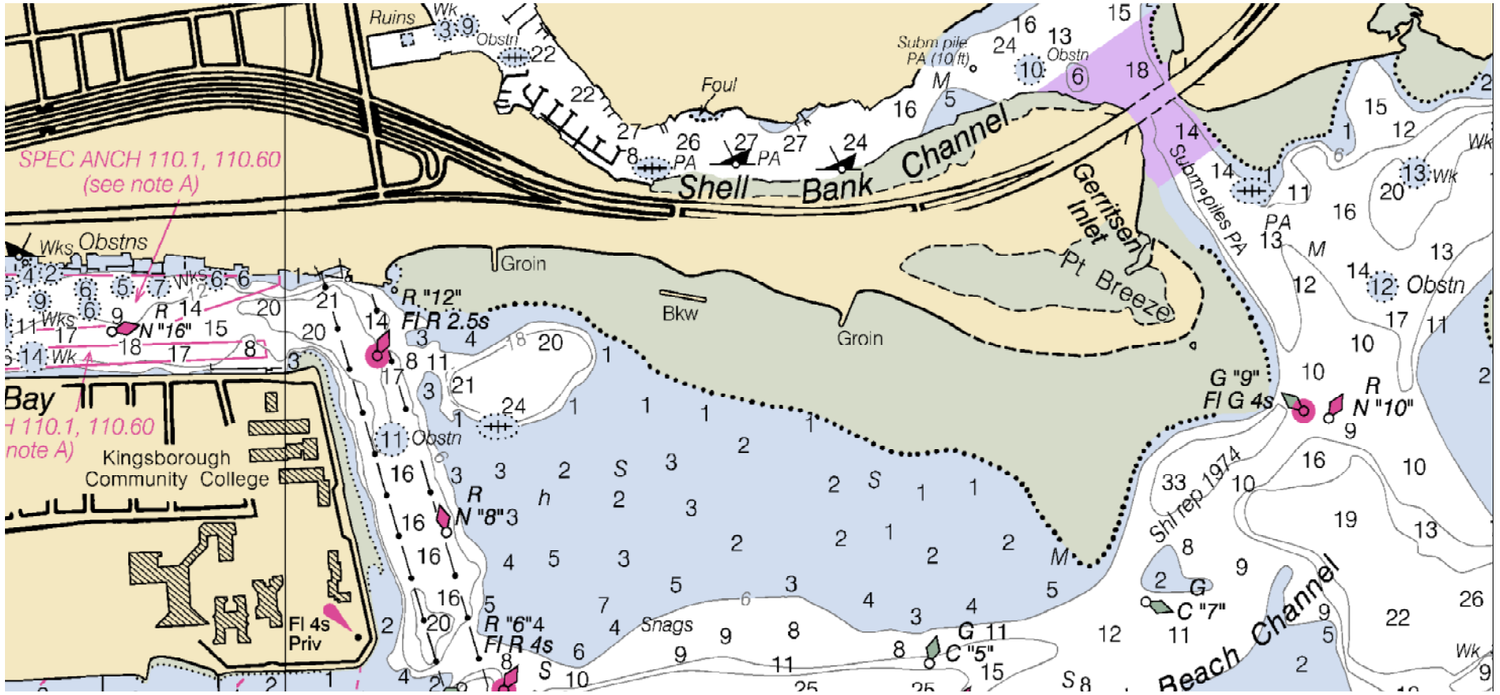


EXISTING NAVIGATION AIDS IN THE VICINITY OF THE PROJECT

EXISTING NEAR-SHORE STRUCTURES IN THE VICINITY OF THE PROJECT

PLUMB BEACH BREAKWATER





LIVING BREAKWATER HABITATS

EXISTING CONDITIONS

Location of geotechnical borings and sediment samples

GEOTECHNICAL BORINGS

- **30% DESIGN GEOTECHNICAL BORINGS**
- **60% DESIGN GEOTECHNICAL BORINGS**

2015 ONSHORE AND OFFSHORE SEDIMENT SAMPLE ANALYSIS

MFS Onshore Sediment Samples
Hill Offshore Sediment Samples
Sediment Analysis Measured in D50

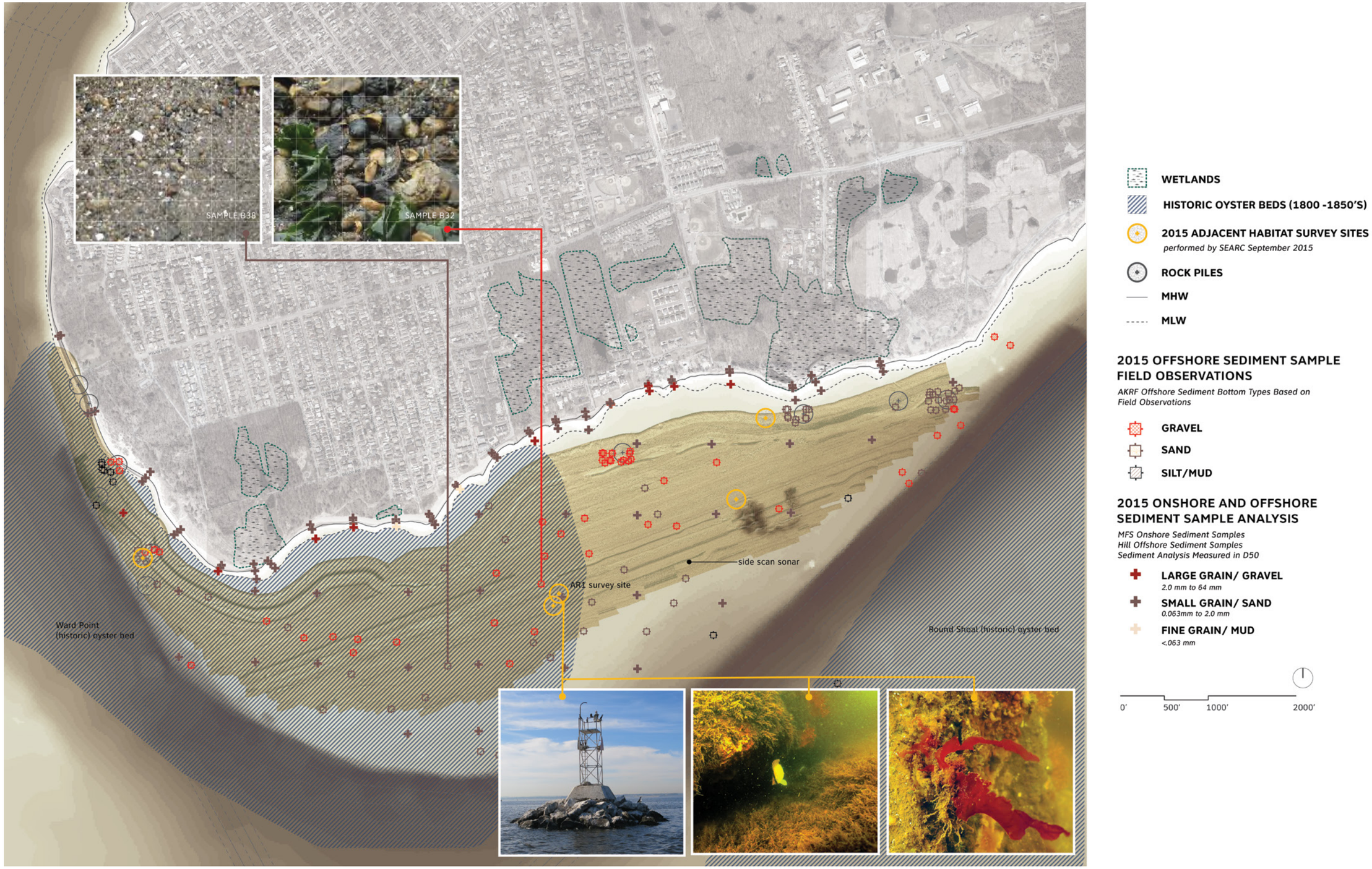
- **LARGE GRAIN/ GRAVEL** *2.0 mm to 64 mm*
- **SMALL GRAIN/ SAND** *0.063mm to 2.0 mm*
- **FINE GRAIN/ MUD** *<.063 mm*

