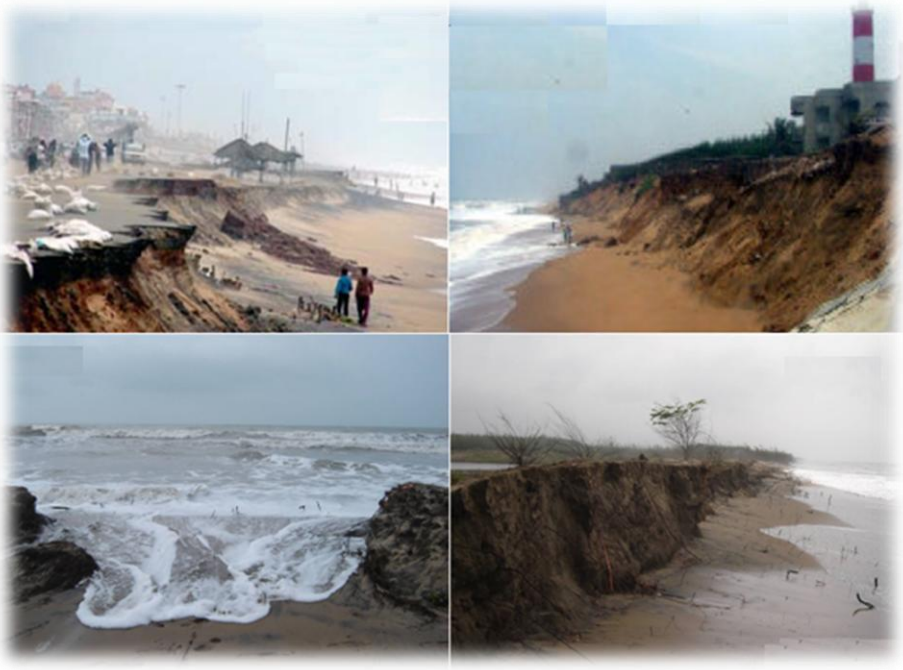
Status Report on Coastal Protection & Development in India



Central Water Commission

New Delhi

December, 2016

Foreword

The Coastline of Country extending from West Bengal to Tamil Nadu in the Bay of Bengal and Kerala to Gujarat in the Arabian Sea is perpetually exposed to vagaries of Sea. The cumulative damages caused by the ravages of the sea are enormous. The valuable property and developmental infrastructure are irreversibly destroyed causing miseries to all the population. The issue of Coastal Erosion has been in the focus of Government of India and Beach Erosion Board (BEB) was constituted as early as in 1966 to study the problem along the Kerala Coast which was having severe problem. Later on, it was realized that same program and attention is required for the entire coastline of India and scope of BEB was extended to cover the entire coast. With the objective of the development in the protected coastal zone and the pressure of population in the densely populated areas in the coastal zone, the Beach Erosion Board was reconstituted and rechristened as Coastal Protection and Development Advisory Committee (CPDAC) in April, 1995 with the major objective to identify and develop the various resource potential available behind the protected areas.

Since then, various initiatives have been taken at national level as well as state level to address the problem in a more scientific manner. This compilation gives the synoptic view of the coastal erosion problem in general in India, measures undertaken to combat the problem, data requirements for coastal protection and development with current status, role of various agencies engaged in the field and national level initiative taken in the area for management and protection of vulnerable coast.

I am sure, the compilation will prove quite handy and useful for future reference by all those engaged in Coastal Protection and Development works.

New Delhi
December, 2016

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Preface

Indian Coastline has been experiencing erosion problem and around 45.5% percent of our coastline is affected by it in varying magnitude. While almost all the maritime states are facing the problem, States like Kerala, Maharashtra are having chronic problem where extensive coastline is affected by erosion.

There have been several measures adopted in India to counter the problem of erosion in the form of hard measures such as Sea Wall, revetments, Groynes etc. Their suitability and adverse effects are debatable however it is now increasingly felt world over that soft-measures and non-structural measures such as Beach Nourishment etc. should be employed in conjunction with traditional hard measures while dealing with coastal erosion problem.

