NATURAL AND NATURE BASED FEATURES BEACHES AND DUNES

John Winkelman

US Army Corps of Engineers - Coastal Working Group Lead

29 July 2018

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SESSION OUTLINE

- What is a beach/dune fill
- Basics of design and construction/maintenance
- Benefits of these features
- What are the typical challenges
- Downside of these features – why natural is not perfect
- Jens
  - Dunes as part of hybrid coastal defense systems

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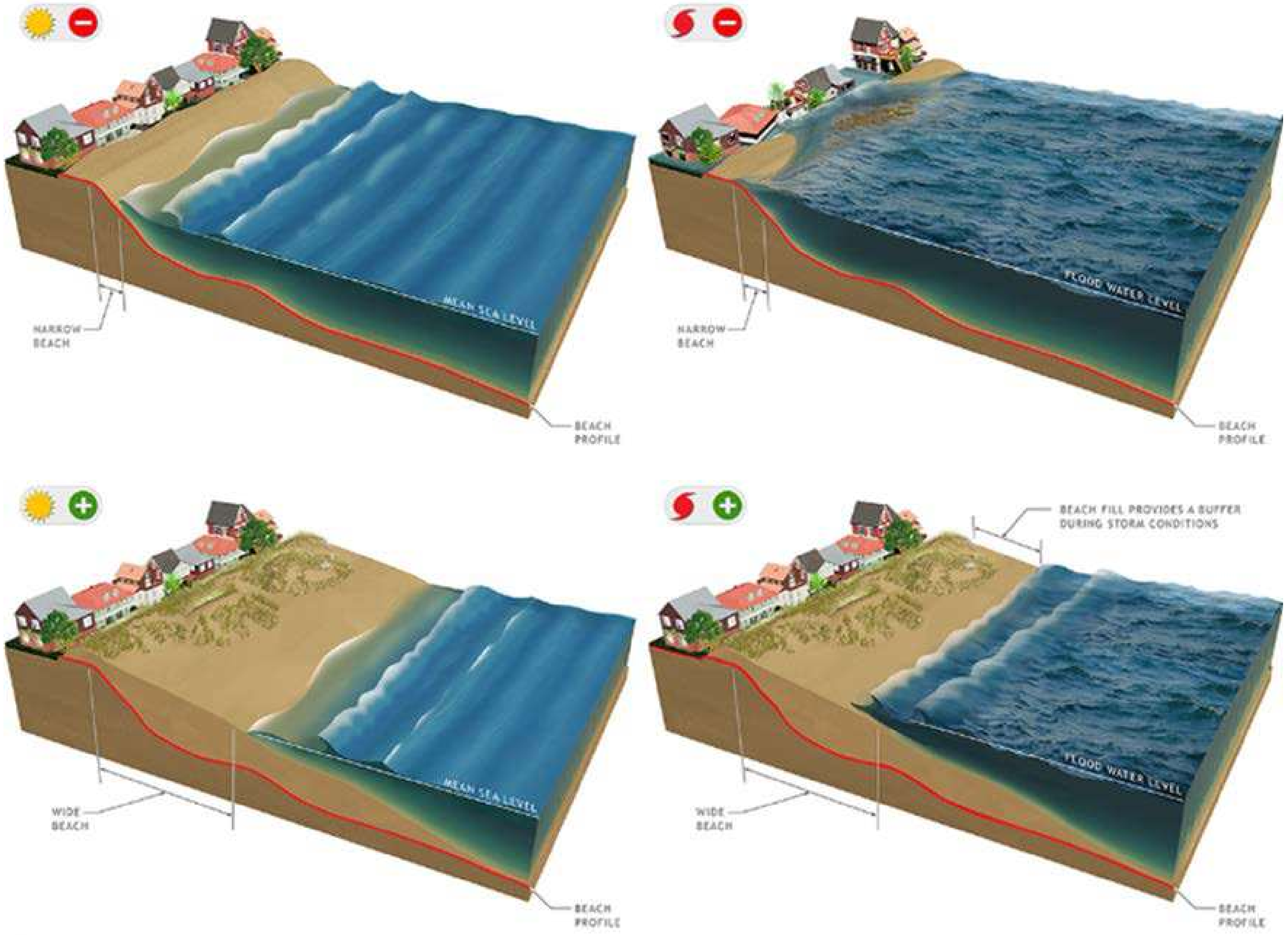
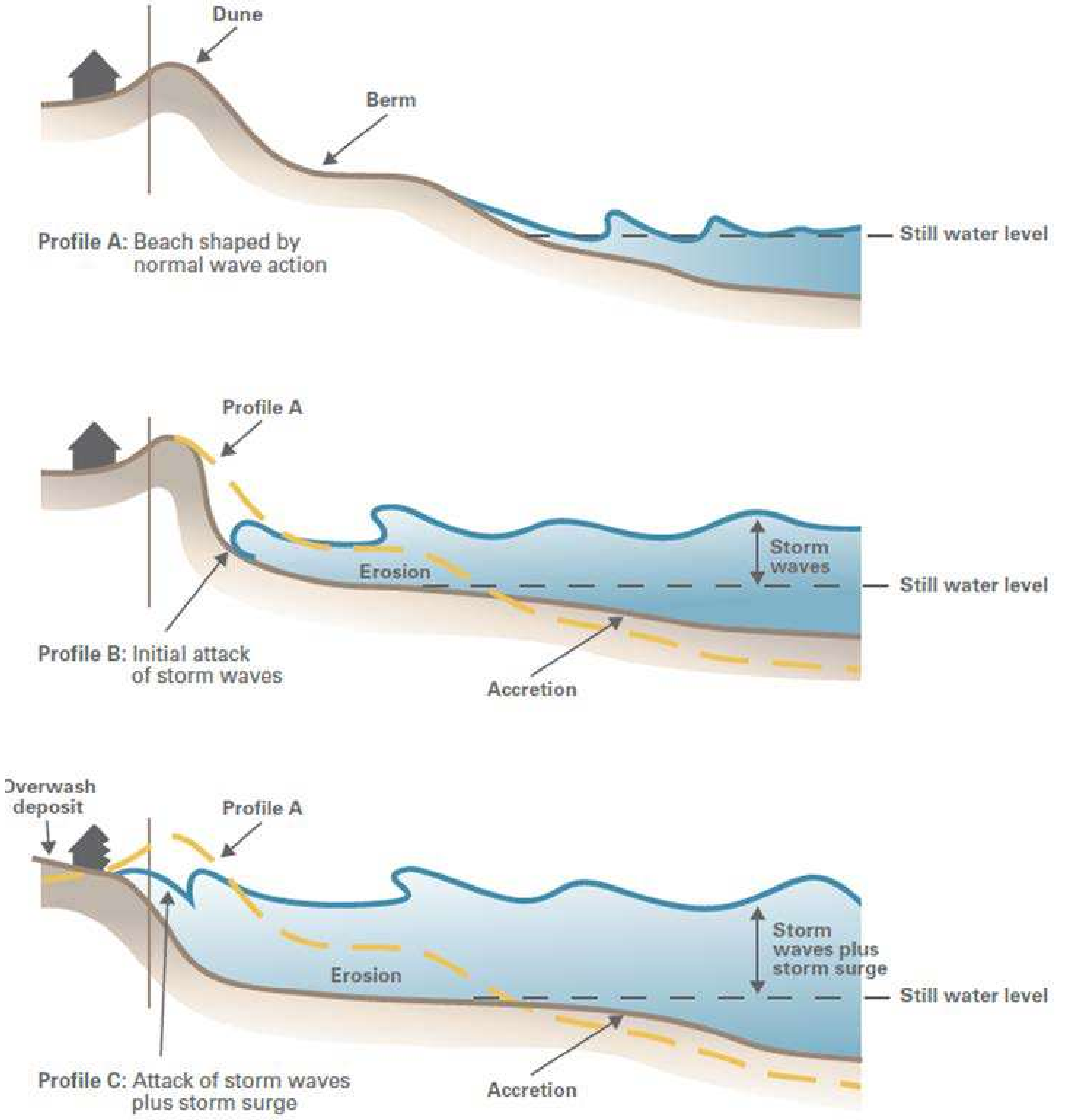
BEACH NOURISHMENT AND DUNES

Can reduce land loss and inundation risk of the hinterland while providing high amenity and environmental benefits.