TRANSECTS WITHIN TSPP PROJECT AREA

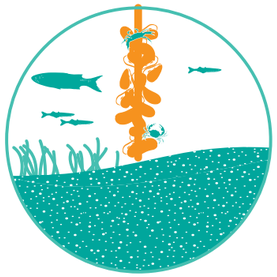
TRANSECTS OUTSIDE TSPP PROJECT AREA

EXISTING CONDITIONS

Habitat on Site



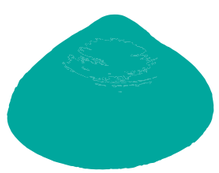
TARGET SPECIES



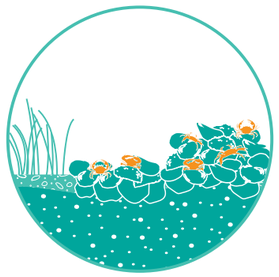
HABITAT FORMING SPECIES

EASTERN OYSTER
Crassostrea virginica

BLUE MUSSEL
Mytilus edulis



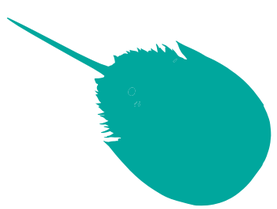
HARD CLAM
Mercenaria mercenaria



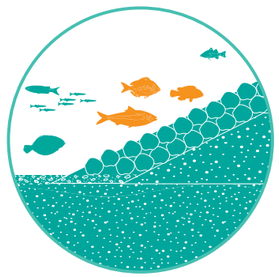
MOTILE BENTHIC INVERTEBRATES

BLUE CRAB
Callinectes sapidus

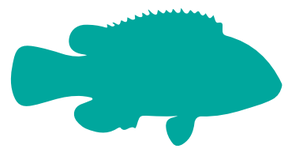
AMERICAN LOBSTER
Homarus americanus



HORSESHOE CRAB
Limulus polyphemus

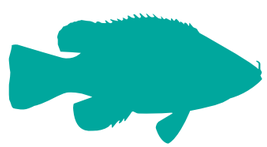


STRUCTURE ORIENTED REEF FISH

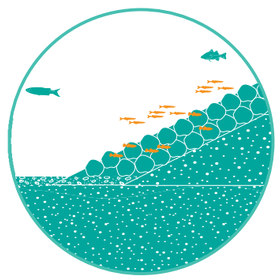


TAUTOG
Tautoga onitis

BLACK SEA BASS
Centropristis striata



CUNNER
Tautogolabrus adspersus

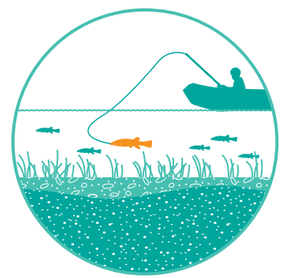


FORAGE FISH

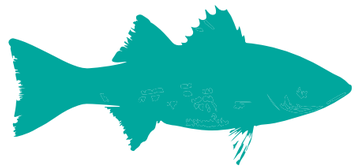
FEATHER BLENNY
Hypsoblennius hentz

ATLANTIC SILVERSIDES
Menidia menidia

NAKED GOBY
Gobiosoma bosc

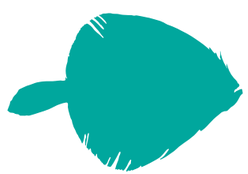


TRANSIENT RECREATIONAL AND COMMERCIAL FISHERY

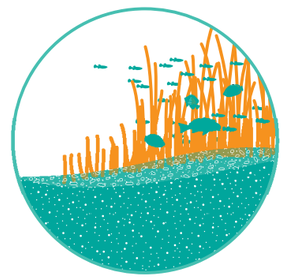


ATLANTIC STRIPED BASS
Morone saxatilis

BLUEFISH
Pomatomus saltatrix



WINDOWPANE
Scophthalmus aquosus



VEGETATION

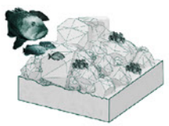
EELGRASS
Zostera marina

TARGET SPECIES

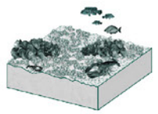
FUNCTIONAL GROUPS	COMMON NAME	SCIENTIFIC NAME	Breakwater target species	Project target species	Regulatory interest	Commercially significant	Restoration priority	Historically present	Currently present	Proposed for restoration	LIFE STAGE: SPAWNING	EGG	LARVAE	YOY*	JUVENILE	ADULT
HABITAT FORMING SPECIES	Eastern Oyster	*Crassostrea virginica*	■	■	■		■	■		■			■			■
	Blue Mussel	*Mytilus edulis*		■											■	■
	Hard Clam	*Mercenaria mercenaria*			■	■			■							
	Little gray barnacle	*Chthamalus fragilis (Crustacea)*	■	■												■
	Bryozoa	*Watersipora cucullata*	■	■												■
	Branching sponge	*Axinella sp. (Porifera)*	■	■												■
MOTILE BENTHIC INVERTEBRATES	Blue Crab	*Callinectes sapidus*	■	■		■			■						■	■
	American Lobster	*Homarus americanus*	■	■		■									■	■
	Horseshoe Crab	*Limulus polyphemus*		■	■	■		■								■
STRUCTURE ORIENTED REEF FISH	Tautog	*Tautoga onitis*	■	■		■			■				■	■	■	■
	Black sea bass	*Centropristis striata*	■	■		■			■					■	■	■
	Cunner	*Tautogolabrus adspersus*									■	■	■	■	■	■
STRUCTURE ORIENTED FORAGE FISH	Naked goby	*Gobiosoma bosc*									■	■	■	■	■	■
	Seaboard goby	*Gobiosoma ginsburgi*									■	■	■	■	■	■
	Feather blenny	*Hypsoblennius hentz*									■	■	■	■	■	■
OTHER FORAGE FISH	Scup	*Stenotomus chrysops*	■	■				■	■					■	■	■
	American sand lance	*Ammodytes americanus*										■	■	■	■	■
	Atlantic menhaden	*Brevoortia tyrannus*	■	■		■		■	■				■			■
	Atlantic silversides	*Menidia menidia*	■	■		■		■	■							■
	Bay anchovy	*Anchoa mitchilli*	■	■				■	■		■	■	■	■	■	■
	Inland silverside	*Menidia beryllina*														■
	Mummichog Killifish	*Fundulus heteroclitus*	■	■				■	■			■				■
	Rainbow smelt	*Osmerus mordax*										■	■			
	Sheepshead minnow	*Cyprinodon variegatus variegatus*														■
	Spot	*Leiostomus xanthurus*	■	■					■		■	■	■	■	■	■
	Tidewater silverside	*Menidia peninsulae*												■	■	■
	Tomcod	*Microgadus tomcod*														■
TRANSIENT RECREATIONAL & COMMERCIAL FISHERY	Winter Flounder	*Pseudopleuronectes americanu*		■	■				■		■	■	■	■	■	■
	Summer Flounder	*Paralichthys dentatus*		■	■			■	■			■			■	■
	Striped bass	*Morone saxatilis*	■	■		■			■							■
	Atlantic Striped Bass	*Morone saxatilis*										■	■	■	■	
	Bluefish	*Pomatomus saltatrix*	■	■		■		■	■				■			■
	Weakfish	*Cynoscion regalis*	■	■		■		■	■				■	■	■	■
	Windowopane	*Scophthalmus aquosus*									■					■
	American eel	*Anguilla rostrata*				■		■	■					■	■	■
VEGETATION	Eelgrass	*Zostera marina*					■	■								■
	Boring sponge	*Cliona sp. (Porifera)*	■	■												■
	Tube worm	*Dasychone bairdi (Polychaeta)*	■	■												■
	Calcareous tubeworm	*Serpulidae worm (Polychaeta)*	■	■												■
	Hard tube worms	*Spirorbid worms (Polychaeta)*	■	■												■
	Red crust	*Schizoporella sp. (Bryozoa)*	■	■												■
	White crusts	*Didemnum sp. (Ascidiacea)*	■	■												■
	Bowerbank's halichondria	*Halichondria bowerbanki (Porifera)*	■	■												■
	Haliclona	*Haliclona (Reniera) cinerea (Porifera)*	■	■												■

* Young of the Year (yoy)

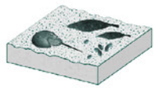
LEGEND
Habitat Type:



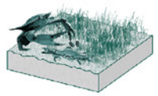
Hard Substrate
cobble/boulder - artificial substrate



