Co-funded by the
Erasmus+ Programme
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MARE

Coastal protection and shoreline Managements

Coastal Erosion and Beach Loss

- A natural process that redistributes sediments along coasts
- Becomes a problem when coastal development impedes or ignores the natural movement of sediment along the shore
- Exacerbated by continued sea level rise

Coastal erosion is a natural process

Coastal development makes erosion a problem

Wave erosion caused by strong storms, Long Island, New York

Sea-level rise makes the problem worse

Studies show a 150x erosion multiplier for sea level rise on sandy shorelines. Hence, for a mean 0.24 m rise by 2050, beaches will recede 36 m (118 ft). (*Leatherman et al., 2000)*

Stabilizing the shore

- Shoreline erosion is influenced by several local factors including
  - Proximity to sediment-laden rivers
  - Degree of tectonic activity
  - Topography and composition of the land
  - Prevailing wind and weather patterns
  - Configuration of the coastline and nearshore areas

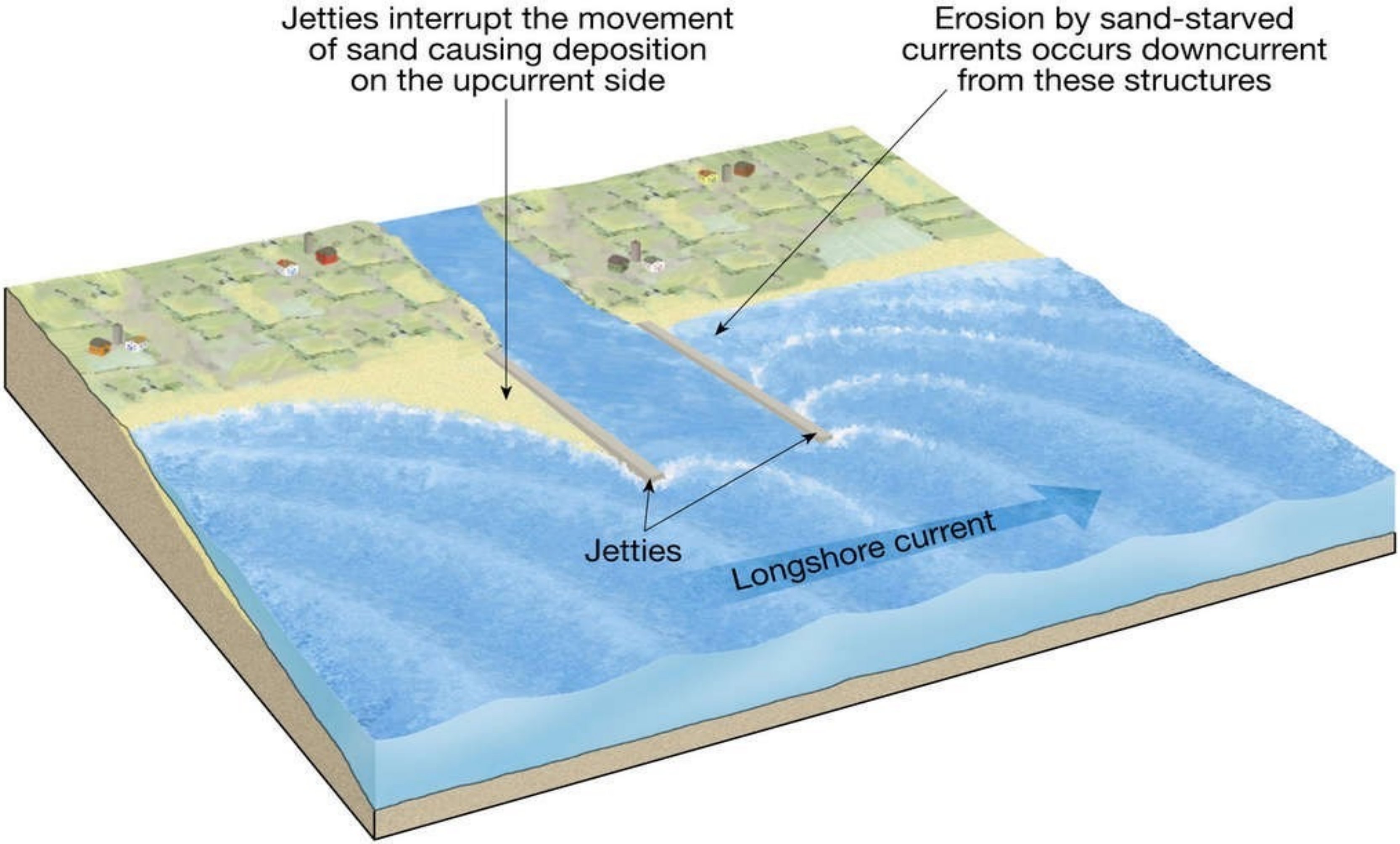
Stabilizing the shore

- Three basic responses to erosion problems
  - Building structures (Hard stabilization)
  - Beach nourishment
  - Relocation

Stabilizing the shore

- Hard stabilization perpendicular to the shore
  - Jetties
    - Usually built in pairs to develop and maintain harbors
    - Extend into the ocean at the entrances to rivers and harbors

Jetties are built to prevent deposition

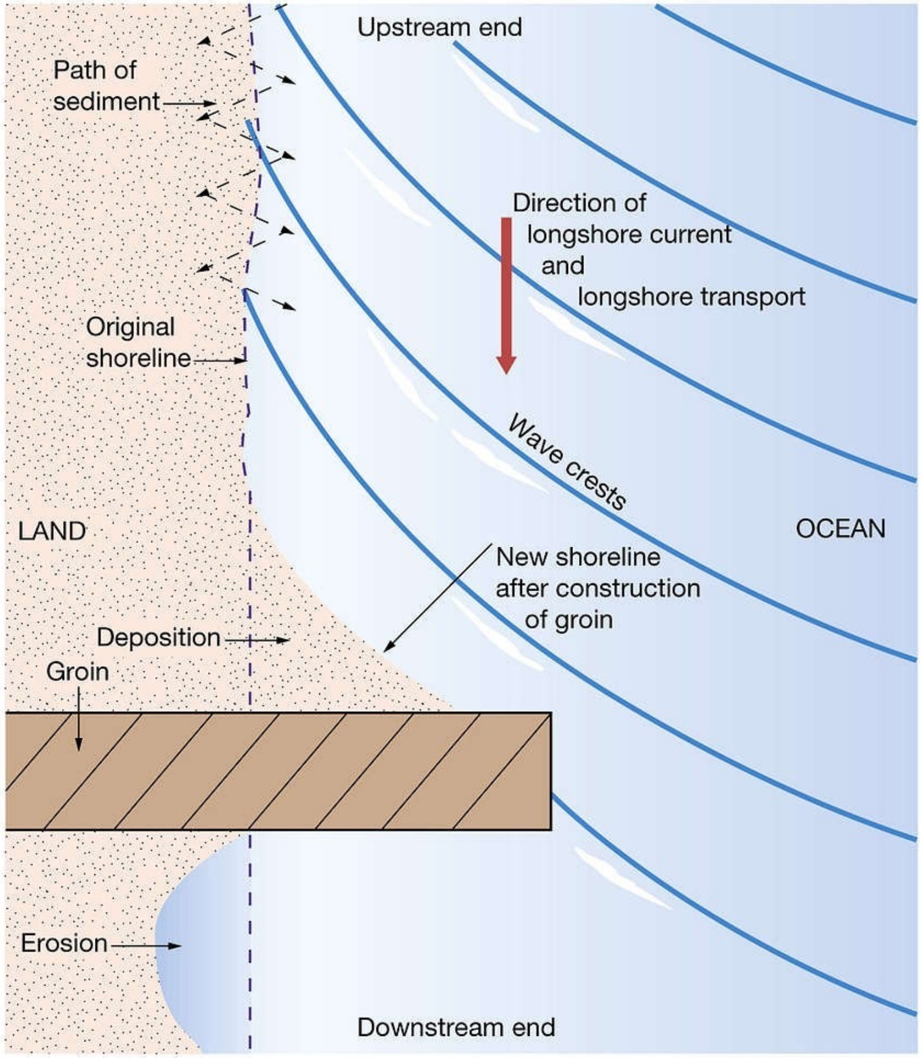


Stabilizing the shore

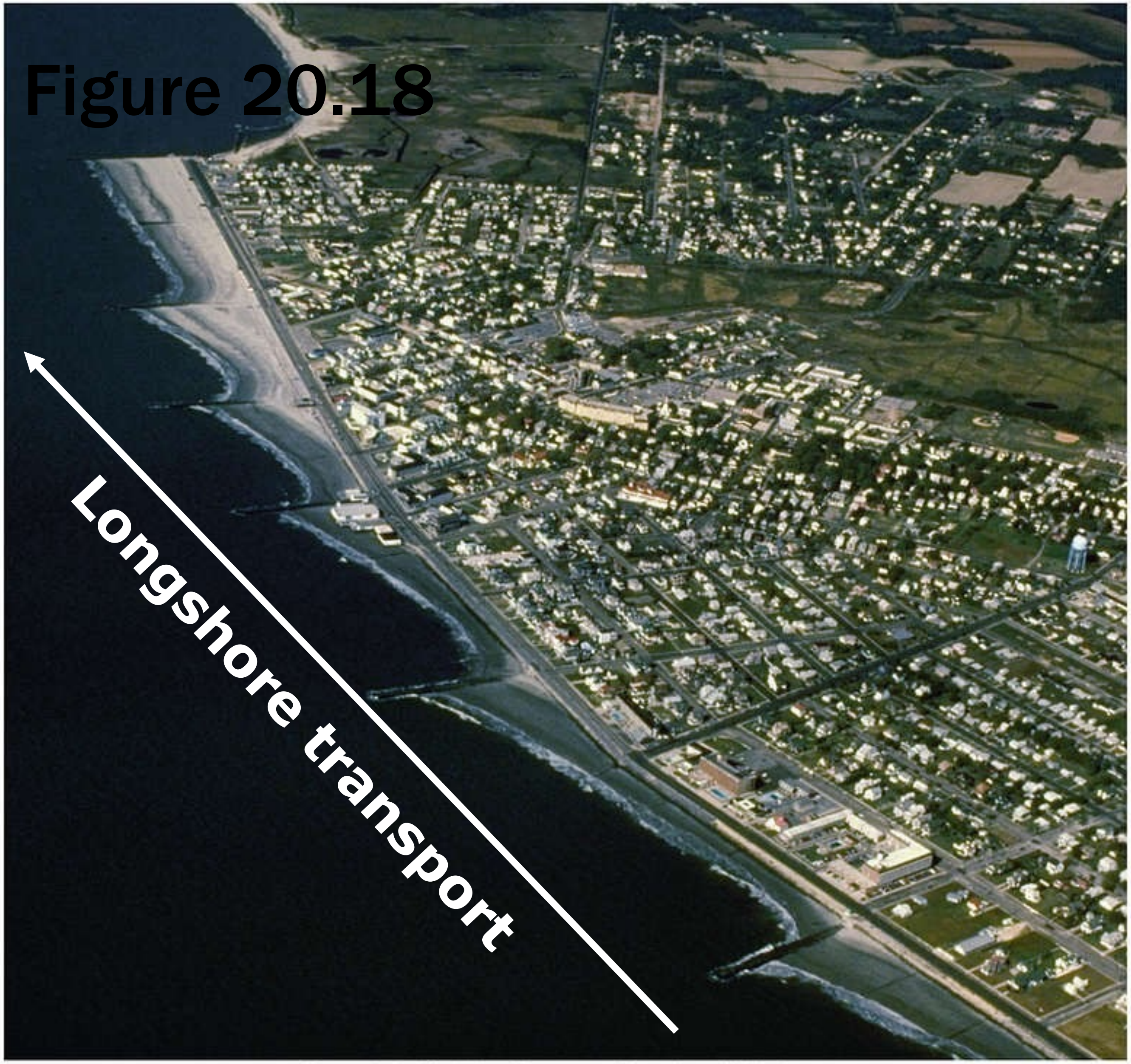
- Hard stabilization perpendicular to the shore
  - Groins
    - Built to maintain or widen beaches
    - Constructed at a right angle to the beach to trap sand
    - Because of increased erosion on the downdrift side of the groin, additional groins may be built resulting in a groin field

Interference of sand movement

- Hard stabilization like the groin shown here interferes with the movement of sand along the beach, causing deposition of sand upstream of the groin and erosion immediately downstream, modifying the shape of the beach.



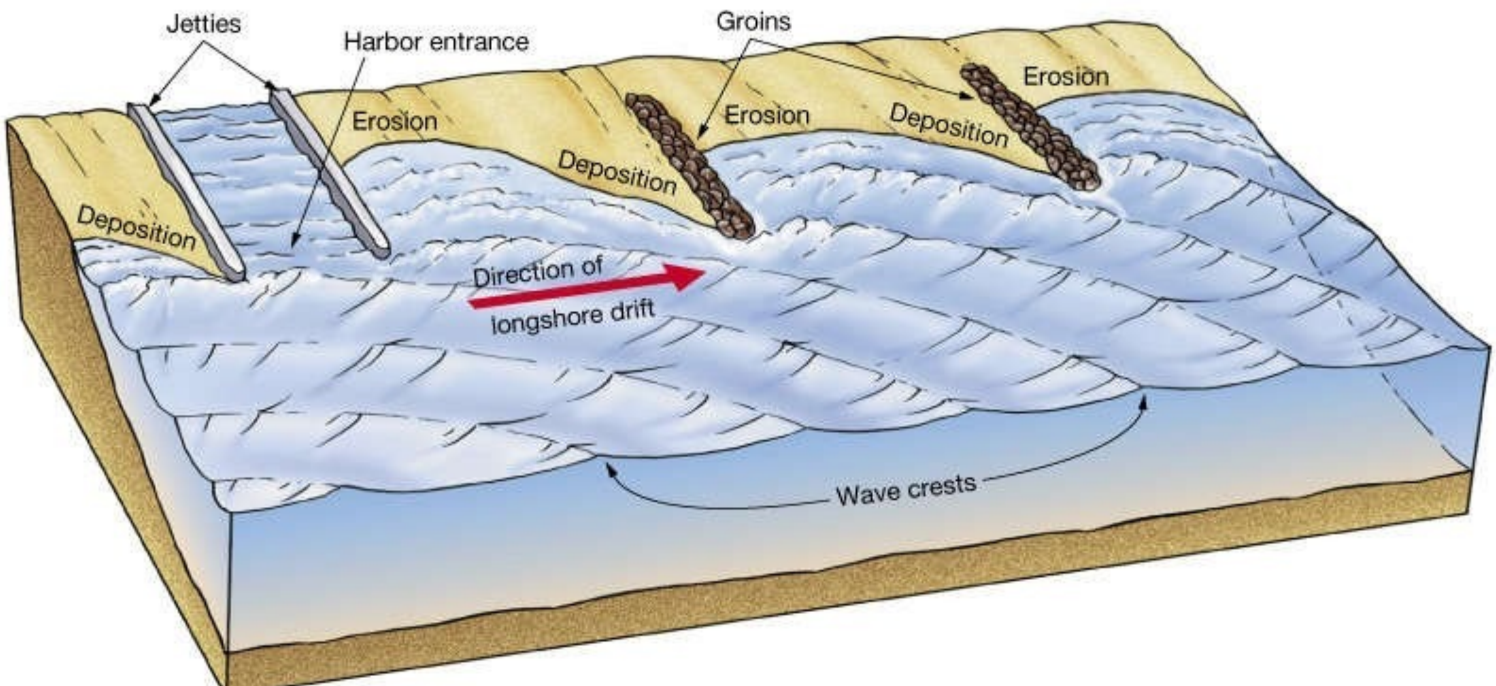
11.20-Thurman and Trujillo, 2004



Groins along the New Jersey Shore at Cape May

Jetties and Groins

- Jetties are always in pairs
- Groins can be singular or many (groin field)
- Both trap sand upstream and cause erosion downstream