- **Best understood NNBF alternative**
  - **Storm performance can be modeled**
  - **Long term evolution calculable/modeled**
  - **Lifecycle costs, maintenance, performance can be determined**
  - **Long term experience provides additional info and confidence**
- **Far from perfect**
  - **Still large uncertainty**
  - **Models need improvement**
  - **Dunes and vegetation lacking**
  - **Post storm recovery**
  - **Nearshore placement**
- **Long term maintenance**

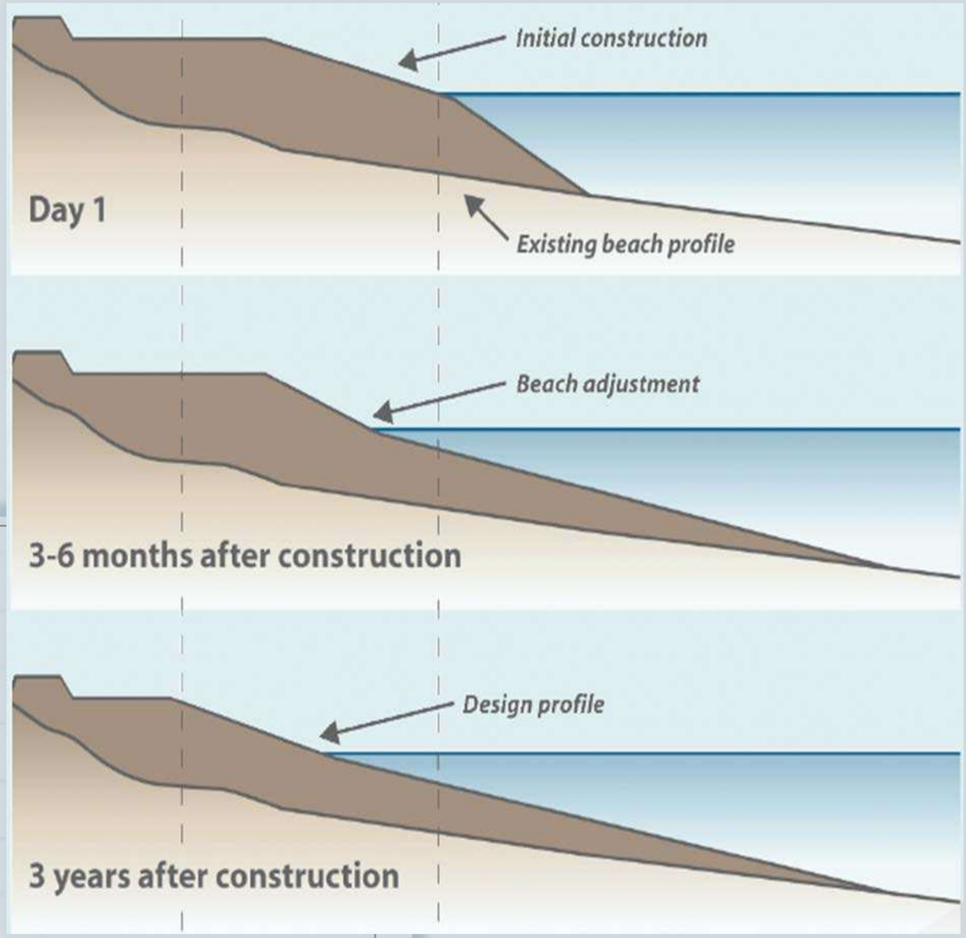
BEACH FILL AND DUNE PROJECT PURPOSE

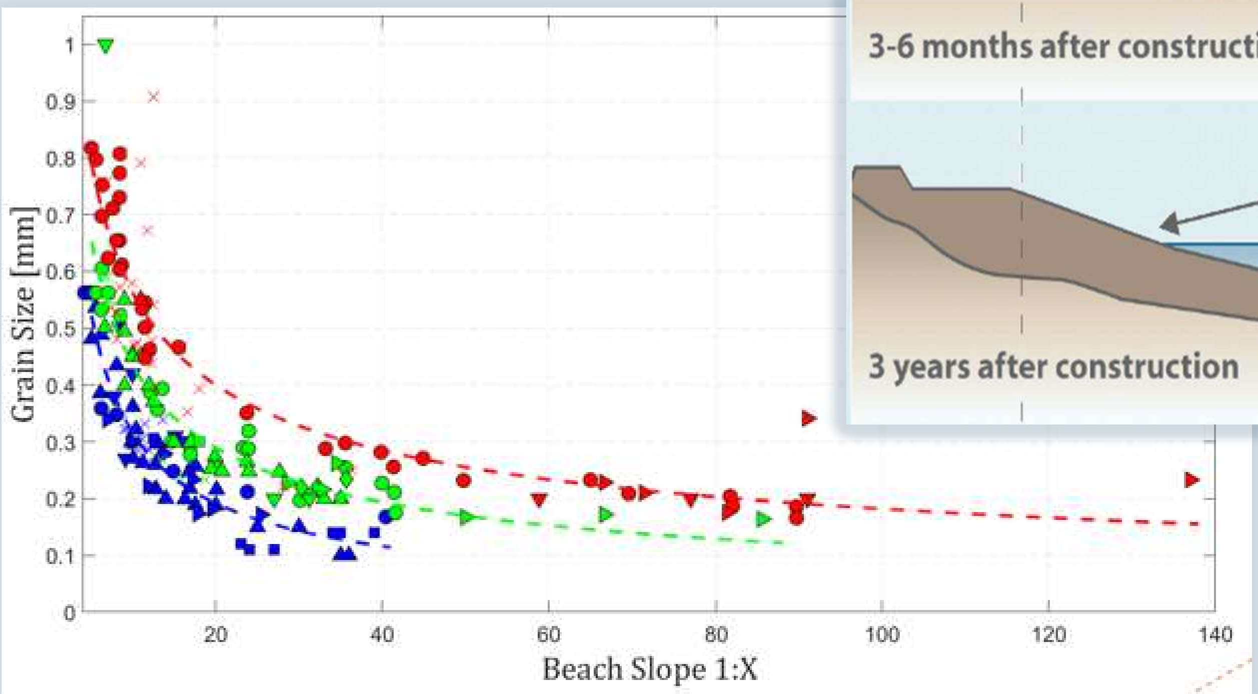




BEACH FILL DESIGN BASICS

- Cross Section
  - Berm Elevation
  - Dune configuration
- Equilibration





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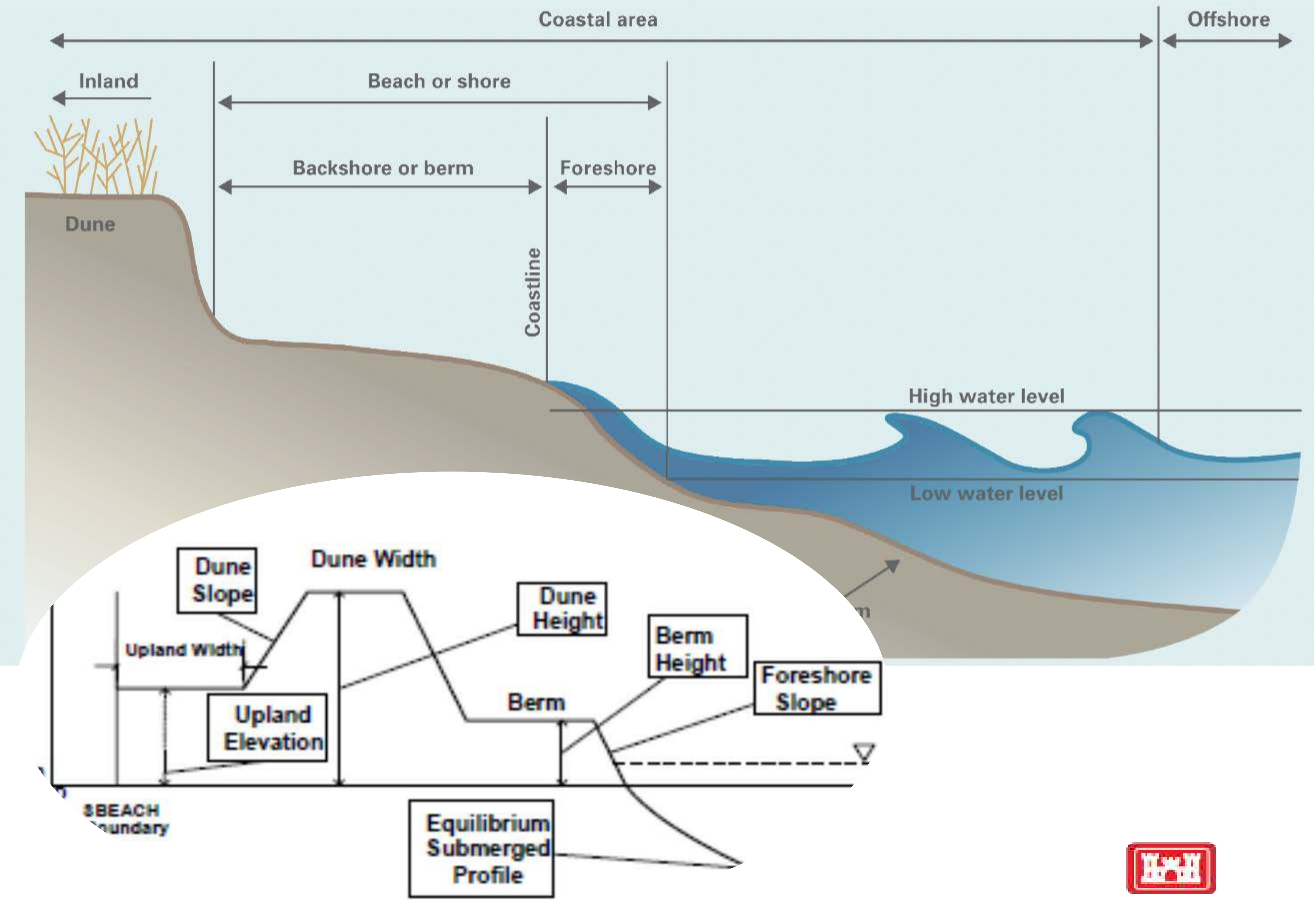
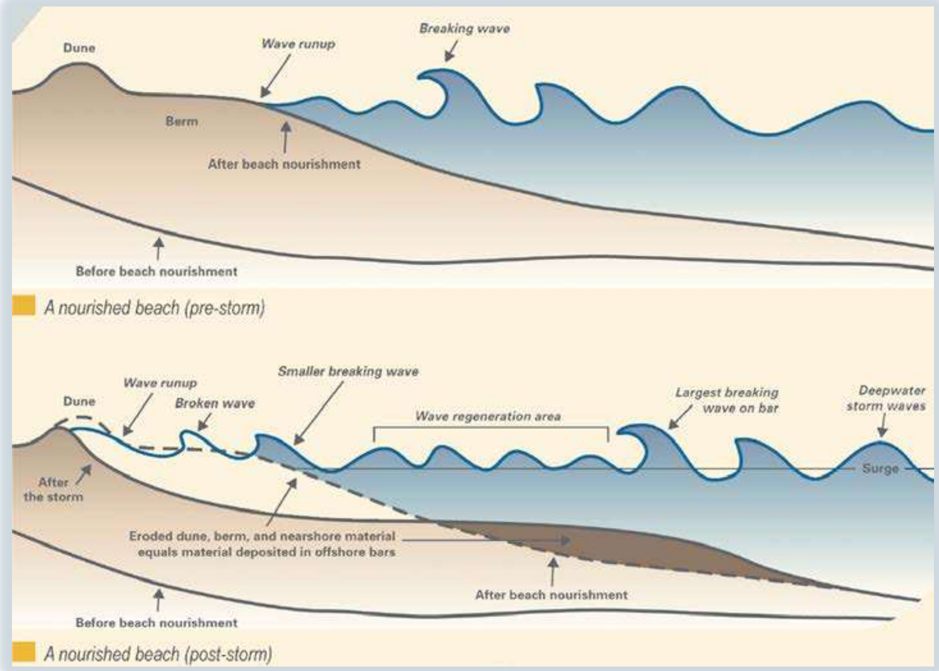
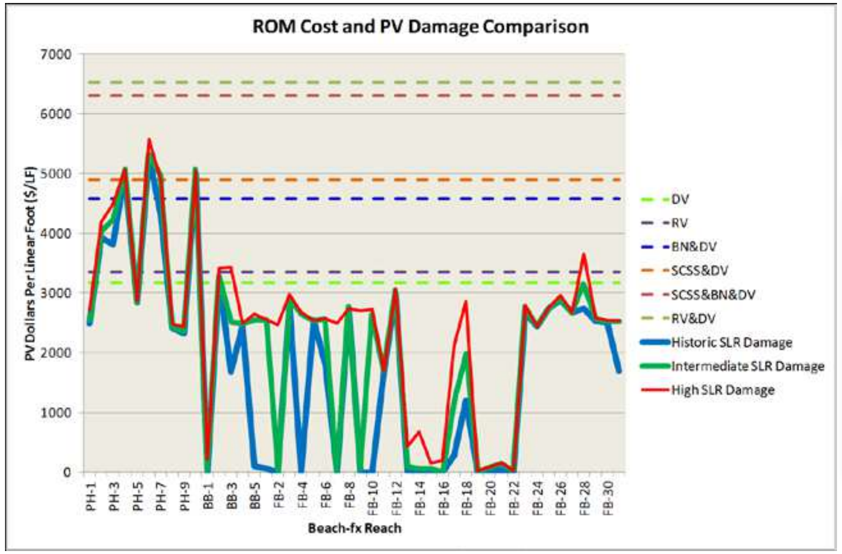
BEACH FEATURE DEFINITIONS

