Strategic Alternatives For Coastal Protection : Multipurpose Submerged Reefs

11th Meeting of the Coastal Protection and Development Advisory Committee (CPDAC)

Chennai, 4th January, 2010

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In the News

New coastal policy threatens beaches

The livelihood of the fishermen and an entire stretch of coastline in Tamil Nadu is under threat.

New Chennai bridge displeases ecologists

If the Tamil Nadu government has its way, Chennai could have an elevated corridor from the Light House to the East Coast Road.

Gujarat's mangroves under threat

Gujarat, the state which has India's longest coastline is home to one of the country's largest ports and special economic zone.

India's dying beaches

A study conducted recently by the National Institute of Oceanography, Goa, says that 23 per cent of India's shoreline is getting eroded.

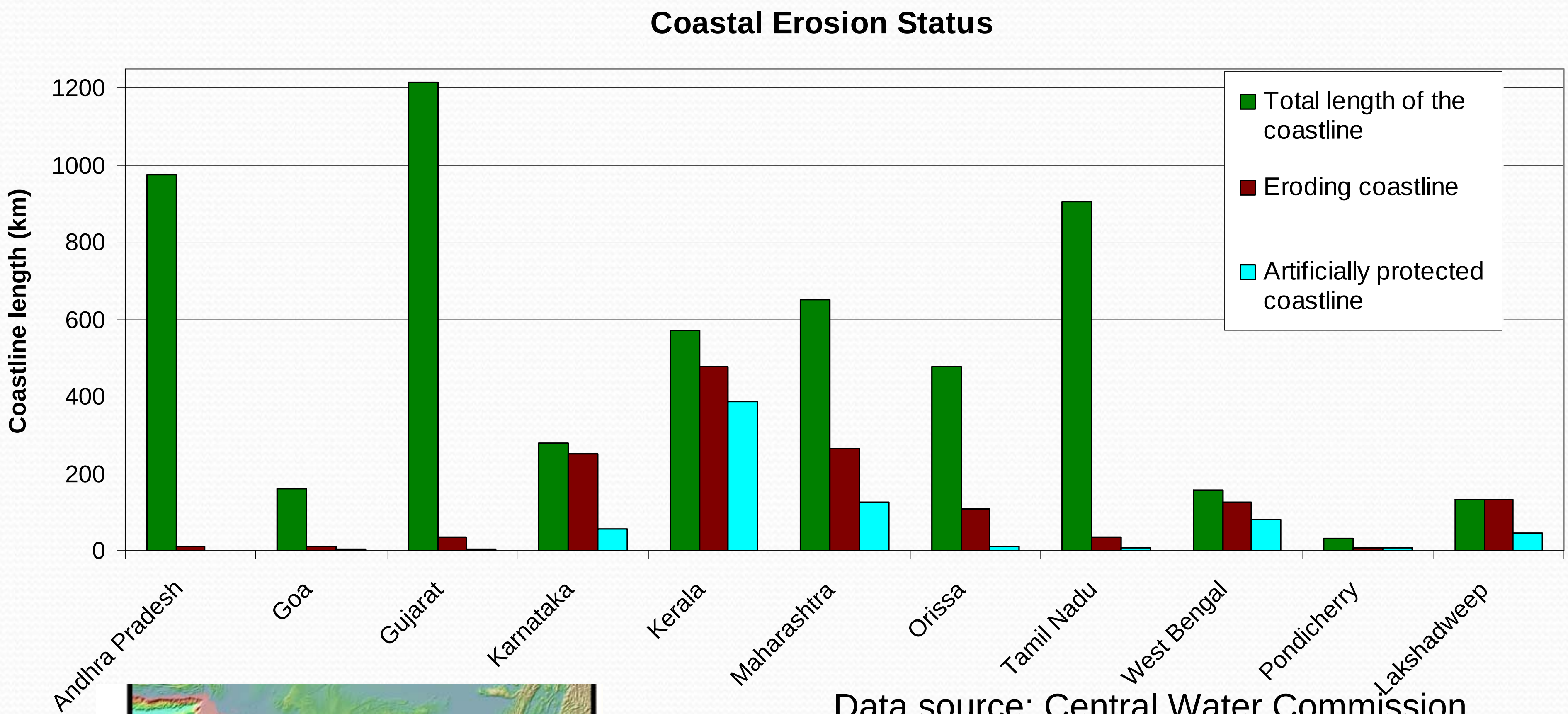
The death of India's beaches

It's being called one of the biggest disasters India's environment is facing. Our beautiful beaches are being killed.

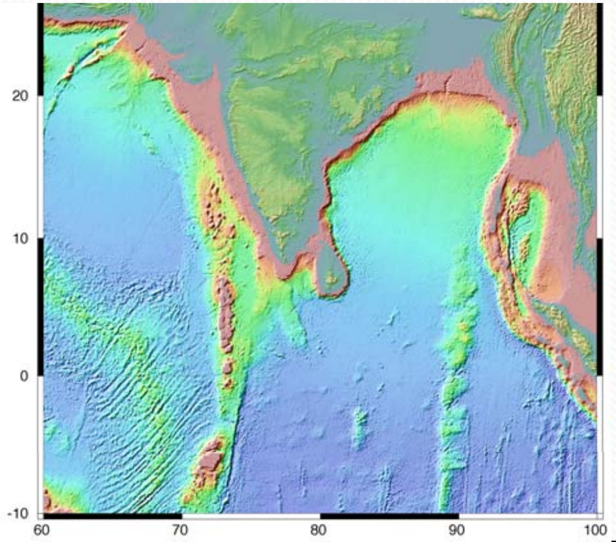
Coastal erosion : Indian scenario

(National Coastal Protection Project Proposal)

- About 1380 km of Indian coastline (excluding Andaman and Nicobar Islands), faces serious impact , i.e. 25 % of the 5,550 km
- Most of the impact zones are actively retreating, some of them in spite of coastal protection works.
- About 625 km of the coastline are protected by hard structures (seawall or groyne)
- Another 728 km is in need of protection
- Amount spent for coastal protection so far is over Rs. 400 crores
- Annual loss due to coastal erosion is estimated to be over Rs 575 crores
- Area lost or seriously impacted by erosion is estimated to be about 450 Ha per year



Data source: Central Water Commission




SAVE BEACHES
HELP PEOPLE

The List: Coastal Protection Options

'Traditional'

- Seawalls
- Groynes
- Bulkheads
- Detached Breakwaters

"What's driving the changes in preference to coastal protection options?

'Modern'

- Dune Restoration
- Submerged Breakwaters/Reefs
- Nourishment
- Bypassing/Circulation
- Hybrid Solutions

- Values
  - Amenity
  - Aesthetics
  - Understanding
  - Economics
  - Sustainability
  - Legislation

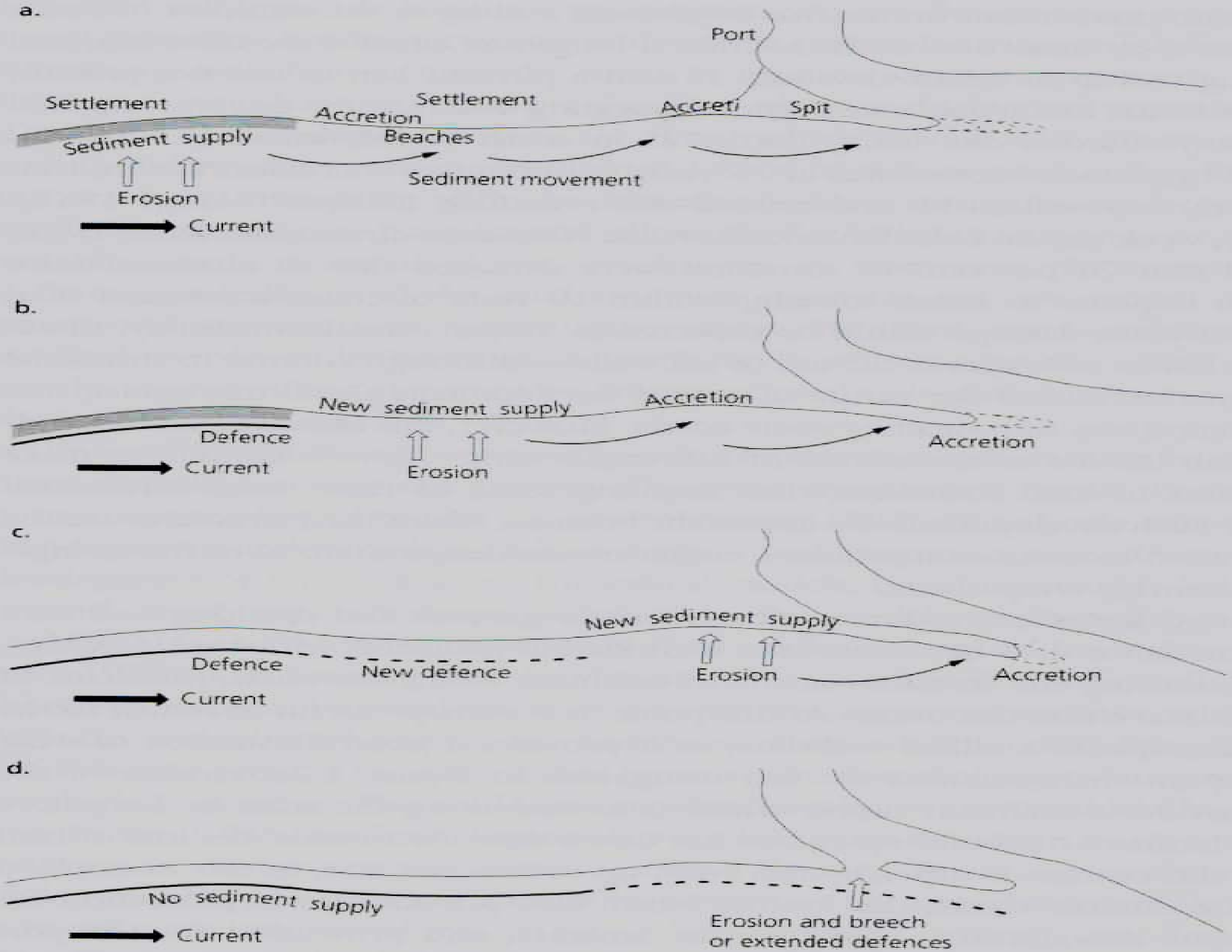


Figure 1.2 Progressive erosion scenario for defended coasts. As more defences are added to prevent erosion, so focus of that erosion is transferred along coast (After French 1997).

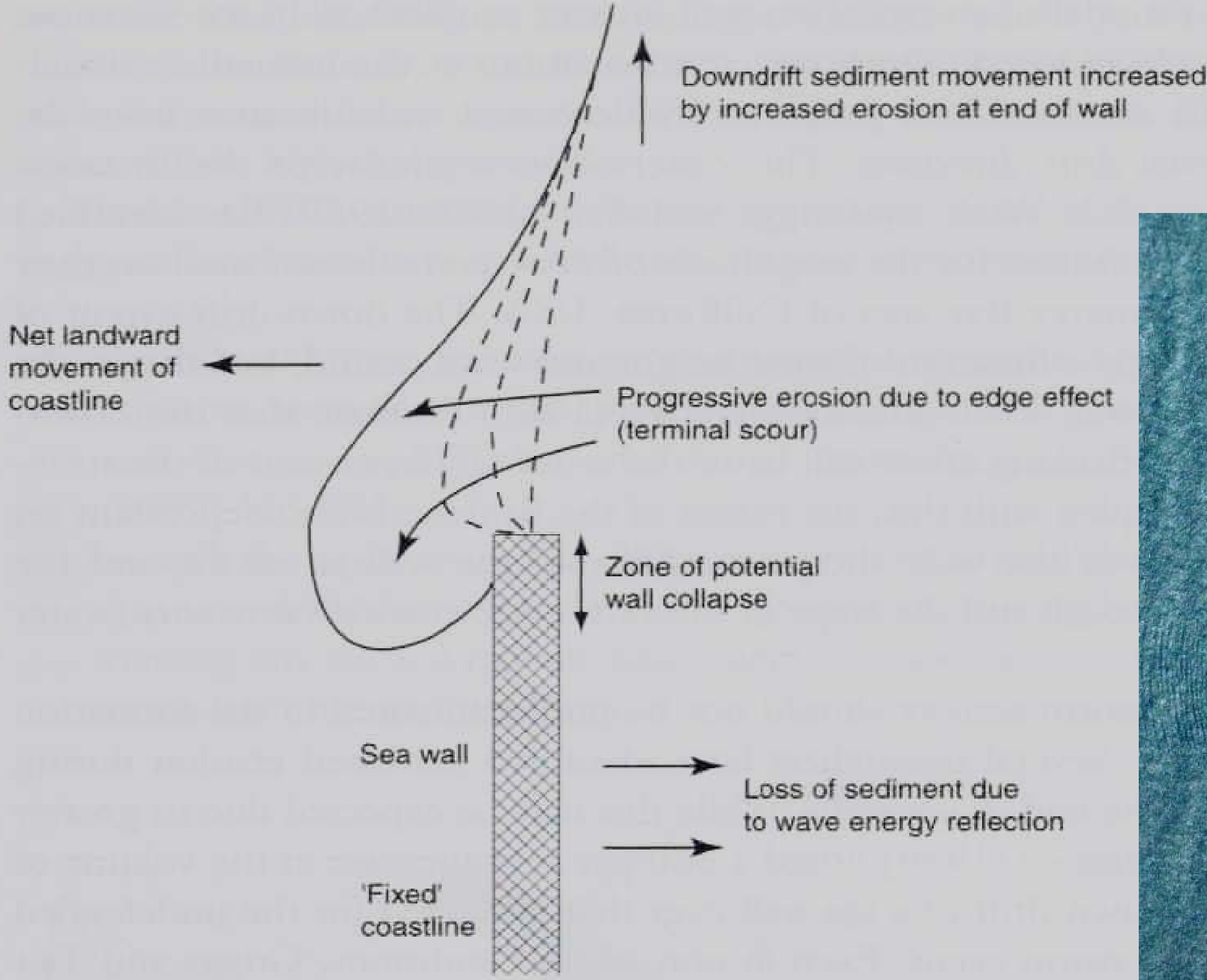
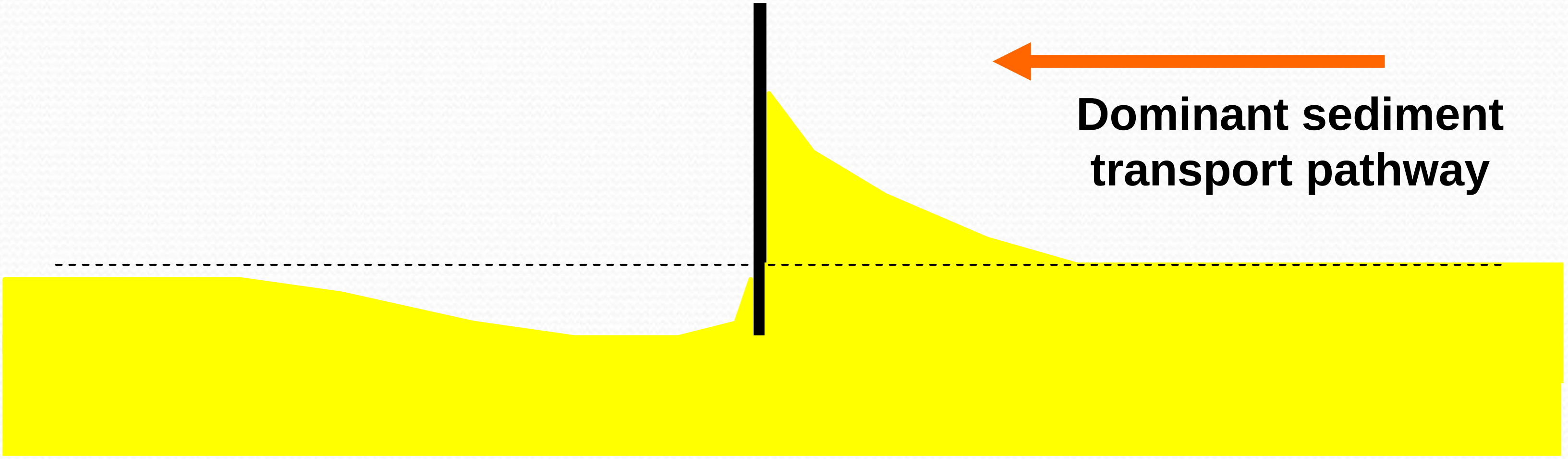


Figure 3.2 Typical end effects (terminal scour) associated with a sea wall. Note the scour which removes support from end of structure and leads to undermining at end of wall.

Groynes - Function

Are effective where alongshore sediment transport is dominant

Function by 'trapping' sediment moving along the coast – they mimic natural headlands

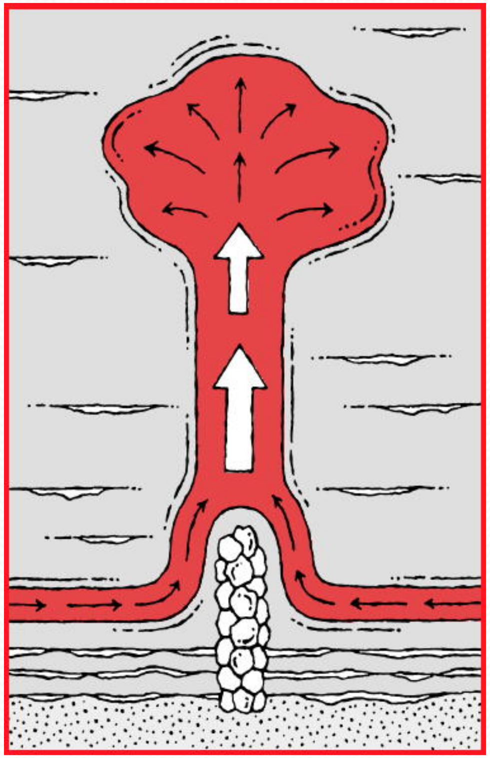


Groynes

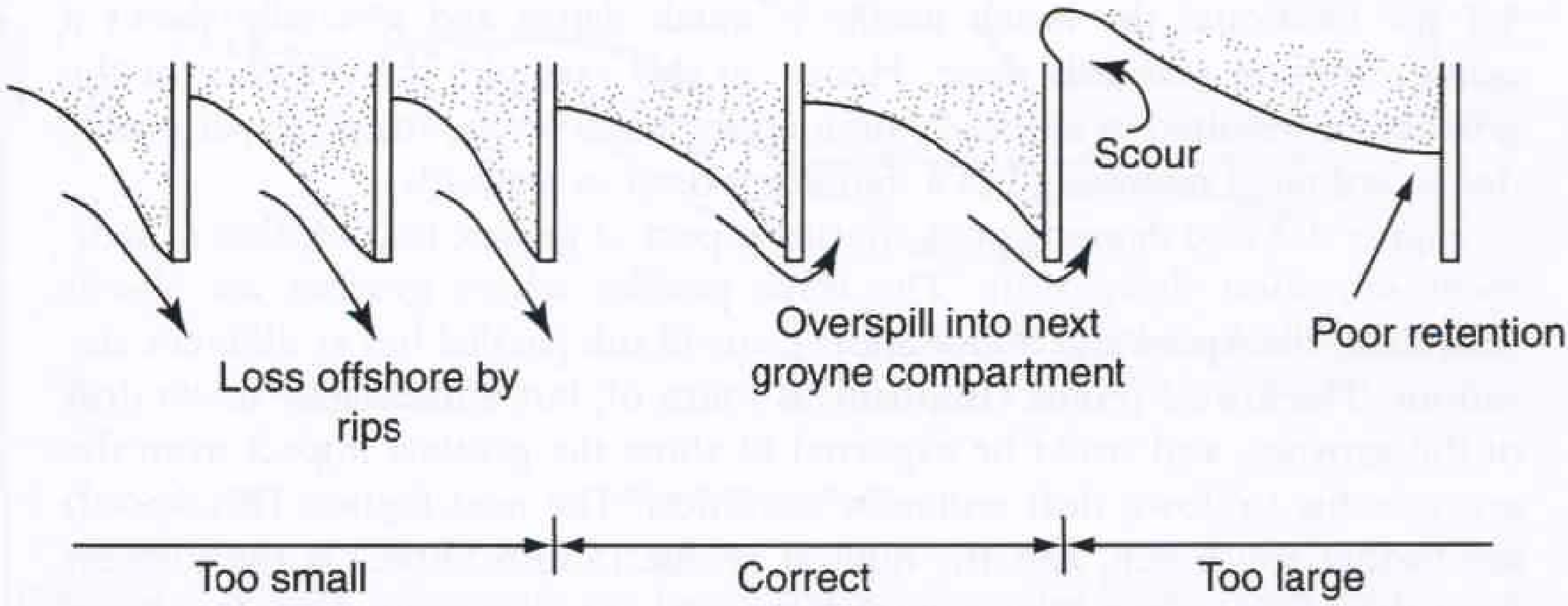
Downcoast impacts can be reduced by continuous groyne-fields within a littoral cell or decreasing consecutive groyne length, ‘tapering’.

Poole Bay, England – 60 groynes in 19 miles

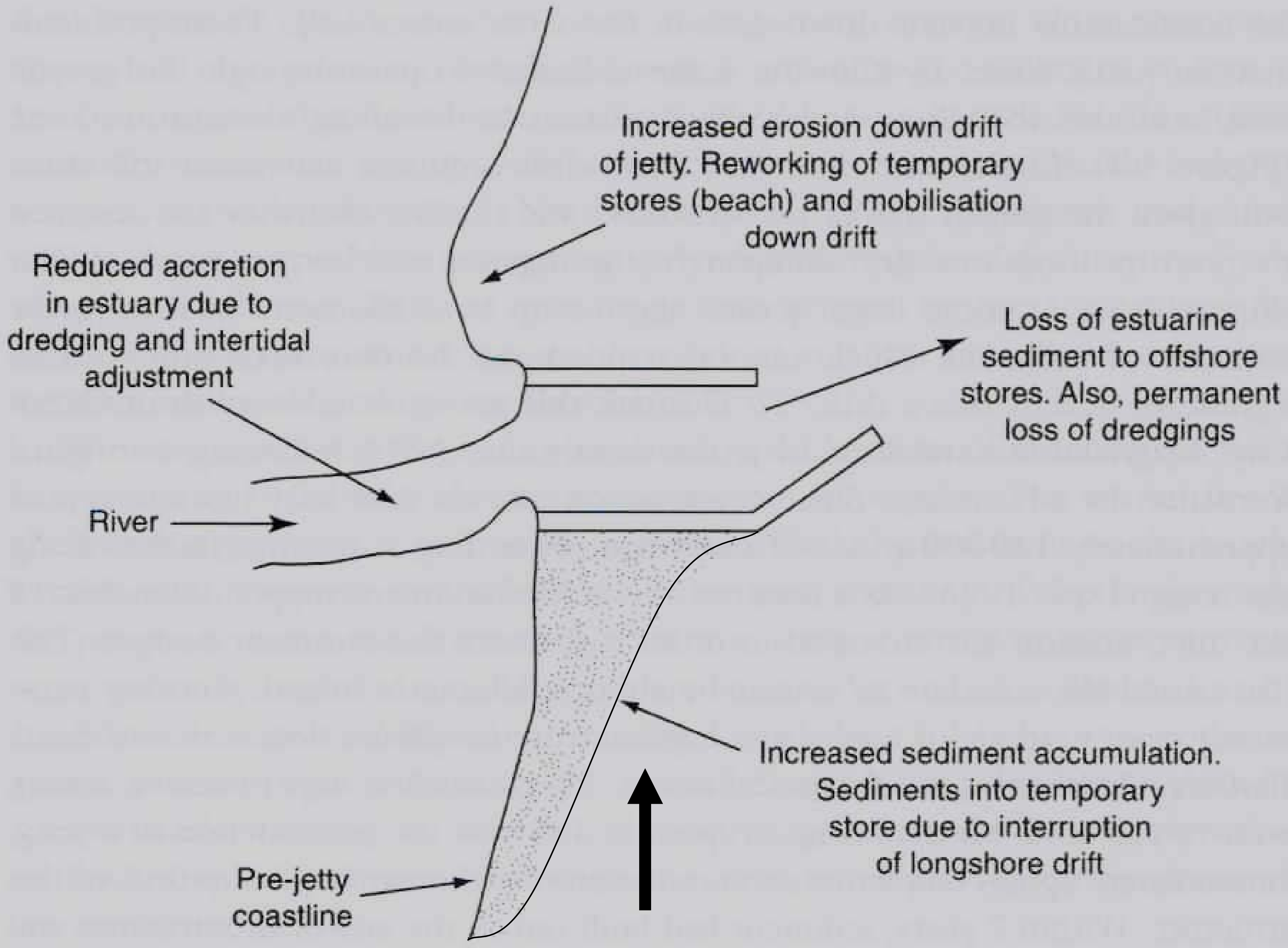
Can impact negatively on swimming safety, aesthetic and alongshore beach access



Are ineffective at preventing cross-shore sediment transport and can increase the loss of beach sand.


Scour
Loss offshore by rips
Overspill into next groyne compartment
Poor retention
Too small
Correct
Too large

Impacts of jetties on sediment budget



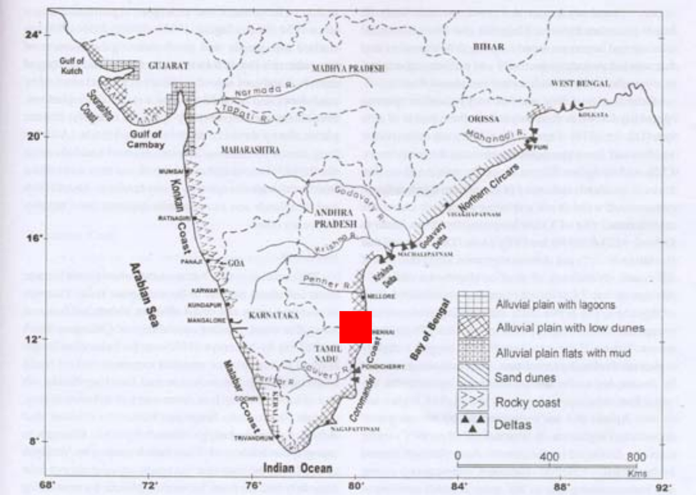
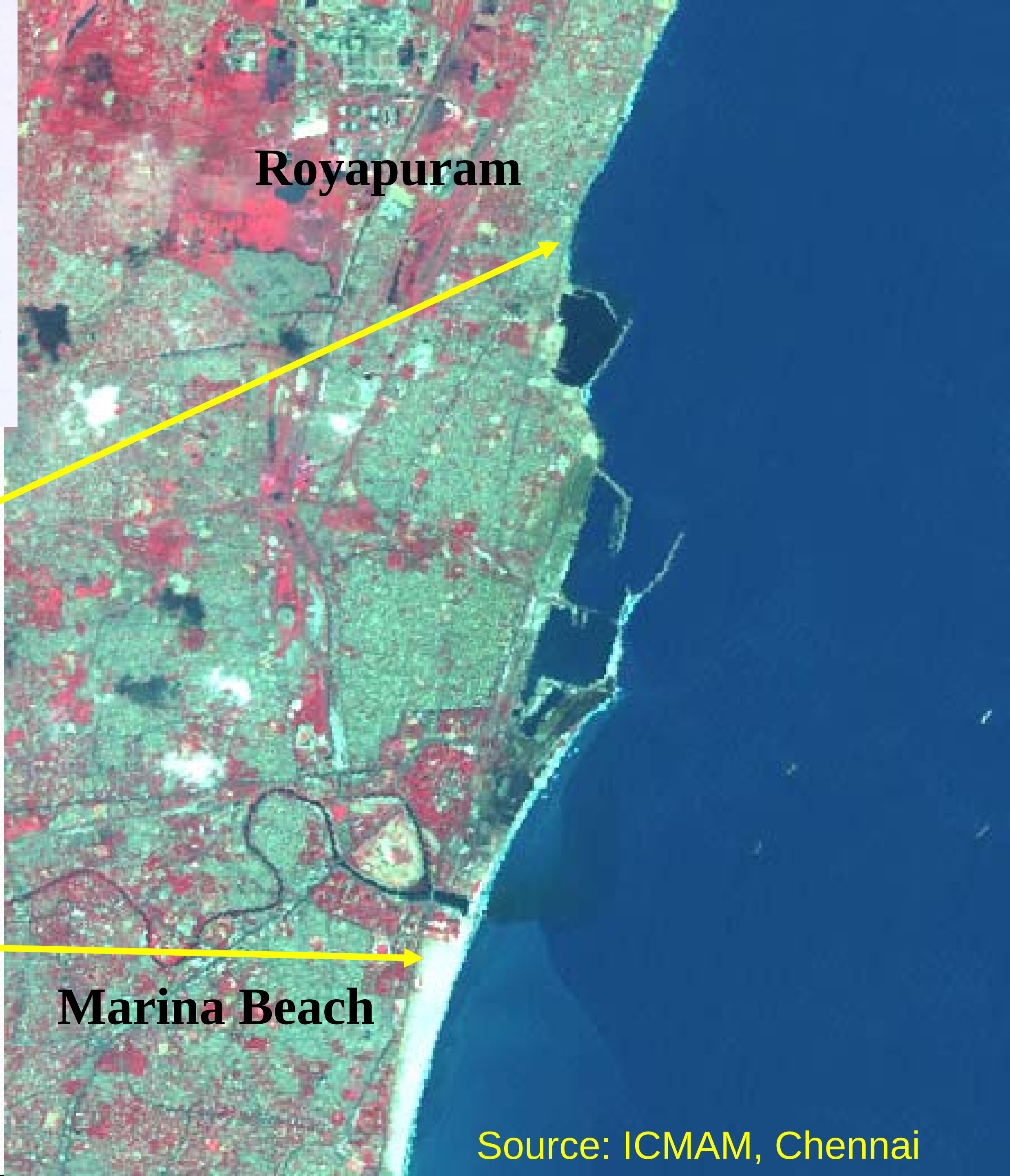
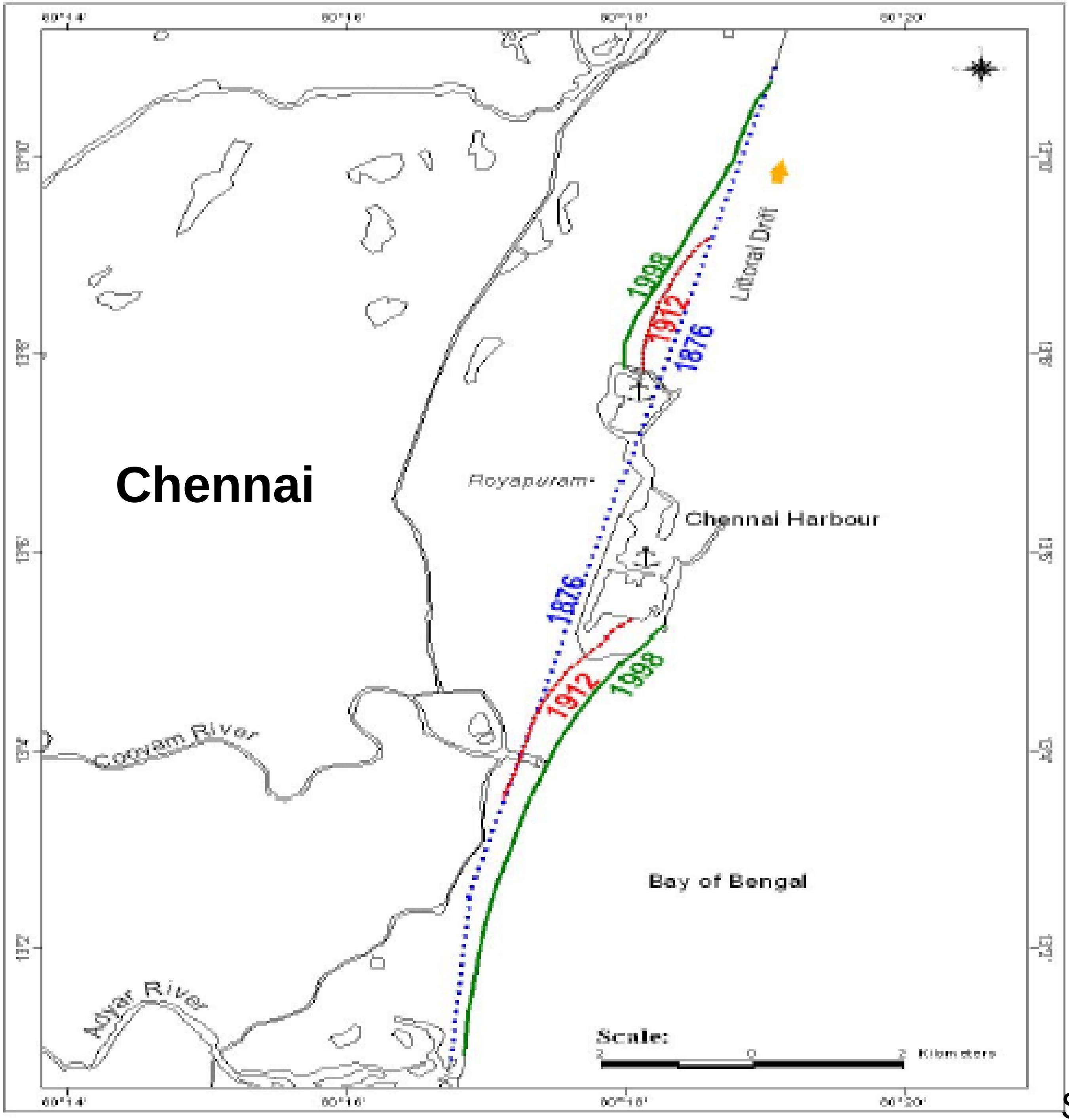


Fig.1. Coastal geomorphic features of India.