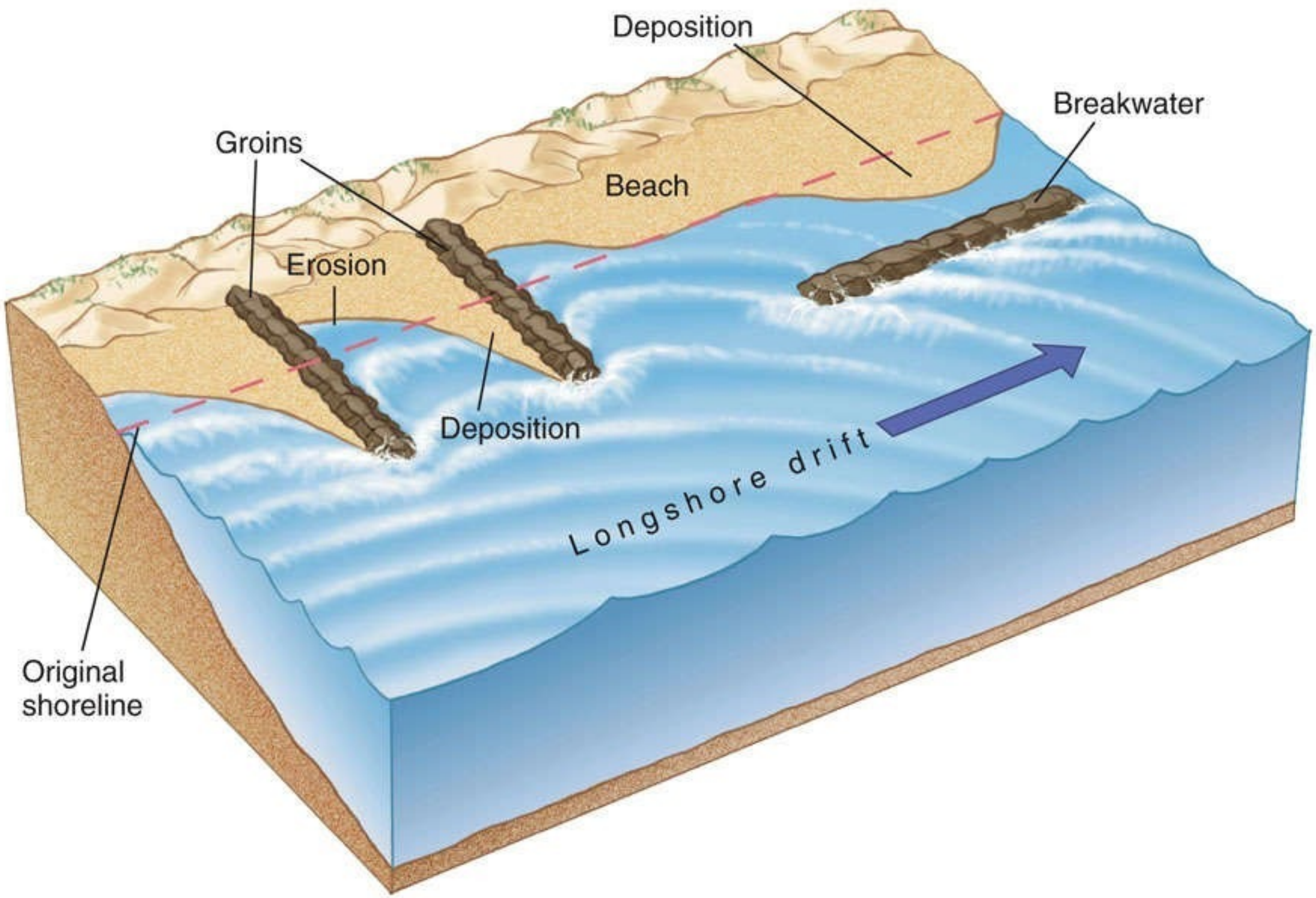


11.22-Thurman and Trujillo, 2004

Stabilizing the shore

- Hard stabilization parallel to the shore
  - Breakwater
    - Barrier built offshore and parallel to the coast
    - Protects boats from the force of large breaking waves

Groins and Breakwaters



11.7-Jones and Jones, 2003

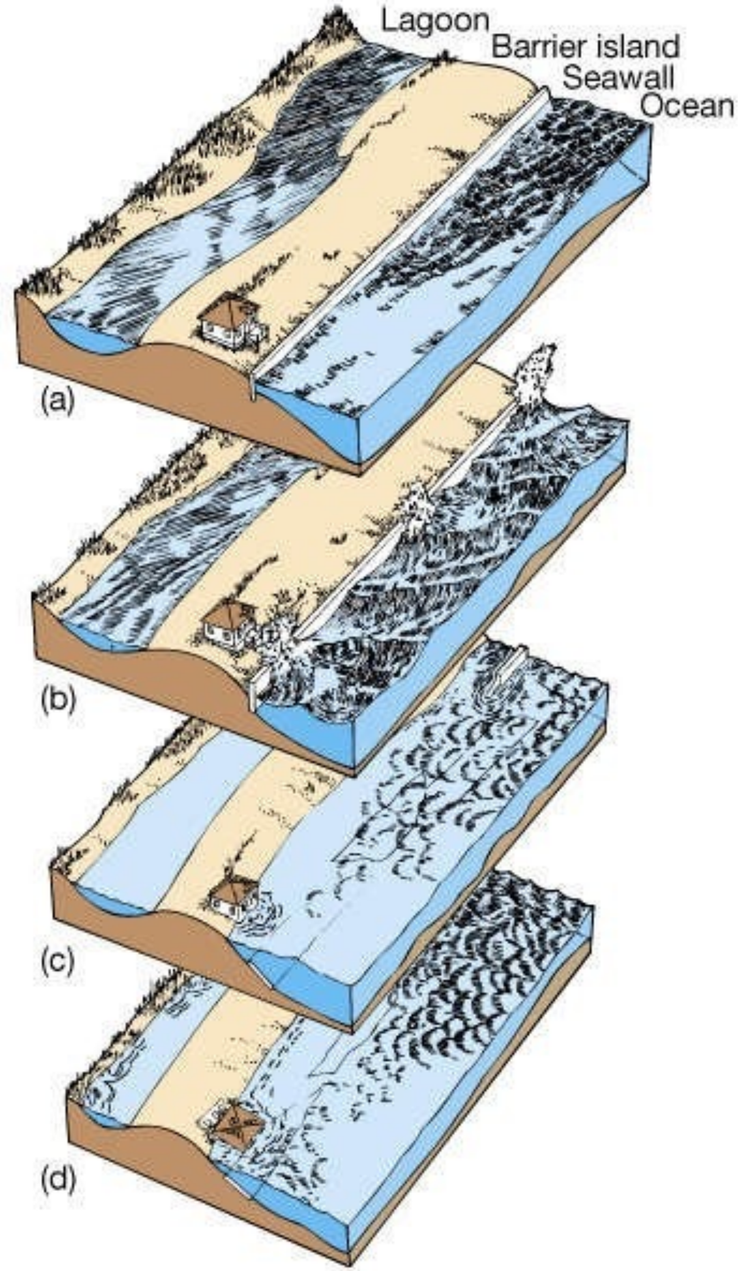

Breakwater

Stabilizing the shore

- Hard stabilization parallel to the shore
  - Seawall
    - Barrier parallel to shore and close to the beach to protect property
    - Stops waves from reaching the beach areas behind the wall
  - Often the building of structures is not an effective means of protection

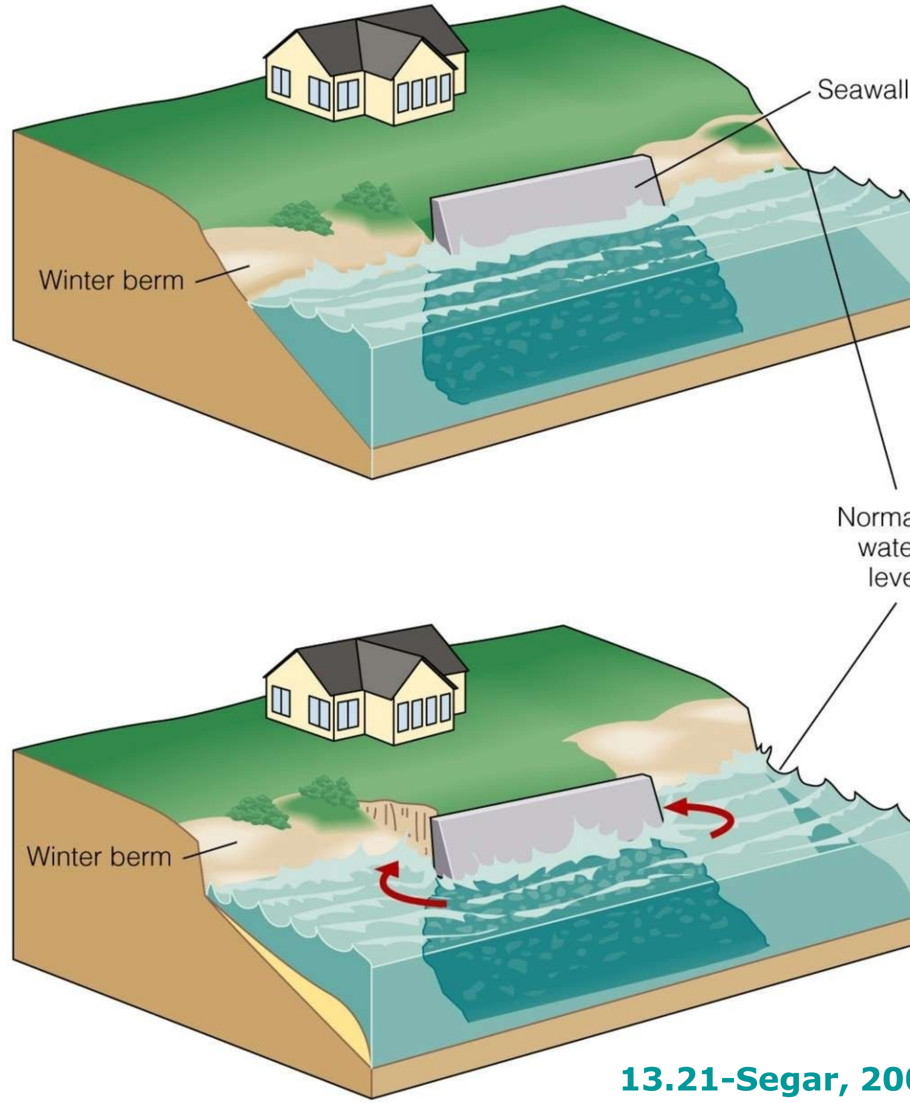
Seawalls and beaches

- Seawalls are built to reduce erosion on beaches
- Seawalls can destroy recreational beaches
- Seawalls are costly and eventually fail



11.25-Thurman and Trujillo, 2004

Seawalls are designed to protect beachfront property from erosion



13.21-Segar, 2007

Seawall in Seabright, New Jersey

Wine Island?

- Seawalls can't compete with sea-level rise

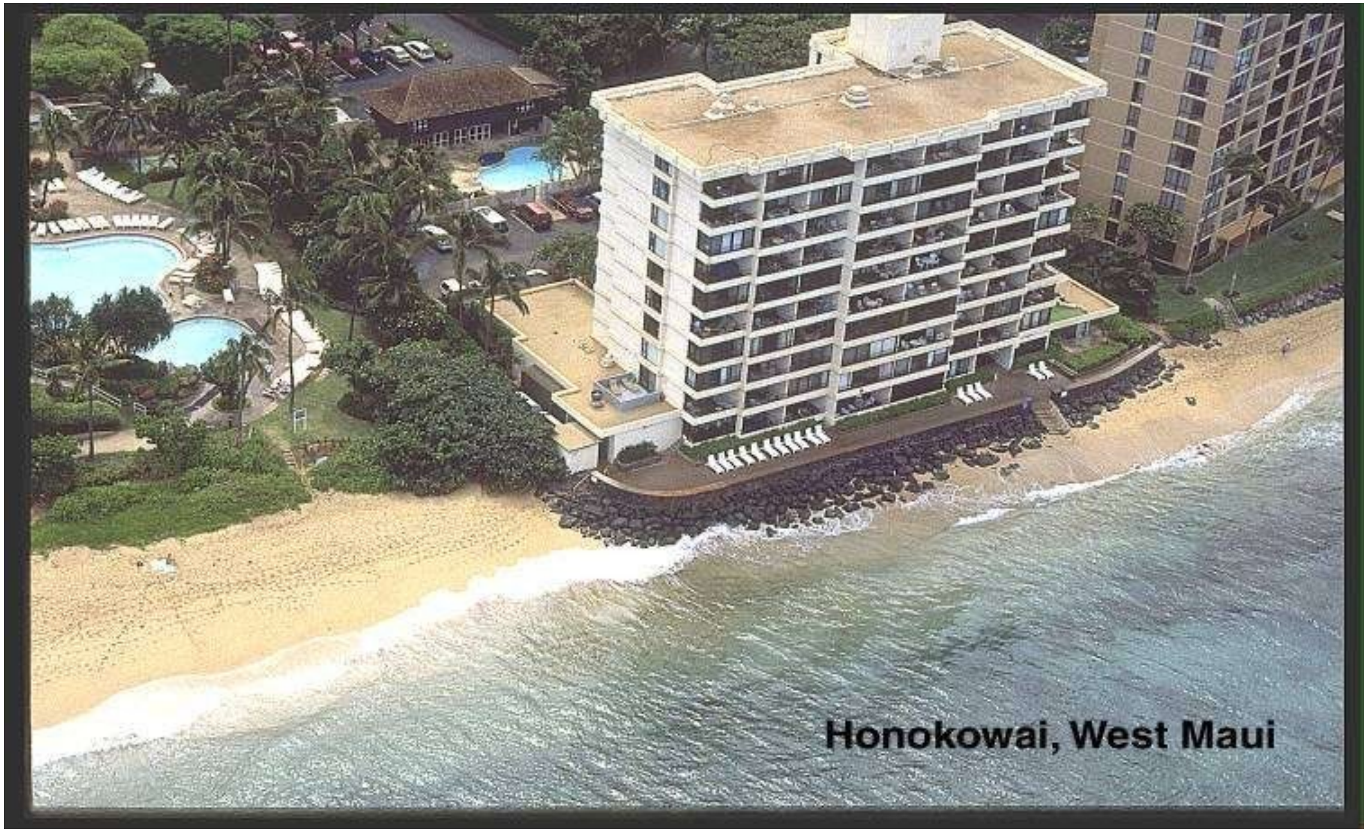
10.26-Merritts et al., 1998

Responses to Coastal Erosion and Beach Loss

- Hard stabilization
  - “Armoring” the shoreline

Responses to Coastal Erosion and Beach Loss

- Hard stabilization
  - “Armoring” the shoreline



Responses to Coastal Erosion and Beach Loss

Illegal extraction of beach sand is one of the major causes of coastal erosion

USGS

Illegal extraction of beach sand is one of the major causes of coastal erosion

Morelock et al.