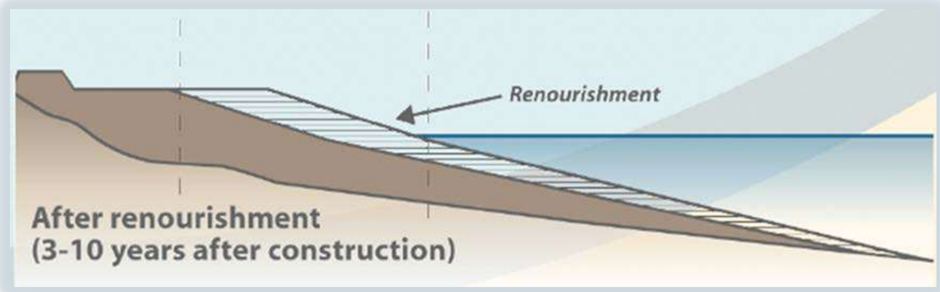


BEACH FILL PERFORMANCE

- Storm
- Longevity
- Lifecycle







SEDIMENT SOURCES

Where sediment comes from?

- **Sand from the sea floor**
- **Accreting harbours, channels, estuaries and lagoons**
- Land quarries
- Bypassing
- Recycling (Backpassing)
- Existing accreting beaches
- River channels and alluvial plains
- Waste and artificial sediment.

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BEACH FILLS AND MAINTENANCE – HEAVY CONSTRUCTION

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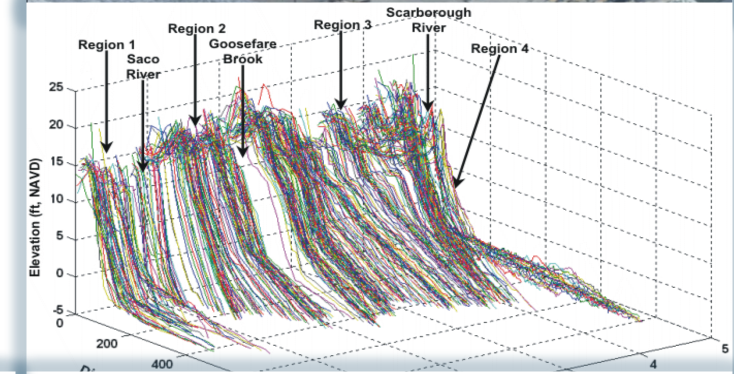
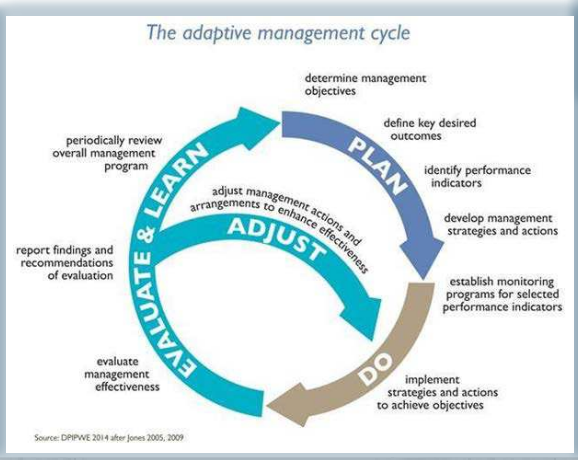
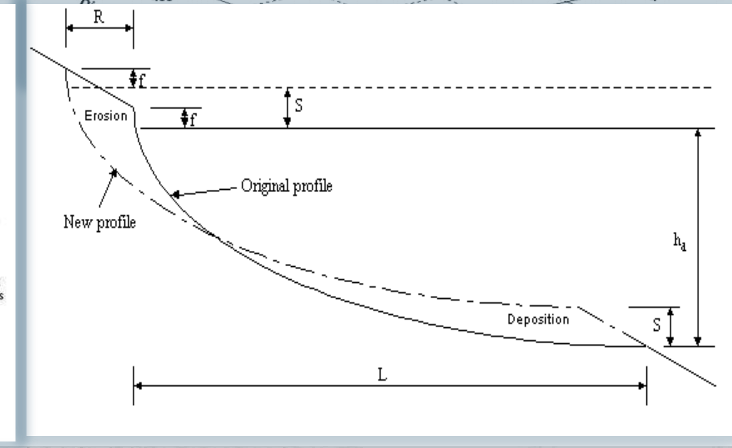
ENGINEERING AND SOCIETAL BENEFITS

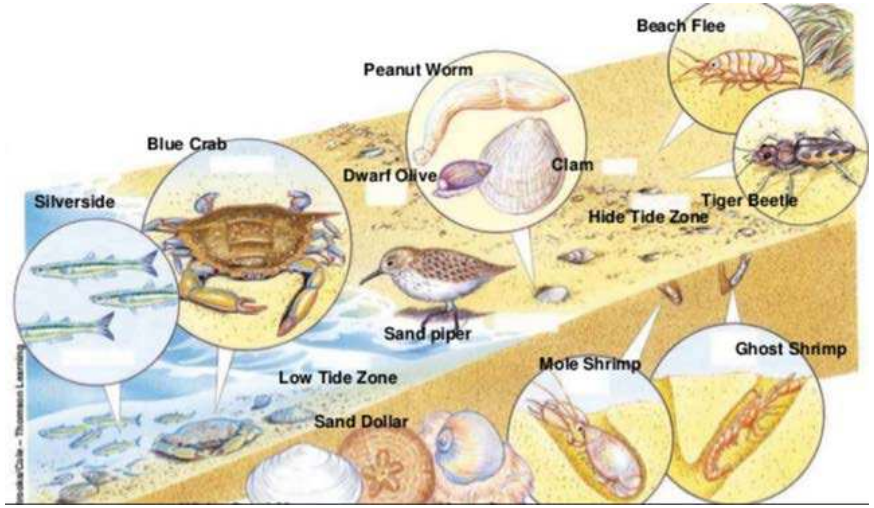
- Storm damage risk reduction
- Resiliency
  - Post storm
  - Adaptive
  - Sea level change
- Environmental
  - Reduced impacts
  - Benefits
- Cost effective
- Recreation

