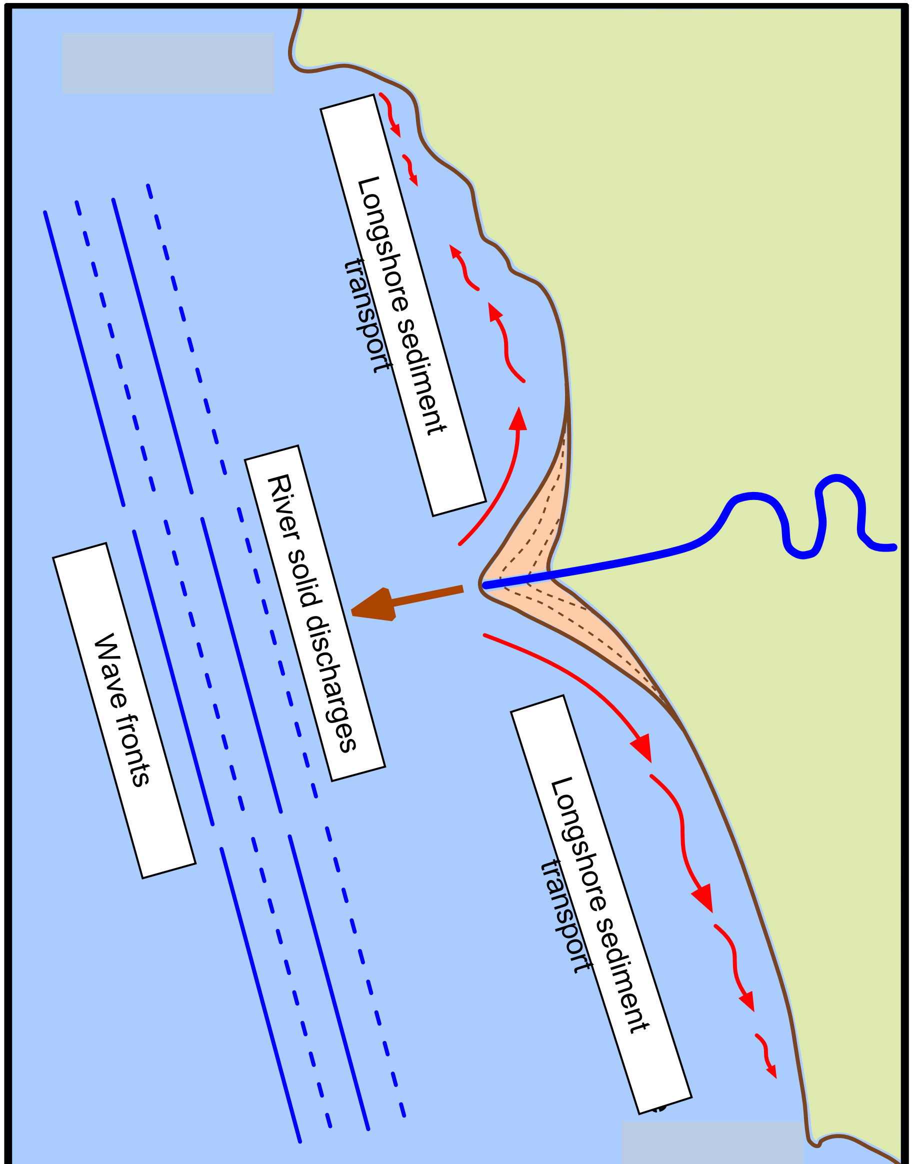
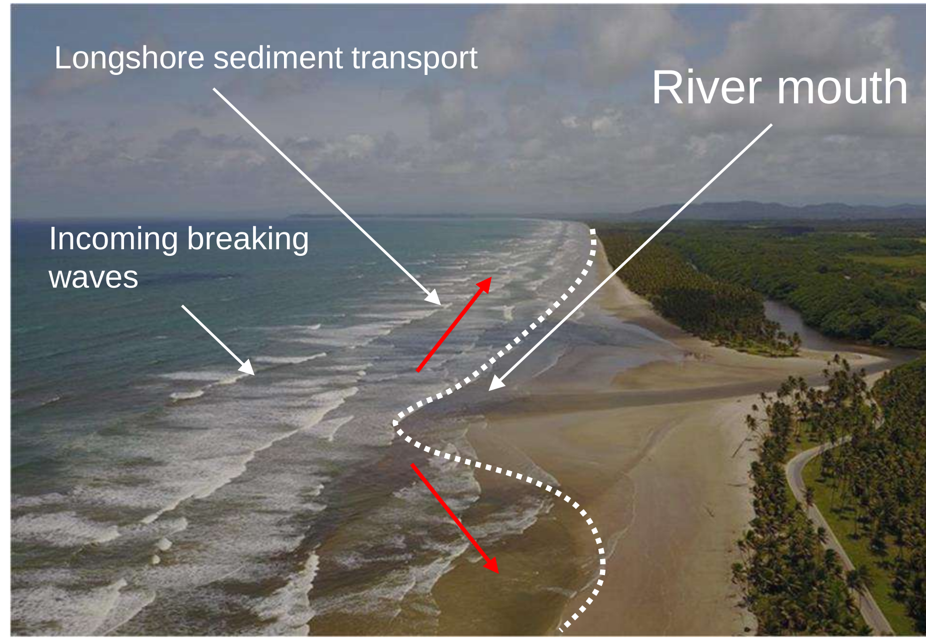
Erosione delle coste : cause e rimedi

prof. Leopoldo Franco

Coastal dynamics

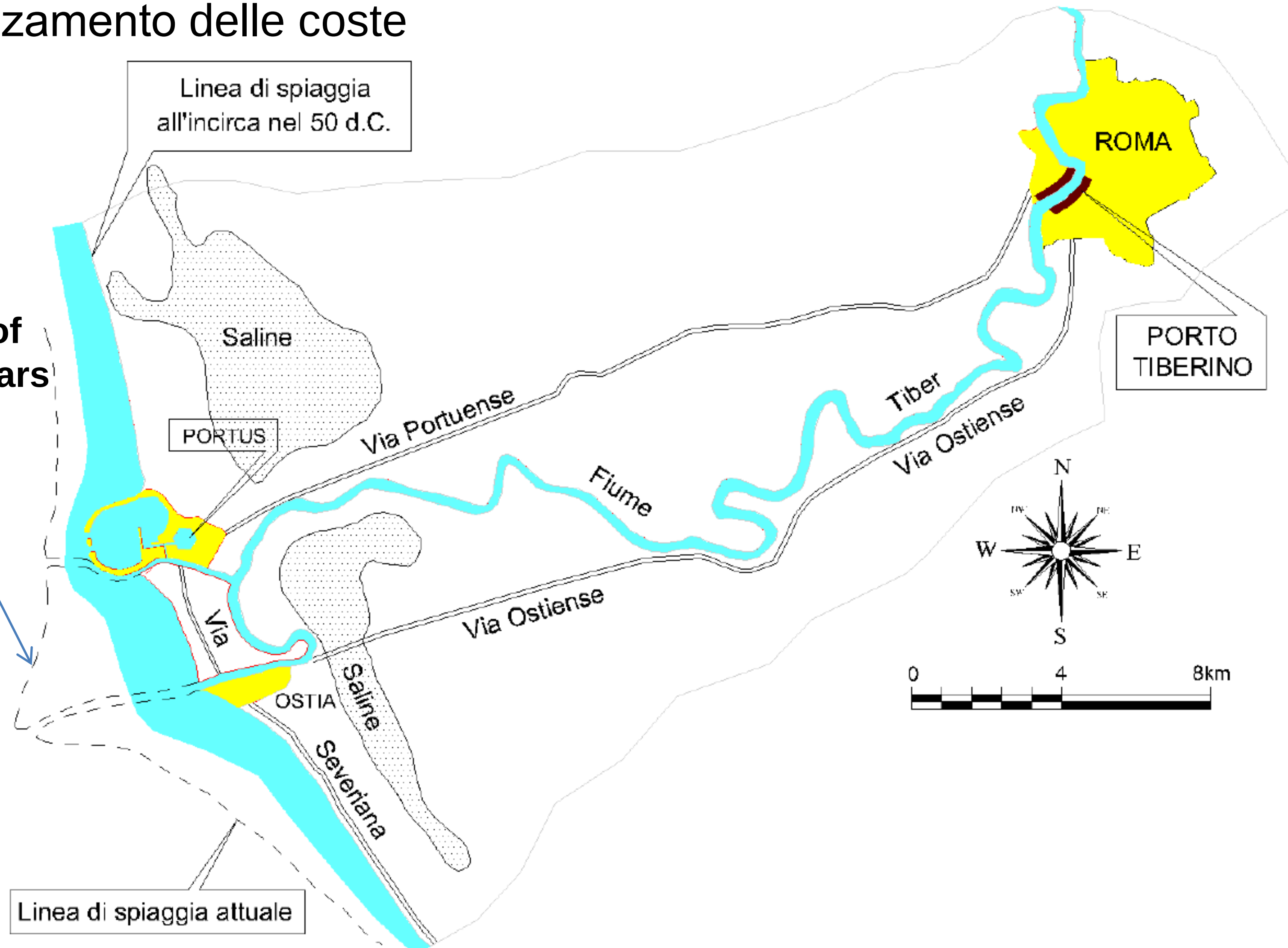




Longshore and cross-shore currents induced by breaking waves distribute the sediments coming from the river along the adjacent coasts.

I litorali incoerenti sono alimentati dallo smantellamento dei rilievi terrestri ad opera degli agenti atmosferici che trasportano il materiale solido attraverso la rete idrografica fino alla costa. Questo fenomeno (dissesto idrogeologico) dà luogo all'avanzamento delle coste

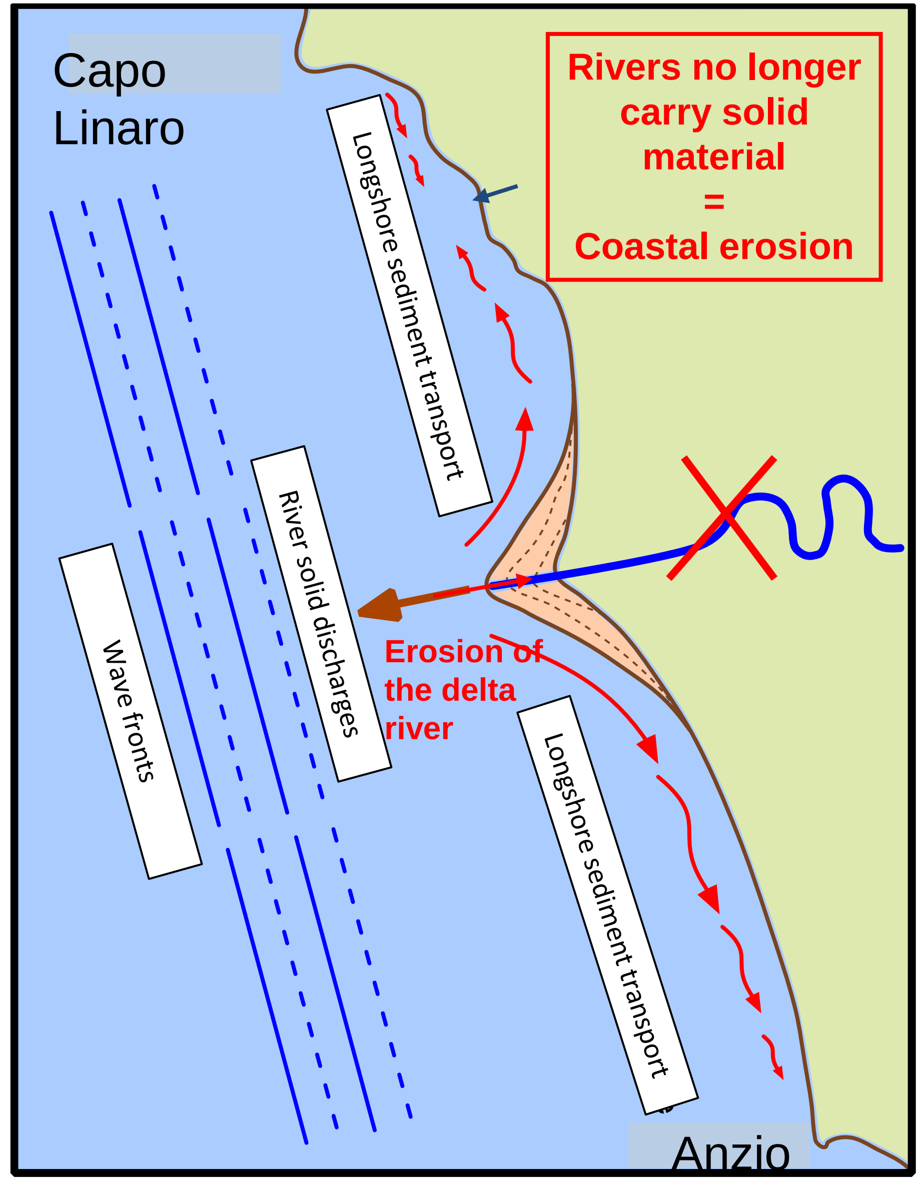
Advancement of 4km in 2000 years

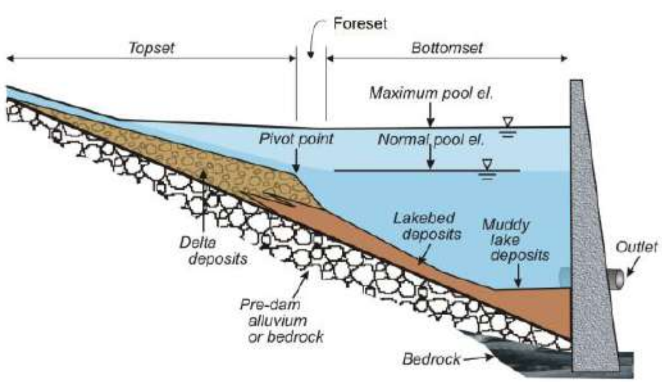


The port of Claudio and Traiano (Portus) was a **transhipment port** (maritime - fluvial)

Tuttavia dalla metà del secolo scorso gli apporti solidi fluviali si sono molto ridotti per la stabilizzazione dei versanti e la costruzione di dighe e traverse per proteggere e sfruttare i terreni. Quindi quasi tutte le coste hanno iniziato ad arretrare rendendo necessaria la loro protezione o l'abbandono

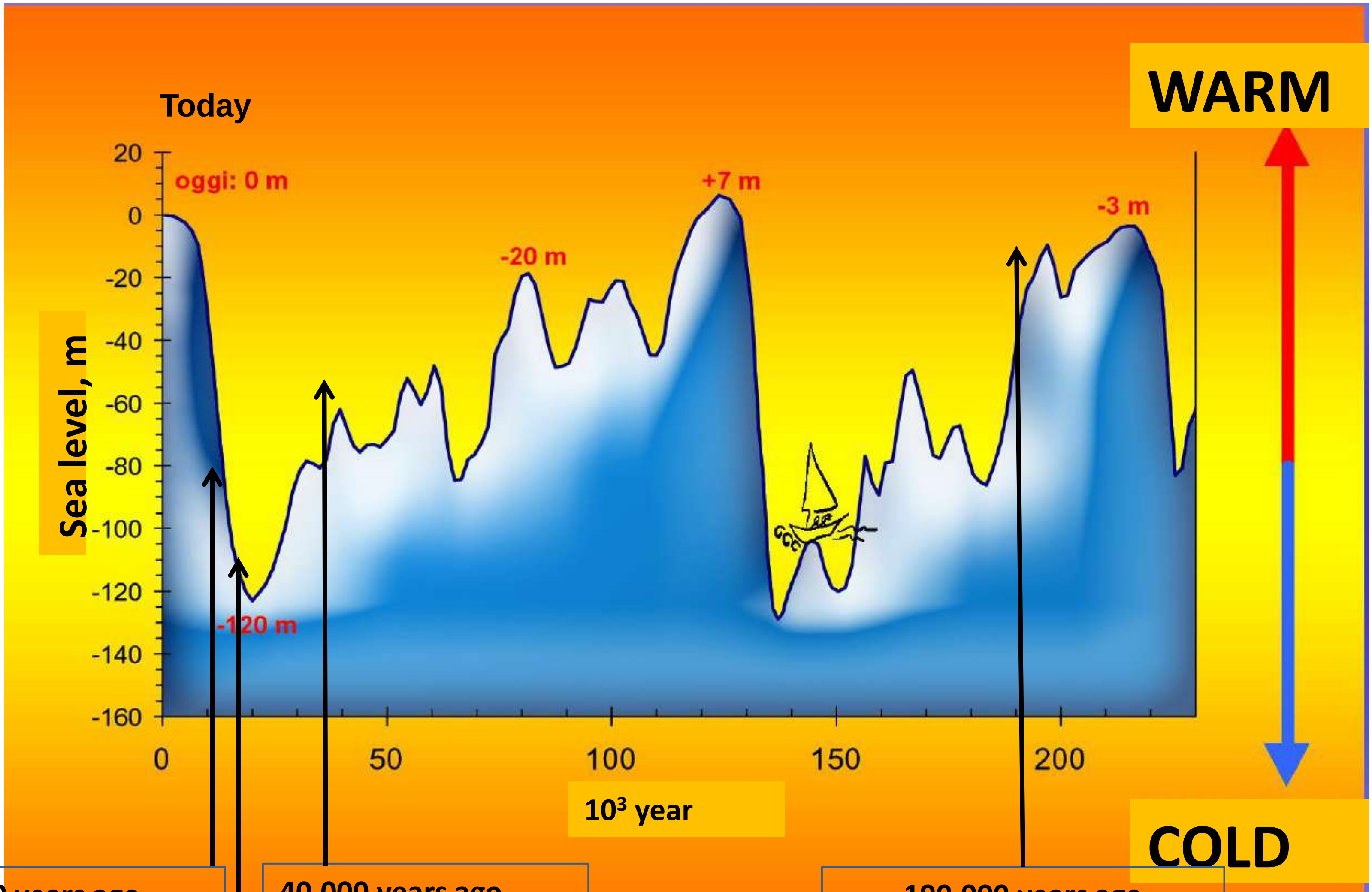
PRESENT





Dragaggio invasi ?!