Stabilizing the shore

- Alternatives to Hard Stabilization
  - Beach nourishment
    - The addition of large quantities of sand to the beach system
    - Only an economically viable long-range solution in a few areas
  - Abandonment and relocation of buildings away from the beach

Responses to Coastal Erosion and Beach Loss

- Beach nourishment

Wrightsville Beach, NC

10.24-Merritts et al., 1998

Beach nourishment, Miami Beach

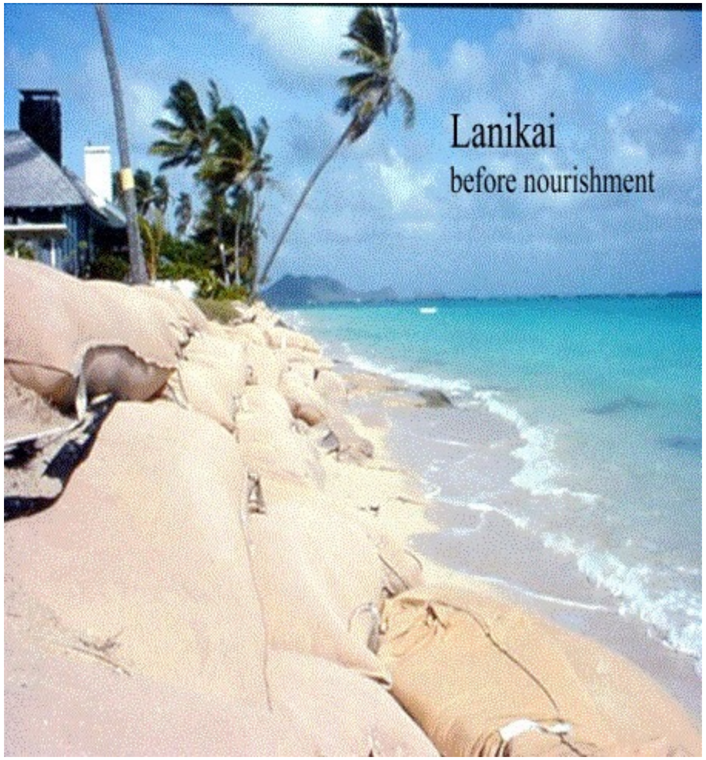
A. B.

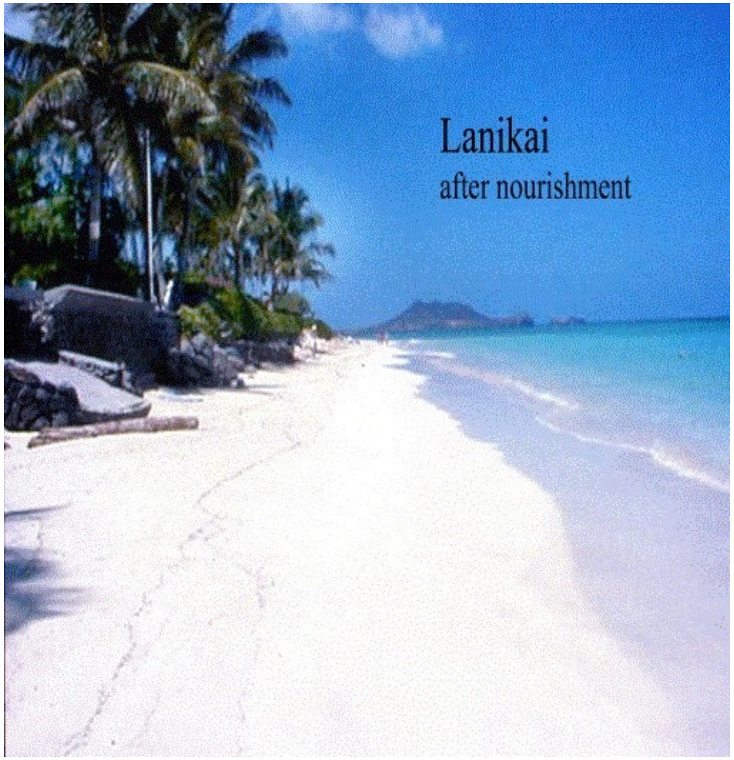
Responses to Coastal Erosion and Beach Loss

- Caveats of beach nourishment
  - Not permanent solution
  - Expensive
  - Need appropriate sand source

Responses to Coastal Erosion and Beach Loss

- Still, with appropriate financial and sand resources, nourishment can be a viable solution in some settings





Responses to Coastal Erosion and Beach Loss

- Abandonment and relocation

Alternatives to hard stabilization

- Restrict the building of structures too close to the shore
- Eliminate programs that encourage construction in unsafe locations
- Relocate structures as erosion threatens them

Relocation of the Cape Hatteras lighthouse, North Carolina

Coastal Hazards

- Increasing coastal development and rising sea level puts more people and property at risk

Combined wind and storm surge damage

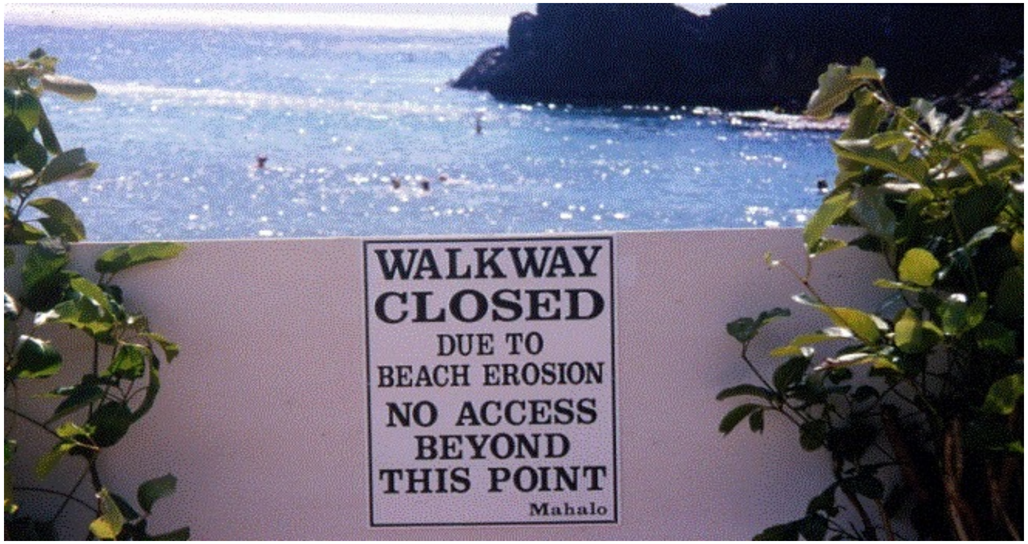
Iniki flooding reached
>800 ft inland
>25 ft above sea level

New Directions?

- Avoid development of eroding lands
- Discourage additional development in erosion hazard zones
- Enforce “setbacks”
- Acquire high-value coastal lands
- Construction guidelines for hazard areas
- Nourish eroding shorelines

New Directions?

- Without a sound understanding and appreciation of the dynamics of the coastal zone, and thoughtful environmental management of the shore
- We may lose one of our most precious natural resources



Group discussion

Divide into 8 groups and find out response to erosion problems

DISCUSSION

- You are a NGO, what should you choose to response to erosion problems?

Response to erosion problems???

Group work

- Work individually in 5 minutes, point out what should you choose to response to erosion problems
- Each group has 10 minutes to communicate and select the most effective response.

Round-presentation

- Assign 1 speaker.
- Group's speaker has to present your findings in 3 minutes. Convince the class that your solution is top choice. Take note.
- Other members: comment the speaker. Take note.

Coastal Defense Structures

Why coastal defense structures are used?

- To provide beach and shoreline stability control.
- To protect harbors and inlets.
- To stabilize navigation channels at inlets.
- To protect water intakes and outfalls.
- To retain or rebuild natural systems (cliffs, dunes) or protect buildings landward of the shoreline.

What kinds of conditions should be taken into?

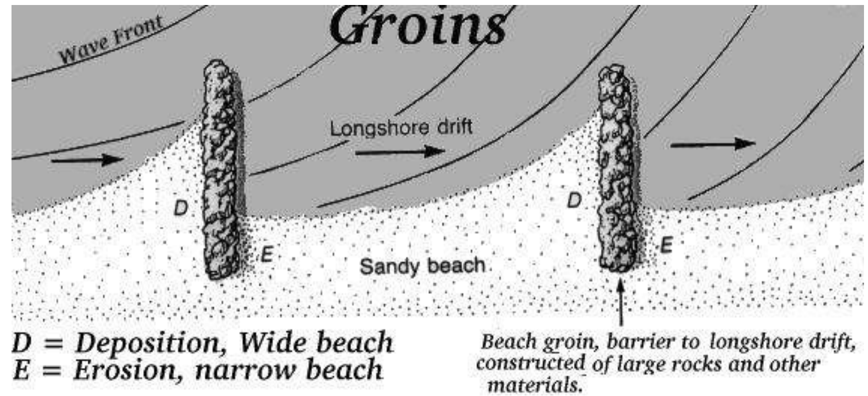
1. Stability
2. Safety
3. Serviceability
4. Economy

Nature vs Man on coastal defense

- COASTAL PROTECTION BY NATURE
  - SHORE ROCK
  - ROCK REEF
  - ROCK ISLAND
  - HEADLAND
  - ROCK PERPENDICULAR TO SHORELINE
  - SEA FLOOR VEGETATION
  - DUNE
  - MATERIALS TRANSFER TO SHORE BY: WIND DRIFT RIVERS LONGSHORE LITTORAL DRIFT
  - SEA BOTTOM TRANSFER
- COASTAL PROTECTION BY MAN
  - SEA WALL
  - SUBMERGED BREAKWATER
  - OFFSHORE BREAKWATER
  - HEADLAND BREAKWATER
  - GROINS
  - BOTTOM MATTRESS
  - DIKE
  - ARTIFICIAL NOURISHMENT FROM LAND SOURCES
  - ARTIFICIAL NOURISHMENT FROM OFFSHORE SOURCES

Hard measures

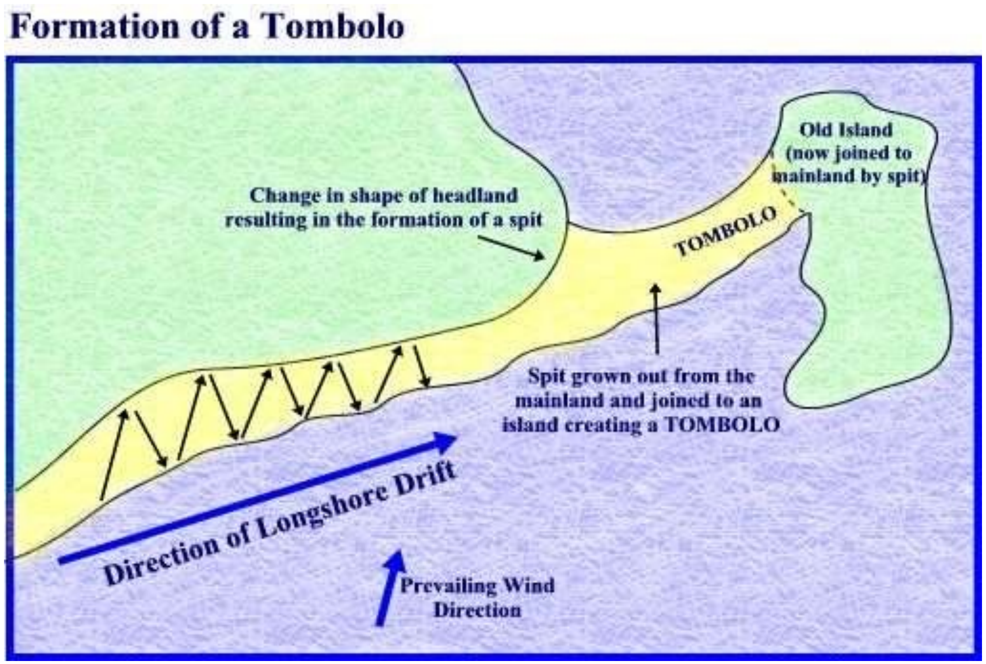
- **Groins** are structures built out from the shoreline to trap sand in the longshore drift.



- A **jetty** is much larger than a groin, and is built to stabilize an inlet or other coastal feature rather than to capture sand.

Hard measures

- A **tombolo** is a sand spit that forms between the beach and a breakwater. A groin and a breakwater are sometimes combined into a T shaped structure.

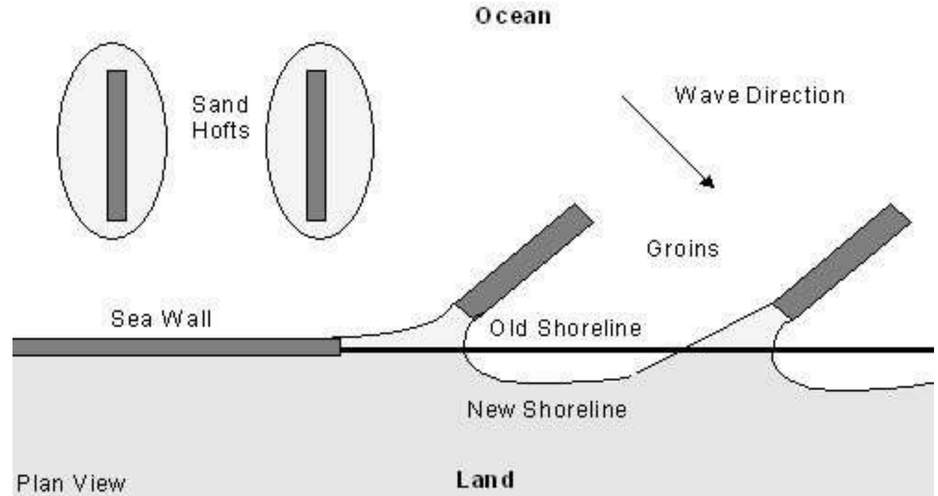


Hard measures

- **Breakwaters** are built offshore, parallel to the coast. The purpose of a breakwater is to lessen the impact of waves on the shore, much like a natural reef, and it need not protrude from the water to do so.

Hard measures

- A **sand hoft** is an offshore island created by the accumulation of sand around an old jetty that is no longer attached to the land due to shoreline retreat. These can have a stabilizing effect on the beach in much the same way a breakwaters and natural barrier islands.



Hard measures

- A **seawall** is an onshore construction used when erosion is so great that there is no beach left. Seawalls are large heavy structures that face the sea, while bulkheads are lighter structures built in protected areas.

Hard measures

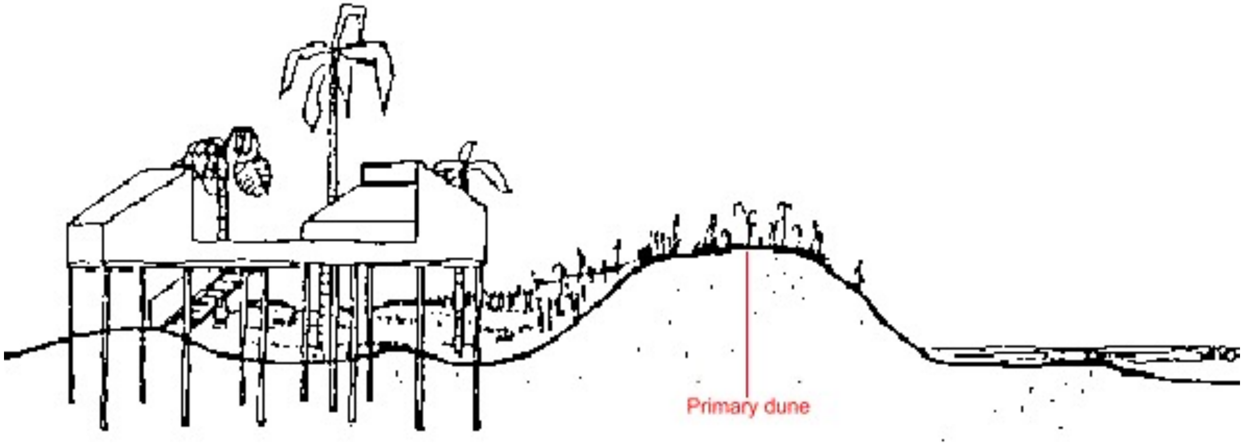
- A **dike** is a natural or artificial slope or wall to regulate water levels. It is used to protect low- lying, coastal areas from inundation by the sea under extreme cond.itions

Soft measures

- **Beach Filling and Subsequent Renourishment** involves the placement of sandy material along the shore to establish and subsequently maintain a desired beach width and shoreline position to dissipate wave energy and enhance beaches, particularly for recreational and aesthetic purposes.