Large Grain
gravel - oyster/clam shell

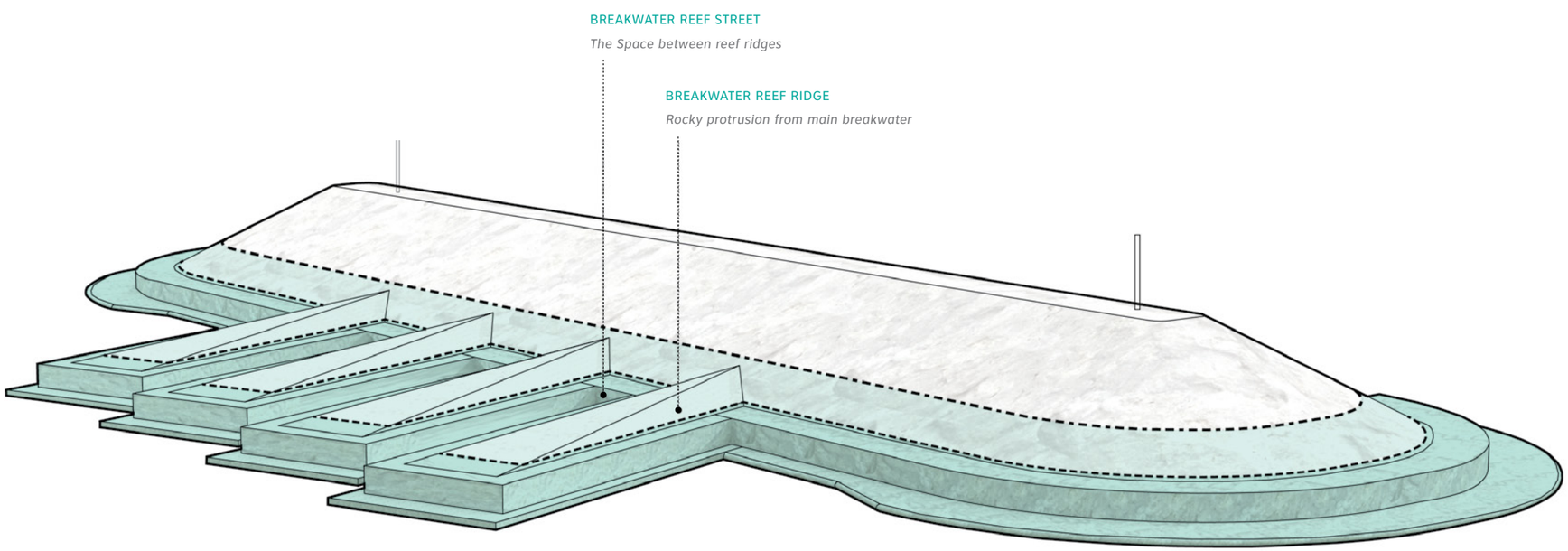


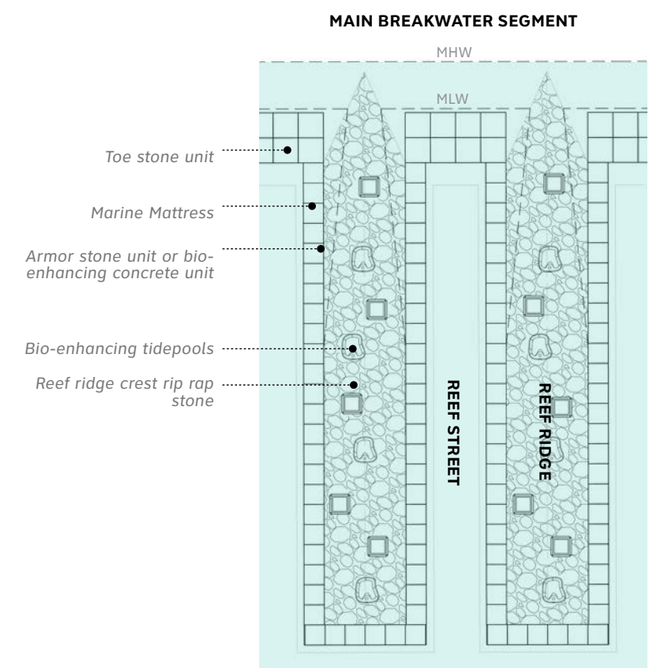
Small Grain
silt - sand



Vegetation

REEF STREETS/REEF RIDGES





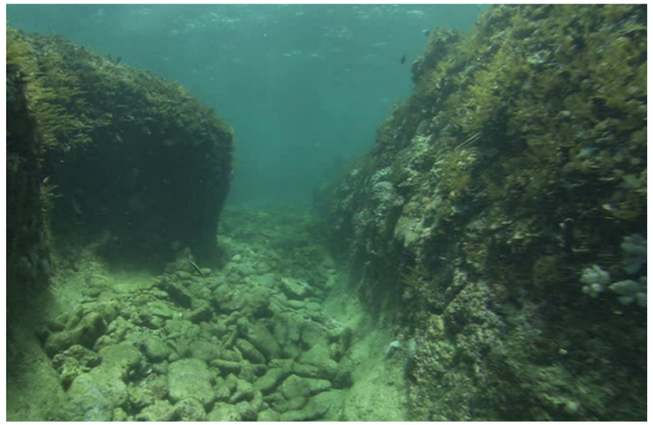
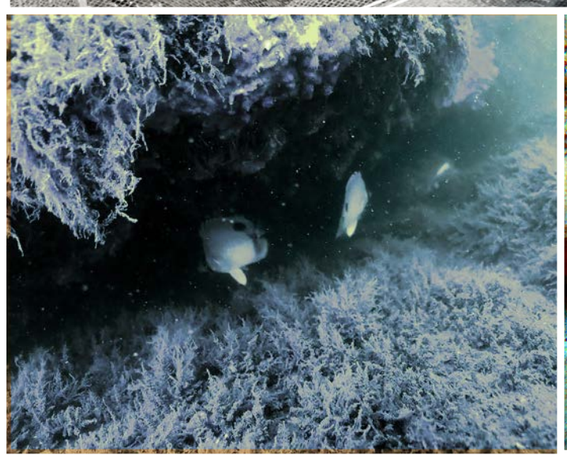
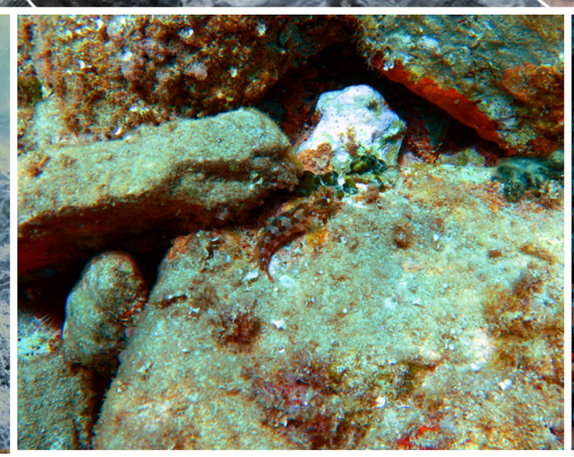
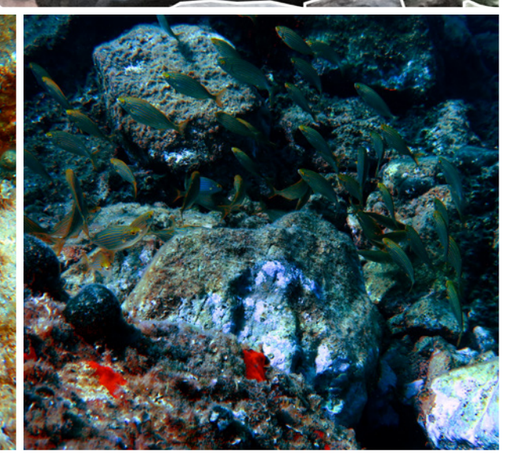


Image credit (top left to right): www.shutterstock.com/video/clip-2691671-stock-footage-underwater-ecosystem-in-fjord.html; www.naplesgov.com/index.aspx?NID=357; http://21stoleti.cz/2008/12/19/nejohrozenejsi-utes-sveta/; (bottom left to right)www.livingoceansfoundation.org/education/portal/course/reef-types/; Justin S. Rogers, 2013.

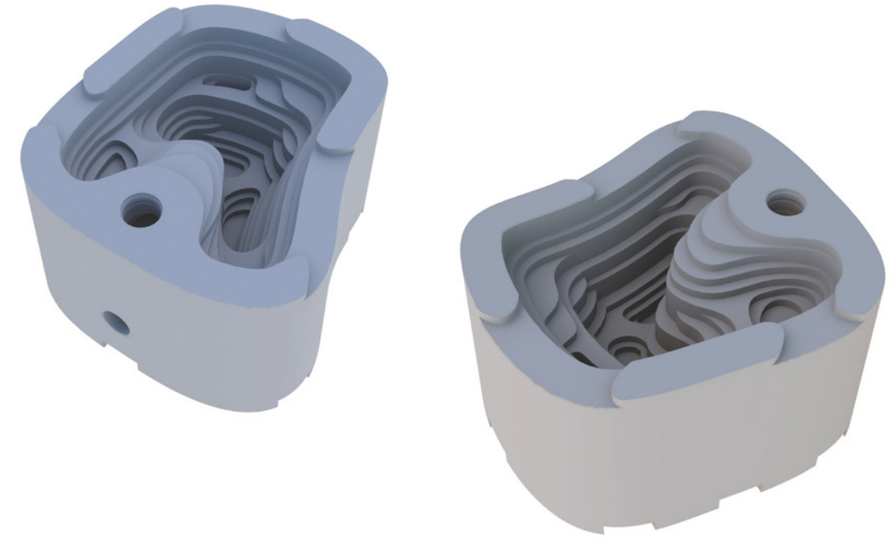
POROSITY & STONE SIZE DIVERSITY

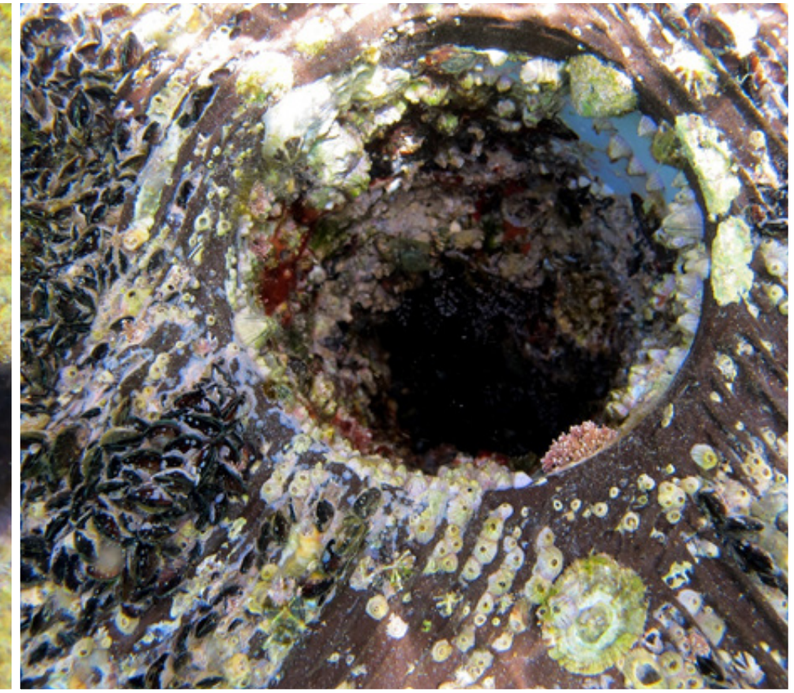






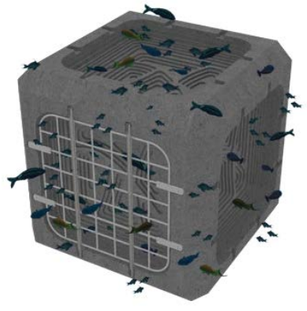
BIO-ENHANCING CONCRETE





SUBTIDAL TREATMENTS

FISH STREETS & CLUSTERS TREATMENTS



FISH HUB 1 (MESH ONLY)

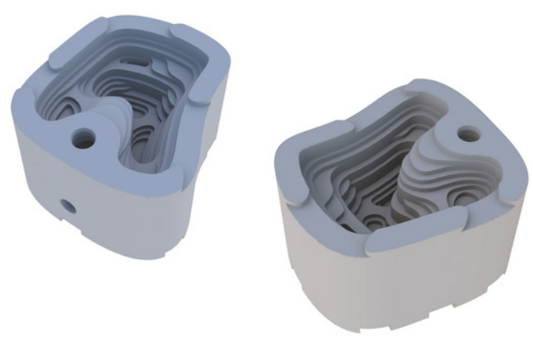
FISH HUB 2 (MESH + ROCKS)

OYSTER STREETS & CLUSTERS TREATMENTS

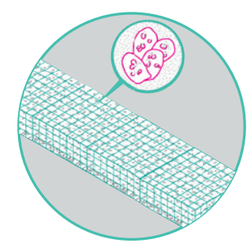
OYSTER HUB 1 (DISKS)

OYSTER HUB 2 (MESH+ SHELL)

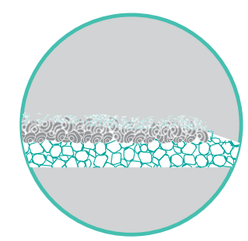
INTERTIDAL & EMERGENT AND EMERGENT TREATMENTS