The sea level in the last 250,000 years



11.500 years ago
Apperance of agricolture

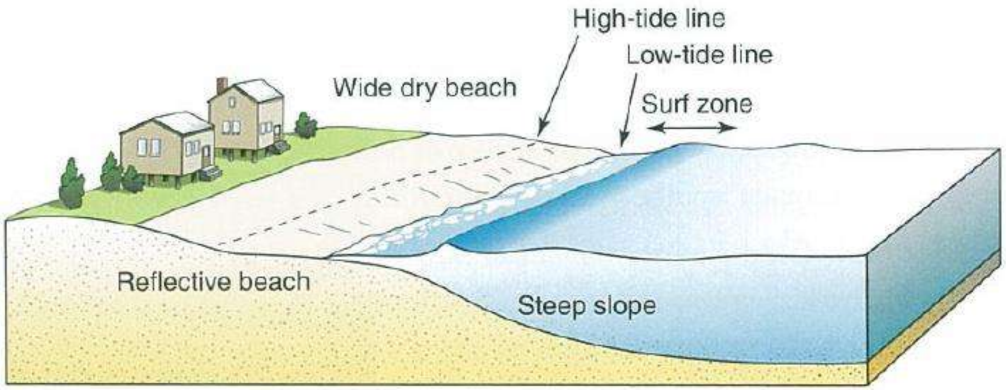
18.000 years ago
Last ice age

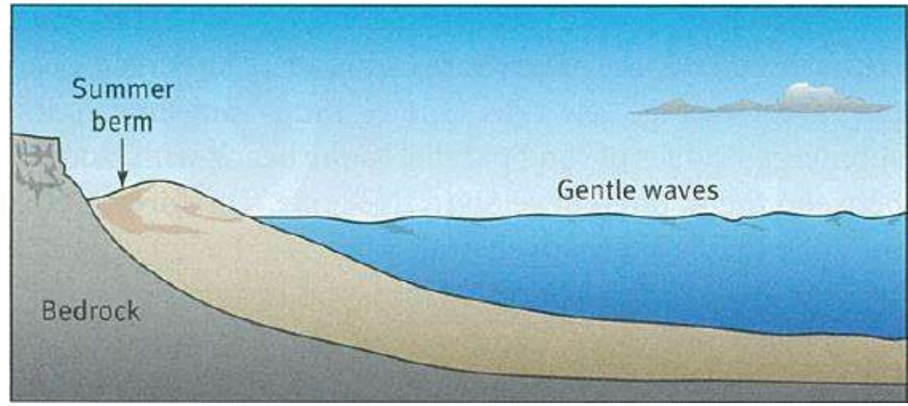
40.000 years ago
Extinction of the Neanderthal

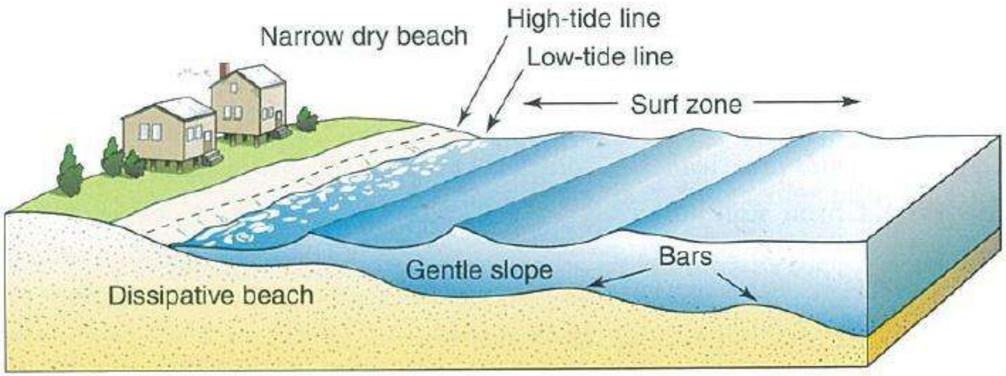
190.000 years ago
Homo sapiens
Homo neanderthalensis

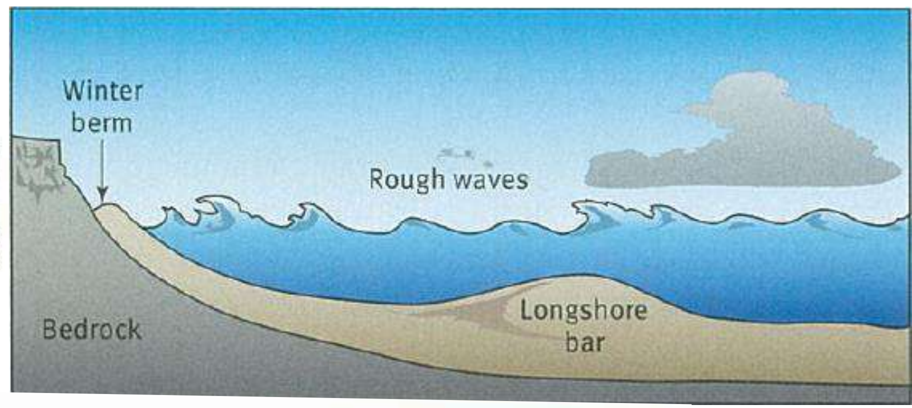
L'eustatismo è ulteriore secondaria causa dell'arretramento delle coste (oggi circa +0.5 mm/anno)

PROFILO di SPIAGGIA ESTIVO e INVERNALE









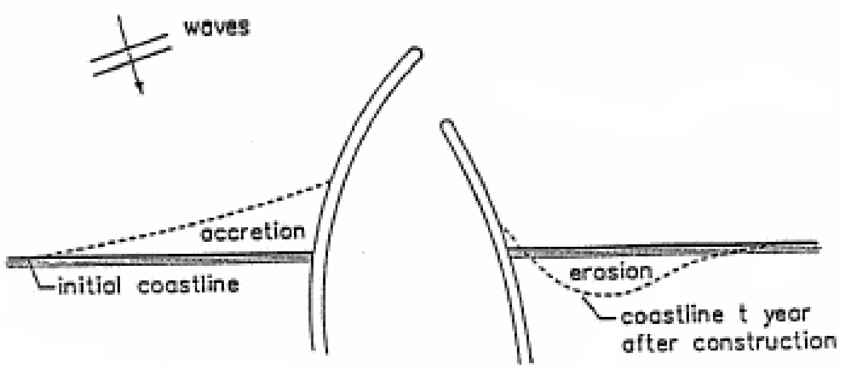
The seasonal contrast in a beach is shown by this beach in southern Portugal. The 2007 summer beach shown here is sandy and has a gentler slope than the 2008 winter

The same beach in the winter of 2008 is steeper and has a high gravel content as a result of the higher-energy winter storm waves. Photo courtesy of Carlos Loureiro.

Two main Erosion Mechanisms

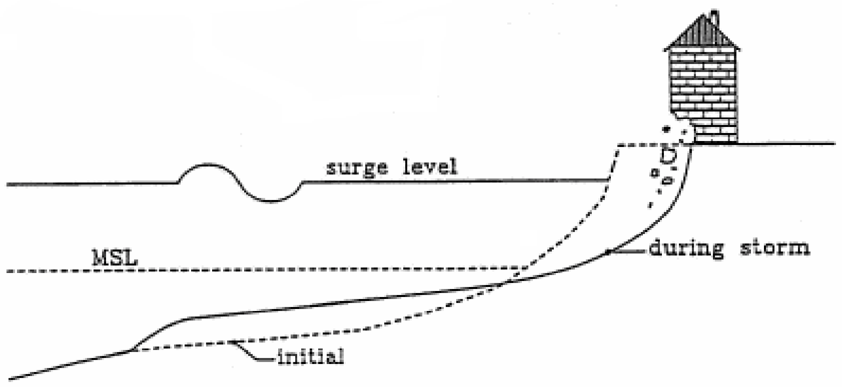
1. **"Structural or Long-term erosion"**

<u>nearly irreversible</u>
due to long-shore transport gradients



2. **"Temporary or Short-term Erosion"**

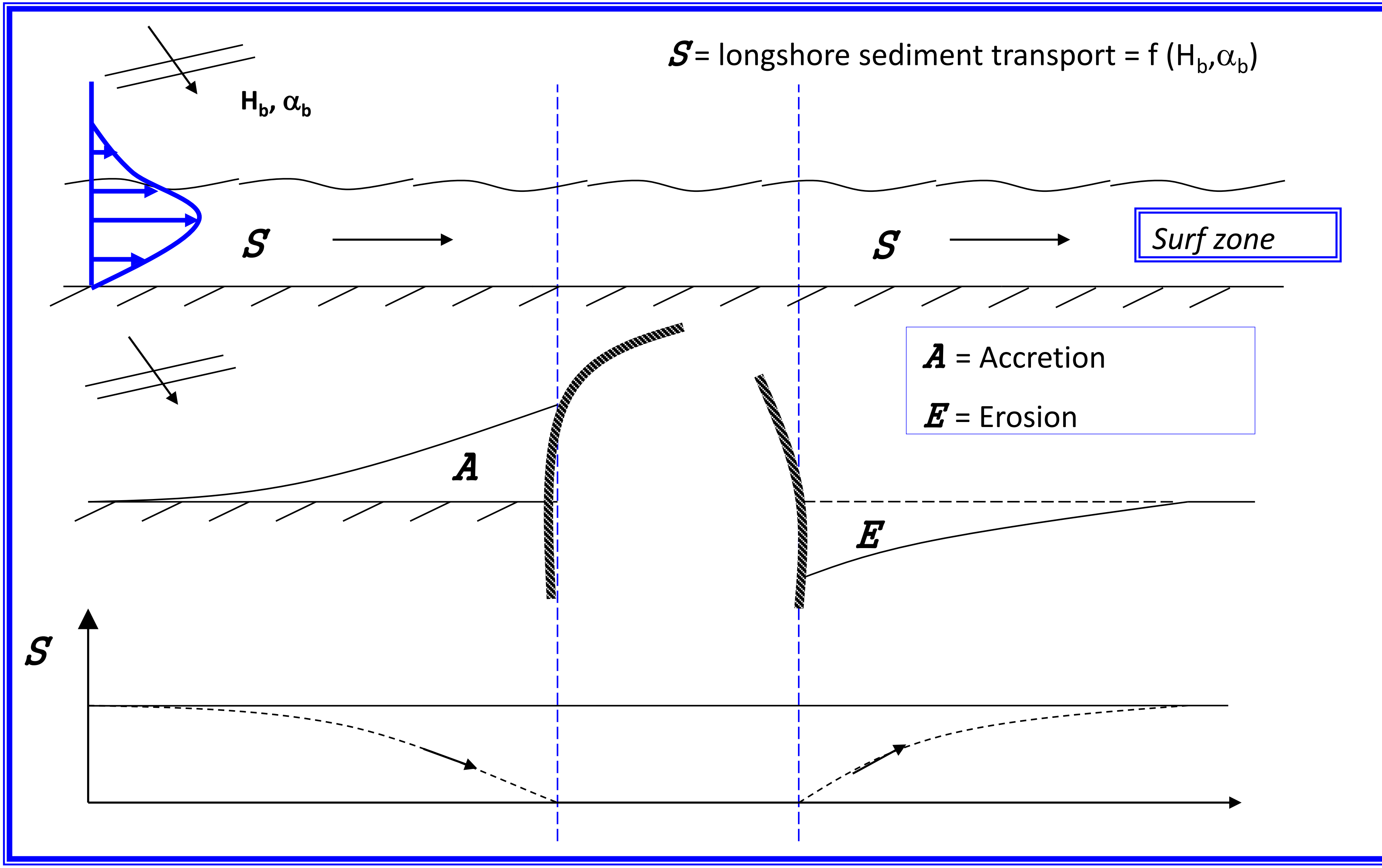
<u>reversibile,</u>
due to storm cross-shore transport



Erosion rate:

10-50 m^3/m/ year

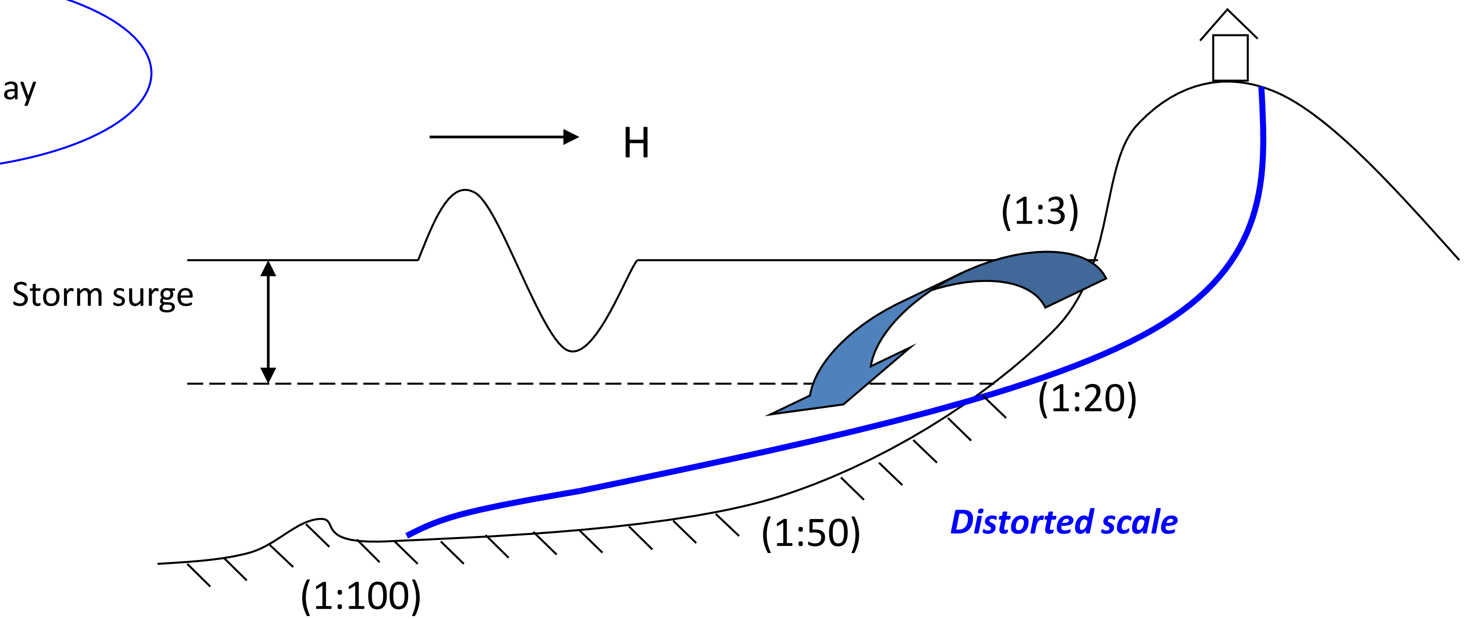
1. Structural Erosion

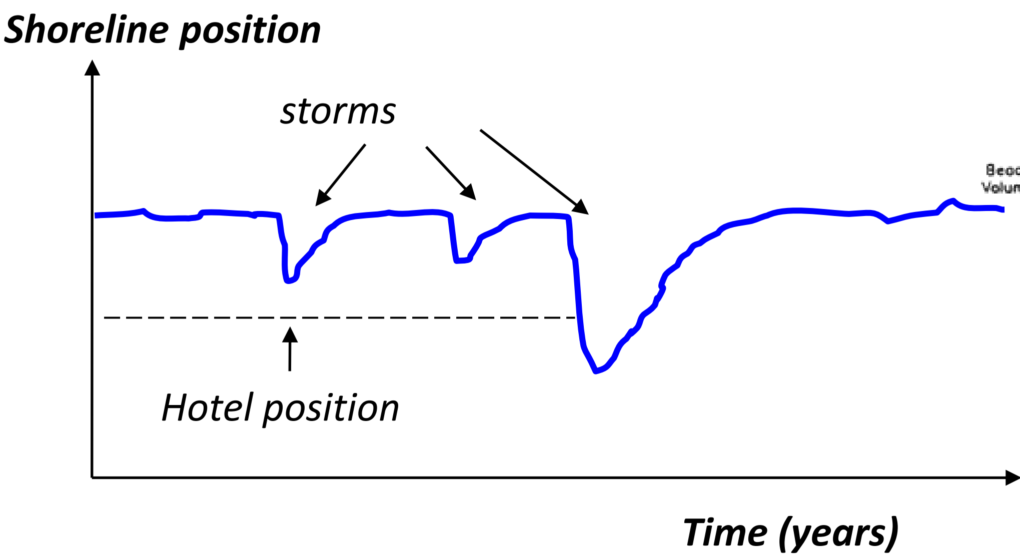


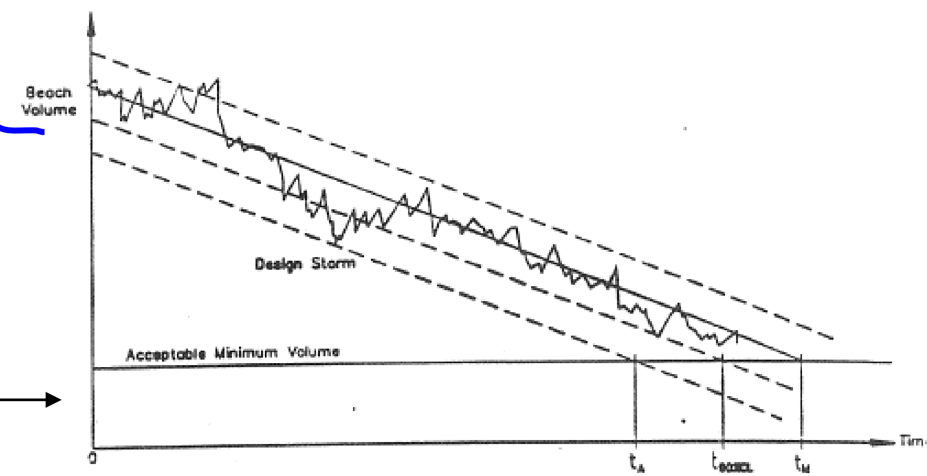
2. Temporary Erosion (‘Dune erosion’)

Erosion rate:

10-100 m^3/m/day







Preliminary design of shore protection: selection criteria

FACTORS to consider for the selection of the optimal solution among the possible alternatives (eg. check-list comparative analysis):

1) Urgency

2) Transport Regime (quantity and direction)

3) Tidal range and surges

4) Morphologic Instability

5) Water circulation and quality

6) Recreation: bathing, sailing, walking, fishing…

7) Navigation (first aid)

8) Visual Impact

9) Ecologic impacts

10) Economic and legal issues

11) Construction aspects

The asset checklist

The design of shore protection works is mainly **FUNCTIONAL** (morphodynamic and environmental impacts) based on plan layout.
It is then followed by the **HYDRAULIC-STRUCTURAL** design (cross section)

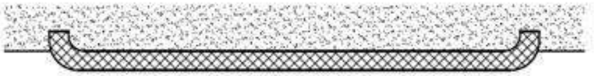
Before choosing the **therapy**, an accurate **diagnosis** and prognosis is needed, understanding the main causes of erosion (illness) and considering the beach value/interests.

