STRUCTURES 101

OR

BREAKWATERS, BACON AND EGGS

A BREAKFAST SEMINAR

by

Dr. Kevin Bodge, PE

olsen associates, inc.
jacksonville, florida

A note regarding the PDF version of this presentation.

This is a condensed version of a live seminar presented at the 2011 National Conference on Beach Preservation Technology, hosted by the Florida Shore & Beach Preservation Association (FSBPA), in Jacksonville Florida, on February 10, 2011.

The presentation includes significant visual animation and narrative describing the physical processes and typical effect of coastal structures along sandy beaches. These live features are not captured in this PDF presentation, nor fully explained through the static images herein. We hope that you might have the opportunity to see a complete presentation of this topic at a future FSBPA conference.

coastal structures

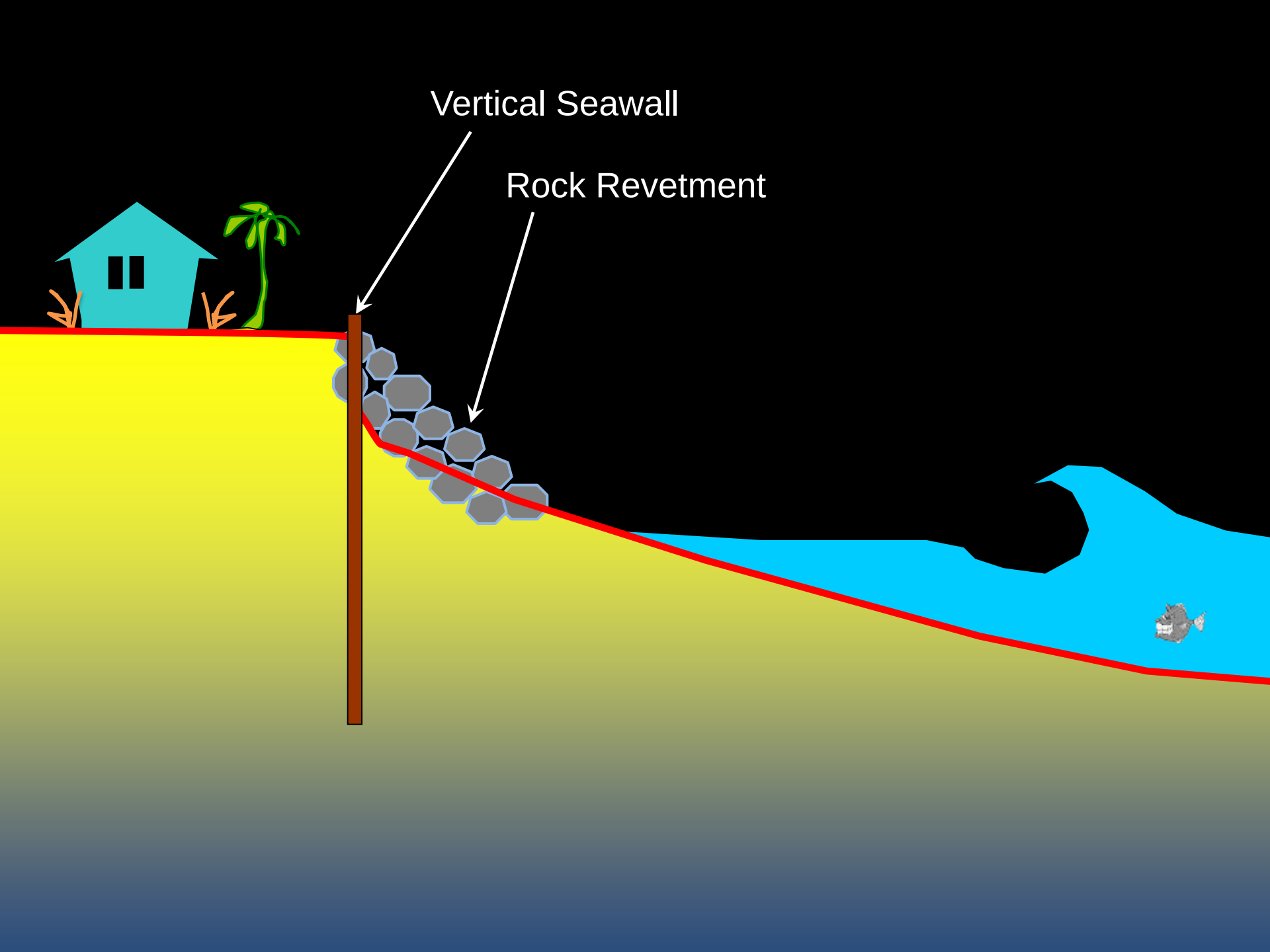
1. **Shoreline armoring** (seawalls, revetments)

2. **Littoral drift structures** (groins, breakwaters)