Coastal Erosion problem is complex effect of various natural processes working in coastal zone and sometimes beyond it. Any intervention to combat erosion requires adequate data in terms of quality and quantity on various processes such as wave, tide, current, wind etc. along with other factors such as bathymetry, beach profile/material etc. Places where rivers are joining sea, poses further challenges in terms of data requirements to account for discharge, silt load etc. In India, data on above aspects are collected by different agencies as per their mandate and requirement and hence co-ordinated approach is lacking. Common platform such as CPDAC can play a major role in integrating the data which can be utilized for various purposes including design of economical, environment friendly and socially acceptable solution to coastal erosion problem.

This compilation is an effort towards achieving above goals by integrating various scattered information in the form of State-wise Shoreline Change, Data requirement, Institutional Set-up etc. It might be a useful contribution towards evolving a better mechanism to address coastal erosion problem holistically.

30/12/2016

New Delhi
December, 2016

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ABBREVIATIONS AND ACRONYMS

A&N	Andaman and Nicobar
ADB	Asian Development Bank
ADCP	Acoustic Doppler Current Profiler
ADP	Automatic Data Processing
ALTM	Airborne Laser Terrain Mapper
AMSR	Advanced Microwave Scanning Radiometer
AP	Atmospheric Pressure
APL	Adaptation Programme Loan
ARG	Automatic Rain Gauge
ASE	Anti-Sea Erosion
AT	Atmospheric Temperature
AUPD	Autonomous Underwater Profiling Drifter
AVHRR	Advanced Very High Resolution Radiometer
AWS	Automatic Weather Station
BEB	Beach Erosion Board
BOD	Biological oxygen demand
CD	Chart Datum
CDO	Central Design Organization
CDOM	Colored Dissolved Organic Matter
CER	Coastal Economic Regions
CERC	Coastal Engineering Research Centre
CEZ	Coastal Economic Zones
CICEF	Central Institute of Coastal Engineering for Fisheries, Bengaluru
CIMU	Coastal Information Management Unit
CMFRI	Central Marine Fisheries Research Institute
CMIS	Coastal Management Information System
COMPAS	Coastal Ocean Monitoring and Prediction System
CPDAC	Coastal Protection and Development Advisory Committee
CRCPMP	Climate resilient coastal protection and management
CRZ	Coastal Regulation Zone
CSIR	Council of Scientific and Industrial Research
CVCA	Critically Vulnerable Coastal Areas
CVI	Coastal Vulnerability Index
CW&PC	Central Water & Power Commission
CW&PRS	Central Water and Power Research Station, Pune
CWC	Central Water Commission
CZMA	Coastal Zone Management Authority
DO	Dissolved Oxygen
DOPR	Deep Ocean Bottom Pressure Recorder

DPR	Detailed Project Report
DST	Department of Science and Technology
DTM	Digital Terrain Model
DWR	Doppler Weather Radar
DWRIS	Development of Water Resource Information System
EEZ	Exclusive Economic Zone
EIA	Environment Impact Assessment
ENC	Electronic Navigation Chart
ESSO	Earth System Science Organization
EWDS	Early Warning and Dissemination System
EXIM	Export Import
FMP	Flood Management Programme
FSI	Falmouth Scientific Inc.
GEF	Global Environment Facility
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GODAE	Global Ocean Data Assimilation Experiment
GODAS	Global Ocean Data Assimilation System
GoI	Government of India
GOVST	Global Ocean View Science Team
GPS	Global Positioning System
GSI	Geological Survey of India
GTS	Global Telecommunication System
HF Radar	High Frequency Radar
Hs	Significant Wave Height
HTL	High Tide Line
ICMAM	Integrated Coastal and Marine Area Management, Project Directorate, Chennai
ICON	Integrated Coastal Observation Network
ICZM	Integrated Coastal Zone Management
IDWR	Indian Daily Weather Reports
IHH	Institute of Hydraulics and Hydrology, Poondi
IIMP	Integrated Island Management Plan
IIOE	International Indian Ocean Expedition
IITM	Indian Institute of Technology Madras, Chennai
IMD	India Meteorological Department
INCOIS	Indian National Centre for Ocean Information Services, MoES
INS	Indian Navy Ship
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data Exchange
IOGOOS	Indian Ocean Global Ocean Observing System
IPZ	Island Protection Zone