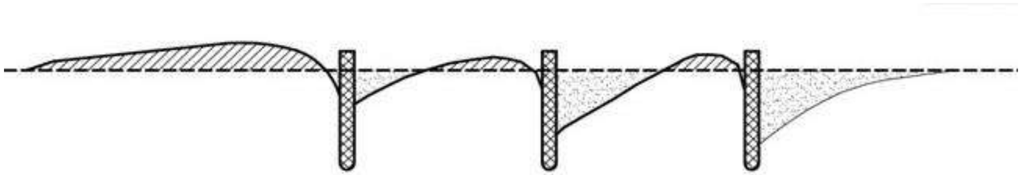
Investigations, studies and models are used to make a comparative analysis of various solutions (including “zero” option).

Monitoring programs are necessary, even with «zero option».

Interventions for the defence of eroding beaches

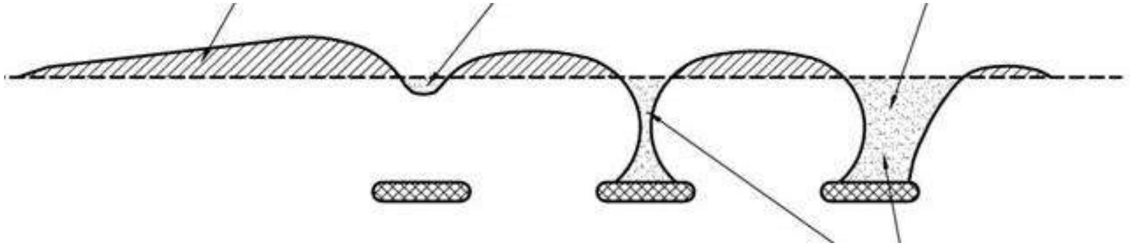
1. **Seawalls / Revetments**
   (retaining structures)

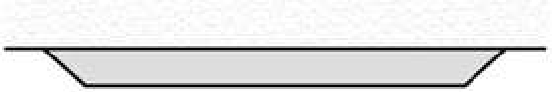




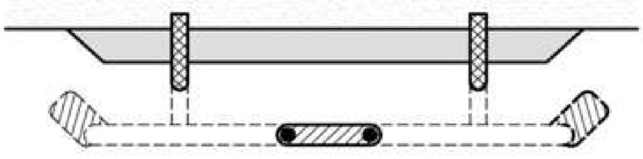
2. Groynes-groins

3. Detached Breakwaters

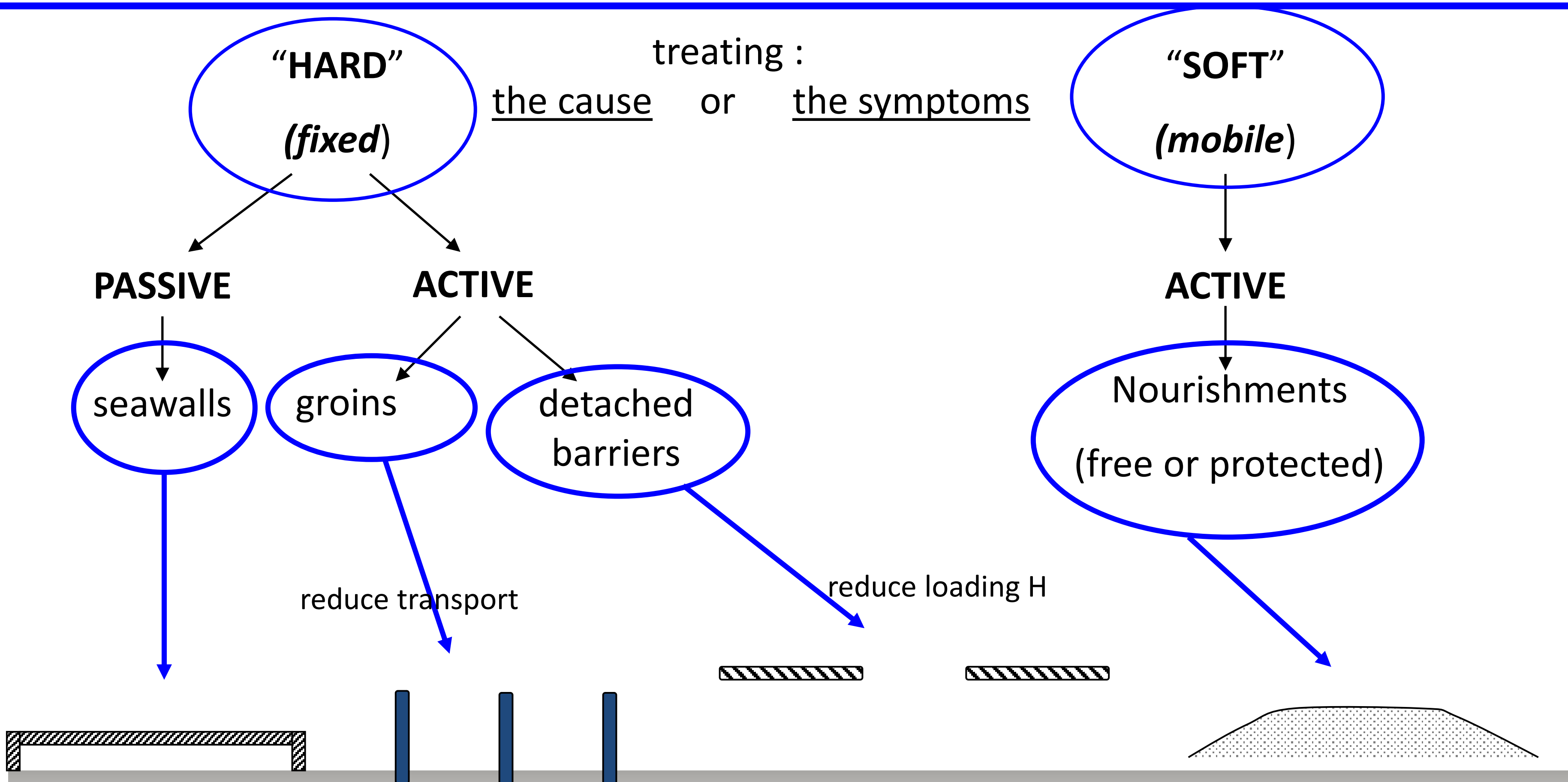




4. Nourishments
4.1 pure or free
4.2 protected or combined



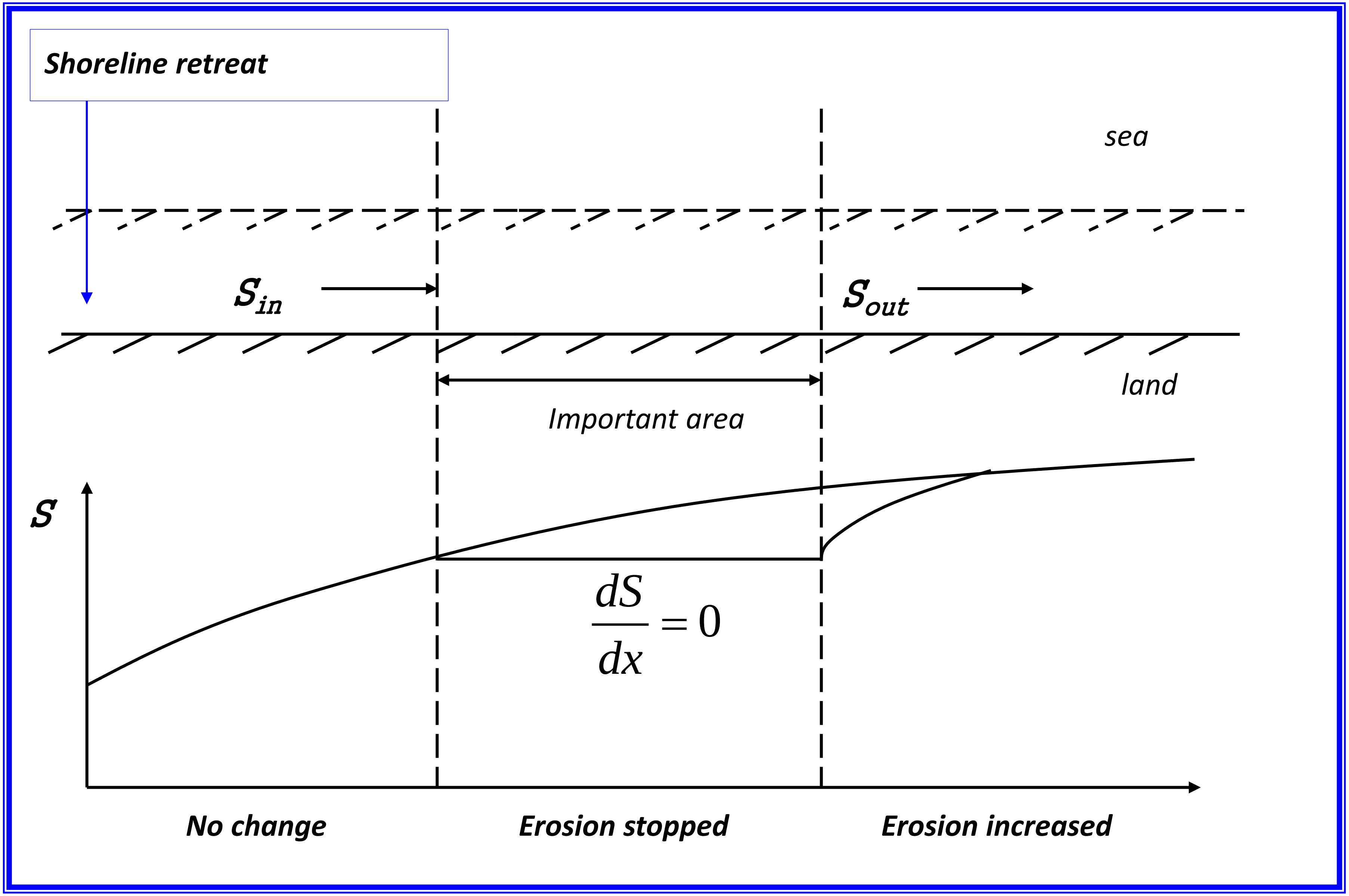
Main Types of Shore Protection Works



Can we modify the forcing boundary conditions??

1. Water Level Setup ? NO
2. Wave Height ? YES, partially

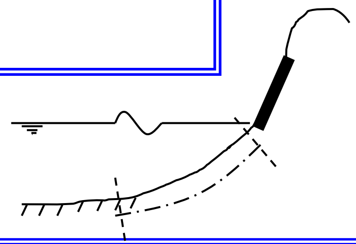
SOLUTIONS against structural erosion

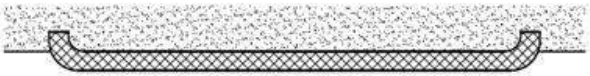


1.SOLUTIONS against structural erosion

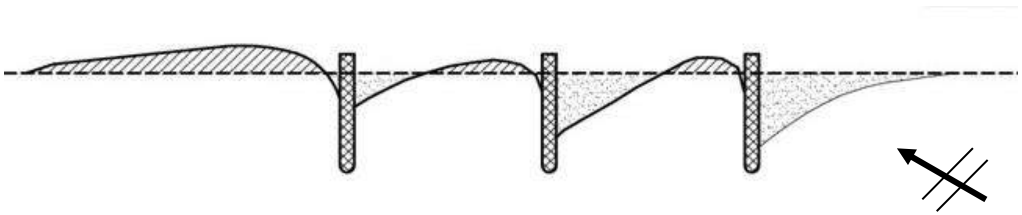
AIM: reduce longshore transport

PLAN LAYOUTS

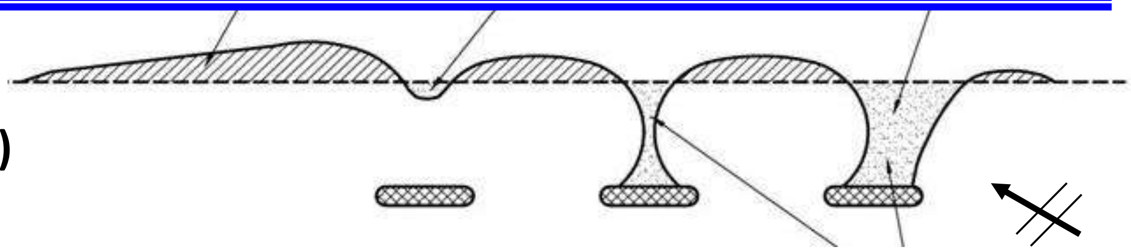




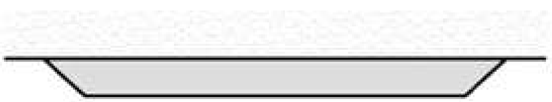
1) **Seawalls (not efficient !!)**



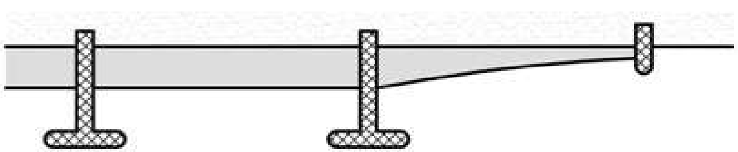
2) **Groins (OK !)**

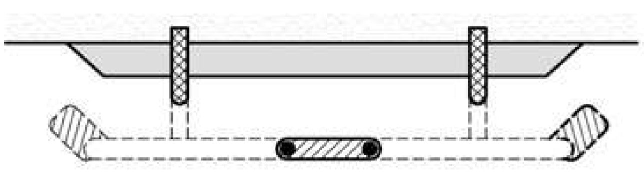


3) **Detached Breakwaters (maybe)**



4) **Nourishments (possibly protected)**

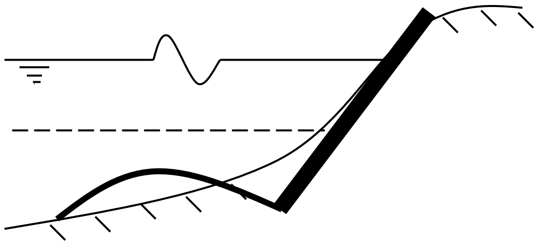




2.SOLUTIONS against dune erosion

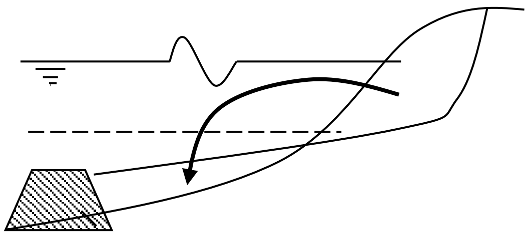
Cross sections

1) Seawall & revetments
(OK, in urgency)



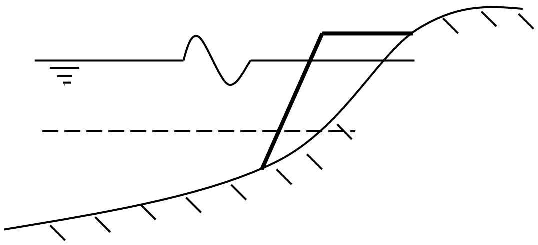
2) Submerged Barriers

(NOT efficient with surge)

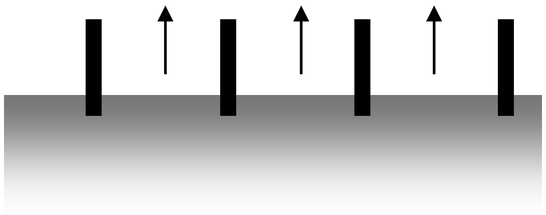


3) Nourishment

(OK)

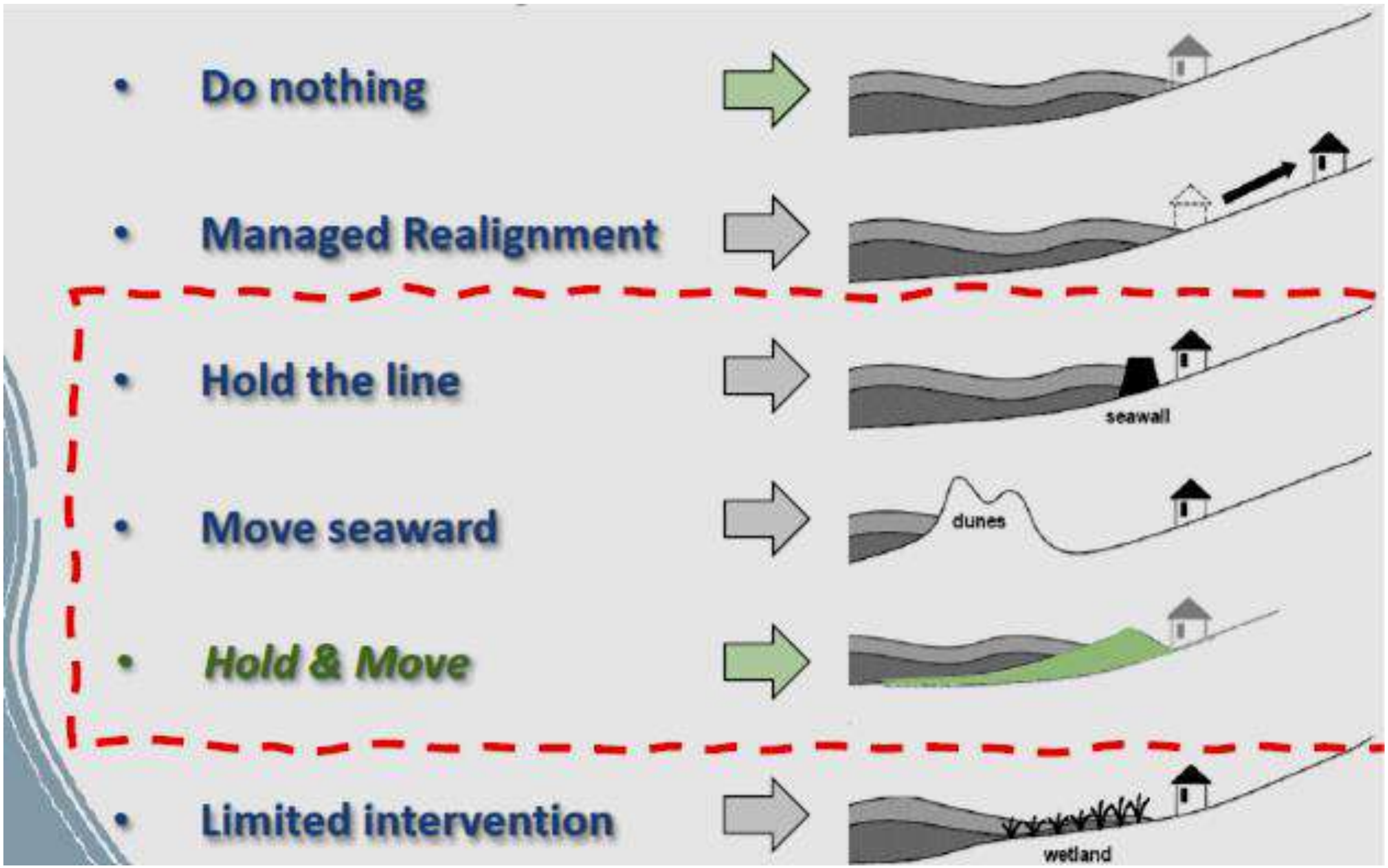


4) Groins (NO)