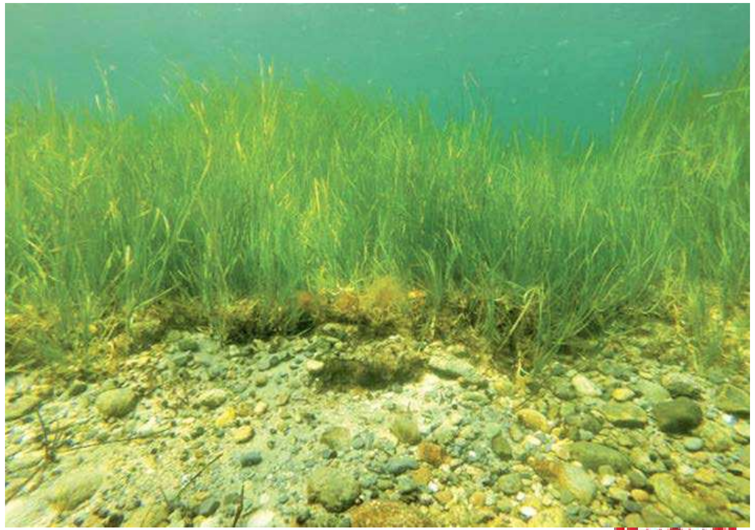






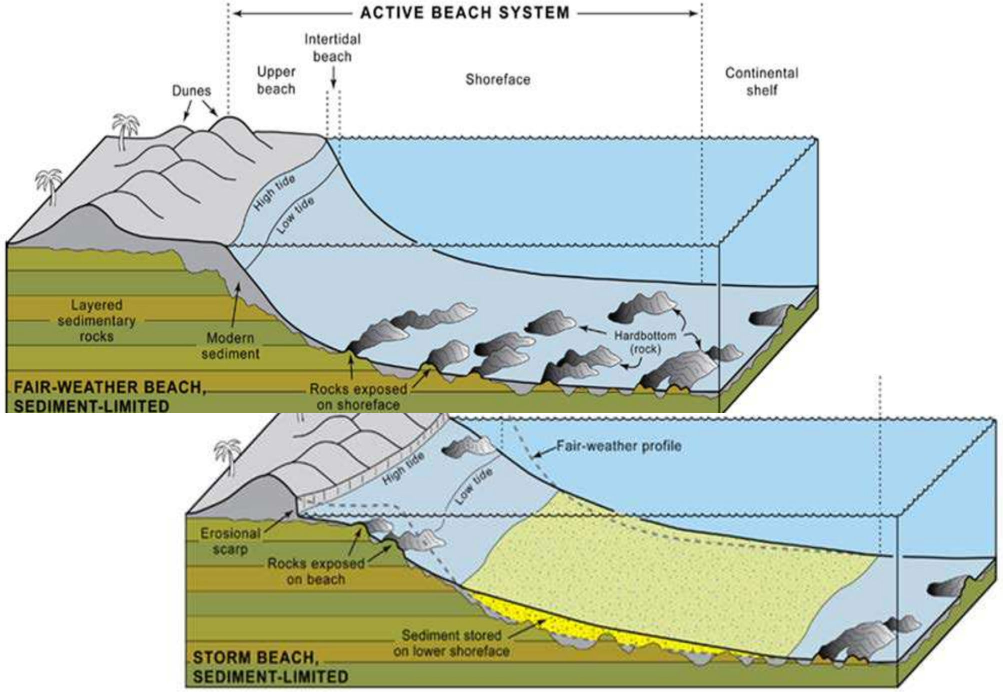
NATURAL BENEFITS TO BEACH FILLS

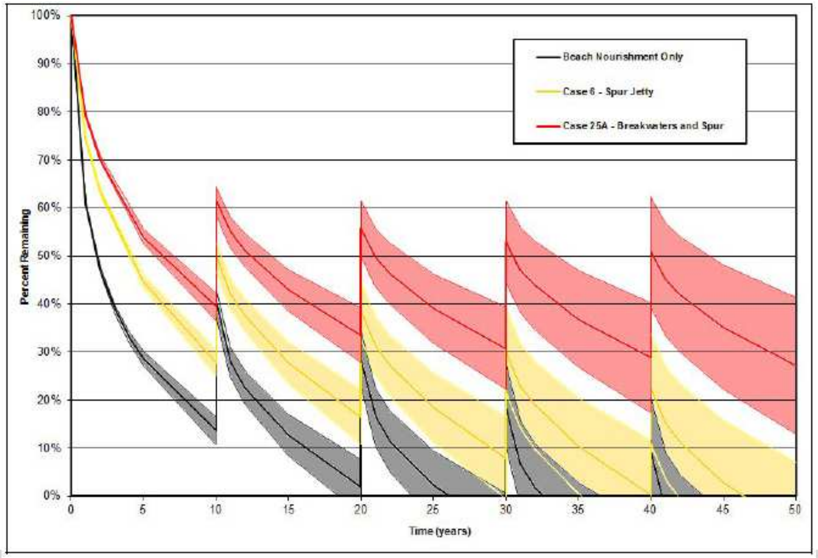




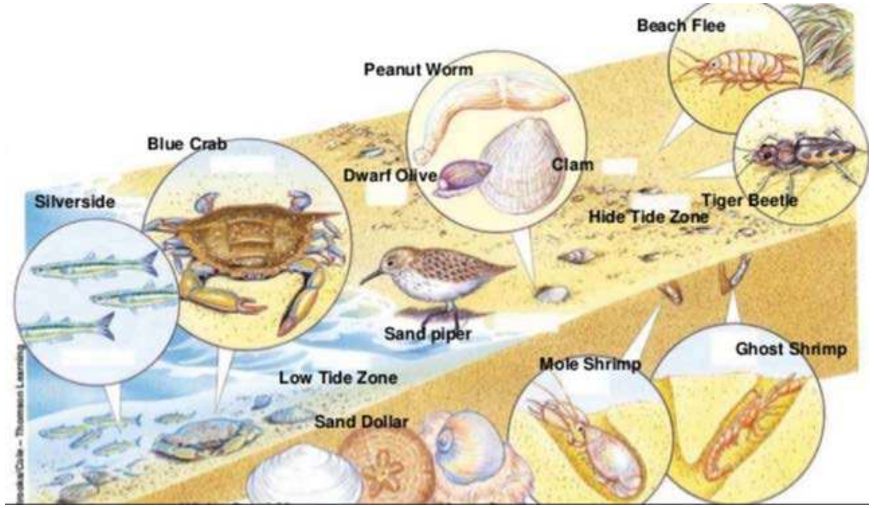
CHALLENGES OF USING BEACH FILLS AND DUNES

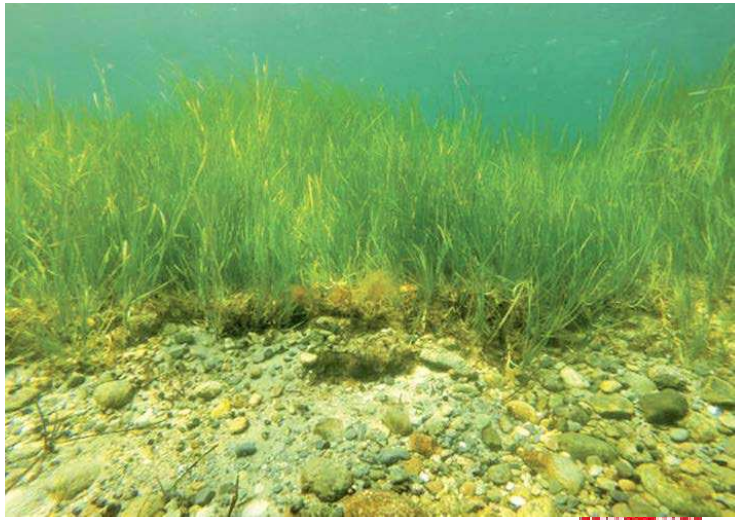
- Impacts and permitting
- Public access requirements
- Sediment Source
- Long term maintenance commitment





CHALLENGES TO USING BEACH FILLS AND DUNES





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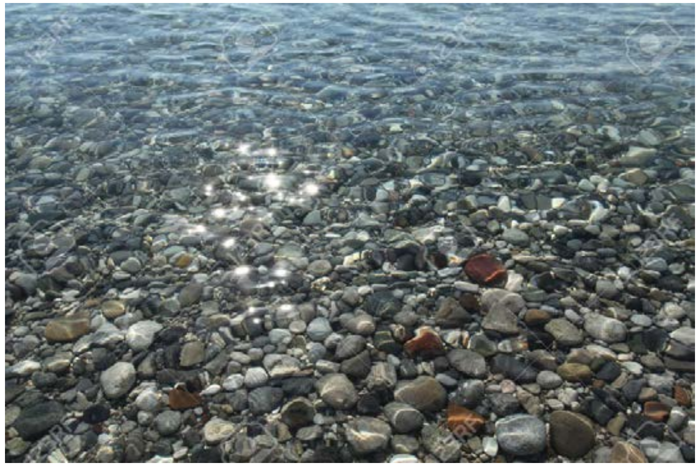
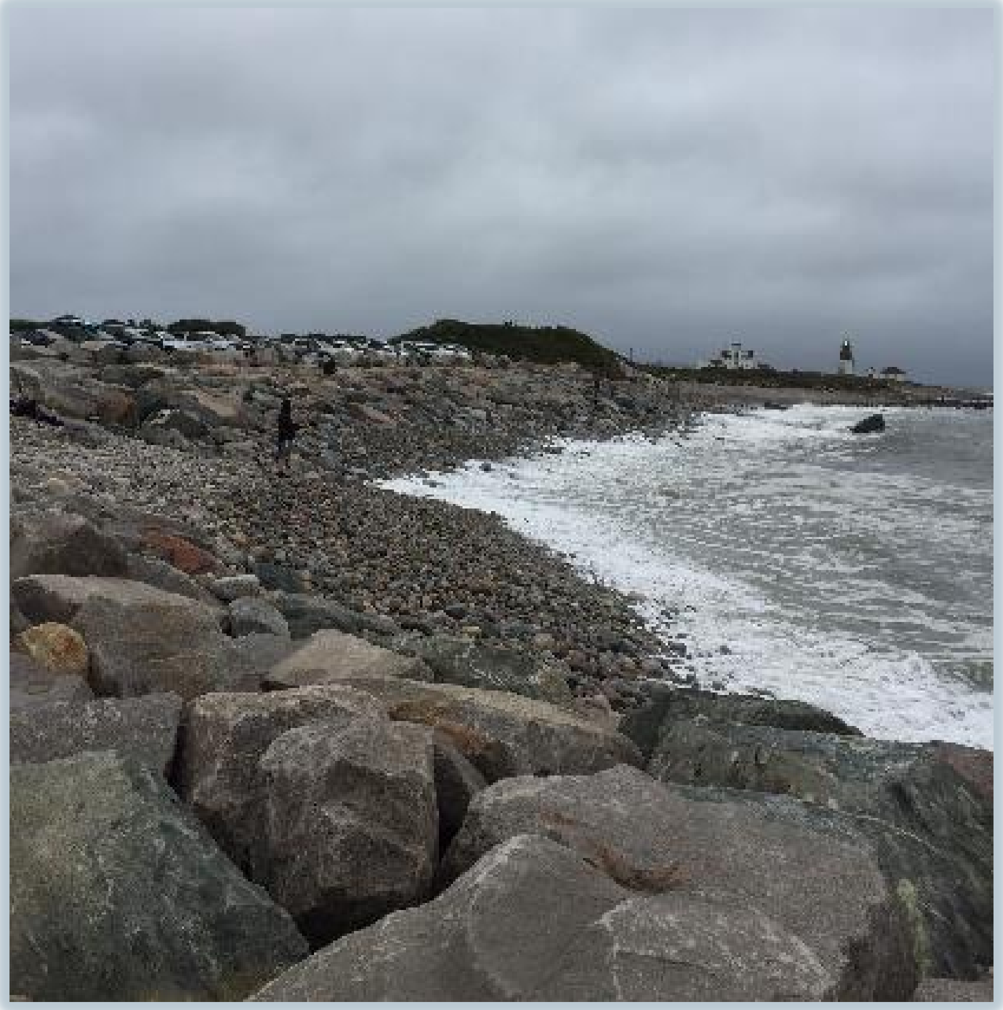
CHALLENGES TO USING BEACH FILLS AND DUNES