Shoreline Armoring

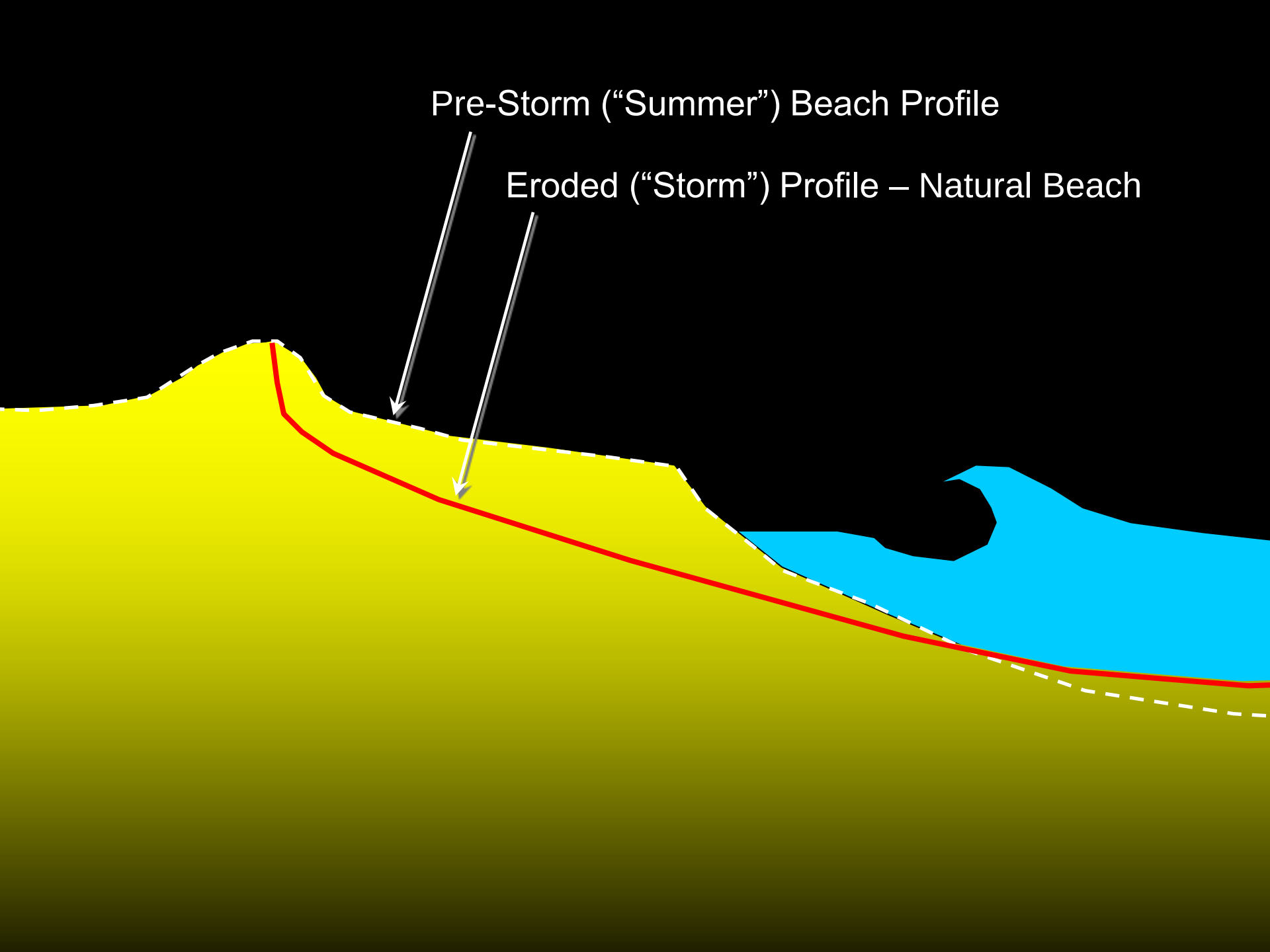
SEAWALL

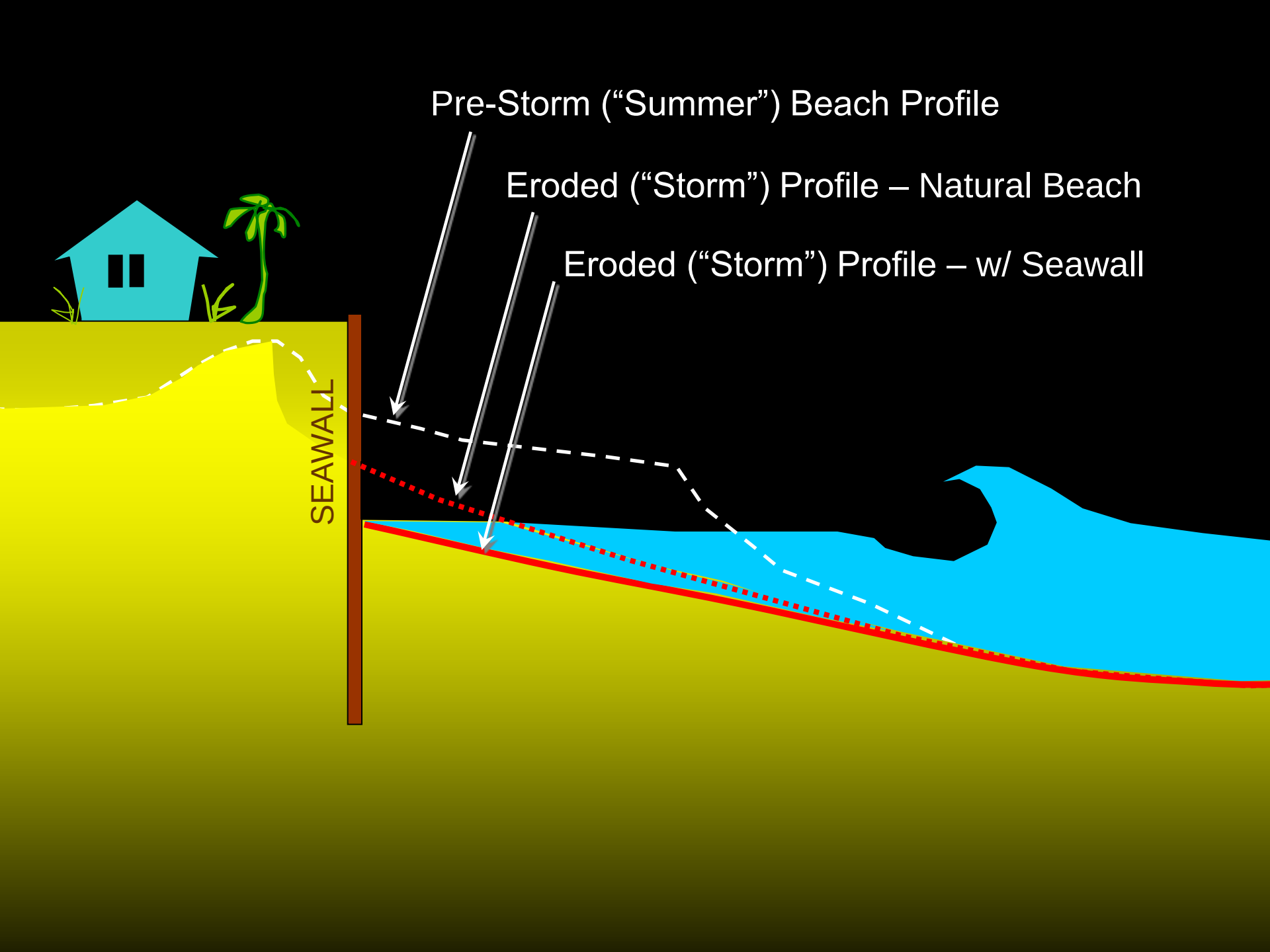
REVETMENT

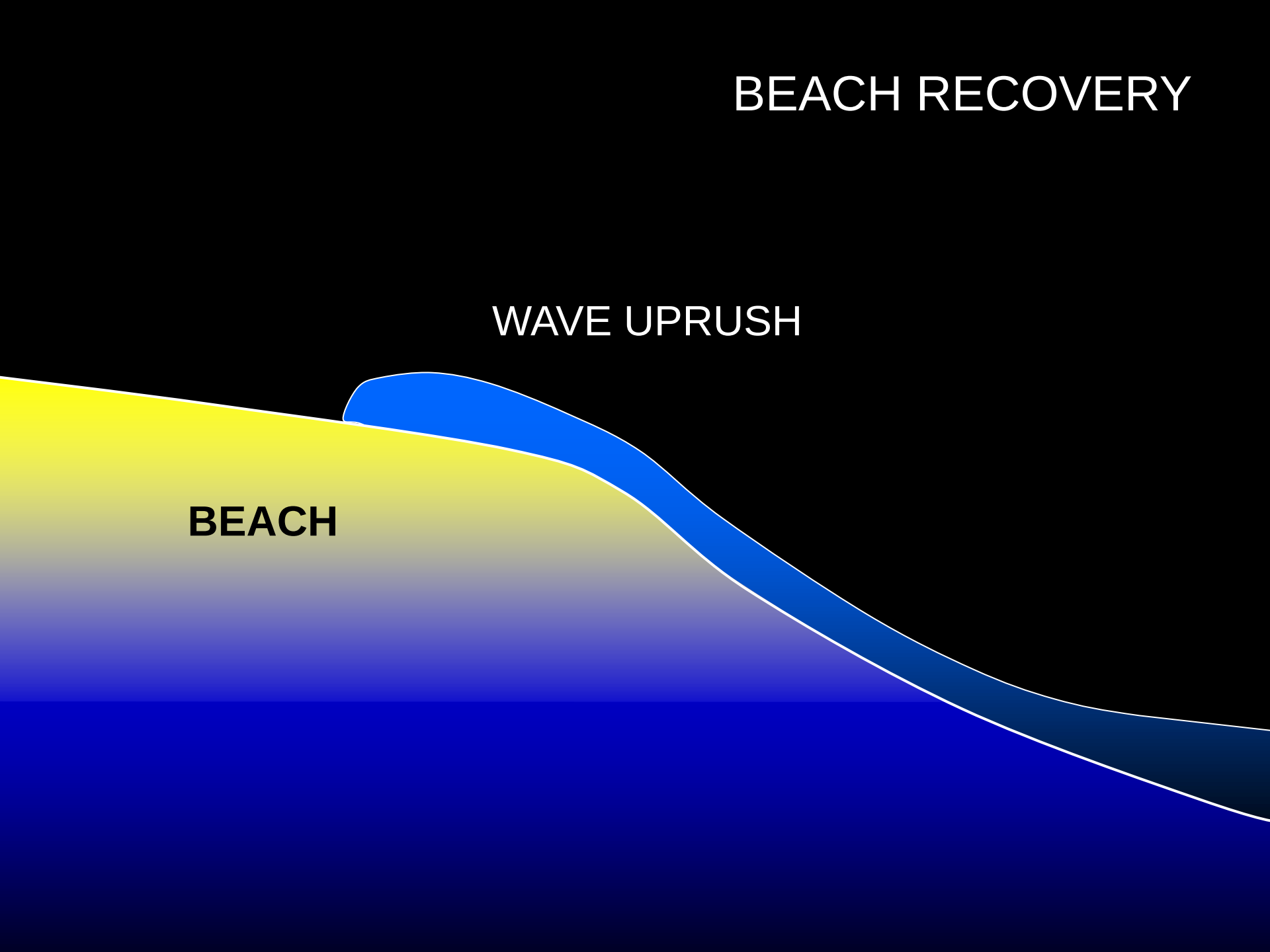

Vertical Seawall
Rock Revetment

Shoreline Armoring

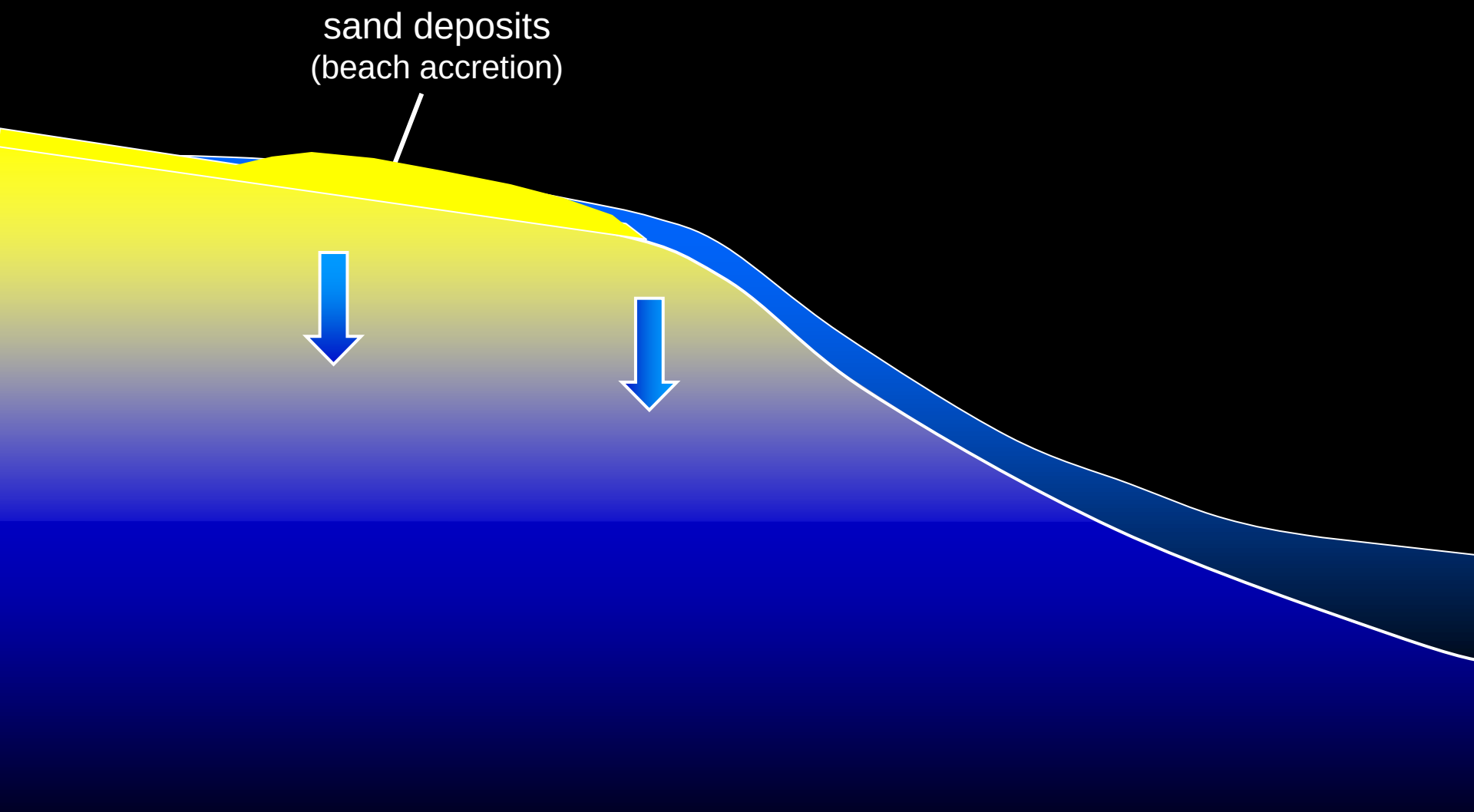
SAND-FILLED GEOTEXTILE TUBES

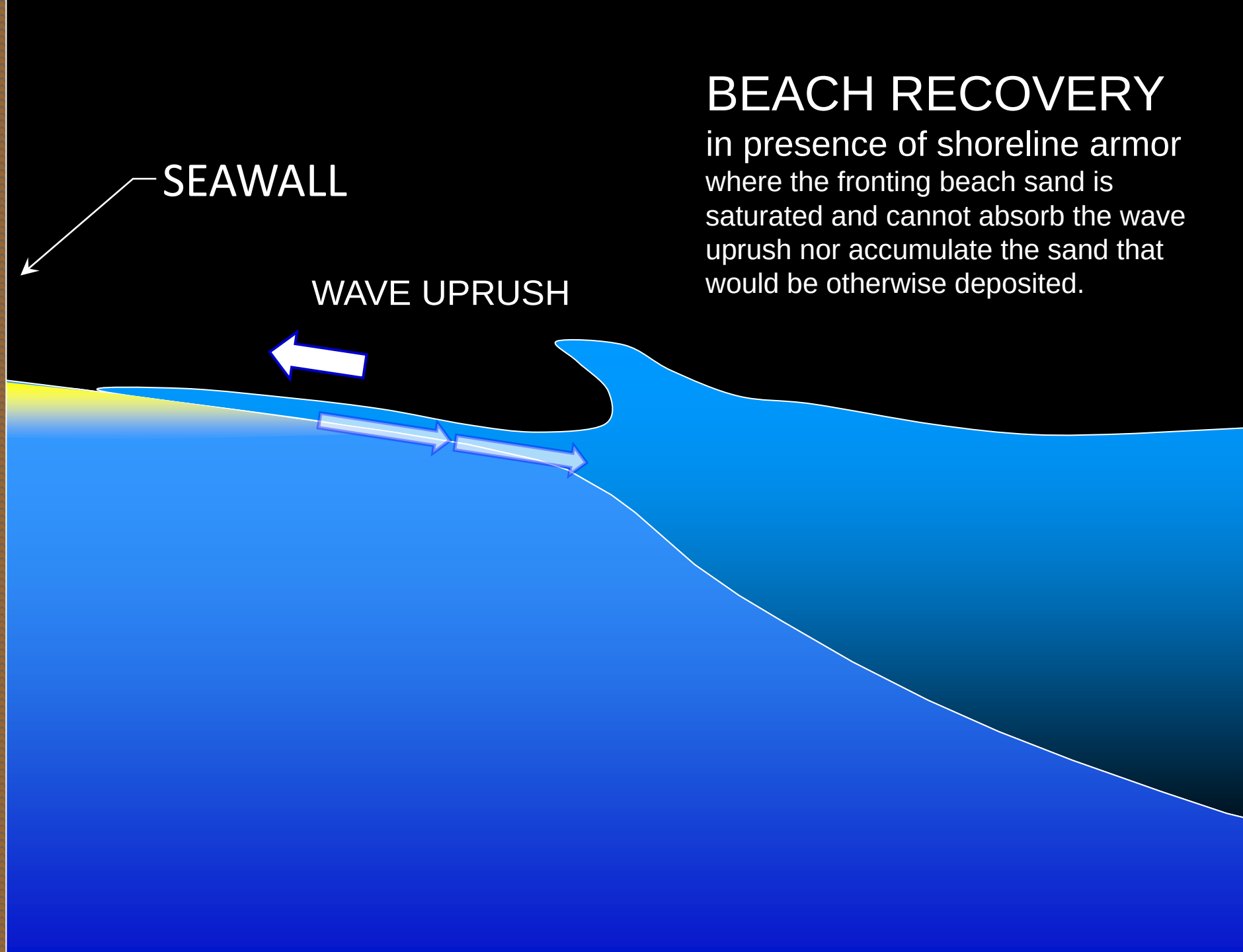

Pre-Storm (“Summer”) Beach Profile
Eroded (“Storm”) Profile – Natural Beach


Pre-Storm (“Summer”) Beach Profile
Eroded (“Storm”) Profile – Natural Beach
Eroded (“Storm”) Profile – w/ Seawall
SEAWALL


BEACH RECOVERY
WAVE UPRUSH
BEACH

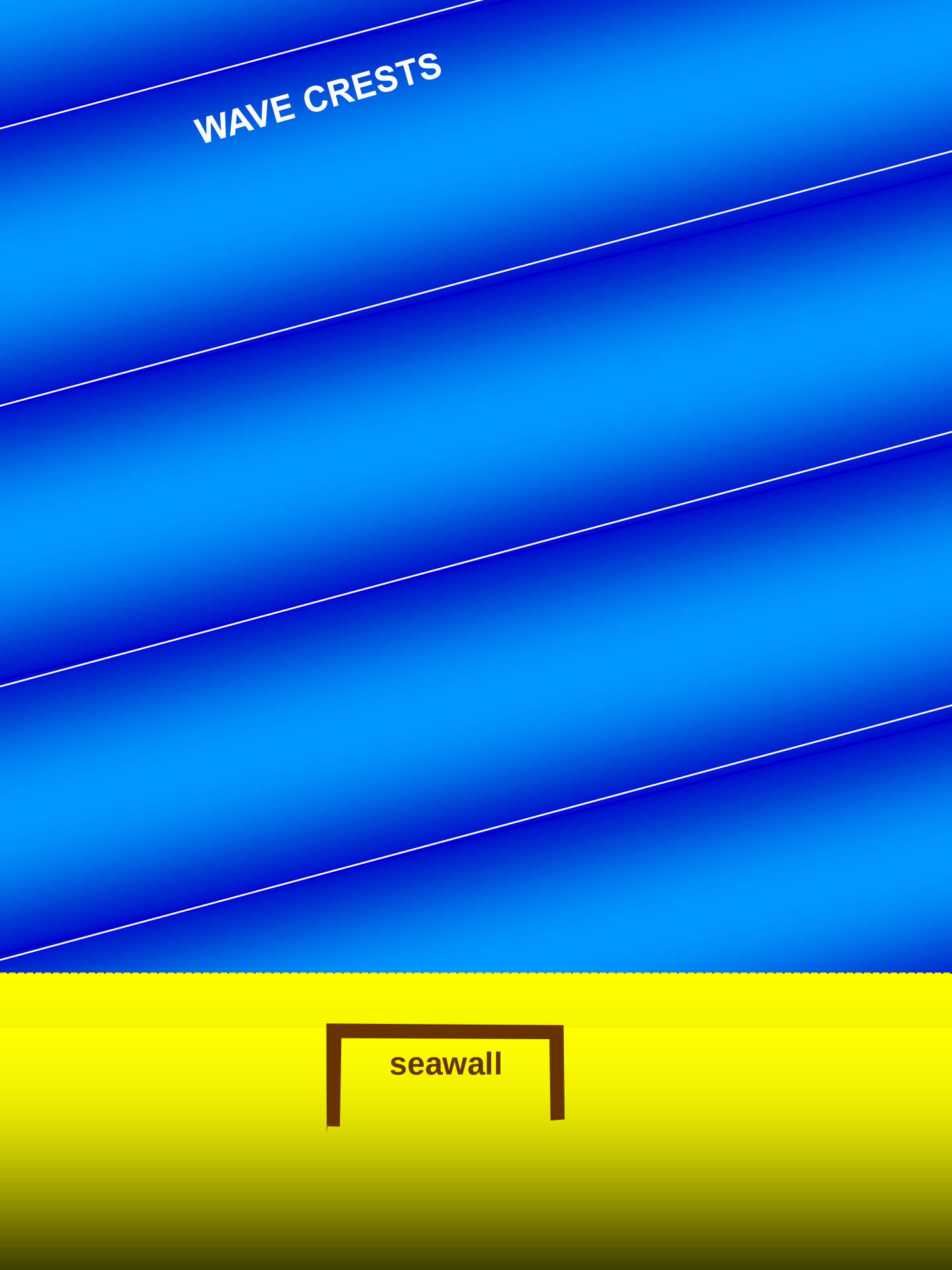
BEACH RECOVERY

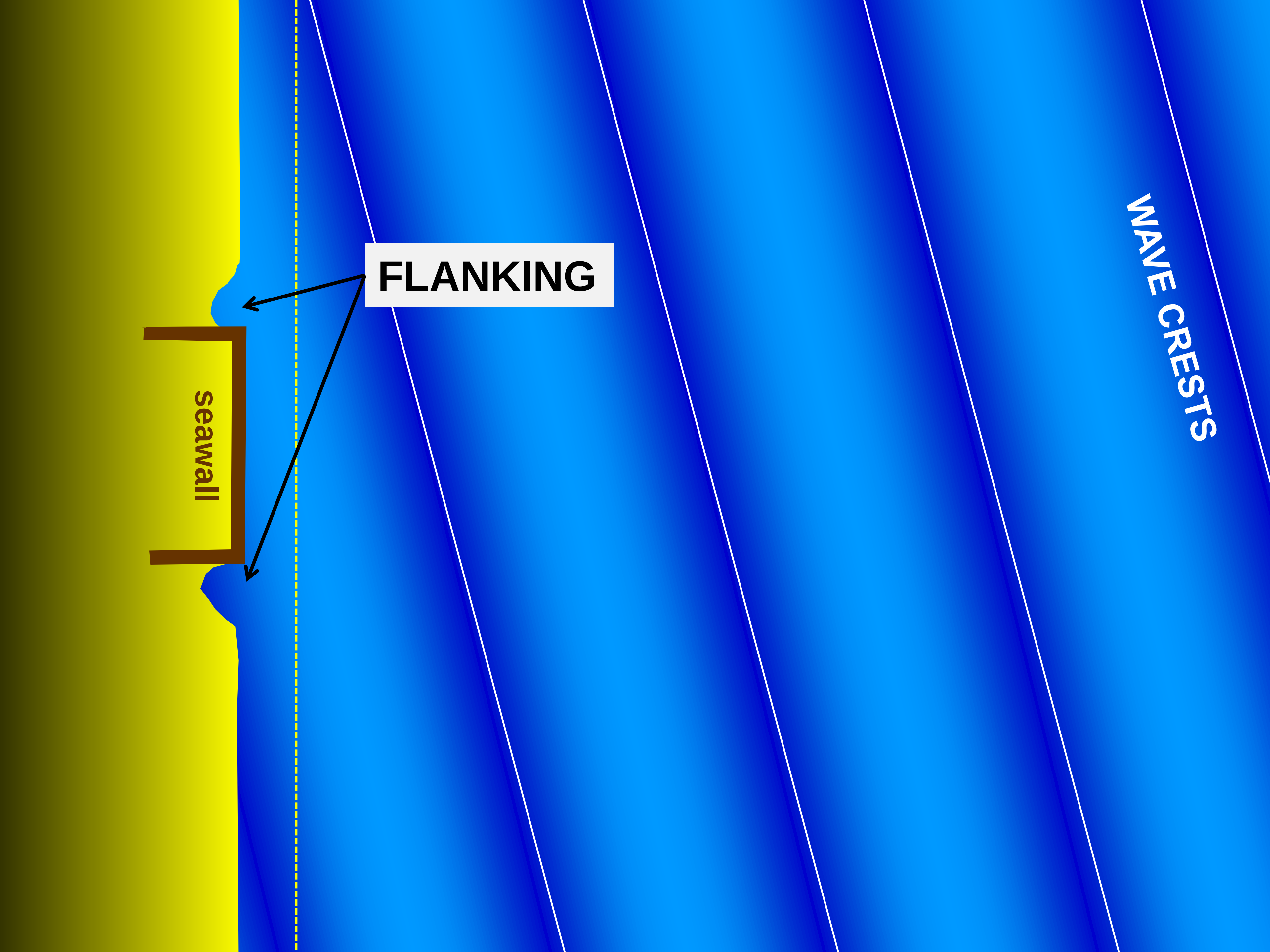


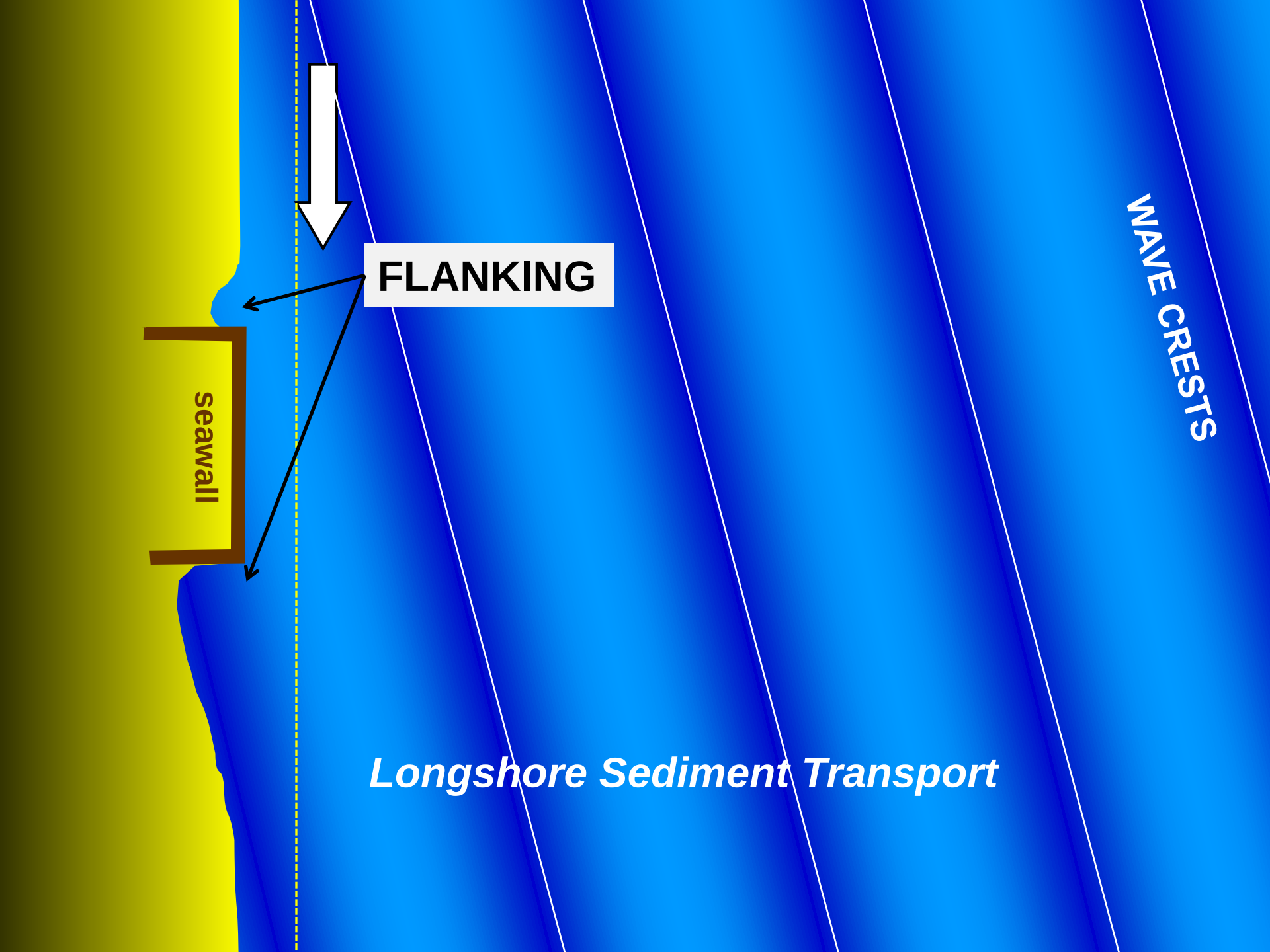

BEACH RECOVERY
in presence of shoreline armor
where the fronting beach sand is saturated and cannot absorb the wave uprush nor accumulate the sand that would be otherwise deposited.
SEAWALL
WAVE UPRUSH

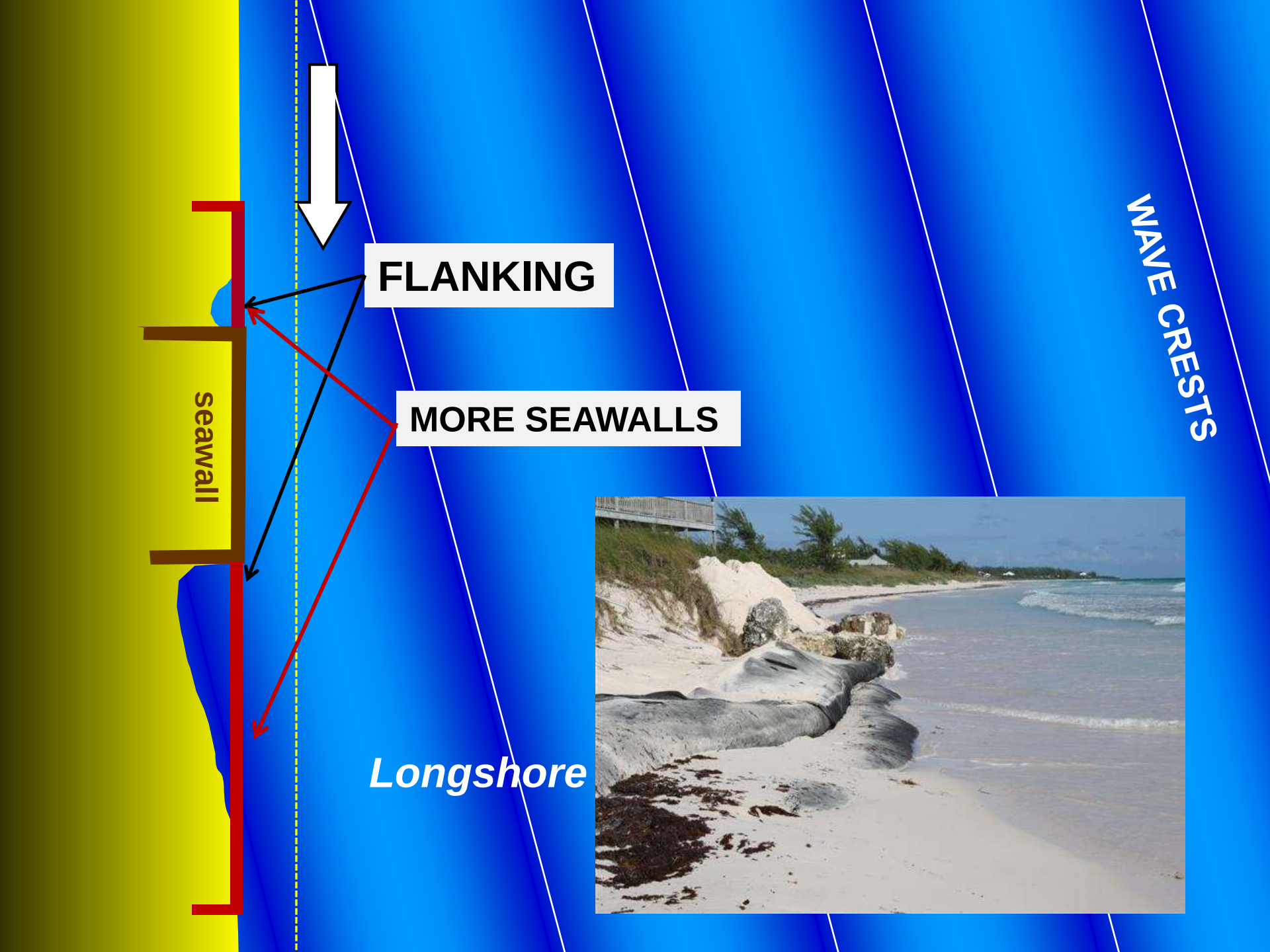
Porous Sill Bulkead

Kailua Beach, Oahu
Hawai'i


WAVE CRESTS
seawall


FLANKING
seawall
WAVE CRESTS


FLANKING
seawall
WAVE CRESTS
Longshore Sediment Transport


FLANKING
MORE SEAWALLS
seawall
WAVE CRESTS
Longshore

Patrick Air Force Base, Florida

Removing the armor from the active littoral system is the best approach to removing its effects upon the beach.