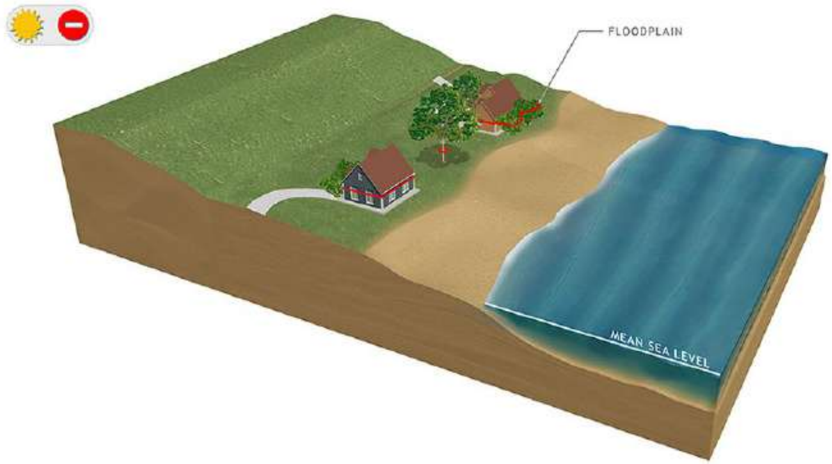
Coastal Defense Management Strategies

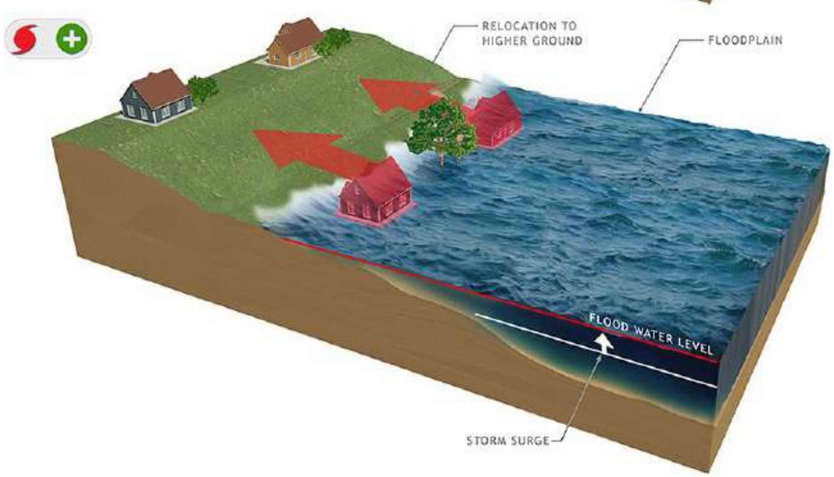
(planning against erosion and inundation)



Non-structural solutions

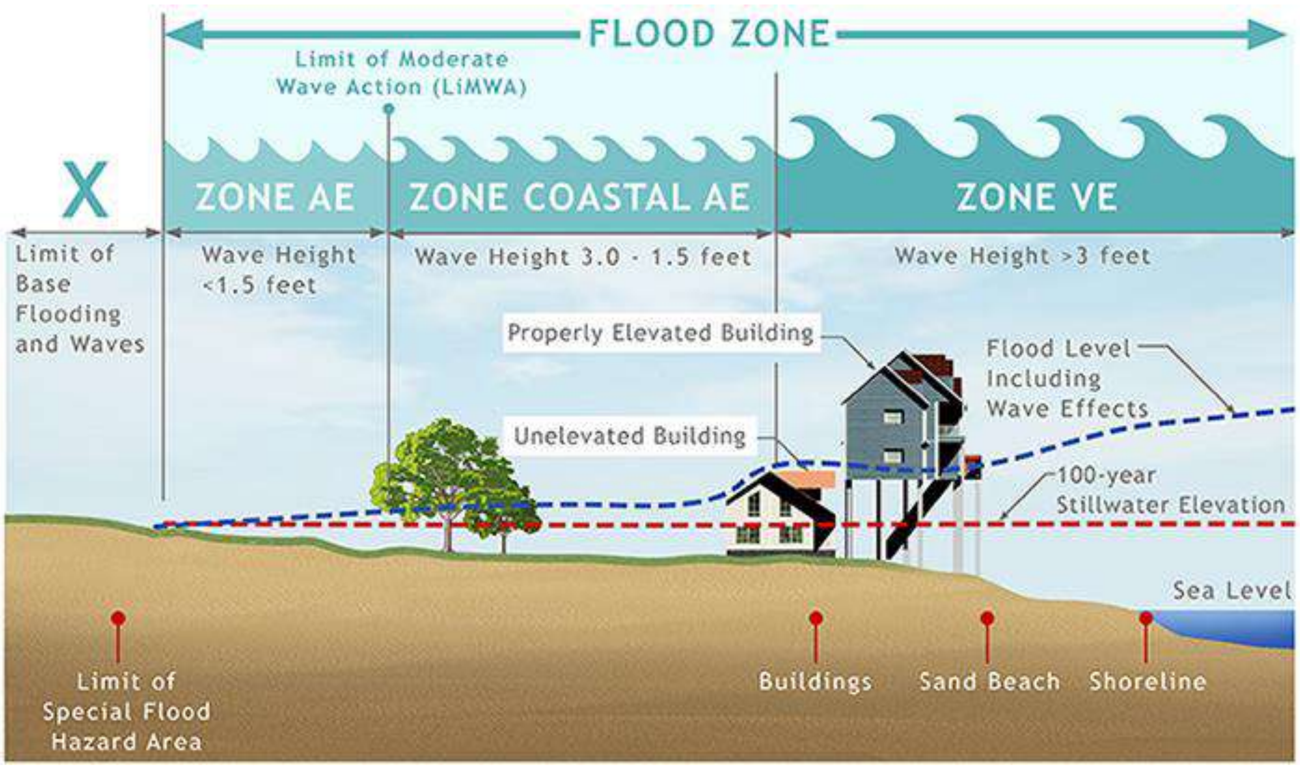
Acquisition and relocation





Often considered a drastic approach to storm damage reduction,property acquisition and structure removal are usually associated with frequently damaged structures.

Acquisition and relocation

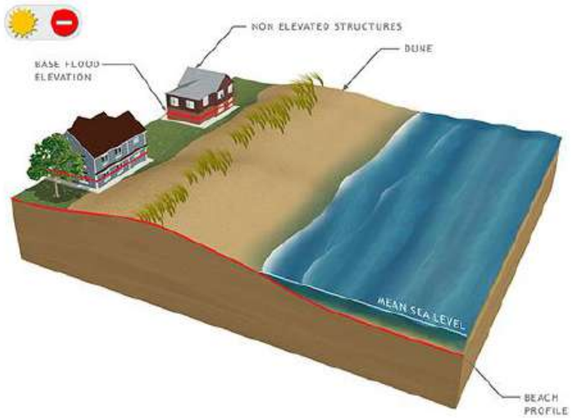


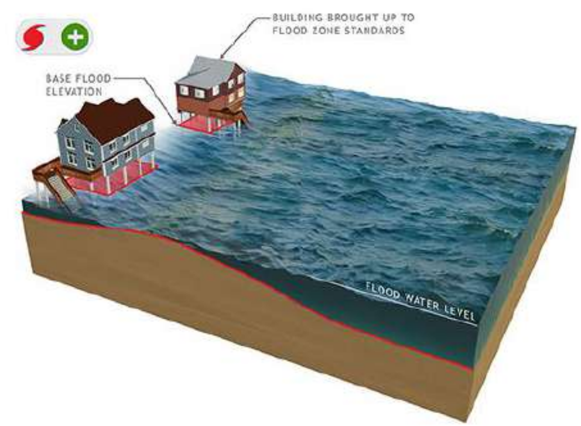
Communities participating in the National Flood Insurance Program are proactive in promoting floodplain management and flood risk awareness.

Building retrofit

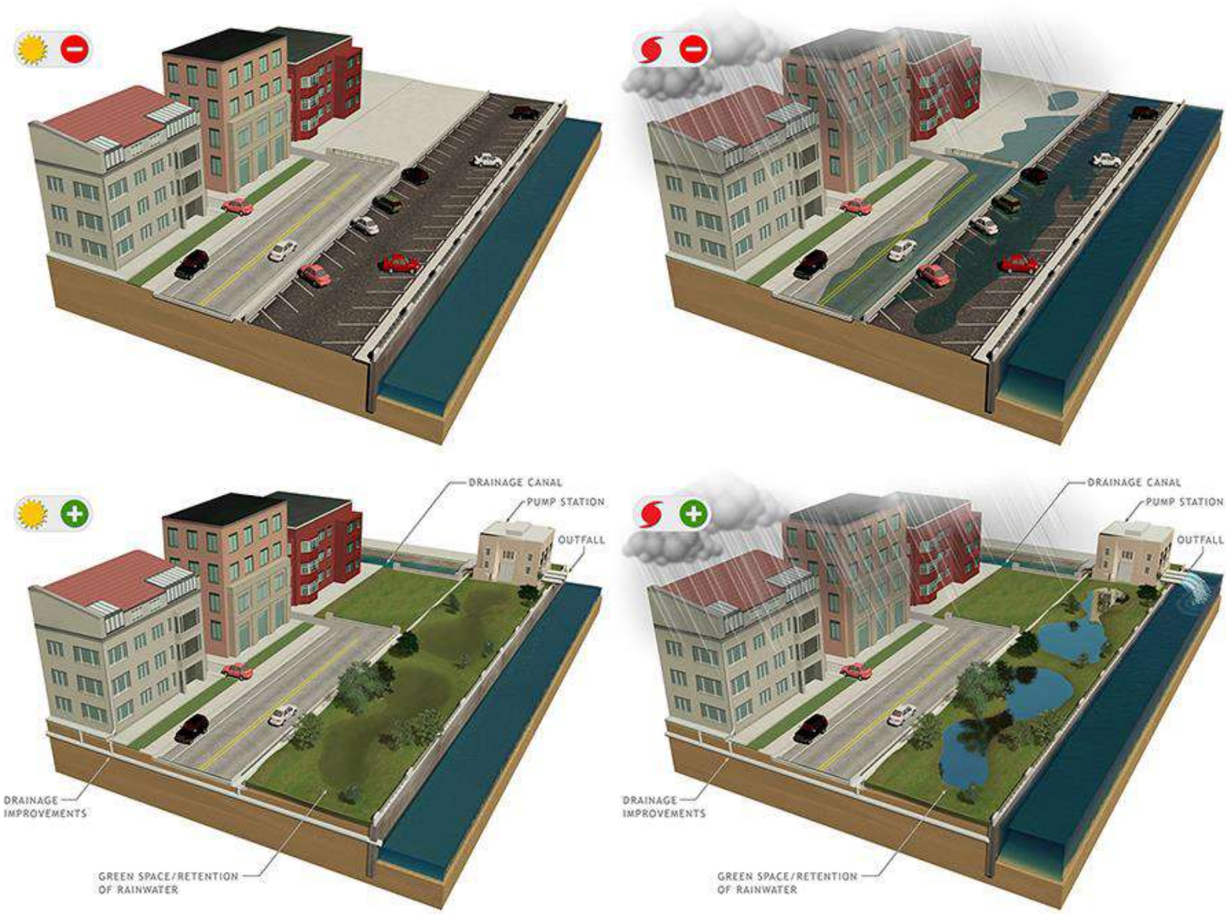
Elevation of a structure or possibly dry flood proofing of a structure (usually limited to smaller residential and commercial buildings)

Whether a structure may be elevated depends on a number of factors, including the foundation type, wall type, size of structure, condition, etc.





Drainage improvements

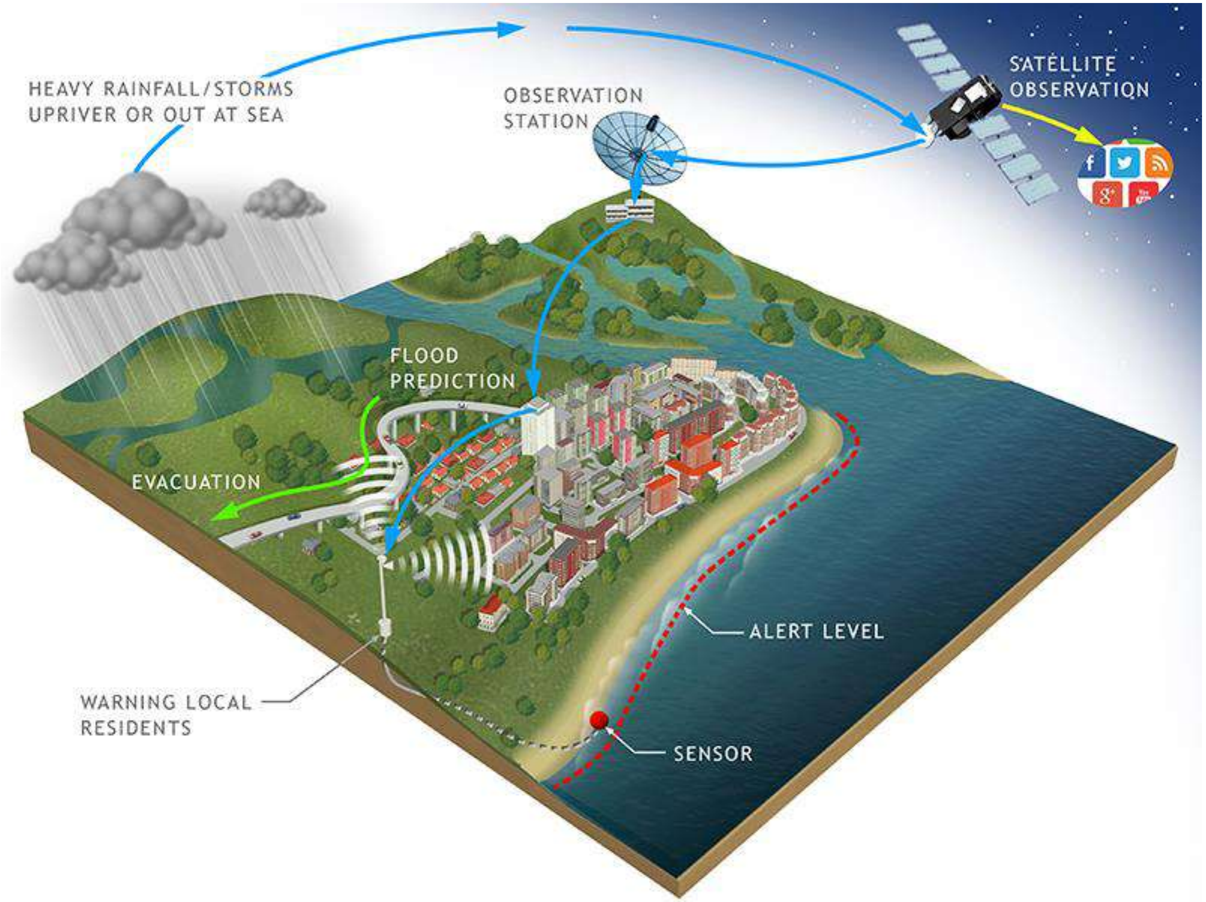


A drainage system can carry water away via conveyance systems and, during times of high water, may store water until it can be carried away in storage facilities.

Conveyance systems utilize measures such as pump stations, culverts, drains, and inlets to remove water from a site quickly and send it to larger streams.

Storage facilities are used to store excess water until the storm or flood event has ended.

Enhanced flood warning and evacuation planning

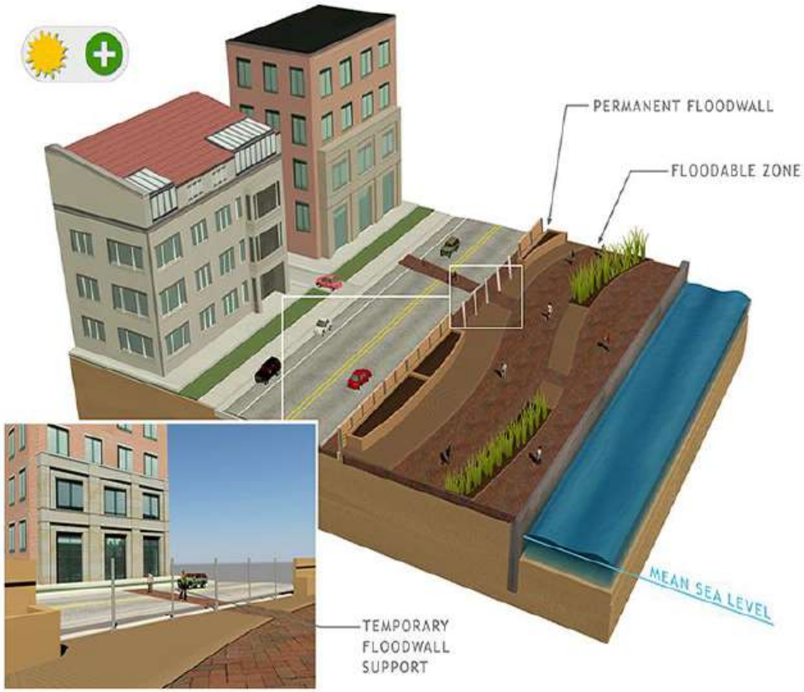


Flood warning systems and evacuation planning are applicable to vulnerable areas. Despite improved tracking and forecasting techniques, the uncertainty associated with the size of a storm, the path, or its duration necessitate that warnings be issued as early as possible. Evacuation planning is imperative for areas with limited access, such as barrier islands, high density housing areas, elderly population centers, cultural resources, and areas with limited transportation options.