IREL	Indian Rare Earth Limited
IRS	Indian Remote Sensing
ISGN	Indian Seismic and GNSS Network
ISRO	Indian Space Research Organization
ITWEC	Indian Tsunami Early Warning Centre
JNPT	Jawaharlal Nehru Port Trust
KERI	Kerala Engineering and Research Institute, Peechi, Kerala
KERS	Karnataka Engineering Research Station
KG Basin	Krishna Godavari Basin
LEO	Littoral Environmental Observation
LISS	Linear Imaging Self Scanner
LTL	Low Tide Line
MERI	Maharashtra Engineering Research Institute
METOP	Meteorological Operational Satellite
MFF	Multi-tranche Facility
MMB	Maharashtra Maritime Board
MoA&FW	Ministry of Agriculture and Farmers Welfare
MoD	Ministry of Defence
MODIS	Moderate Resolution Imaging Spectroradiometer
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoES	Ministry of Earth Sciences
MoHA	Ministry of Home Affairs
MOM	Modular Ocean Model
MoM	Ministry of Mines
MoS	Ministry of Shipping
MoST	Ministry of Science and Technology
MoWR, RD&GR	Ministry of Water Resources, River Development and Ganga Rejuvenation
MSL	Mean Sea Level
NCESS	National Centre for Earth Science Studies, Kerala
NCM	National Coastal Mission
NCPP	National Coastal Protection Project
NCRMP	National Cyclone Risk Mitigation Project
NCSCM	National Centre for Sustainable Coastal Management, Chennai
NCZMA	National Coastal Zone Management Authority
NDMA	National Disaster Management Authority
NHO	National Hydrographic Office (NHO), Dehradun (MoD)
NIDM	National Institute for Disaster Management
NIO	National Institute of Oceanography (CSIR-MoST)
NIOT	National Institute of Ocean Technology, Chennai (MoES)
NITK	National Institute of Technology, Karnataka
NOAA	National Oceanic and Atmospheric Administration

NODC	National Oceanographic Data Centre
NPP	National Perspective Plan
NRDMS	Natural Resources Data Management System
NRSC	National Remote Sensing Center
OCM	Ocean Colour Monitor
ODIS	Ocean Data and Information System
PC	Primary Cells
PFZ	Potential Fishing Zone
PMSS	Probable Maximum Storm Surge
PMU	Project Management Unit
POGO	Partnership for Observing the Oceans
PPTA	Project Preparatory Technical Assistance
PWD	Public Works Department
RBA	Rashtriya Barh Ayog (National Flood Commission)
RCM	Rotor Current Meter
RH	Relative Humidity
RIMES	Regional Integrated Multi-Hazard Early Warning System
RMOS	Regional Model Ocean System
RTSP	Regional Tsunami Service Provider
RV	Research Vehicle
SAARC	South Asian Association for Regional Cooperation
SAC	Space Application Centre, ISRO
SBM	Single Buoy Mooring Systems
SCP&MIP	Sustainable Coastal Protection and Management Investment Programme
SEA	State Executing Agency
SEZ	Special Economic Zone
SFC	Sand Filled Geotextile Containers
SIBER	Sustained Indian Ocean Biogeochemistry and Ecosystem Research
SICOM	Society of Integrated Coastal Management
SLED	Sliding Level Estimation Device
SLR	Sea Level Rise
SMP	Shoreline Management Plan
SMRC	SAARC Meteorological Research Center
SoI	Survey of India
SPOT	(Satellite Pour I' Observation de la Terre) Satellite for Observation of Earth
SST	Sea Surface Temperature
STD	Salinity Temperature Depth
TA	Technical Assistance
UNCED	United Nationals Conference on Environment and Development
UNDP	United Nation Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

UT	Union Territory
UTC	Universal Time Coordinated
VECS	VSAT aided Emergency Communication System
VPN	Virtual Private Network
VSAT	Very Small Aperture Terminal
WGS	World Geodetic System
WRIS	Water Resource Information System
XBT	Expendable Bathythermograph