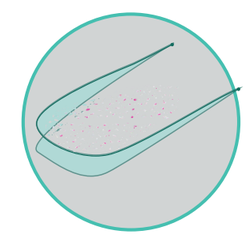
TIDEPOOLS



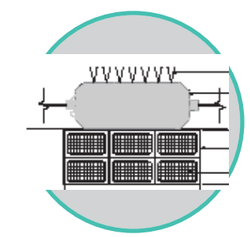
GABIONS



SPAT ON SHELL

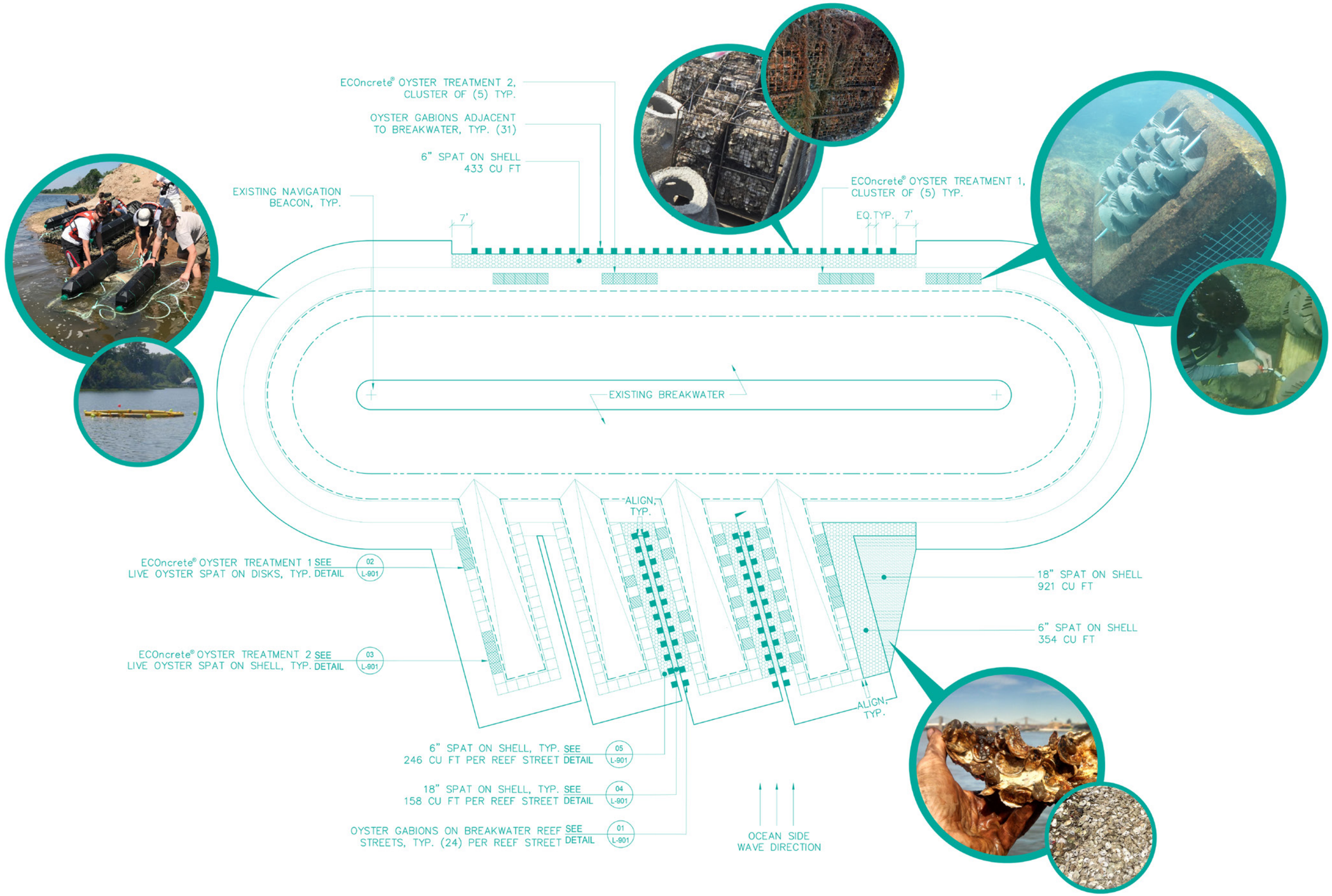


TANKLESS SETTING

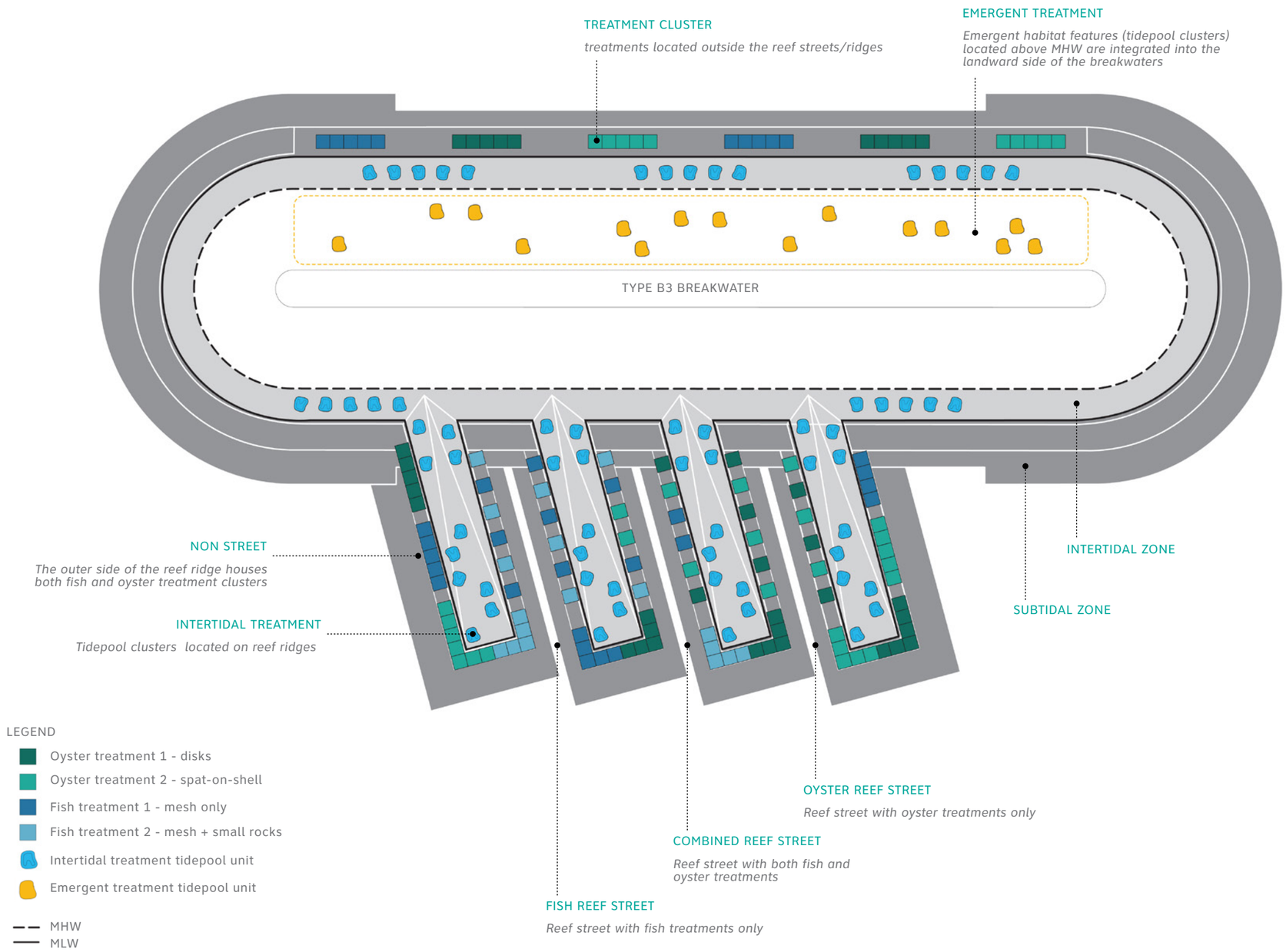


OYSTERGRO[R] UNIT

OYSTER RESTORATION TECHNIQUES



ECOLOGICAL TREATMENT LAYOUT



LIVING BREAKWATERS: DESIGN AND LAYOUT

CURRENT DESIGN

PROJECT ELEMENTS

EXISTING CONDITIONS

- MHW LINE (2015)
- MLW LINE (2015)
- EXISTING TRAIL SYSTEM
- PARKBOUNDARY
- SCHOOLS & COMMUNITY FACILITIES

LIVING BREAKWATERS

- BREAKWATERS
- PROPOSED SHORELINE RESTORATION
- FLOATING DOCK
- OYSTER NURSERY
- WATER HUB LOCATION AND RELATED ELEMENTS
- PATH AND WAYFINDING

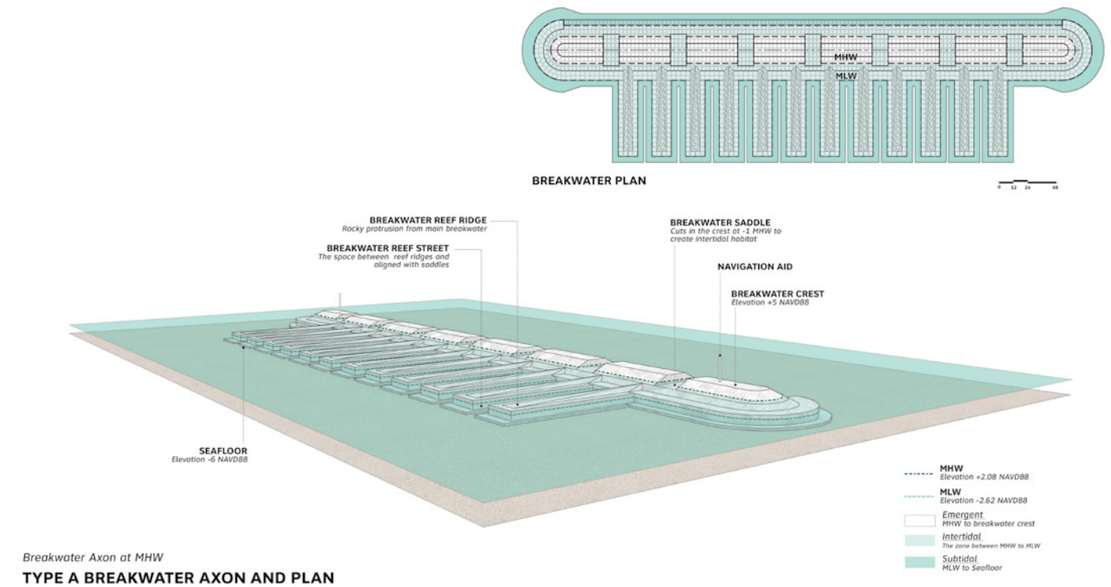
TOTTENVILLE SHORELINE PROTECTION PROJECT

- PROJECT (BERM, DUNE, ECO-REVETMENT, AND RAISED EDGE)
- PROPOSED PATH

0' 500' 1000' 2000'