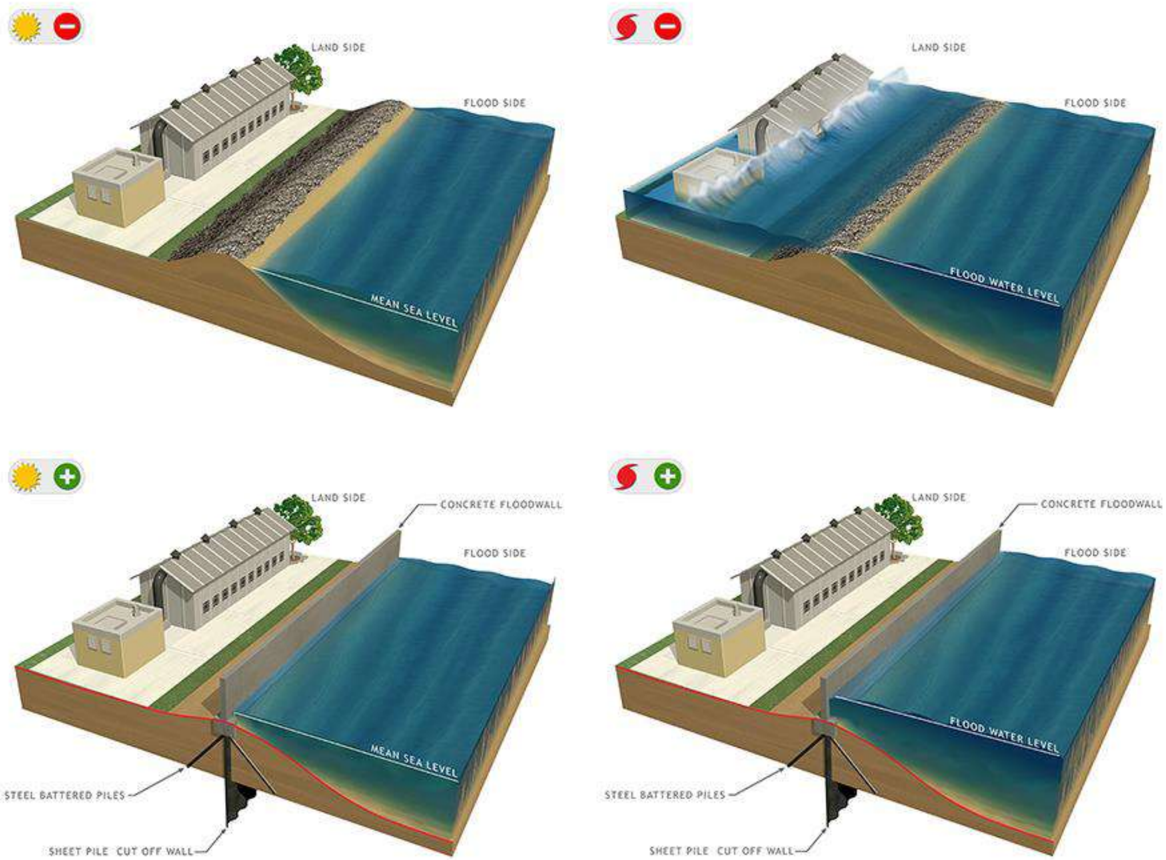
Structural solutions

Deployable floodwalls

Rapid Deployment Floodwalls are structures that are temporarily erected along the banks of a river or estuary, or in the path of floodwaters. They also prevent water from reaching the area behind the structure and are usually used in locations where space is limited.

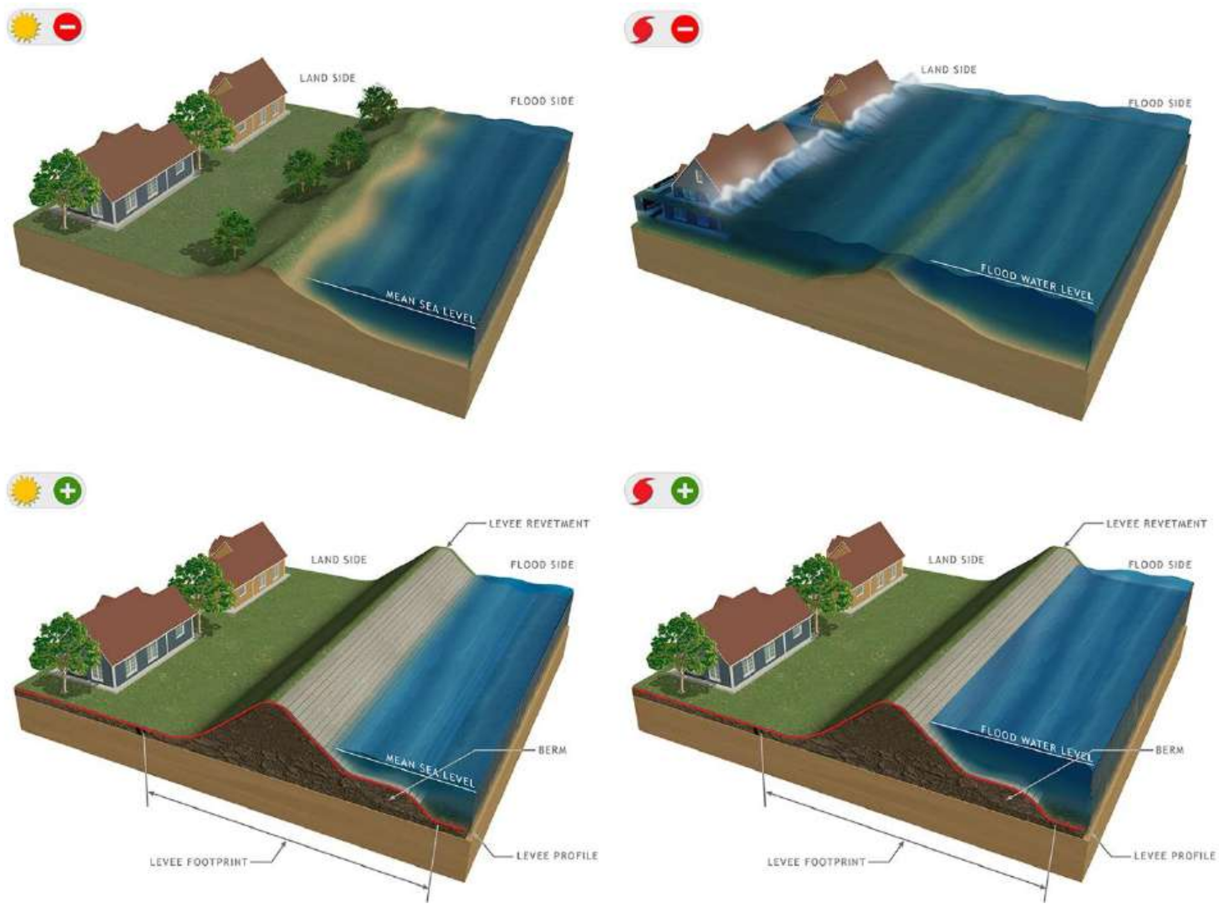


Floodwalls



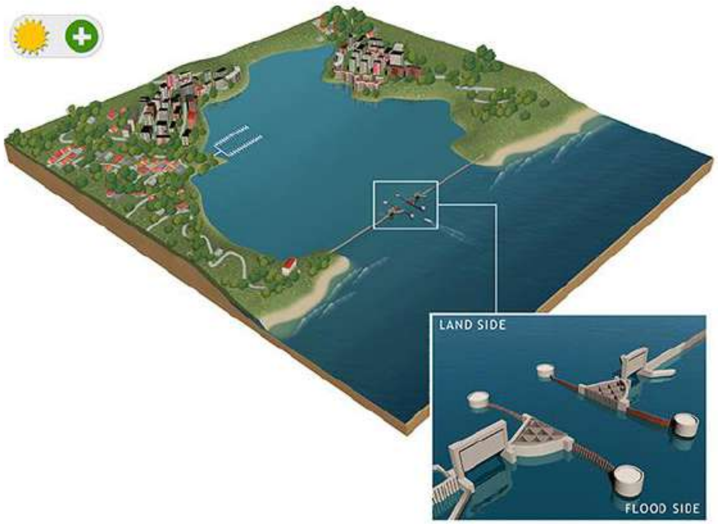
Floodwalls are structures used to prevent flooding and to protect relatively small areas or areas with limited space for large flood protection measures. Floodwalls are most frequently used in urban and industrial areas.

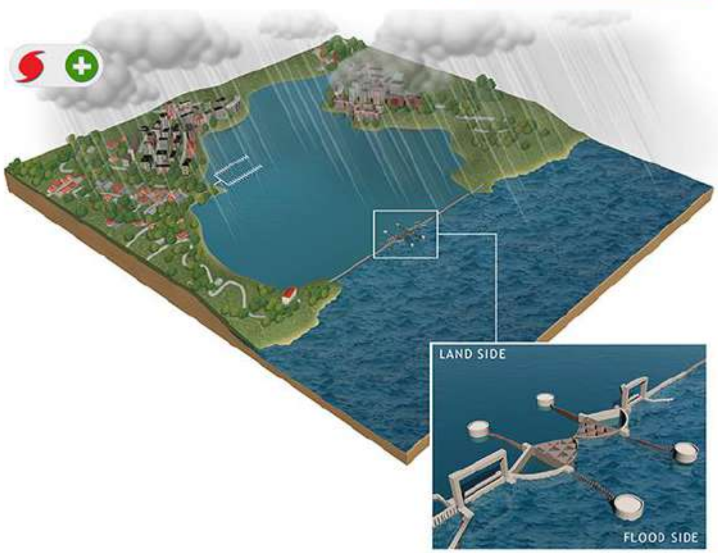
Levees - dikes



Levees and dikes are earth embankments constructed along a waterfront to prevent flooding in relatively large areas for high levels of flood risk. If a levee or dike is located in an erosive shoreline environment, revetments may be needed on the waterfront side for more protection from erosion.

Storm surge barriers





Storm surge barriers reduce risk to estuaries against storm surge flooding and waves.

In most cases the barrier consists of a series of movable gates that normally stay open under normal conditions to let the flow pass (to allow for navigation and saltwater exchange), but are closed when storm surges are expected to exceed a certain level.

Storm surge barriers

Maeslant Barrier (NL)

Thames Barrier (UK)

Eastern Scheldt Barrier (NL)

Ramspol (NL)

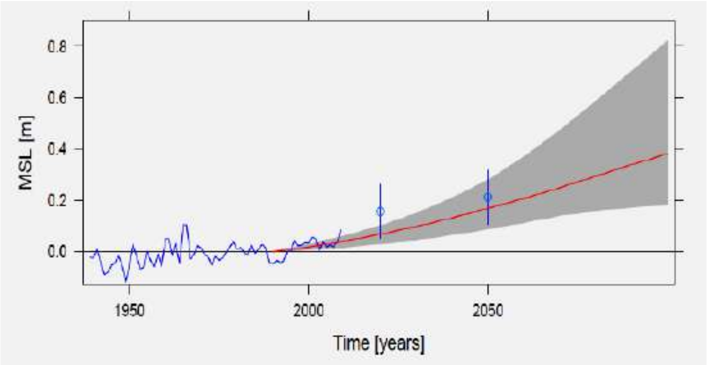
Navigation Pass S-1 (Russia)

IJssel Barrier (NL)

Hartel Barrier (NL)

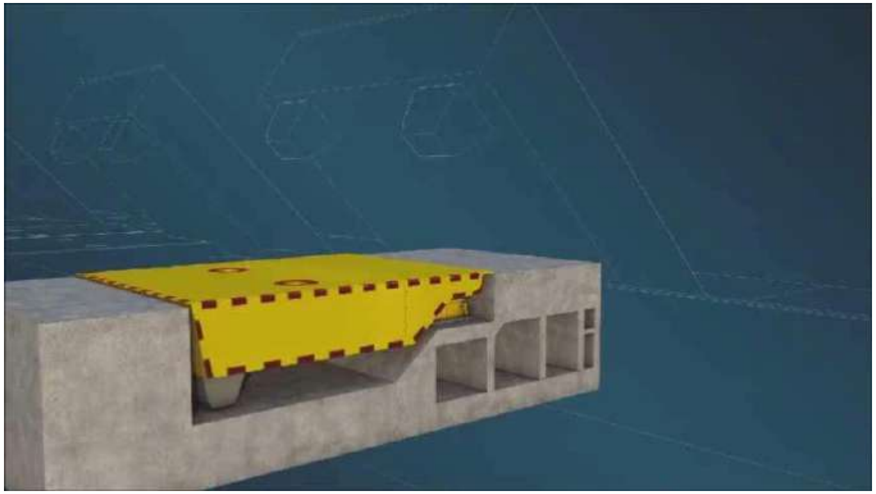
Haringvliet Barrier (NL)

Climate Change: Sea Level Rise

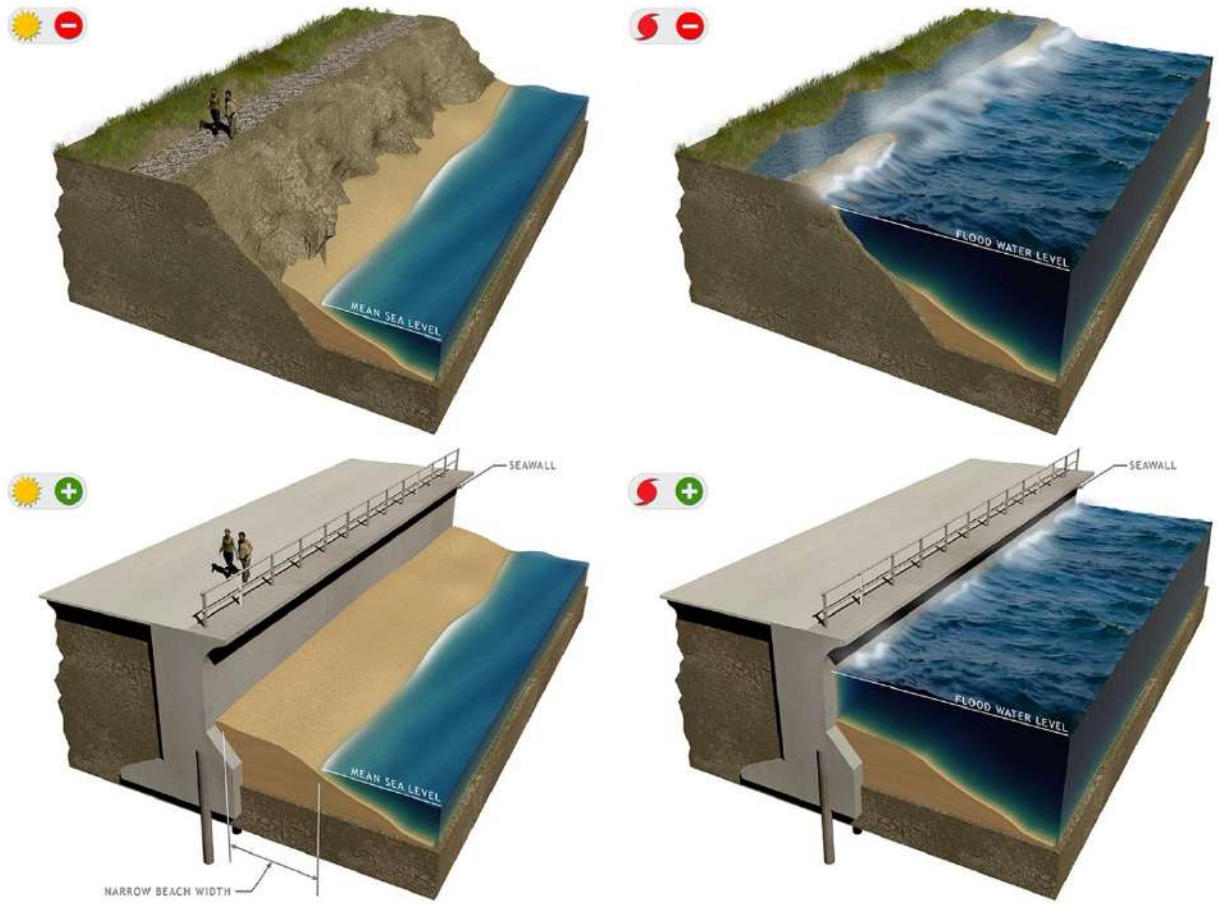


Venezia – Mose
Mobile barriers against high water

The MOSE system: the barrier



Seawalls

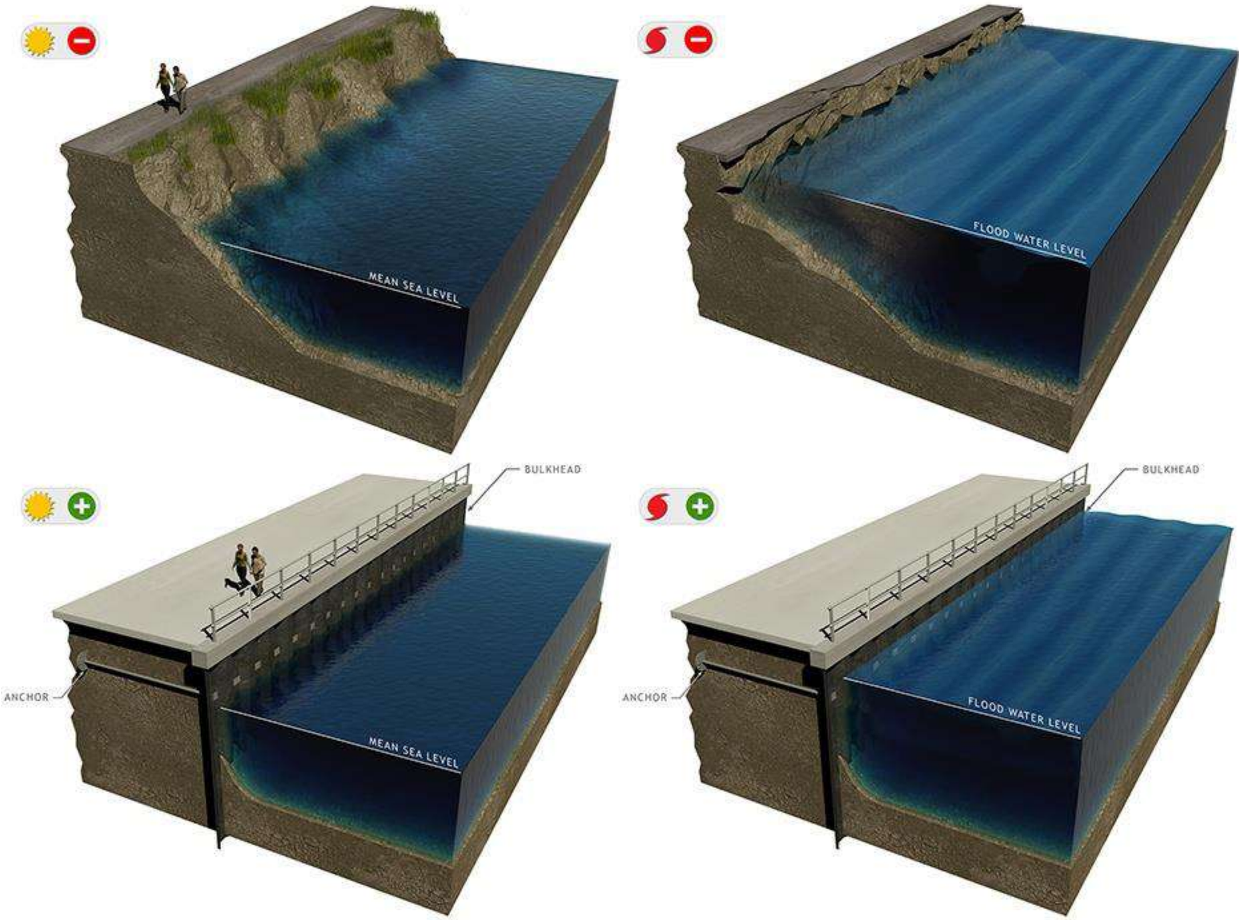


Seawalls, are typically massive structures whose primary purpose is interception of waves and reduction of wave-induced overtopping and flooding.