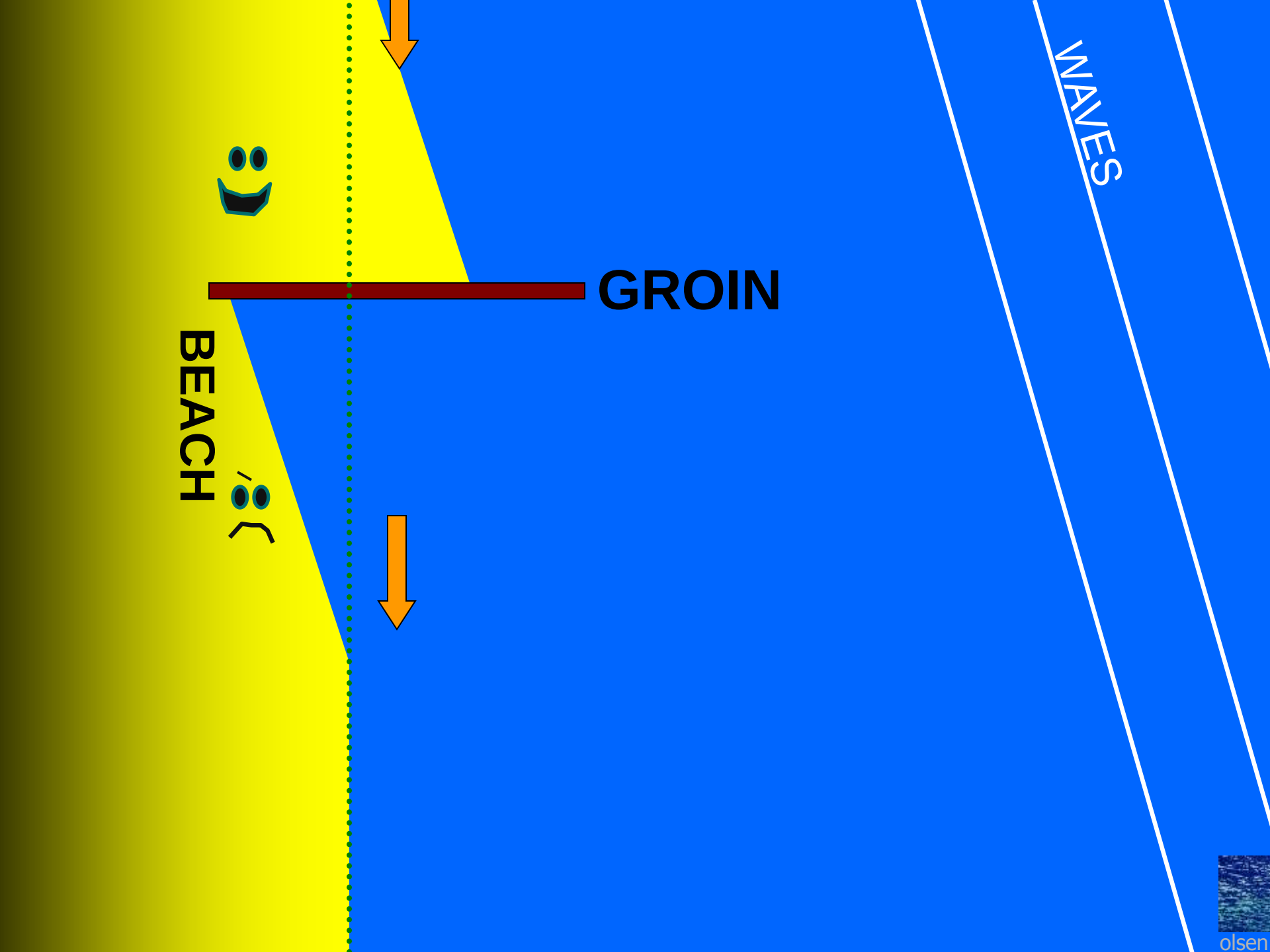
Before Beach Nourishment (1997)

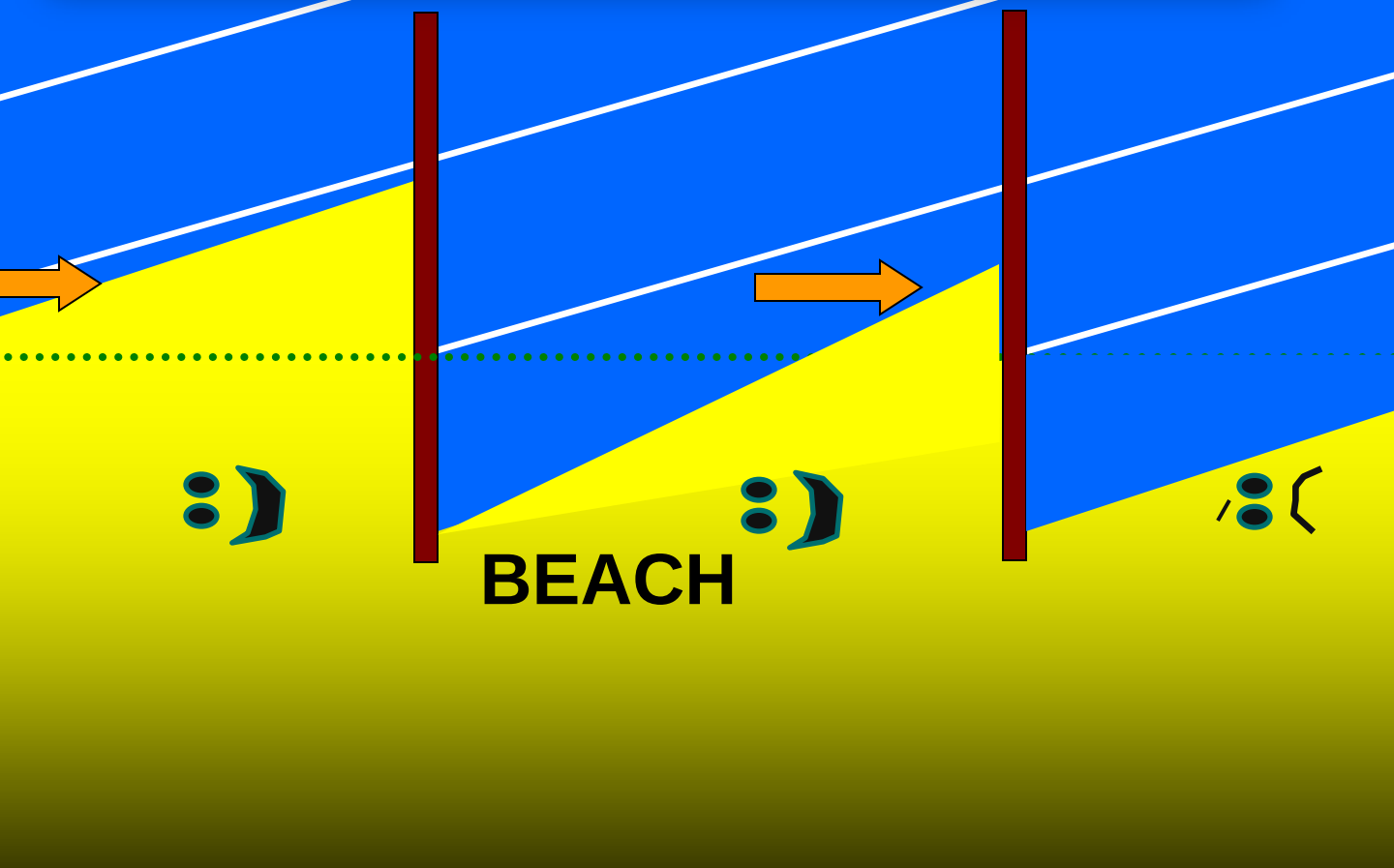
After Beach Nourishment (2010)

“Groins” versus “Jetties”

Example of a **Groin Field**

(Bald Head Island, North Carolina)

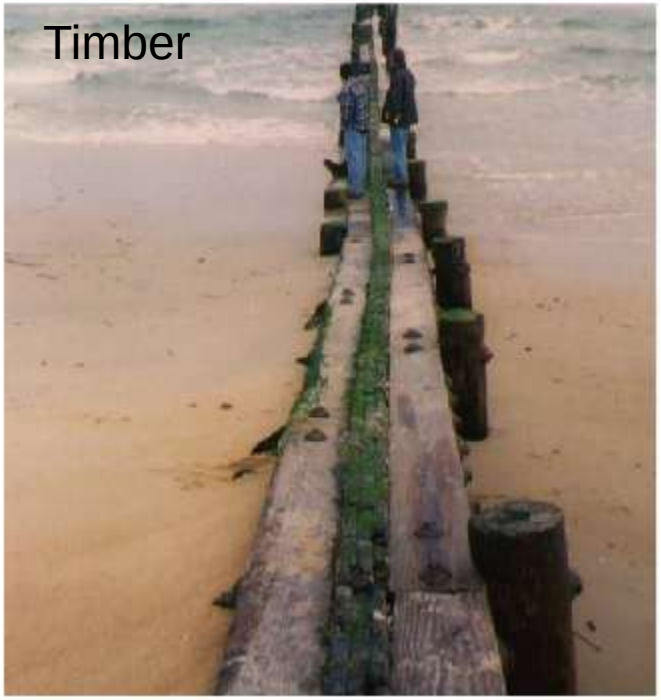

WAVES
GROIN
BEACH



Rock Boulders

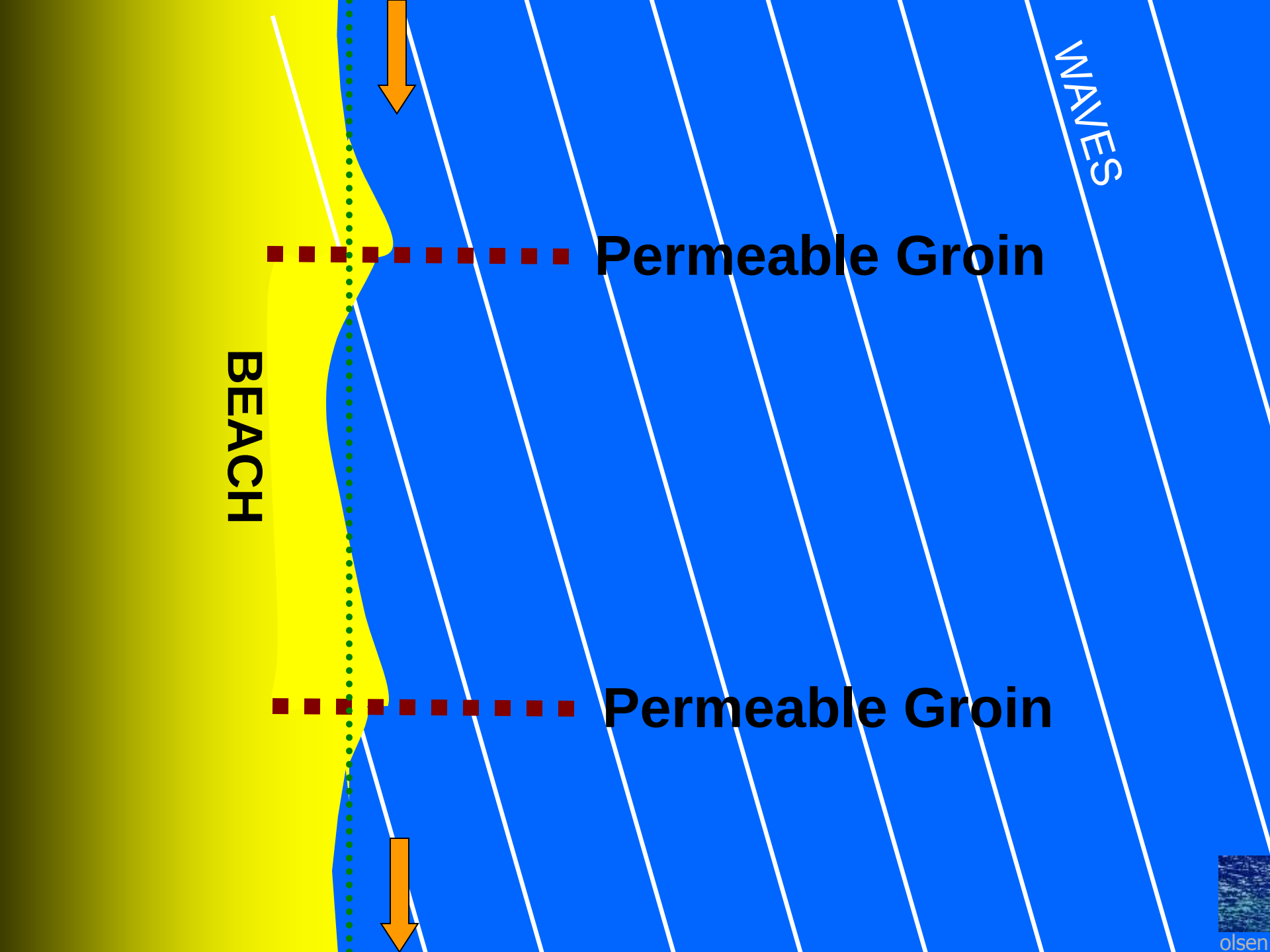
Geotubes

Timber



Steel

The effect of a groin is the same regardless of its material construction.


WAVES
Permeable Groin
BEACH
Permeable Groin

Examples of Permeable Groin Structures

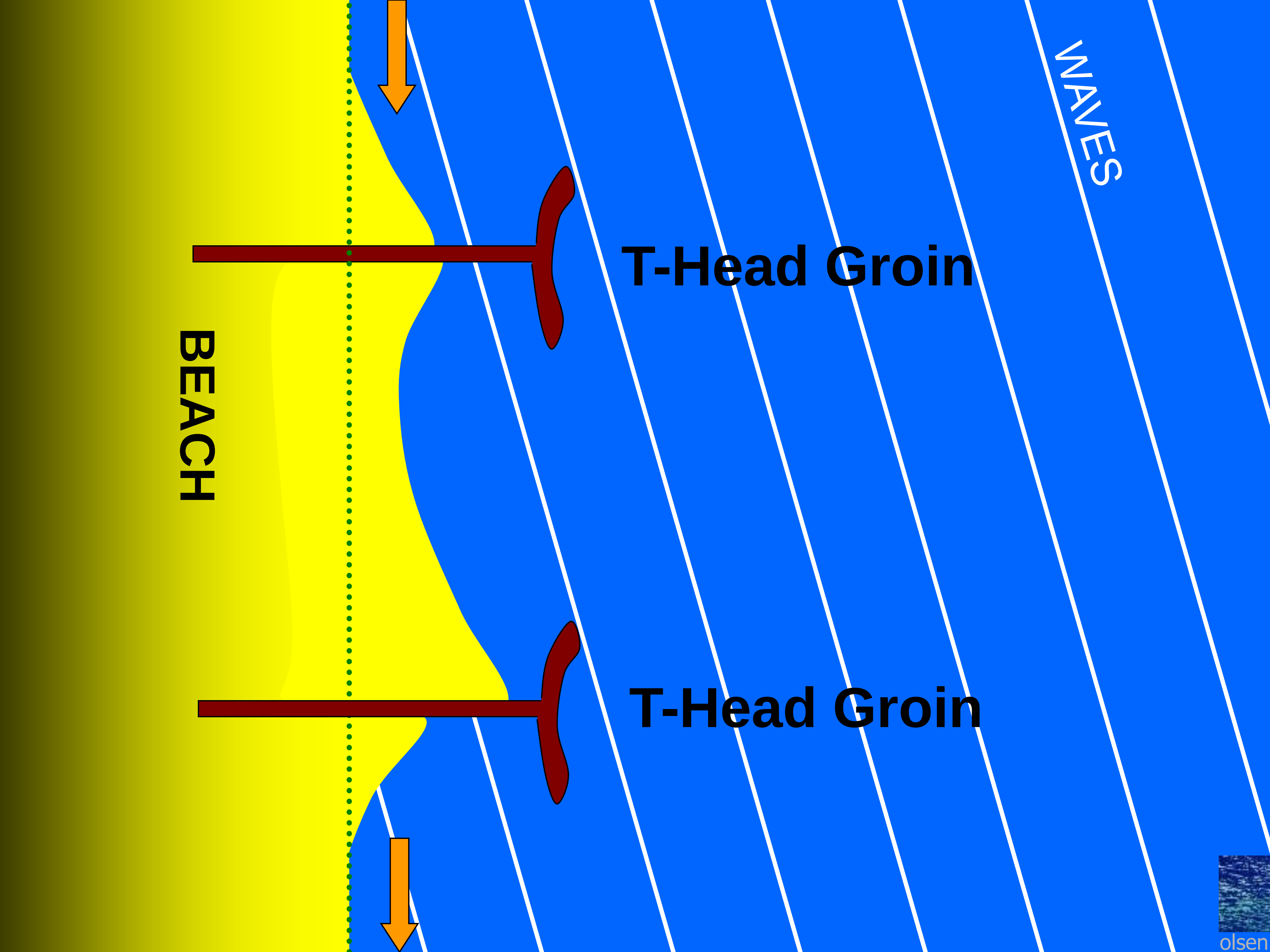
Timber Pile & Dog-Bone Groins

Photos courtesy of Brett Moore; Humiston & Moore

Examples of Permeable Groin Structures

Historical Permeable Groin at the Colony

SYDNEY
MAKEPEACE WOOD
Semi-Permeable Groin



WAVES
T-Head Groin
BEACH
T-Head Groin
olsen

Examples of T-head groins and "pocket" beaches

("crenulate bay" beaches)