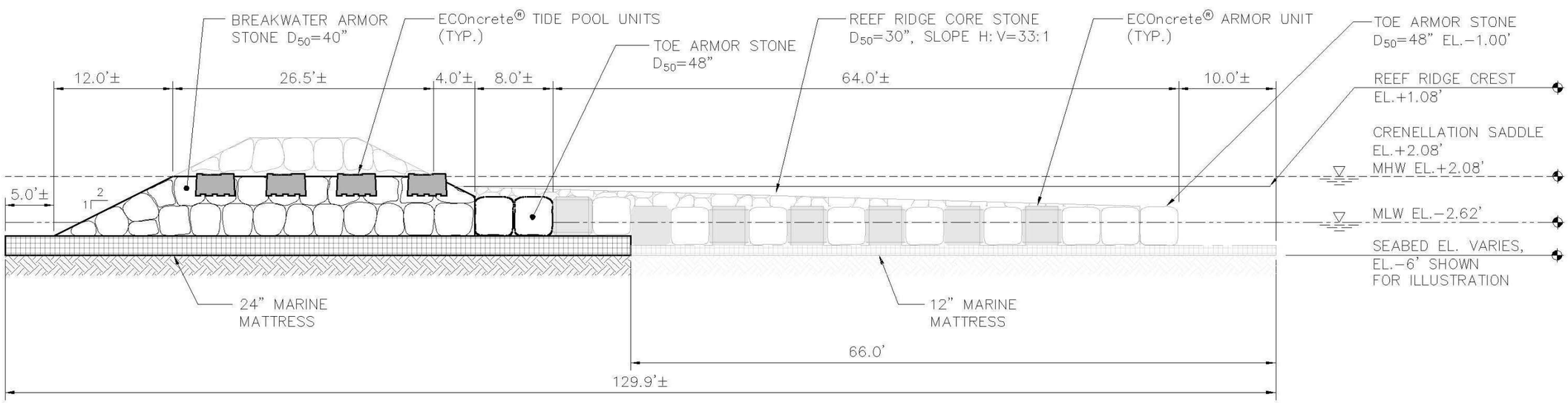
CURRENT DESIGN

LOW-CRESTED BREAKWATERS

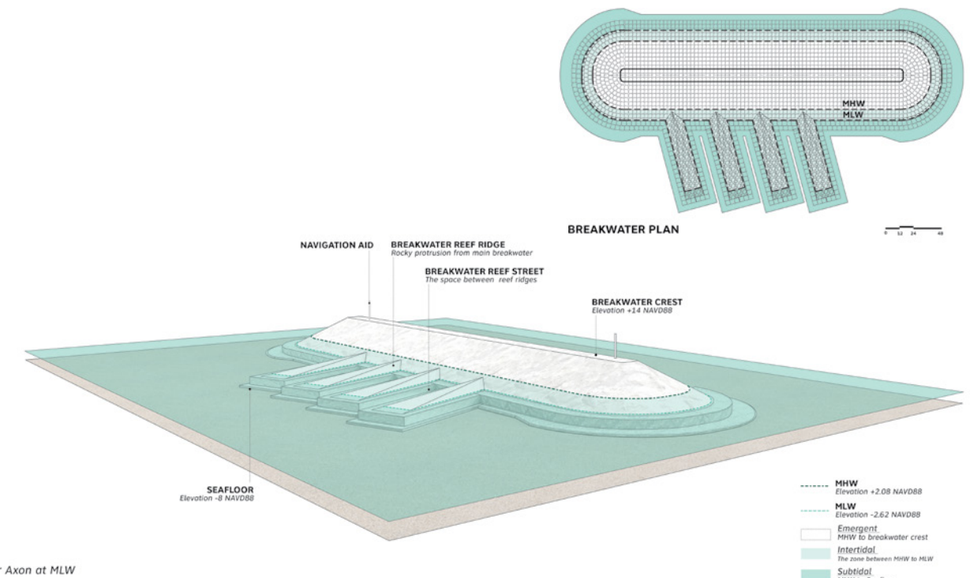


Breakwater Axon at MHW

TYPE A BREAKWATER AXON AND PLAN

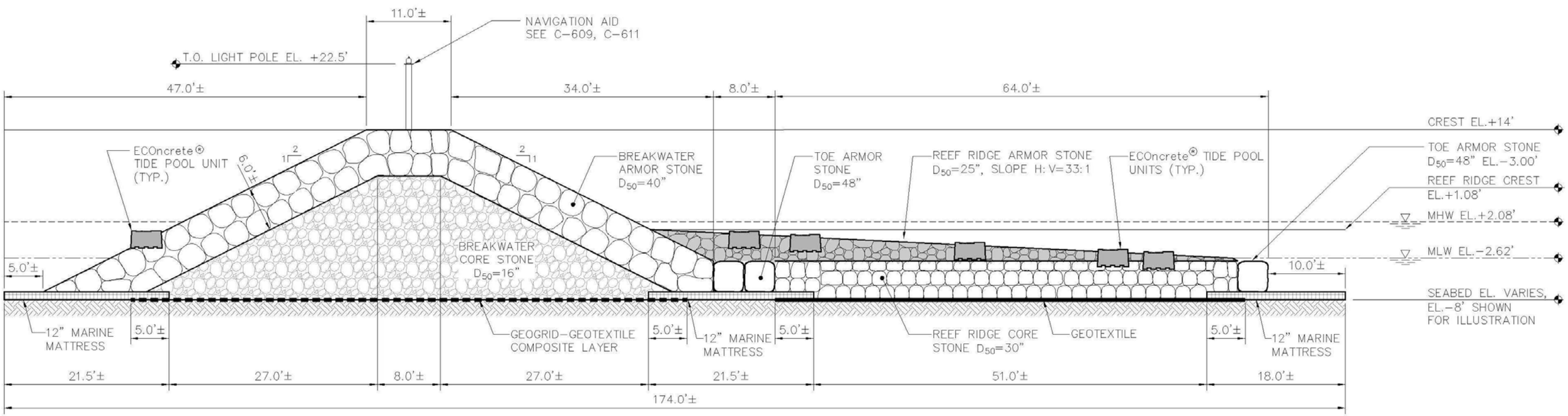


HIGH-CRESTED BREAKWATERS

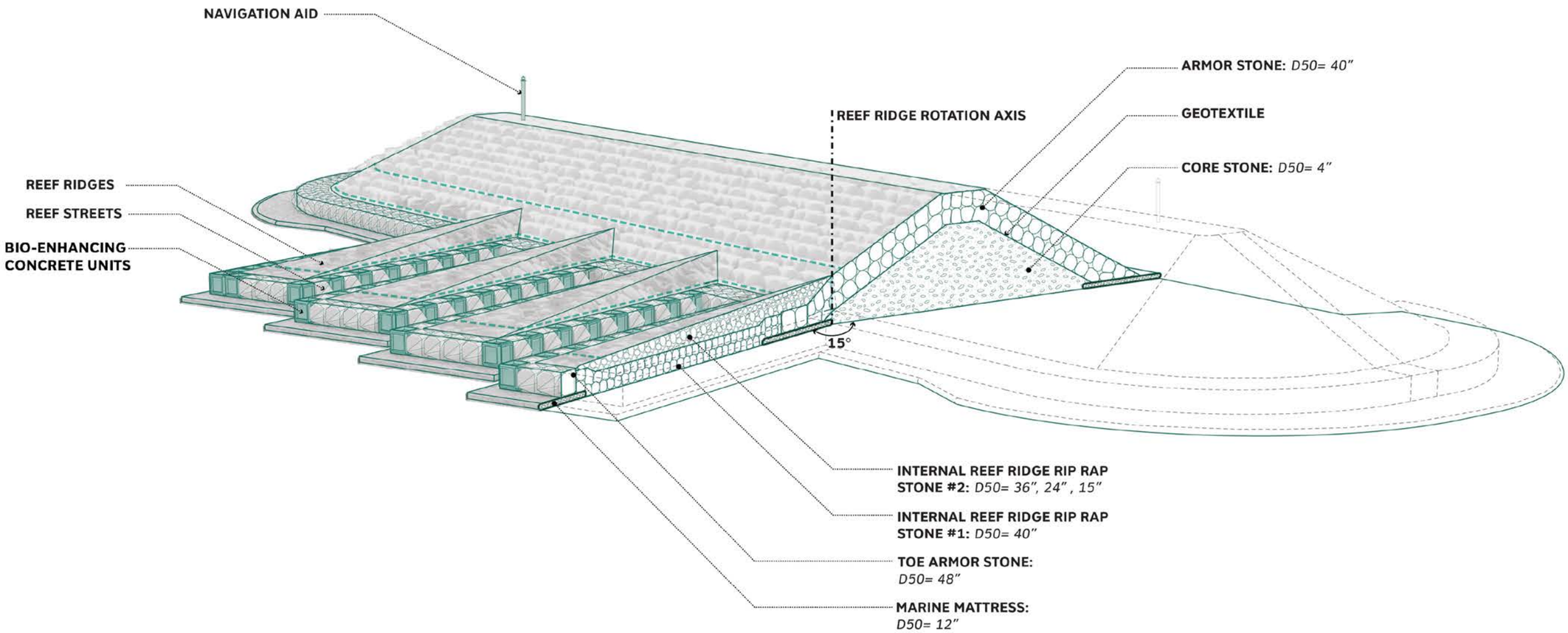


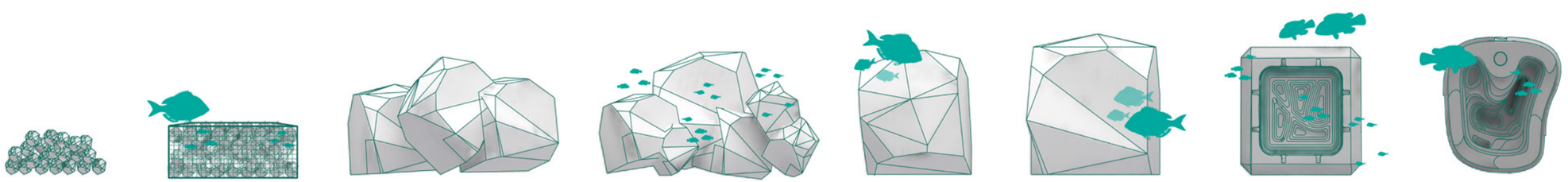
Breakwater Axon at MLW

TYPE B BREAKWATER AXON AND PLAN



ANATOMY OF A BREAKWATER





INTERNAL CORE STONE
D_{50}= 16"

MARINE MATTRESS
HT= 12"

REEF RIDGE CORE STONE
Dmin= 24" D_{50}= 30"
Dmax=36"

REEF RIDGE EXTERIOR STONE
D_{15}= 15" D_{50}= 24"
D_{100}=36"

STONE ARMOR UNIT
D_{50}= 40"

STONE TOE ARMOR UNIT
D_{50}: 48"

ECOncrete® TOE ARMOR UNIT
Dimension: 48"x 48"x 48"

ECOncrete® TIDE POOLS
Dimension: 44"X 48"X27

MATERIALS USED

ARMOR STONE

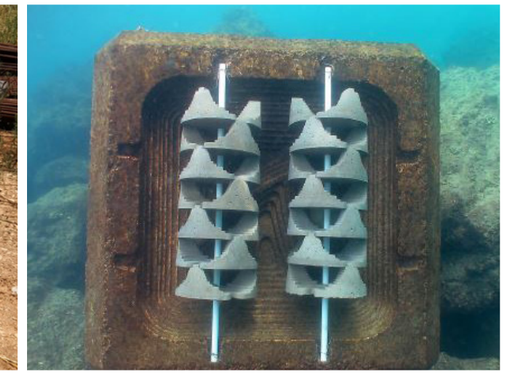
ρ ≈ 165 lb⁄ft3, narrow gradation: Wmin = 1.6 ton, W50 = 2.0 ton, Wmax = 2.4 ton . Armor stone is specified in weight to ensure stability. Equivalent diameters would be Dmin = 37 in, D50 = 40 in, Dmax = 43 in

TOE ARMOR STONE

ρ ≈ 165 lb⁄ft3, narrow gradation: Dmin = 41 in, D50 = 48 in, Dmax = 55 in. Quarried stones alternate with ECOncrete units.

ECONCRETE TIDE POOLS

ECONCRETE ARMOR UNITS



ECONCRETE ARMOR UNIT TREATMENTS

REEF RIDGE ARMOR

REEF RIDGE CORE STONE

ρ≈ 165 lb⁄ft3, narrow gradation: Dmin = 24 in, D50 = 30 in, Dmax = 36 in.