Note that under this definition seawalls do not include structures with the principal function of reducing flood risk to low-lying coastal areas.

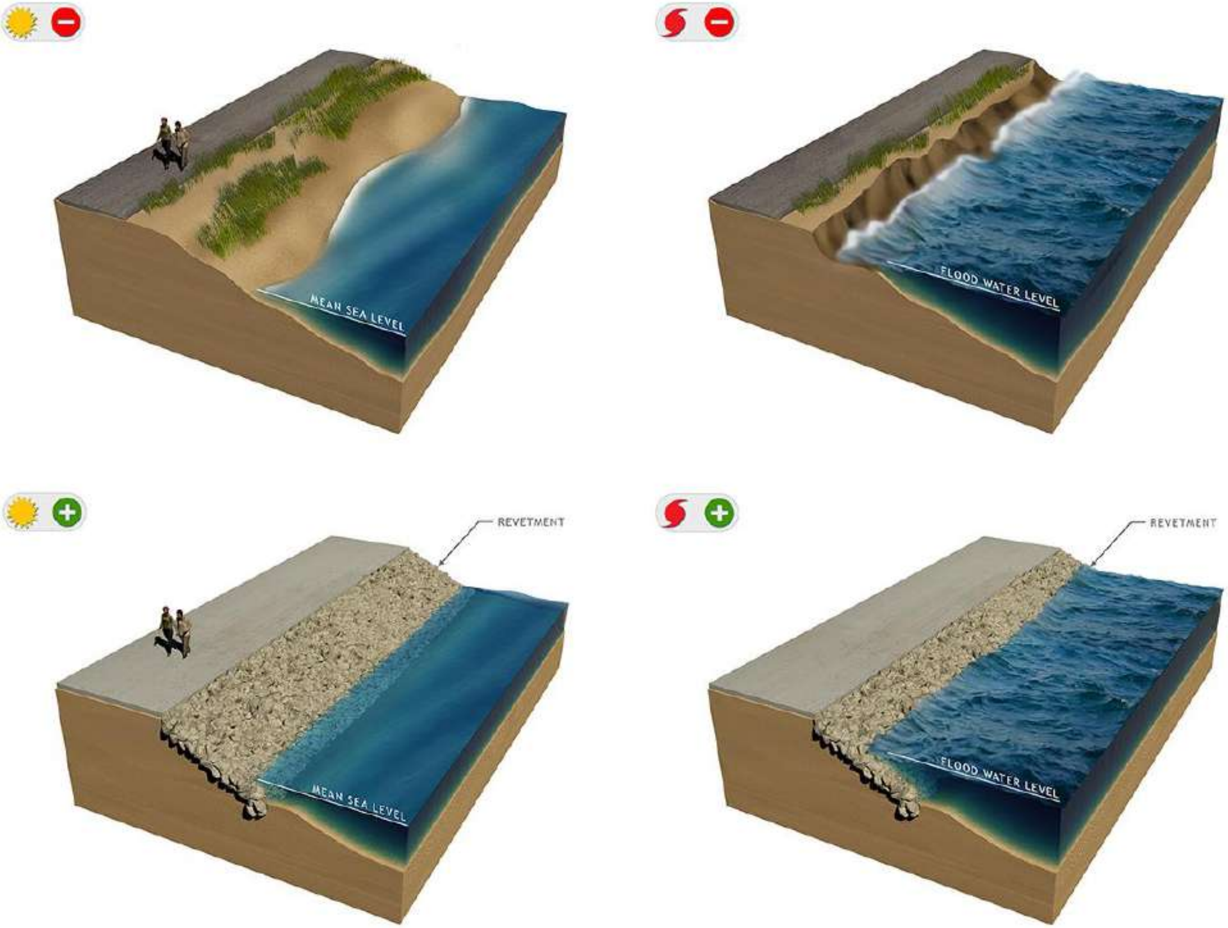
In those cases a high, impermeable, armored structure known as a sea dike is typically required to prevent coastal flooding.

Bulkheads



Bulkheads primarily retain soil and experience little to no wave action.

Revetments

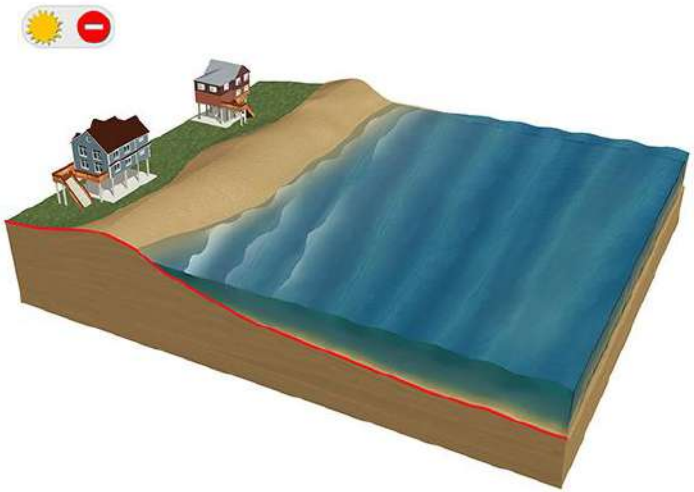


Revetments are onshore structures with the principal function of protecting the shoreline from erosion.

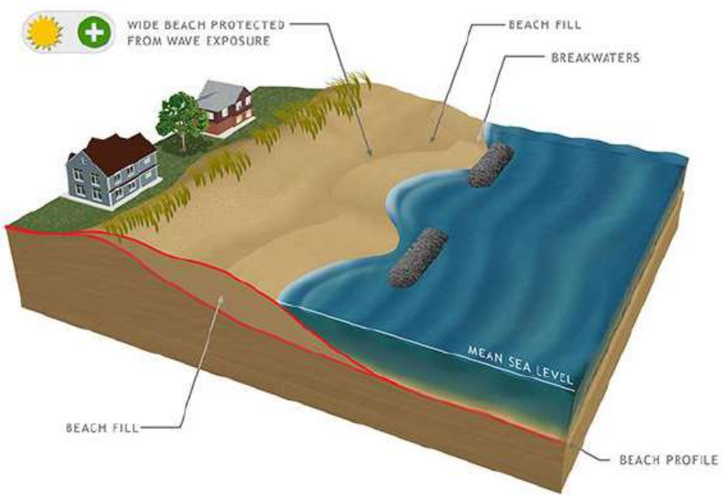
Revetments typically consist of a cladding of stone, concrete, or asphalt to armor sloping natural shoreline profiles.

Erosion and urgent defence of coastal railway in western Calabria (Italy)

detached breakwaters



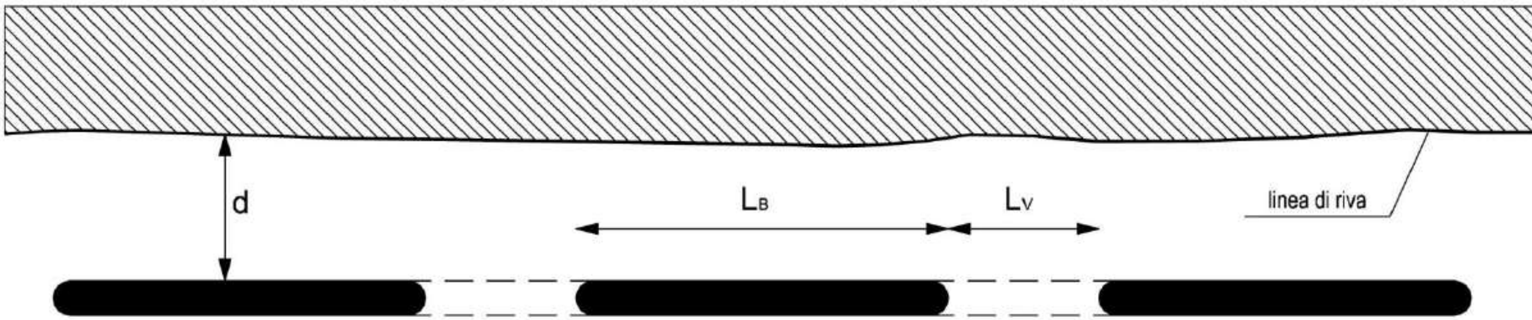
Breakwaters reduce the amount of wave exposure and the sand fill losses. The nearshore currents induced by the longshore gradient of wave heights and level setup form a sand deposition behind the parallel barriers



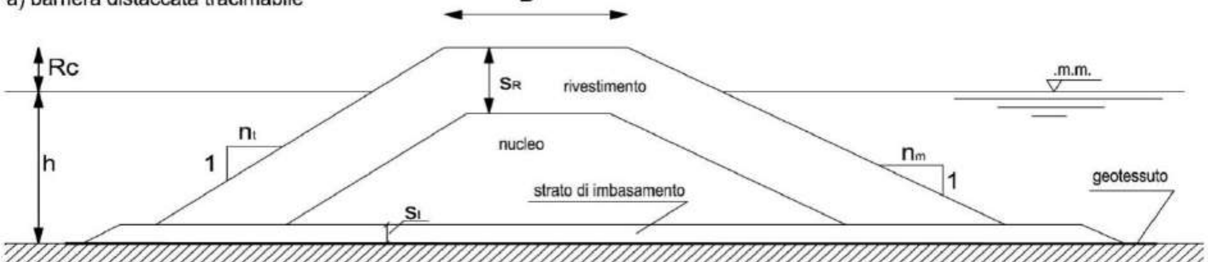
Detached breakwaters

Direct attenuation of wave heights and cross-shore transport

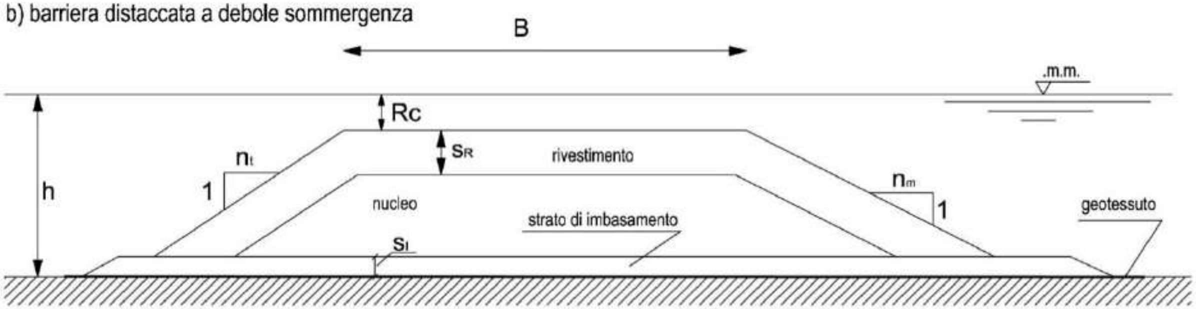
Generally parallel to prevailing wave fronts (and shoreline)



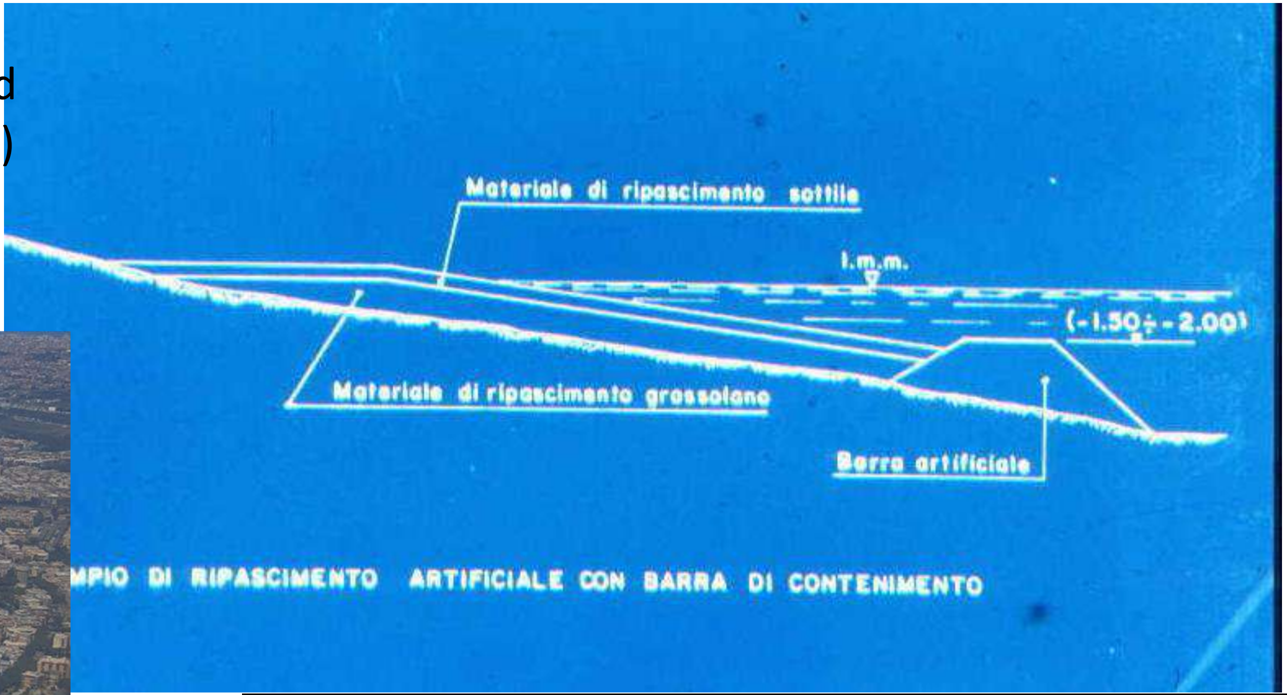
a) barriera distaccata tracimabile



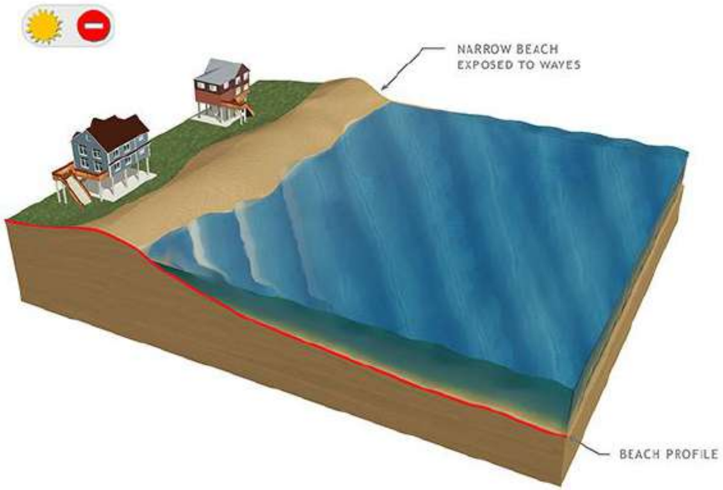
b) barriera distaccata a debole sommergenza



First perched beach scheme at Ostia centro (1.3 Mm3 sand + 3 km deep submerged barrier) **1990**

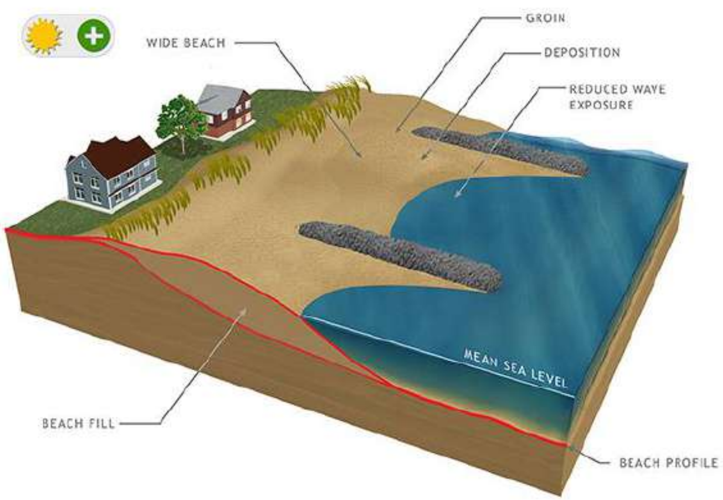


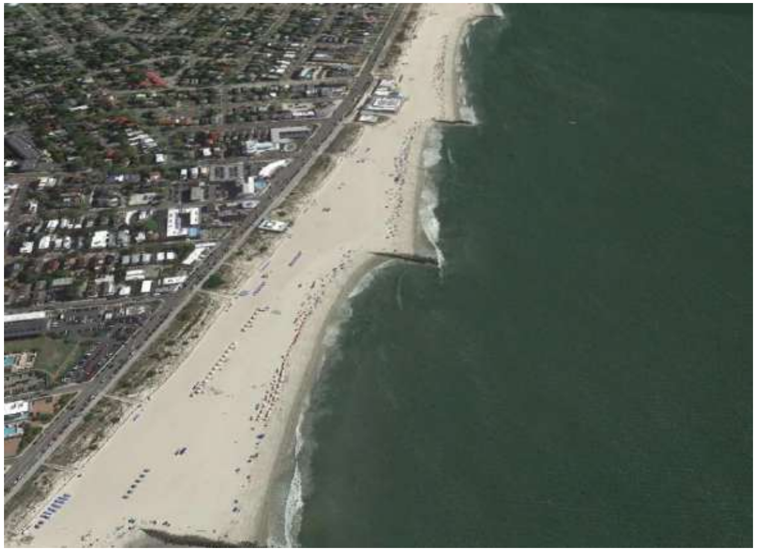
groins



Groins are structures that extend perpendicularly from the shoreline. Groins are usually built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material.

The effect of a single groin is accretion of beach material on the updrift side and erosion on the downdrift side.