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1.0. INTRODUCTION

1.1. Indian Coastal Zone

The Indian peninsula is bordered by the Arabian Sea in the west and south-west, Indian Ocean in the south and the Bay of Bengal in the east and south-east. India's mainland coastline spans from the south-west Indian coastline along the Arabian sea from the Gulf of Kutch in its westernmost corner and stretches across the Gulf of Khambhat, and through the Salsette Island of Mumbai along the Konkan and southwards across the Raigad region and through Kanara and further down through Mangalore and along the Malabar through Cape Comorin in the southernmost region of South India with coastline along the Indian Ocean and through the Coromandal Coast on the South Eastern Coastline of the Indian Subcontinent along the Bay of Bengal through the Utkala Kalinga region until the easternmost Corner of shoreline near the Sunderbans in Coastal East India.

Fig 1 below gives overview of the coastal Zone of India and Table 1 below gives a summary of the characteristic features of the state-wise coastline.

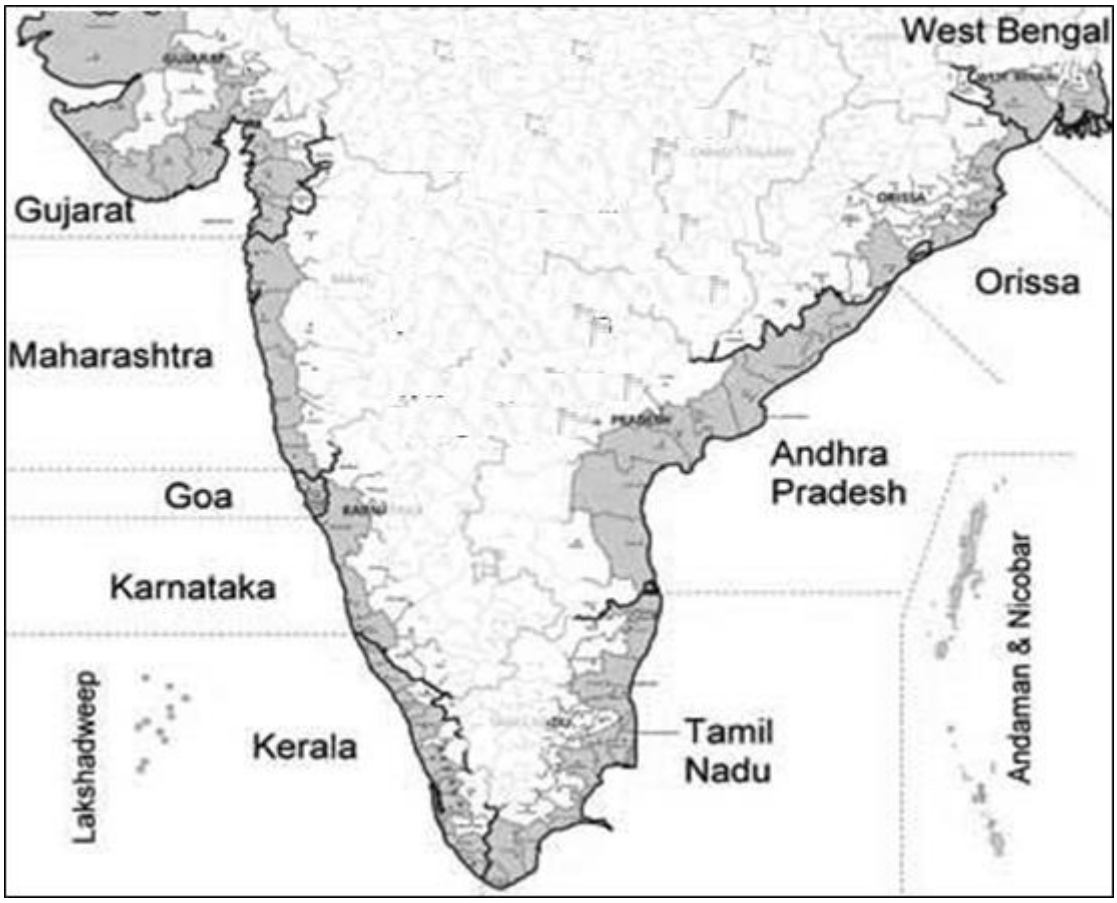

Fig 1: Coastal Zone of India

As per Census 2011, the coastal districts have a share of about 15.5% (nearly 18.8 crore) of the national population and about 4.4 lakh people reside in the Island territories.