Soft measures

- **Dune Building** and/or the maintenance and preservation of existing dunes, in combination with adequate beach strands, provides an effective measure of protection to upland properties against the effects of storm tides and wave action.



Soft measures

- **Wetland/Mangrove Creation** can be accomplished through the placement of fill material to appropriate elevations with subsequent plantations.

Soft measures

- Artificial **reef** can be created by placing environmentally friendly and long lived materials like steel or concrete on the sea floor on which living organisms start go underwater.
- Man made reefs are as productive as natural reefs in enhancing fishing opportunities and serve as under sea barriers to reduce impact of wave energy.

CLASSIFICATION OF COASTAL PROTECTION CONCERNS &SOLUTIONS TO THEM

SHORELINE STABILIZATION

- SEAWALL
- BULKHEAD
- REVETMENT
- GROIN
- DETACHED BREAKWATER
- BEACH NOURISHMENT
- SAND BYPASSING AT INLET

BACKSHORE PROTECTION

- SEAWALL
- PROTECTIVE BEACH
- SAND DUNE
- REVETMENT
- BULKHEAD

HARBOR PROTECTION

- JETTIES
- SHORE- CONNECTED BREAKWATERS
- OFFSHORE BREAKWATERS

INLET STABILIZATION

- JETTIES
- DREDGING

CONSIDERATIONS

Hydraulics
Sedimentation
Control Structure
Maintenance
Legal Requirements
Environment
Economics
Navigation(for harbor pro. and inlet stabil.)

Comparison of effectiveness of Protection Measures

	Advantages	Disadvantages
Seawalls	• Absorb shock of waves • Reduce erosion of shore	• Erosion may lead to collapse of sea wall • Costly
Breakwaters	• Protect coast from high energy waves • Encourage build-up of beach	• Erosion on parts of coast not protected by breakwaters
Groins	• Protect coast from high energy waves • Encourage build-up of beach	• Erosion on parts of coast not protected by groins

Comparison of effectiveness of Protection Measures

	Advantages	Disadvantages
Beach Noursihment	• Improves beach quality • Improves storm protection	• Expensive • Affects marine ecosystem • Requires constant supply of new sand
Planting of mangroves	• Helps trap sediments • Prevents coastal erosion	• Affects investment opportunities in coastal areas
Stabilizing dunes	• Vegetation can be done • Protects coast from sea	• Dunes are easily eroded if vegetation is not present
Growth of coral reefs	• Reduces wave energy • Improves fishing opportunities	-

Types of hard stabilization

- Hard stabilization perpendicular to the coast within the surf zone:
  - **Jetties**—protect harbor entrances
  - **Groins**—designed to trap sand
- Hard stabilization parallel to the coast:
  - **Breakwaters**—built beyond the surf zone
  - **Seawalls**—built to armor the coast

Jetties and Groins

- Jetties are always in pairs
- Groins can be singular or many (groin field)
- Both trap sand upstream and cause erosion downstream

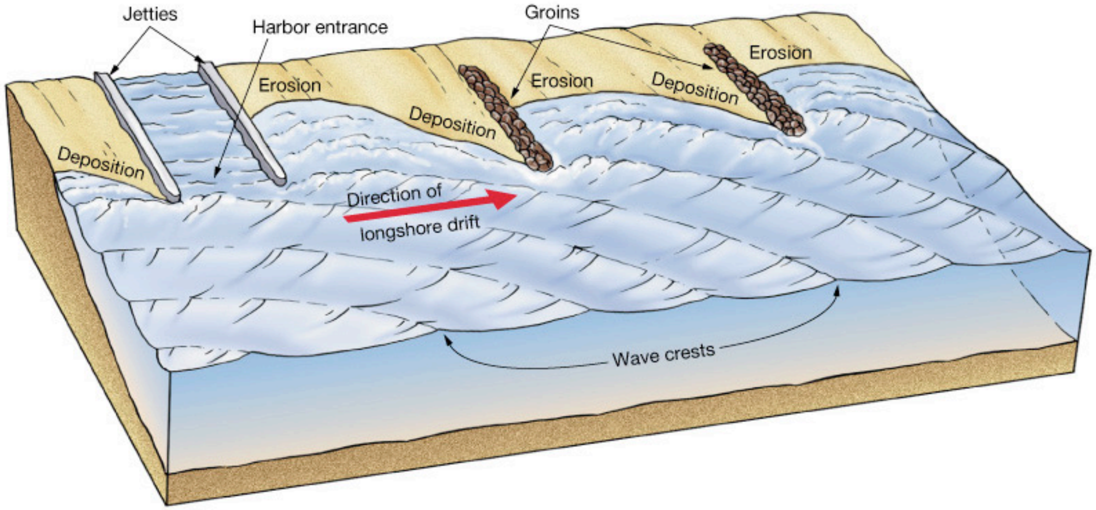


Figure 10-21

Breakwater at Santa Barbara Harbor, California

- Provides a boat anchorage
- Causes deposition in harbor and erosion downstream
- Sand must be dredged regularly

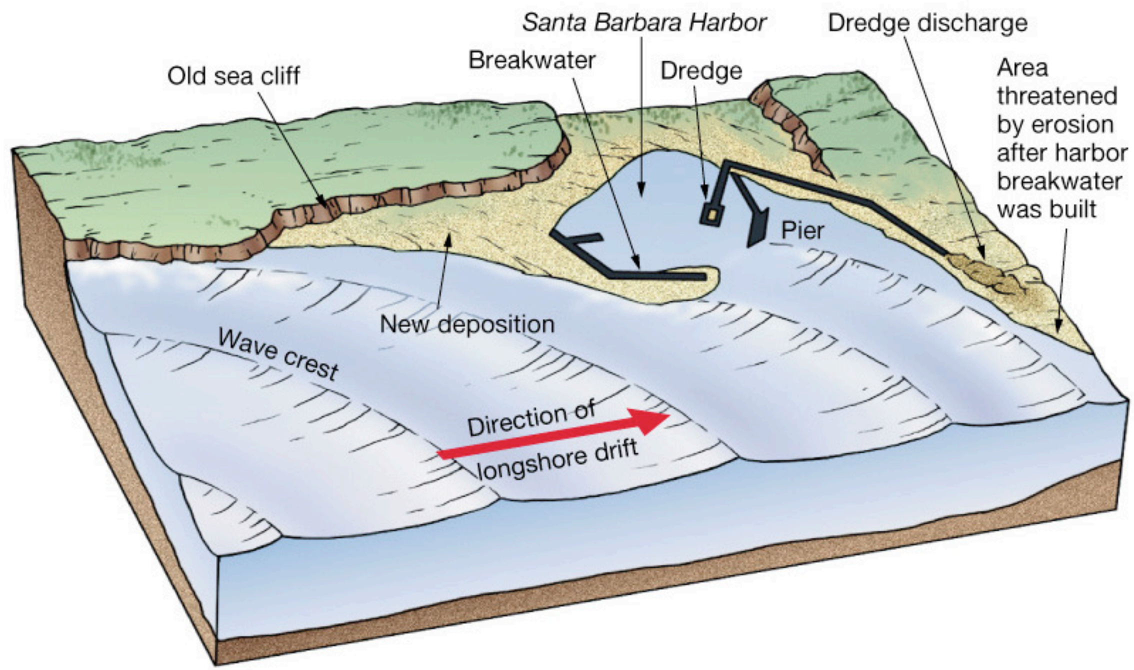


Figure 10-22

Seawalls and beaches

- Seawalls are built to reduce erosion on beaches
- Seawalls can destroy recreational beaches
- Seawalls are costly and eventually fail

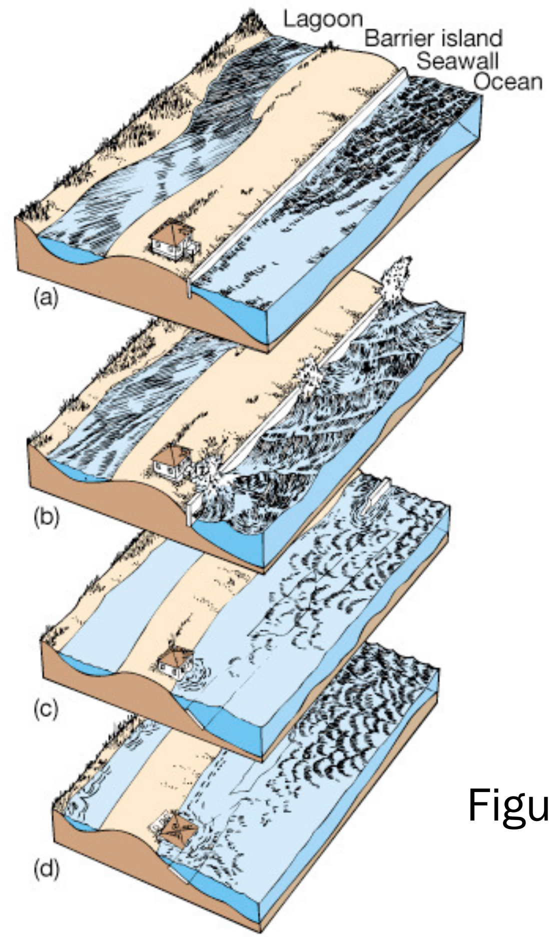


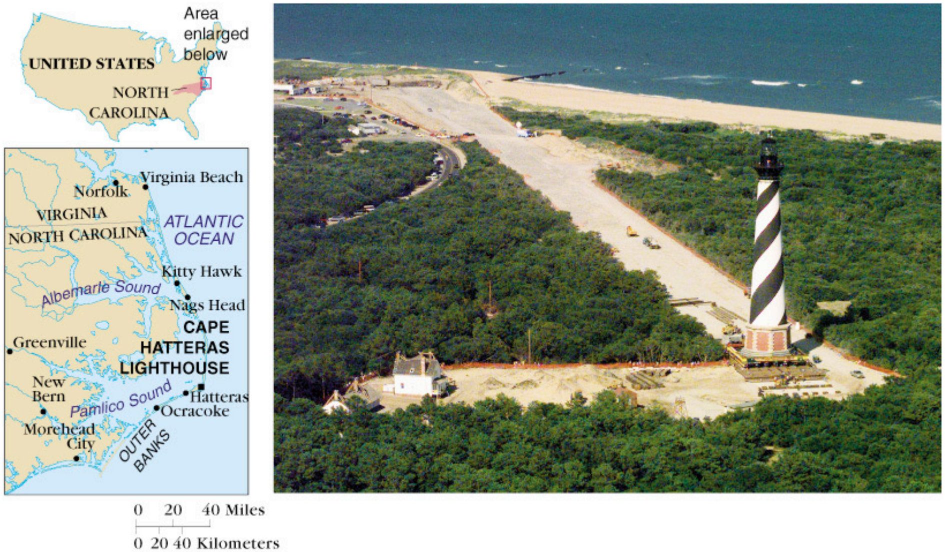
Figure 10-24

Seawall damage in Leucadia, California

Figure 10-25

Alternatives to hard stabilization

- Restrict the building of structures too close to the shore
- Eliminate programs that encourage construction in unsafe locations
- Relocate structures as erosion threatens them



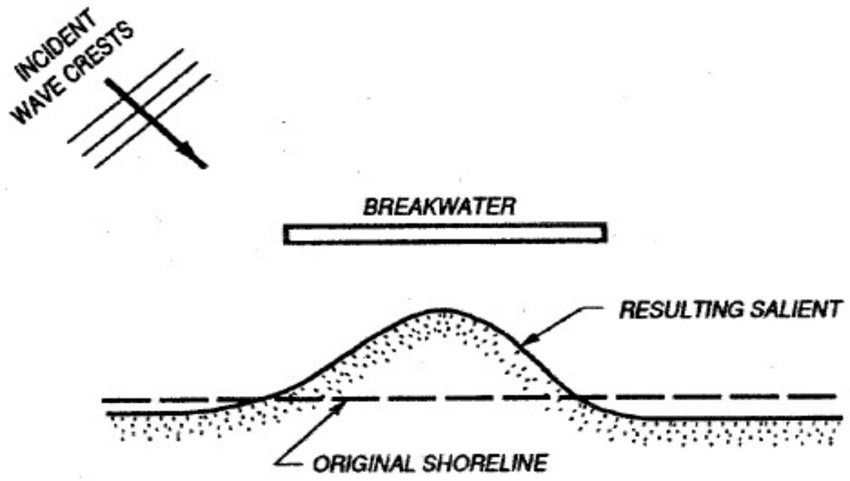
Relocation of the Cape Hatteras lighthouse, North Carolina

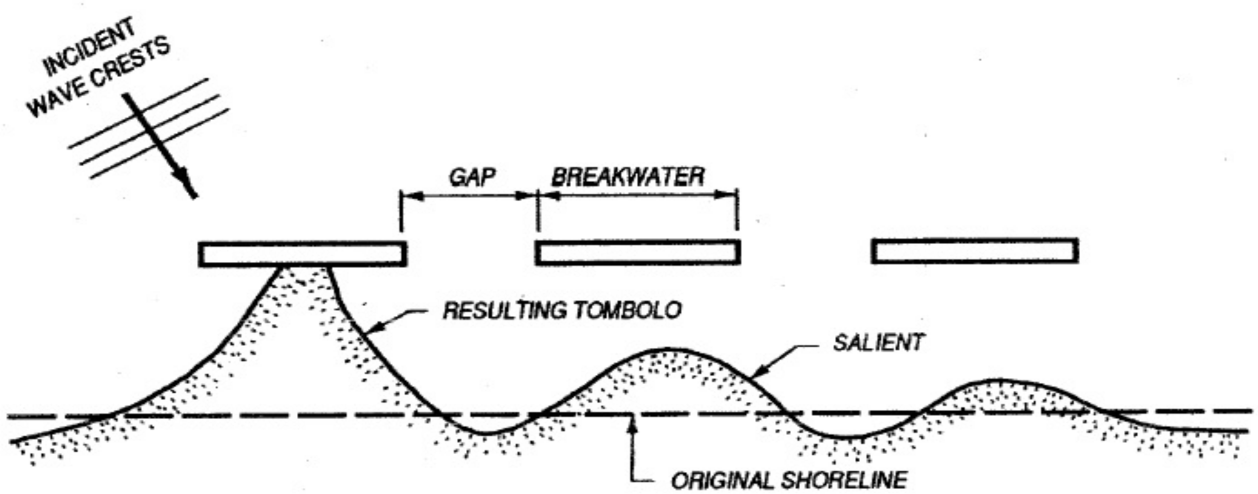
Figure 10C

Coastal Structures

- Break waters: (rubble mound, sheet pile, stone asphalt, Dolos, concrete caissons, floating structures (coastal & offshore))
- Jetties & Groins (normal to the shorelines)
- Sea walls
- Bulkheads, Revetments, G-tubes
- Sand Bypassing (continue the littoral process; passive and active)
- Ports, Harbors and Marinas