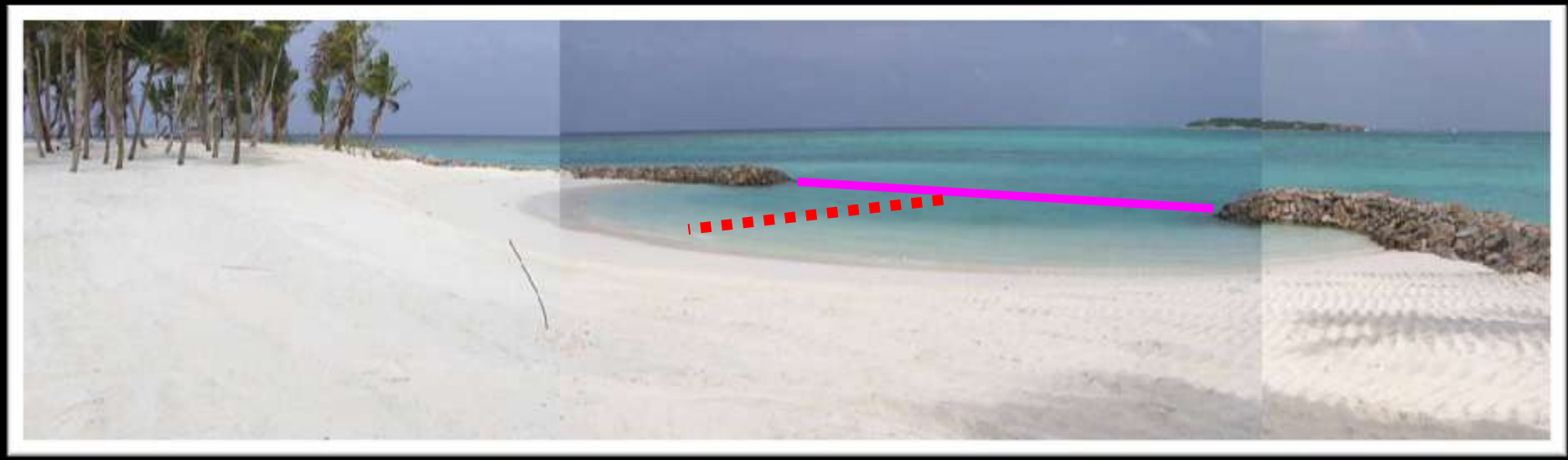
Tybee Island, Georgia

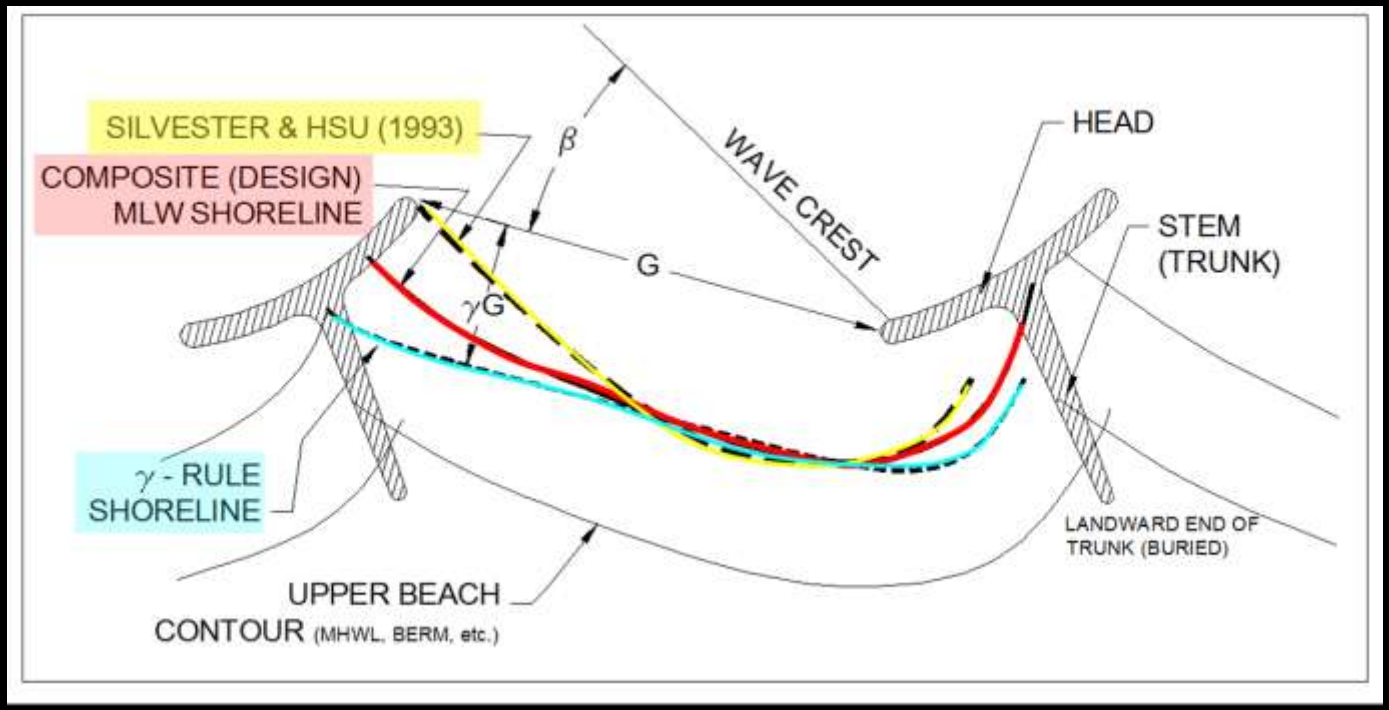
Pre-Structures

Post-Structures

Reethi Rah, Maldives

T-head groins and “pocket” beaches





T-head groins and “pocket” beaches

TABLE 4.2 MEANS FOR DETERMINING RADII RATIOS (R/R_O)

	Coefficients in Eq. (4.4)			Values of R/R_o for θ^o =							
β^o	C_o	C_1	C_2	30	45	60	75	90	120	150	180
20	0.054	1.040	−0.094	0.705	0.497	0.39	0.324	0.280	0.225	0.191	0.168
22	0.054	1.053	−0.109	0.768	0.543	0.426	0.354	0.305	0.244	0.206	0.181
24	0.054	1.069	−0.125	0.829	0.588	0.461	0.383	0.330	0.263	0.222	0.194
26	0.052	1.088	−0.144	0.887	0.633	0.497	0.412	0.355	0.281	0.237	0.207
28	0.050	1.110	−0.164	0.944	0.677	0.532	0.442	0.379	0.300	0.251	0.219
30	0.046	1.136	−0.186	1.000	0.721	0.568	0.471	0.404	0.319	0.266	0.230
32	0.041	1.166	−0.210		0.763	0.603	0.500	0.429	0.337	0.280	0.242
34	0.034	1.199	−0.237		0.805	0.638	0.529	0.453	0.355	0.294	0.252
36	0.026	1.236	−0.265		0.845	0.672	0.558	0.478	0.373	0.307	0.262
38	0.015	1.277	−0.296		0.883	0.706	0.586	0.502	0.390	0.320	0.272
40	0.003	1.322	−0.328		0.919	0.739	0.615	0.526	0.407	0.332	0.281
42	−0.011	1.370	−0.362		0.953	0.771	0.643	0.550	0.424	0.344	0.289
44	−0.027	1.422	−0.398		0.983	0.802	0.670	0.573	0.441	0.356	0.297
46	−0.045	1.478	−0.435			0.832	0.698	0.596	0.457	0.367	0.304
48	−0.066	1.537	−0.473			0.861	0.724	0.619	0.473	0.378	0.311
50	−0.088	1.598	−0.512			0.888	0.750	0.642	0.489	0.388	0.317
52	−0.112	1.662	−0.552			0.914	0.775	0.664	0.505	0.398	0.322
54	−0.138	1.729	−0.592			0.938	0.800	0.686	0.520	0.408	0.327
56	−0.166	1.797	−0.632			0.960	0.823	0.707	0.535	0.417	0.332
58	−0.196	1.866	−0.671			0.981	0.846	0.728	0.549	0.425	0.336
60	−0.227	1.936	−0.710			1.000	0.867	0.748	0.563	0.434	0.339
62	−0.260	2.006	−0.746				0.888	0.768	0.577	0.441	0.342
64	−0.295	2.076	−0.781				0.908	0.787	0.590	0.449	0.345
66	−0.331	2.145	−0.813				0.927	0.805	0.603	0.456	0.346
68	−0.368	2.212	−0.842				0.945	0.823	0.615	0.462	0.348
70	−0.405	2.276	−0.867				0.963	0.840	0.627	0.468	0.349
72	−0.444	2.336	−0.888				0.981	0.857	0.638	0.473	0.349
74	−0.483	2.393	−0.903				1.000	0.874	0.649	0.478	0.348
76	−0.522	2.444	−0.912					0.891	0.660	0.482	0.347
78	−0.561	2.489	−0.915					0.909	0.670	0.486	0.346
80	−0.600	2.526	−0.910					0.927	0.680	0.489	0.343

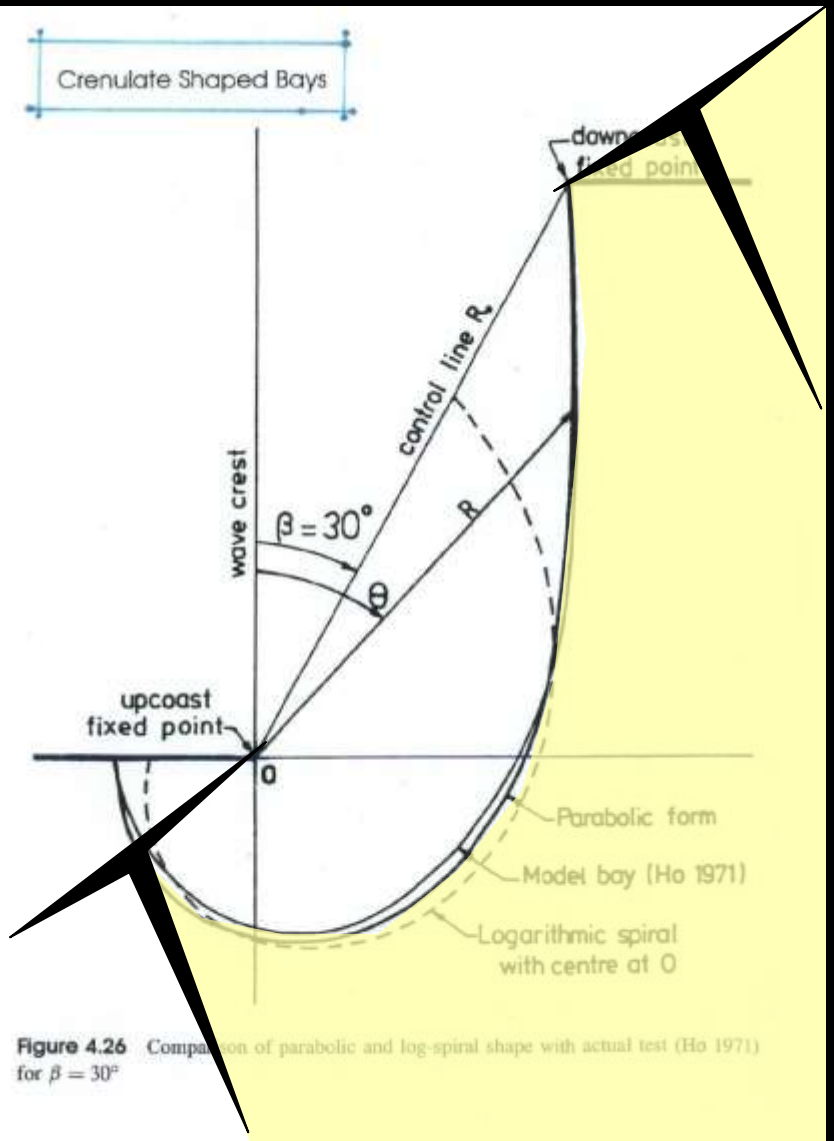


Figure 4.26 Comparison of parabolic and log-spiral shape with actual test (Ho 1971) for $\beta = 30°$


z z z z z z

Terminal Structures

“Leaky” (Permeable) Structures

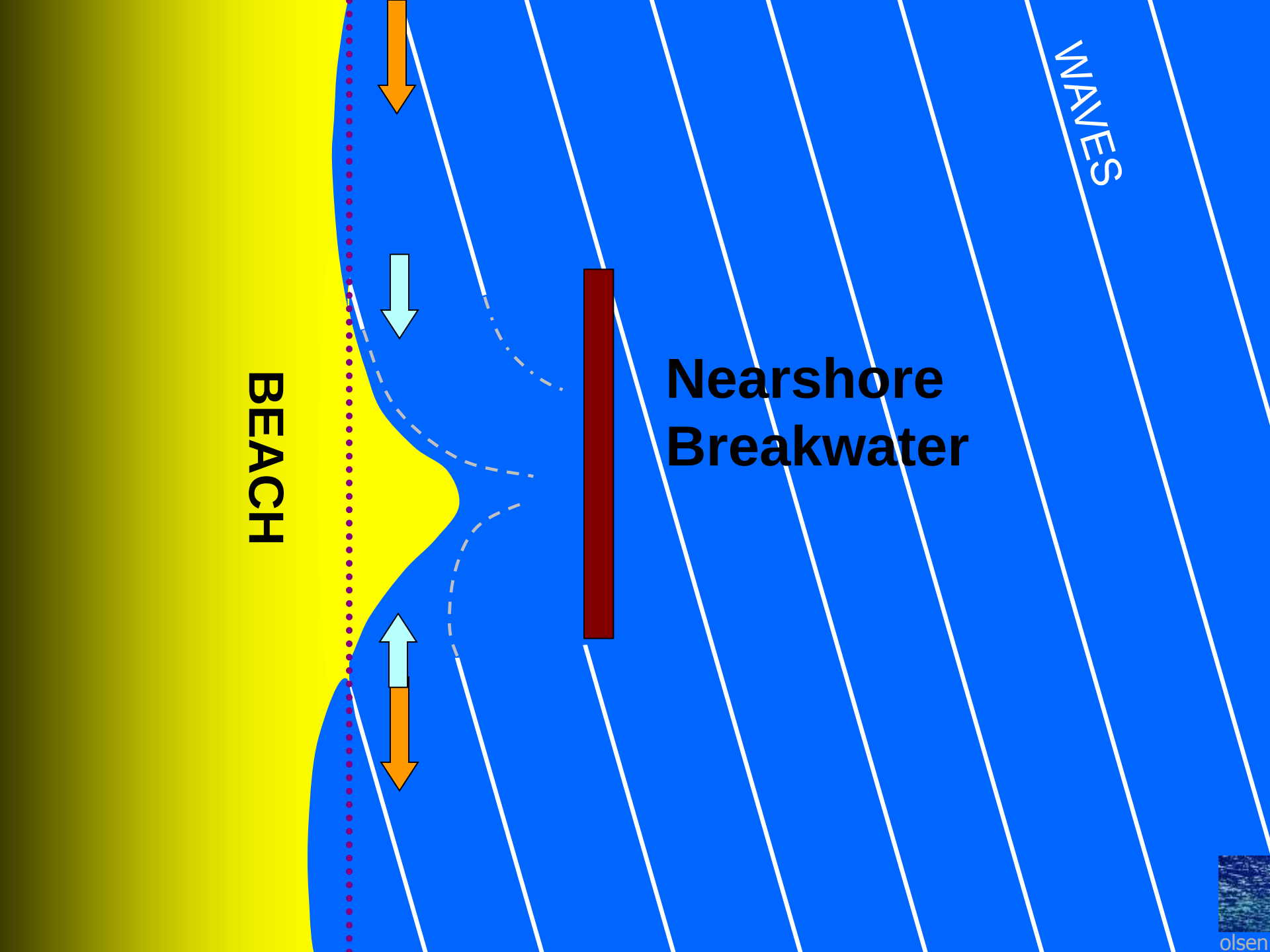
Amelia Island, Nassau Sound, FL

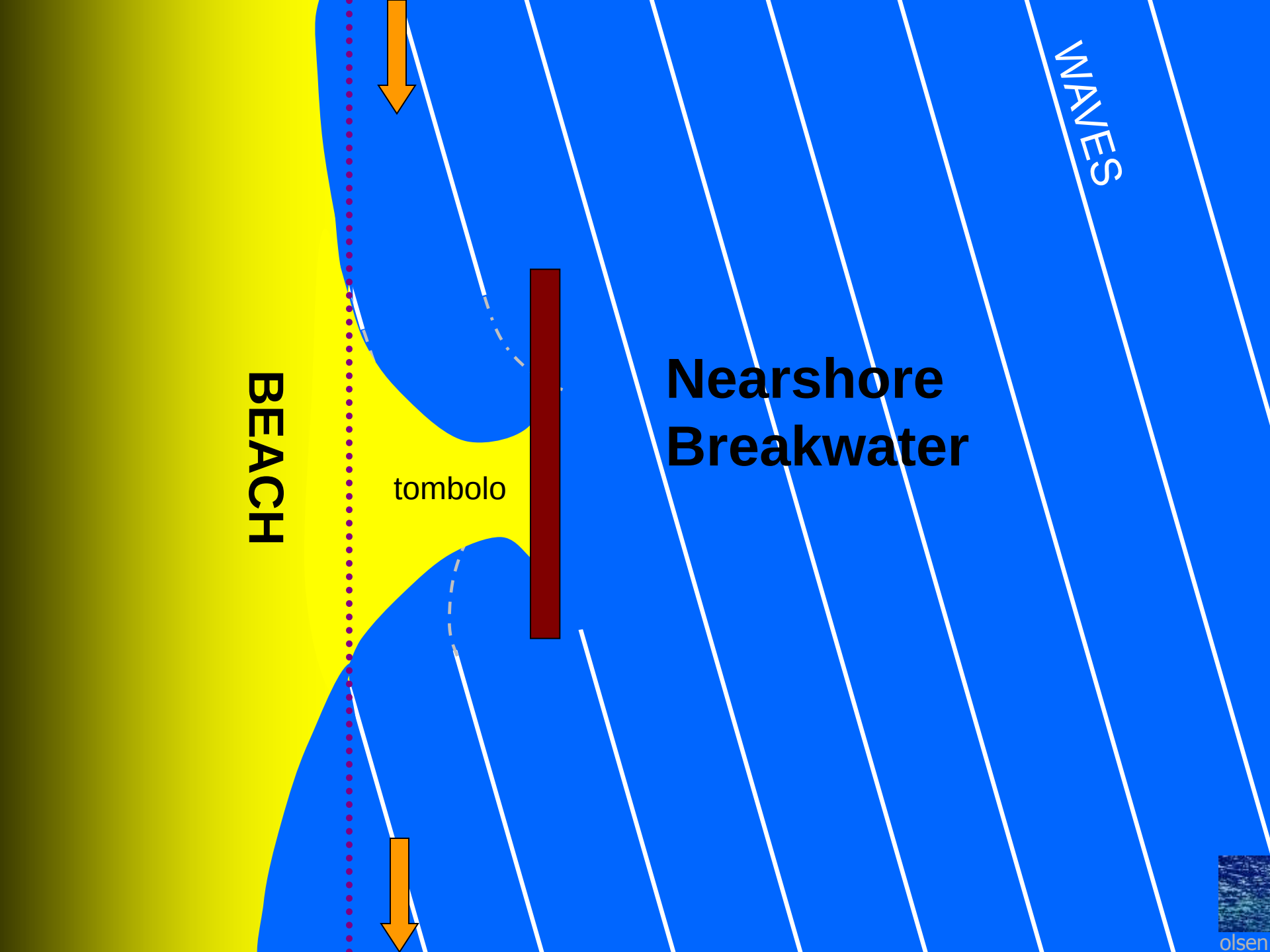
Shore-Parallel Structures:

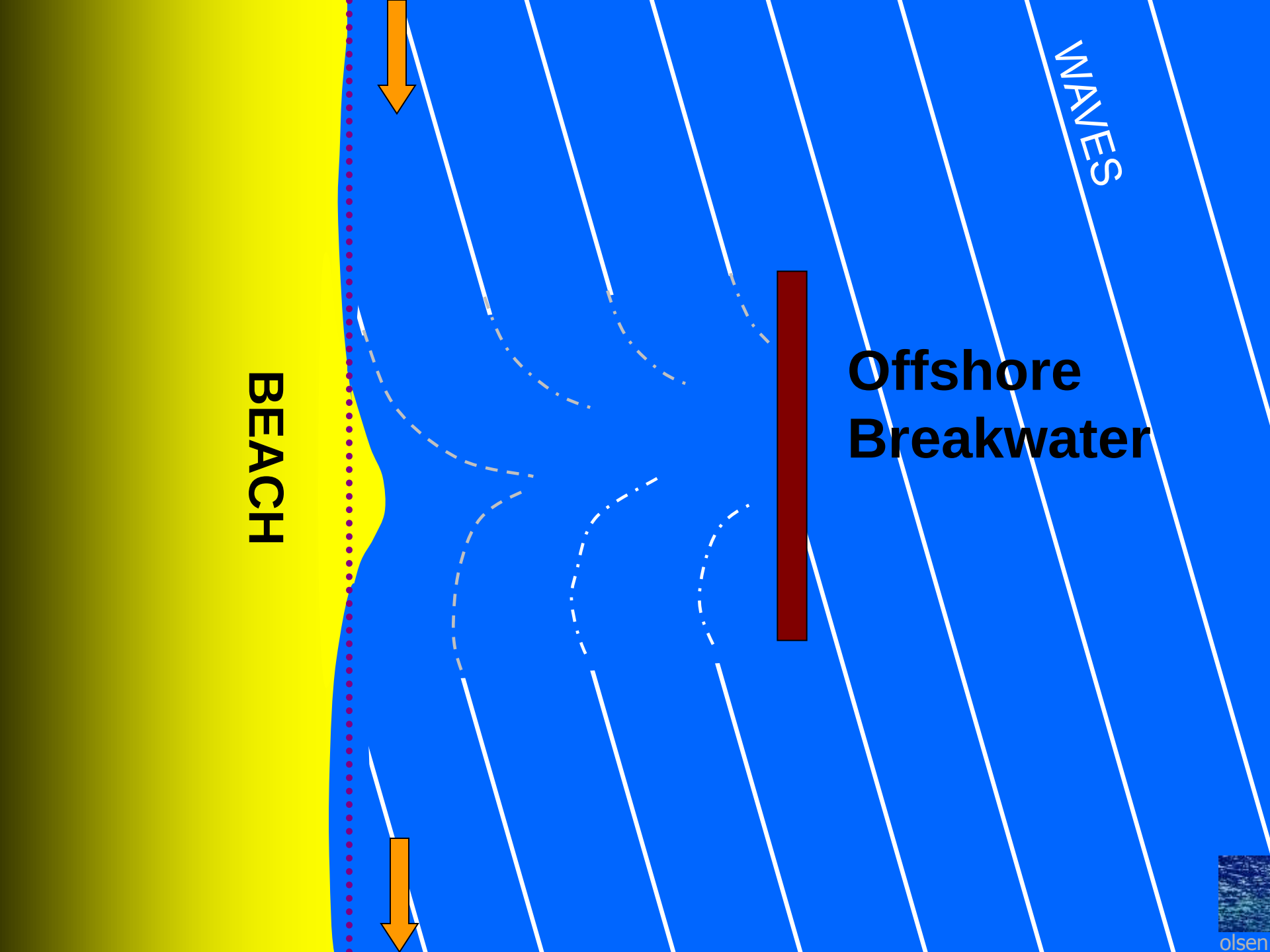
Nearshore Breakwaters

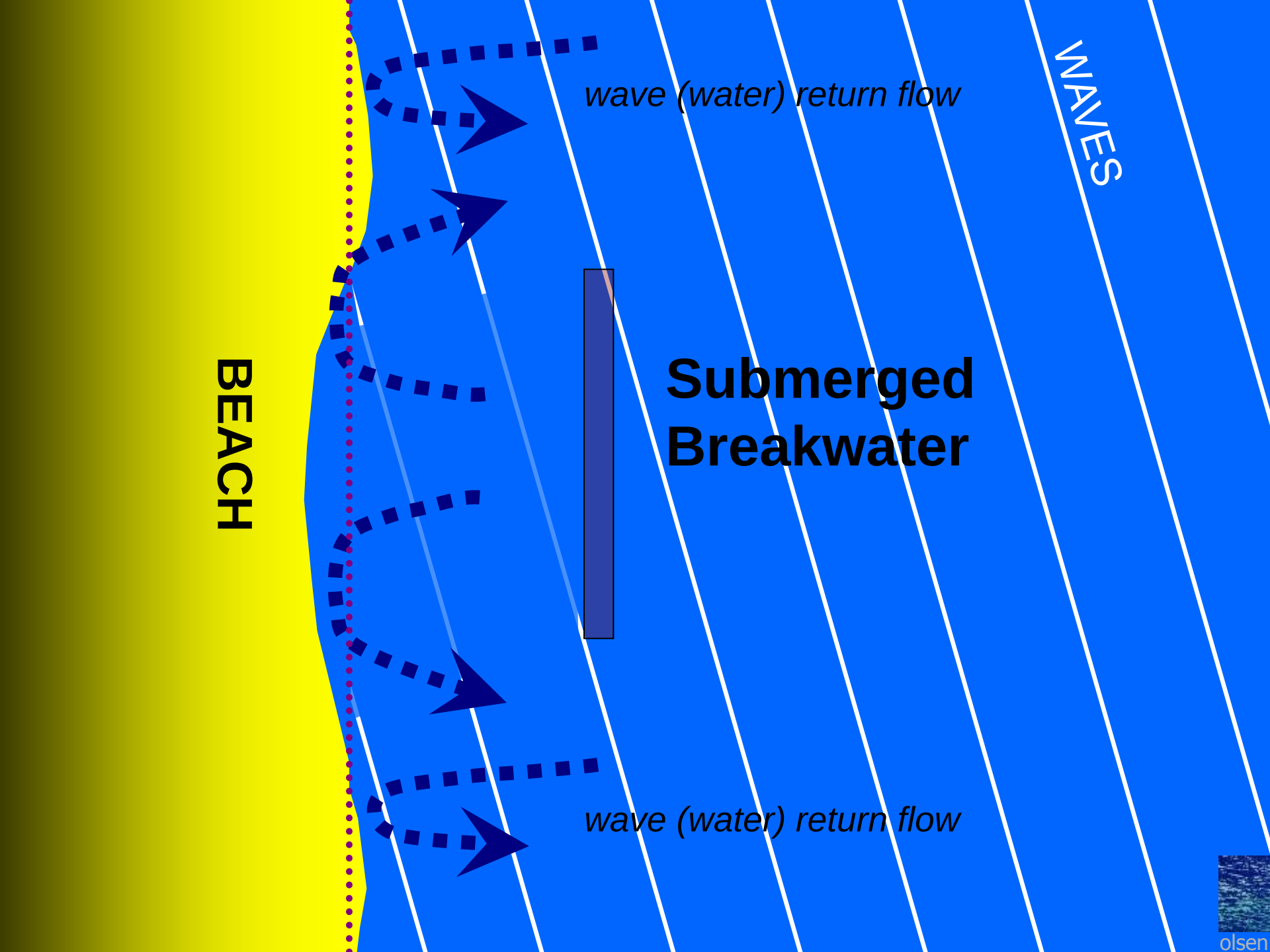
Pinellas County, Gulf of Mexico, FL

Amelia Island State Park, Atlantic Ocean, FL


WAVES
BEACH
Nearshore
Breakwater


WAVES
BEACH
tombolo
Nearshore
Breakwater


WAVES
BEACH
Offshore
Breakwater

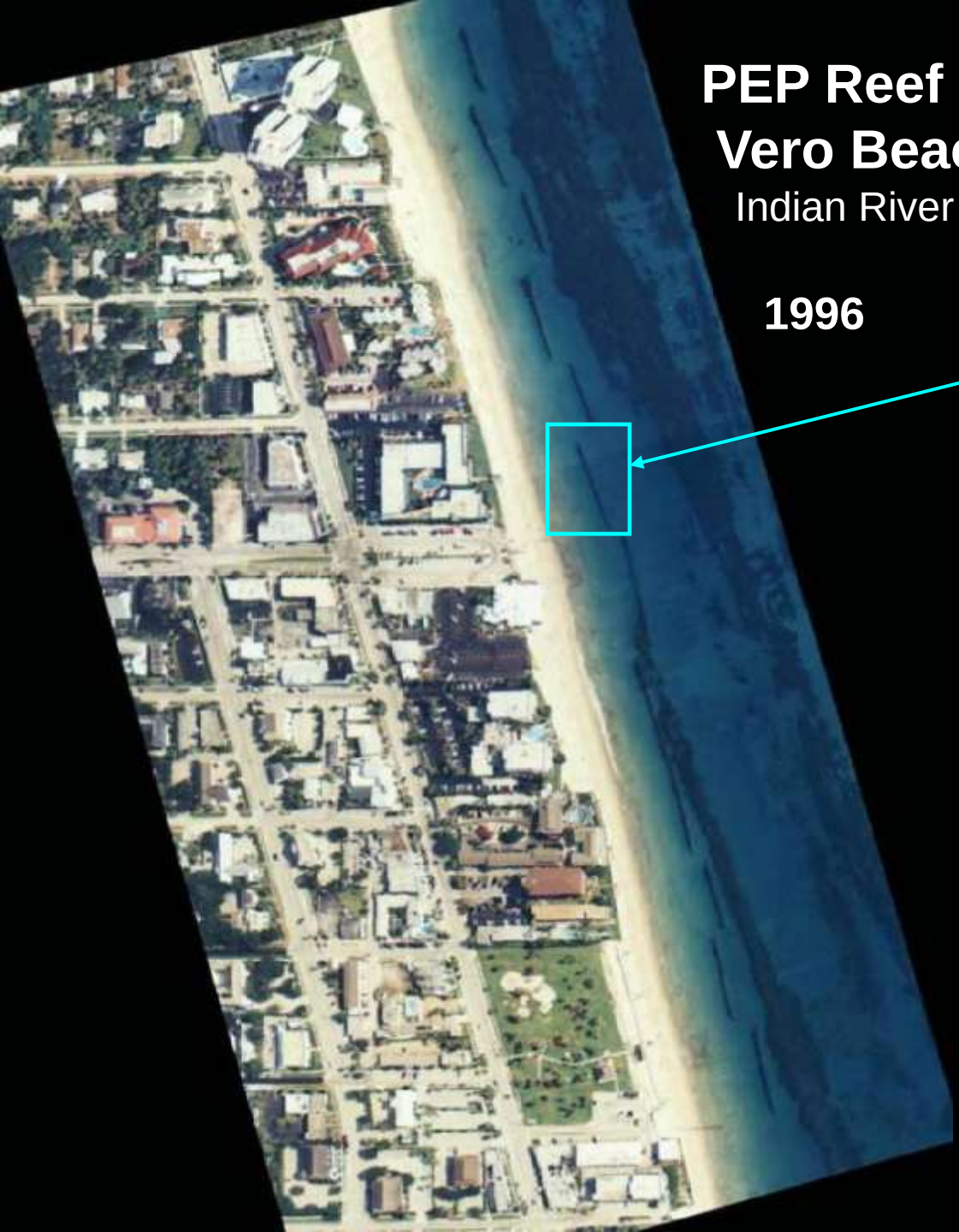

wave (water) return flow
WAVES
BEACH
Submerged
Breakwater
wave (water) return flow
olsen

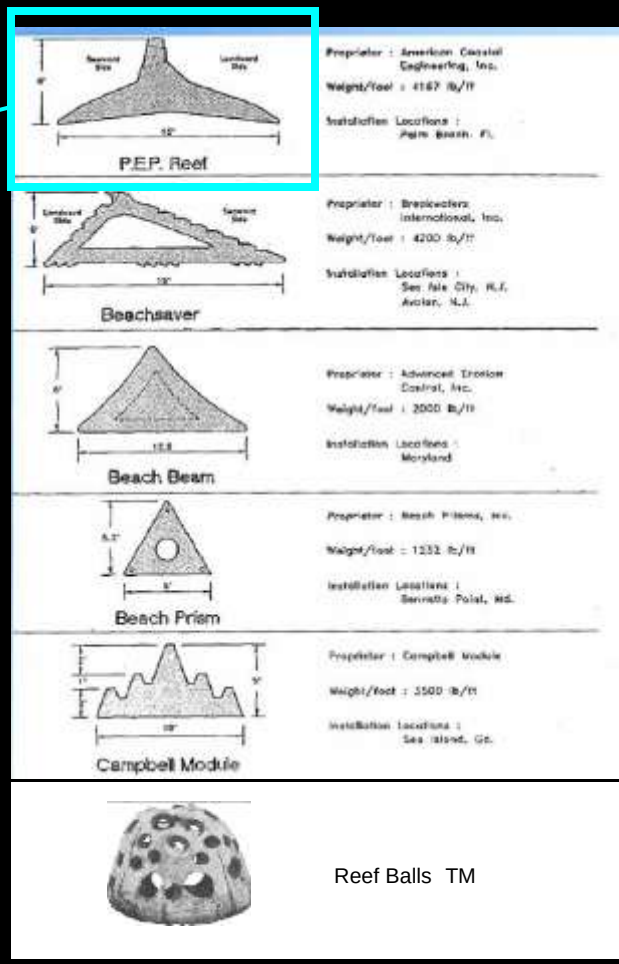
PEP Reef Installation
Vero Beach

Indian River County, FL

1996

Proprietary Structure Modules





Reef Balls TM

Adapted from FDEP/BBCS

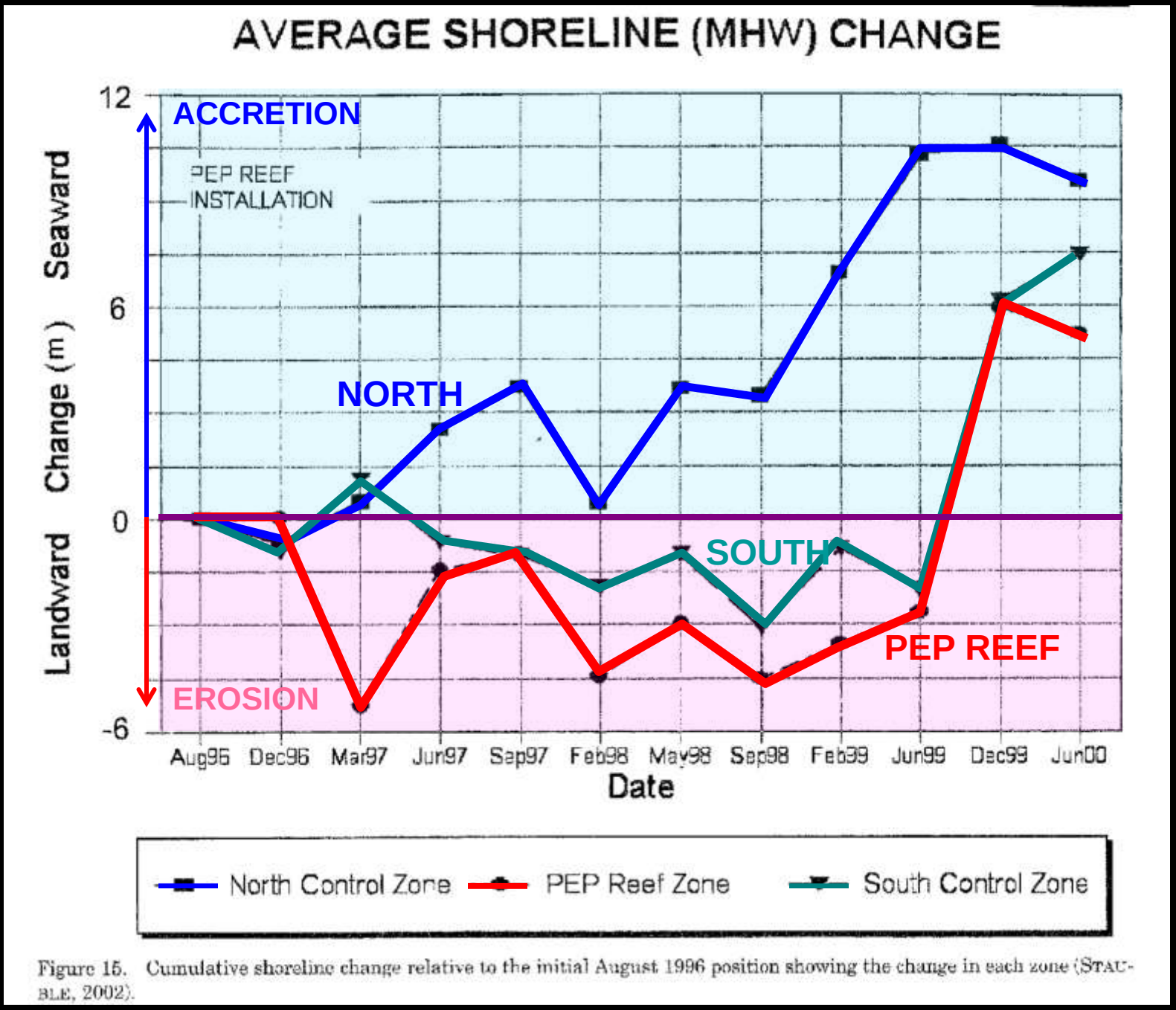


Figure 15. Cumulative shoreline change relative to the initial August 1996 position showing the change in each zone (STAUBLE, 2002).

Shoreline Change along PEP Reef Installation

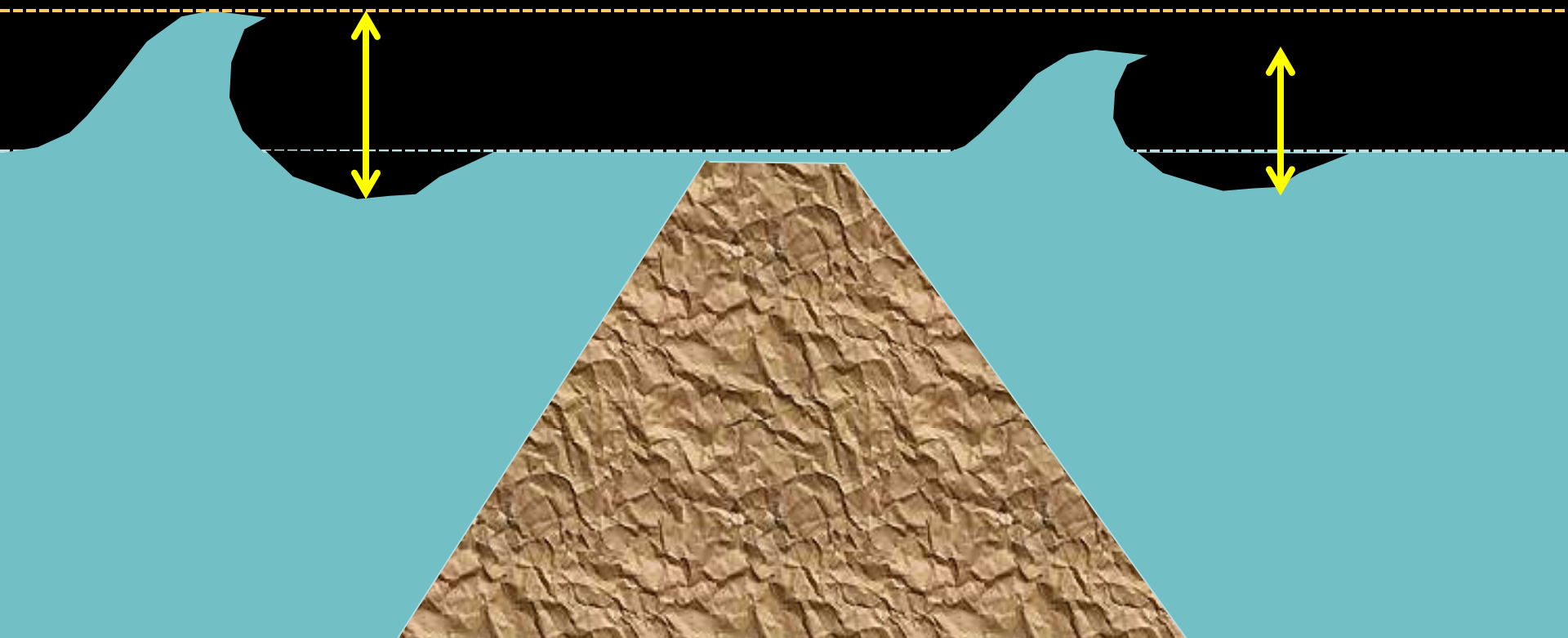
1996-2000

Vero Beach

from Stauble (2002)