Table 1: Characteristics of Indian Coastline

State	Coastal regions	Characteristic features of coast line*
Gujarat and Daman & Diu	Kachchh, Morvi, Jamnagar, Devbhoomi Dwarka, Porbandar, Junagadh, Gir Somnath, Amreli, Bhavnagar, Anand, Ahmedabad, Vadodara, Bharuch, Surat, Navsari, Valsad and Daman (Daman & Diu)	Gulf of Kachchh and Gulf of Khambat with extensive continental shelf area and shallow coast; sandy intertidal zone with vast stretches of muddy or sand stone areas
Maharashtra	Palghra, Thane, Raigarh, Ratnagiri, Sindhudurg, Mumbai City, Mumbai Suburban	Rocky coastal belt broken by small bays, creeks and fringed with islands; no major rivers
Karnataka and Goa	Goa, Uttar Kannada, Udupi, and Dakshin Kannada	Straight coastline broken at numerous places by rivers, rivulets, creeks and bays; northern part is rocky coast
Kerala	Kasaragod, Kannur, Kozikhode, Mallappuram, Ernakulam, Kollam, Thrissur, Alappuzha, and Thiruvananthapuram	Chain of brackish water lagoons and backwaters parallel to the coast, beaches and estuaries
Tamil Nadu and Puducherry	Tiruvallur, Kancheepuram, Vilupuram, Puducherry (Karaikal), Cuddalore, Nagapattinam, Thanjavur, Thiruvarur, Pudukkottai, Ramanathapuram, Tuticorin, Tirunelveli, and Kanyakumari	Narrow belt of sand dunes, low lying beach, plains mostly formed by rivers
Andhra Pradesh	Srikakulam, Vizianagaram, Vishakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore	Coast line is smooth with inundations ; deltaic coast of Krishna and Godavari, marshy muddy coasts
Odisha	Baleshwar, Bhadrak, Kendrapara, Jagatsinghpur, Puri, Khordha and Ganjam	Coast is depositional, formed by Mahanadi, Brahmani and Baitarani delta

West Bengal	North 24 Parganas, South 24 Parganas Haora, Purba Medinipur	Ganga and Brahmputra river systems create large intertidal, deltaic mass. Hooghly mouth is uneven formed by massive sedimentation, coast sand riffed with numerous tidal creeks & estuaries

*** Source: Ramesh & Ramachandran (2003)**

Coastal environment plays a vital role in nation's economy by virtue of the resources, productive habitats and rich biodiversity. The coastal zone is also endowed with a very wide range of coastal ecosystems like mangroves, coral reefs, sea grasses, salt marshes, sand dunes, estuaries, lagoons, etc. The coastal areas are assuming greater importance in recent years, owing to increasing human population, urbanization and accelerated developmental activities.

1.2. Coastal Length

Proper determination of coastal length is very important as the planning in respect of protection works and coastal zone management depends on it. Coastal length is one of the basic parameter to gauge the extent of problem of the coastal erosion State-wise. However there is subjectivity in determining the coastal length because of dynamic nature of coast and confluences of the river and tidal inlets. The more the number of the estuary in a state there will be larger subjectivity in the coastal length of the state.

In past, assessment of the coastal length has been made by **Rashtriya Barh Ayog** (RBA), National Hydrographic Office (NHO) and respective maritime State/UT agencies.