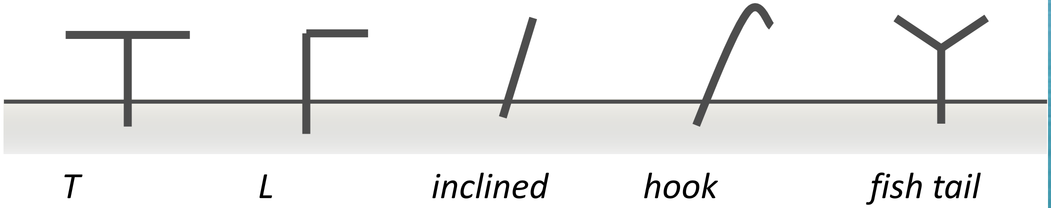




Groins: Geometries and materials

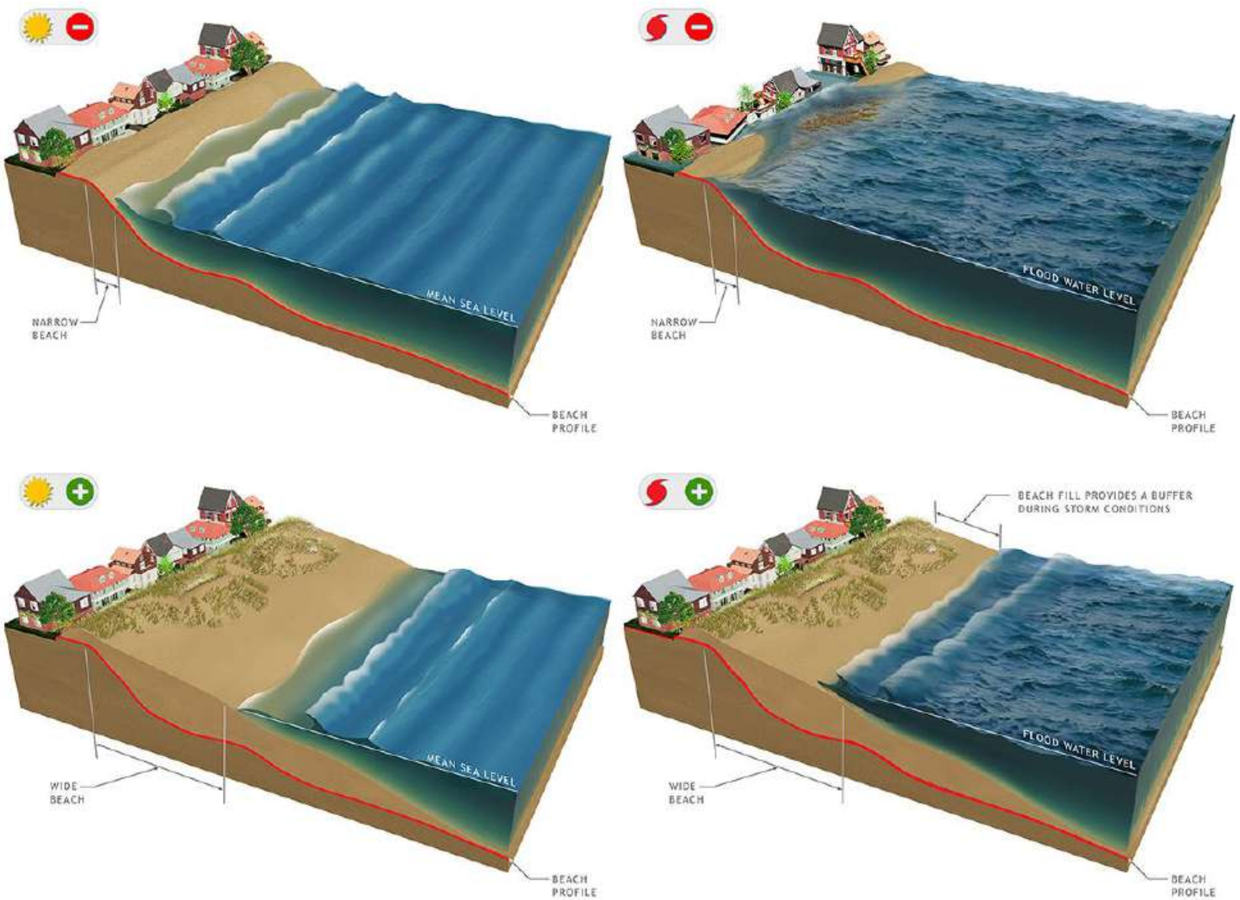
Materials:

- concrete
- rock
- wood (>0.3 m logs)
- steel
- geobags-geotubes

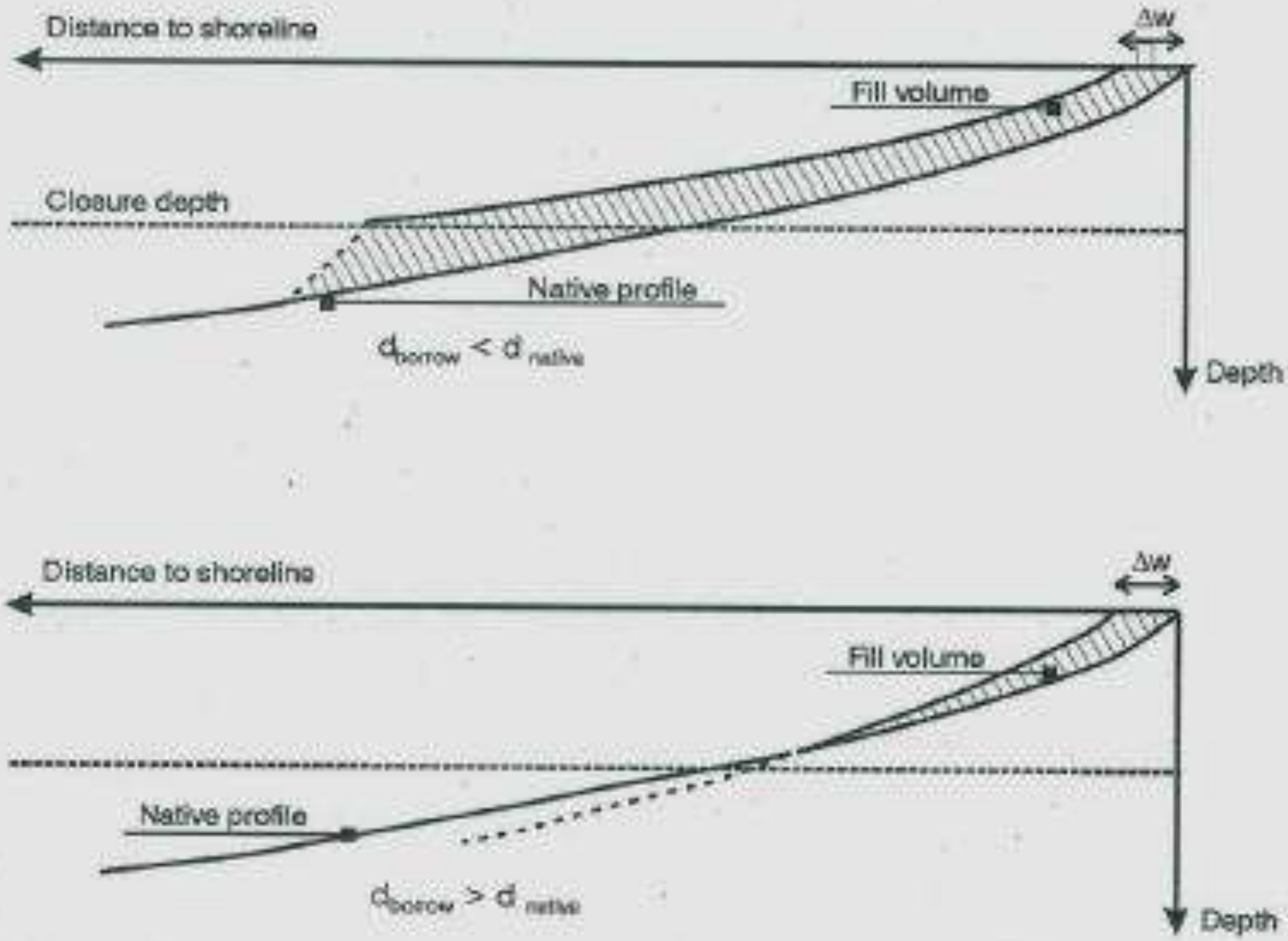


Combined Structural/Natural solutions

Beach nourishment



Relatively narrow beach and low dunes fronting a typical beachfront development.
A beach fill has a wide berm and high, vegetated dunes.



ig 12.28 *Equilibrium conditions for nourished beaches required to obtain an additional beach width of Dw with borrow sand which is finer and coarser than the native sand (upper and lower, respectively).*

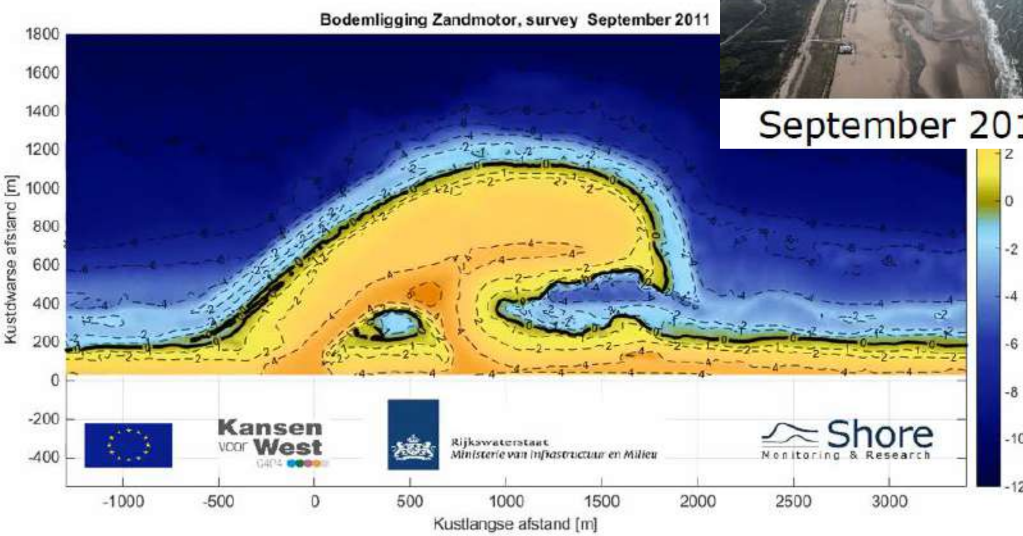
Zandmotor
(Rotterdam,Netherlands 2011)

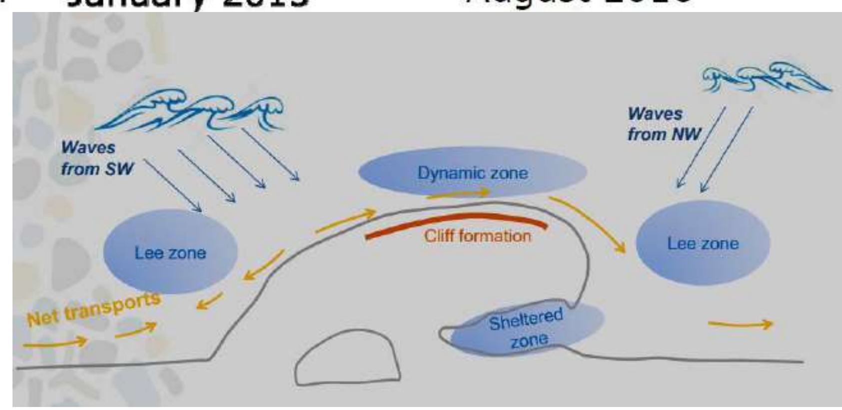
21.5 million m^3 of sand

The first **Sand Engine** was introduced in **2011** on the Dutch coast and offers an effective soft coastal management solution making use of natural processes. The method entails depositing a large volume of sand in a location from which it is distributed by coastal processes over a larger part of the coast. This method is expected to be more cost effective and also helps nature by reducing the repeated disruption caused by replenishment.

Zandmotor (Netherlands 2011)

Simulation 2011 - 2018





Free sand beach nourishment at Maronti (Ischia) 2002

Teresita, Tenerife

Malaga, Spain

Pellestrina (Venezia). Protected beach nourishment within cells made of groynes and submerged detached breakwater (late 90's)

Shore protection works in Abruzzo at Pescara- Francavilla

Living shorelines

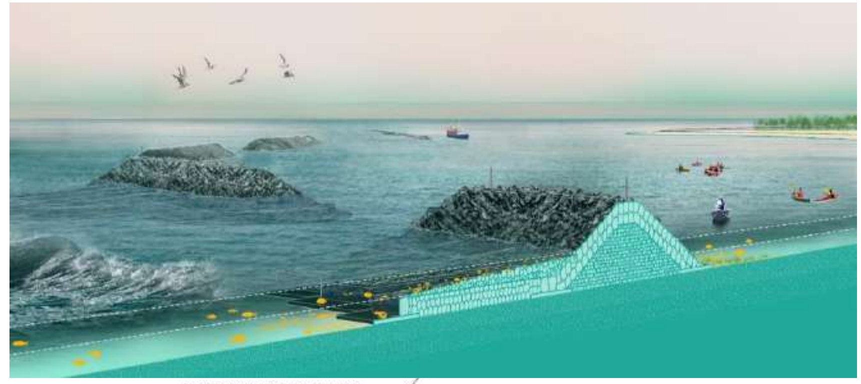
Living shorelines are essentially tidal wetlands constructed along a shoreline to reduce coastal erosion.

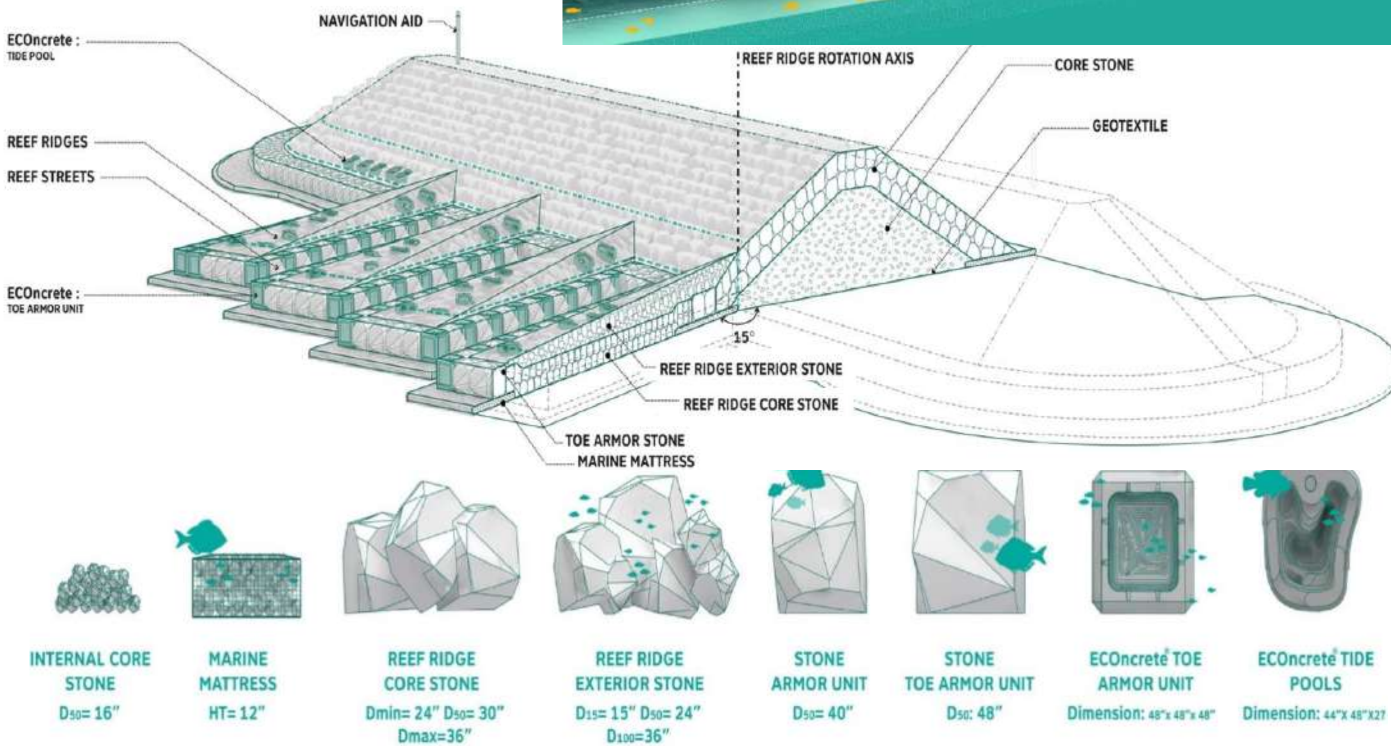
Living shorelines maintain dynamic shoreline processes, and provide habitat for organisms such as fish, crabs and turtles.

An essential component of a living shoreline is constructing a rock structure (breakwater/sill) offshore and parallel to the shoreline to serve as protection from wave energy that would impact the wetland area and cause erosion and removal of the tidal plants.