Shore Protection Projects-Breakwaters





Shore Protection Projects- Breakwaters

Shore Protection Projects- Breakwaters

Breakwater

Waterway Navigation

Jetties

RUBBLE MOUND BREAK-WATER

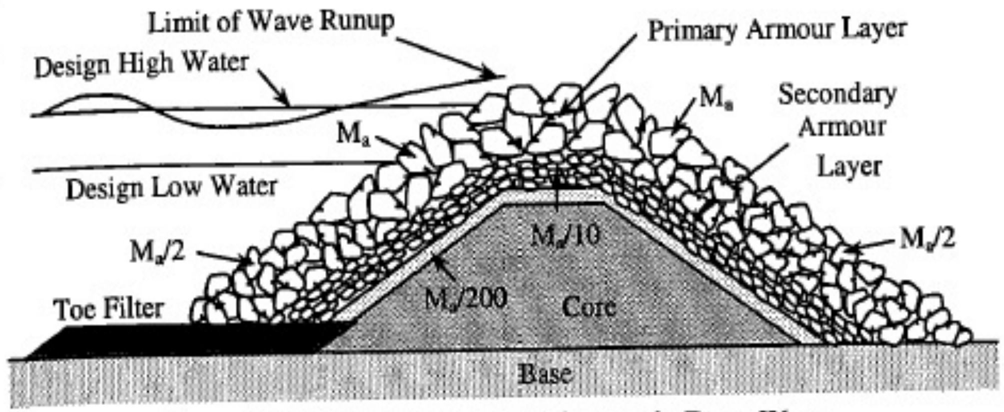


Figure 9.8 Rubble Mound Breakwater in Deep Water (after CERC, 1984)

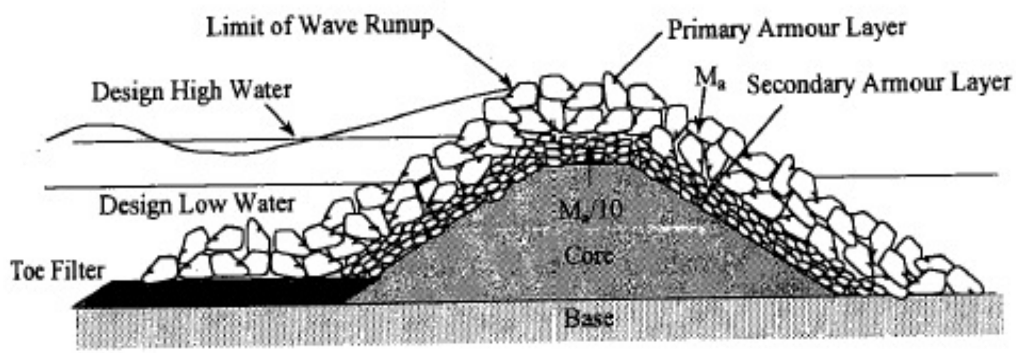
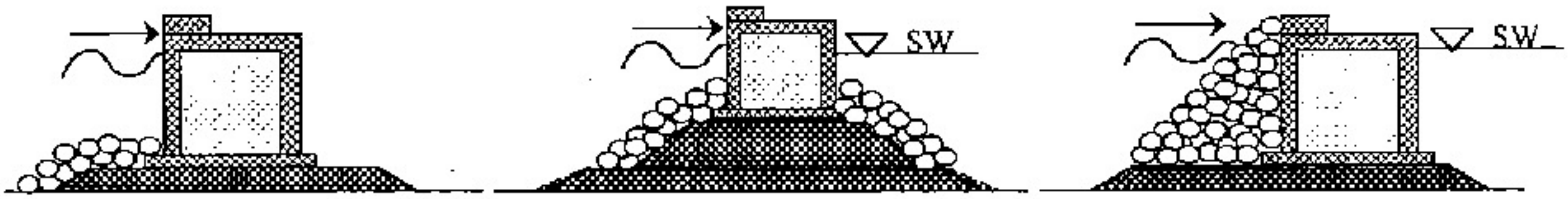


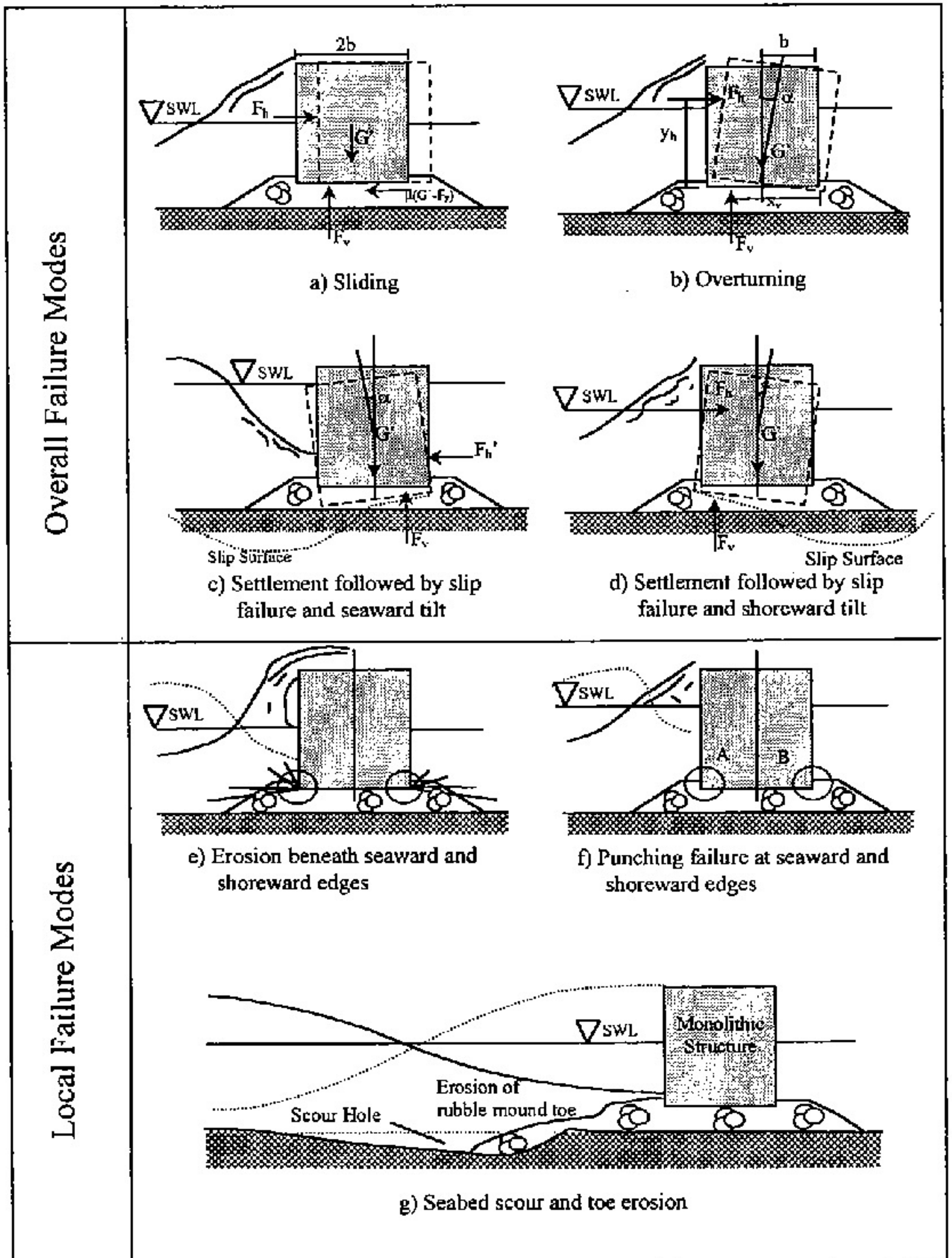
Figure 9.9 Rubble Mound Breakwater in Shallow Water (after CERC, 1984)