Erosion on the northern side of Chennai fishing harbour

Accretion on the southern side of Chennai port (Marina beach)





- An area of 350 hectares of land lost between 1893 and 1989

- The shoreline receded by about 100 m between 1978 and 1995.

Source: ICMAM, Chennai

Traditional Coastal Protection Methods:

Seawalls , Groynes, ..

- **Address the effects of erosion and not the cause**
- **“Hold the line” approach**

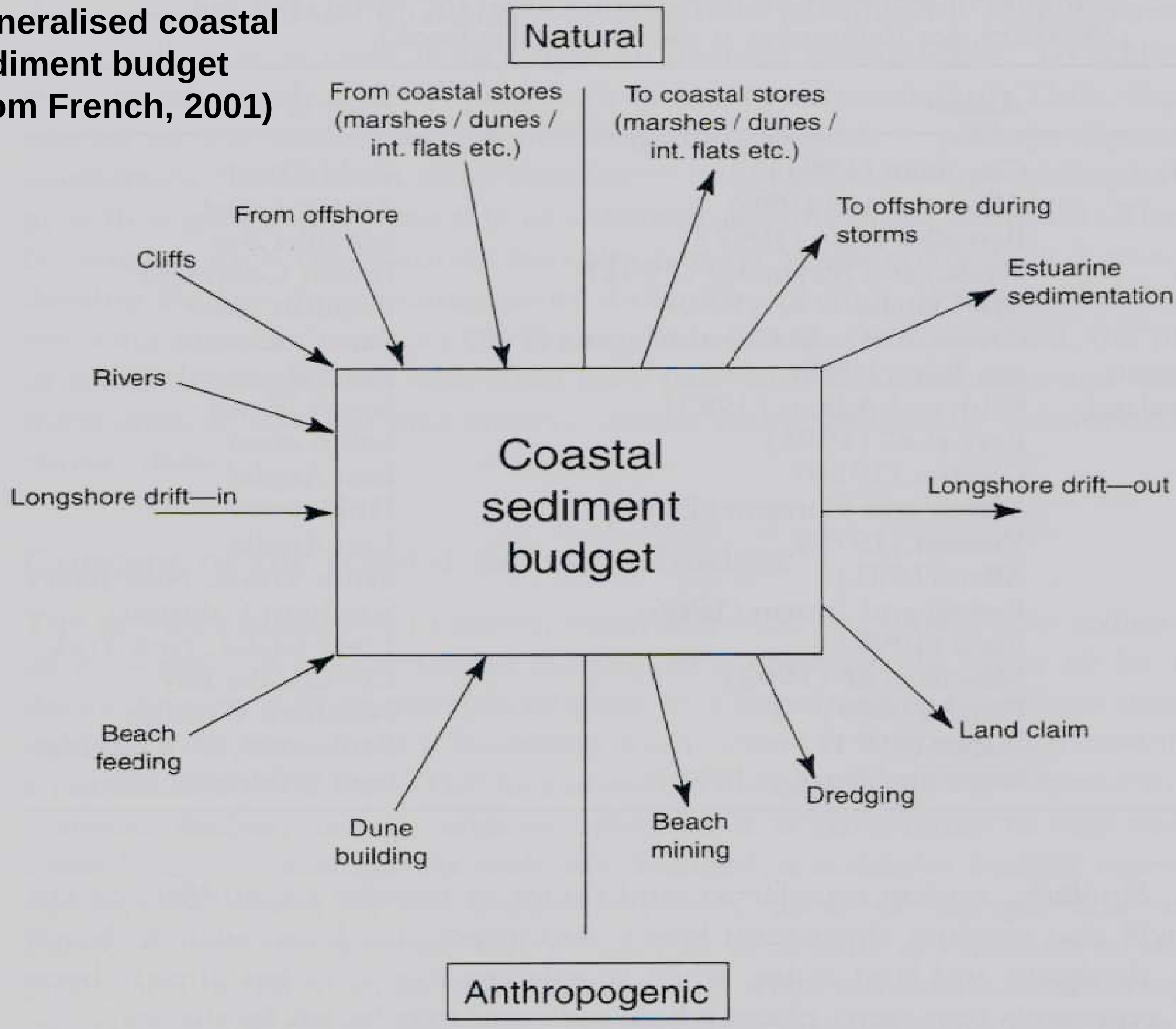
Common problems with coastal protection

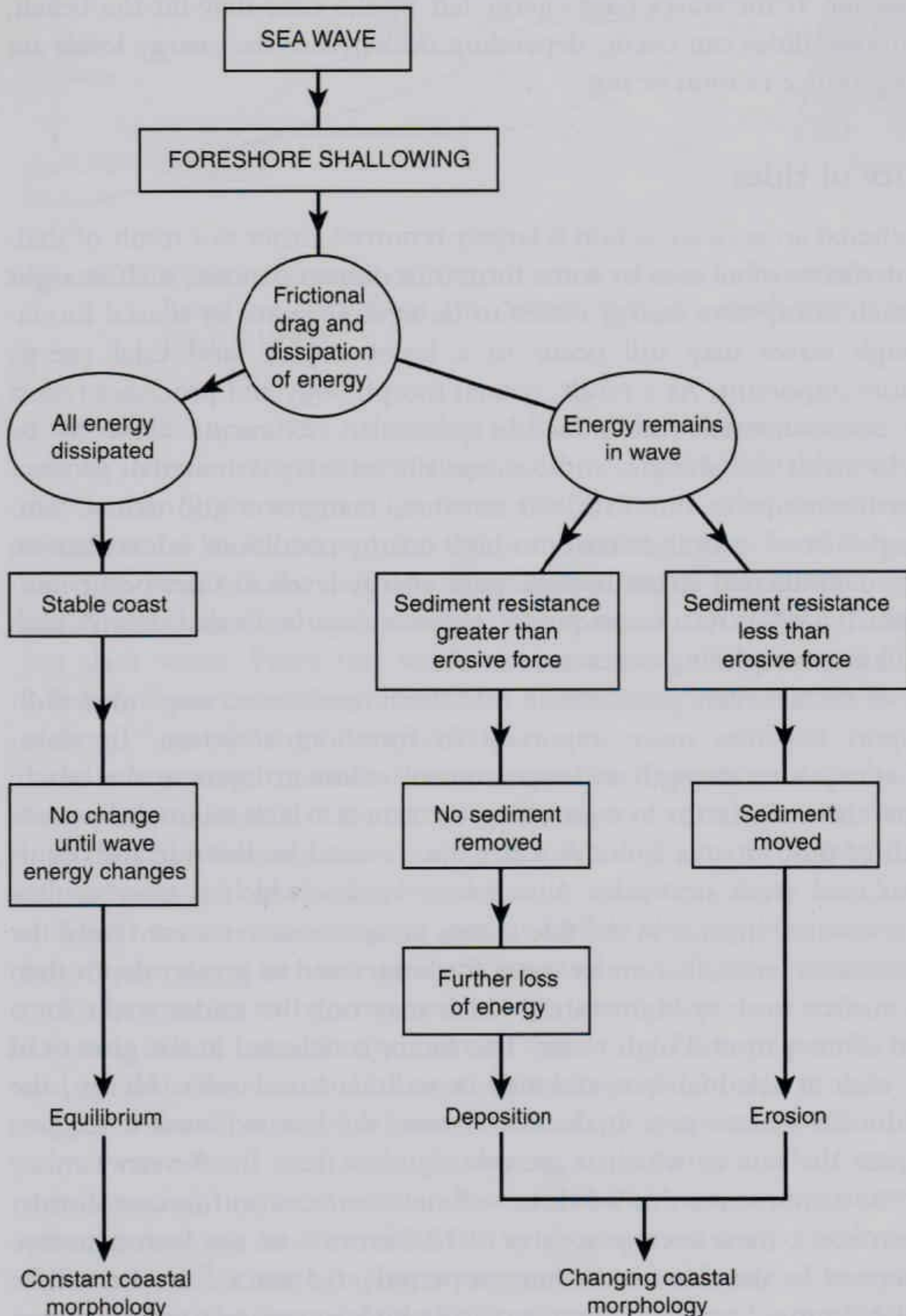
- Interruption of sediment supply
- Interference with natural processes
- Lack of understanding of how coastal processes work – including processes relating to post-construction

Need to Consider:

- Benefit : Loss Approach (Sediment Budget)
- Habitat creation
- Integrating all aspects of coastal use into one management plan

Generalised coastal sediment budget (from French, 2001)




SEA WAVE
FORESHORE SHALLOWING
Frictional drag and dissipation of energy
All energy dissipated
Energy remains in wave
Stable coast
Sediment resistance greater than erosive force
Sediment resistance less than erosive force
No change until wave energy changes
No sediment removed
Sediment moved
Further loss of energy
Equilibrium
Deposition
Erosion
Constant coastal morphology
Changing coastal morphology

Nature's way. Offshore reefs naturally protect the coast

Natural Examples of Submerged Reefs

Maine, USA

Salients

Natural Examples of Submerged Reefs

Budgewoi, Australia

Multi-Purpose Reefs:

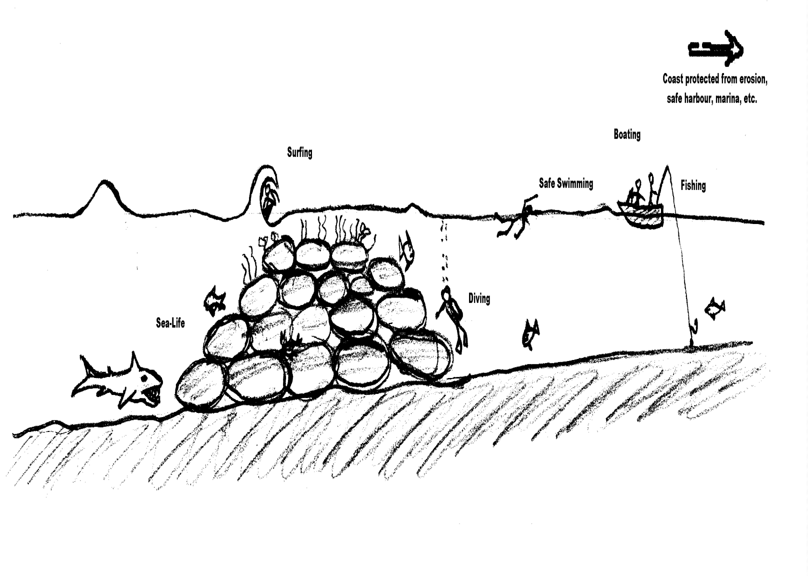
A Technology Inspired by Nature

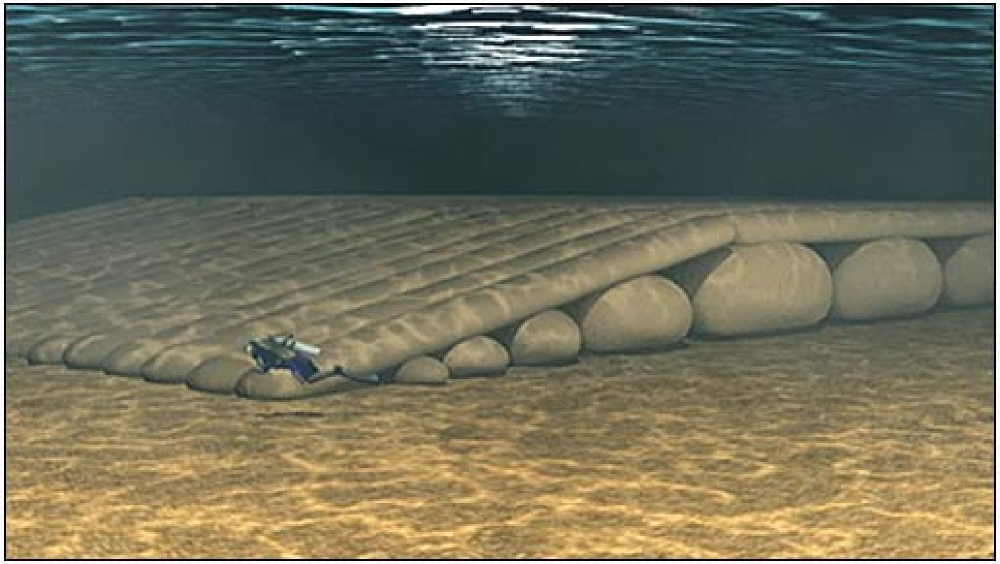
- Coastal Protection
  - Ecology Enhancement
    - Recreational Benefits

Multi-purpose Offshore Reefs

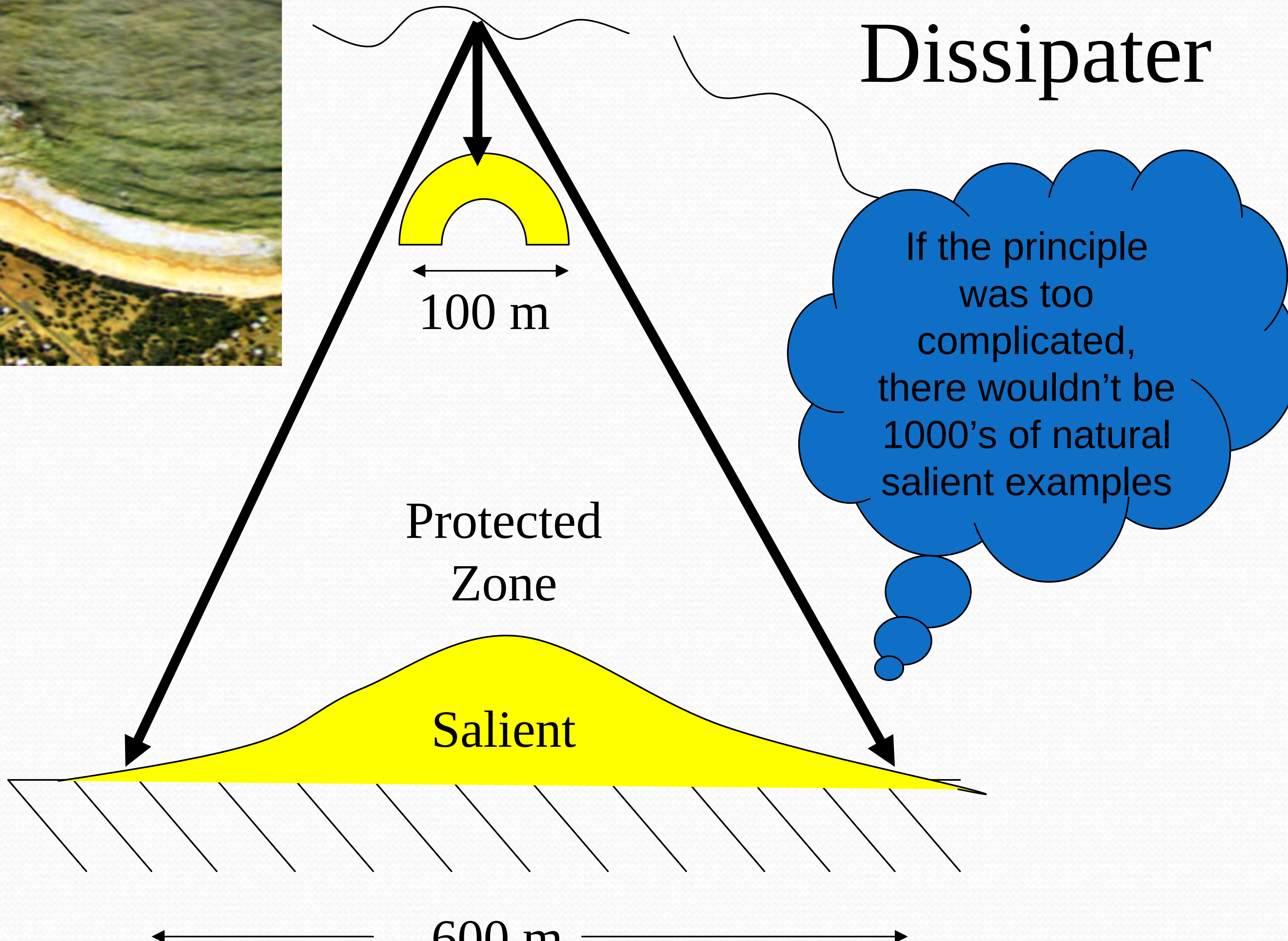
What is a multi-purpose reef?

- A multi-purpose mound on the seabed
- Constructed offshore
- Mimics nature
- Multiple benefits



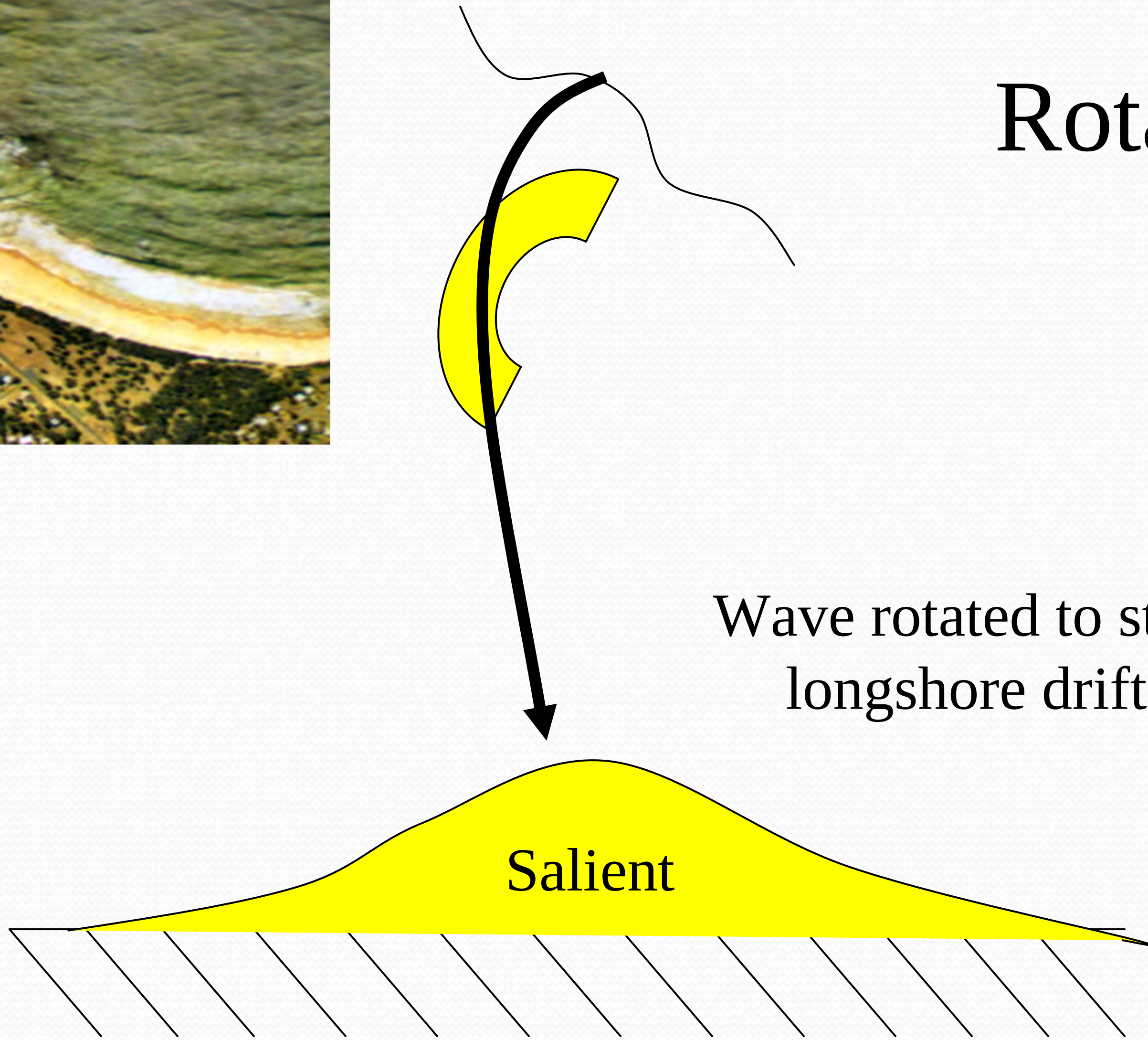


Dissipater



One reef of 100 m protects 400-600 m of coast

Rotator

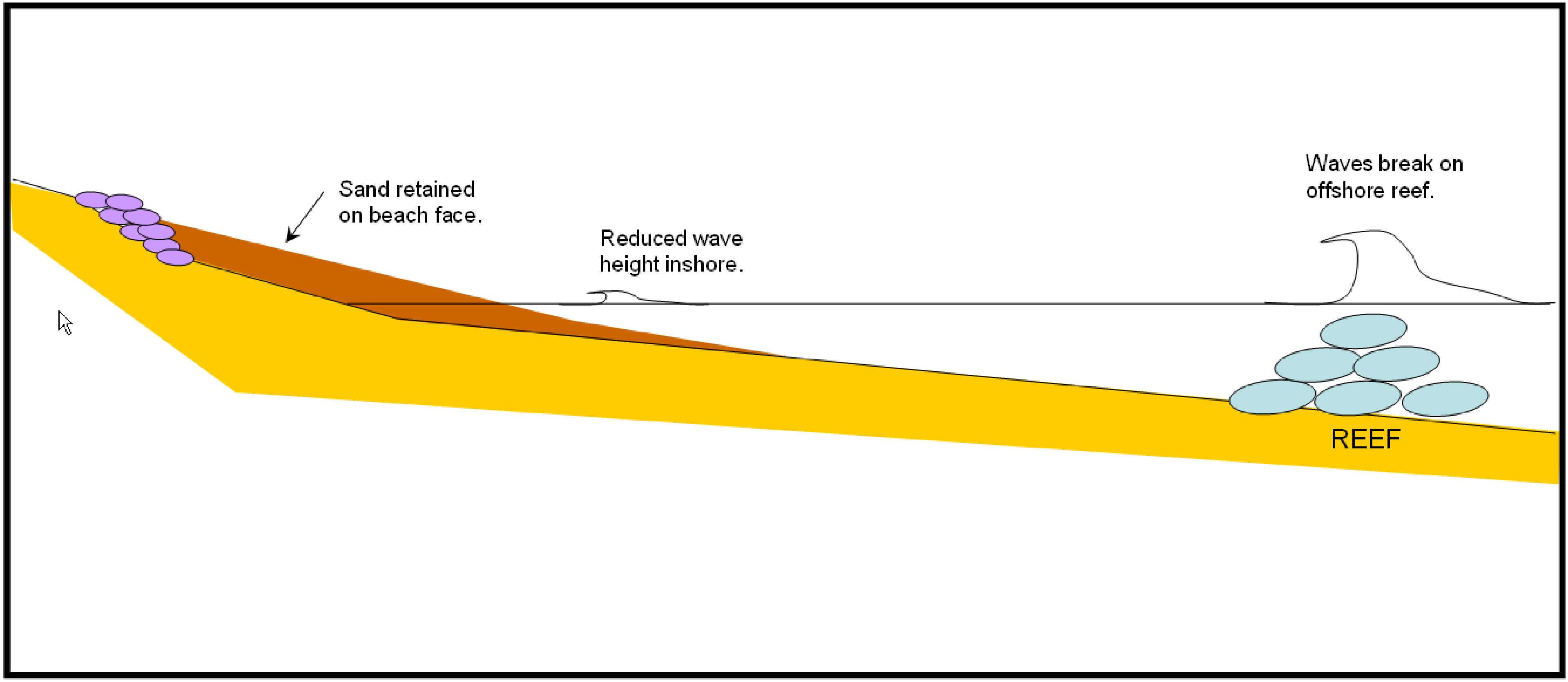


Wave rotated to stop longshore drift

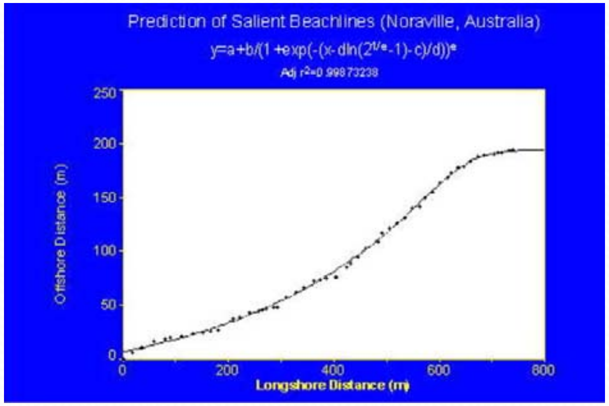
600 m

One reef of 100 m protects 400-600 m of coast

Side view of the principle

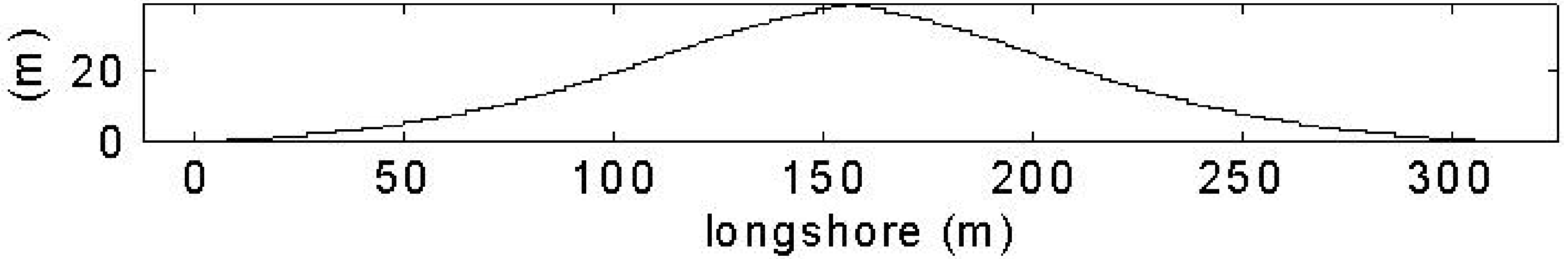


Prediction of Shoreline Response



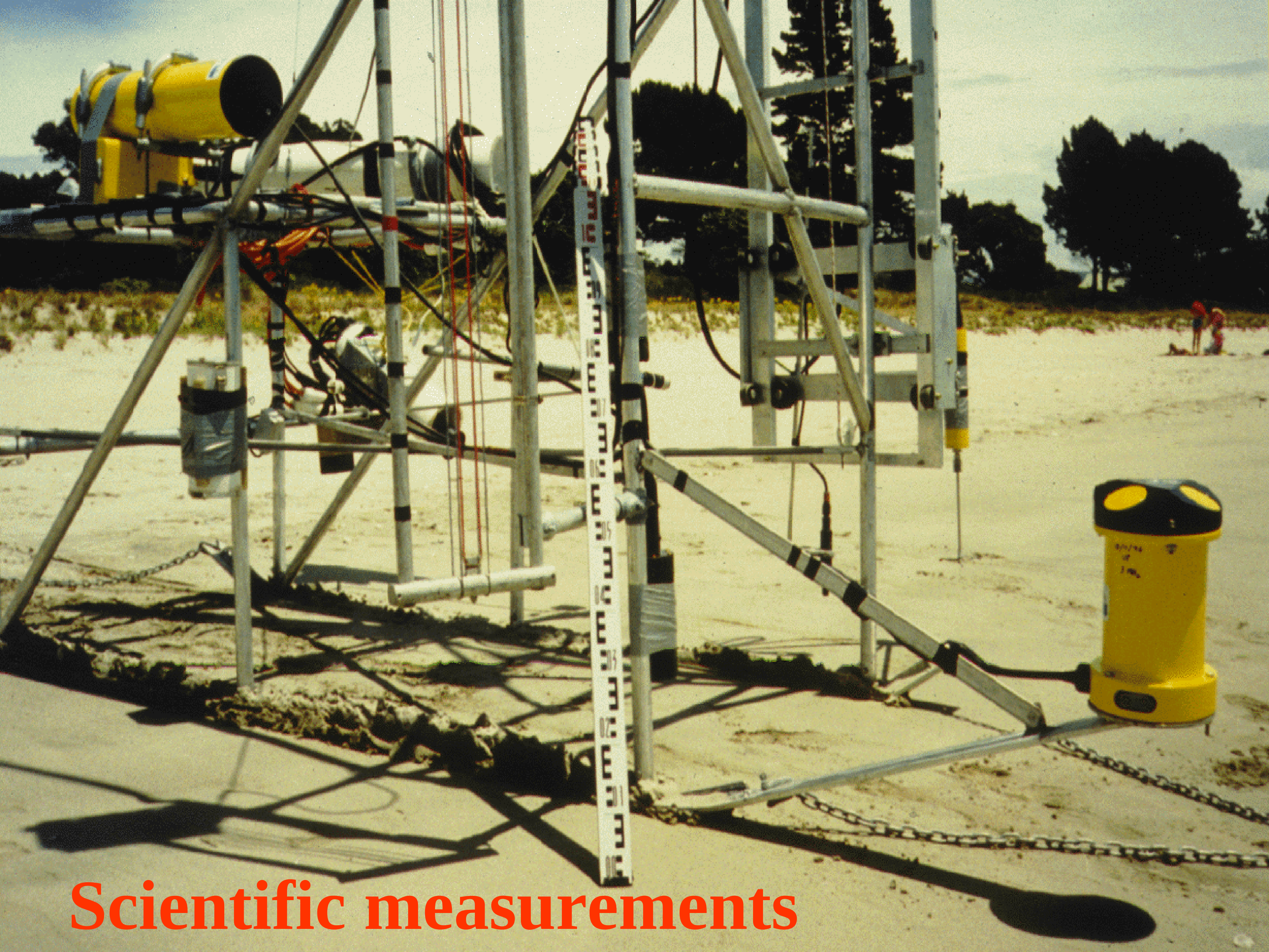
$$y = -0.052 + \frac{1.317}{\left(1 + \exp\left(-\frac{\left(\chi' - 0.356\ln\left(2^{\frac{1}{0.356}} - 1\right) - 2.249\right)}{0.356}\right)\right)^{0.356}}$$