BERM STRUCTURES AND COBBLE/GRAVEL BEACHES



SUMMARY

- Beach Fills and Dunes are best understood NNBF alternative
- Improvements are still needed for many aspects of beach fills
- Beaches can be designed and maintained in a relatively predictable manner
- They are one of the most widely used coastal storm damage risk reduction features
- They have both benefits and challenges – often related to each other
- They typically require maintenance that that can be challenge
- All beaches are not sand

Hybrid Coastal Defenses with Dunes

Jens Figlus
Department of Ocean Engineering
Texas A&M University

ICCE Short Course on Engineering with Nature Concepts

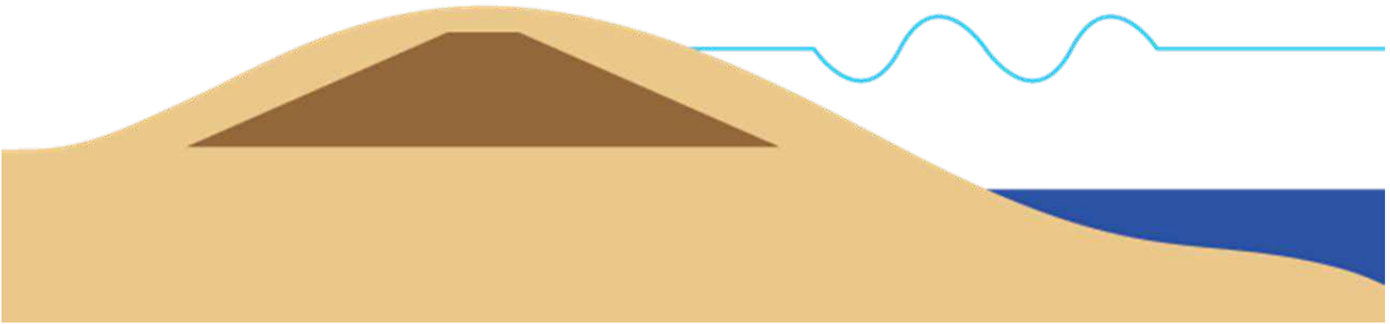
July 29, 2018

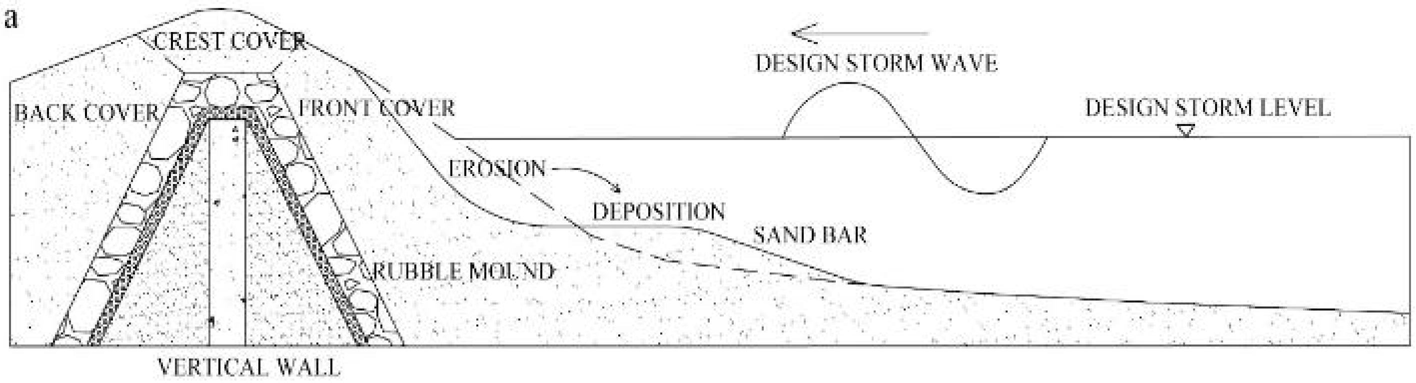
OCEAN ENGINEERING
TEXAS A&M UNIVERSITY

Coastal Beach & Bay Foundation

The Center for Texas Beaches and Shores

Combine Hard and Soft Engineering Concepts



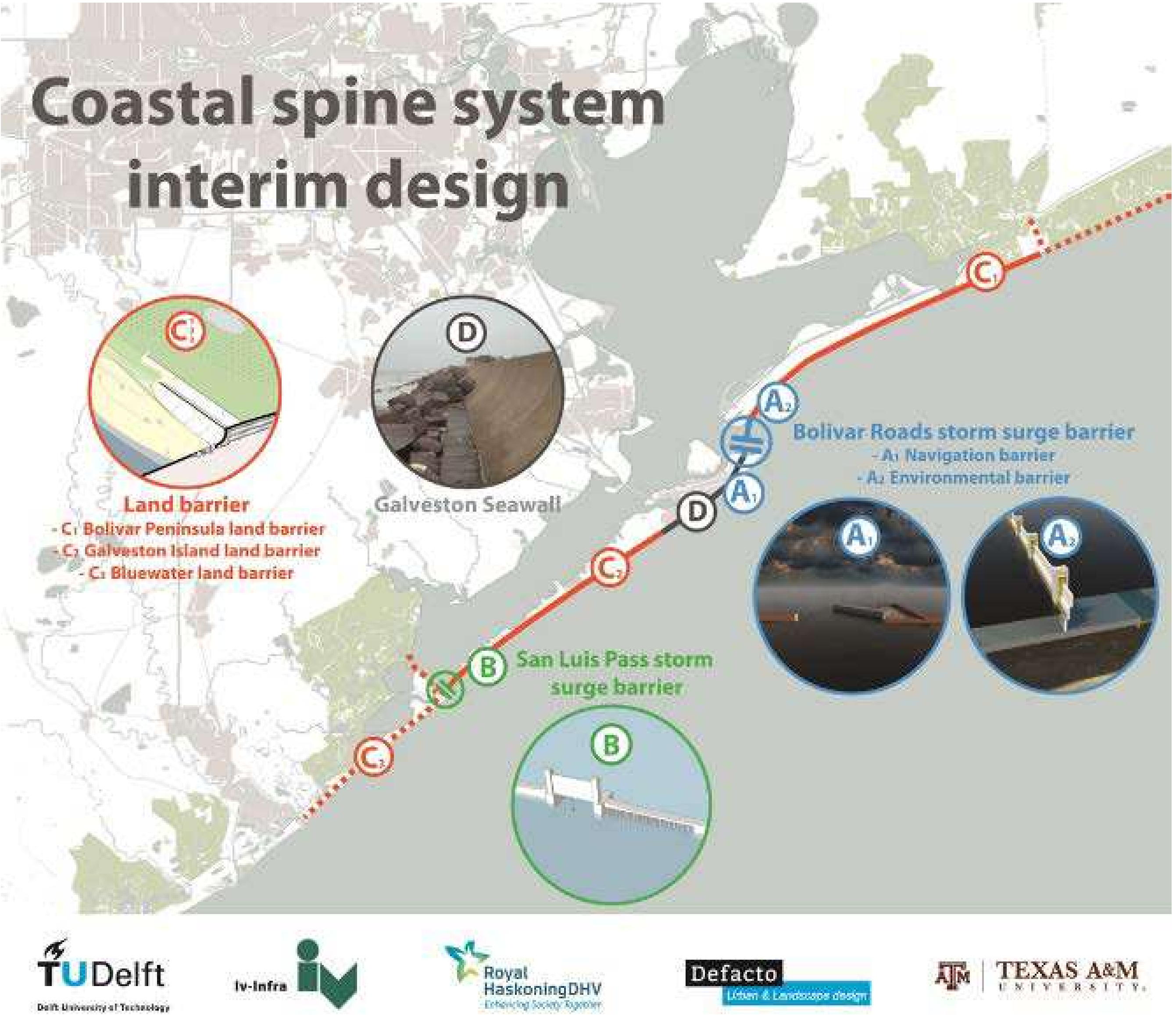


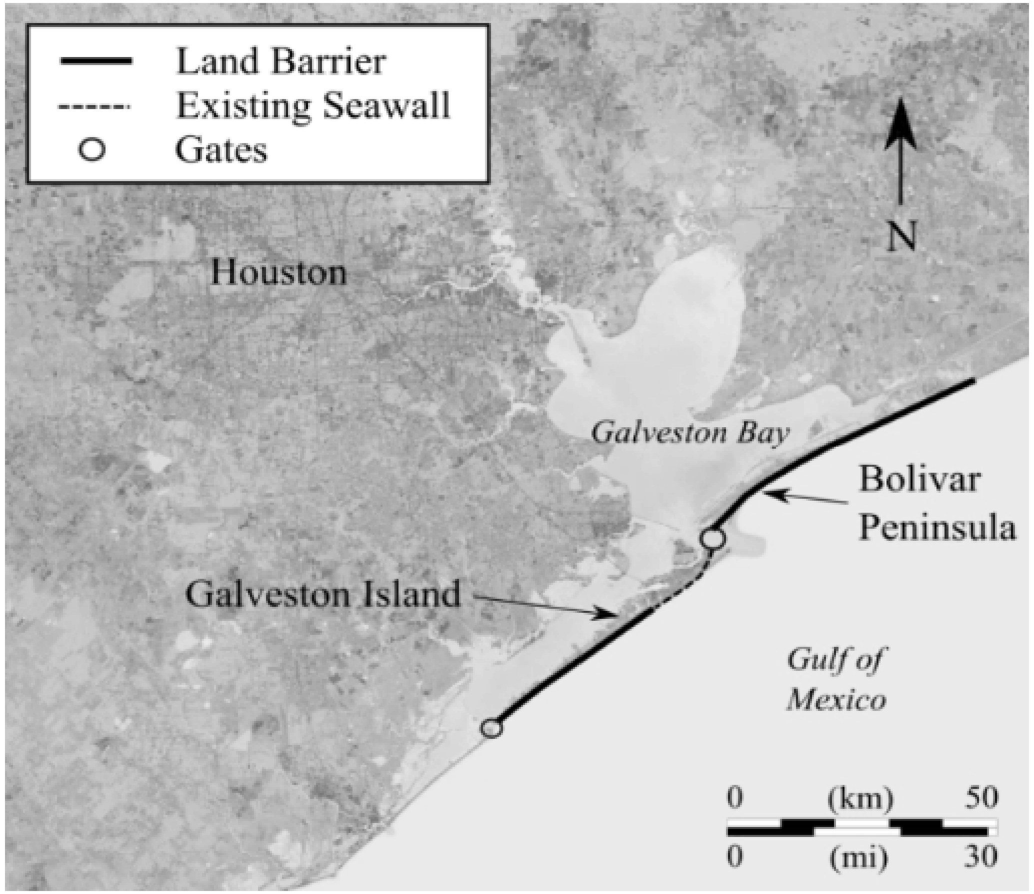