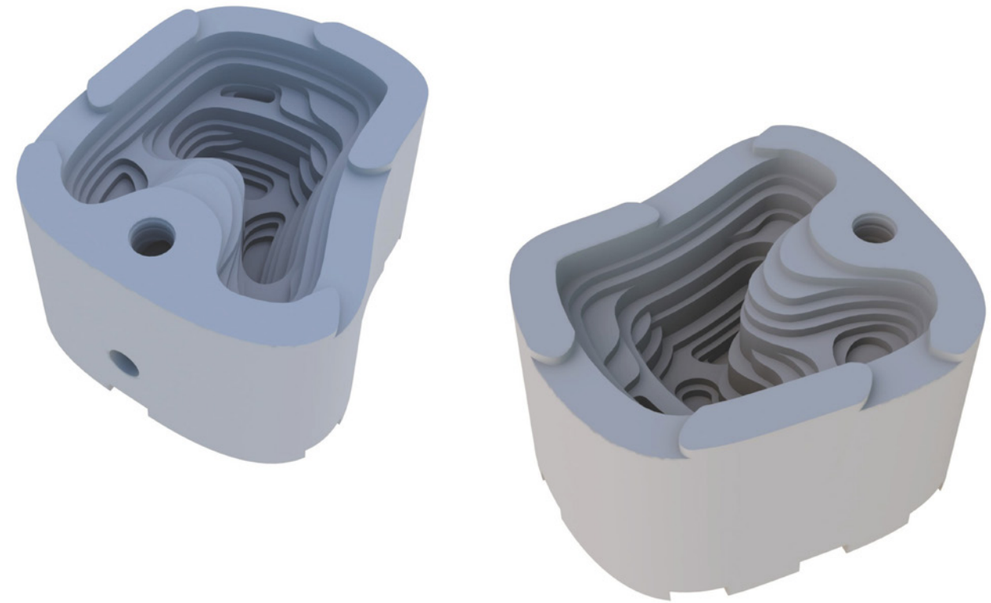
CORE STONE

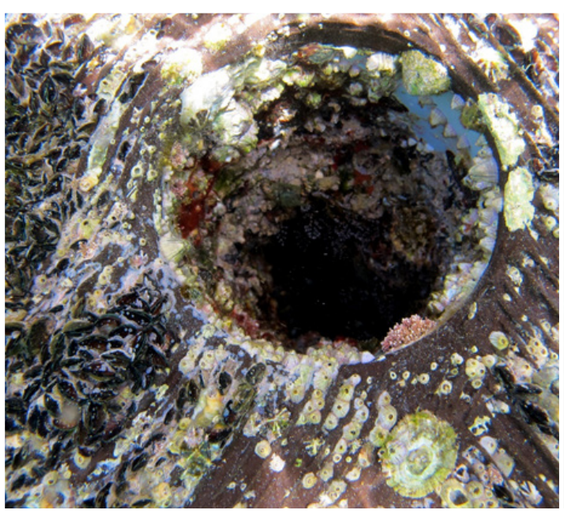
ρ ≈ 165 lb⁄ft3, narrow gradation: Dmin = 24 in, D50 = 30 in, Dmax = 36 in.

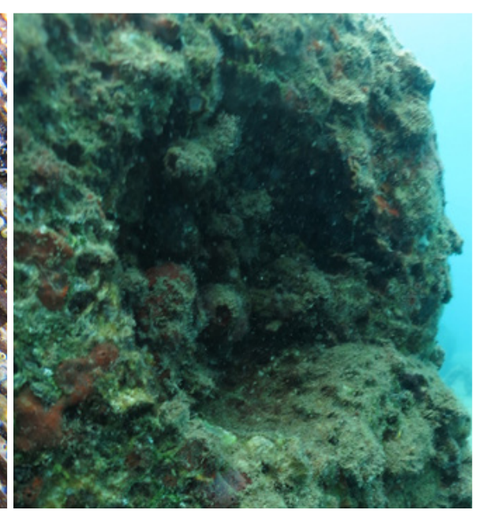
MARINE MATTRESS

GEOTEXTILE

MATERIALS USED: BIO-ENHANCING CONCRETE

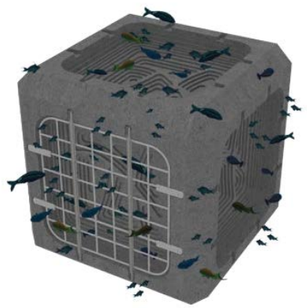






SUBTIDAL TREATMENTS

FISH STREETS & CLUSTERS TREATMENTS



FISH HUB 1 (MESH ONLY)

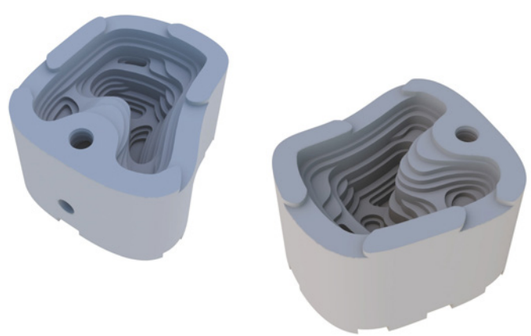
FISH HUB 2 (MESH + ROCKS)

OYSTER STREETS & CLUSTERS TREATMENTS

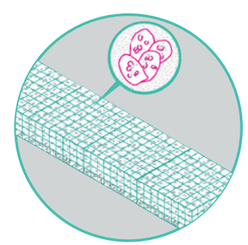
OYSTER HUB 1 (DISKS)

OYSTER HUB 2 (MESH+ SHELL)

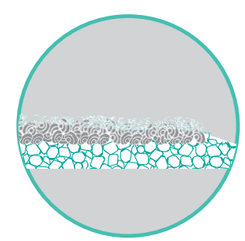
INTERTIDAL & EMERGENT AND EMERGENT TREATMENTS



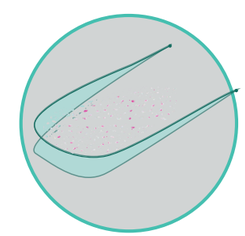
TIDEPOOLS



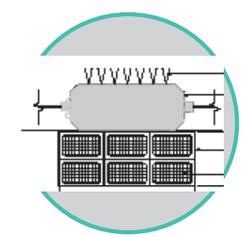
GABIONS



SPAT ON SHELL



TANKLESS SETTING



OYSTERGRO[R] UNIT

BREAKWATER STONE

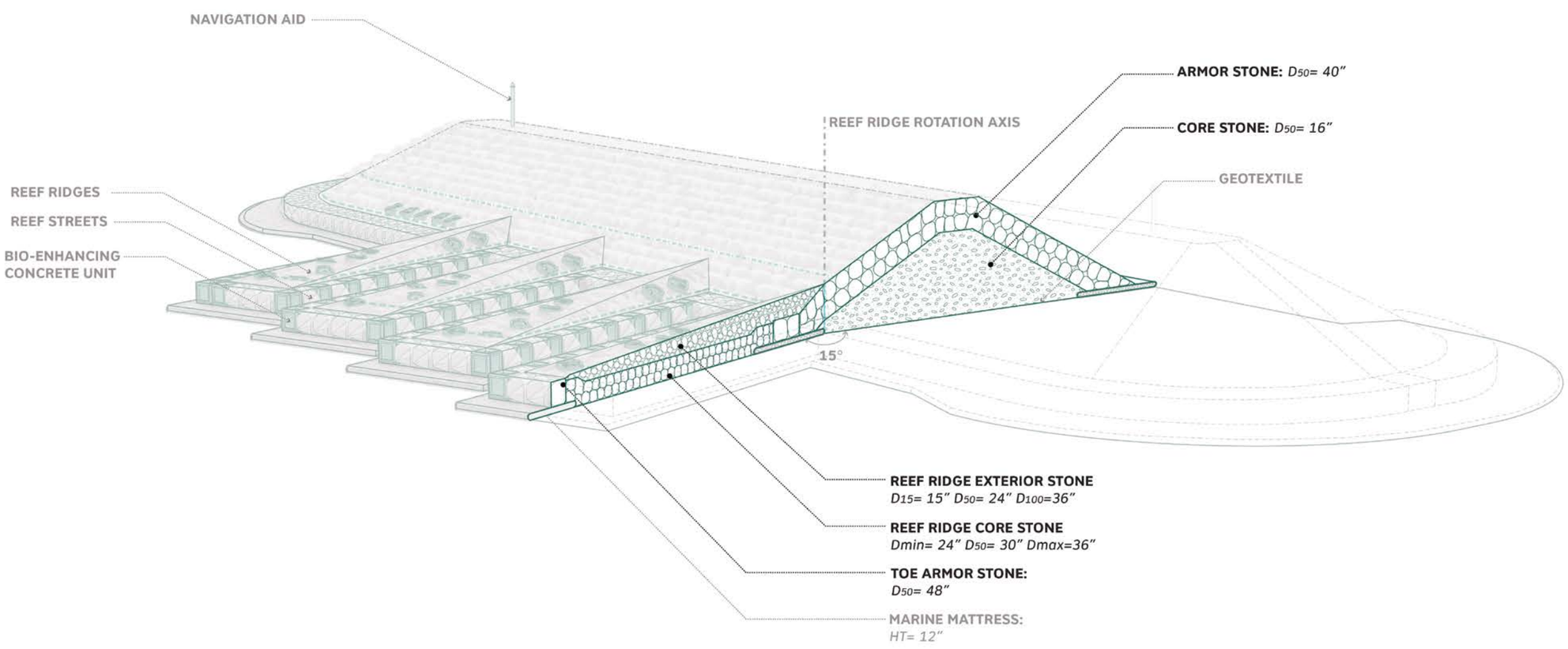
HOW IS STONE BEING USED IN THE LIVING BREAKWATERS?

The breakwaters will be primarily constructed of stone. The stone will be hard, durable, and sourced from quarries within the region in order to minimize transportation distance and cost. There are a variety of stone sizes within the Living Breakwaters, with each stone size serving a different function:

ARMOR STONE is the large visible stone that clad the outside layer of the breakwaters. They function to dissipate wave energy as waves hit the exterior of the breakwaters and move through the gaps between the stones. The main breakwater segment will be covered in armor stone two layers thick. Most of the stones will be approximately 3.3 feet in diameter. In some locations in the breakwaters, the exterior armor stones will be replaced with bio enhancing concrete armor units (see sheet on bio-enhancing concrete units). Slightly larger armor stones (**TOE ARMOR STONES**) 4 feet in diameter will be used along the base of the wave side of the breakwaters to provide additional structural support.

CORE STONE is the smallest size stone used and forms the central core of the breakwater, establishes the side slopes for the breakwater segment, and provides the base for the armor stone to sit on. The approximate average diameter of the core stone is 1.33 feet. The core stone sits on top of a geotextile to prevent the stones from settling into the sandy bottom.

RIP RAP stone will be used primarily within the reef ridge of the breakwater and will consist of a bottom layer of stone with an average diameter of 2.5 feet (**REEF RIDGE CORE STONE**), as well as a top layer of stone with greater variation in stone size in order to create a wider range of crevices between the stones for fish and other marine life to inhabit **(REEF RIDGE EXTERIOR STONE**); these will have an average diameter of 2 feet. Smaller stone (1' diameter or less) will also be found in the **MARINE MATTRESS**, stone-fill geogrid "bags" used at the base of the breakwaters (see cut-sheet on marine mattresses).