The Government of India set up the Rashtriya Barh Ayog (National Flood Commission) in 1976 to evolve a coordinated, integrated and scientific approach to the flood control problems in the country and to draw out a national plan fixing priorities for implementation in the future. The RBA report was submitted in 1980 and was accepted by Government. As per the assessment made by the Rashtriya Barh Ayog (RBA), the state-wise distribution of the coastline is given below:

Table 2: State/UT wise Coastal length in India (RBA, 1980)

Sr. no.	State/UT	Coastline length (in km)
1.	Gujarat	1600
2.	Maharashtra	512
3.	Goa	84
4.	Karnataka	280
5.	Kerala	560

6.	Tamil Nadu	980
7.	Andhra Pradesh	960
8.	Odisha	432
9.	West Bengal	280
10.	Puducherry (UT)	20
	Total:	5708

However, the widely accepted and adopted data on the coastal length of India is taken from the assessment done by National Hydrographic Office (NHO), Dehradun and Survey of India in 1970. As per the 1970 assessment, the total coastal length of India is **7516.6 km**. India's mainland has a coastline of 5422.6 km and island territories have a total coastline of 2094 km together. The mainland India comprises of the 9 coastal states and the 2 mainland UTs of Daman & Diu and Puducherry. The Andaman & Nicobar Islands and the Lakshadweep Islands are the 2 Island territories. The state/UT-wise break up of Indian coastline, as per the above assessment is shown below:

Table 3: State/UT wise Coastal length in India (NHO 1970 Assessment)

Sl. No.	**State/UT**	**Coastline (in km)**
1	Andhra Pradesh	973.7
2	Goa, Daman & Diu	160.5
3	Gujarat	1214.7
4	Karnataka	280.0
5	Kerala	569.7
6	Maharashtra	652.6
7	Orissa	476.4
8	Tamil Nadu	906.9
9	West Bengal	157.5
10	Andaman & Nicobar	1962.0
11	Lakshadweep	132.0
12	Pondicherry	30.6
	Total	**7516.6**

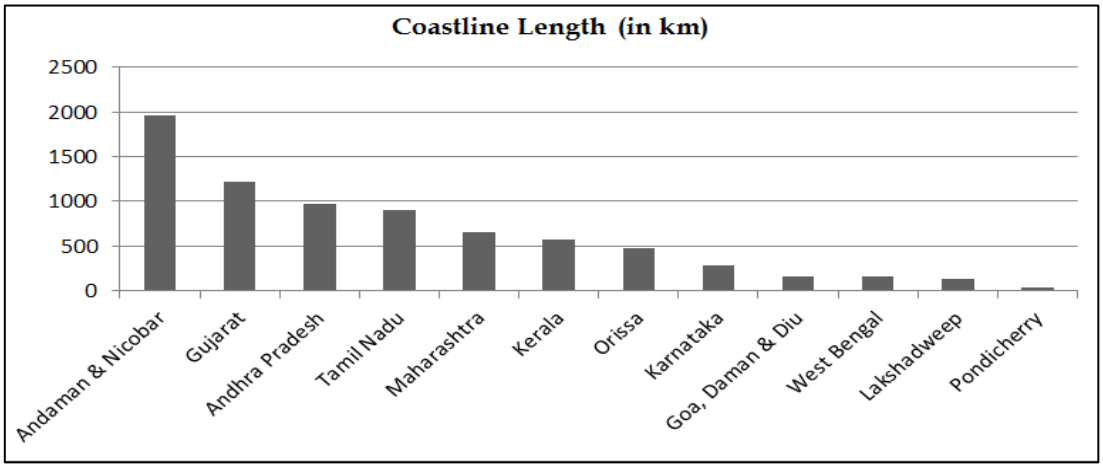

Fig 2: Coastline lengths of Indian States/UTs (1970 Assessment)

1.3. New Assessment of the Coastline length by NHO

Inconsistencies in the Coastal Length reported by various agencies including the State Govts have been in the agenda of the Coastal Protection Development Advisory Committee (**CPDAC**) of the Government of India.

In the 11th Meeting of CPDAC (January, 2010) representative from NHO, Dehradun informed the committee that a comprehensive exercise of re-evaluating coastal length is being taken up in the wake of methodological changes based on Survey of India maps and proposed that the exercise of re-evaluating the coastline will be done closing the river mouth and treating offline islands as separate entity. In view of huge importance of coastal length as a parameter for coastal zone management and protection works, it was suggested that NHO should document standardized procedure for evaluating the coast line and same should be circulated to state authorities and suggested for specific timeline for this whole exercise.