Investigate traditional “hard” coastal structures with complete sand dune cover to protect from storm surges and improve coastal system performance

Combine effective surge suppression characteristics of core structure with aesthetic appeal (residents, tourists) and ecological benefits (plants, animals) of dunes

Account for the added energy dissipation capacity afforded by the “sacrificial” dune cover to reduce design dimensions of the core structure (cost savings)

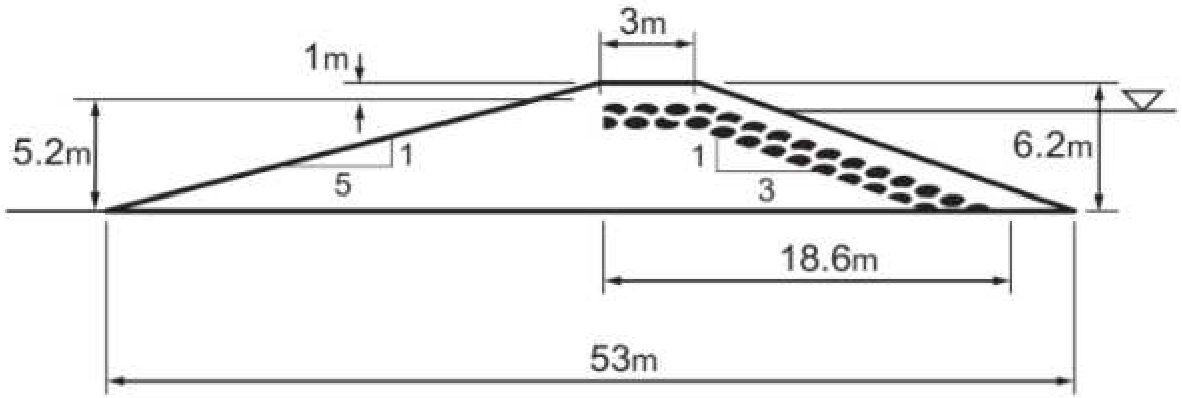
A Coastal Spine for Houston/Galveston?





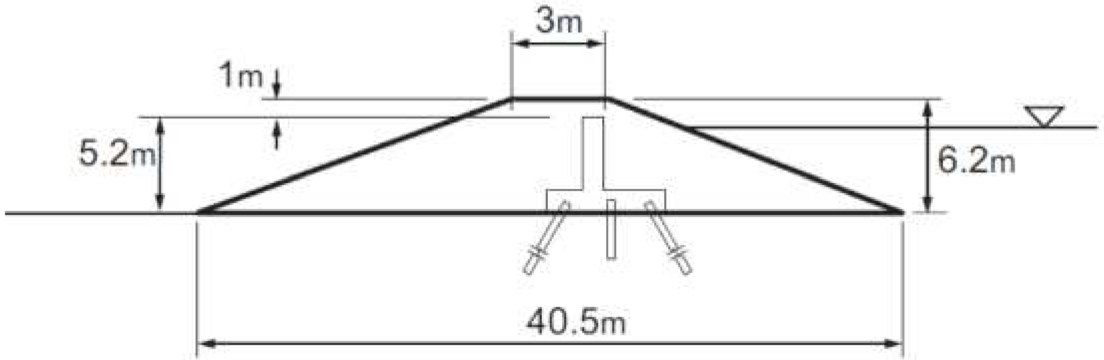
- Block/reduce surge at the coast
- Incorporate existing Galveston seawall
- Add hydraulic gates at inlets & land barrier on Galveston Island and Bolivar Peninsula

Land Barrier Concepts: Core-Enhanced Dunes



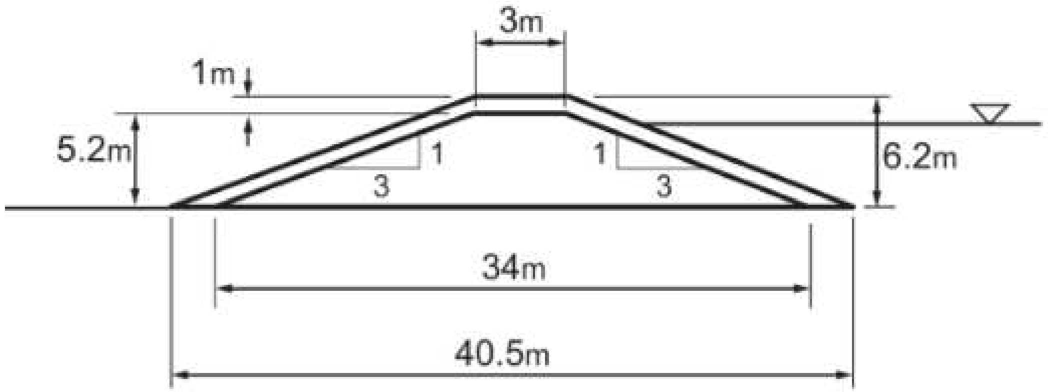
Armor stone revetment

(common shore protection)



T-wall

(Successful, proven design, e.g. New Orleans)



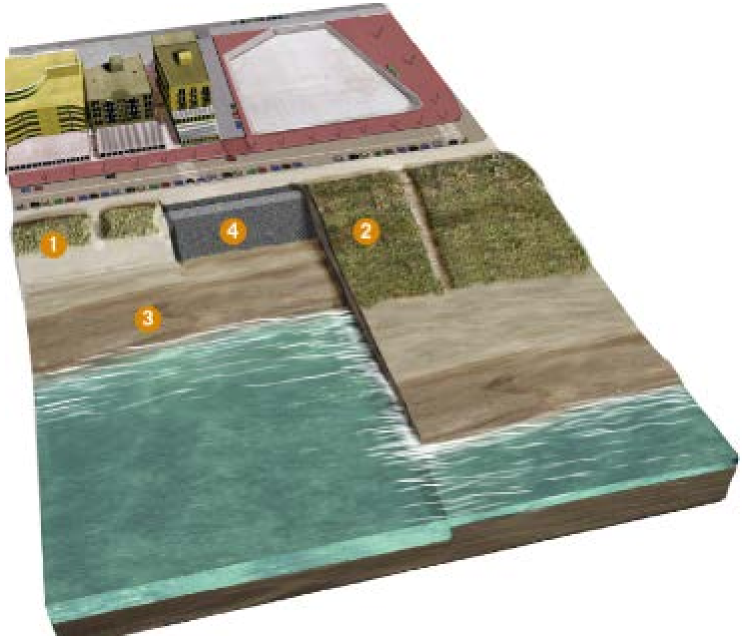
Clay levee

(Cheaply available local material)

(West, 2014)