WILL THE STONES MOVE AROUND ON THE BREAKWATERS?

Stone sizes are specified by engineers based on an analysis of wave conditions to ensure that they will withstand the wave energy of daily waves and storm wave conditions. Stones are also placed in an fitted manner to ensure the stability and performance of the breakwaters. Some initial settling—slight (a few inches) movement and sinking--of the stones is typical immediately following construction.

HOW WILL THE STONE BE BROUGHT TO THE SITE?

It is anticipated that the stone will be shipped by barge to the project site either directly from the quarry or from an intermediate site where stone for the project is stockpiled and stored (a "staging area"). Once at the breakwater location within the project site, barges with a crane or large backhoe will lift and place stone materials in the water to construct the breakwaters.

WHAT TYPE OF STONE IS USED AND WHERE ARE THEY FROM?

At this time, it is assumed that granite is the preferred stone. The USACE Engineering Manual specifically identifies granite as the top ranked stone for this type of application, although there are several other types of stone that may be successfully used in marine construction. These include, but are not limited to, granite, diabase, basalt, gneiss, and limestone. Various quarries in the New York/New Jersey region have been identified as capable of providing stone for the Living Breakwaters project. The preferred method of stone transportation is by barge along the waterways connected to the project area.

WHERE HAS IT BEEN USED BEFORE?

PLUMB BEACH PROJECT
BROOKLYN, NEW YORK
USACE

The project uses stone in the construction of two groins on the eastern and western ends of Plumb Beach as well as in a stone breakwater. The structures were designed to alleviate long-term erosion and prevent the need for further re-nourishment. Specifically, the groins prevent sand from moving laterally along the beach, while the breakwater mitigates wave power.

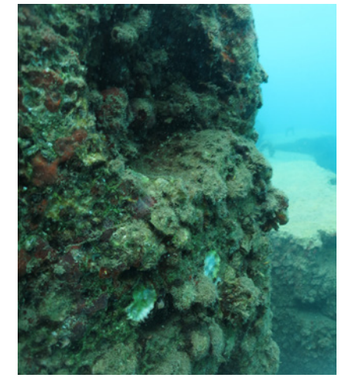
SIMS BREAKWATERS
BROOKLYN, NEW YORK
COWI

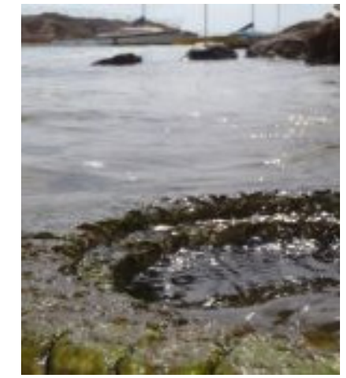
Submerged and emergent breakwaters have been constructed to provide wind-wave and wake-wave protection, reduce shoreline erosion and improve aquatic habitat. Three integrated, nearshore reef units were designed and created to take advantage of local hydro-graphic conditions and availability of rock from the nearby deepening of the harbor, and be self-maintaining structures.

BIO-ENHANCING CONCRETE UNITS

HOW ARE BIO-ENHANCING CONCRETE UNITS BEING USED IN THE LIVING BREAKWATERS?

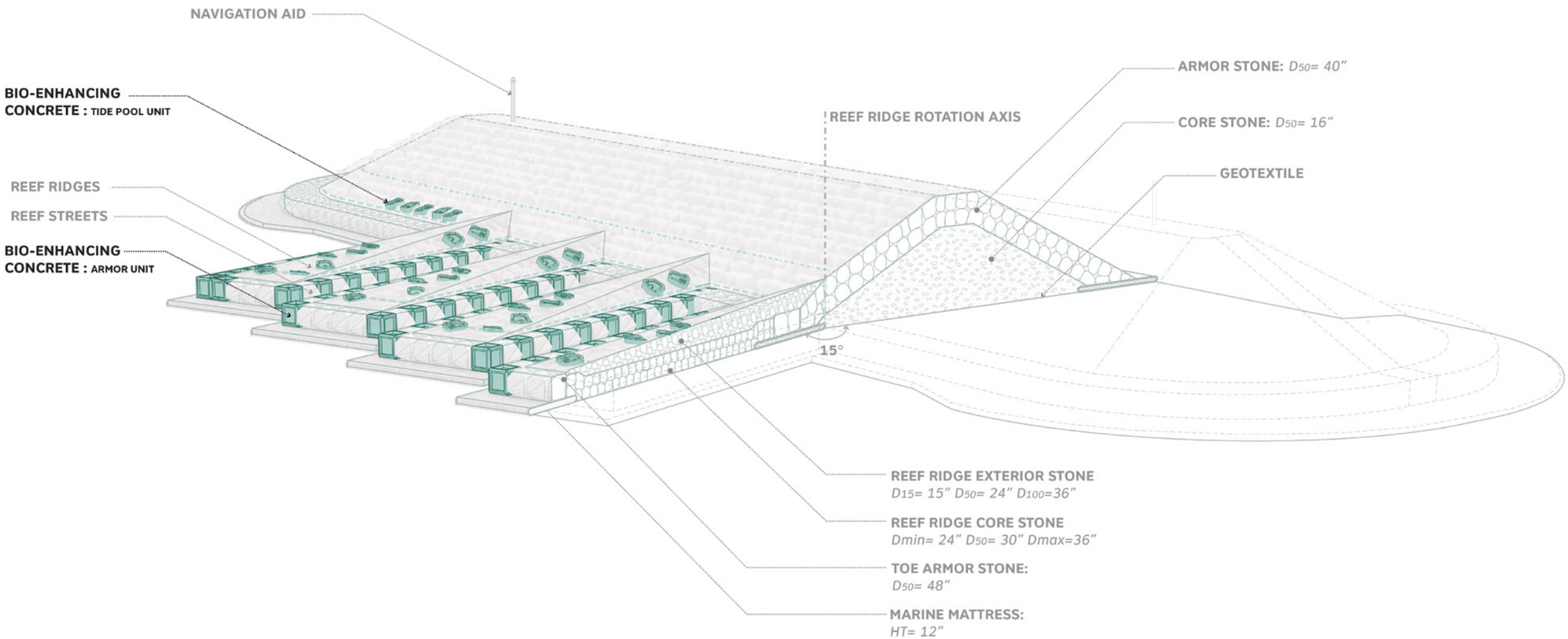
Throughout the breakwaters, some of the armor stone units will be replaced with bio-enhancing concrete armor units. Using these units will maintain the structural stability of the breakwaters, while enhancing their ability to recruit marine organisms and promote diverse and vibrant aquatic ecosystems. Overall, approximately 1 out of every 47 armor units will be made of bio-enhancing concrete (based on volume); the remainder will be stone. There are two types of bio-enhancing concrete units that will be used in the breakwaters:





BIO-ENHANCING CONCRETE ARMOR UNITS are cubed-shaped armor units with chamfered edges and faces specifically contoured (textured) to create complex surfaces that attract biological organisms and allow them to settle and stay on the units.

BIO-ENHANCING CONCRETE TIDE POOL UNITS are designed to mimic the form of natural rock pools; they are basin-shaped and capable of holding water between tides. These units will be placed within the intertidal zone of the breakwater to provide additional habitat and will be flushed with the tidal fluctuations.



WHAT ARE BIO- ENHANCING CONCRETE ARMOR UNITS?

Bio-enhancing concrete armor units are engineered to function structurally the same way as armor stone. They are also designed to provide a substrate that promotes the recruitment of marine plants and animals through science based chemical composition and physical design.

ARE BIO-ENHANCING CONCRETE UNITS STRUCTURALLY SOUND?

All bio-enhancing concrete units fully comply with the requirements for marine construction, and are designed to engineered specifications. They have been previously used for different marine applications in case studies spanning over 5 years in harsh marine environments. For the Living Breakwaters project, scaled physical models of the breakwaters will incorporate these units to test and verify the structural stability of the design.

WHY ARE THE BIO-ENHANCING UNITS CONCRETE

The concrete used within the bio-enhanced units is specifically designed to enhance natural recruitment of the region's diverse marine life by eliminating and replacing certain negative elements within the concrete mix and providing complex micro-surfaces, without effecting the concrete's structural performance. In previous case studies and lab tests, the bio enhanced concrete was successful in supporting a range of marine life, increasing localized biodiversity and favoring key marine species such as oysters.

WHERE HAS IT BEEN USED BEFORE?

BROOKLYN BRIDGE PARK
BROOKLYN, NEW YORK

USACE

Bio-enhancing concrete (ECOncrete®) was used as a constructive solution for the deteriorating timber piles damaged by marine burrowers. Bio-enhancing concrete pile encapsulation jackets provided the necessary constructive support and required protection, while creating a new and productive habitat for marine plants and animals thus decreasing the ecological footprint of the structure. Bio-enhancing concrete tideopools were also used within the park's rip-rap revetment to enhance the potential species recruitment and biodiversity in the intertidal zone.

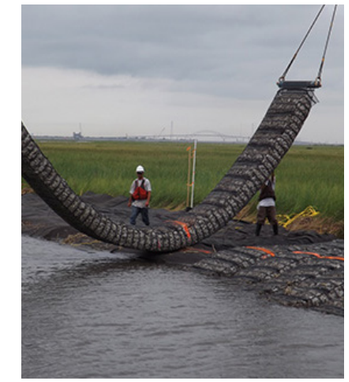
HAIFA PORT
EAST MEDITERRANEAN SEA, ISRAEL