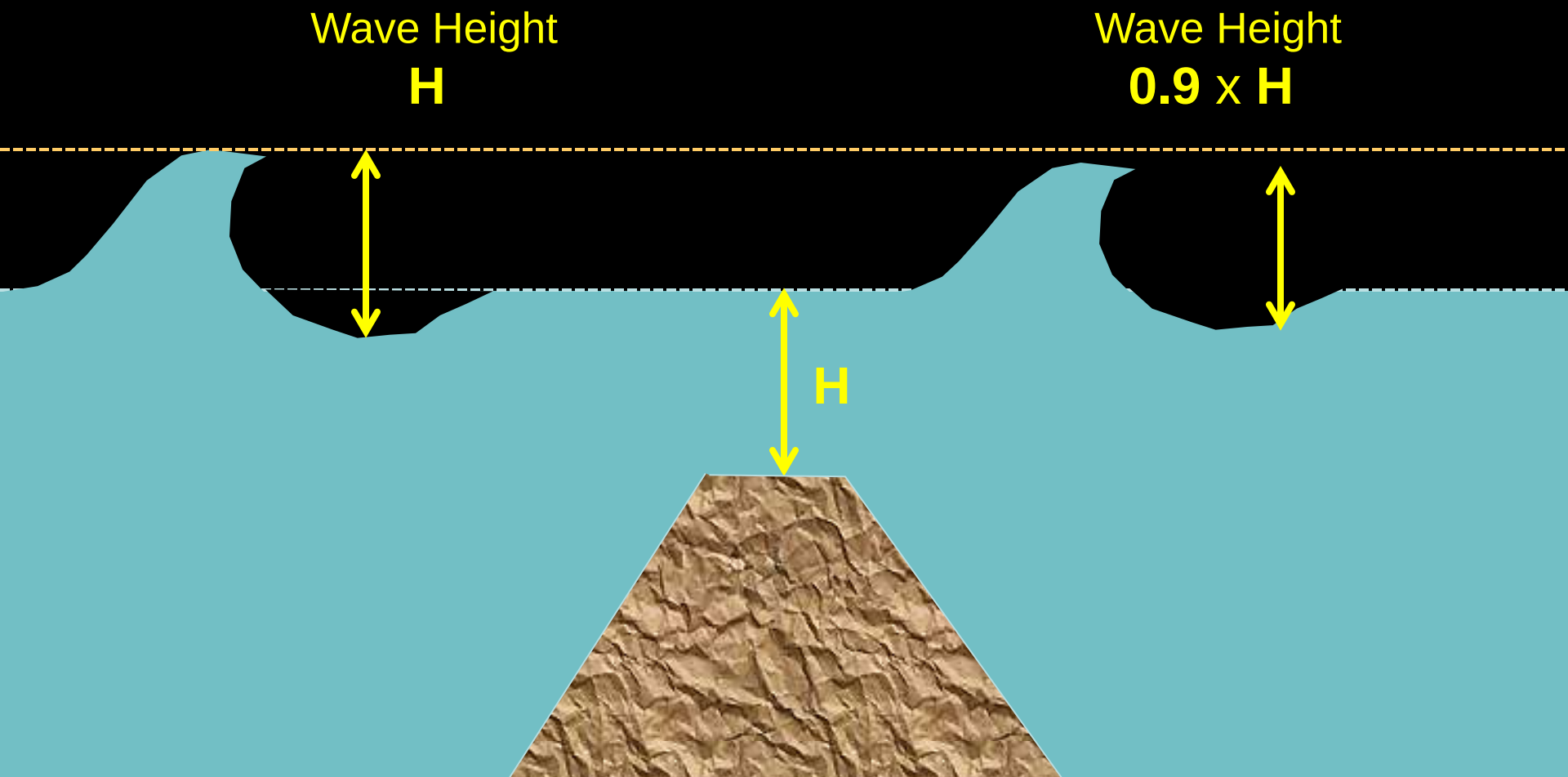
wave blockage by a submerged breakwater

An engineered structure that does not break
the water surface reduces wave height by about 20%.



wave blockage by a submerged breakwater

An engineered structure that is one wave height below the water surface reduces wave height by only 10%.



Northern Sunny Isles ***Submerged Breakwaters***

(Miami-Dade County)

Applicability of structures

- Unusually high erosion rates
- Transfer erosion stress from a “hot spot” to a “cool spot”
- Protect nearshore environmental resources
- Terminus of littoral system *
- Isolated (closed) littoral location *

* Only applications with least likelihood of causing downdrift erosion.

Fisher Island (Miami-Dade County), Florida

19-years post-construction

"Closed System"

John U. Lloyd State Park; Port Everglades (Ft. Lauderdale), Florida

Pre-Project

4-yr Post-Project

“Terminal End of System”

Upham Beach

north St. Petersburg
Pinellas County

2005

Blind Pass

COASTAL PLANNING & ENGINEERING, INC.

Naples (2000)

North of Gordon Pass

Collier County

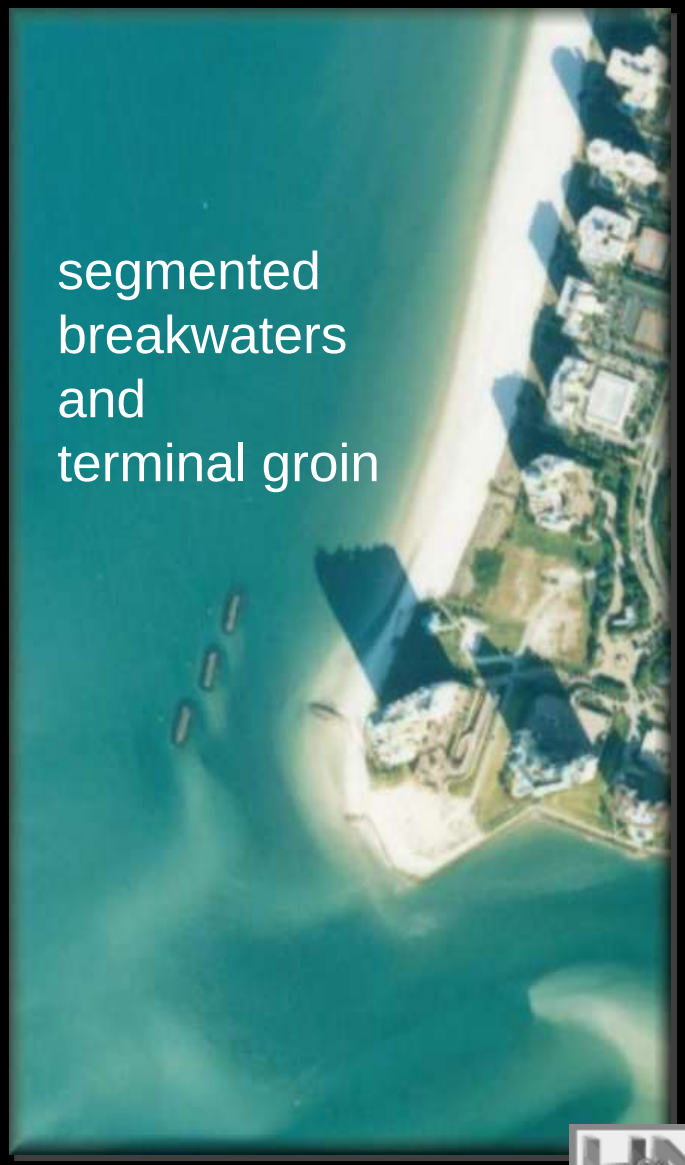
Pre-Construction
1998

Post-Construction
2002

Two permeable T-groins and two permeable wood groins; with 6000 cy fill

Marco Island (1996)

Collier County



Humiston & Moore Engineers

Cumberland Islan

Fort Clinch

Ft. Clinch State Park

Nassau County, FL

Fernandina
Beach

olsen

Fort Zachary Taylor State Park
Key West, Florida

c. 1990

Photo – courtesy of FDEP/DRP and Mike Walther

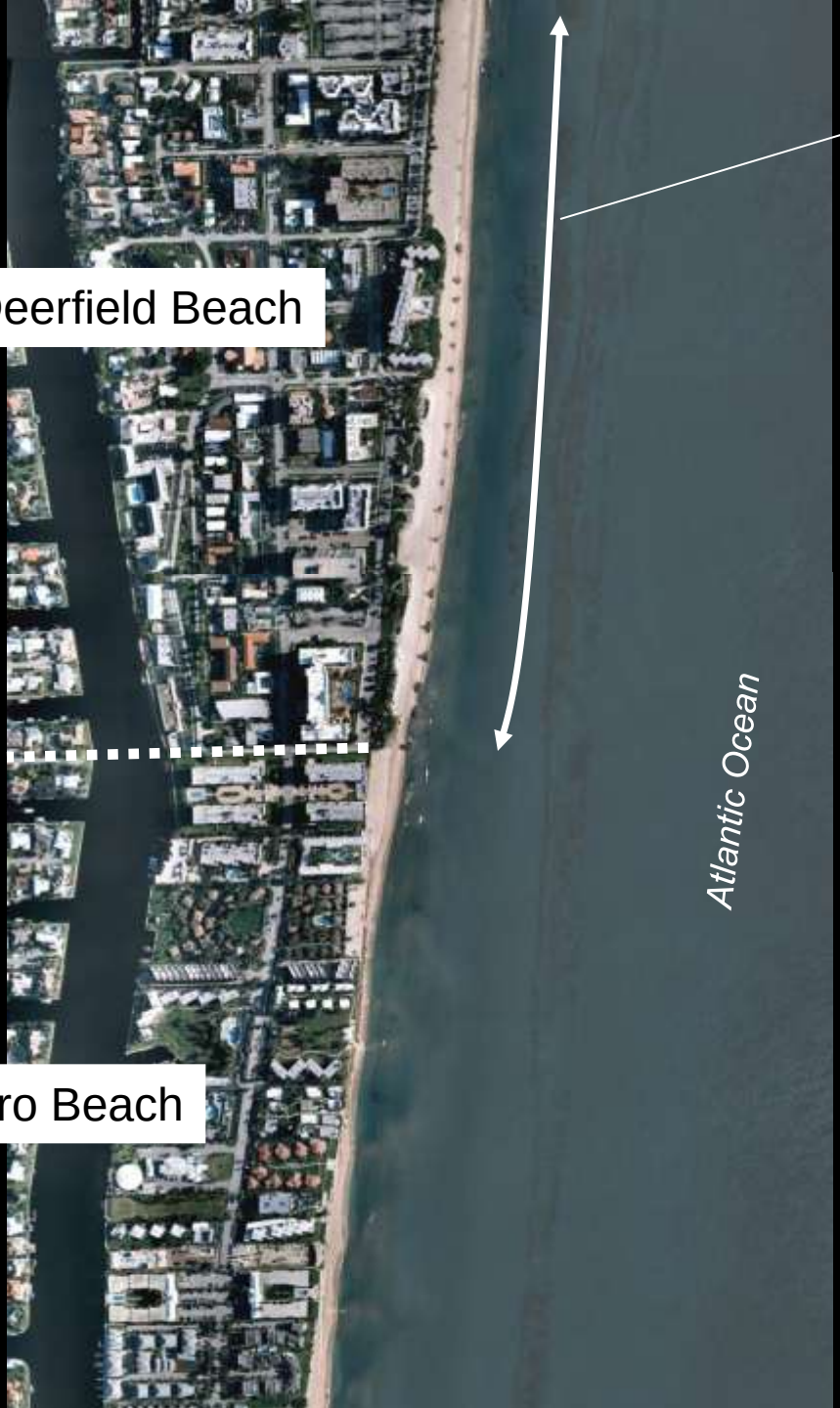
COASTAL TECH

Ocean Ridge

South Lake Worth Inlet
Palm Beach County

8-years post construction

(Bypassed sand is placed in beach cells nearest inlet)



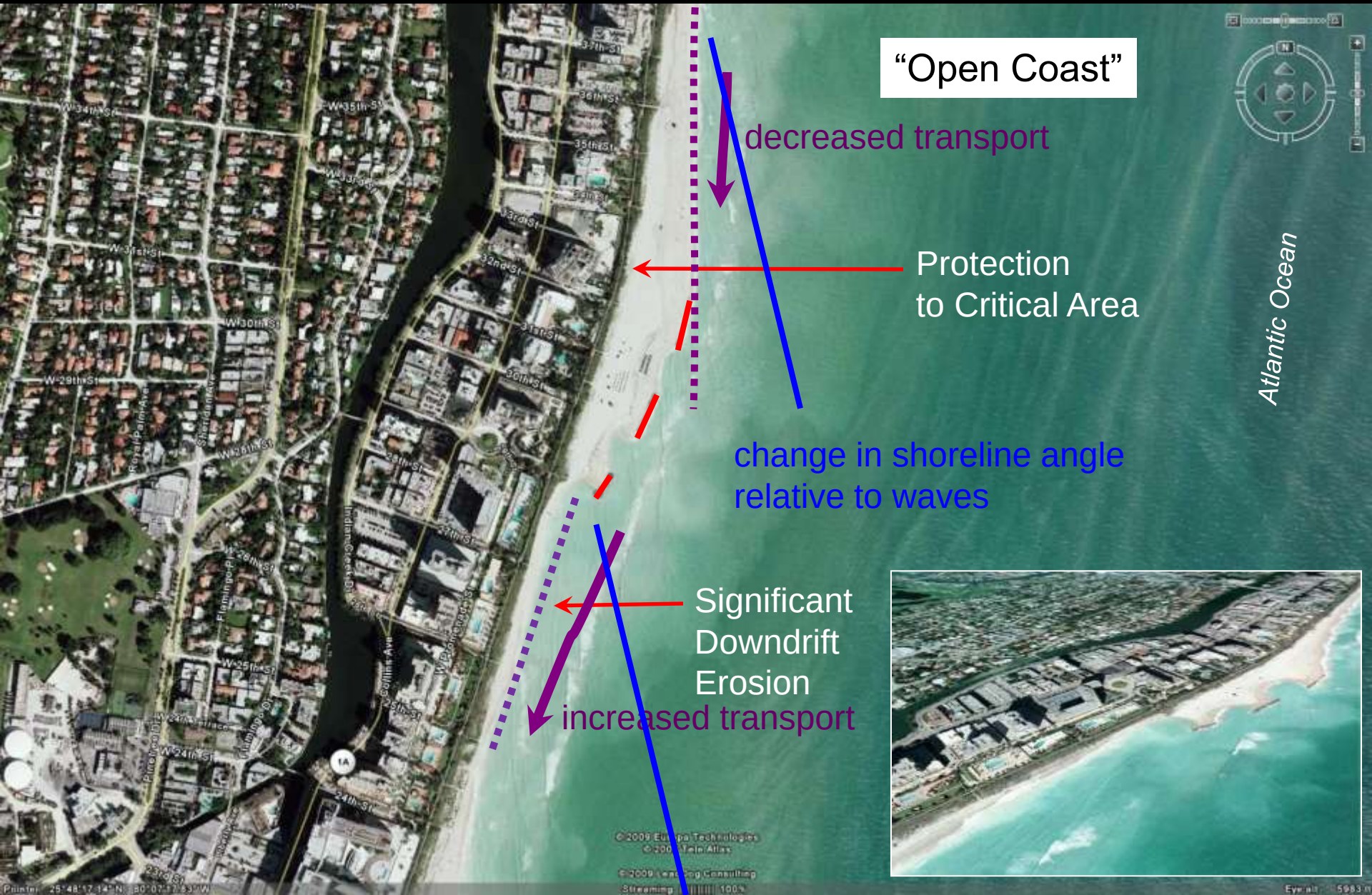
Deerfield Beach Groin Field

Broward County, Florida

- Constructed in 1960's
- ~ 50 groins
- ~ 6,000 ft
- ~ 125-ft spacing

"Open Coast"

32ND Street - Miami Beach, FL



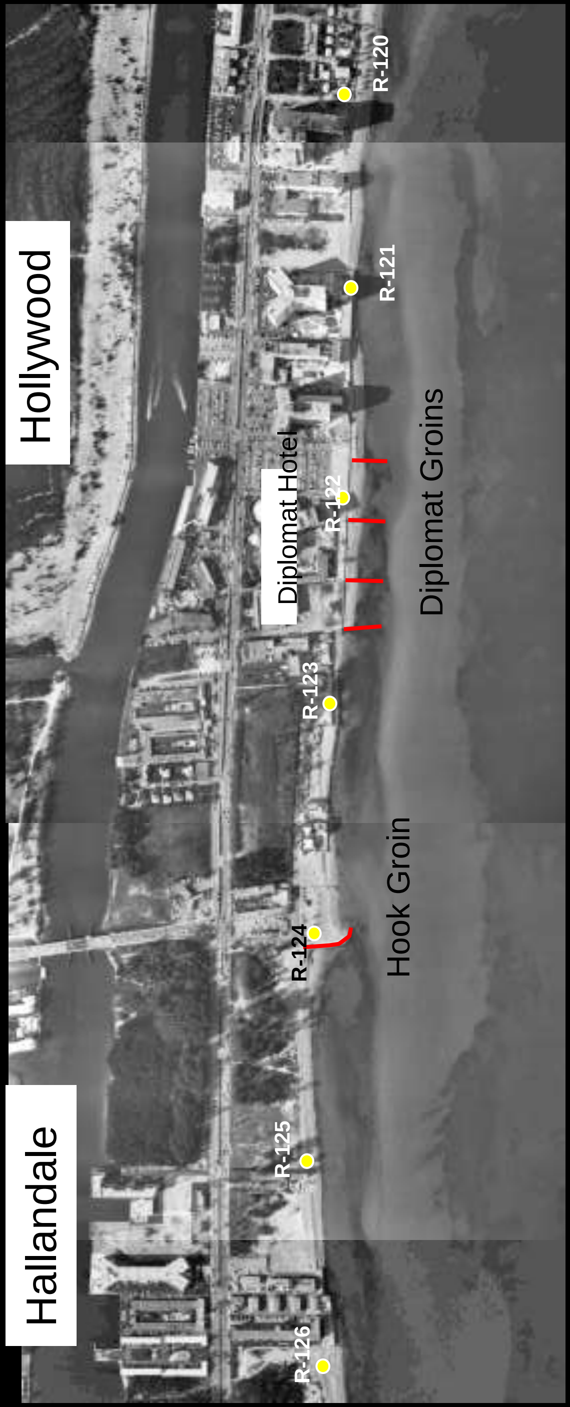
Minimizing downdrift effects

- Advance fill with sand
- Locate project at terminal or isolated littoral cell
- Do not induce offshore losses
- Effects will be worse if located in zone of accelerating alongshore transport