Black & Andrews (2001a,b)



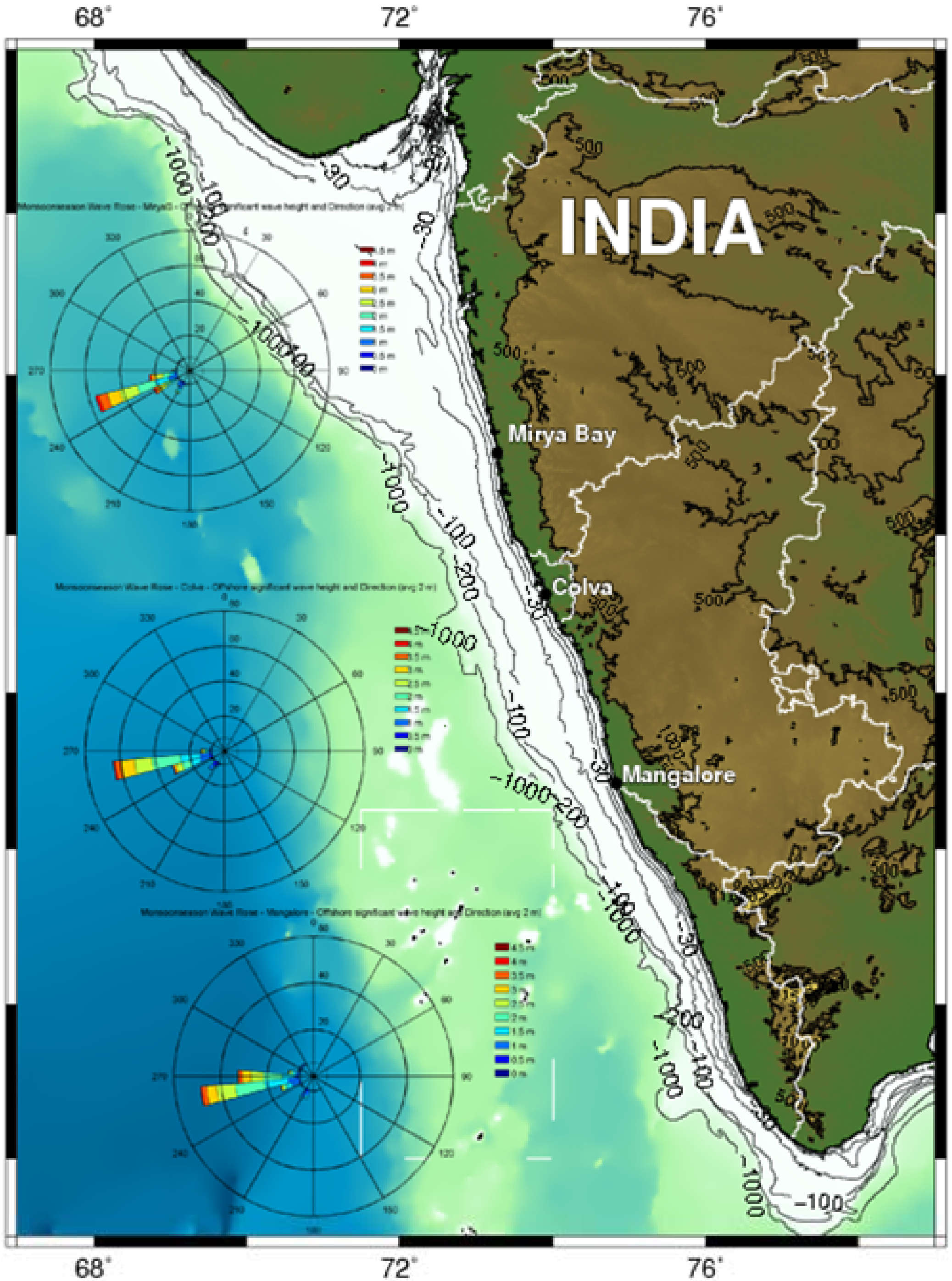
Reef design criteria

- **Distance offshore**
- **Depth of the reef crest**
- **Placement around natural depths**
- **Reef length**
- **Reef width**
- **Length/width ratio**
- **Orientation**
- **Refraction/diffraction character**
- **Induced currents**



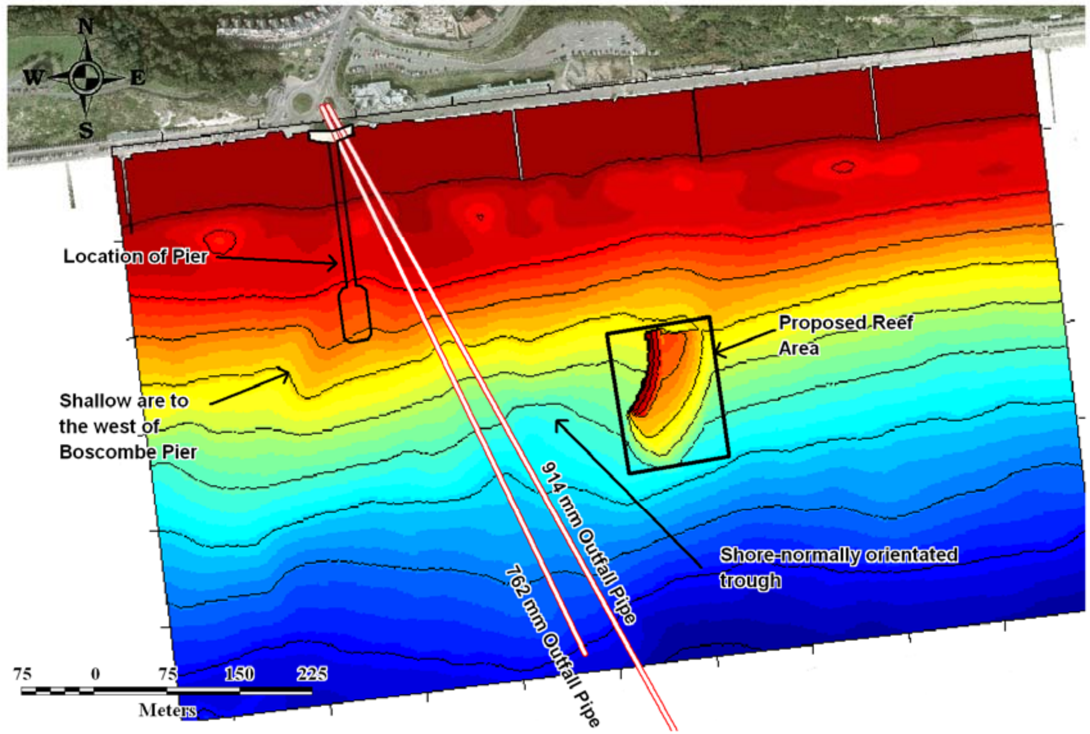
Scientific measurements

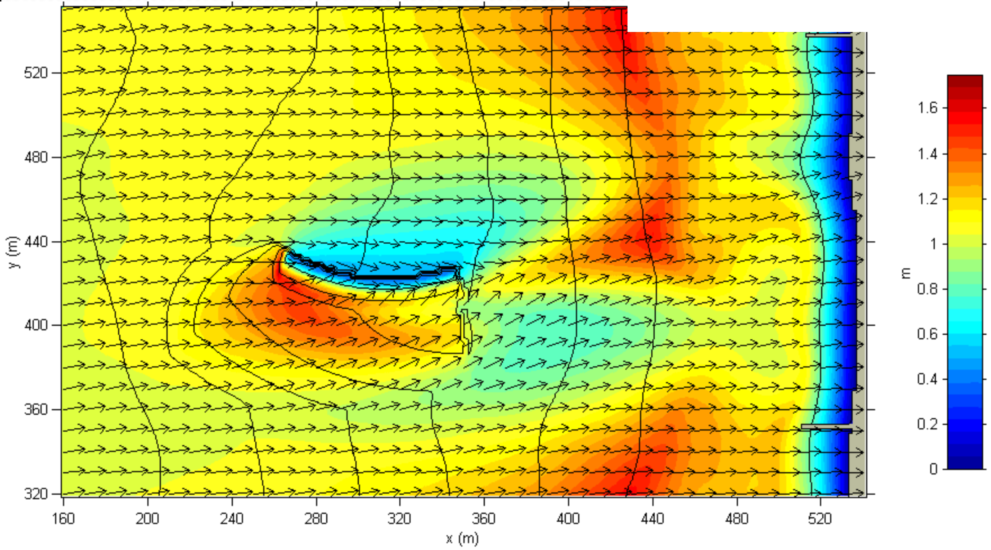
Beach experiments

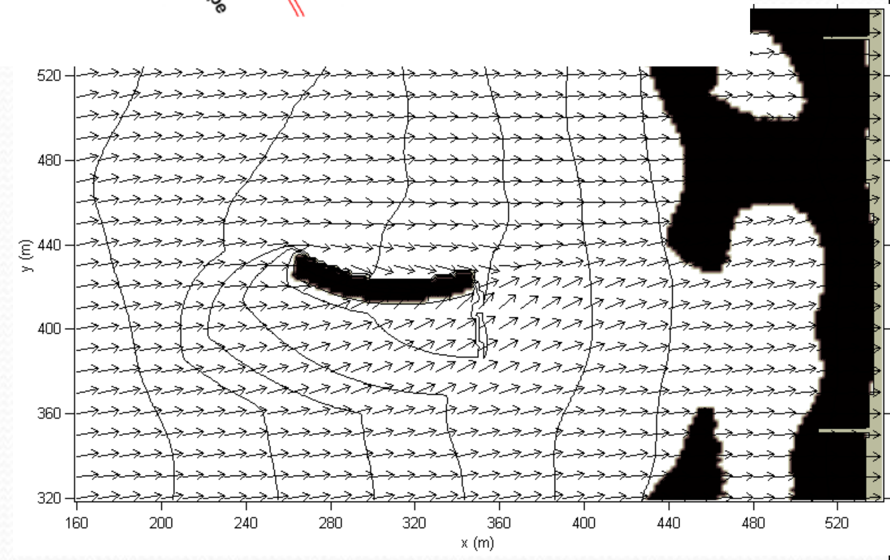


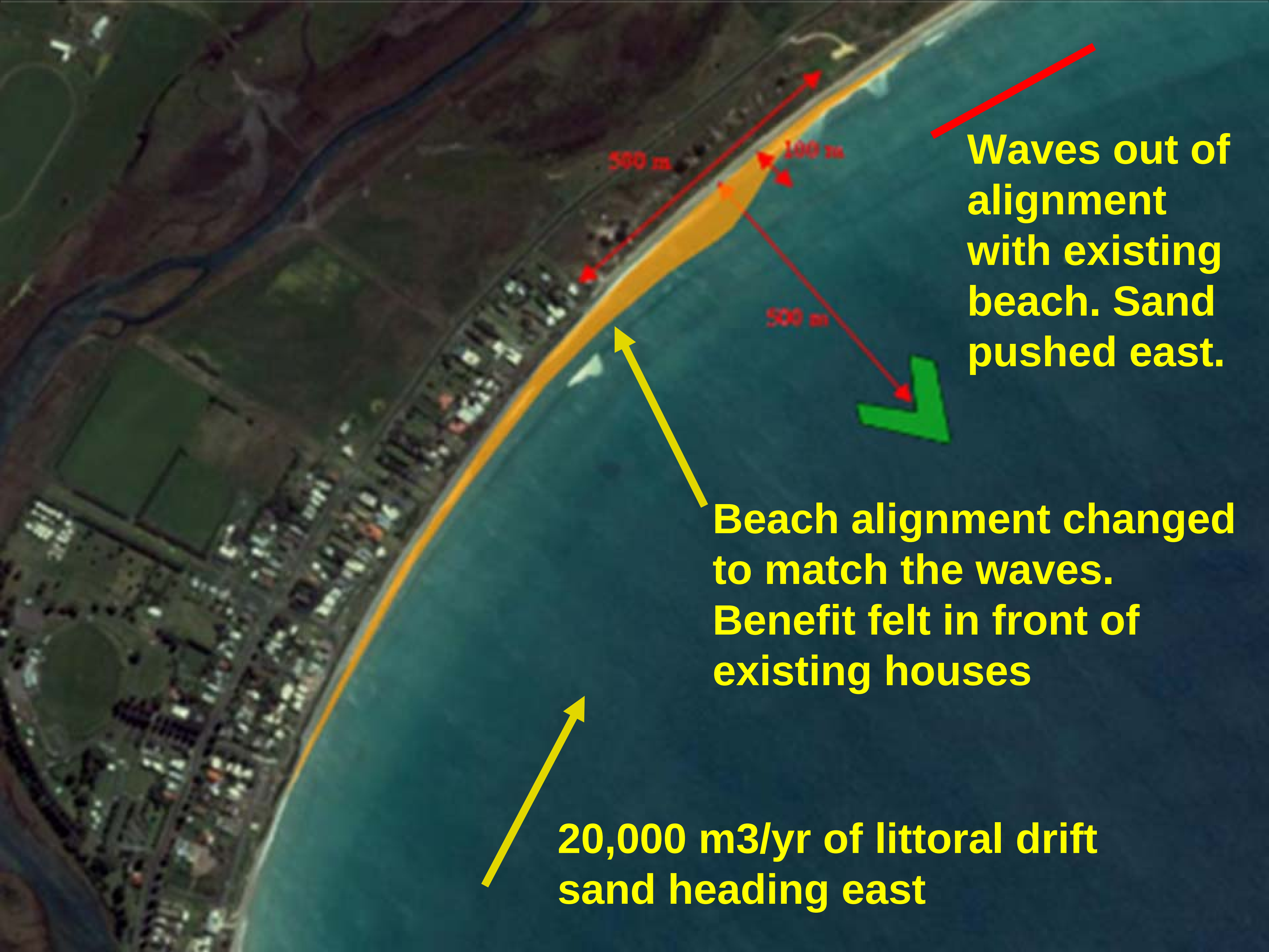
INDIA
Mirya Bay
Colva
Mangalore
68°
72°
76°
20°
16°
12°
8°

Site specific design








Waves out of alignment with existing beach. Sand pushed east.
500 m
100 m
500 m
Beach alignment changed to match the waves. Benefit felt in front of existing houses
20,000 m3/yr of littoral drift sand heading east

Case Study : Gold Coast Reef, Australia

- Major initiative in Queensland
- Won the prestigious State Environmental Award
- Monitoring of beach with Argus has confirmed that the reef has met the coastal protection expectations
- Designed to improve the surfing.
- Marine ecology is greatly enhanced

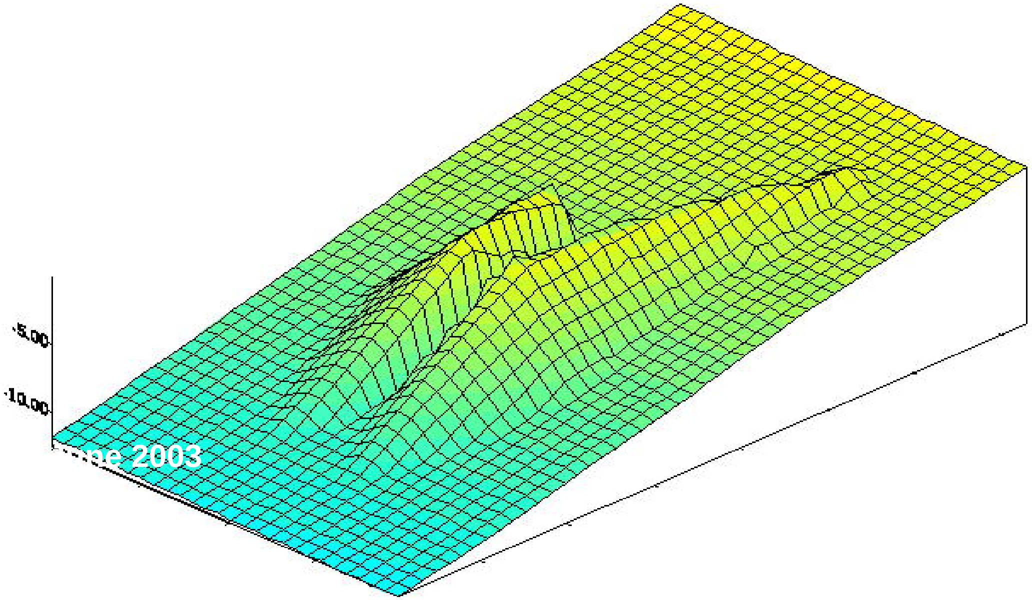
Gold Coast Reef goals

The specific sedimentation criteria for the Gold Coast Reef were:

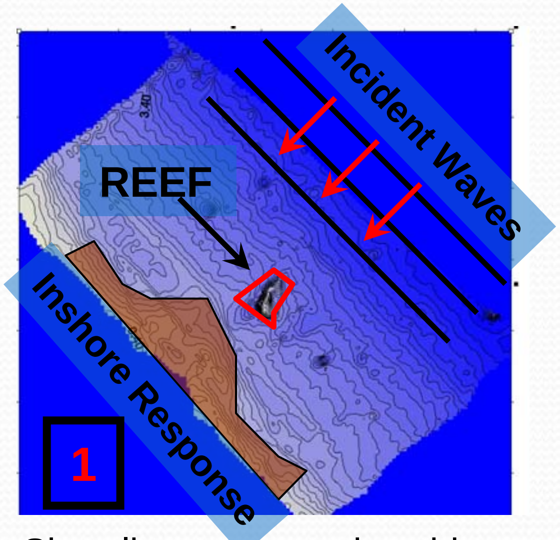
- Provide a coastal control point to assist the maintenance of the widened beaches at Surfers Paradice
- No more than approximately 80,000 m^3yr^{-1} of re-nourishment should be needed on the downstream (northern) side of the reef
- Beach adjustment should cause minimal impact on adjacent beaches.

Thus, the reef was designed to “leak sand” and was never meant to totally eliminate maintenance dredging at Surfer’s Paradise. As such, beach erosion at Surfers was anticipated to continue occurring but the reef was meant to slow the losses.

Narrowneck Reef – Gold Coast



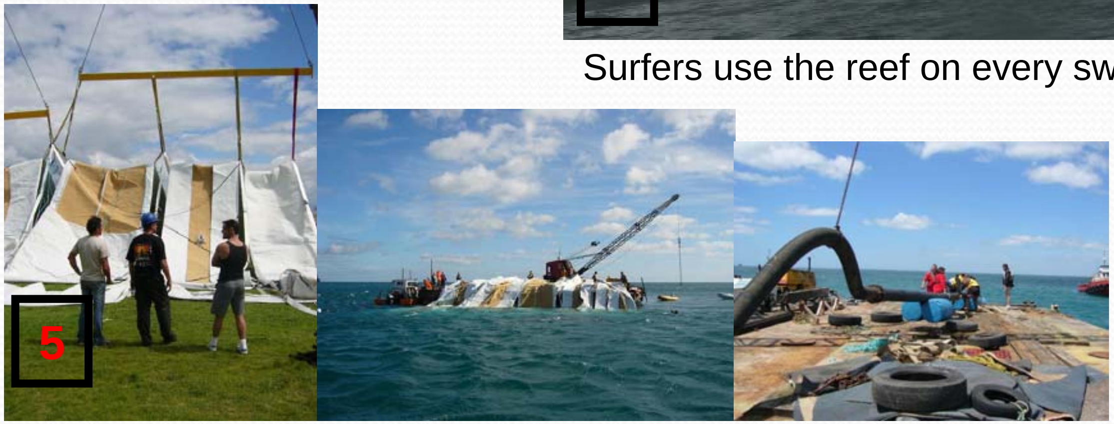
Mount Reef, New Zealand



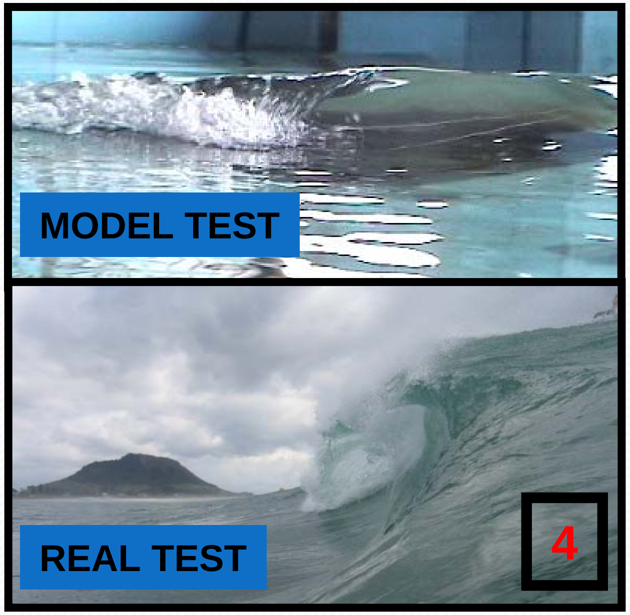
Shoreline response is evident.

Diverse biology living on the reef.

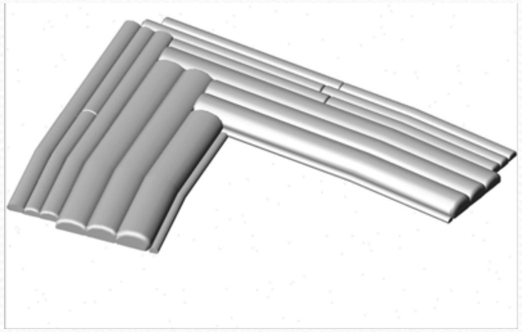
Surfers use the reef on every swell.



Engineering and construction have gone really well.



Outcomes are **very** similar to predictions.



Aerial view of Boscombe Reef (UK) under construction – June 2009

Boscombe Surf Reef (at low tide)

August 2009

Precedents


Gold Coast

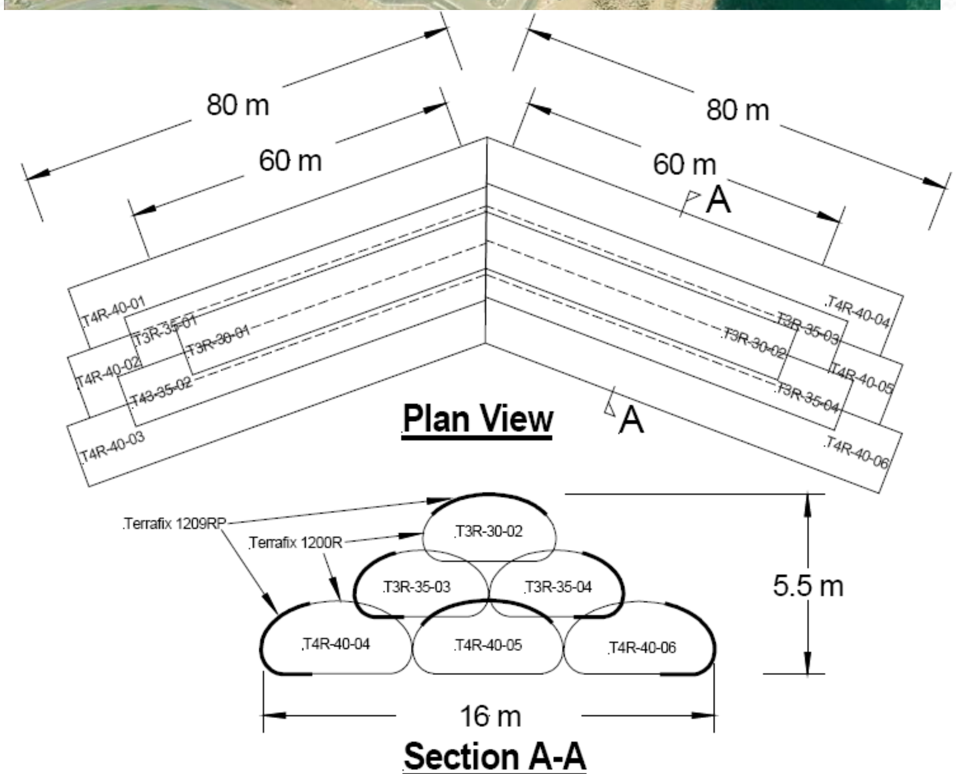

Mt Maunganui


Mt Maunganui


Gold Coast


Dominican
Republic

Limeburners Breakwater



$250 m^3$ – $420 m^3$ geotextile sand containers

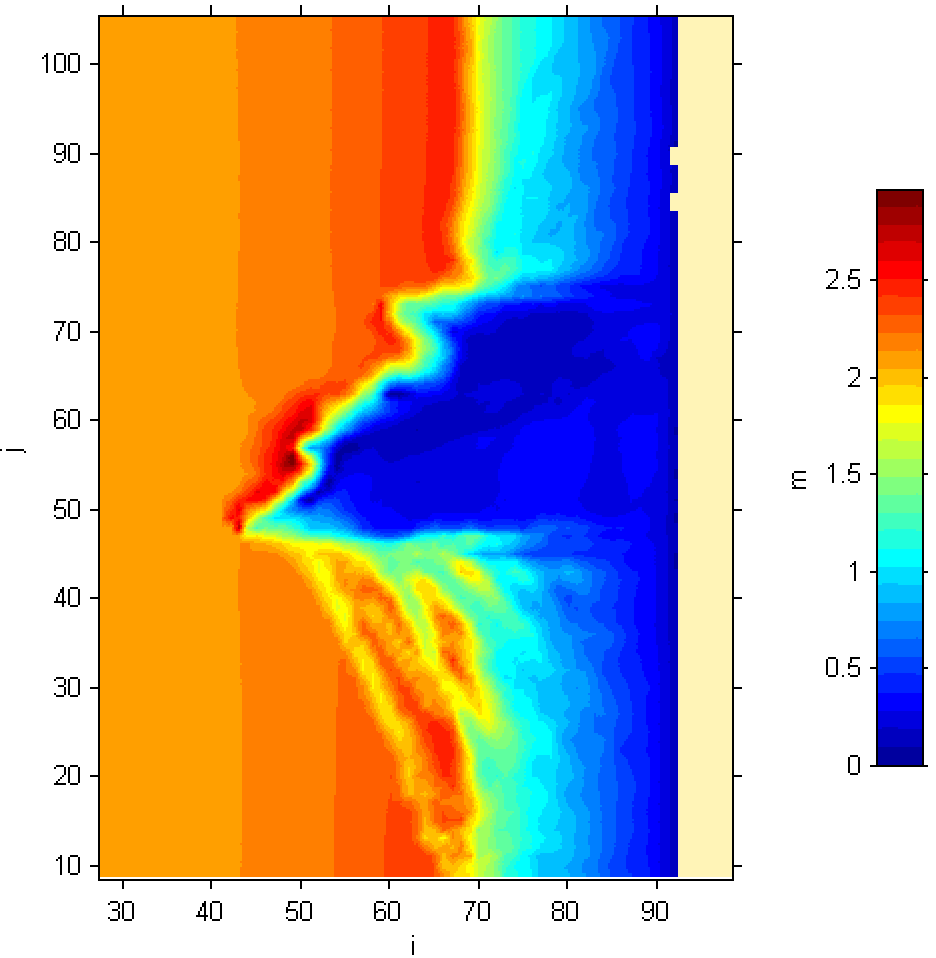
Multi-purpose offshore soft reefs: An option that actually improves the beach

- Beach protection
- Wider beach
- Reduced storm surge and flooding
- Improved ecology
- Improved property values
- Better economic returns for the community
- Healthy sporting activities
- Safer swimming

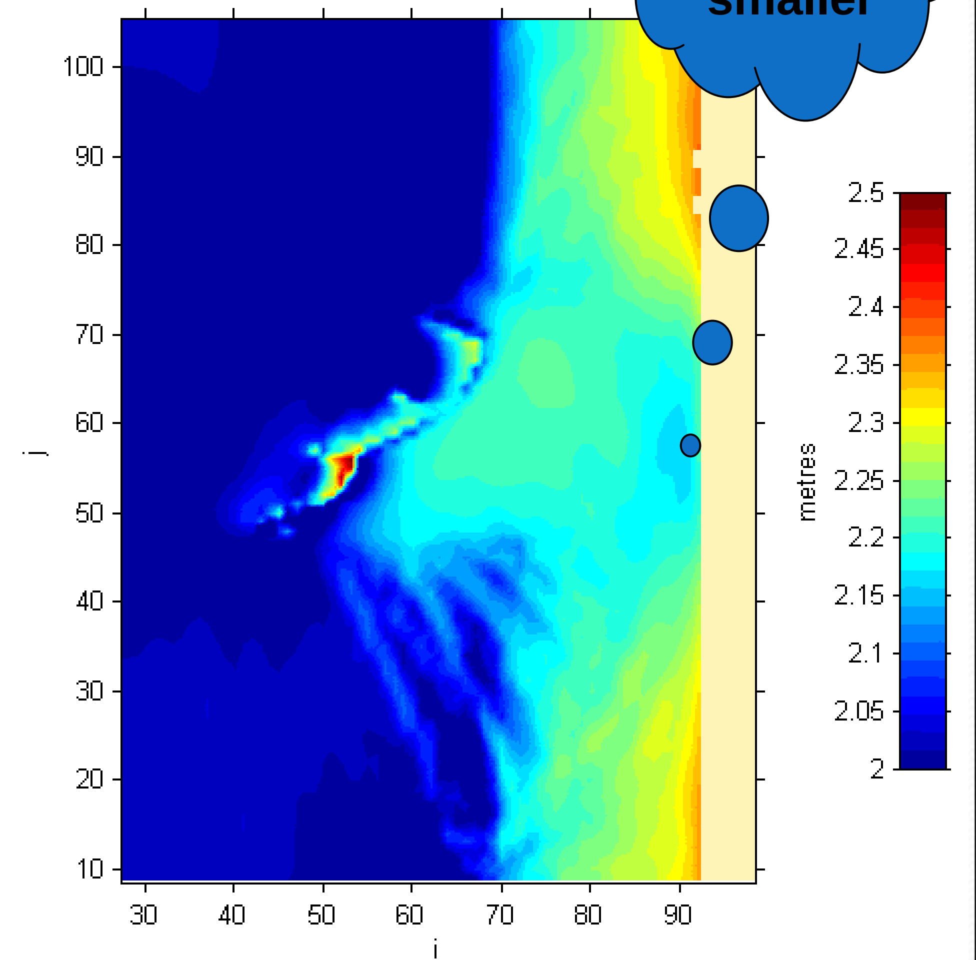
Set up in the lee of reefs

Storm surge much smaller

Wave height



Sea level



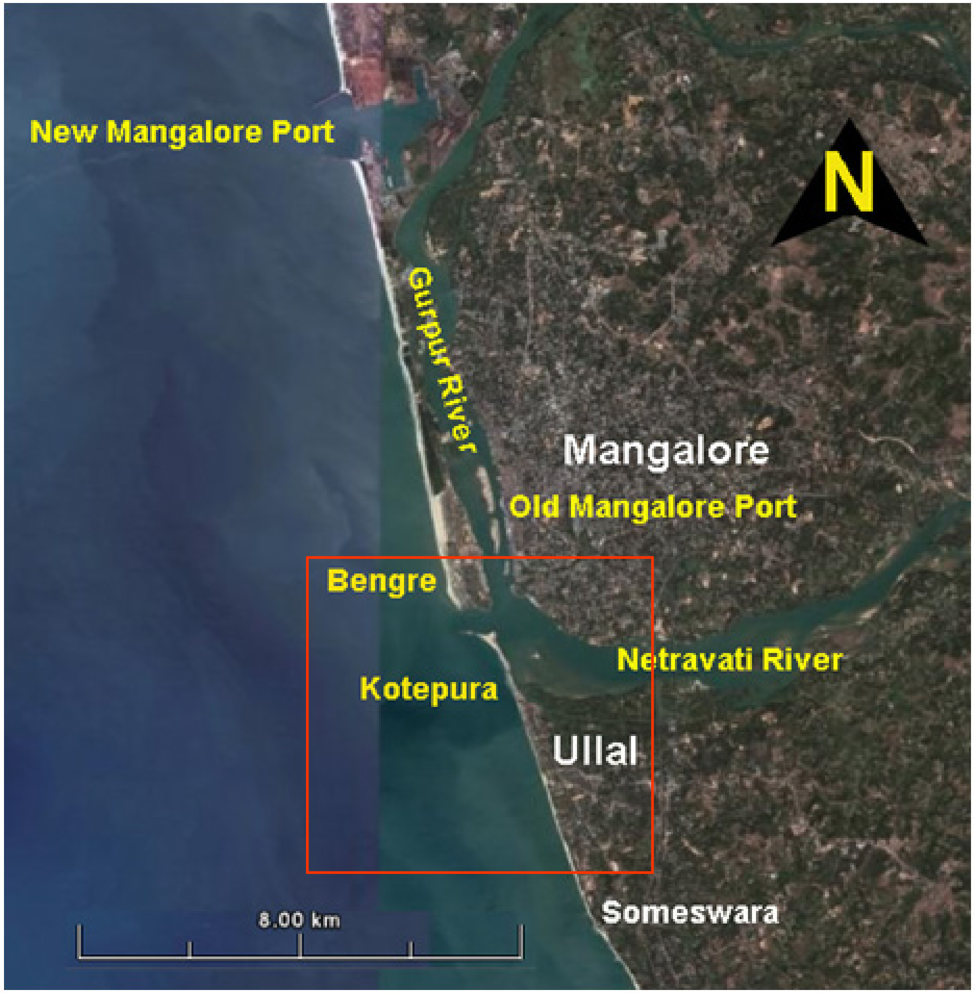
The ADB technical assistance (TA) project:

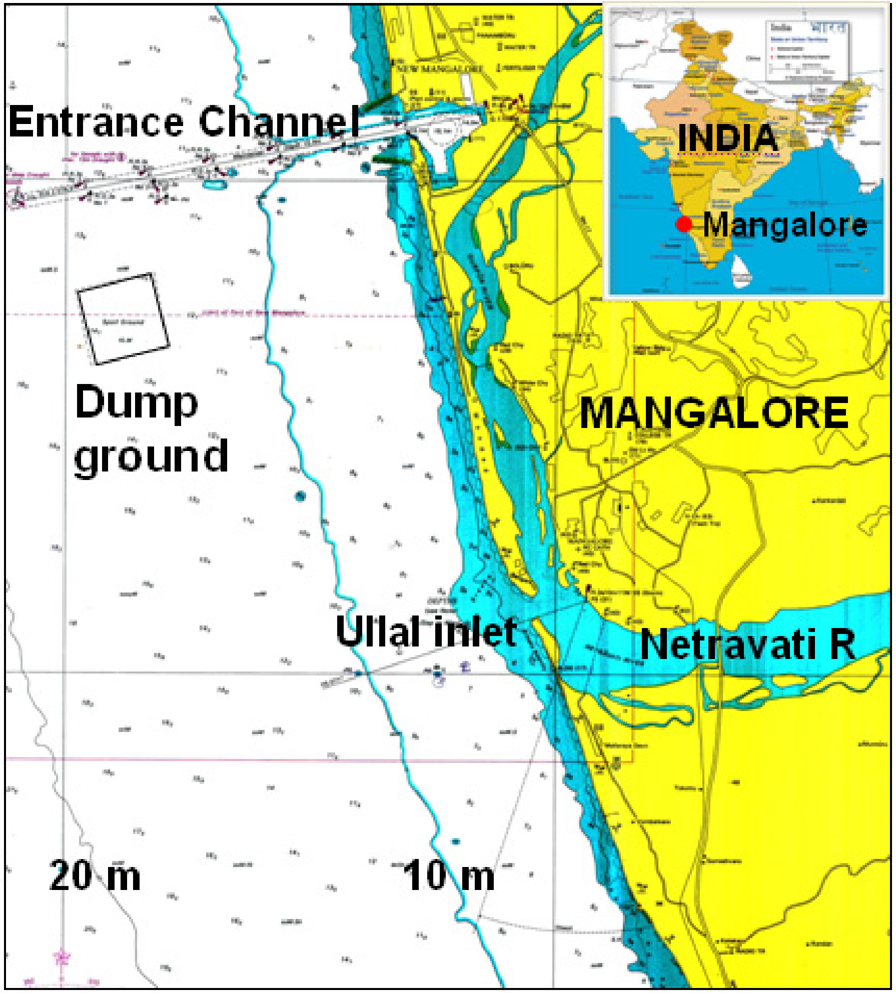
"Sustainable Coastal Protection and Management"

- Participating states :

  Karnartaka, Goa, Maharashtra

ULLAL COASTAL EROSION AND INLET IMPROVEMENT PROJECT





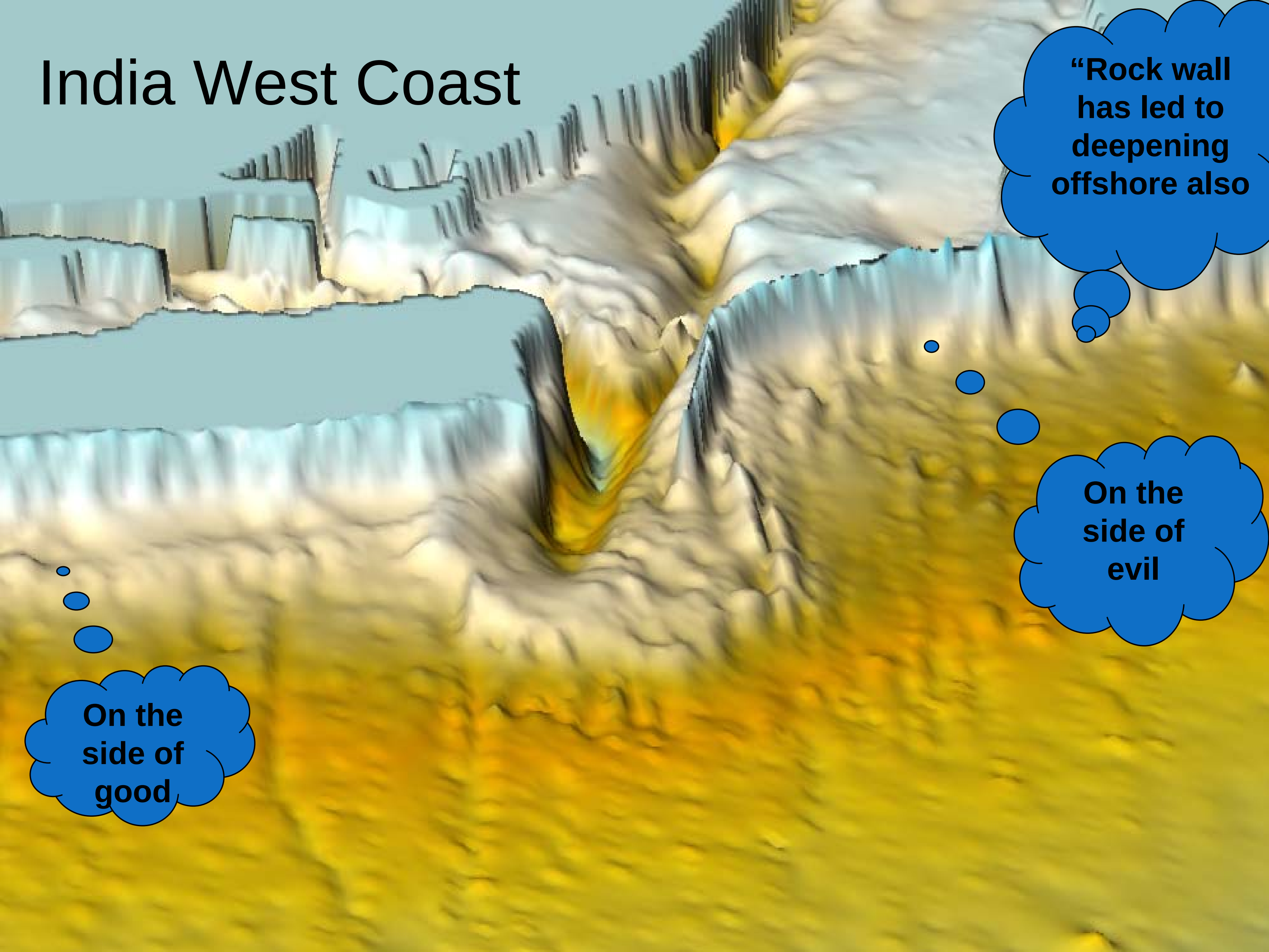
The Proposed Project

- Ullal beach in southern Karnataka has suffered from serious erosion over several decades
- The local people are under severe attack from waves
- Many houses have been lost to the south of the breakwater of the old Mangalore port.
- Currently a large area is threatened by waves flooding year round and under severe threat during the monsoon.

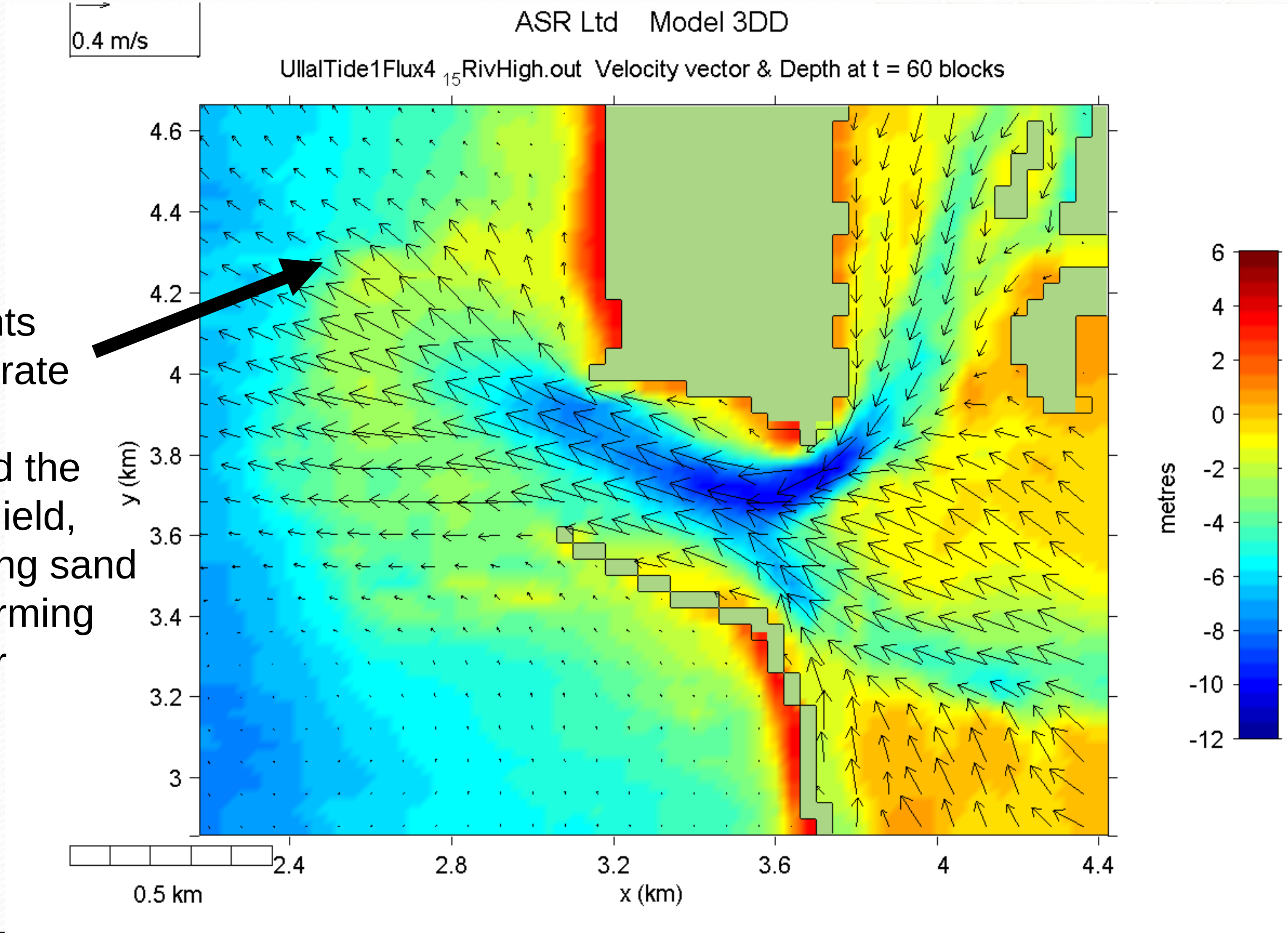
ULLAL COASTAL EROSION AND INLET IMPROVEMENT PROJECT

- Northern beaches were vulnerable to erosion (1970s)
- Sedimentation in channels and boat capsizing
- Breakwater constructed (1991-94) to prevent sediment entering the estuary
- North breakwater : 375 m
- South breakwater : 580 m
- Entrance : 500 m

Navigation channel draft : 4 m
But Bar only 1-2 m deep

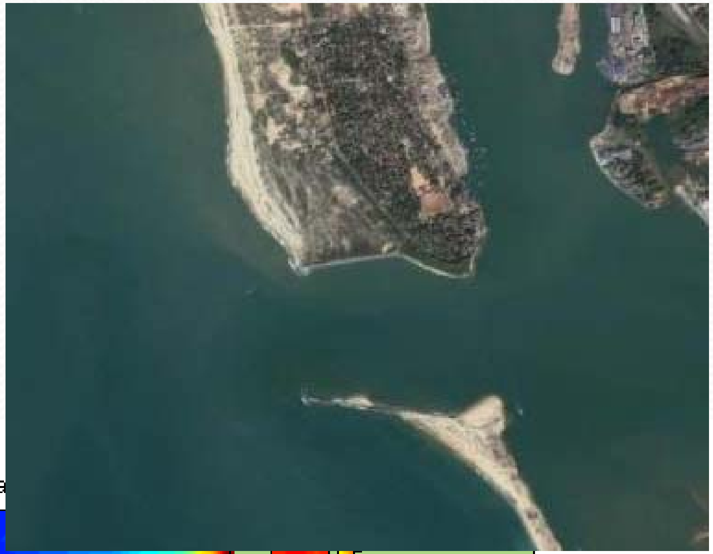

India West Coast
“Rock wall has led to deepening offshore also
On the side of evil
On the side of good

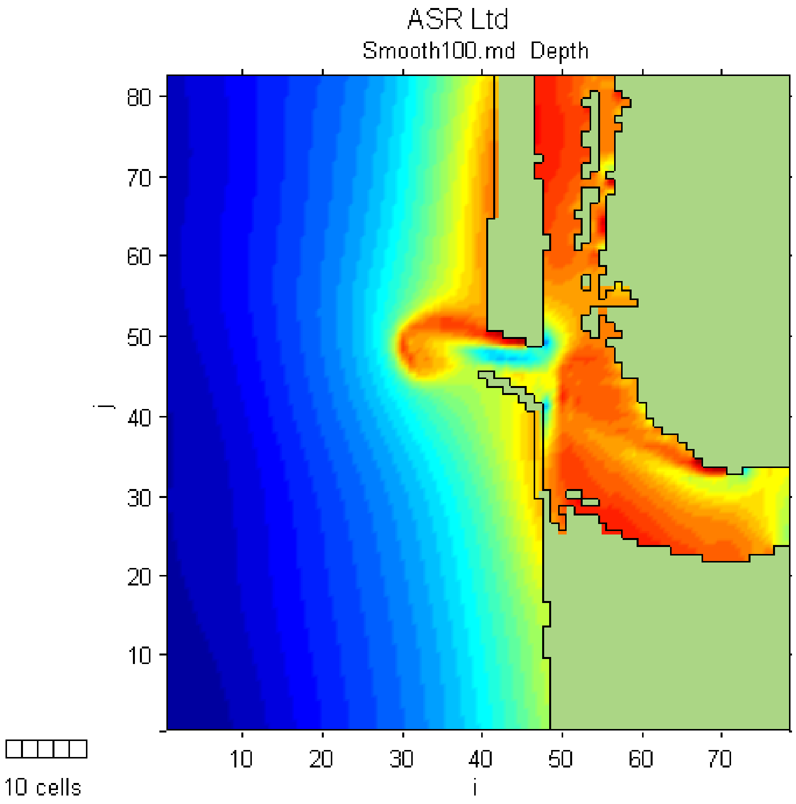
Monsoon Peak Ebb Velocity and Depth (ENTRANCE)

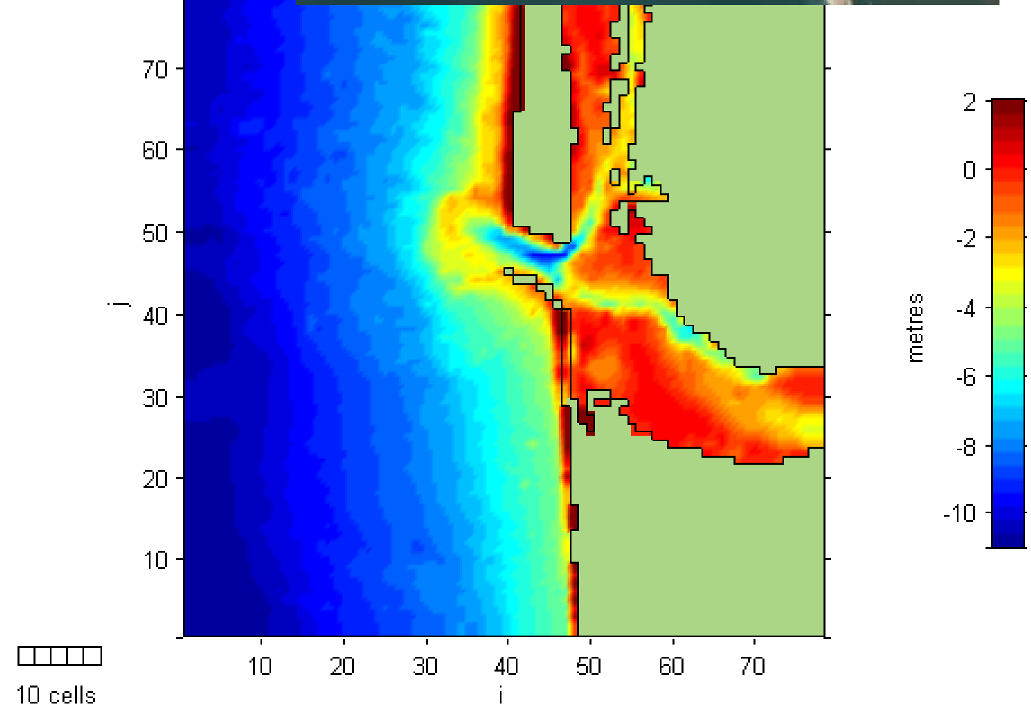


Currents decelerate rapidly beyond the ebb shield, dropping sand and forming the bar

Understanding using models





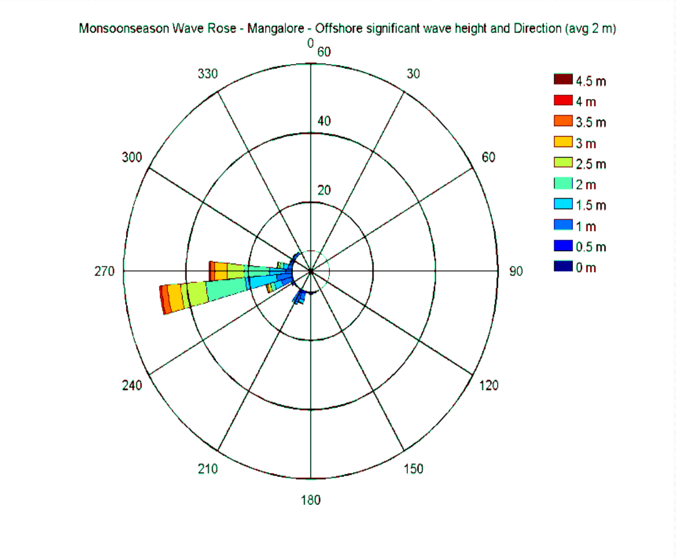


Detailed investigations **based on field and numerical model studies** ***have revealed that Ullal Beach is eroding for two key reasons:***

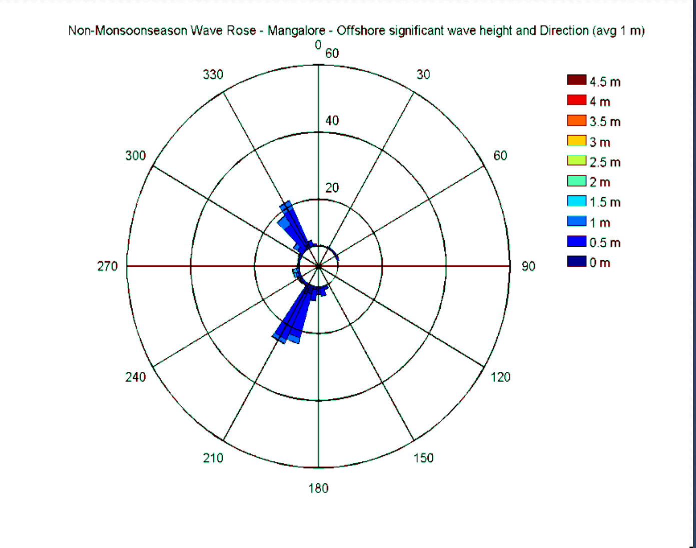
- The alignment of the beach is not in equilibrium with the wave climate, with extremely large amounts of sand being lost to the south each year

- Insufficient sand is being provided from the northern beaches and the river, due to several factors including:
  - **the northern bias in the alignment of the breakwater**

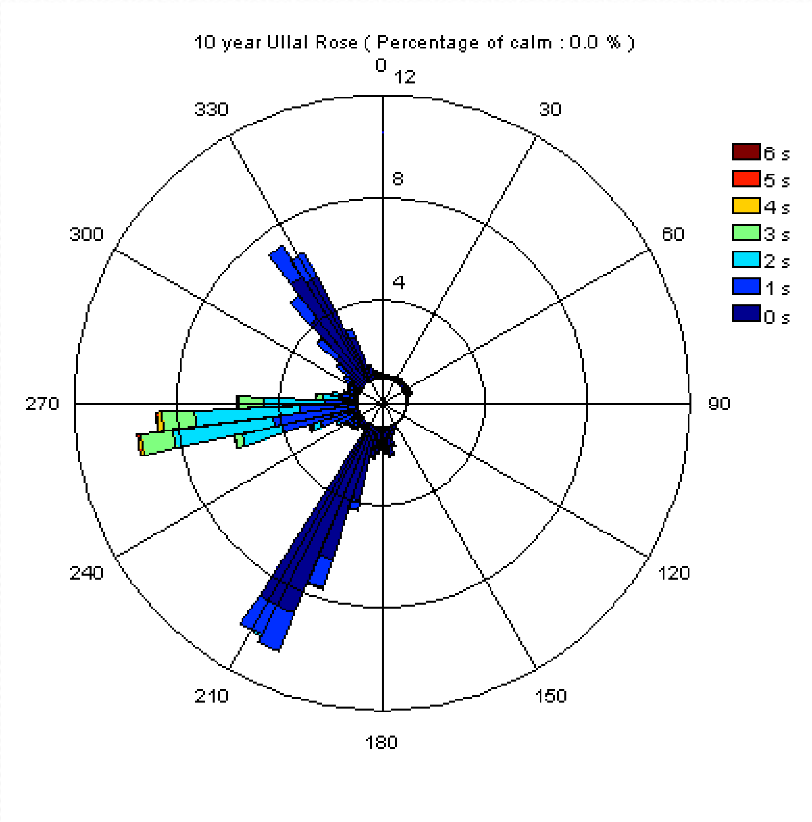
Monsoon



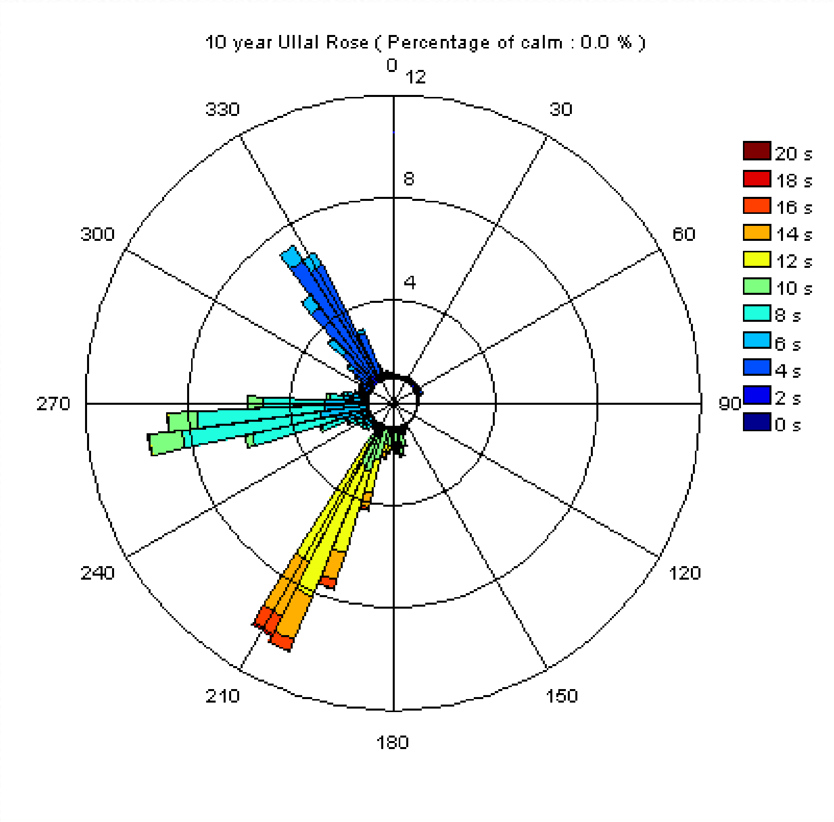
Non-monsoon



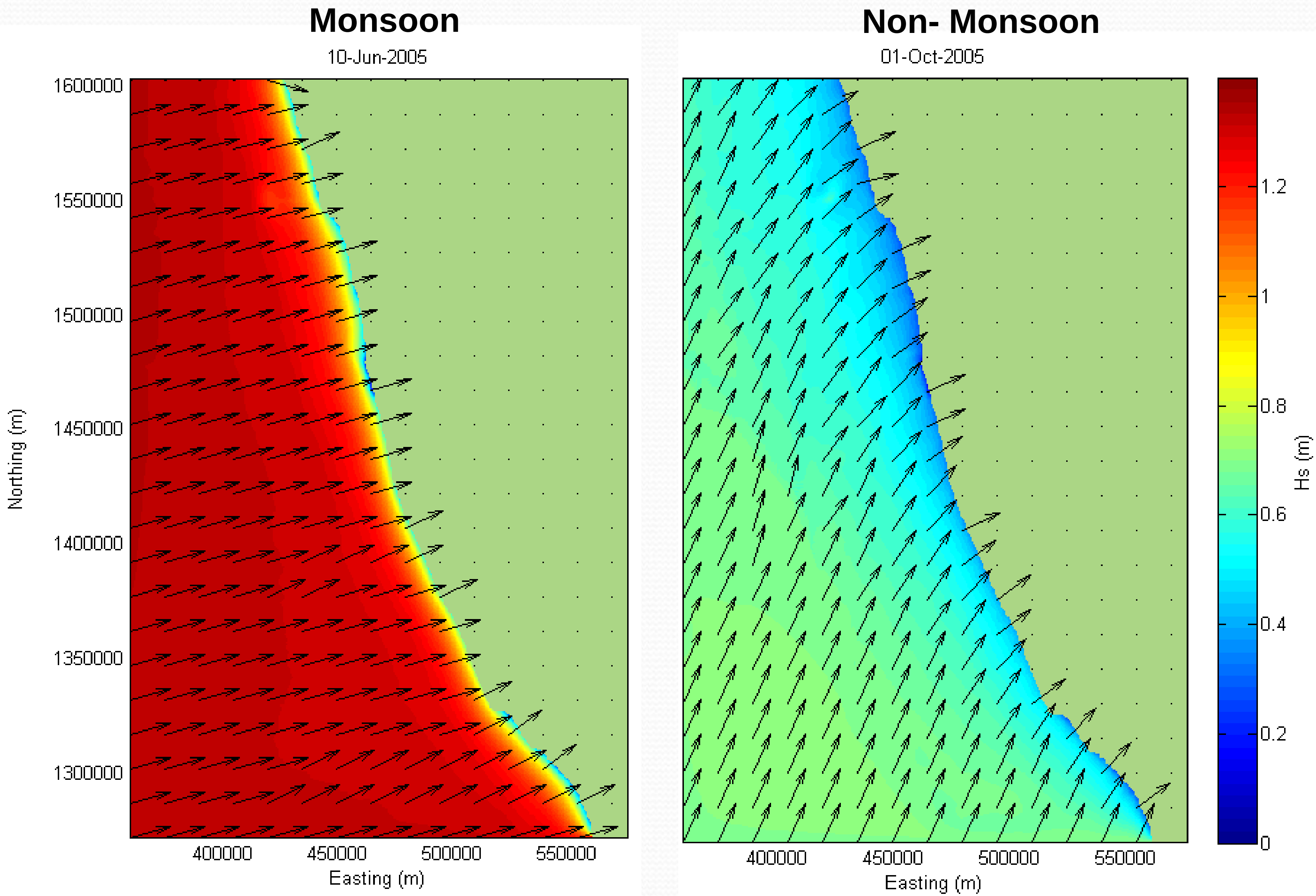
Significant wave height



Peak period



A 10 year record of waves from the NOAA WW3 wave model showing directionally binned significant wave height and directionally binned peak period