VERTICAL BREAKWATER FIGURES

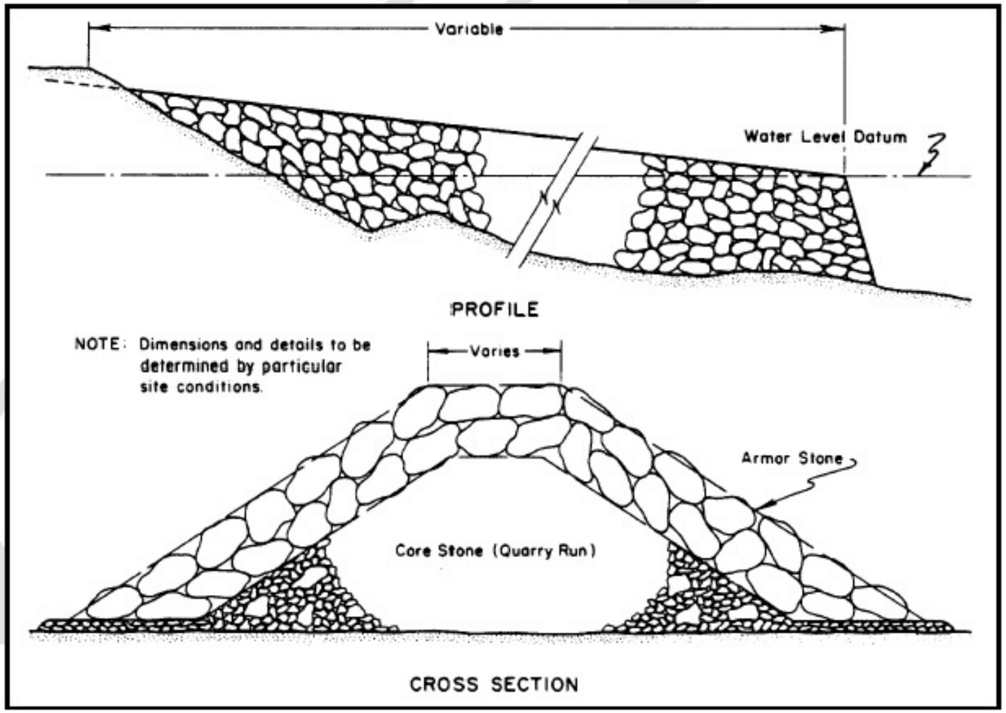


a) Vertical Caisson   b) Composite Breakwater   c) Armoured Caisson

Design Considerations



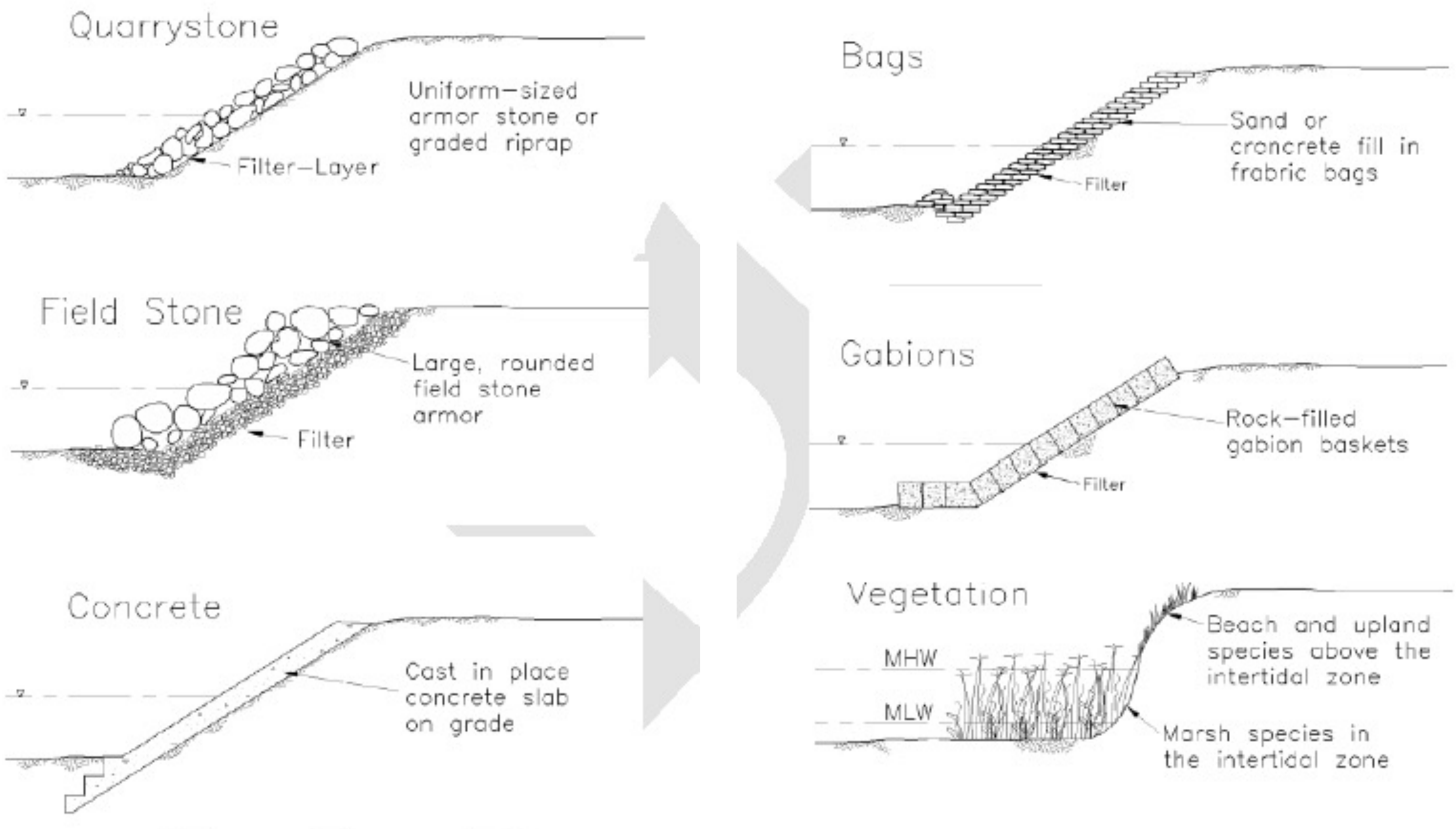
Shore Protection Projects- Groins



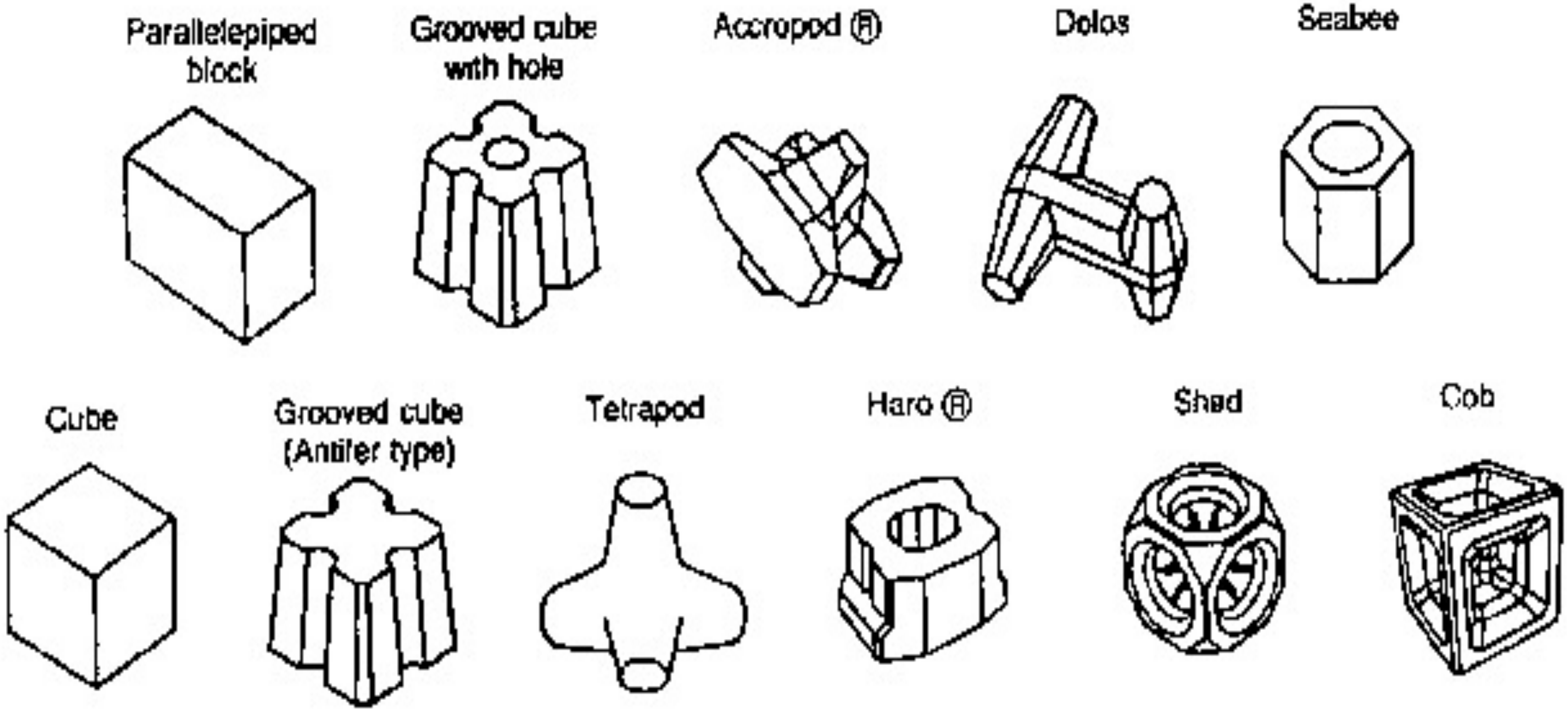
Shore Protection Projects- Groins

Shore Protection Projects- Groins

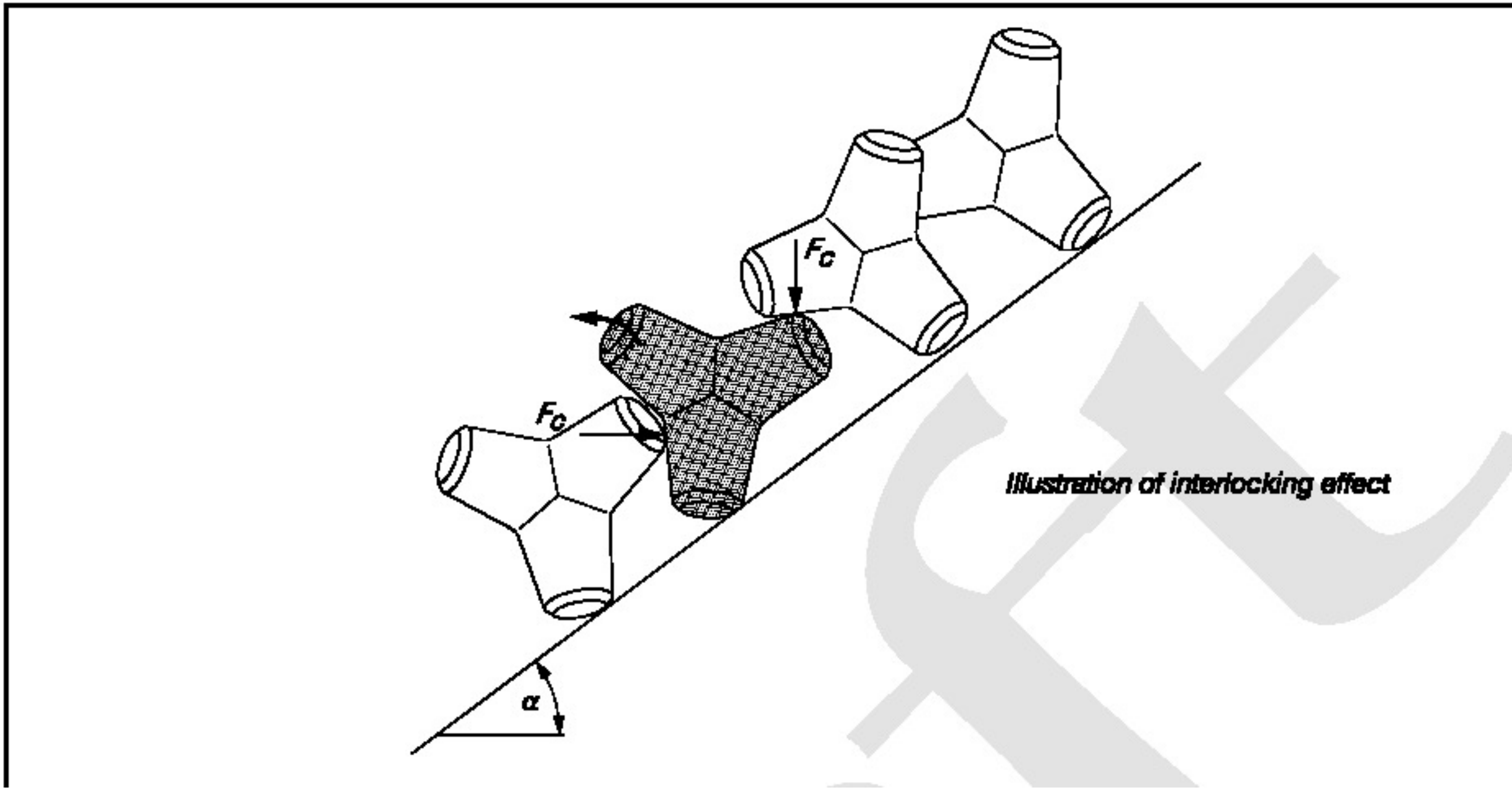
Shore Protection Projects- Revetments



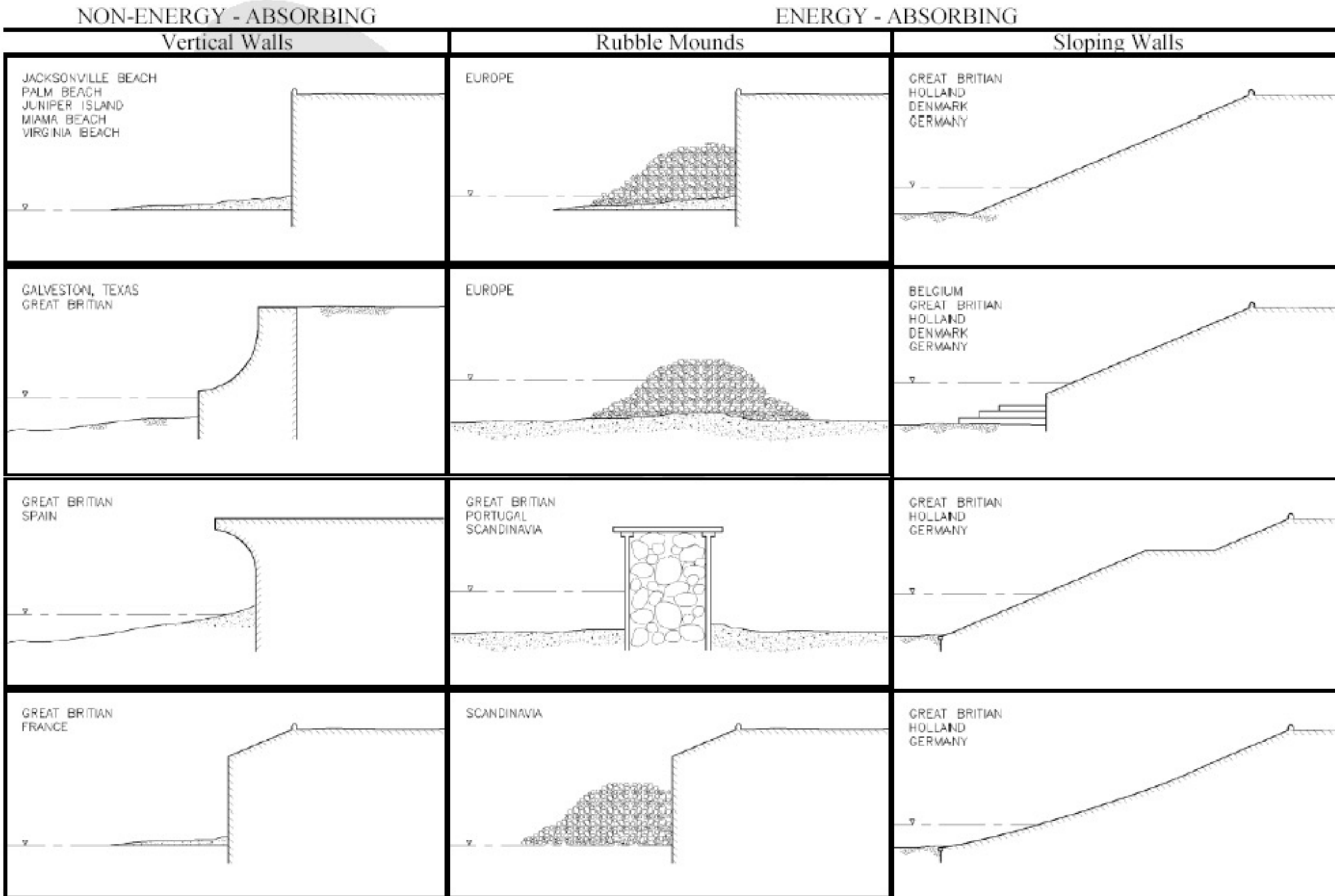
Different Kinds of Dolos
Concrete & Reinforced Concrete