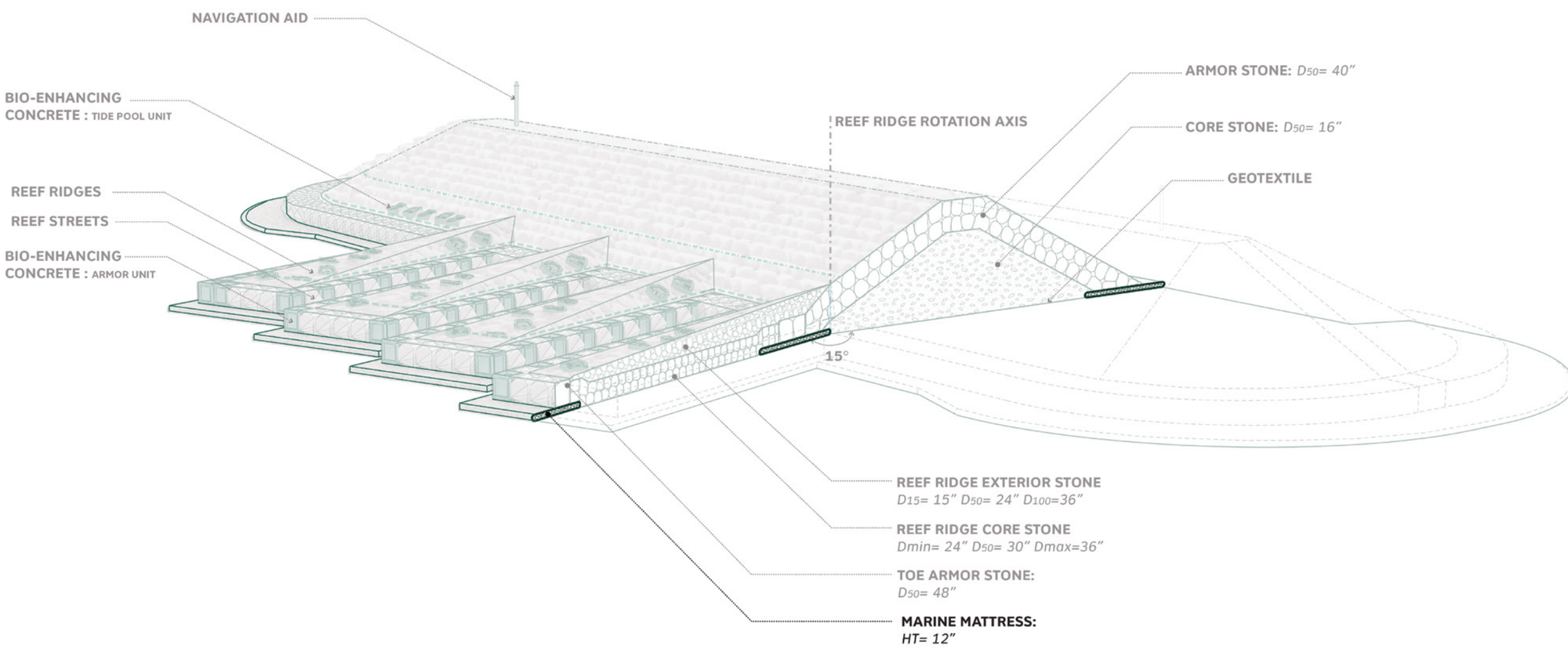
Bio-enhancing concrete (ECOncrete®) ecological cube-shaped armoring units called antifers, were used as a part of the construction of a new port breakwater. Three years of monitoring demonstrated their ability to create bio-diverse habitats. In comparison to standard concrete armoring units, bio-enhanced concrete armoring units yielded nearly double the number of invertebrate and fish species on the units.

MARINE MATTRESS

HOW ARE MARINE MATTRESSES USED IN LIVING BREAKWATERS?

Marine mattresses will be placed underneath the breakwater to reinforce the sediment located on the sea floor and to provide a secure foundation for the placement of additional stone and bio-enhancing concrete units. This material is critical to the performance of the breakwater because it prevents ocean currents and waves from eroding the sediment at the base of the breakwaters (scour).





WHAT ARE MARINE MATTRESSES?

Marine mattresses are a commonly used material in marine construction. They are composed of high strength mesh enclosure filled with stone. The mesh will be composed of durable materials able to withstand marine conditions.

The marine mattress forms a stabilized base on which the breakwaters can be constructed and works to prevent scour around the structures. Marine mattresses are known in the field of coastal engineering for their ability to provide reinforcement as well as their durability in coastal conditions.

Stone is used as fill material in the marine mattress and is sized according to the desired thickness of the mattress.

HOW WILL MARINE MATTRESS BE PLACED IN THE PROJECT SITE?

In typical placement of marine mattress, lifting loops are constructed on each end of the mat and rigged to spreader beams, a lifting device used to help cranes pick up heavy loads and distribute weight of materials throughout the placement process. Once attached to the spreader beams, the marine mattress can be lifted to horizontally and place into the desired location as specified within the engineering drawings.

WHERE HAS IT BEEN USED BEFORE?

HOLLY BEACH BREAKWATER
GULF COAST, LOUISIANA
USACE

Marine mattresses were used in the construction of a breakwater system along the coast of Louisiana. Specifically, marine mattress served as the foundation layer before the placement of stone breakwater units in each segment.

LIGHTHOUSE SCOUR PROTECTION
BARNEGAT INLET, NEW JERSEY
USACE

A revetment, similar to an underwater retaining wall, was constructed of armor stones placed over a bedding layer of marine mattress. Instead of placing mattresses individually, up to six mattresses were tied together to form mats measuring 20 ft by 30 ft that were then deployed during ebb tide when currents are reduced.

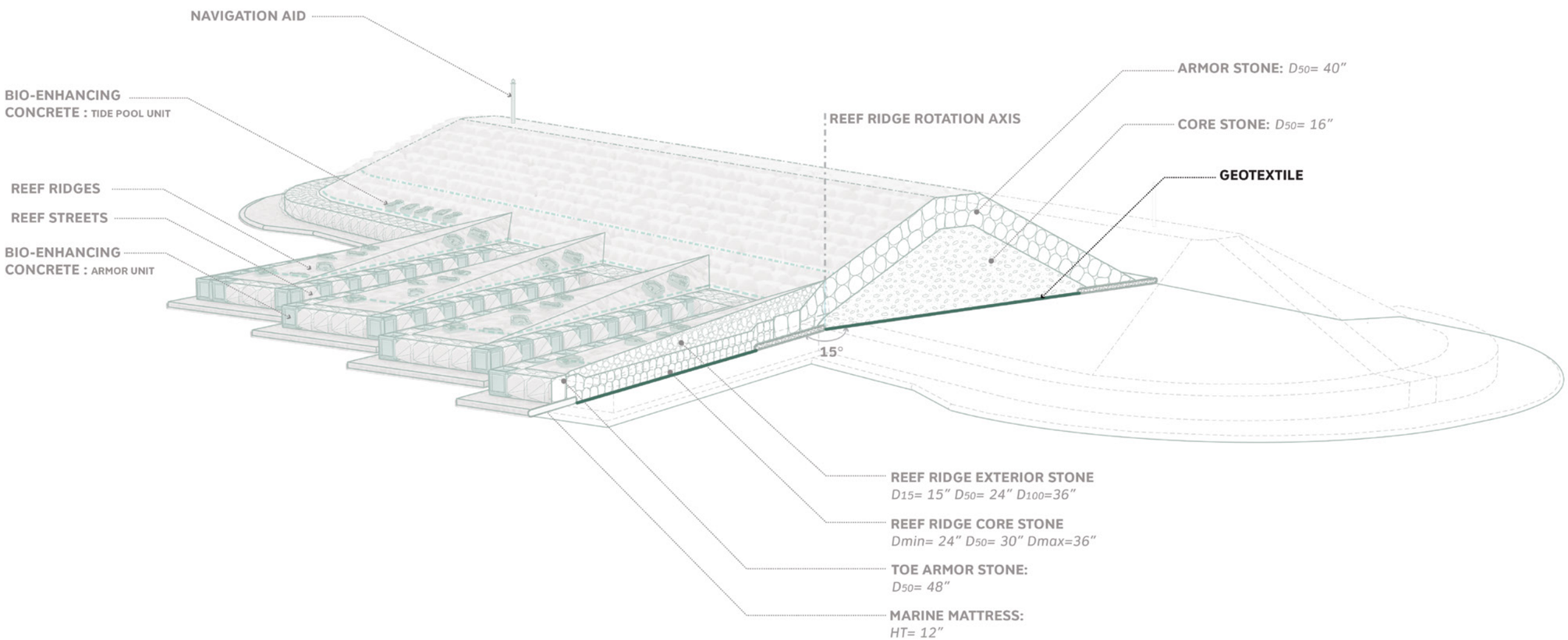
GEOTEXTILE

HOW ARE GEOTEXTILES USED IN THE LIVING BREAKWATERS?

Within the Living Breakwaters project, a geotextile will be placed under the breakwater before the stone is laid down to reinforce surficial soil at the sea floor and distribute loads of the breakwater to help ensure stability throughout the structure. Geotextiles may also be placed between adjacent layers of stone (e.g. core stone and armor stone) in order to prevent mixing and help minimize the overall volume of stone needed for construction. Geotextiles are commonly used materials within marine environments and serve as an important element to successfully install and secure breakwater materials.

WHAT OTHER TYPES OF STRUCTURES UTILIZE GEOTEXTILES?

Since geotextiles are widely used within marine construction, there are many applications for the material in coastal infrastructure. Groins, breakwaters, seawalls, and revetments are just a few of the many marine structures in which geotextiles are commonly used.



WHAT ARE GEOTEXTILES? WHAT ARE THEY MADE OF?

Geotextiles are either woven or non-woven permeable fabric, synthetic material and are used in conjunction with soil, rock, or earth to control erosion and increase soil stability. The different types of geotextiles are a function of their purpose, which may entail separation, filtration, drainage, reinforcement, confinement and/or erosion protection. Geotextile materials are designed to last indefinitely, only affected negatively if directly exposed to UV radiation consistently.

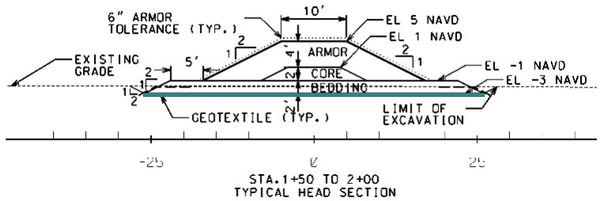
WHY ARE GEOTEXTILES USED IN MARINE CONSTRUCTION?

Geotextiles are used in marine construction as permeable protection layers, to secure other materials in place to reduce the potential for erosion, resuspension of sediment, or mixing of materials. Another key application is providing a foundation to prevent the erosion of base soils and ensure the structural stability of coastal structures such as breakwaters, groins, and jetties. In marine construction, it is important to specify a geotextile that serves the necessary purpose and can withstand the physical conditions such as waves and currents as well as chemical conditions such as salinity. The first documented uses of geotextile within the U.S. date back to the late 1950's, when waterfront property owners began looking for a more efficient way to provide a filter layer for protective structures, in place of the costlier graded granular layers that were normally used. In 1972, after 10 years of evaluating the new concept, the USACE issued their first comprehensive specification for filter fabrics, thus accepting geotextile layers as the superior construction technique.

WHERE HAS IT BEEN USED BEFORE?

PLUMB BEACH PROJECT
BROOKLYN, NEW YORK
USACE

This coastal management project consisted of constructing three stone structures: two stone groins and a permanent stone breakwater along with sand placement. During construction, geotextile fabric was layered between the structure base and the seafloor for both the breakwater and groins.



BREAKWATER PROJECT
FORT PIERCE, FL
USACE

The waterfront protection project included 12 island breakwaters and a peninsular structure designed to protect a marina from damaging storm waves. All of the structures use geotextile fabric in some capacity. Geotextile tubes were an integral component deployed in the construction of perimeter dikes, in the core of the groins in each island, as well as in constructing the living shoreline.