Wave transformation studies: Significant wave height and peak wave direction

Recommended solution

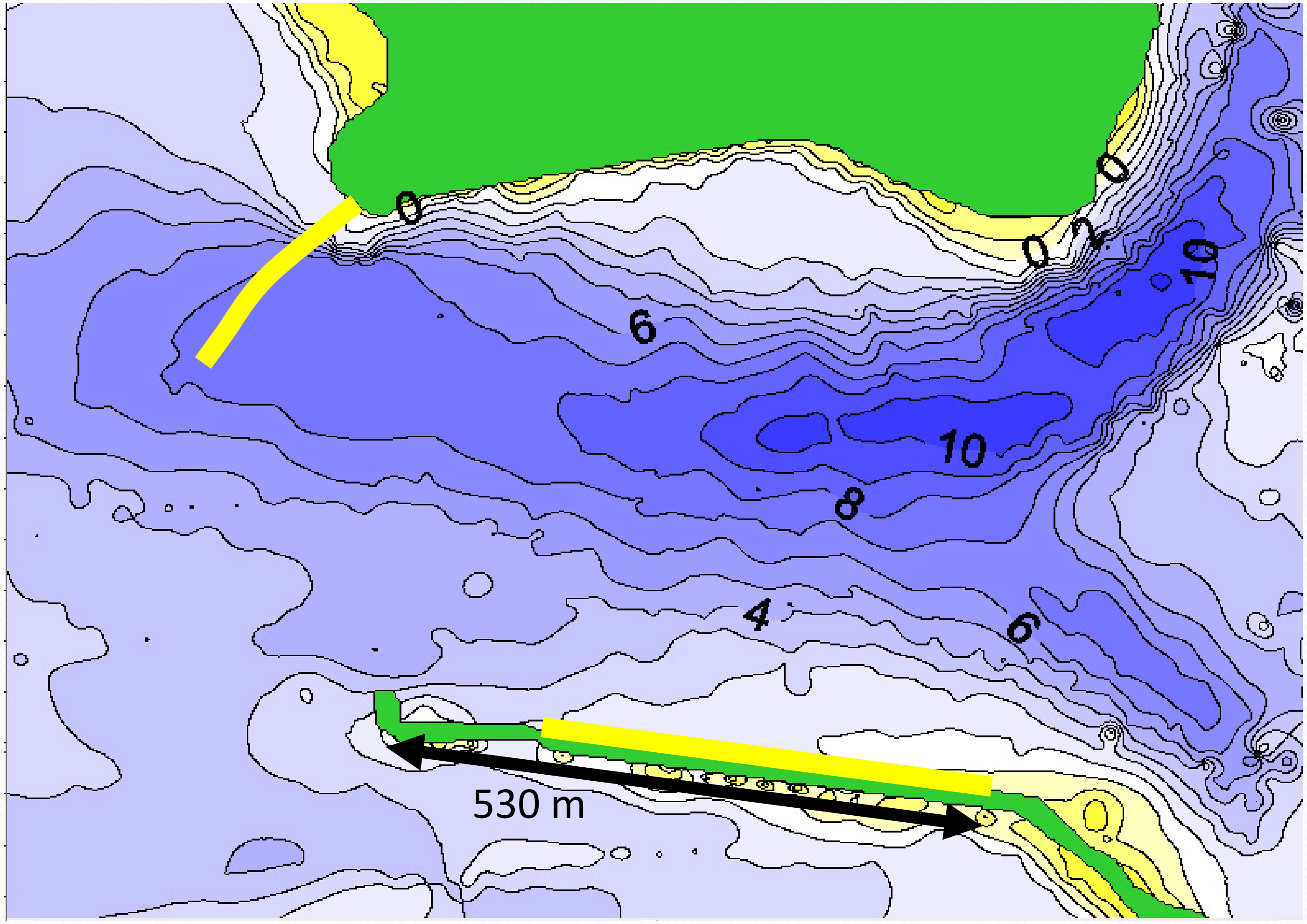
A hybrid solution was proposed to address the Ullal erosion problem :

- Altered north breakwater to ensure that sand coming from the river is driven south and that natural by-passing occurs more effectively
- Re-alignment of the Ullal Beach to face more directly into the waves, and thereby stop the large quantity of sand moving south and being lost from the beaches
- Nourishment of the beach to “catch up” on the long history of erosion and sediment loss
- Construction of two offshore multi-purpose artificial submerged reefs (M-ASR’s) and four nearshore berms to hold the nourishment in place


Erosion management options at Ullal
Natural Sediment bypassing
Offshore submerged reefs
Image © 2008 DigitalGlobe
© 2008 Europa Technologies

Breakwater realignment :

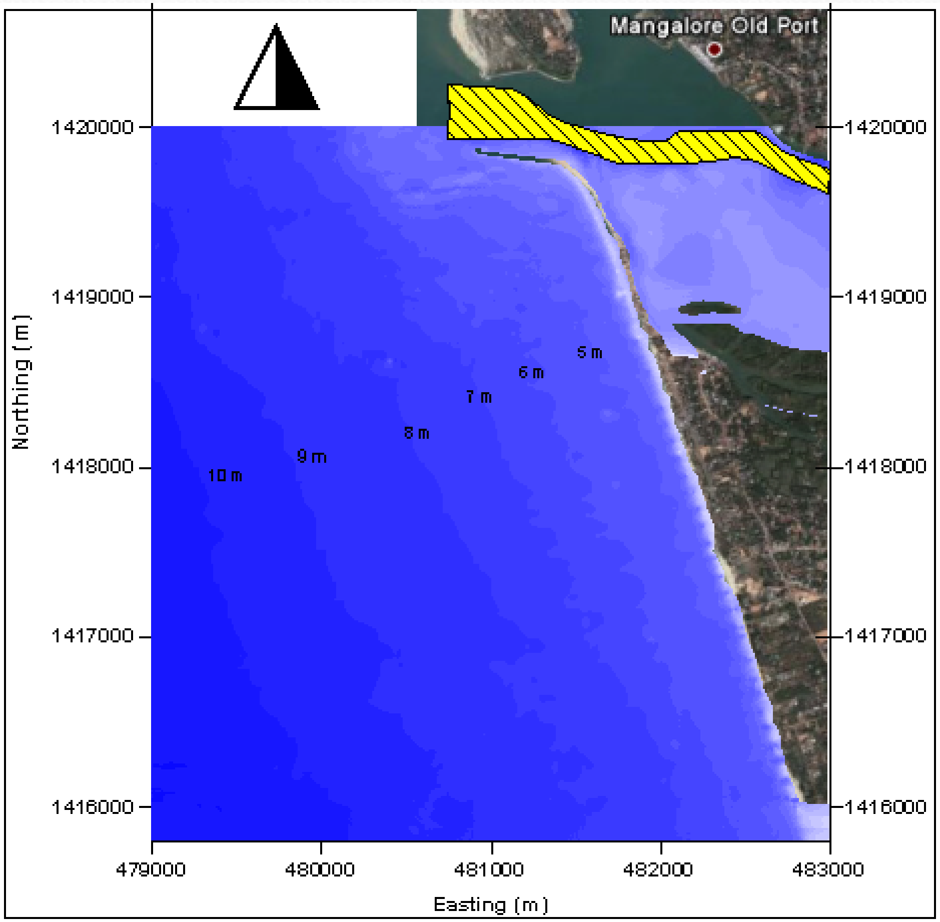
Proposed changes to the breakwater. The north breakwater is extended across the channel by 200 m. The south breakwater is being shortened by 150 m



BEACH NOURISHMENT

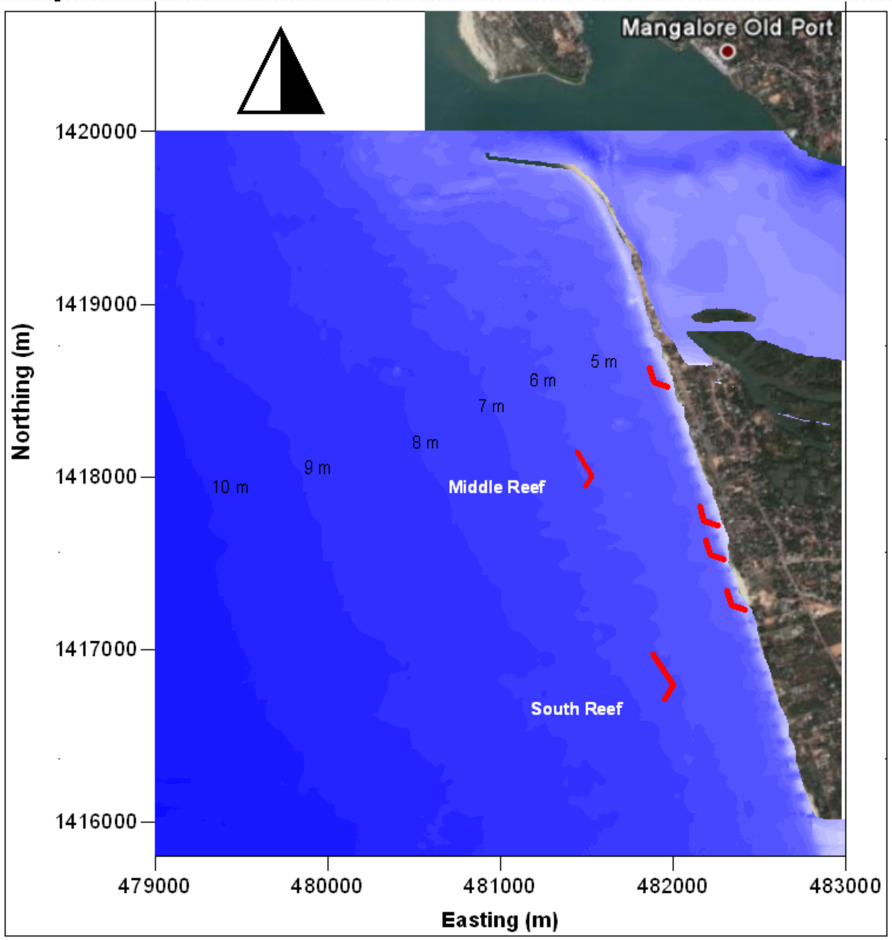
- To nourish the beach (450,000 m^3)and fill the geotextile containers (70,000 m^3)will be sourced from the shoals that exist in the Ullal Inlet and Netravati river bed

- A layer of 1 m of sediment will be removed over the channels



Ullal offshore reefs:

Two offshore reefs in combination with four nearshore berms constructed of sand filled geotextile containers to dissipate incoming wave energy and stabilise the beach nourishment placed on shore.



The volume of the reef is governed by several key factors:

Cross-shore width of the reef: If the reef is too narrow the waves don't have sufficient time to shoal and properly break. If the reef is too wide, then volume is wasted unnecessarily.

Longshore length of the reef: The model tests have shown that the reef needs to have a minimum length of about 250 m to provide effective coastal protection.

Crest elevation: The crest height has been set to 1 m above Chart Datum which has been shown by laboratory tests and similar other projects and present modelling.

Sinkage and pancake: A geomat will be placed under the reef to prevent individual bags from sinking. It is essential to allow a minimum of 0.5 m for sinkage and "pancake" filling of the bags.

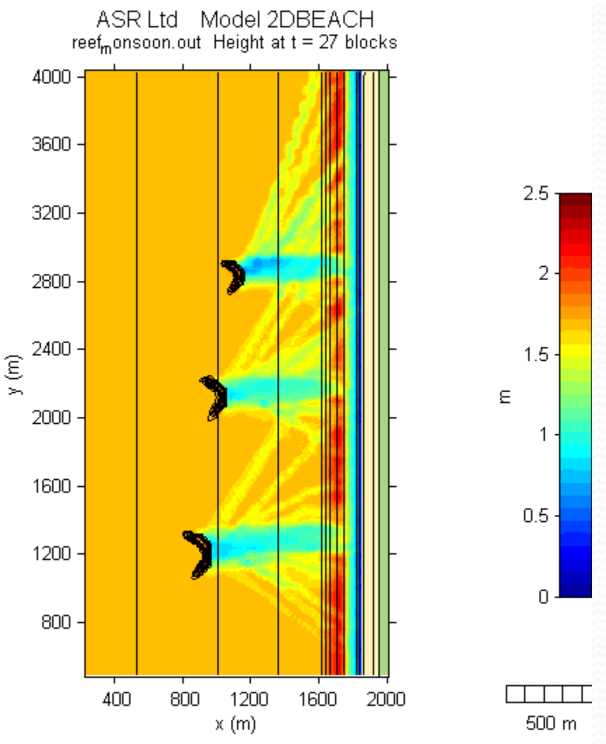
Compression of sand: Under the very high compression forces the grains are forced into each other.

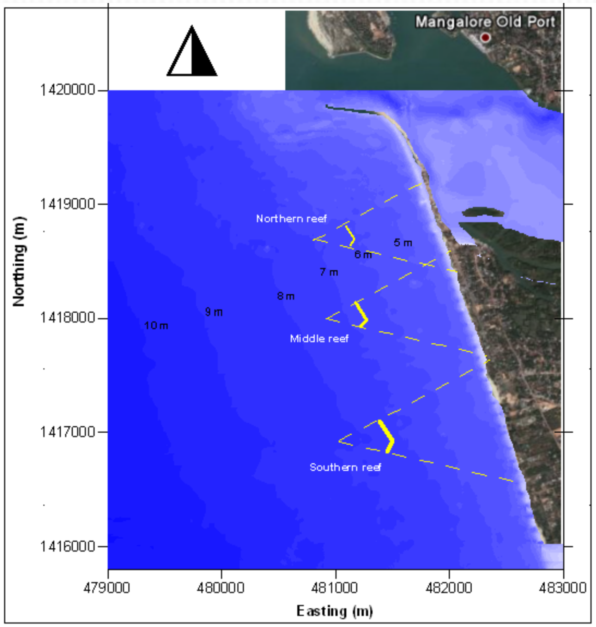
To achieve the coastal protection goals, the optimum reef volume is selected.

Offshore reefs provide a high level of shoreline protection by :

- blocking the wave energy from a wide variety of directions, and
- re-orienting the waves es and thereby minimize or negate the longshore currents.

The reefs are placed well offshore to get maximum benefit by creating wide shadow zone





Local Example Shipwreck salient North of Ullal entrance

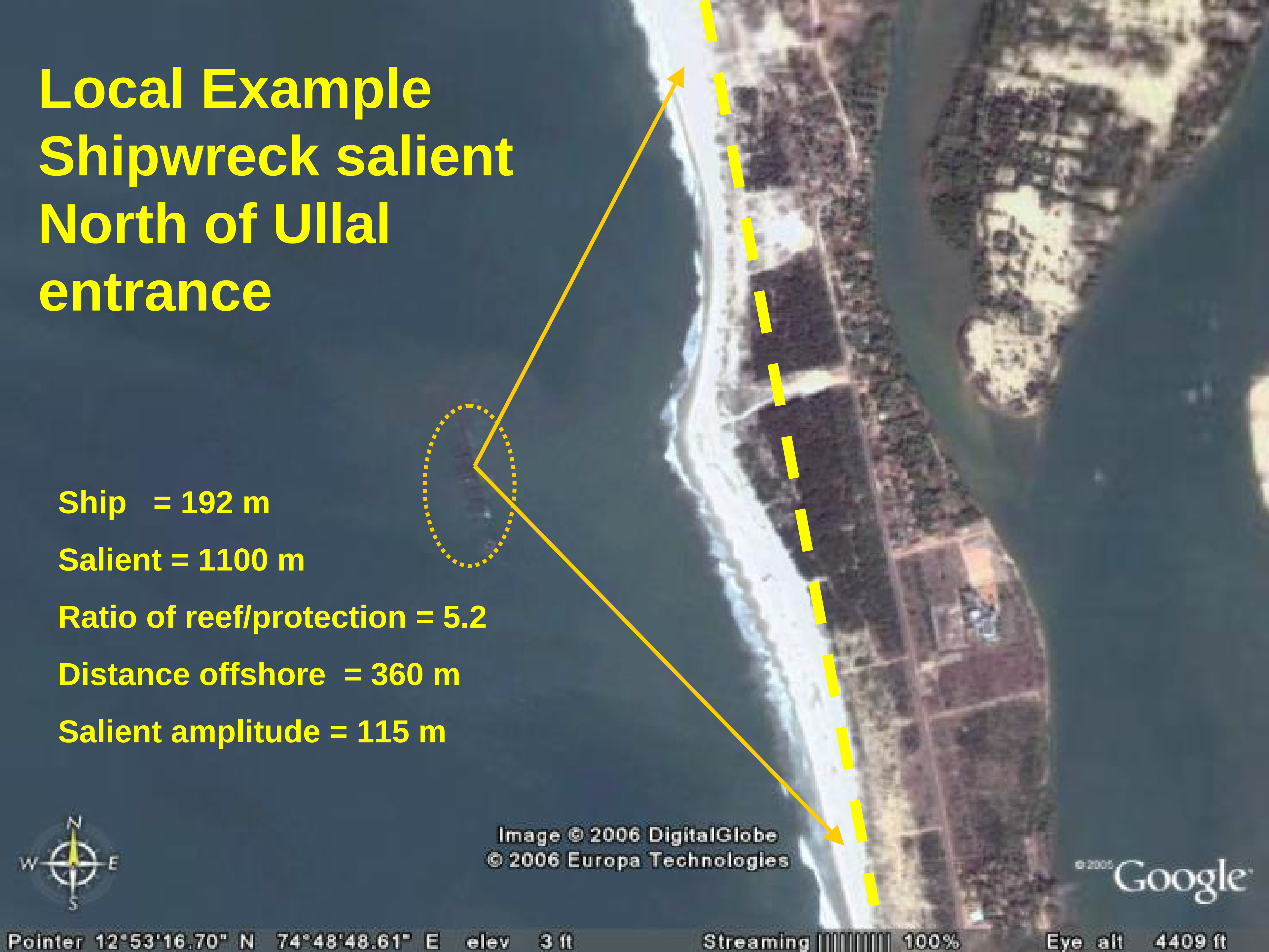
Ship = 192 m

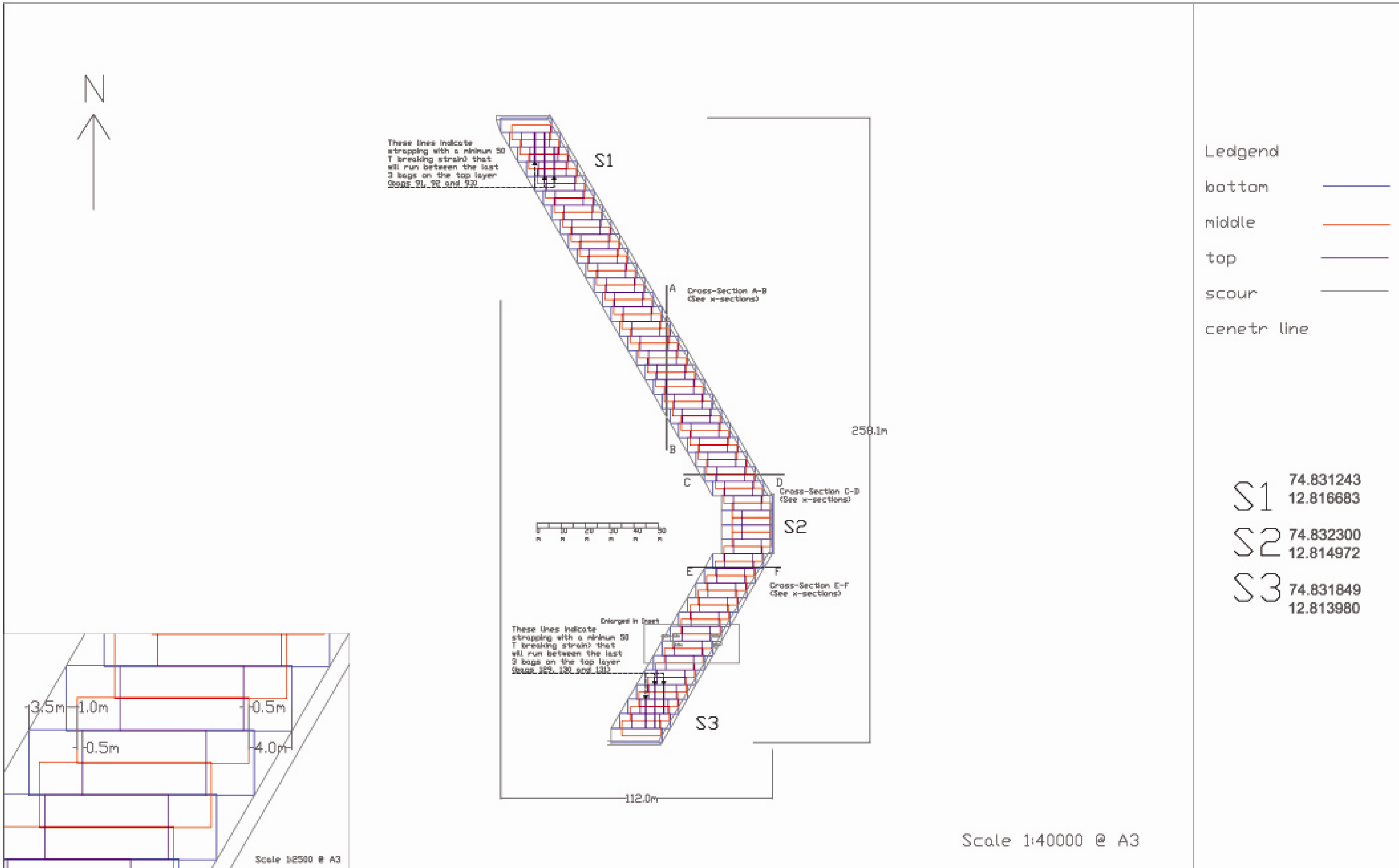
Salient = 1100 m

Ratio of reef/protection = 5.2

Distance offshore = 360 m

Salient amplitude = 115 m





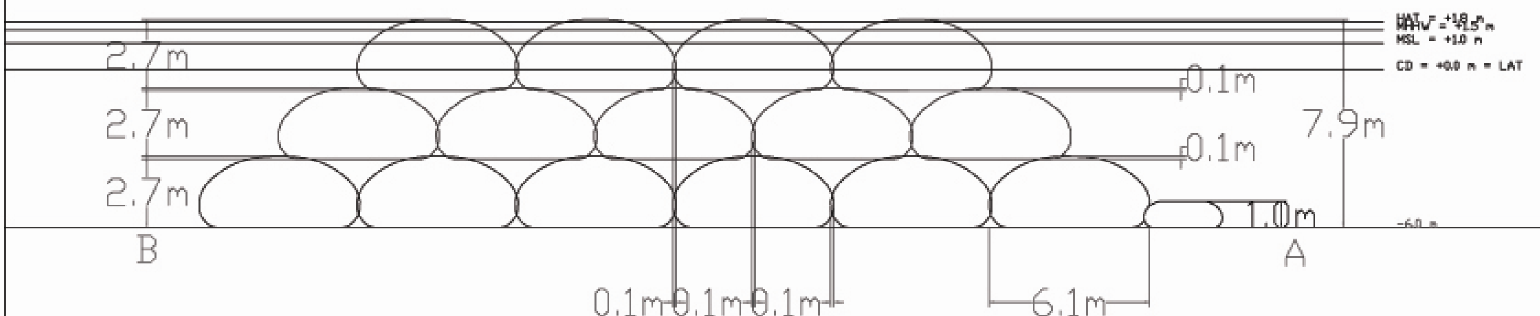
Ullal South Geotextile Reef, Karnataka : Reef Bag Layout

Bag Layout - South Reef

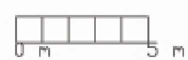
Fig. No. Reef Layout	Date 06/10/2009	Designed

NOTE:

Indicated water levels are relative to the structure immediately after construction.
post construction settlement has been calculated to be up to 1 m.
The indicated crest height will be reduced accordingly.



Cross-Section B-A



Scale

Scale 1:5000 @ A3

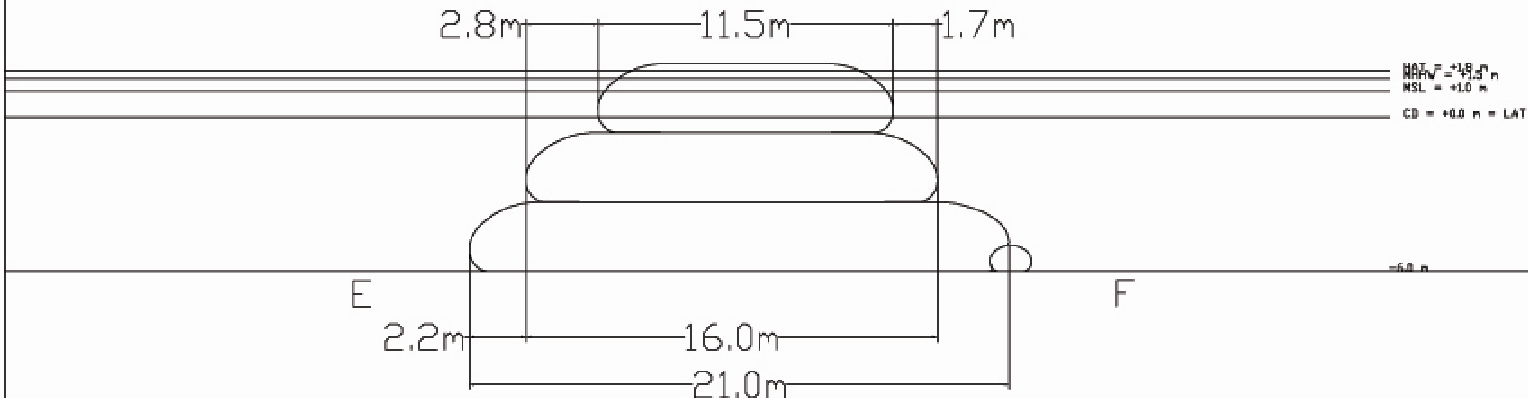
Ullal South Geotextile Reef, Karnataka

Reef Cross-Section A-B

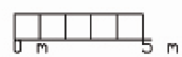
Fig. No. Cross Section A	Date 20/10/2009	Designed	

NOTE:

Indicated water levels are relative to the structure immediately after construction, post construction settlement has been calculated to be up to 1 m. The indicated crest height will be reduced accordingly.



Cross-Section E-F



Scale 1:5000 @ A3

Ullal South Geotextile Reef, Karnataka

Reef Cross-SectionE-F

Fig. No. Cross Section C	Date 20/10/2009	Designed	

Maharashtra sub-project site : Mirya Bay

Mirya Bay - Present Problem

The prime causes of erosion include:

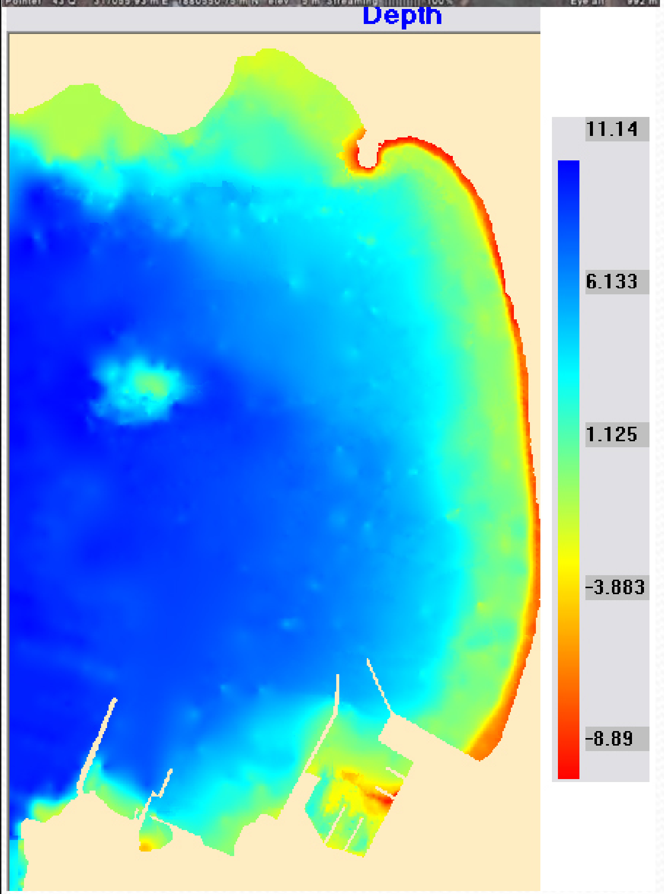
• Sand is being trapped in the fishing port

• Dredged sand from the port is being placed on land, rather than being put back to the bay.

• The beach which originally provided coastal protection is now degraded due to the lack of sand supply and offers virtually no protection.