Dolos



Various Sea Walls



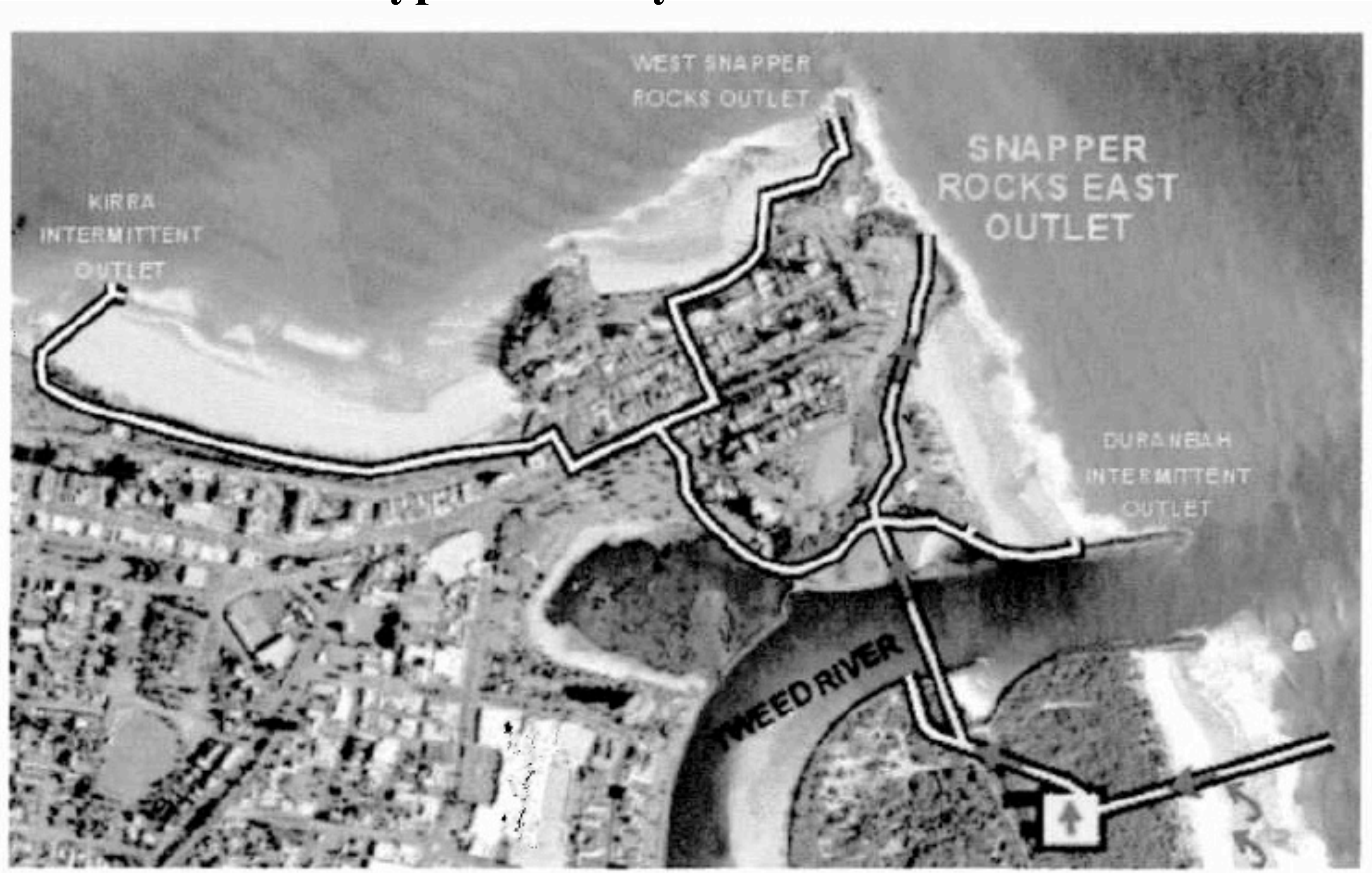
Shore Protection Projects - Seawalls

Construction of Galveston seawall ~ 1902

Ports and Harbors

Ports and Harbors

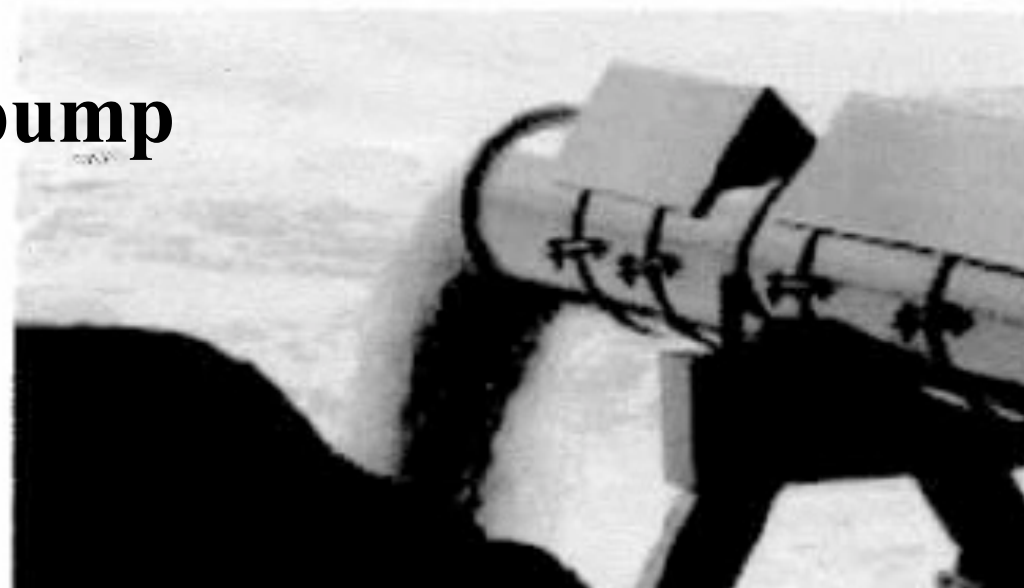
Sand Bypass Facility



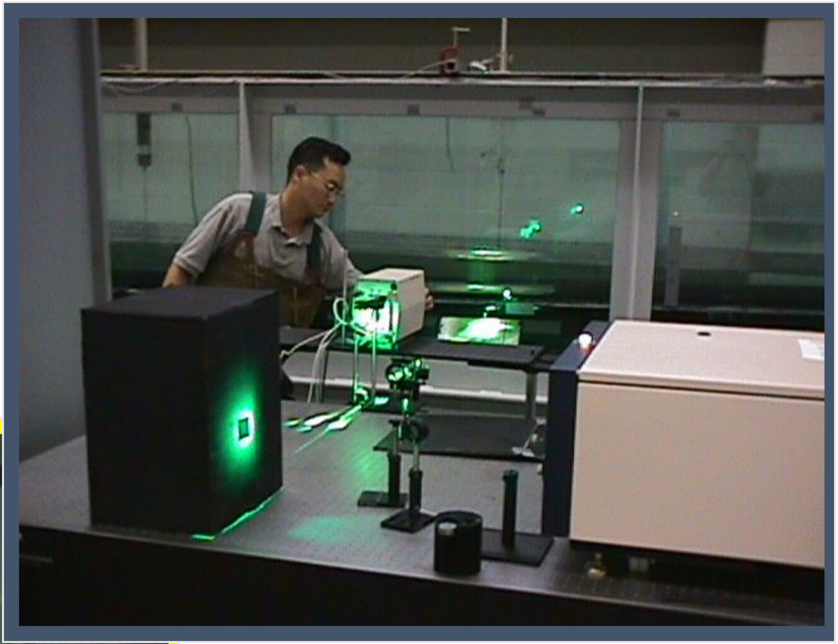
New South Wales and Queensland, Australia

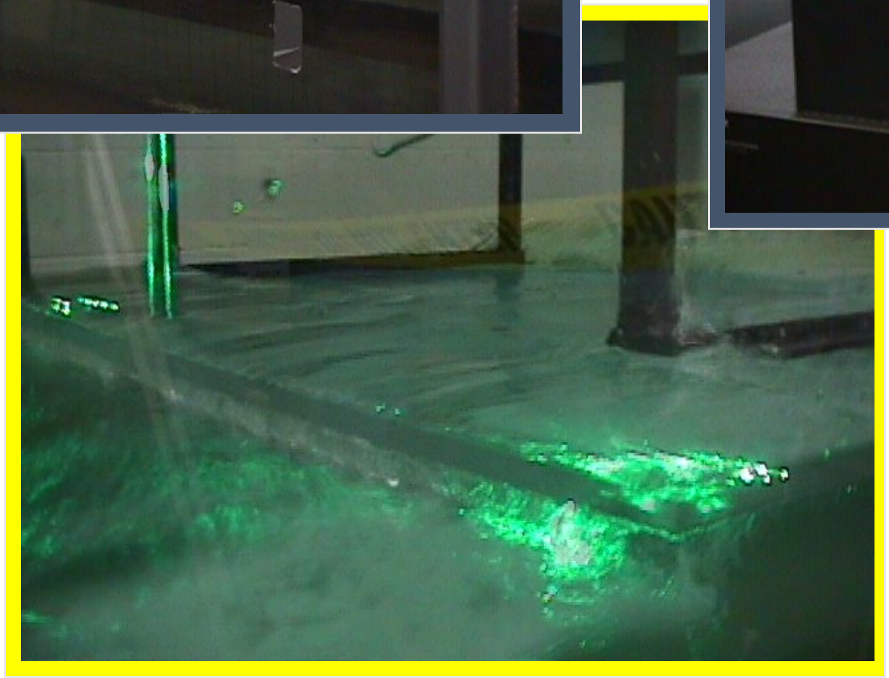
Jetties at the entrance of Tweed River

Outlet of the sand pump



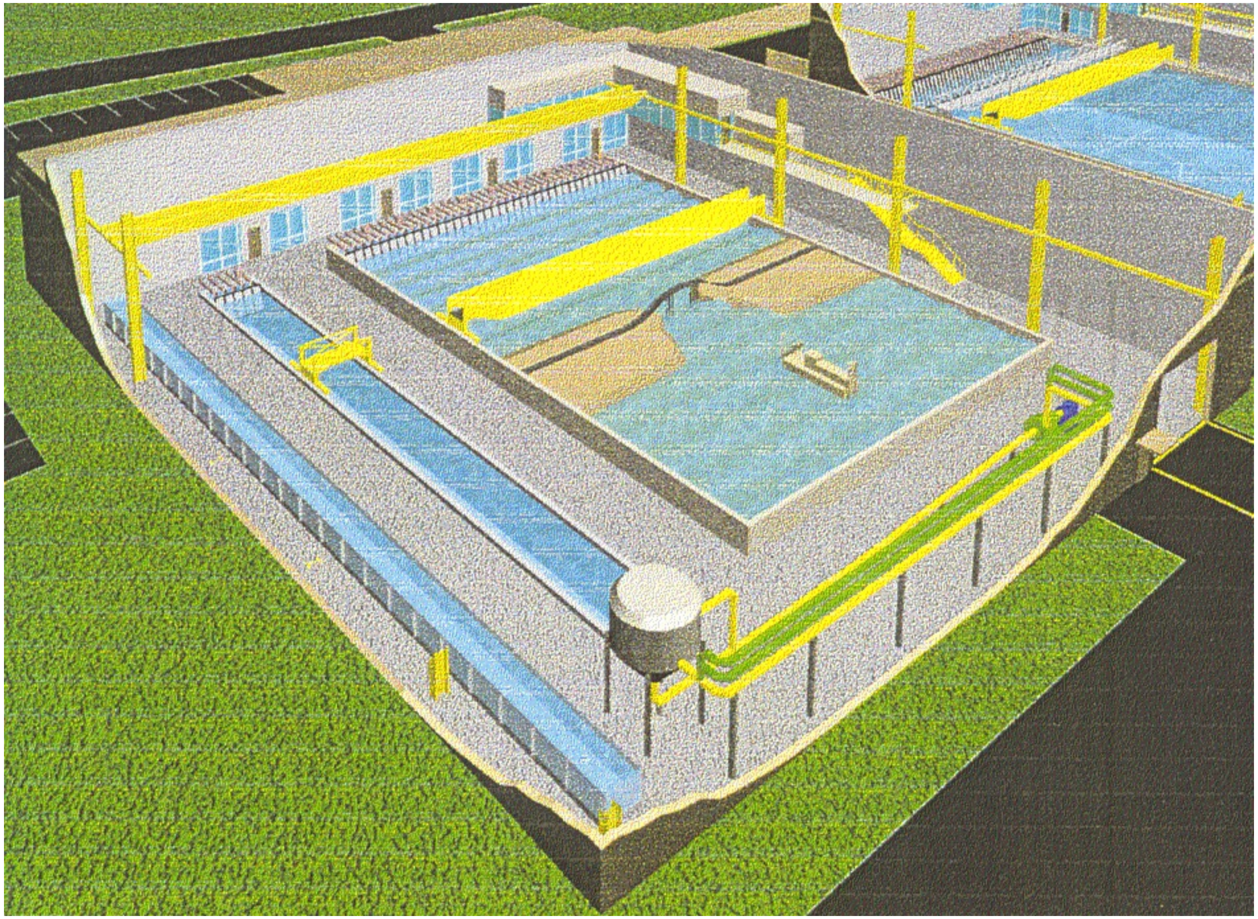
Laboratory Research





Research Experience for Undergraduates (REU) Program

Haynes Coastal Engineering Laboratory



COASTAL DEFENCES
Some methods used in areas of weak rocks in Britain and France

- There are many techniques used for reducing the power of waves before they erode a coastline.
- Rip-rap is a sheet of boulders used at the toe of a slope to add weight and break the force of the waves. Rip-rap is made of resistant rocks, often gabbro, dolerite, granite or gneiss, which will not weather or break down. Because the blocks are angular, they fit together tightly, but still allow water to drain through back to the sea.
- Concrete walls are usually slightly curved at the top so that waves are deflected slightly so that water is returned to the sea. They may have drainage holes so that any water which overtops the wall can drain back into the beach.

COASTAL DEFENCES

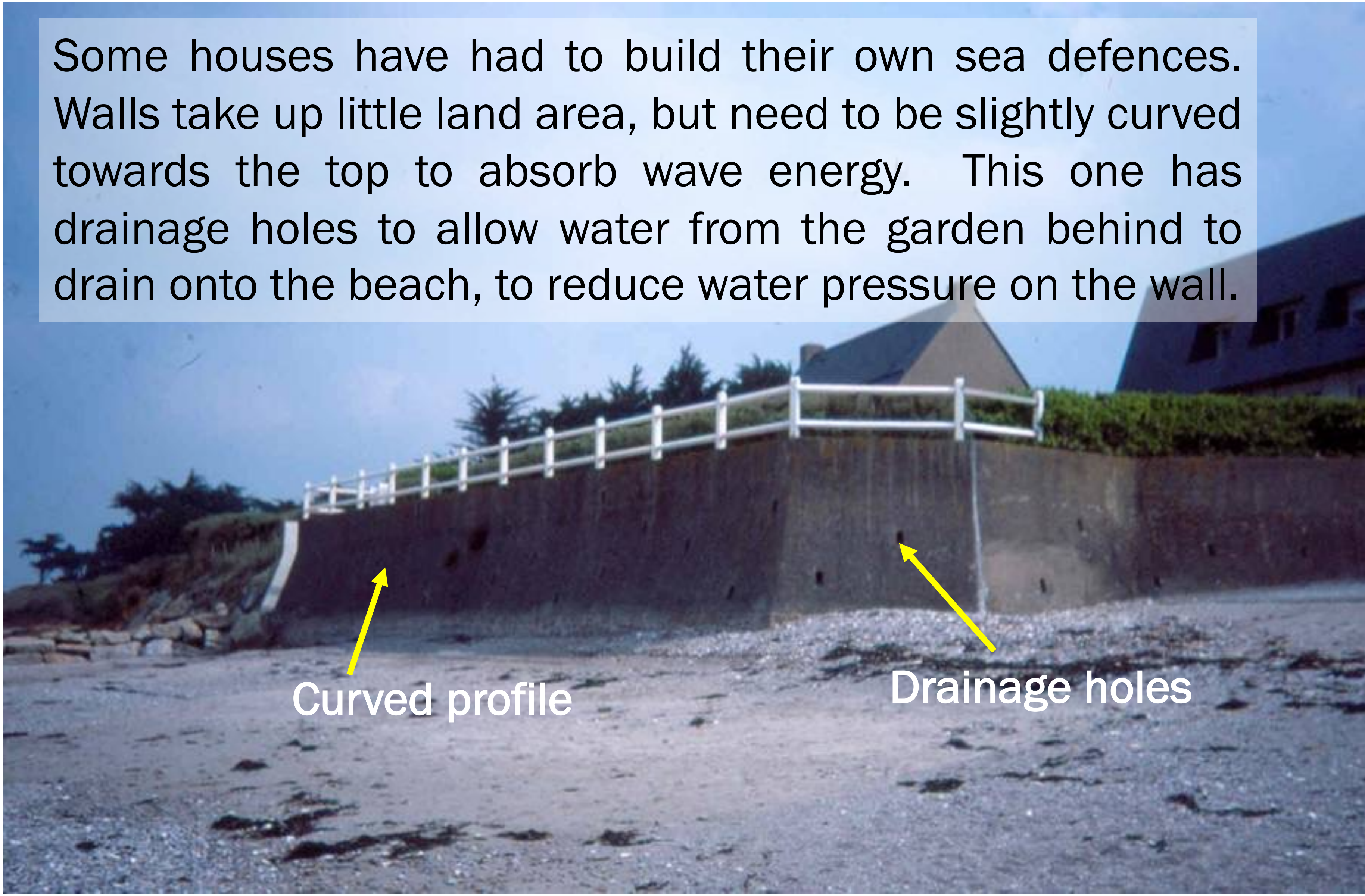
- Concrete shapes can be arranged to nest together so that they are wedged tightly enough not to be moved by large waves. They allow water to drain back to the beach and also allow sand to build up around them, which helps to stop sand from washing out to sea.
- Geotextiles can fix slopes which have been reduced in angle and encourage vegetation to grow back. Marram grass grows in pure sand, has very long roots and can cope with waves and dry conditions.
- Offshore breakwaters break the force of the waves and ensure that wave energy is dispersed. They also allow the build-up of sand in the low energy areas next to the shore.

Le Croisic, Brittany

This coastline is made of schists which are very unresistant and easily eroded by the sea.

The houses are protected from the sea by rip-rap - large boulders of resistant rock brought from outside the area. They absorb the energy of the waves but are permeable so that water can drain through them back to the sea.

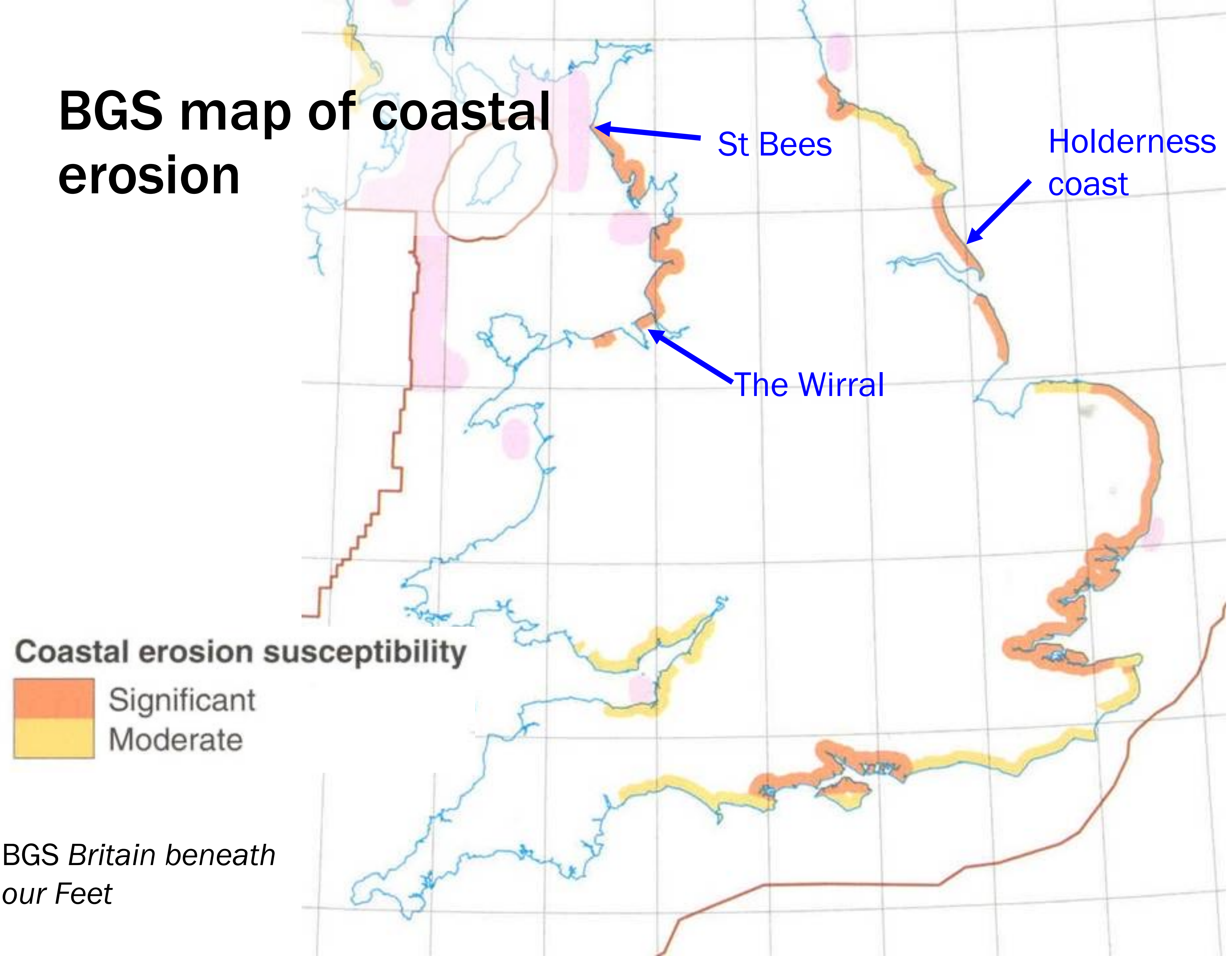
Some houses have had to build their own sea defences. Walls take up little land area, but need to be slightly curved towards the top to absorb wave energy. This one has drainage holes to allow water from the garden behind to drain onto the beach, to reduce water pressure on the wall.