Some modern modeling results of the effect of structures along an open coastline

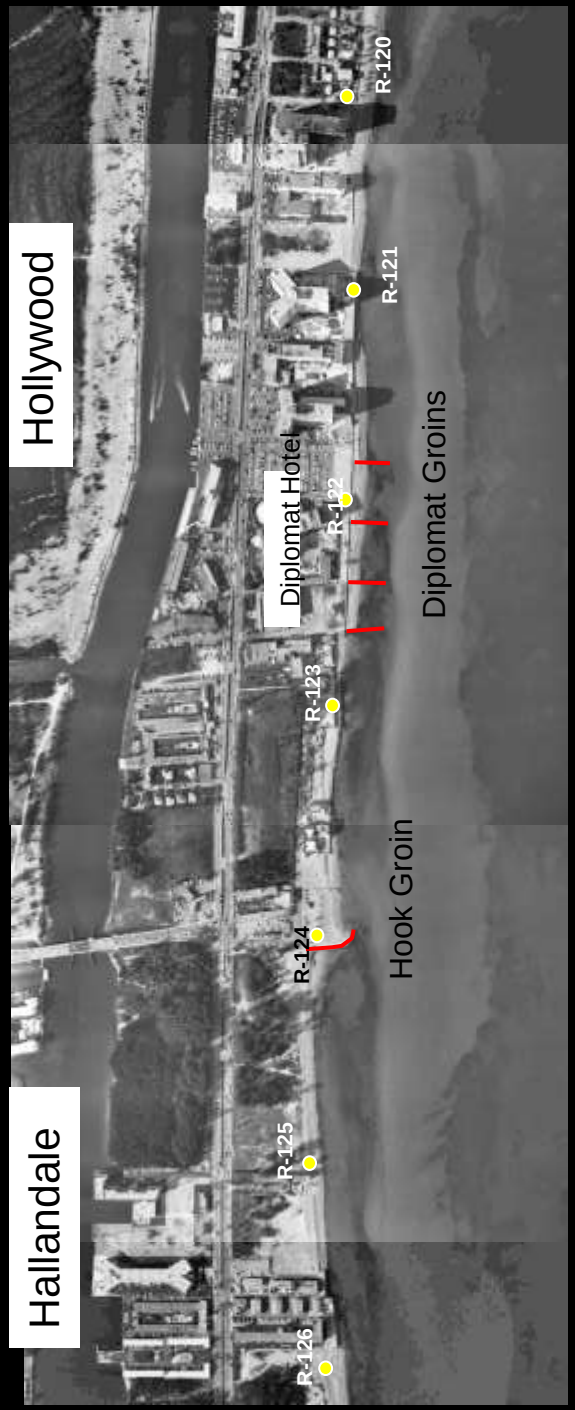
1967 Shoreline Conditions

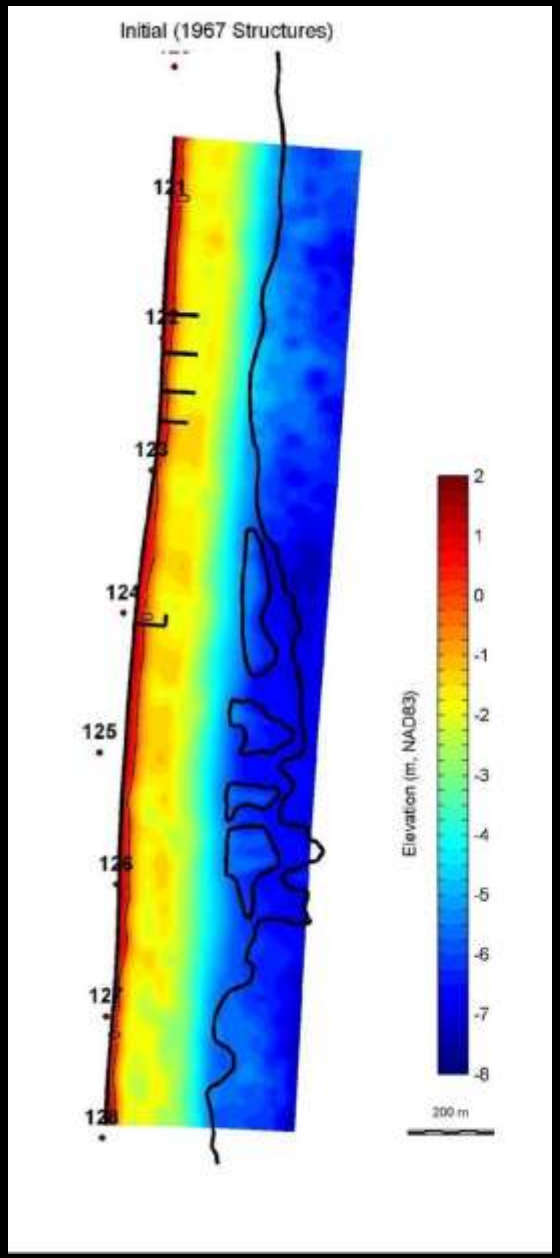
South Hollywood/Hallandale



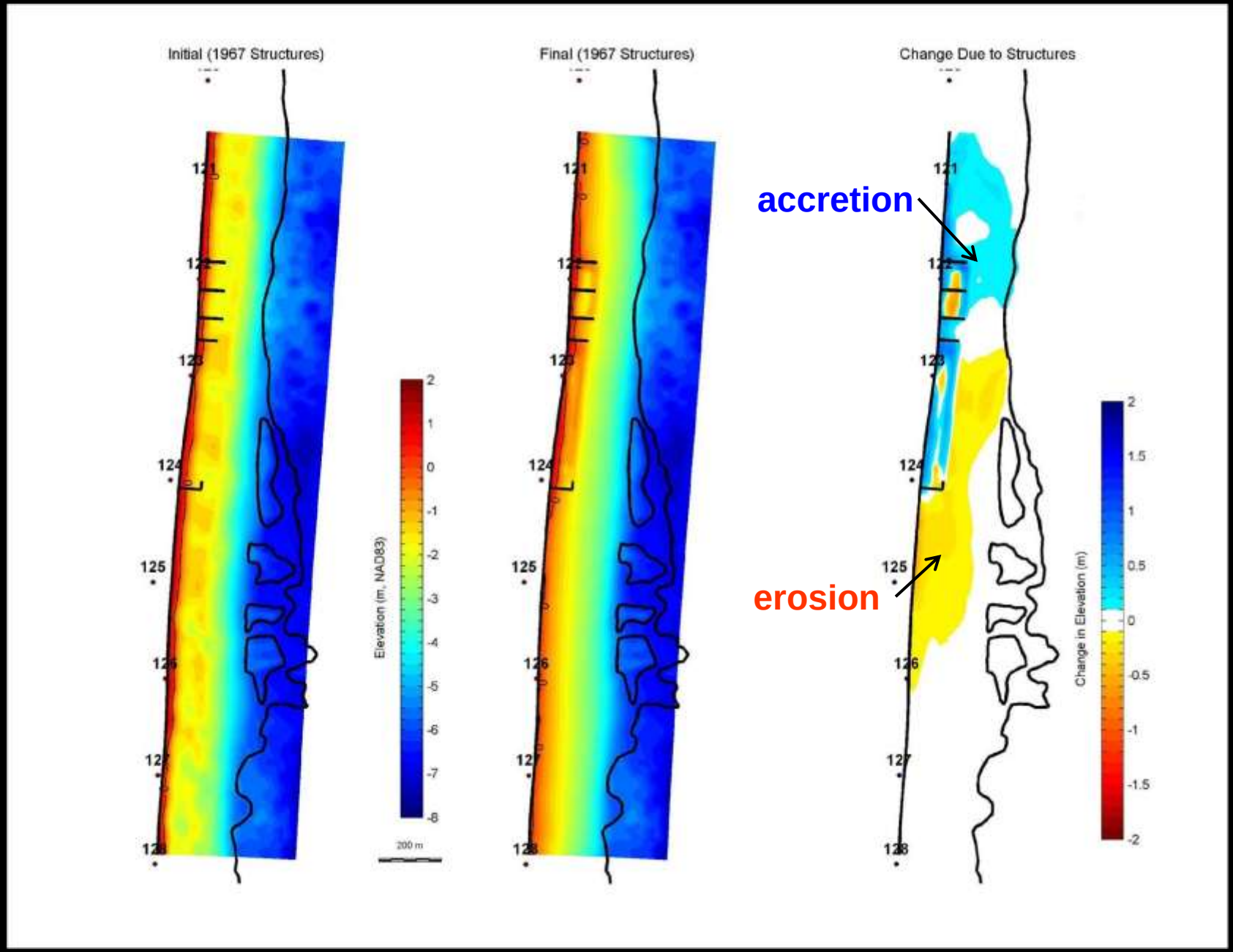
1967 Shoreline Conditions

South Hollywood/Hallandale





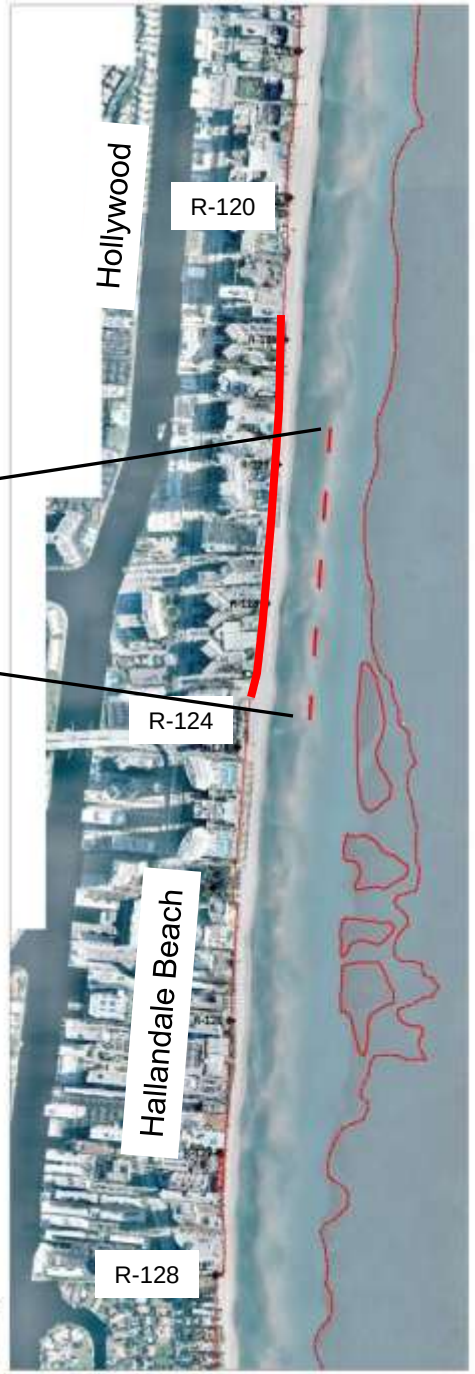
1967 Structures (Southern Hollywood)



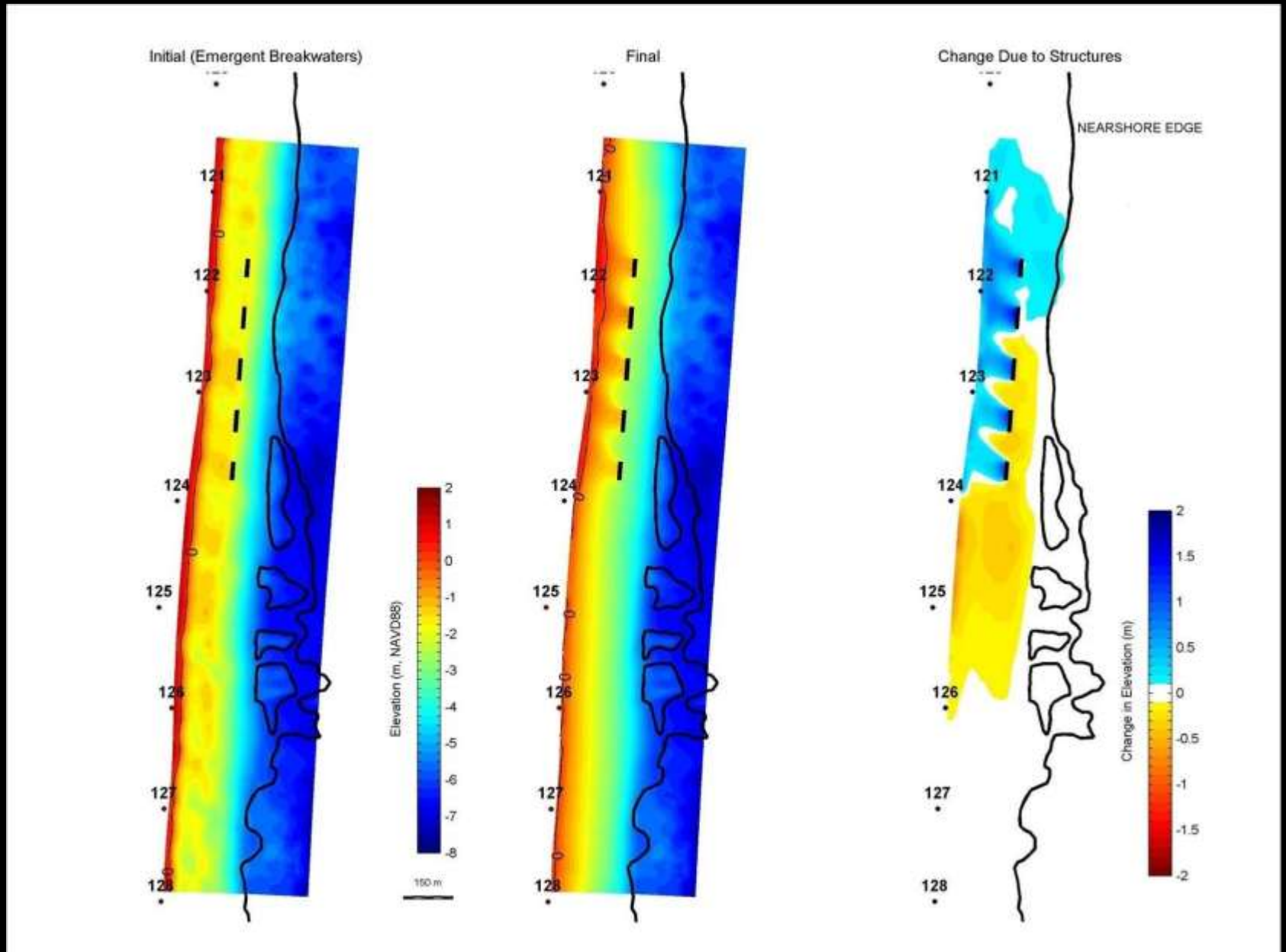
Southern Hollywood/ Hallandale

Modeled Breakwaters

(Both emergent and submerged)

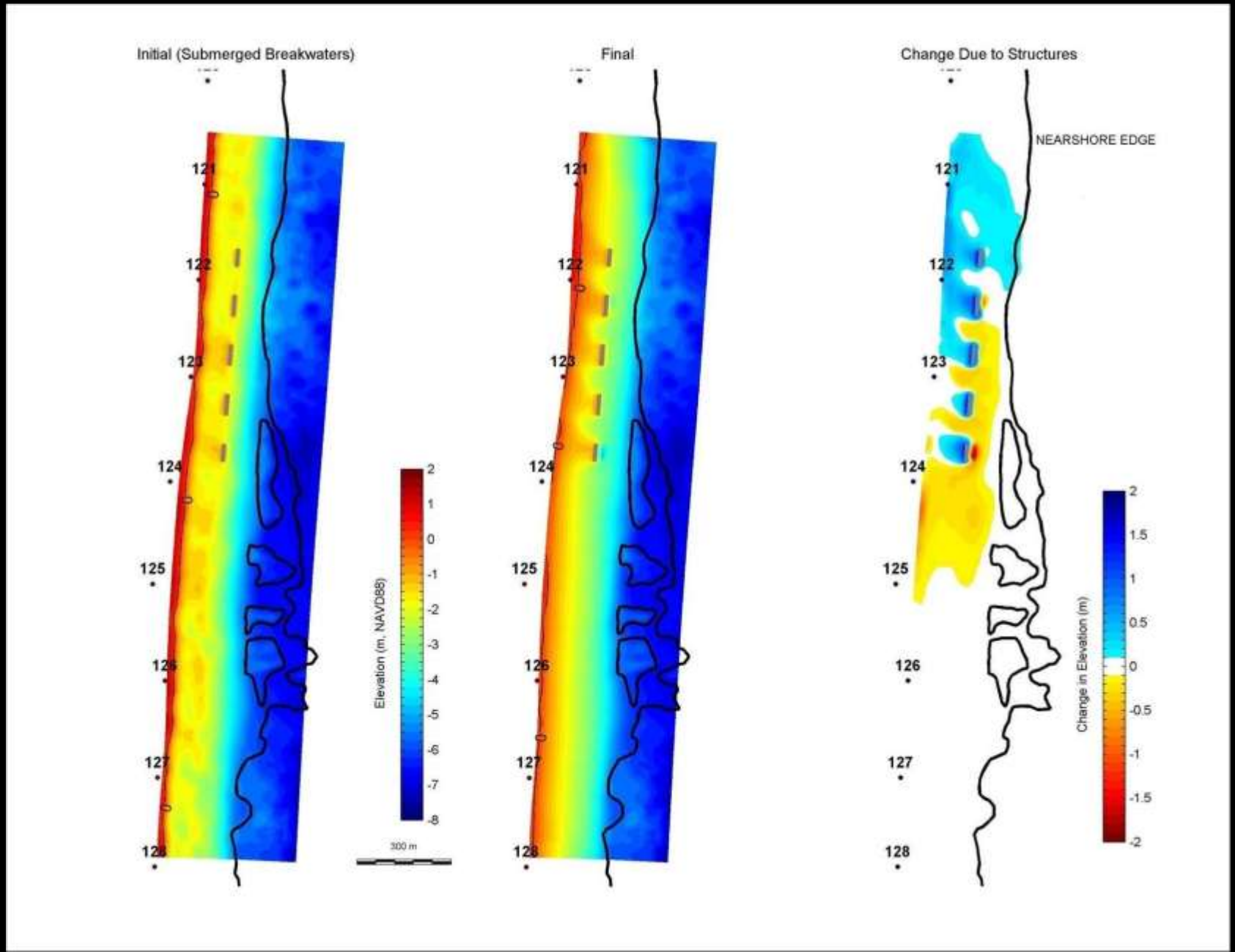


Emergent Breakwaters (Southern Hollywood)

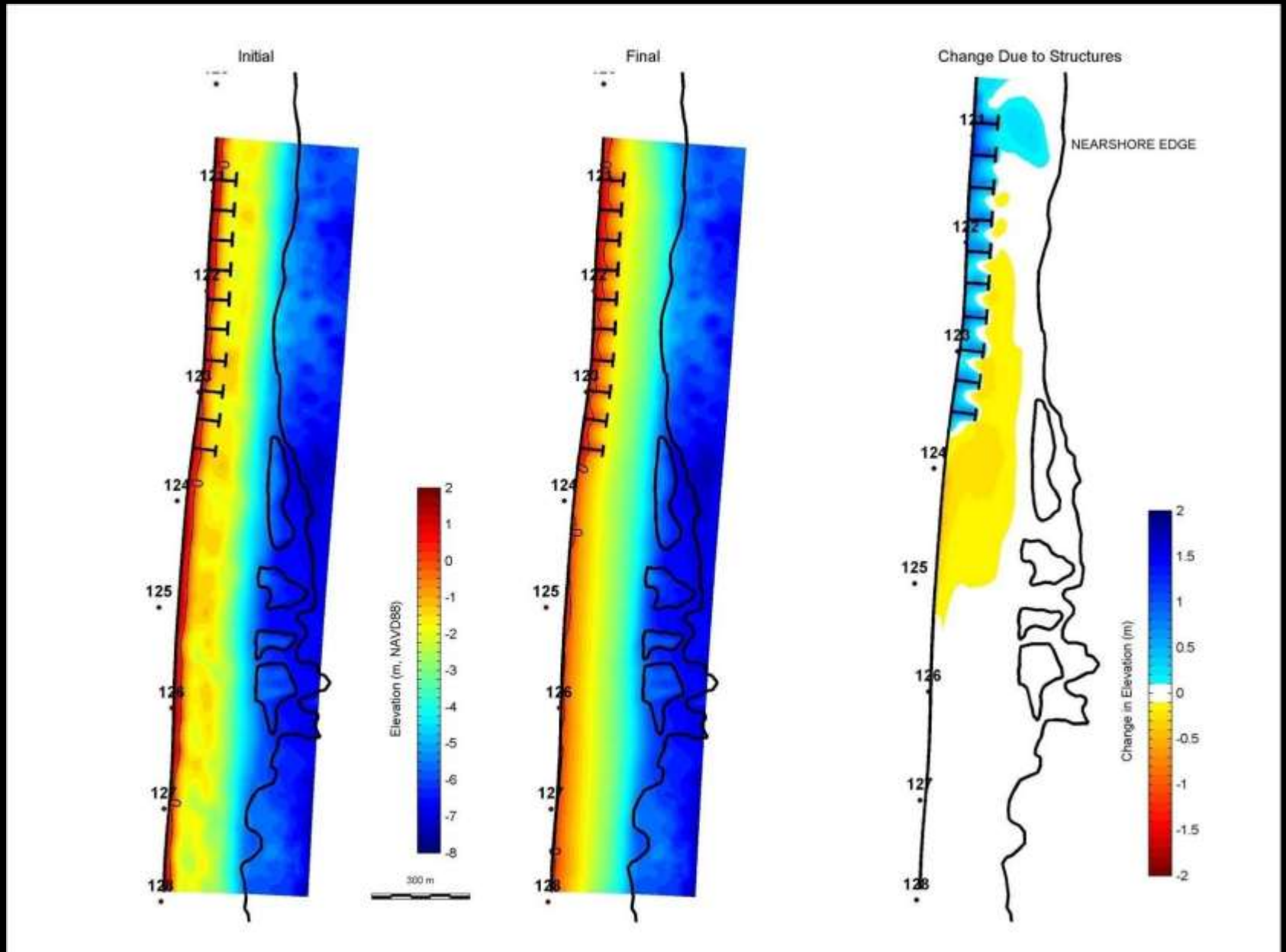


olsen

Submerged Breakwaters (Southern Hollywood)