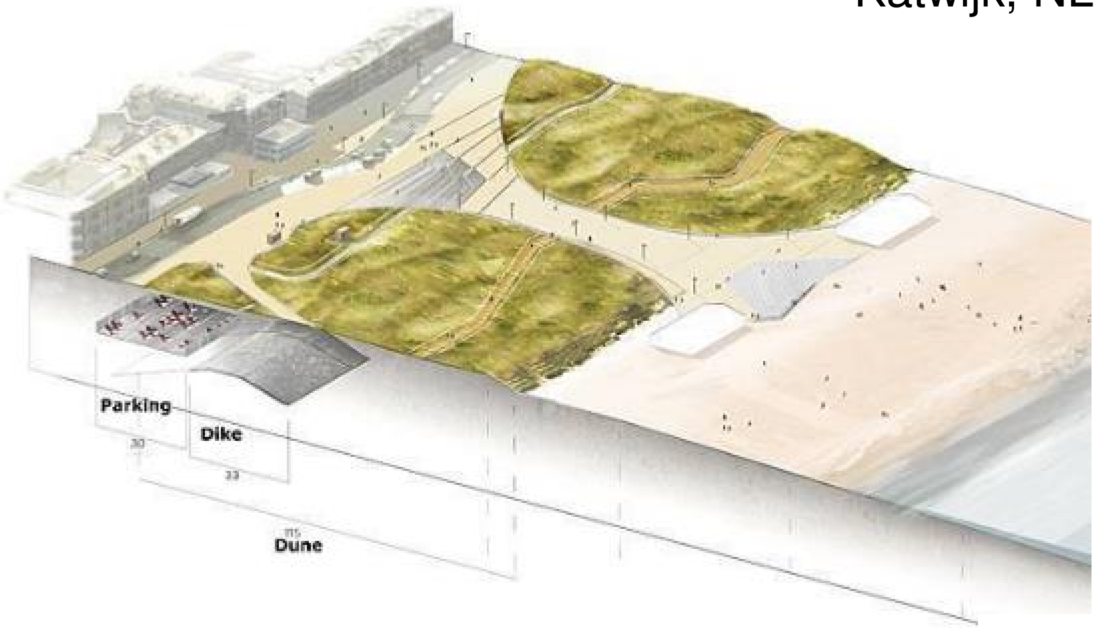
Existing “Hybrids”

Noordwijk, NL

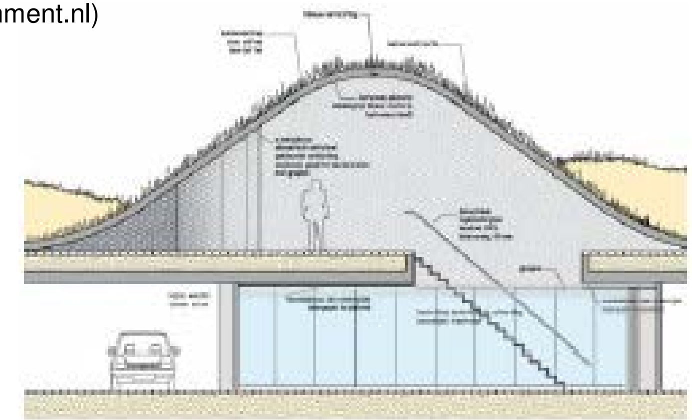


(Dr. Henk J. Steetzel, Arcadis, 2010)

Katwijk, NL



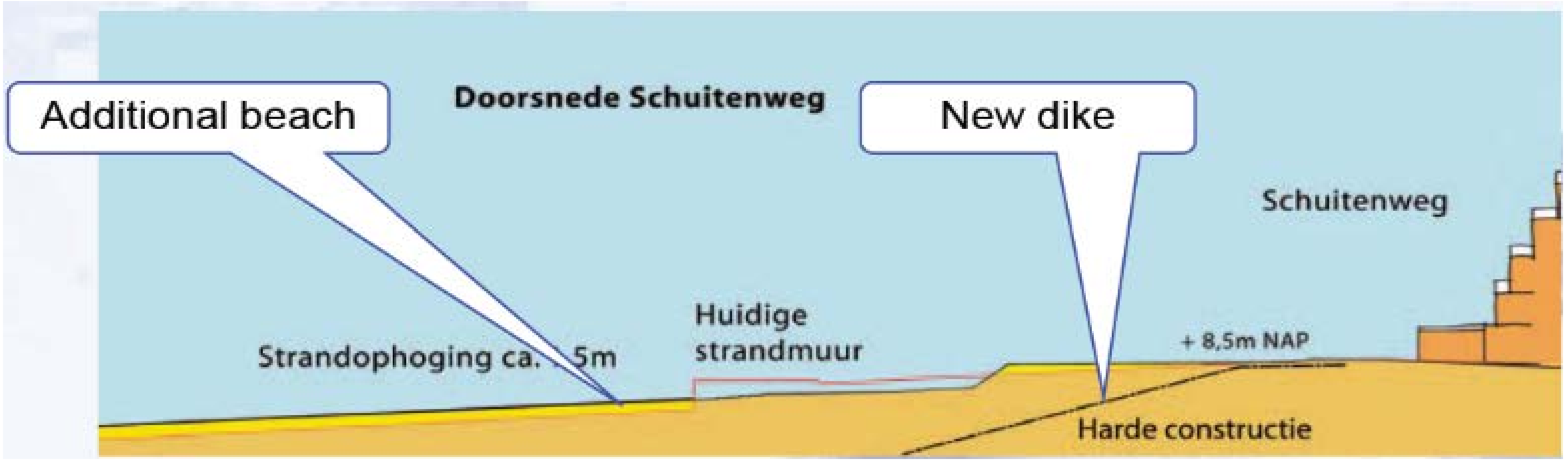
(www.government.nl)



Dike-in-Dune concept (rock-protected sand core covered with dune)

Multi-use coastal defense concept (car parking in dunes)

Existing “Hybrids”

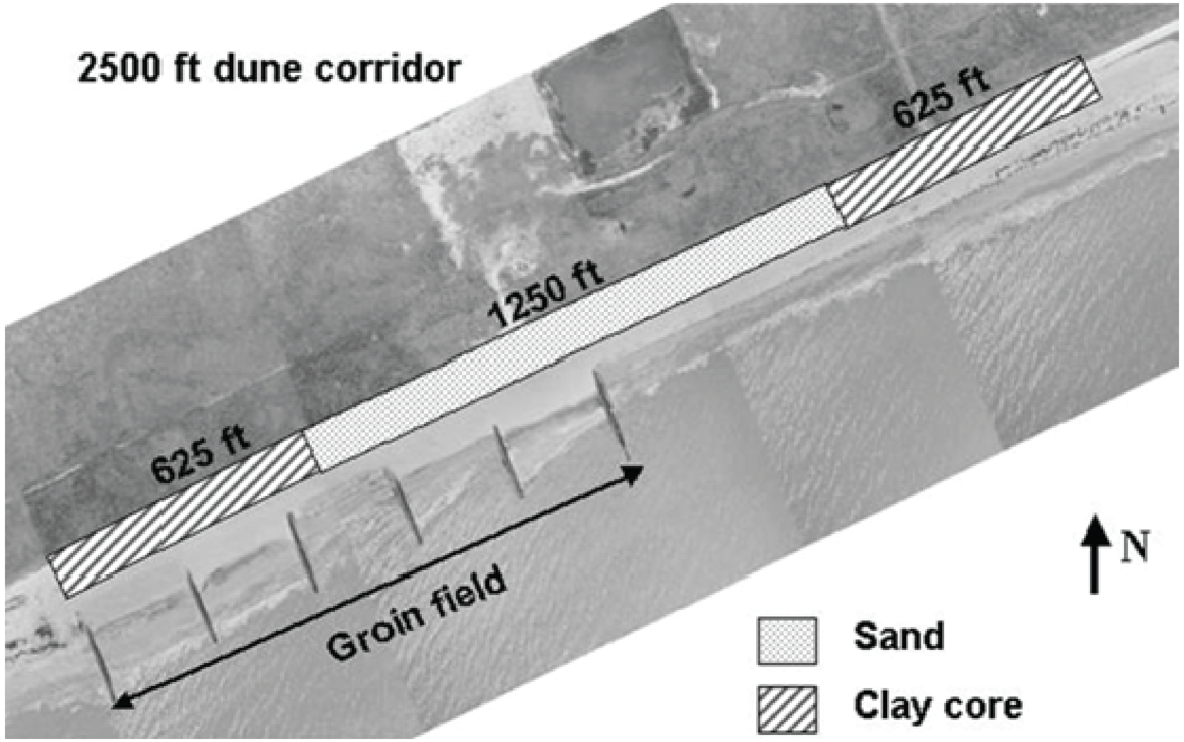


Scheveningen, NL

Concept: Dike-in-Boulevard + additional beach

(Dr. Henk J. Steetzel, Arcadis, 2010)

Existing “Hybrids”



Jefferson County, TX, USA

USACE experimental low-volume beach nourishment with clay core dunes (Wamsley et al. 2011)

During Hurricane Ivan (2004) clay core dunes showed only 10% erosion compared to 50% for regular sand dunes

Existing “Hybrids”

Bay Head, NJ, USA

Photo: Jen Irish, Virginia Tech

Photo: Jon Miller, Stevens Institute of Technology

Relic rock seawall exposed by Superstorm Sandy afforded superior protection to homes and infrastructure compared to other locations (Irish et al. 2013)

Runup and Overtopping Functional Design of Hard Structures

Runup
Example Equations:

$$\frac{R_{u2\%}}{H_s} = 1.6\,\xi'_{op}$$

with

$$\xi'_{op} = \frac{tan\alpha}{\sqrt{\frac{H_s}{L_{op}}}}$$

Overtopping
Example Equations:

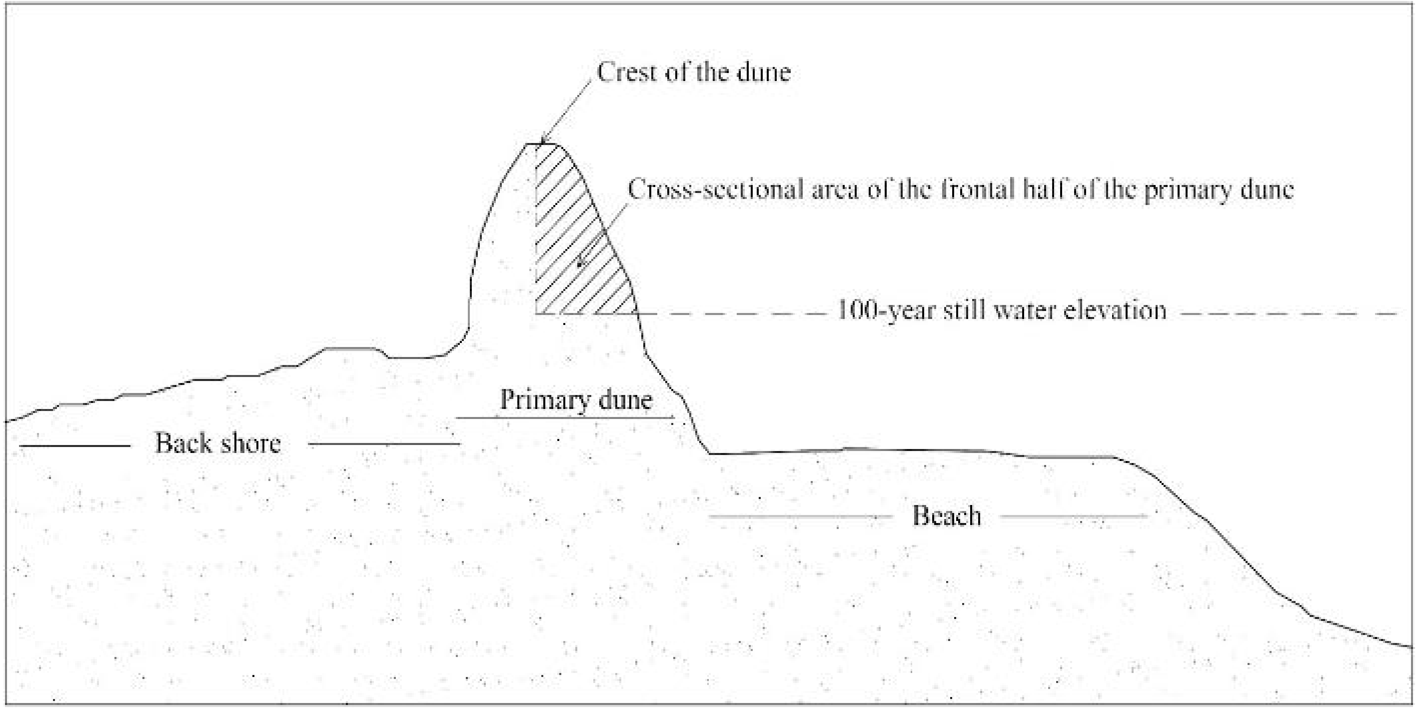
$$\frac{q}{\sqrt{gH_s^3}} = 0.2\exp\left(-2.6\frac{R_c}{H_s}\frac{1}{\gamma_b\gamma_d\gamma_\beta\gamma_f}\right)$$

Non-breaking waves

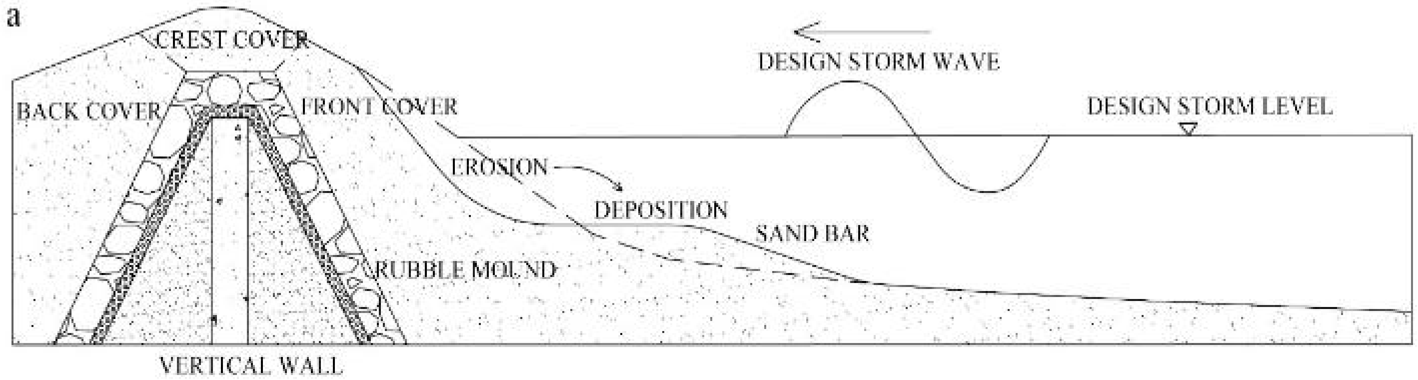
$$\frac{q}{\sqrt{gH_s^3}}\sqrt{\frac{s_{op}}{tan\alpha}} = 0.06\exp\left(-5.2\frac{R_c}{H_s}\sqrt{\frac{s_{op}}{tan\alpha}}\frac{1}{\gamma_b\gamma_d\gamma_\beta\gamma_f}\right)$$

Breaking waves

Engineered Dunes



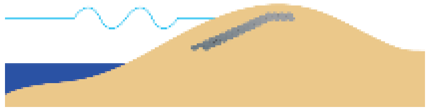
Cross-sectional area of frontal half of primary dune above 100-year design water level:
540 ft³/ft increased to 1100 ft³/ft (FEMA, 2011)



How to incorporate in hybrid design?

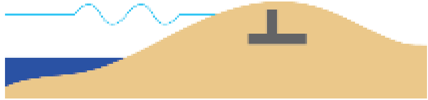
Physical Model Testing (Wave Flume - 2D)

DC1:
Armor Stone Core



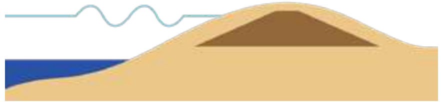
Dual layer (placed)
1:3 slope
D_{50} = 6.5cm
γ_s = 26 kN/m^3

DC2:
T-Wall Core

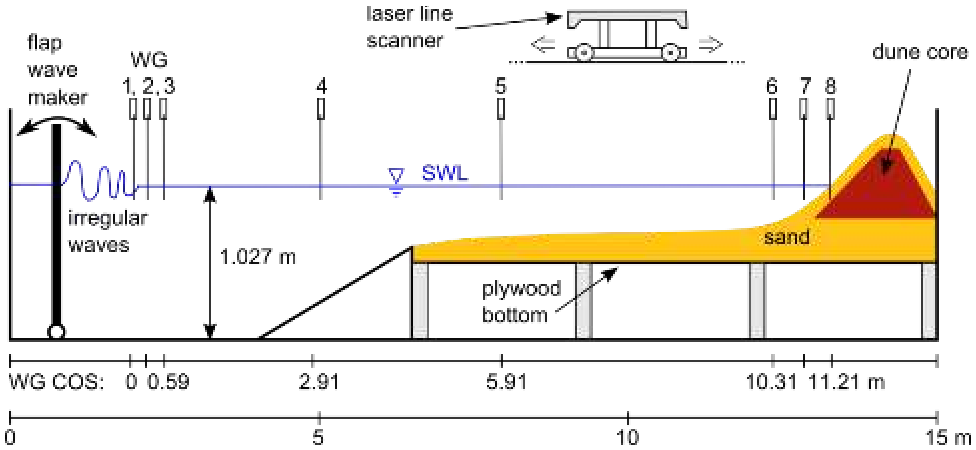


29cm vertical at
front vertex of crest
5cm sand cover
17cm base width

DC3:
Clay Levee Core



Beaumont clay/silt
1:3 slope
D_m = 16µm, σ = 33µm
LL = 59, PI = 34
τ_{sp} = 317 kN/m^2



Overtopping Tests with Rubble-Mound

Physical Model Testing (Wave Basin - 3D)

Physical Model Testing (Wave Basin - 3D)

Future Research Objectives and Goals

- Advance **design guidelines** for hybrid coastal structures.
- Investigate **wave overtopping** for hybrid coastal structures.
- Understand **morphodynamics** of hybrid coastal systems.
- Advance **physical** and **numerical model** investigations.
- Investigate **structural stability** of hybrid systems and identify how critical failure mechanisms are modified (e.g. overtopping, piping, instability of the structure via infiltration and erosion, etc.).

Open Research Questions

- How do sand-covered hard structures behave under storm conditions (e.g. runup, overtopping/overwash, and morphological evolution)?
- How can sand/dune cover thickness/volume be incorporated into empirical functional design equations? Does dynamic sand cover have similar effects as a static crown wall? How does the added sand volume affect scour that is usually associated with conventional hard coastal structures?
- Is there an optimal sand cover thickness or ratio related to freeboard? How can freeboard be defined for hybrid structures with sand cover?
- Will there be any dune stability or migration issues due to wave action during calm conditions and storm events?
- Dunes usually buy time for coastal residents (i.e., the time it takes a storm to erode the dunes). Is that still the case when dunes are integrated into hybrid defenses? Are there any related maintenance issues or concerns?