Le Croisic, Brittany

The part of the coast was in the process of being reinforced with a wall of rip-rap. Beyond the wall was a grassy area with geotextiles and plants to reduce further the force of the waves.

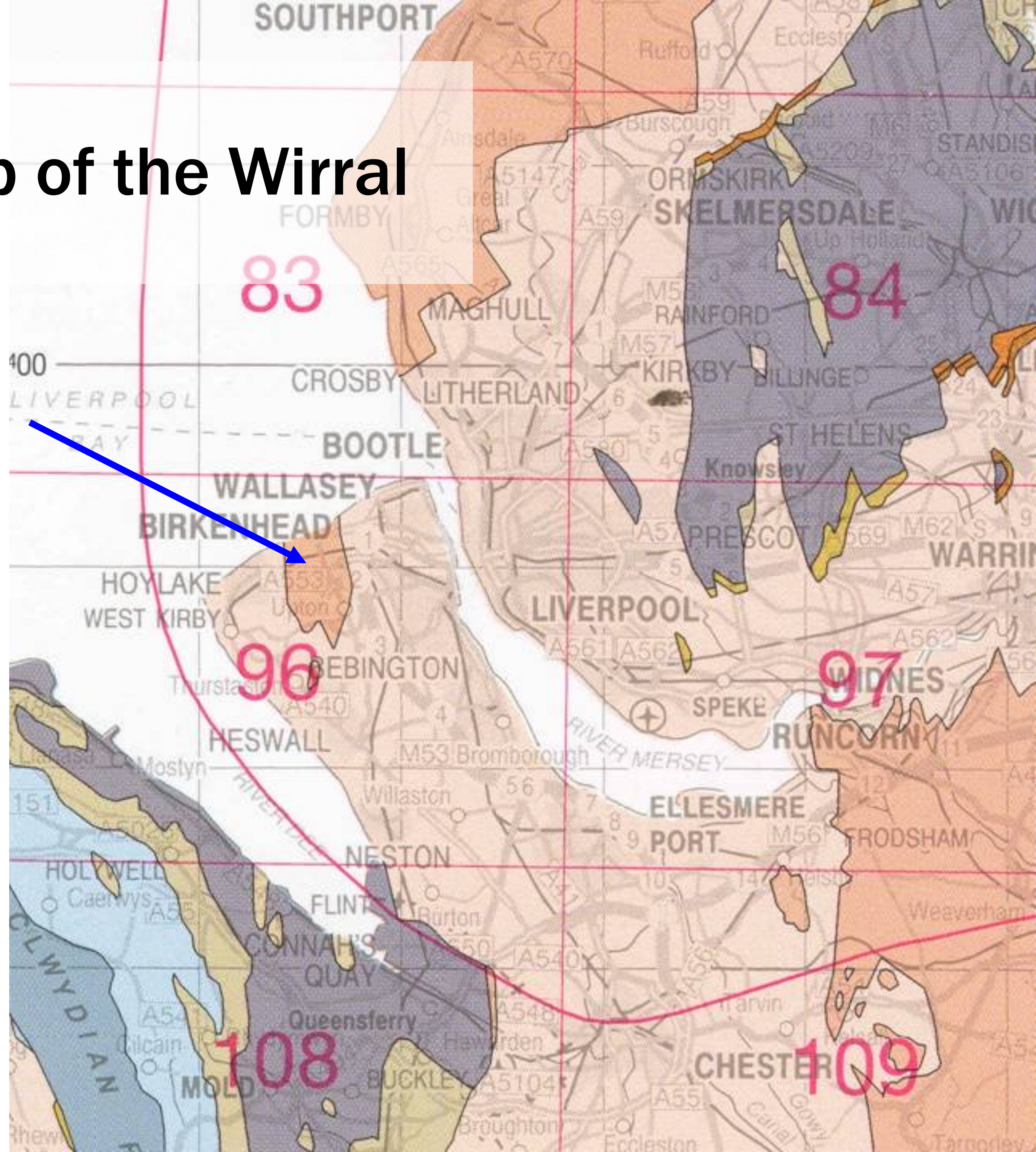
BGS map of coastal erosion



BGS *Britain beneath our Feet*

Geology map of the Wirral

The Wirral is made of Triassic and Permian red desert sediments, covered by glacial till. Both rocks are very susceptible to marine erosion.



The Wirral

Most of the sea-defences consist of corrugated concrete slabs. They are ridged to absorb energy and slow the swash and backwash. They are in slabs, rather than continuously poured concrete, to allow replacement of any damaged section.

The Wirral

Access for visitors to the beach is down gently sloping ramps, which are also designed to allow water to return easily to the sea if waves break over the top of the banking onto the pathway.

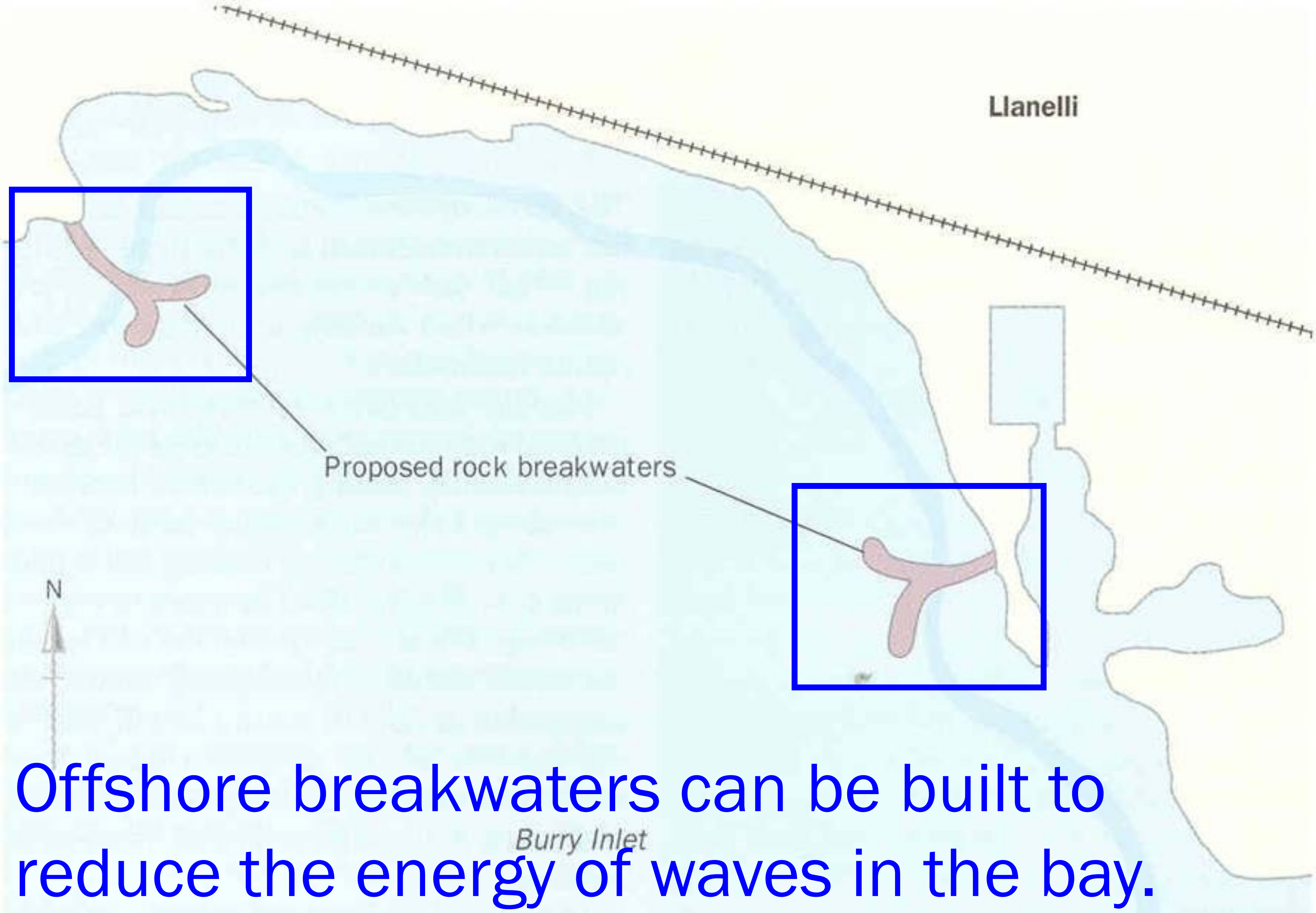
The ramps are also supported by shaped concrete blocks which cause the waves to break early. The swash and backwash can move in a controlled way up and down the banking.

The Wirral

Interlocking concrete blocks which absorb wave energy are used in places, and are strong, cheap and effective. The path beyond the coast is additionally protected by rip-rap.


RIP-RAP
Sand has been encouraged to build up around the rip-rap to produce additional weight and support vegetation, which absorbs more energy.


The old sea-wall is sculptured to reflect the waves back to the sea.

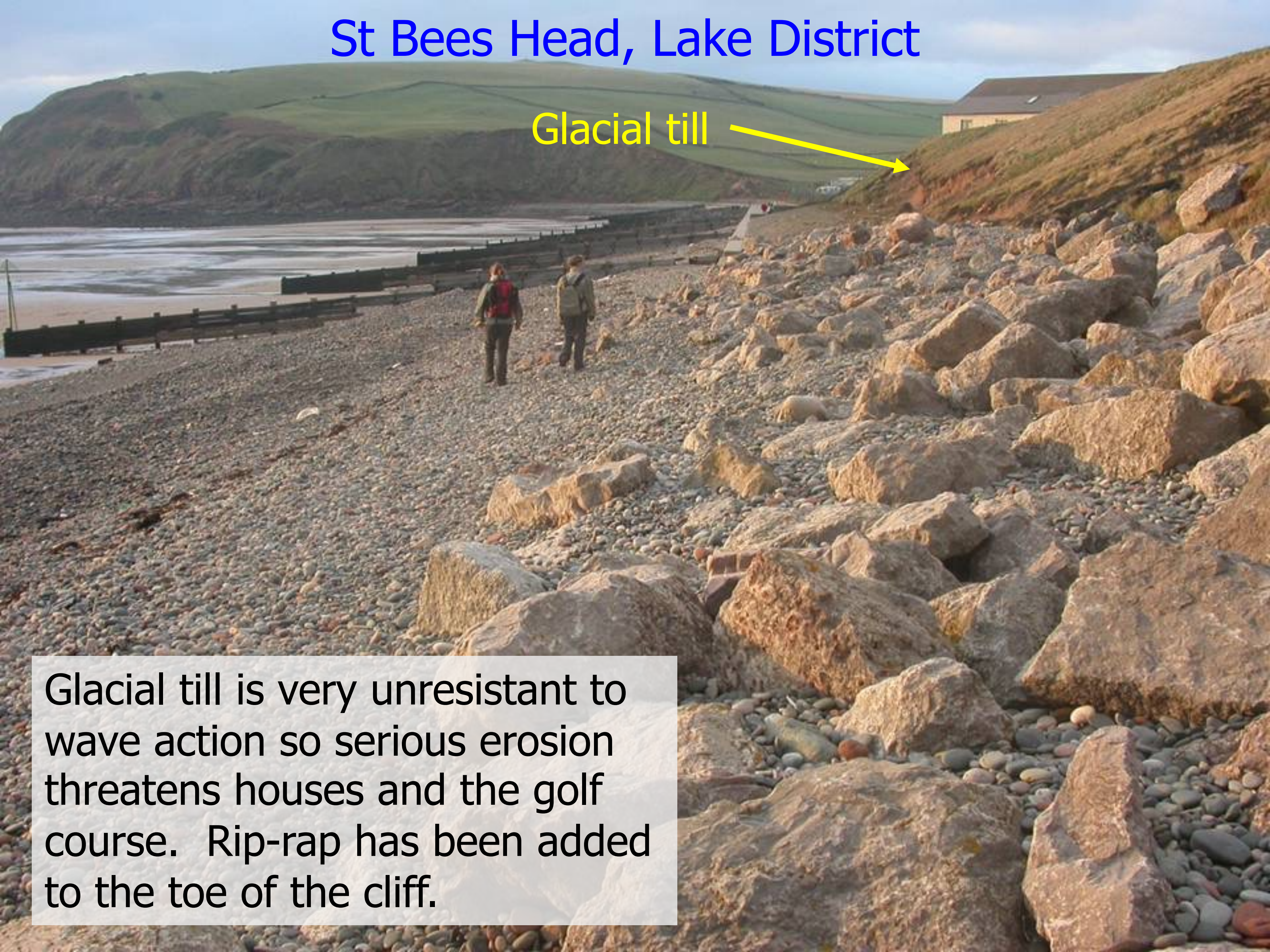


Offshore breakwaters can be built to reduce the energy of waves in the bay.

Figure 3 Option 3: two new rock breakwaters.

Offshore breakwaters reduce wave energy and help sand to build up to protect the coast.

St Bees Head, Lake District



Glacial till is very unresistant to wave action so serious erosion threatens houses and the golf course. Rip-rap has been added to the toe of the cliff.


St Bees Head, Lake District
Glacial till cliffs
Slope angle has been reduced
Rip-rap
Geotextiles help to support the glacial till slope so that vegetation can establish itself.

The Holderness coast from Bridlington to Spurn Point is made from Pleistocene glacial till, which is very unresistant to marine erosion and mass movement slope processes.

Glacial till cliffs suffering undercutting at high tides and in storms.

There are various types of coastal defences along the 50km length of the Holderness coast.


A great variety of sea defences have been used here, just south of Withernsea, near Spurn Point.
Concrete walls stretching half the height of the cliff
Breakwaters
Glacial till slumps are protected by rip-rap.
Breakwaters supported by large boulders
The land-use at the top of the cliff is a caravan site. The caravans can be moved backwards if they are threatened by undercutting.