T-Head Groins (Southern Hollywood)



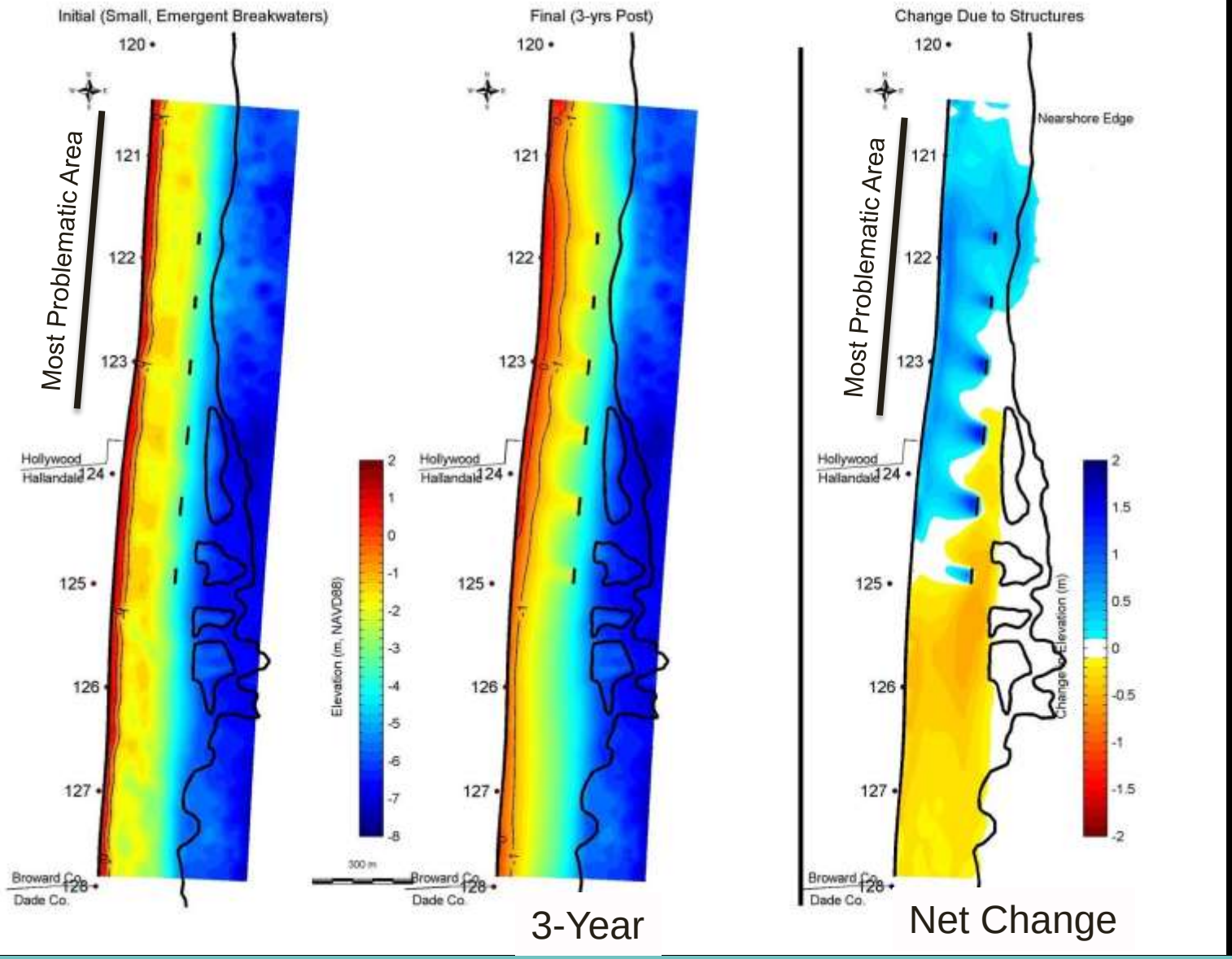
olsen

DELFT 3D MODEL RESULTS

Downdrift Erosion Effect of Modeled Structures

Historic 1967 Groins	-36,600 cy/yr
Emergent Breakwaters	-46,300 cy/yr
Submerged Breakwaters	-34,300 cy/yr
T-Head Groins	-34,300 cy/yr

* Net ambient transport rate = 60,000 cy/yr (approx.)



Small, Emergent Breakwaters (3-yr Results)

(Designed for Very Weak Salients – Mild Effect)

olsen associates, inc.

Existing Conditions	-6,400 cy/yr	+	-21,600 cy/yr	=	-28,000 cy/yr

Example: Renourishment Requirements

Small, Emergent Breakwaters – Mild Effect

Existing Conditions

-6,400 cy/yr + -21,600 cy/yr = -28,000 cy/yr

With Structures

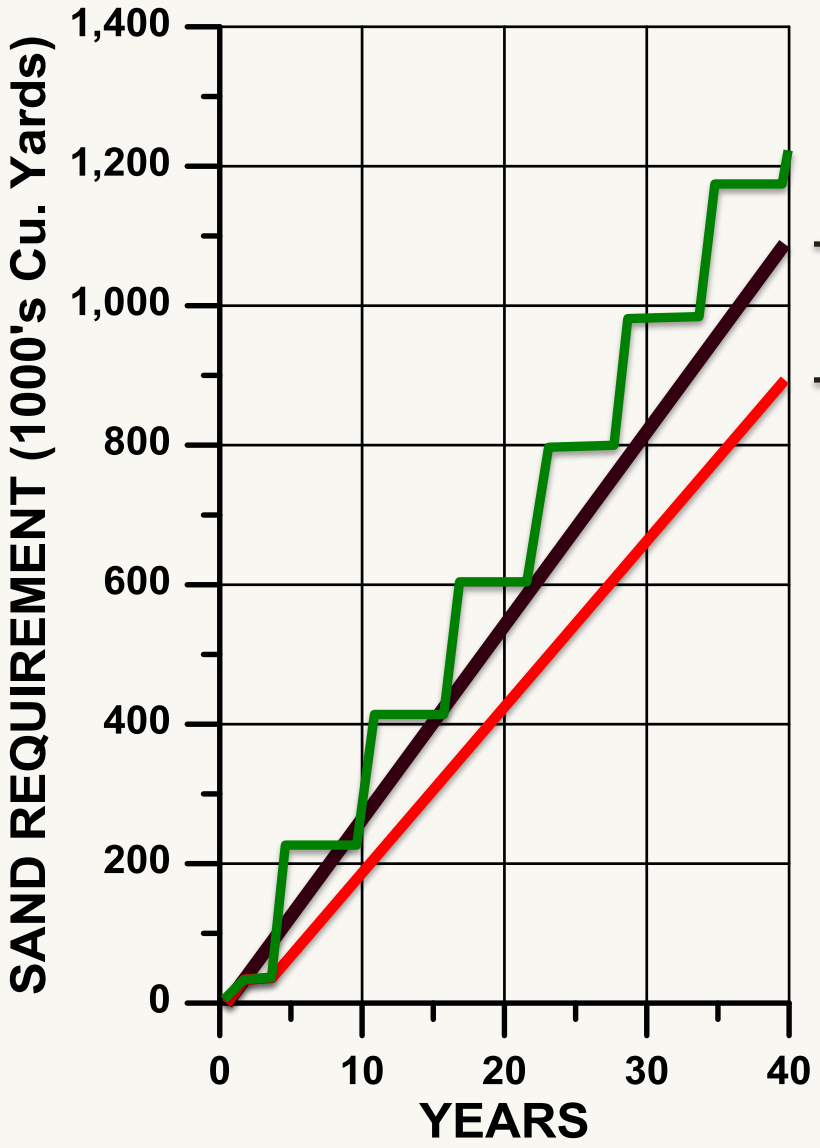
-65,000 cy/yr to -24,000 cy/yr + 0 cy/yr = -24,000 cy/yr

45 to 65 ft erosion

Example: Renourishment Requirements

Small, Emergent Breakwaters – Mild Effect

Comparing Volumes and Costs, with & without Structures



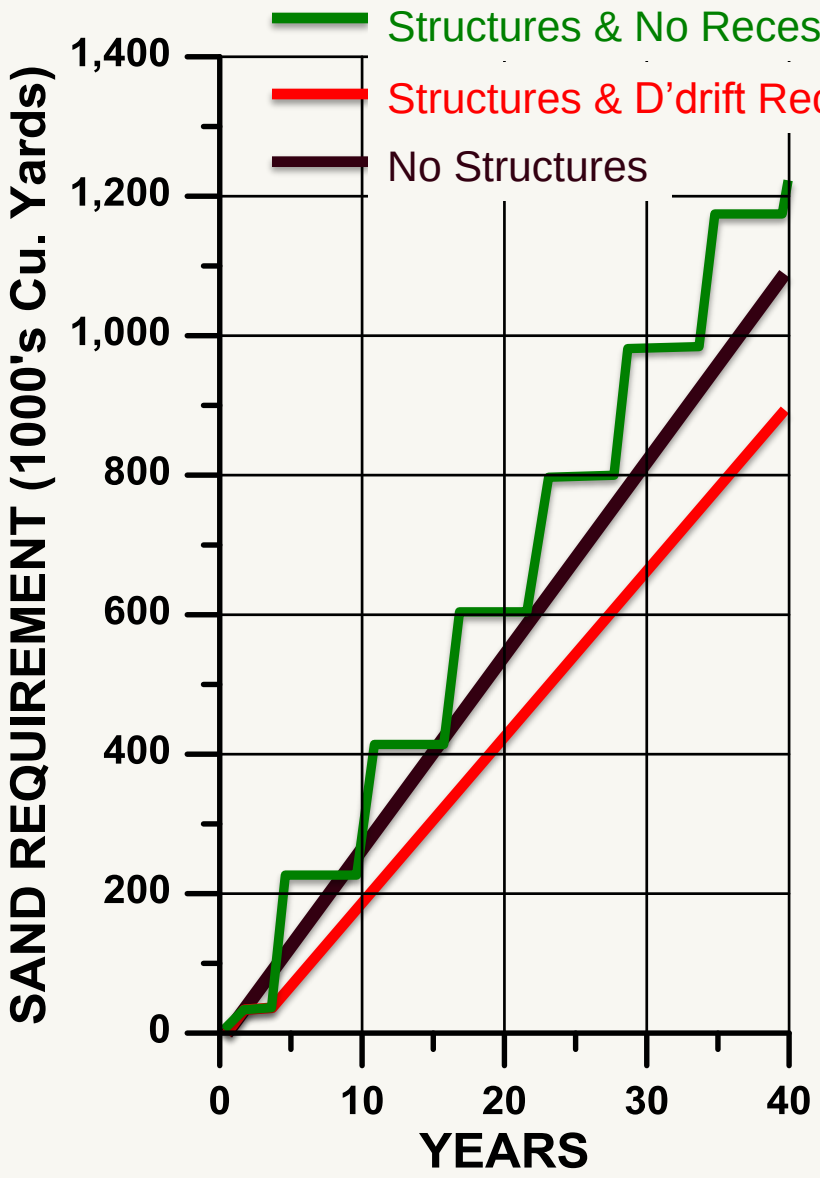
Structures reduce sand requirement by 192,000 cubic yards if downdrift beach is allowed to erode by 45 to 65 feet.

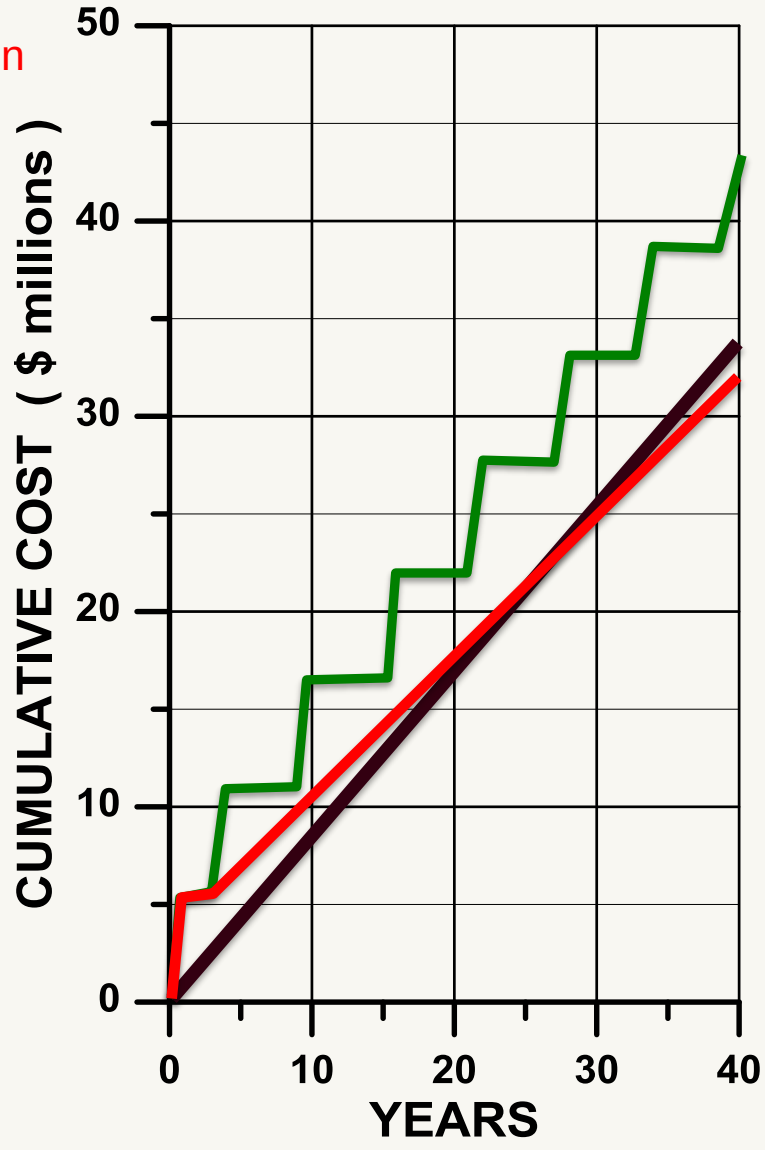
Structures & No Recession

Structures & Downdrift Recession

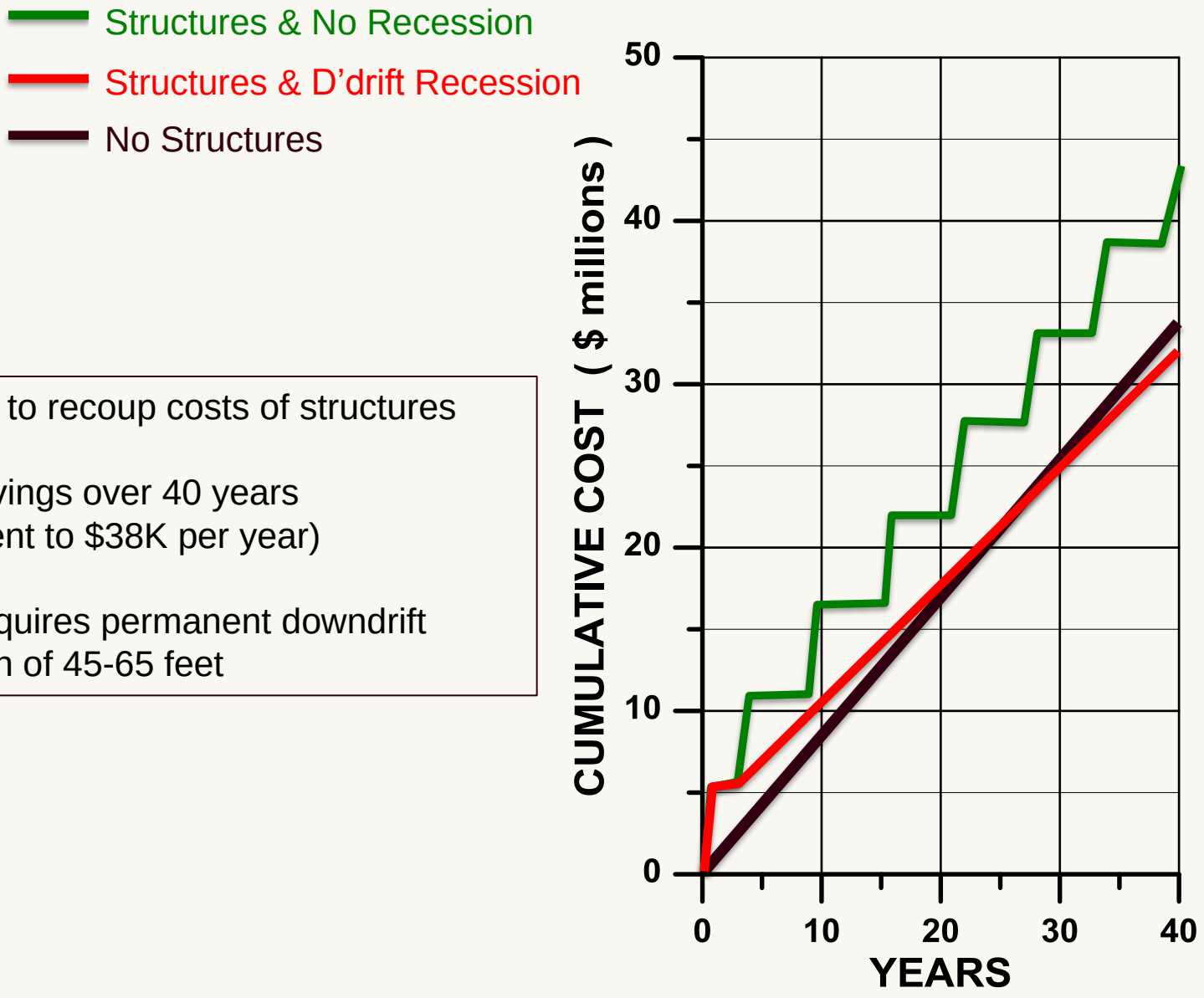
No Structures

Comparing Volumes and Costs, with & without Structures





Comparing Volumes and Costs, with & without Structures



- 25 years to recoup costs of structures
- 4.6% savings over 40 years (equivalent to $38K per year)
- But, it requires permanent downdrift recession of 45-65 feet

CONCLUSION

(Wake up and Pay Attention)

Prudent Applicability of Structures is Highly Site Dependent

- Performance and benefit of any coastal structure depends upon the specific site conditions.
- Structures are typically most effective in a closed system or at the terminal ends of beaches (near inlets, etc.).
- Structures are difficult to implement along an open coast without adverse impacts to adjacent shorelines.
- Structure fields must be advance-nourished with sand.
- Structures *manage* available sand; they *do not create* sand.

STRUCTURES 101

OR

BREAKWATERS, BACON AND EGGS

A BREAKFAST SEMINAR

by

Dr. Kevin Bodge, PE

olsen associates, inc.
jacksonville, florida