Mirkarwada Fishing Harbour - Mirya Bay

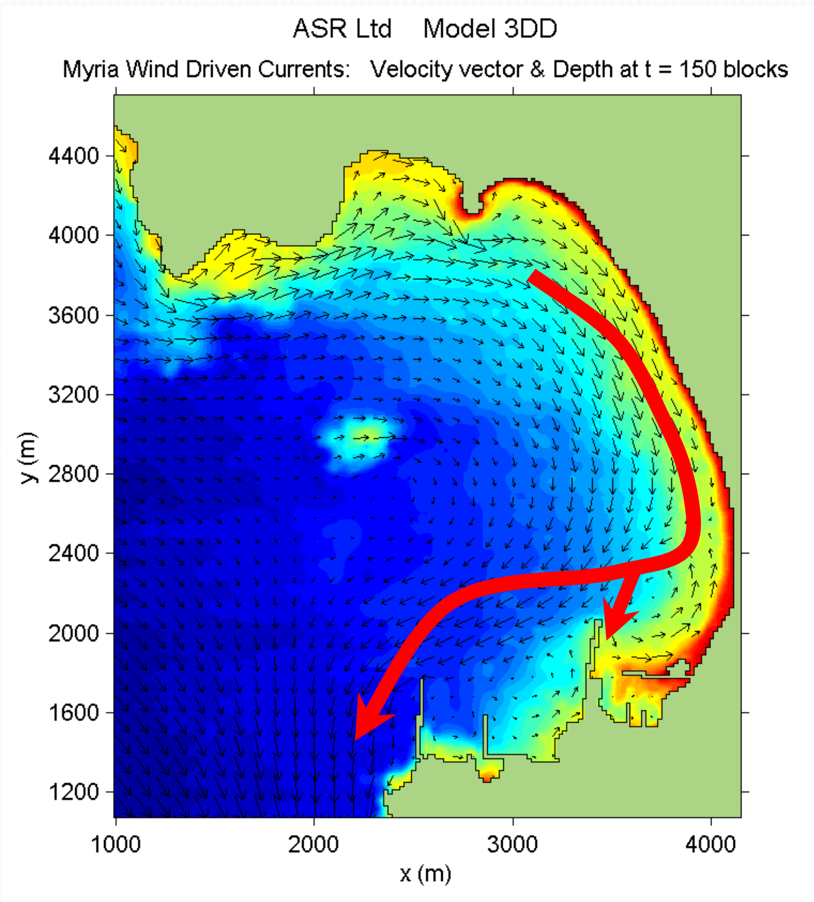
Mirya Bay Fishery Harbour : Stage II Expansion

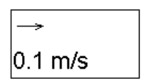


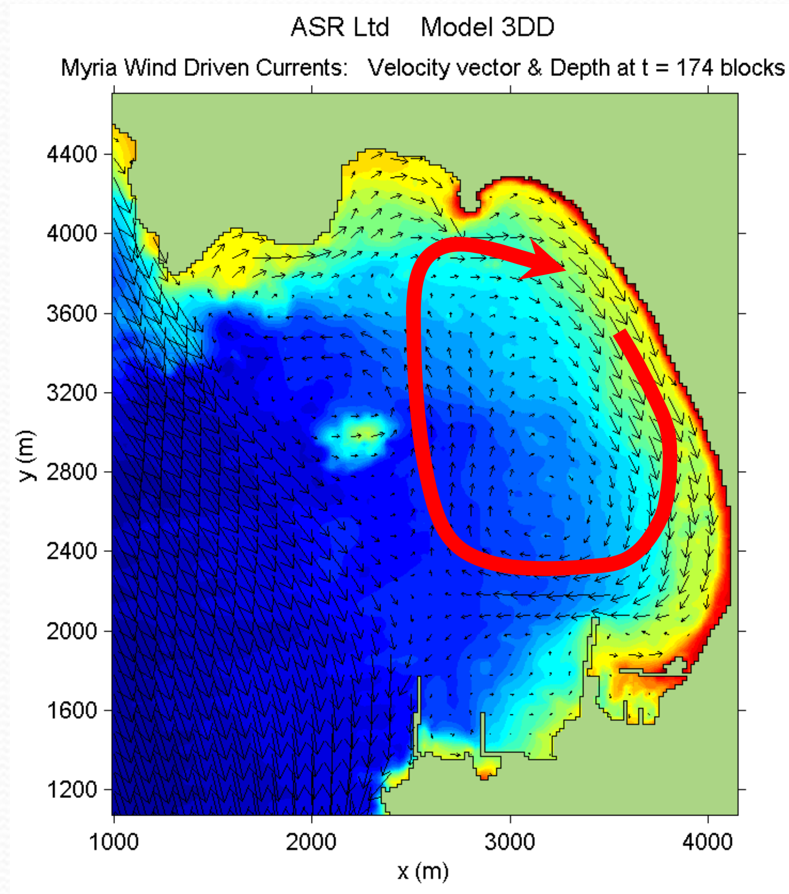
Mirya Bay : Wind driven currents

Monsoon

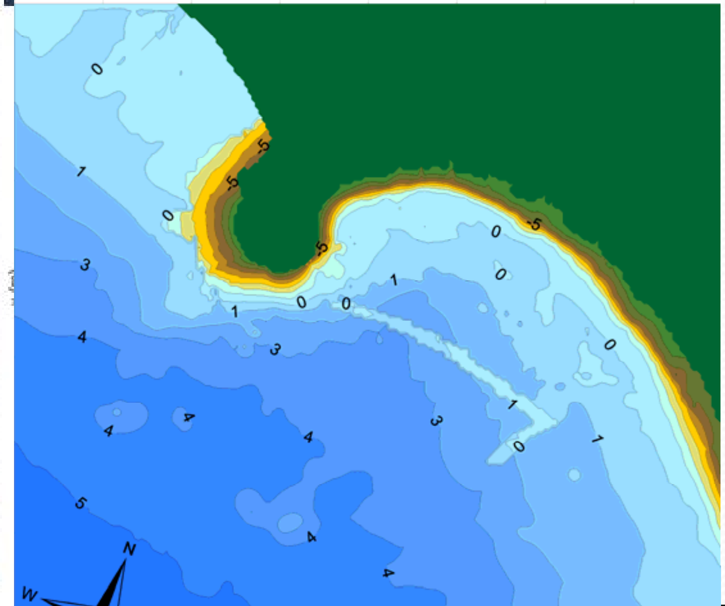
Non-Monsoon



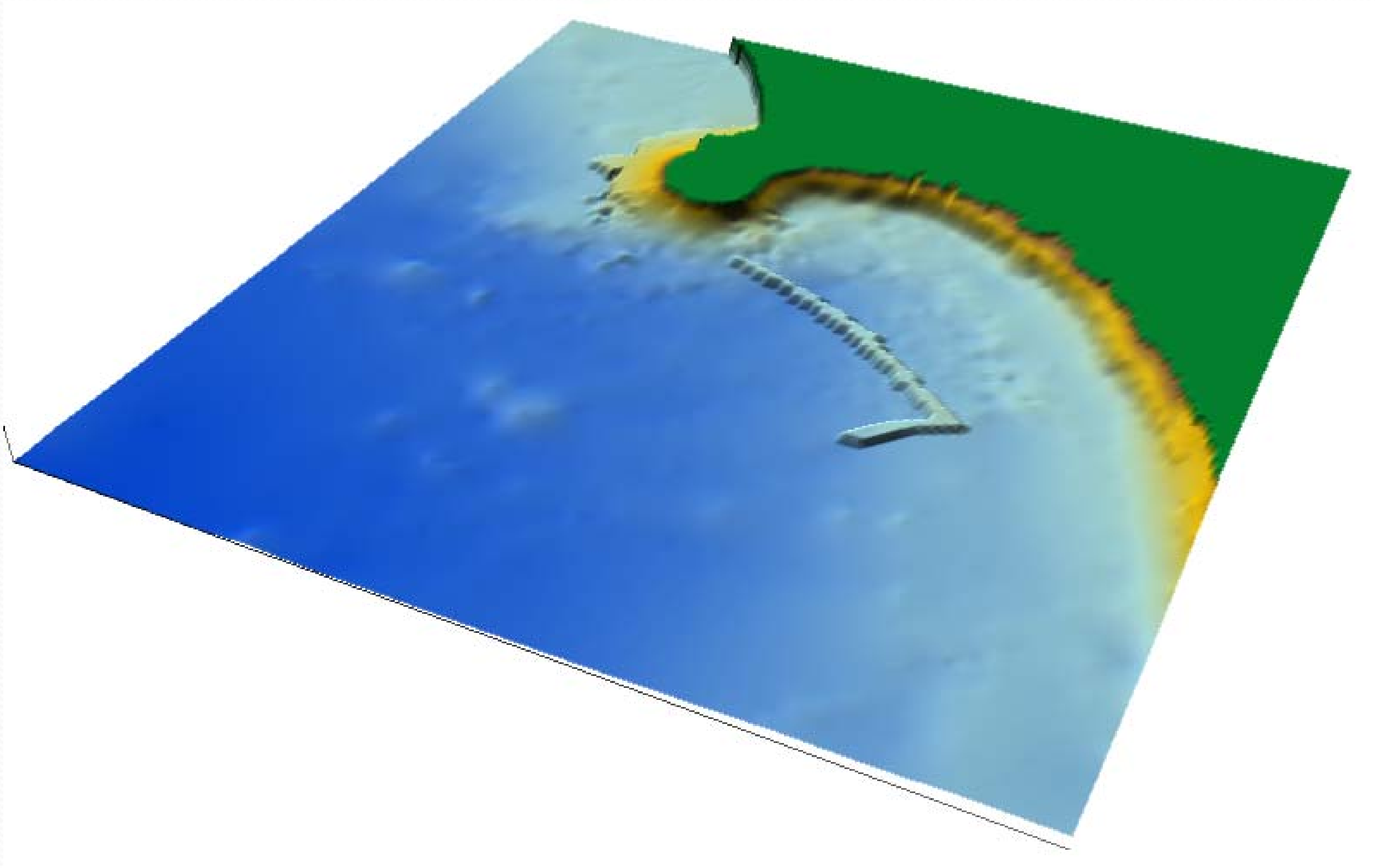




Mirya : Recommended management options



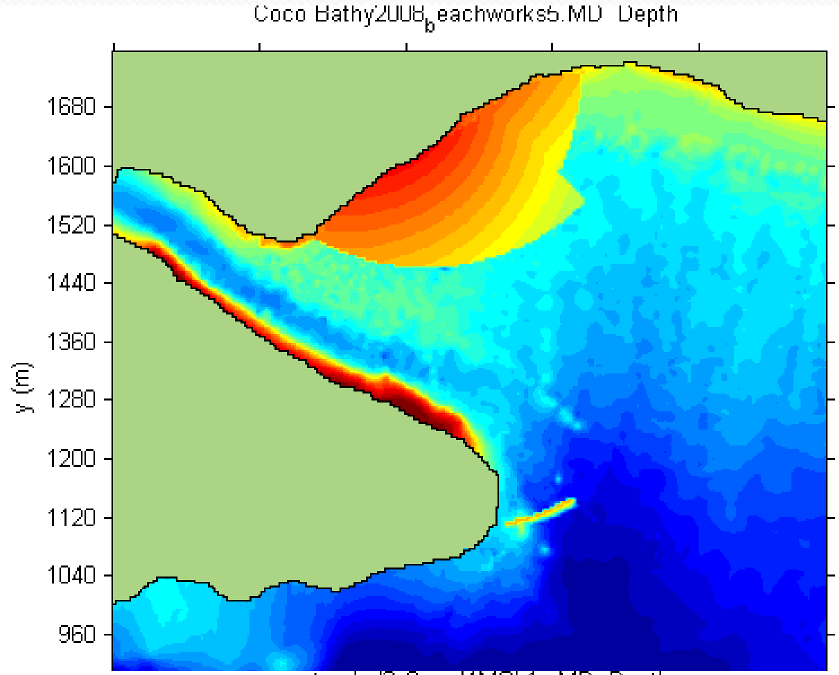
Mirya Geotextile Reef



Coco Beach, Goa

Coco Beach


N
Beach nourishment
Sediment retention
submerged structures



Coco Bathy2008_beachworks5.MD Depth
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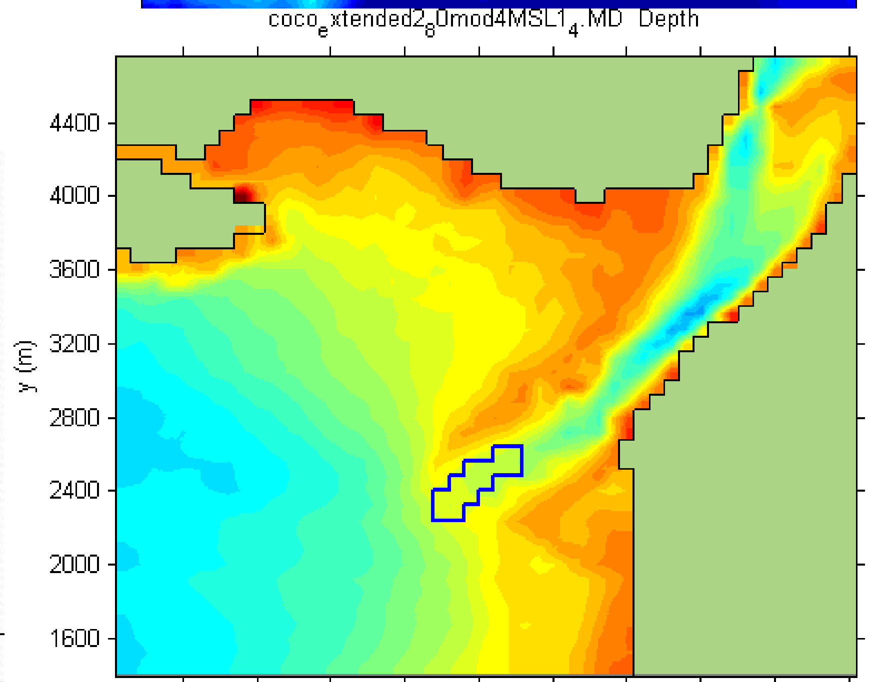
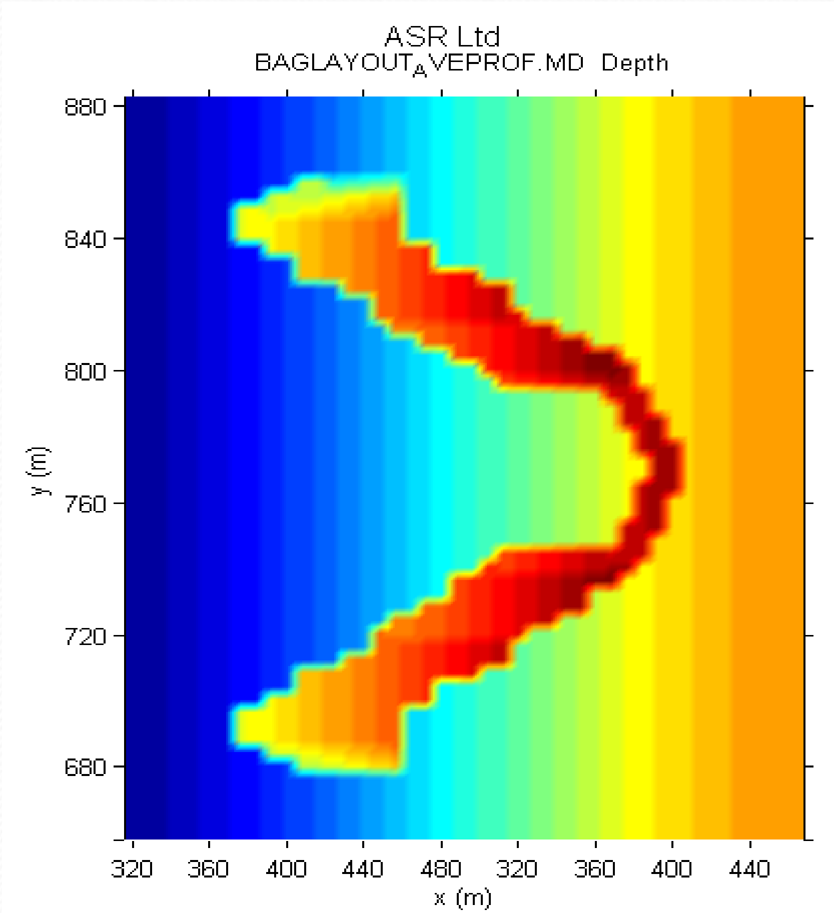
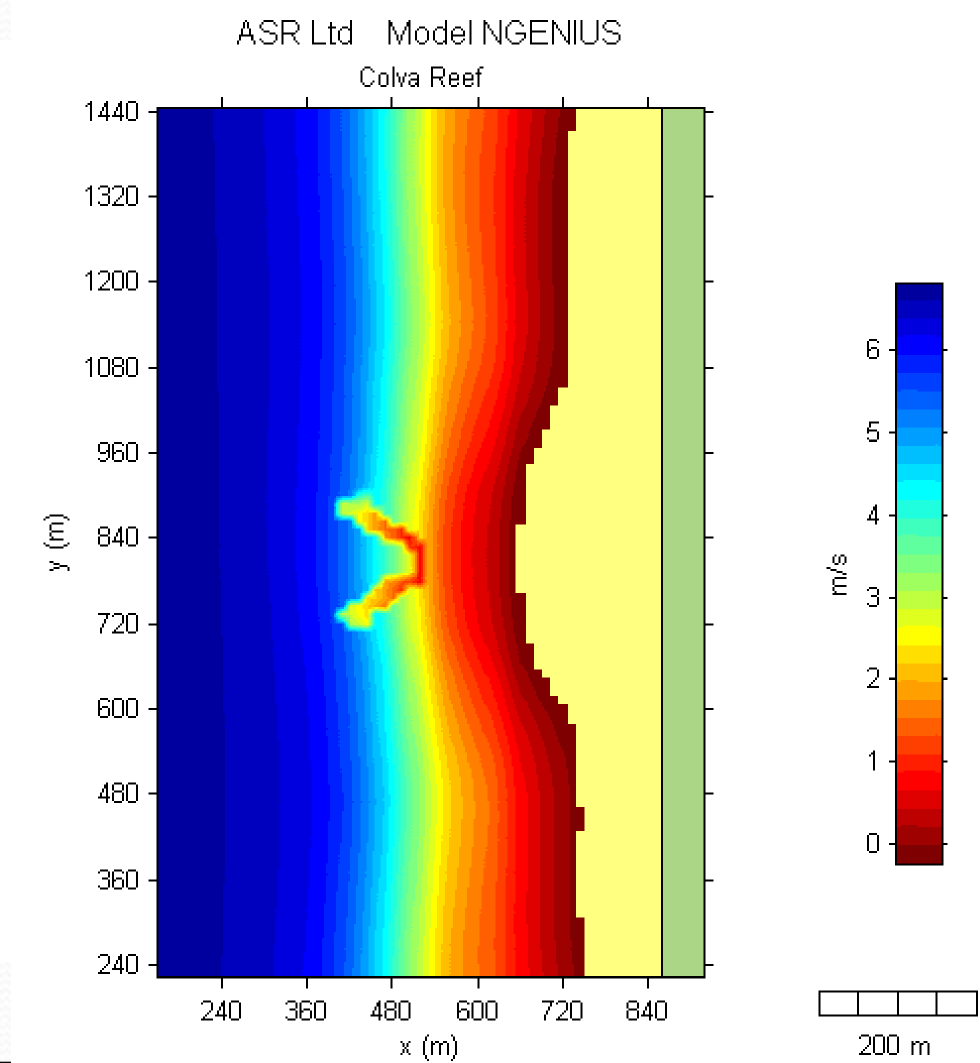
1600
1520
1440
1360
1280
1200
1120
1040
960
y (m)



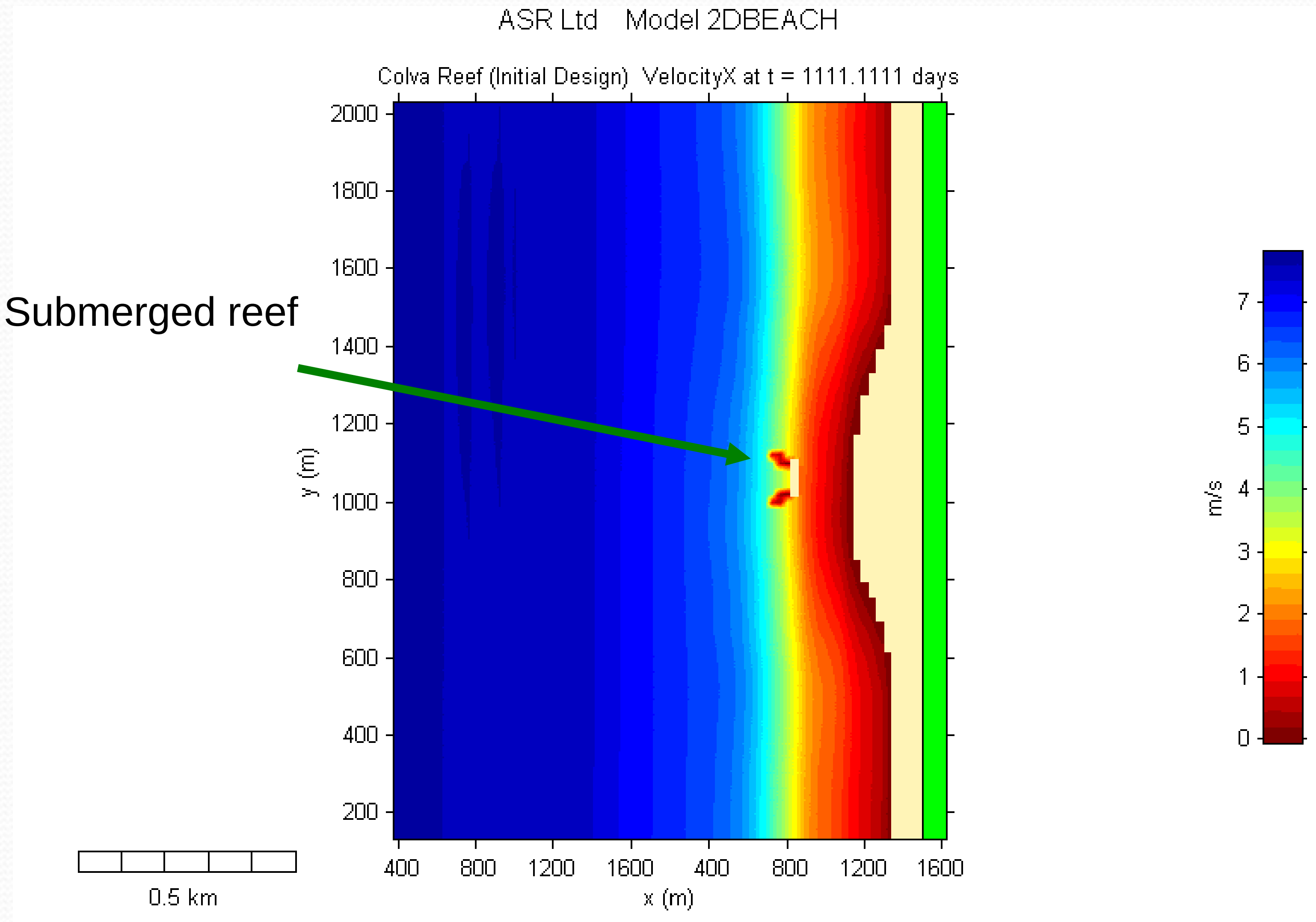
coco_extended2_80mod4MSL1_4.MD Depth
4400
4000
3600
3200
2800
2400
2000
1600
y (m)

Colva Beach M-ASR





No impact on adjacent beaches



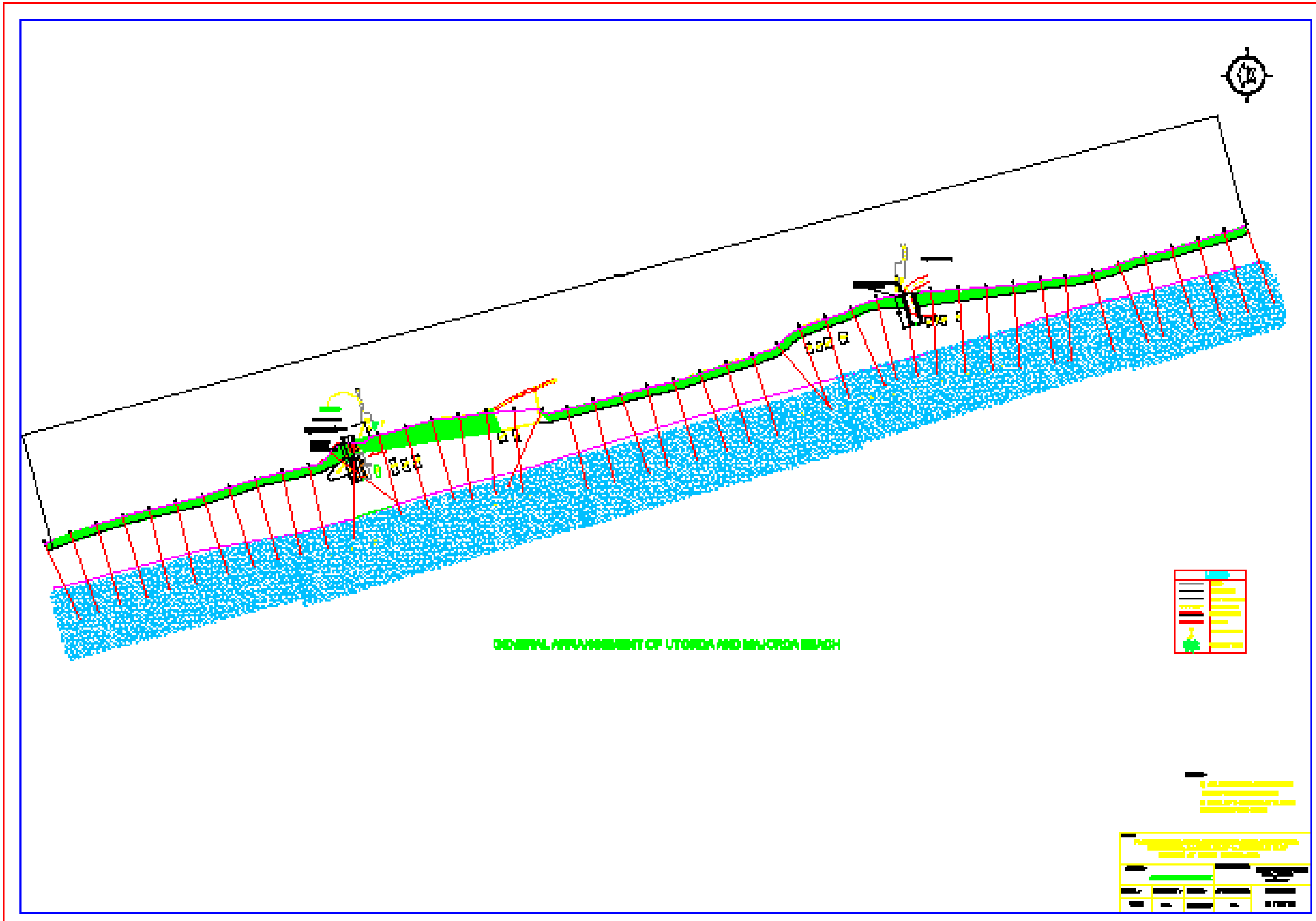
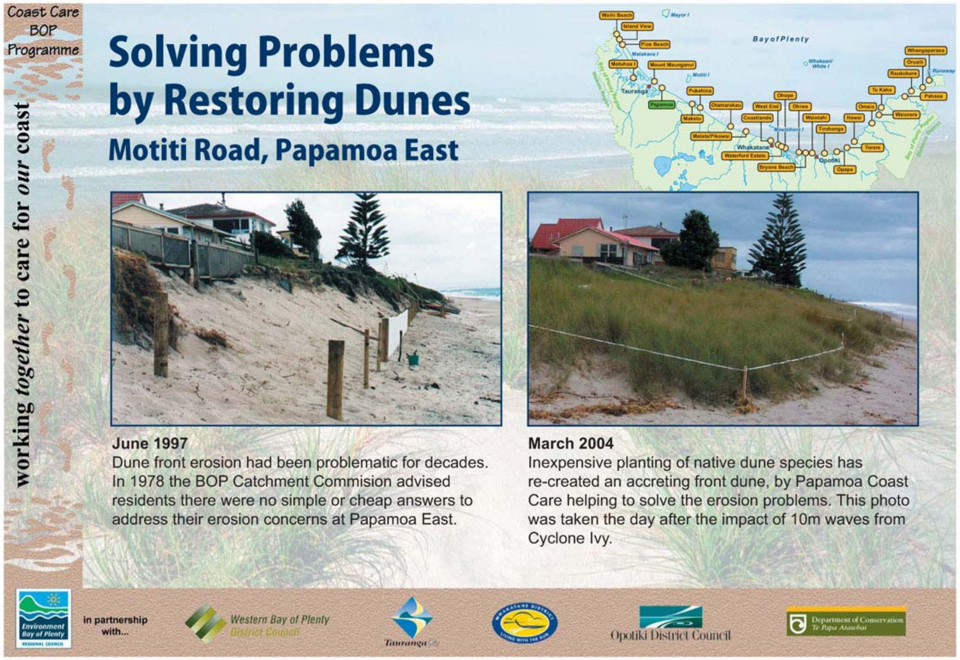
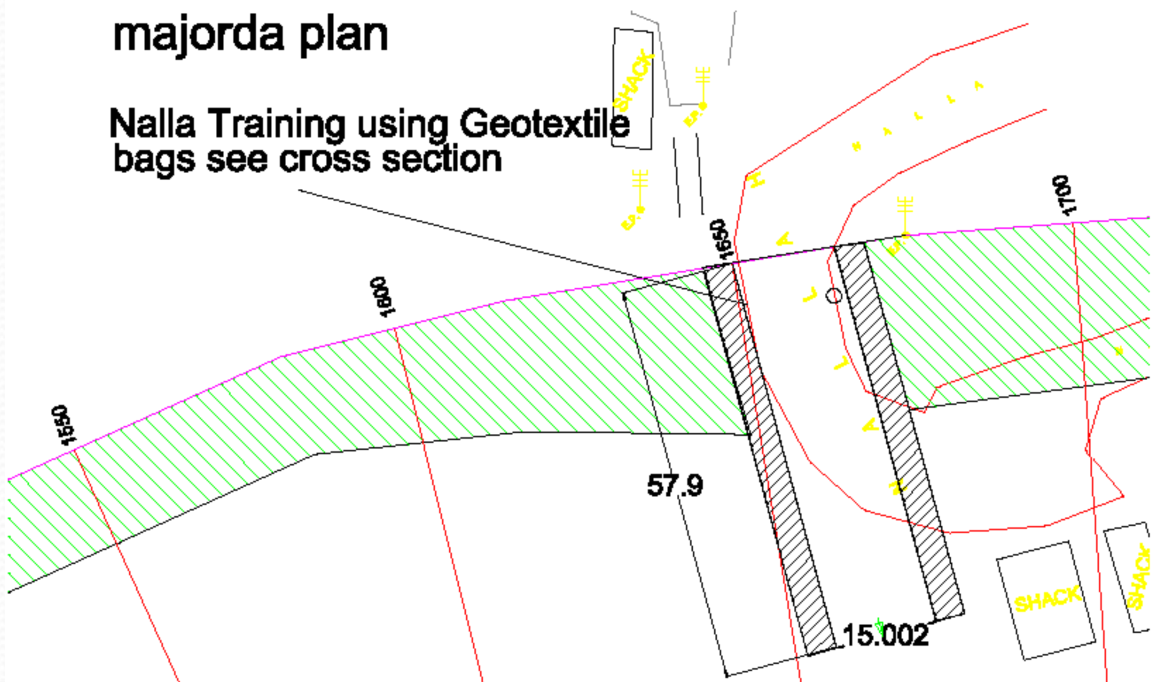

GENERAL ARRANGEMENT OF UTORDA AND MAJORDA BEACH

Photo: Elco Solutions Pvt Ltd.