Living Breakwater Projects, 2014

Tottenville (New York, USA)



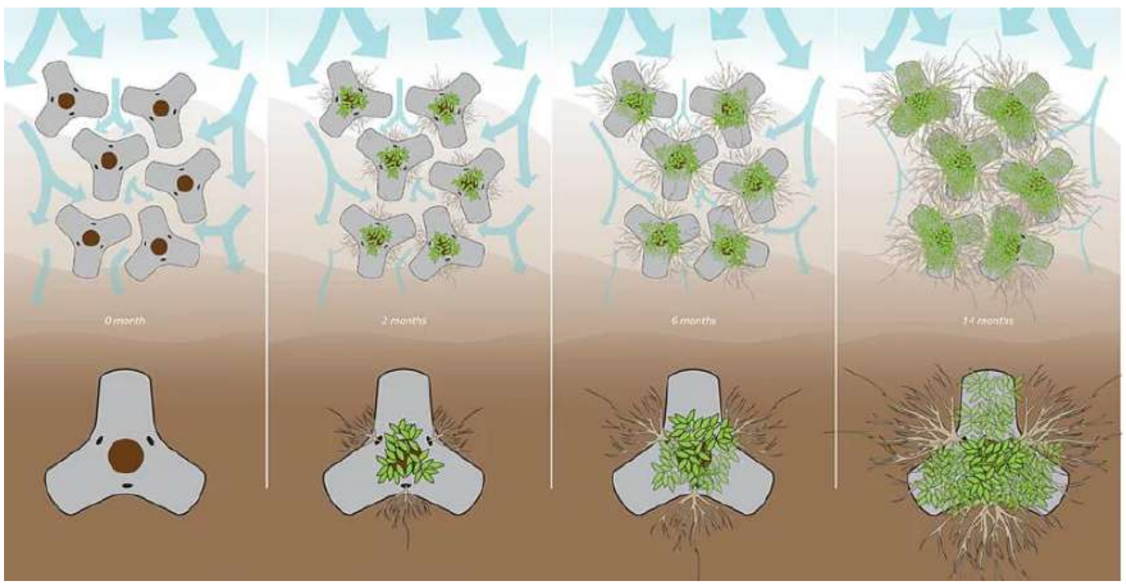


ECOncrete®'s innovative and proprietary concrete technology (Israeli) enhances marine and coastal infrastructure by inducing formation of bio-habitats, while preserving functional and structural properties

[ECO Armor Block](#) [Tide Pool Armor](#) [ECO Mats](#) [ECO Seawall](#)

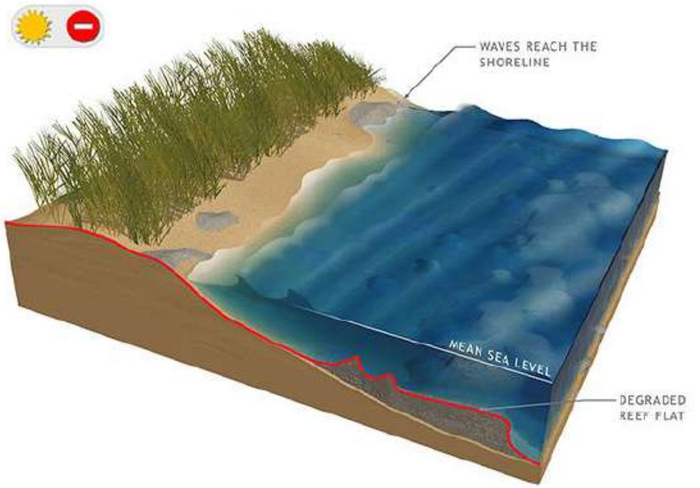
Tetra POT

TetraPOT is a sea defence made of concrete. It comes with plant seeds in a decomposable pot. Randomly distributed TetraPOTs along coast lines will eventually mutually interlock to create a long-lasting sea defence, thanks to the structure as well as the system formed by the growing trees and roots that help keep the blocks in place.



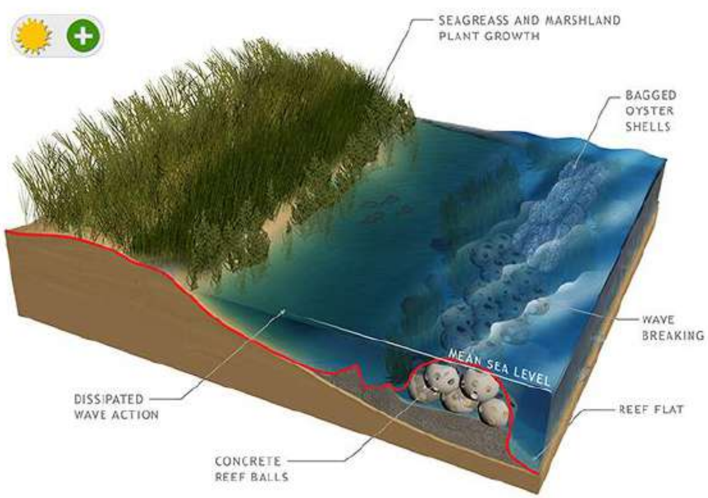
Natural and nature-based solutions

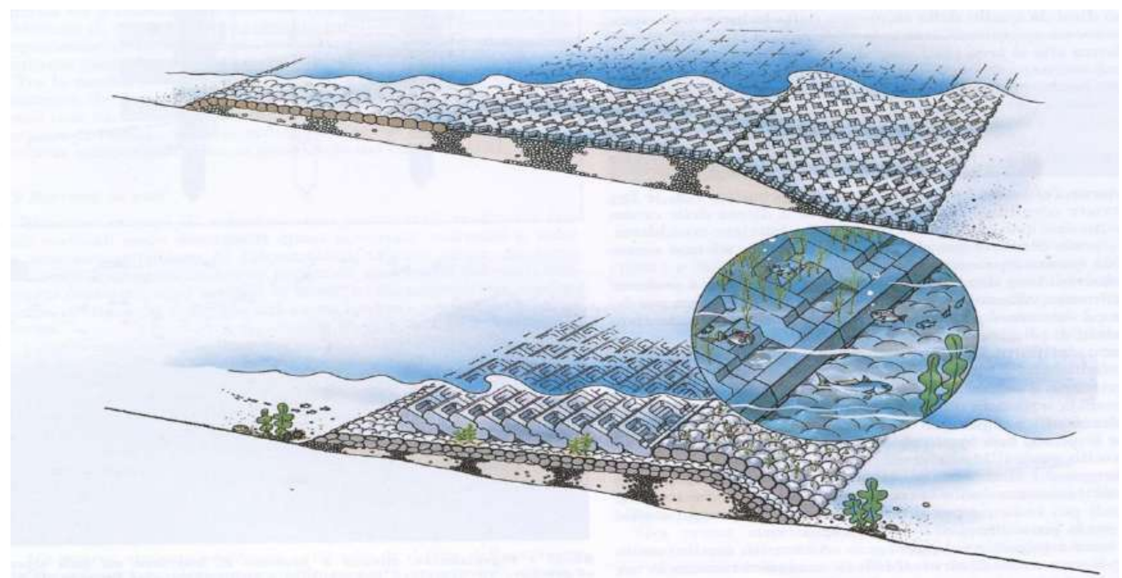
Reefs



Artificial submerged reefs reduce wave action and:

- restore degraded or damaged natural reefs
- provide three dimensional habitat structure above the bottom
- provide fishing and scuba diving opportunities

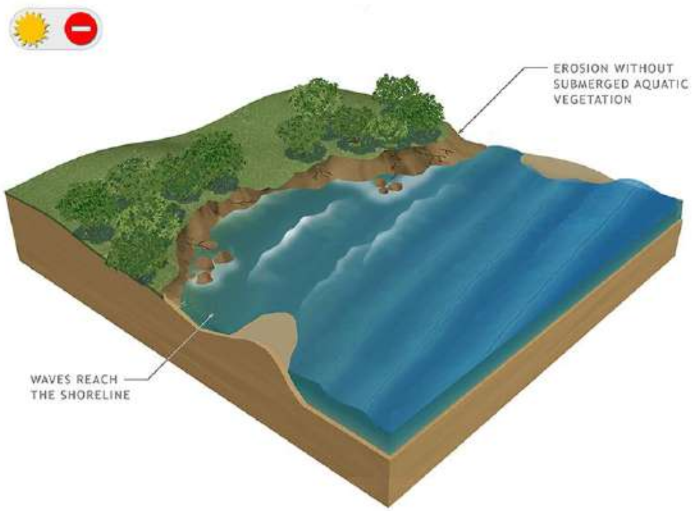




Acropora palmata Restoration Program

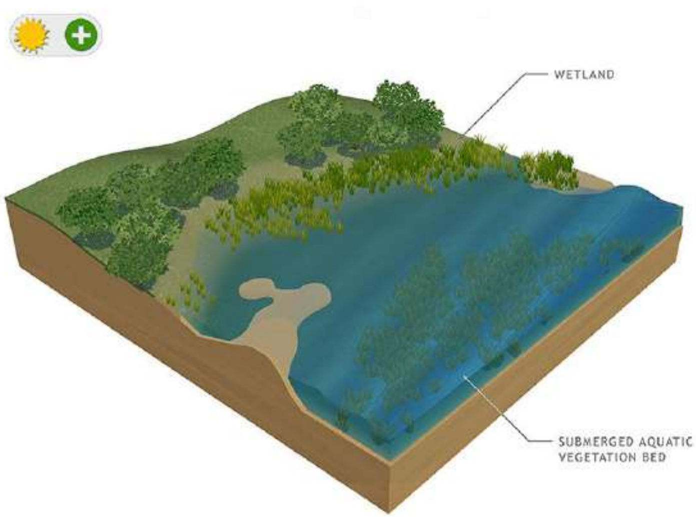
New coral barriers in Gulf of Mexico.
The new barriers will be made through the propagation of *acropora palmata*, an important reef-building coral, with an innovative methodology endorsed by the Nature Conservancy.

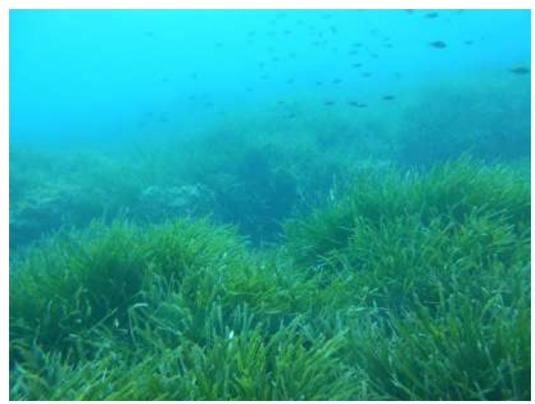
Submerged Aquatic Vegetation



Submerged Aquatic Vegetation performs many important functions, including:

- wave attenuation and sediment stabilization
- water quality improvement
- food web support for secondary consumers
- provision of critical nursery and refuge habitat for fisheries species.





Posidonia oceanica

Wetlands

The dense vegetation and shallow waters within wetlands can slow the advance of storm surge. Wetlands can also dissipate wave energy;

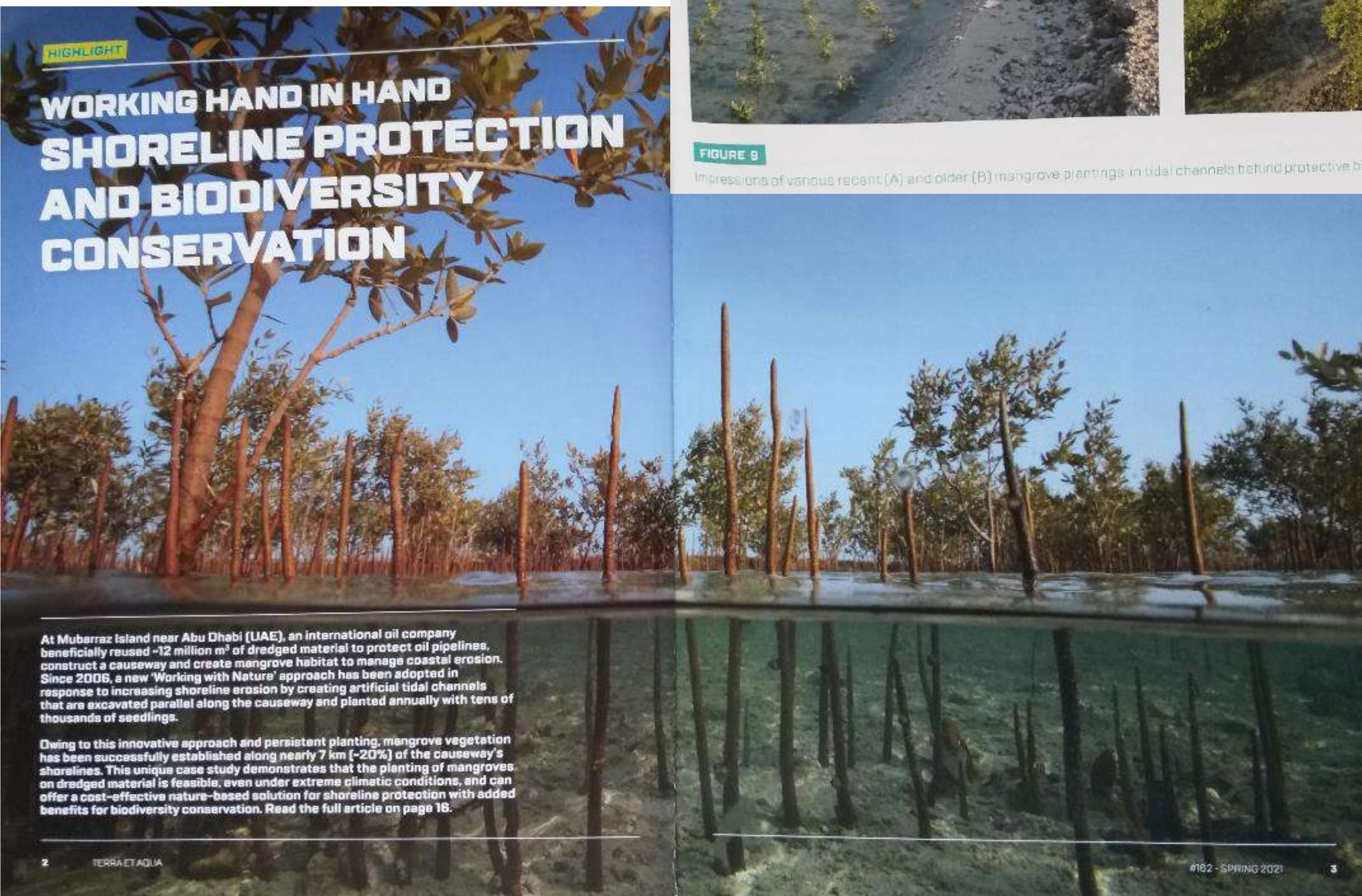
mangroves

Recycled Christmas trees for marsh restoration in Lousiana

Planting of mangroves on dredged material, Abu Dhabi (Terra et Aqua april 2021)

FIGURE 9

Impressions of various recent (A) and older (B) mangrove plantings in tidal channels behind protective berms along the causeway



HIGHLIGHT

WORKING HAND IN HAND
SHORELINE PROTECTION AND BIODIVERSITY CONSERVATION

At Mubarraz Island near Abu Dhabi (UAE), an international oil company beneficially reused ~12 million m³ of dredged material to protect oil pipelines, construct a causeway and create mangrove habitat to manage coastal erosion. Since 2006, a new 'Working with Nature' approach has been adopted in response to increasing shoreline erosion by creating artificial tidal channels that are excavated parallel along the causeway and planted annually with tens of thousands of seedlings.

Owing to this innovative approach and persistent planting, mangrove vegetation has been successfully established along nearly 7 km (~20%) of the causeway's shorelines. This unique case study demonstrates that the planting of mangroves on dredged material is feasible, even under extreme climatic conditions, and can offer a cost-effective nature-based solution for shoreline protection with added benefits for biodiversity conservation. Read the full article on page 16.

2 TERRA ET AQUA

#162 - SPRING 2021 3

Demak district (Indonesia 2016)

Permeable dam structures with bamboo and brushwood. These partially submerged structures trap sediment from coastal erosion but allow water to pass freely. Over time, these structures collect and build back shorelines, which provides a stable coast for mangroves to regrow. The growth of new mangroves and their interconnected web of roots further fortifies the coast.

ICCE

38TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING

ROME 2024

8-14 SEPTEMBER

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Chair:
Prof. Leopoldo Franco - Roma Tre University

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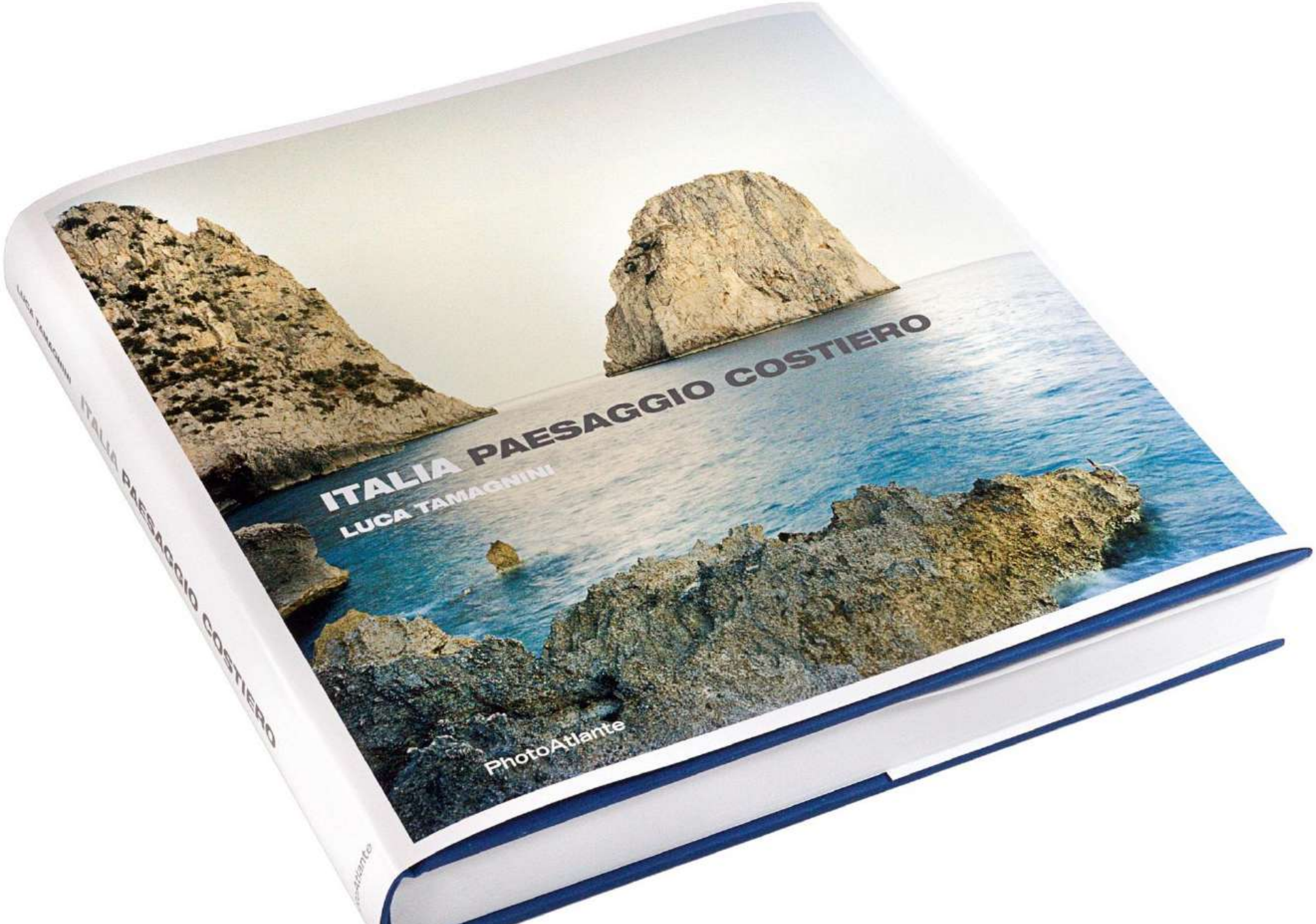
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