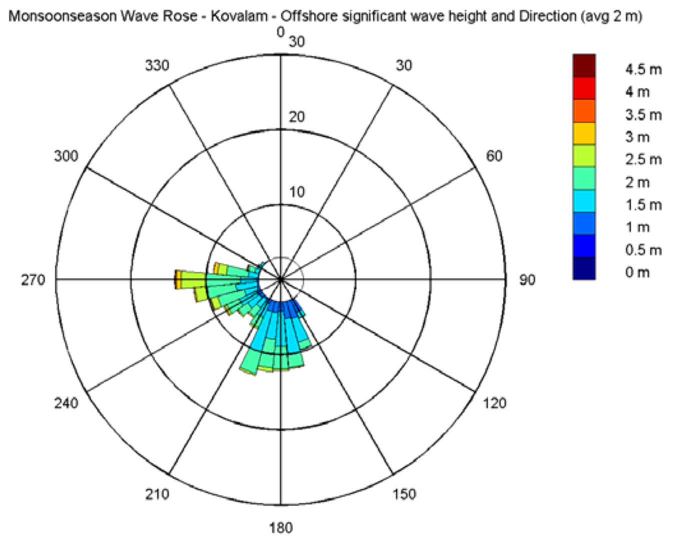

majorda plan
Nalla Training using Geotextile
bags see cross section
SHACK
1550
1600
1650
1700
57.9
15.002
SHACK
SHACK

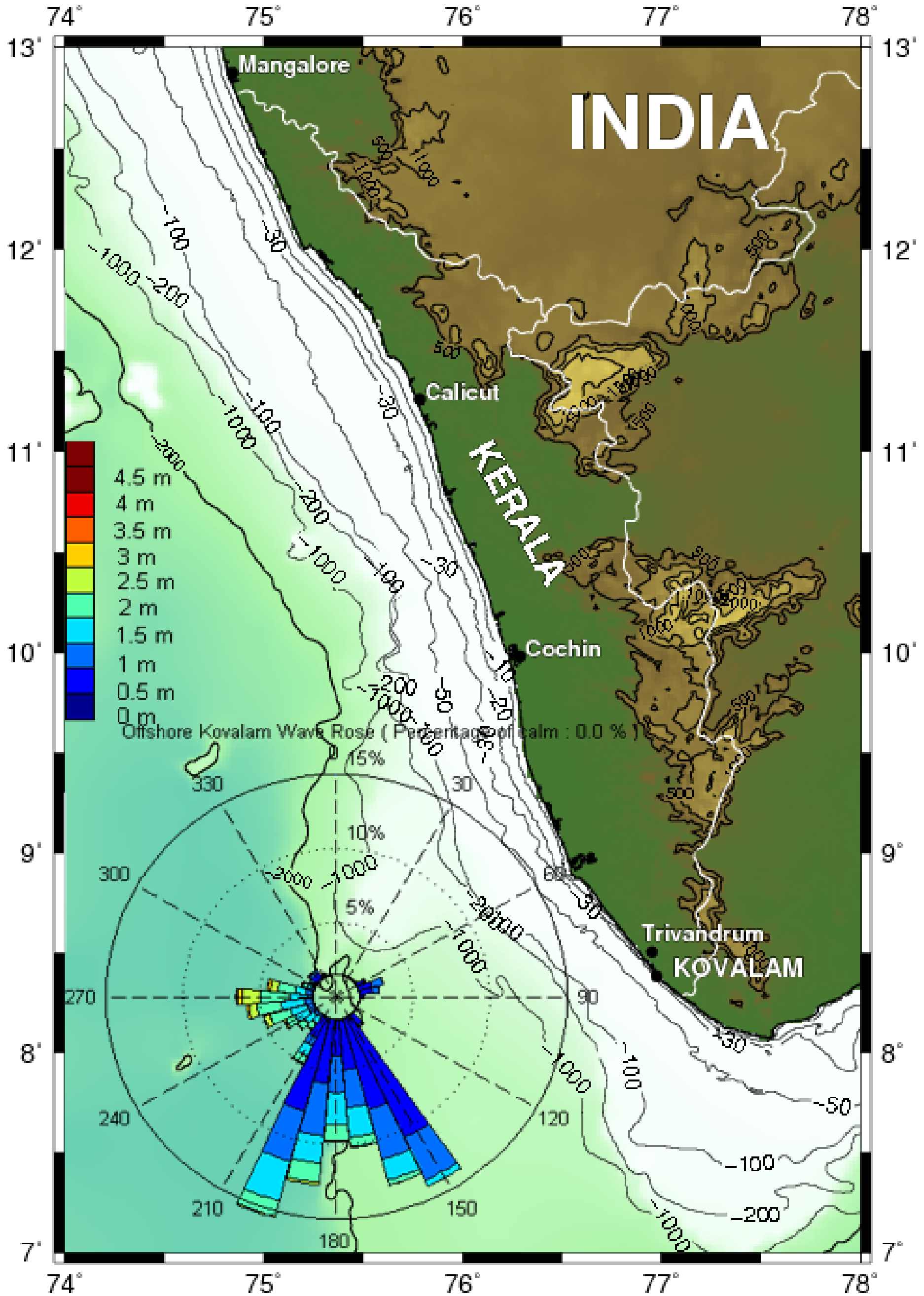
Kovalam Multi-purpose Reef

An initiative of the Government of Kerala for Coastal Protection, Ecology Enhancement and Future Prosperity

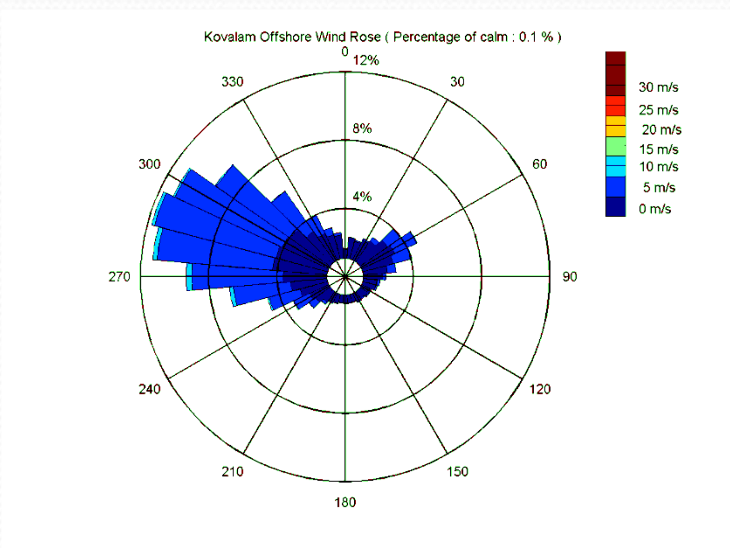
Kovalam – Wave climate.

Two swell directions at all times

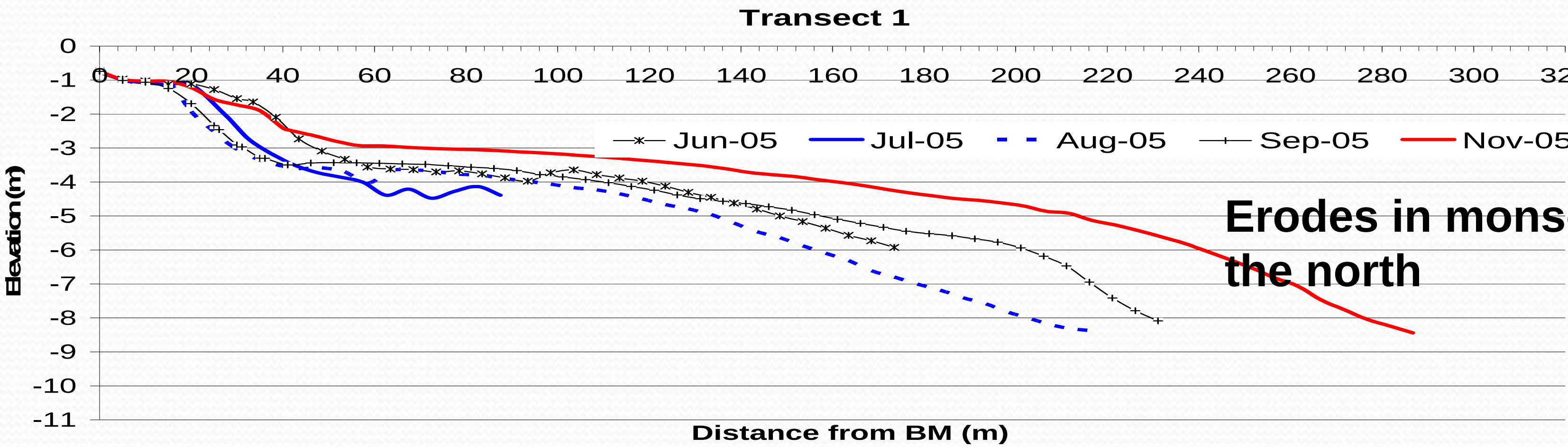




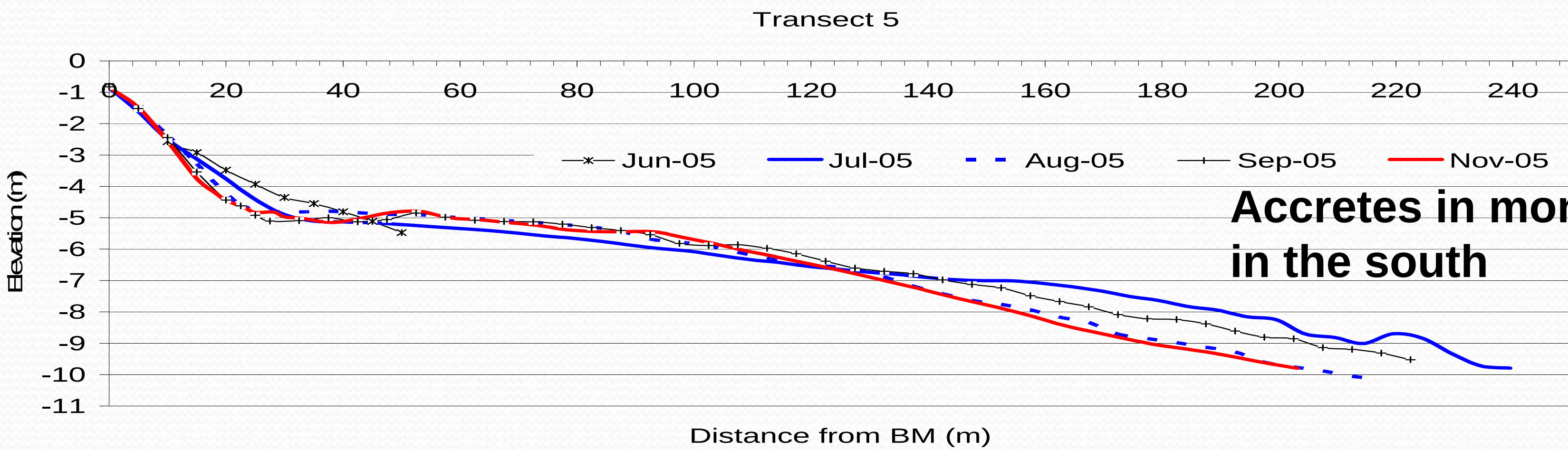
Beach much narrower at the north in monsoon. Bay eroded.



Kovalam – 2DBEACH



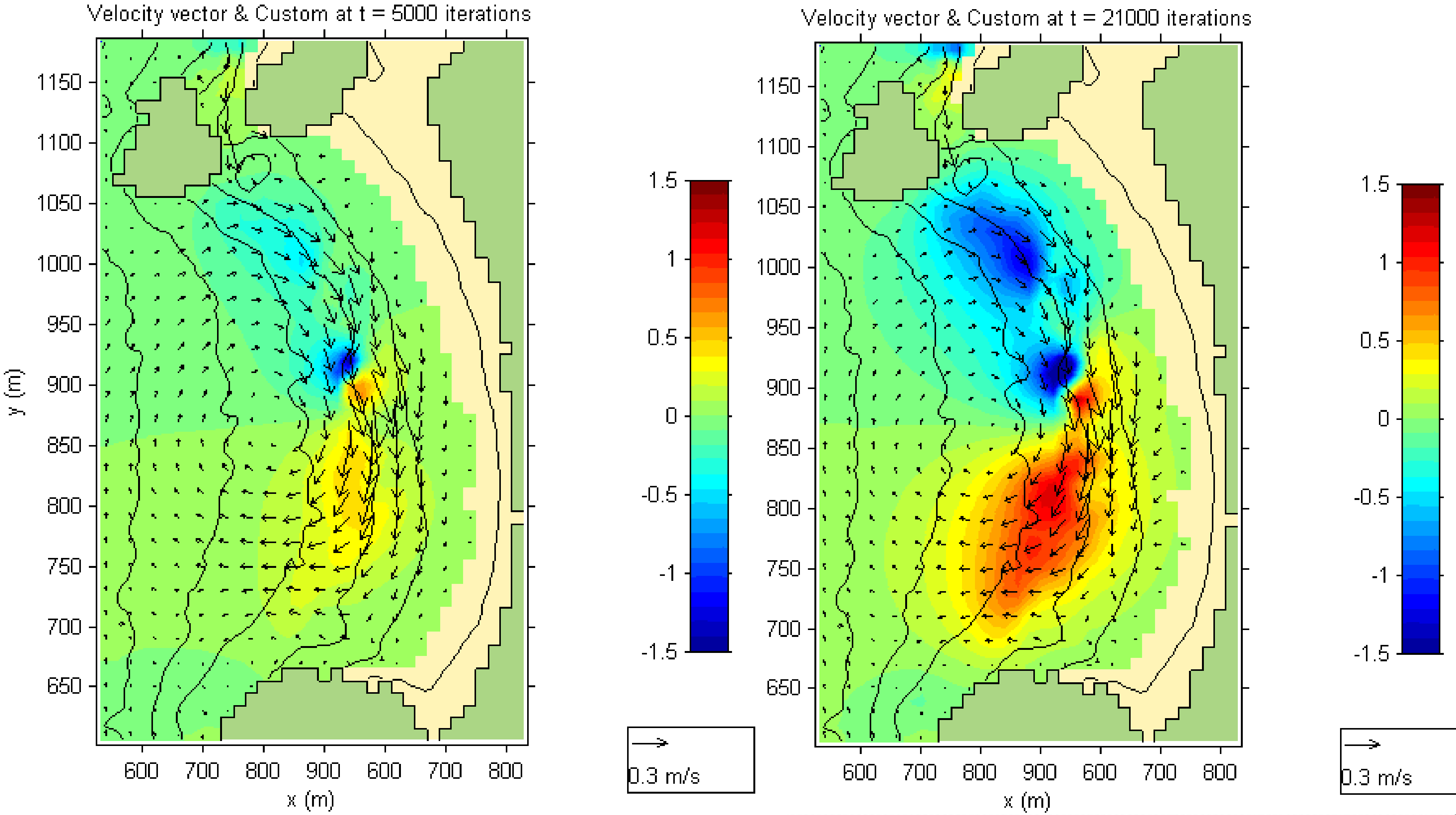
Erodes in monsoon in the north



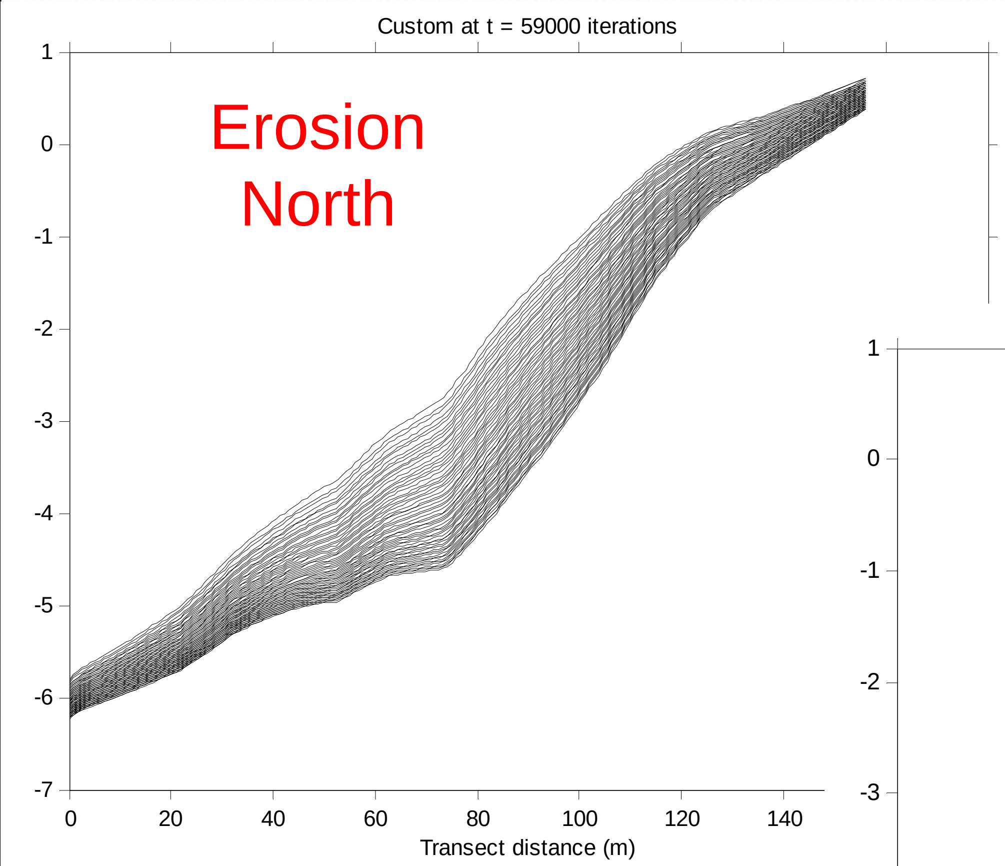
Accretes in monsoon in the south

Need to know what are the processes

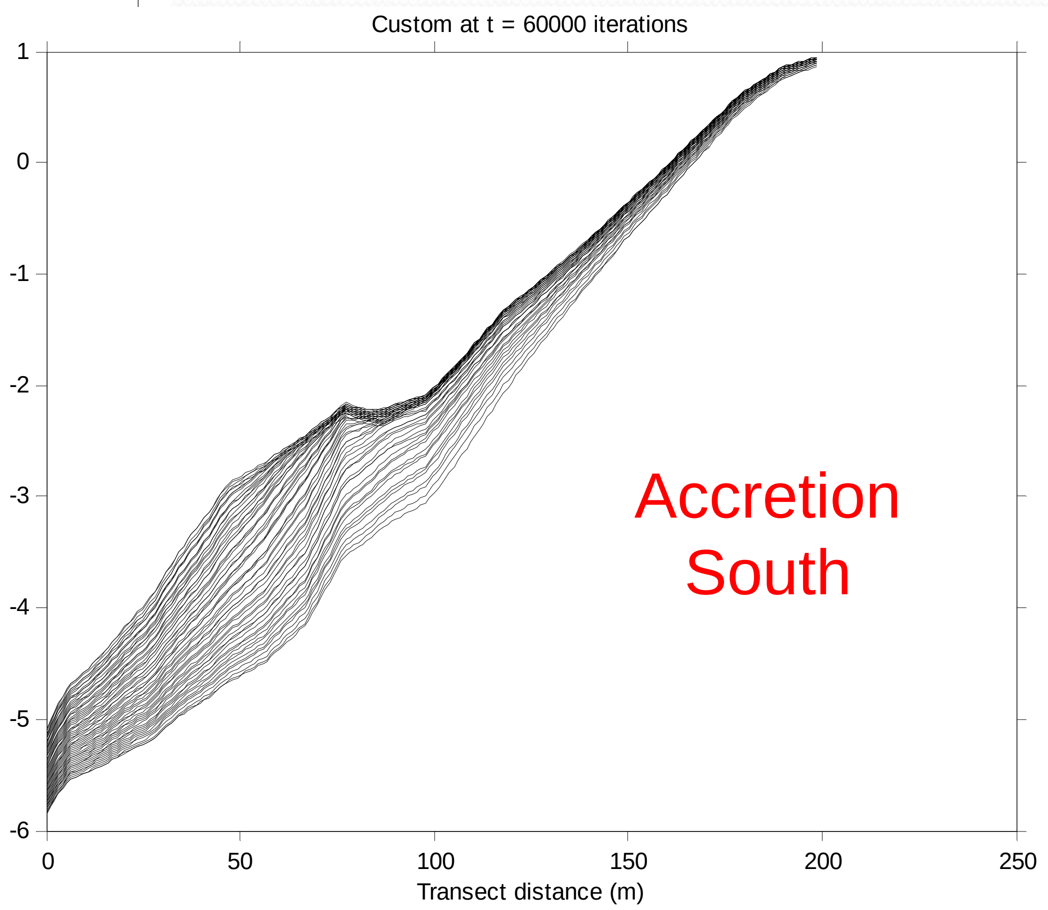
Kovalam – 2DBEACH



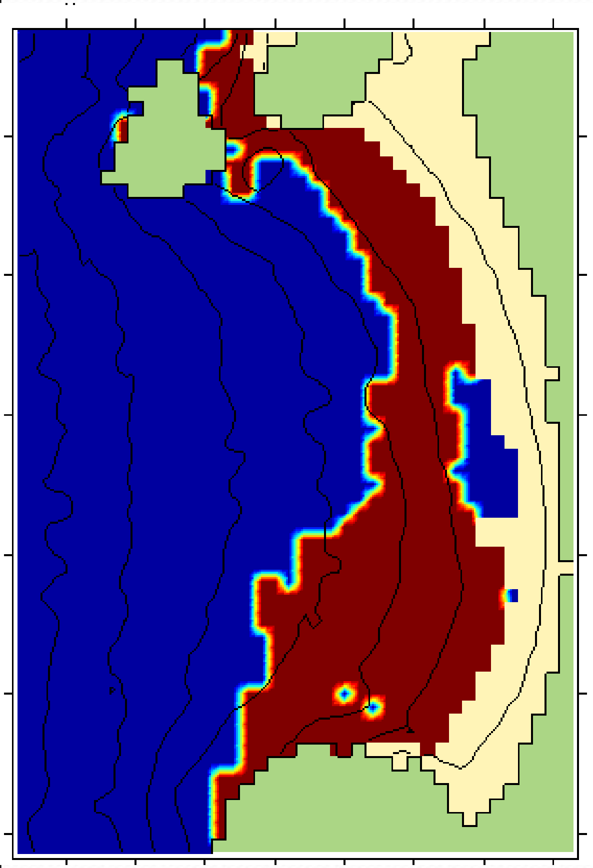
Kovalam – 2DBEACH



2DBEACH explains the beach dynamics

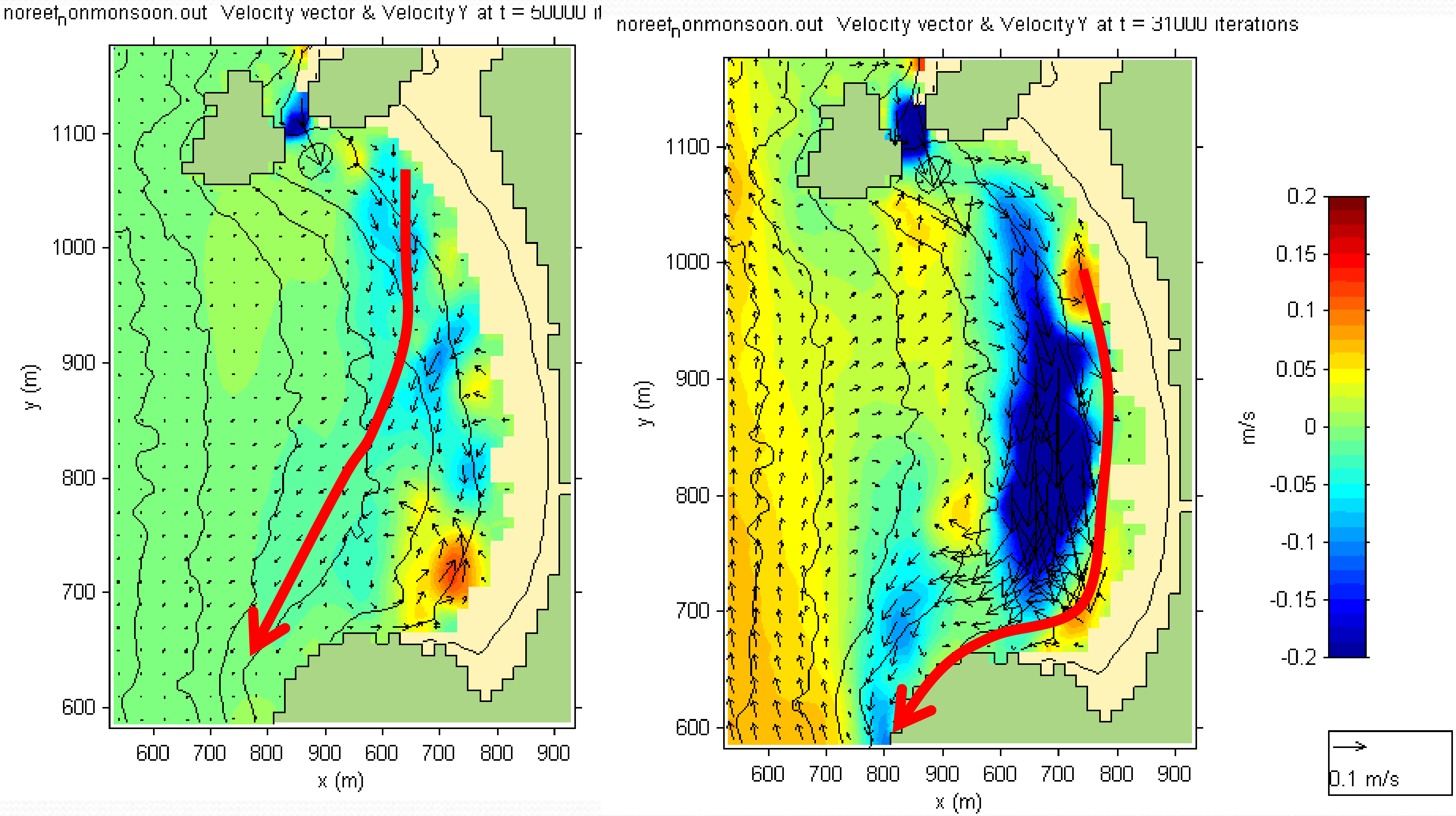


Kovalam – 2DBEACH



Kovalam – The reason for erosion

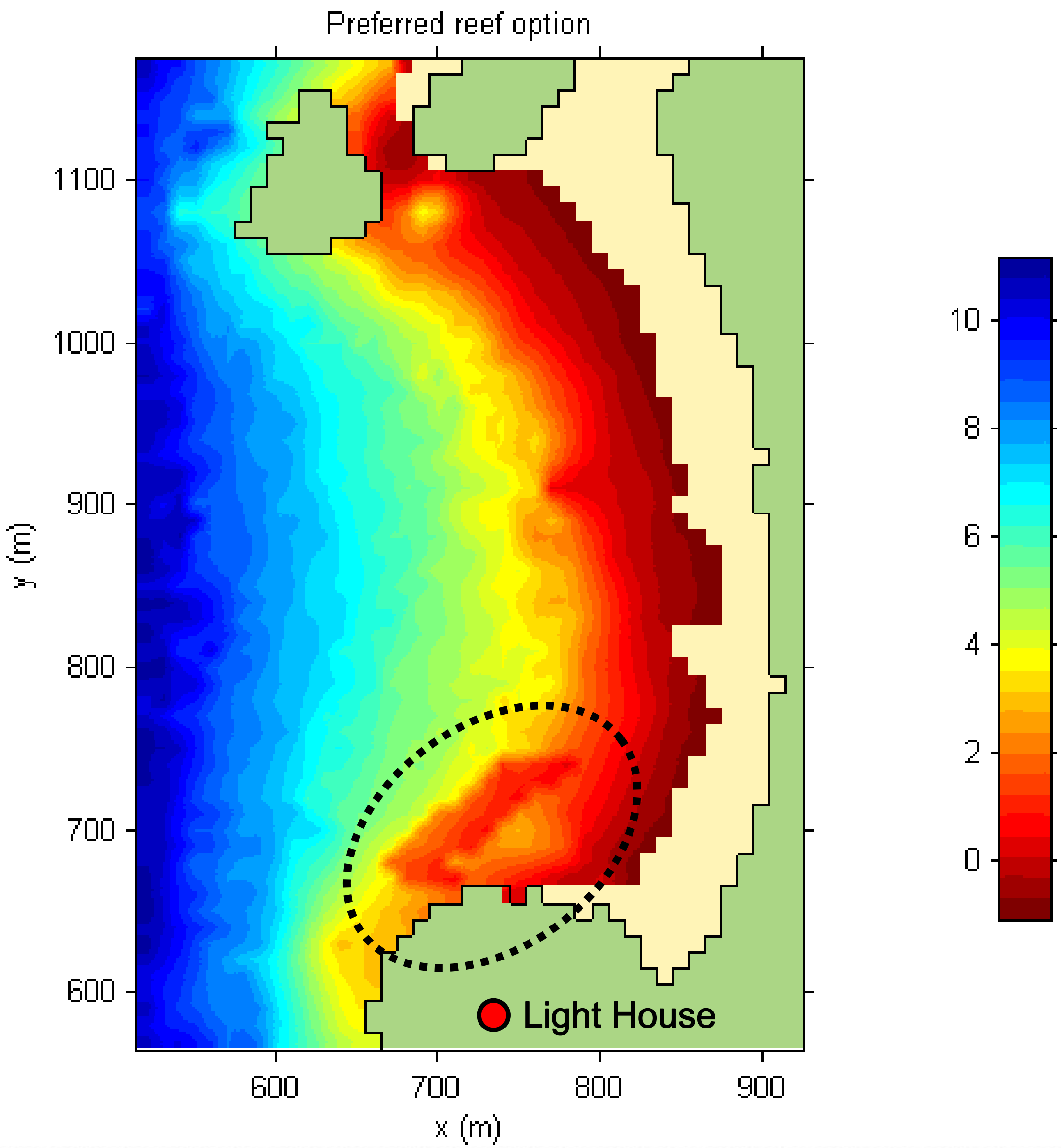
Sand lost from beach

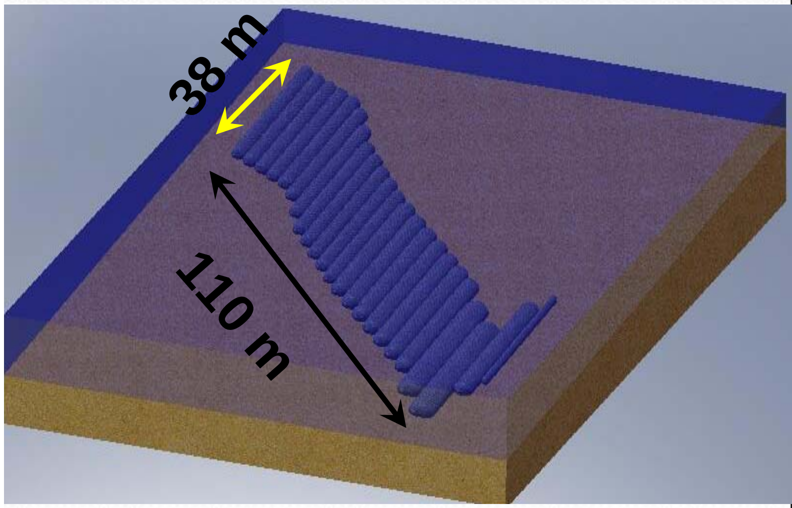


August 2009

September 2009

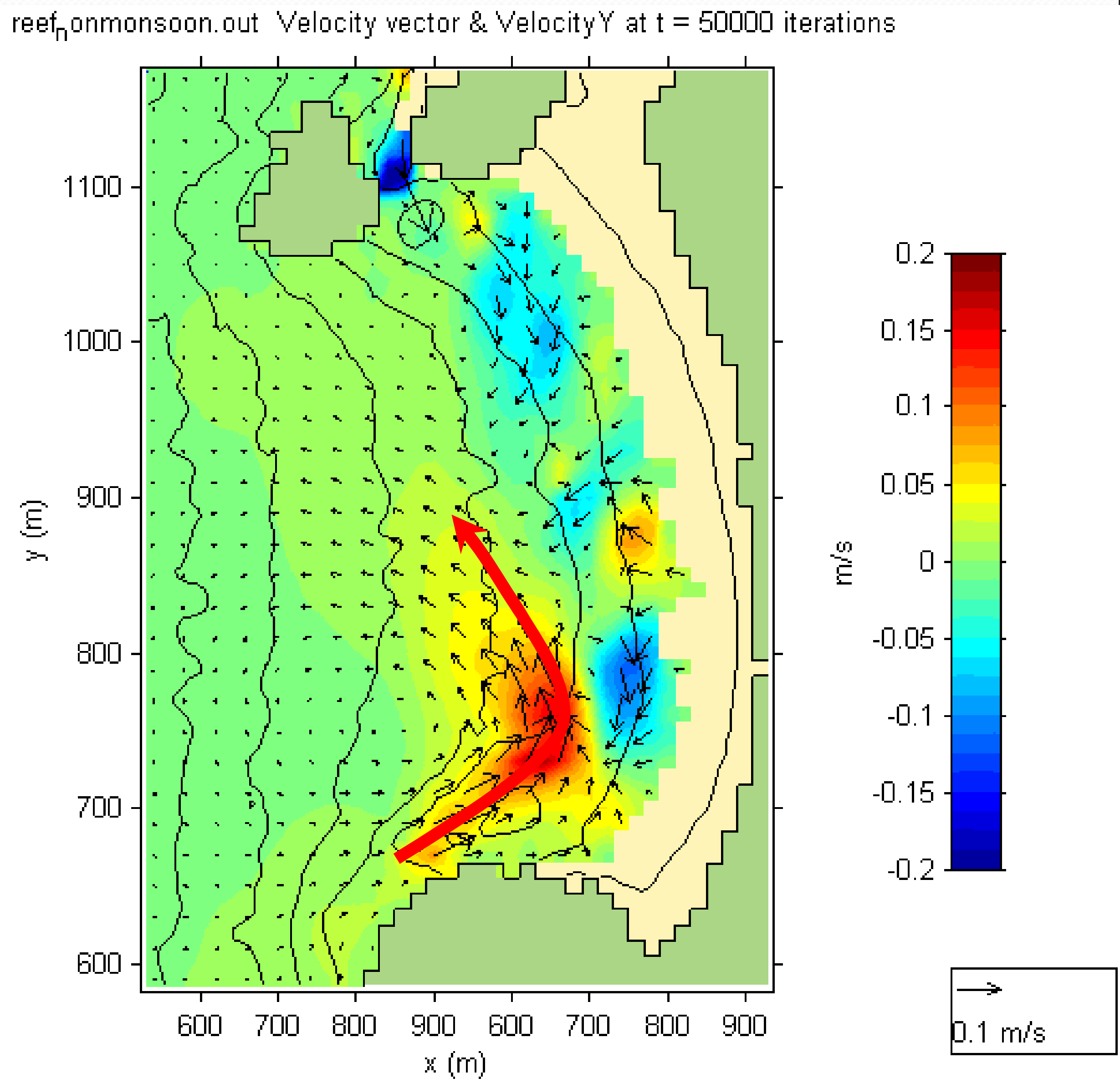
Kovalam Reef – site specific solution

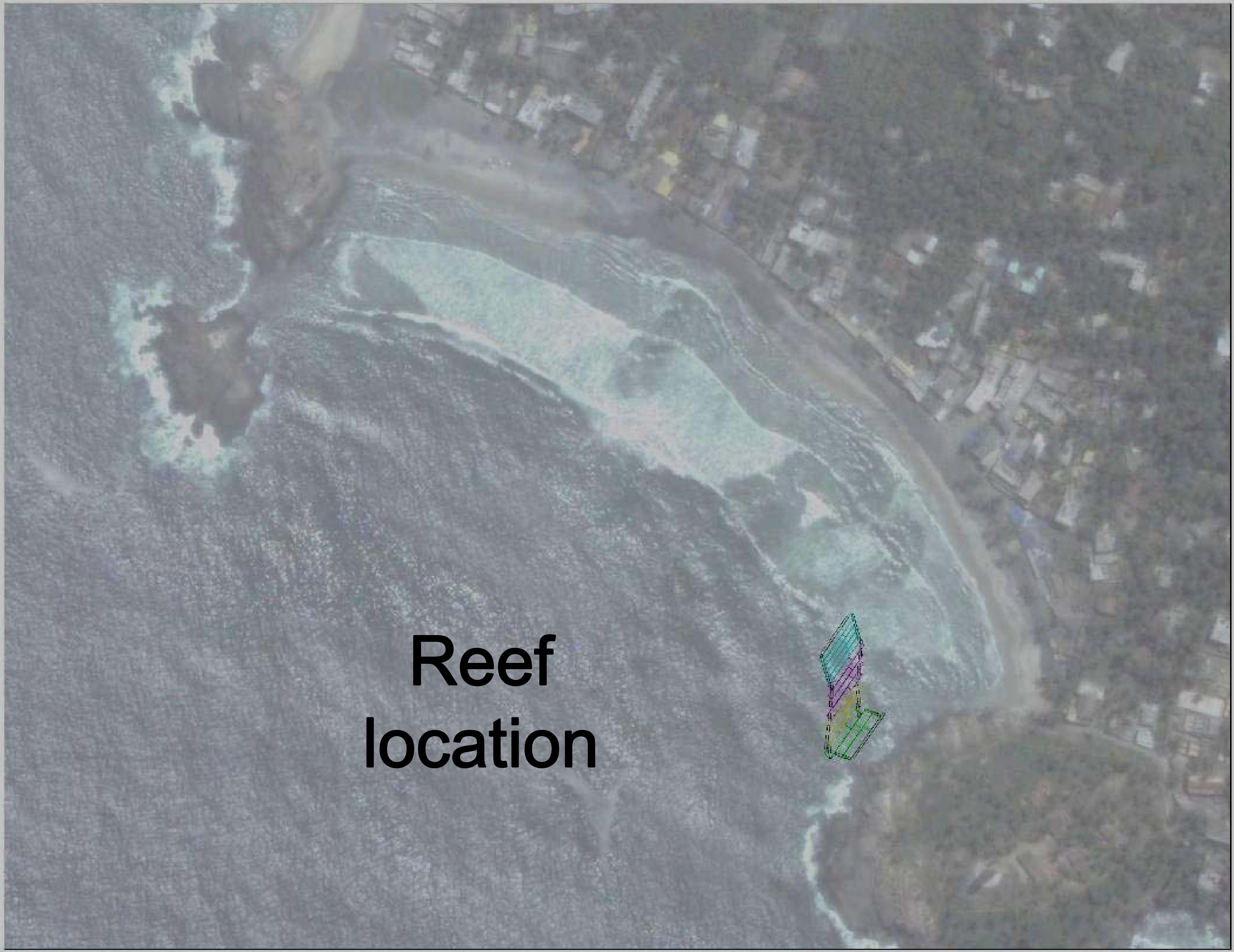




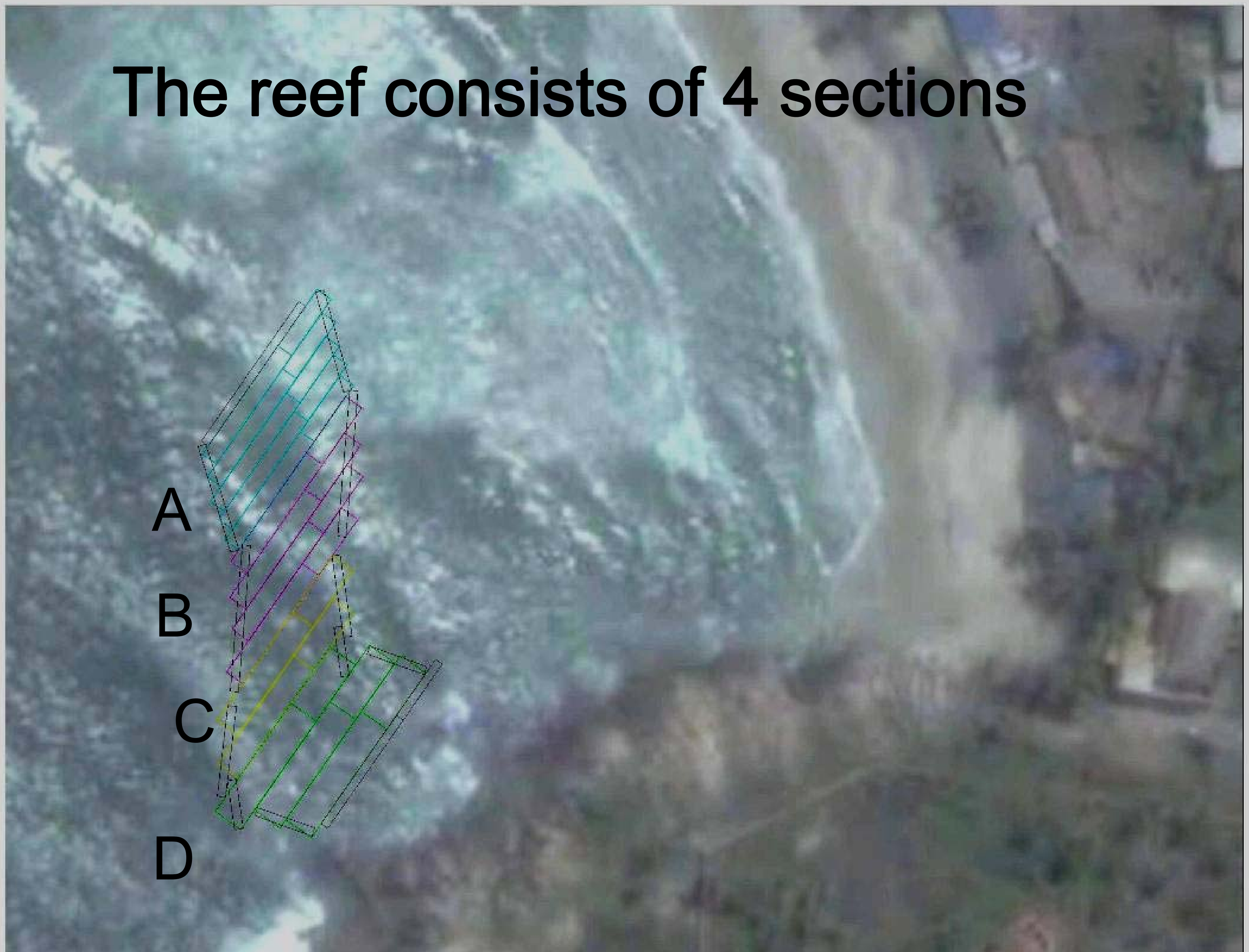
3-D representation of the geocontainers layout to be used

Kovalam – Currents reversed




Reef
location

The reef consists of 4 sections

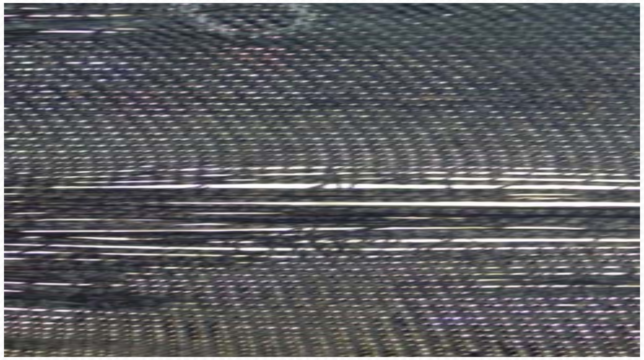


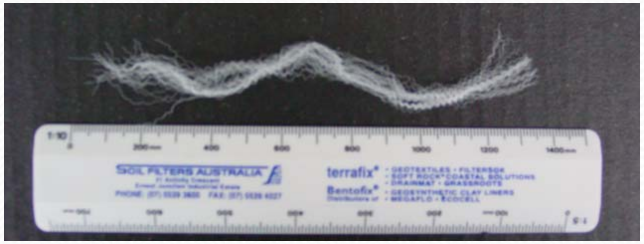
Reef Construction

Reef construction using geotextile

Important considerations when designing with geosynthetics in coastal applications include;

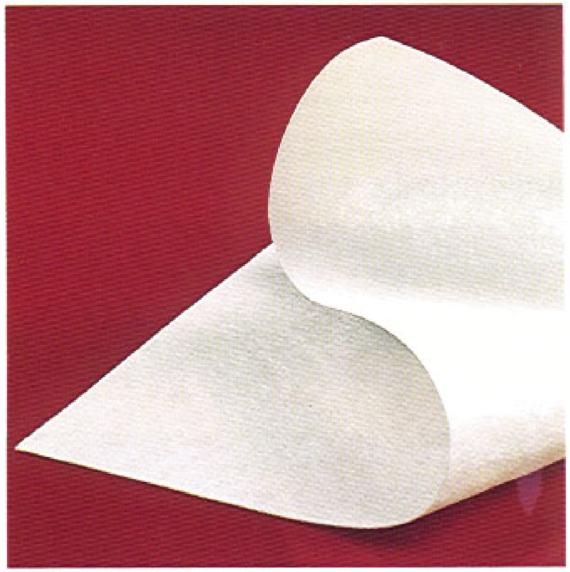
- UV Resistance
- Abrasion Resistance
- Damage Resistance
- Fines Retention
- Permeability
- Seam Strength





Selected material: Nonwoven, Staple Fibre Geotextile

Woven and non-woven geotextiles

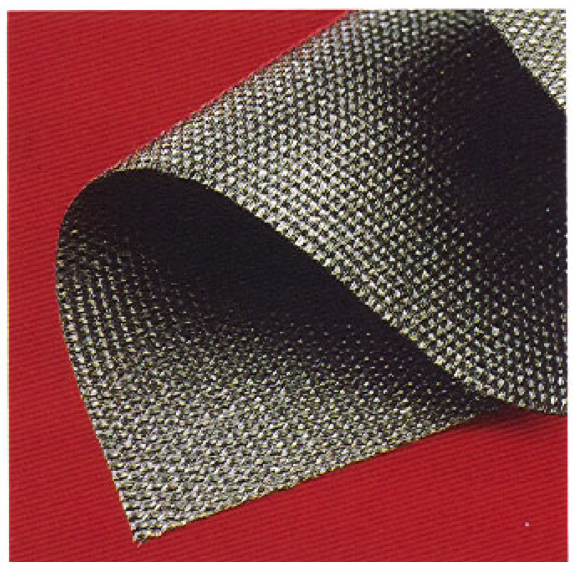


(A) Thermally-bonded nonwovens

(B) Mechanically-bonded nonwovens

(C) Specialist wovens/monofilaments

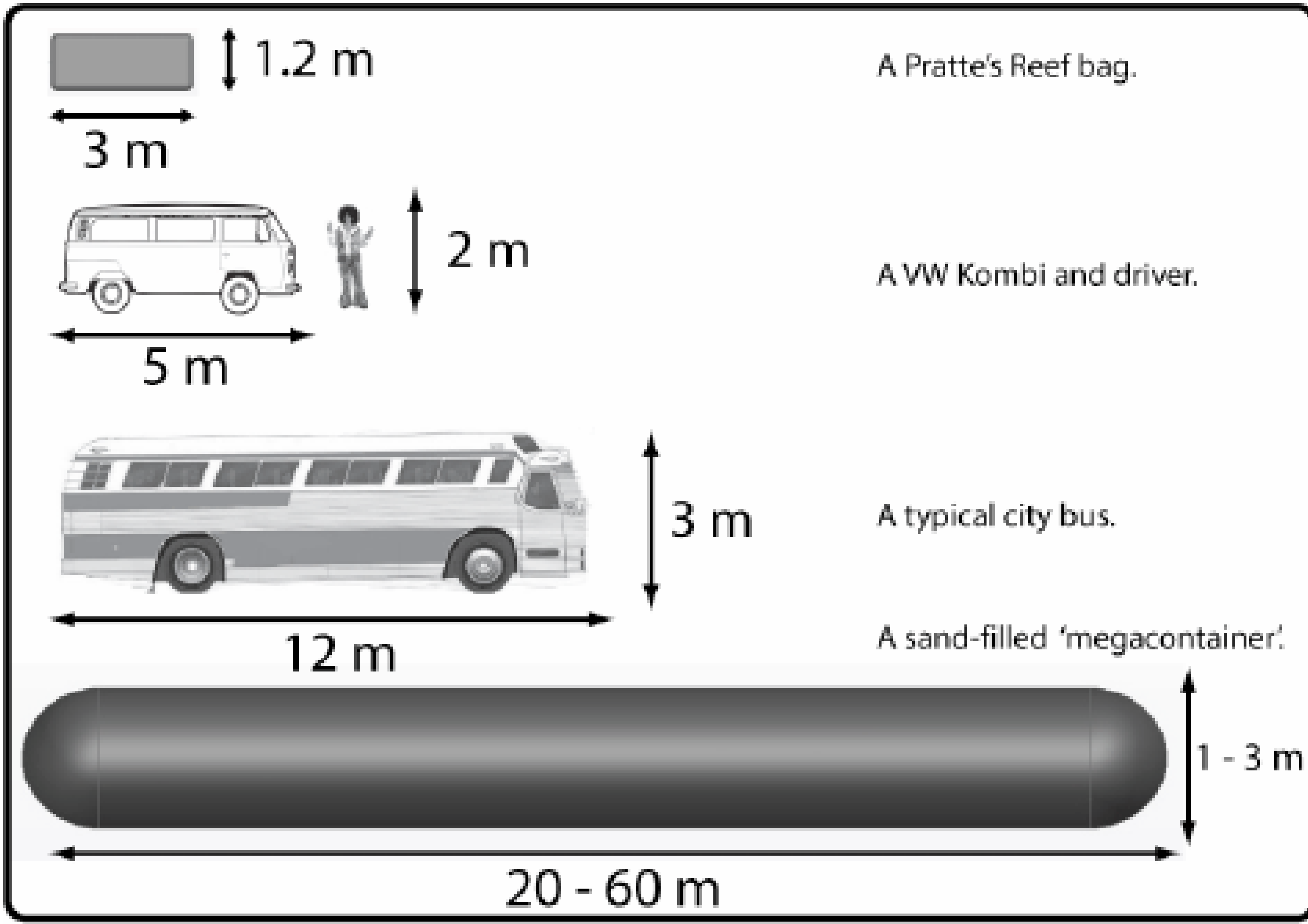
(D) Meshes

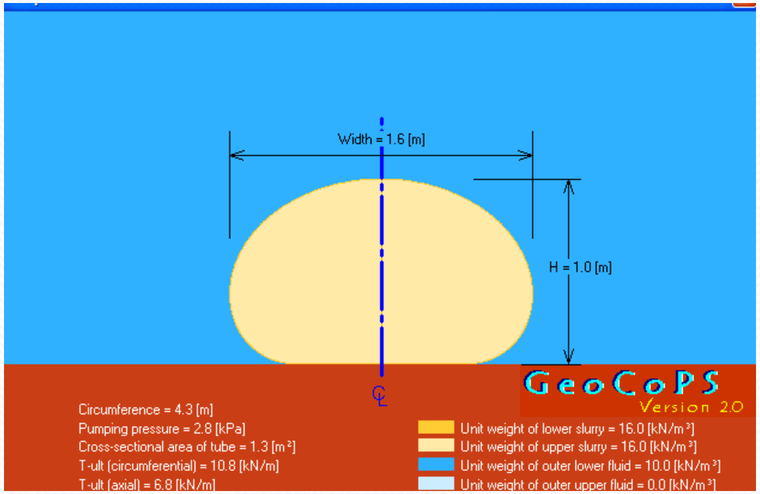


(E) Woven polypropylene

(F) Woven polyester

Relative sizes of submerged reefs built from geotextile containers

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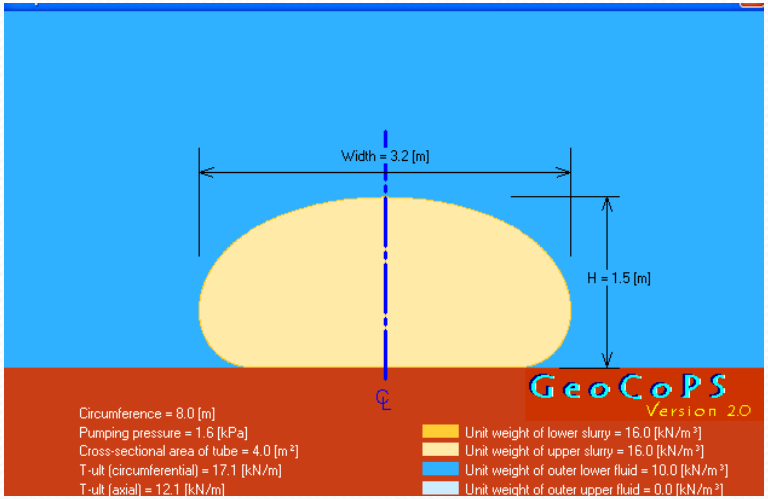
Version 2.0
Circumference = 4.3 [m]
Pumping pressure = 2.8 [kPa]
Cross-sectional area of tube = 1.3 [m²]
T-ult (circumferential) = 10.8 [kN/m]
T-ult (axial) = 6.8 [kN/m]
Unit weight of lower slurry = 16.0 [kN/m³]
Unit weight of upper slurry = 16.0 [kN/m³]
Unit weight of outer lower fluid = 10.0 [kN/m³]
Unit weight of outer upper fluid = 0.0 [kN/m³]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T-ult (axial) = 12.1 [kN/m]
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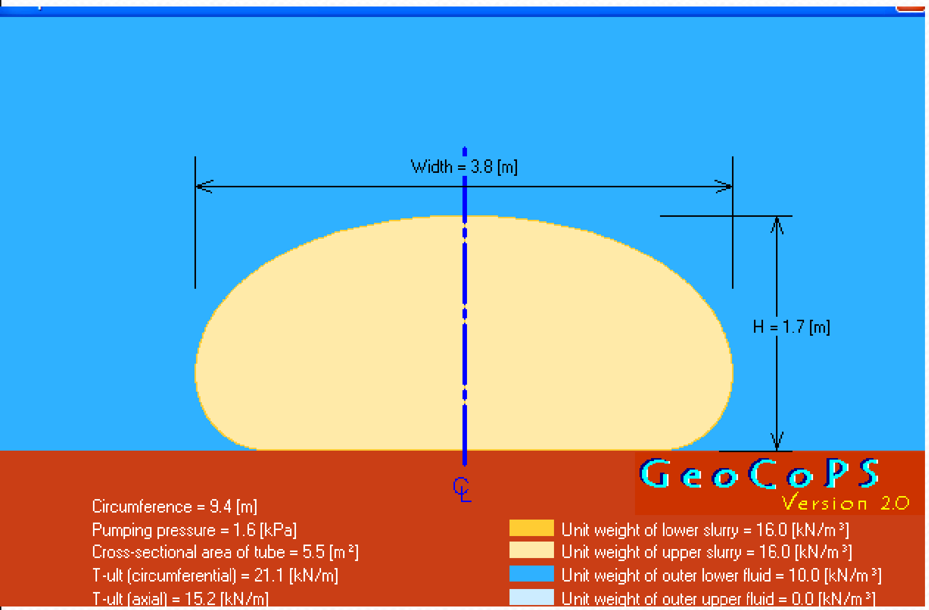
Unit weight of outer lower fluid = 10.0 [kN/m³]
Unit weight of outer upper fluid = 0.0 [kN/m³]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Version 2.0
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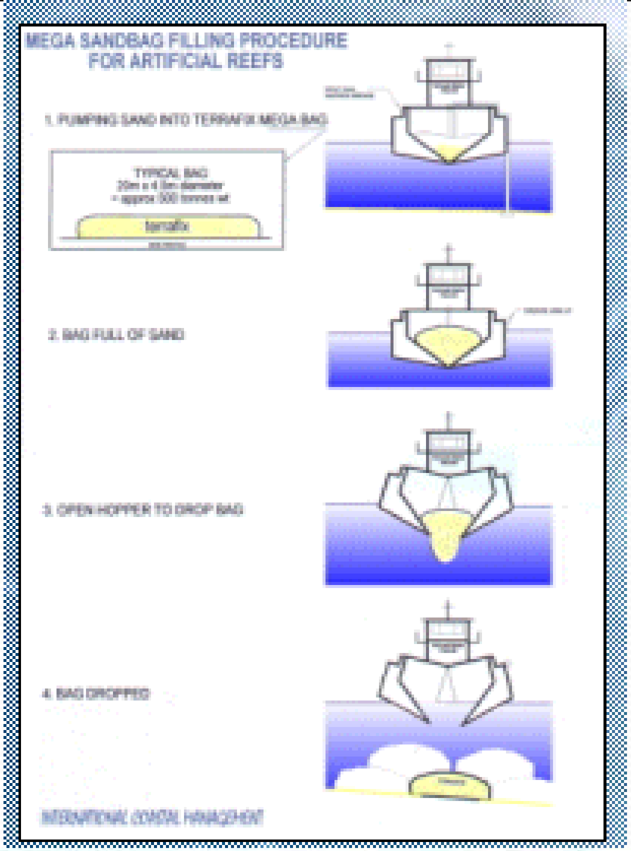
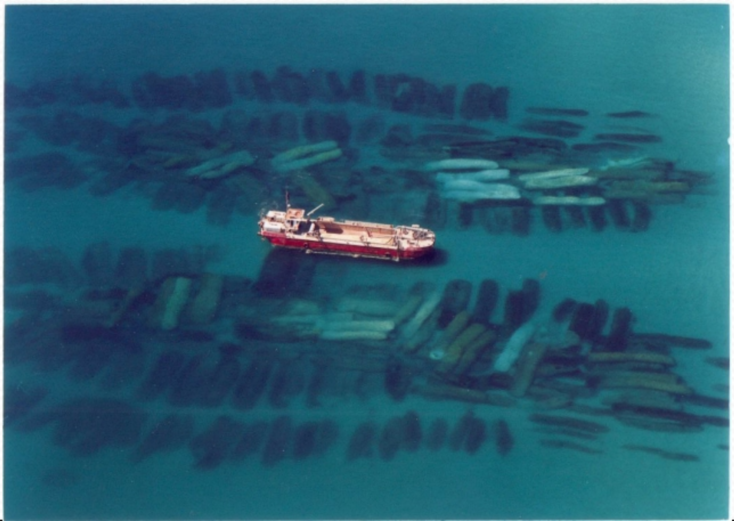
Cross-sectional area of tube = 5.5 [m²]
T-ult (circumferential) = 21.1 [kN/m]
T-ult (axial) = 15.2 [kN/m]
Unit weight of lower slurry = 16.0 [kN/m³]
Unit weight of upper slurry = 16.0 [kN/m³]
Unit weight of outer lower fluid = 10.0 [kN/m³]
Unit weight of outer upper fluid = 0.0 [kN/m³]

- When applying geosystems, the major design considerations/problems are related to the integrity of the units during release and impact (impact resistance, seam strength, burst, abrasion, durability etc.), the accuracy of placement on the bottom and the stability.

- When applying this technology the manufacturer's specifications should be followed. The installation needs an experienced contractor or an experienced supervision.



SPLIT HULL HOPPER DREDGE FILLING SANDBAG




2006 11 21
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7 20 '99

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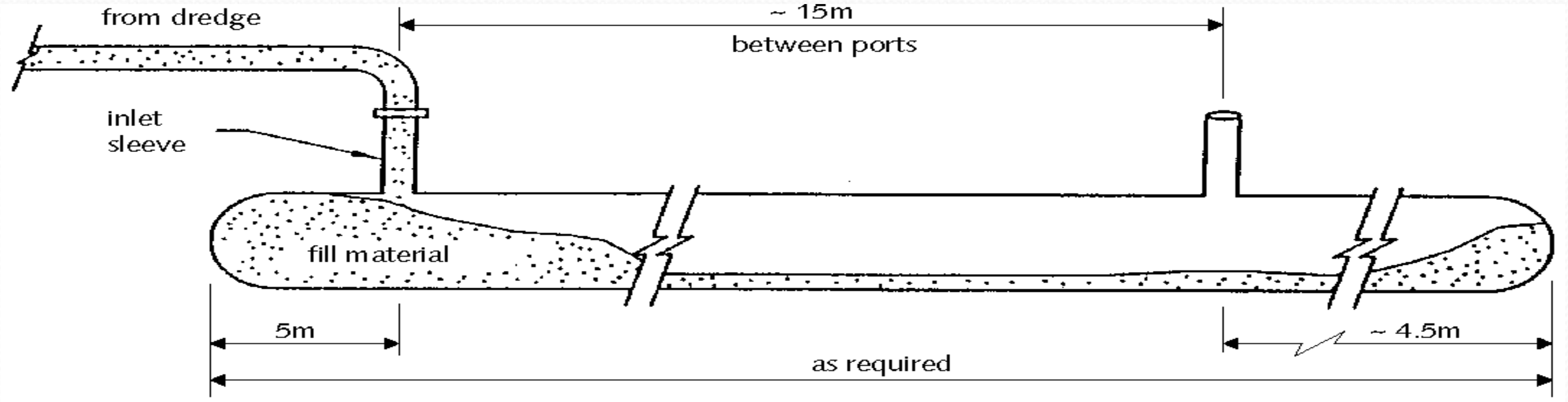
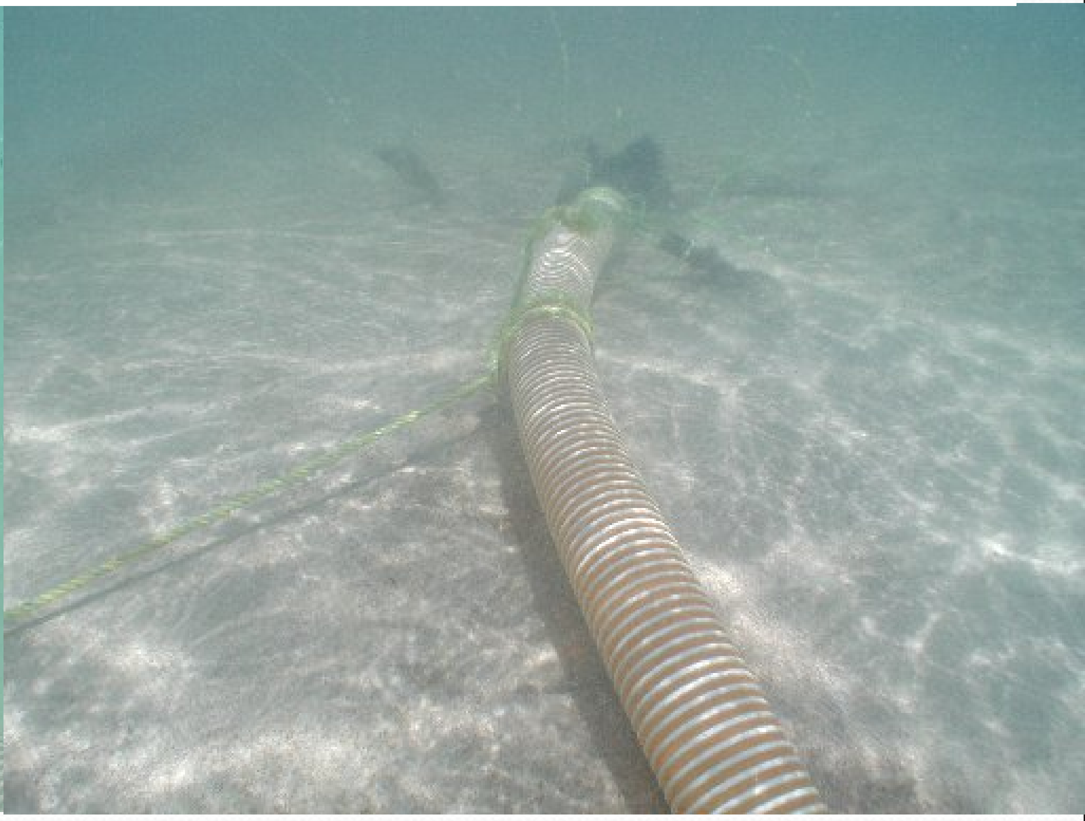
2006 11 15

RAD Method, Mount Reef, New Zealand

In-situ Sand-filling Containers





KOVALAM REEF


211209_PullingThePipelineIntoPosition
File Edit View Window Help
00:00:00


2009-12-27 11 23 48
File Edit View Window Help
00:00:00

Take a Balanced Approach

- Understand the Site for a site-specific design
- Make a preliminary Selection of Options that will ‘work’ at the site
- Aim to address the causes of erosion not the effects
- Evaluate <u>all</u> factors to determine the best option(s)
- Use technical tools (mathematical and physical models) because the beach is complex
- Consider the social and environmental impacts
- Protect the beach and the land - not just the land
- Coastal protection is a national issue applied at local level

Save Beaches




help people