Further, in the 13th CPDAC Meeting (February, 2012), representative from NHO, Dehradun presented the provisional coastline length of various maritime States/UTs of the country and also the methodology adopted for the computation. NHO stated that while evaluating the length of the coastline, the mouths of creeks were closed along the general direction of the coast. The state boundaries were extracted from available information at NHO. As per the data presented, the total length of coast line has now been arrived at **11,084.50 km**. The provisional coastline data was circulated to the maritime States/UTs for their feedback, after their verification of the data.

Further, in the 14th CPDAC Meeting (February, 2014), the computation methodology and the coastline length as computed by NHO, Dehradun was accepted by the CPDAC. However representative of Govt. of Odisha intimated that there is deviation in coastline length evaluated by NHO and record available with State Govt. After follow-up, the State Govt. of Odisha has communicated its concurrence for the

revised coastline length evaluated by NHO. Further action on promulgation of coastline length is to be taken up through consultation with concerned agencies.

The details of the methodology and coastline length of all the maritime States/UTs as computed by NHO, Dehradun and accepted by CPDAC are given below:

1.3.1 Computation methodology adopted by NHO, Dehradun:

Given below is the methodology adopted by NHO, Dehradun for the computation of the coastline length:

(a) The Sources of data are viz., Electronic Navigation Charts (ENC's), Large Scale Navigation Charts and digital hydrographic surveys of National Hydrographic Office (NHO).

(b) The data was compiled using state–of-the-art GIS software projected in geodetic coordinates in WGS 84 datum.

(c) Whilst evaluating the length of coastline, the mouths of creeks have been closed along the general direction of the coast.

(d) Mangroves on the fringes of the coasts and Islands have been considered for computation.

(e) The coastline computed is not generalized i.e., the actual shape on ground of the coastline has been considered for computation.

(f) State boundaries were extracted from available information at NHO.

(g) The high water line was accepted as coastline.

(h) The base year for computation is 2011.

1.3.2 Revised Coastline Length: NHO, 2011

Table 4: State/UT wise Coastal length in India (NHO 2011)

S. NO.	State/UT	Coastline Length (km) (Ungeneralised)
1.	Gujarat	2,125.82
2.	Maharashtra	896.98
3.	Karnataka	309.59
4.	Kerala	597.43
5.	Tamil Nadu	1,064.98
6.	Andhra Pradesh	1,272.55
7.	Odisha	667.12

8.	West Bengal	662.90
9.	Goa	181.48
10.	Daman & Diu	63.10
11.	Puducherry	42.11
12.	A&N Islands	3,078.52
13.	Lakshadweep & Minicoy Islands	121.92
	Total	**11,084.50**

The comparison between the state-wise coastal data of the two assessments is given in the table below:

Table 5: Coastal length comparison (1970 and 2011 Assessments)

S.N	State/UT	NHO & SoI (1970)	NHO (2011)	% Change
1	Gujarat	1,214.70	2,125.82	75.01%
2	Maharashtra	652.60	896.98	37.45%
3	Karnataka	280.00	309.59	10.57%
4	Goa	160.50	181.48	52.39%
5	Daman & Diu		63.10	
6	Kerala	569.70	597.43	4.87%
7	Lakshadweep	132.00	121.92	-7.64%
8	Tamil Nadu	906.90	1,064.98	17.43%
9	Puducherry	30.60	42.11	37.61%
10	Andhra Pradesh	973.70	1,272.55	30.69%
11	Odisha	476.40	667.12	40.03%
12	West Bengal	157.50	662.90	320.89%
13	Andaman and Nicobar	1,962.00	3,078.52	56.91%
Total		**7,516.60**	**11,084.50**	47.47%

In general, increase in the coastline length can be attributed to change in methodology in computation of coastline such as inclusion of river mouth etc. and other such factors.

1.4. Physical Set-up Of the Indian Coast

The Indian mainland coast consists of nearly 43% sandy beaches, 11% rocky coast with cliffs and 36% muddy flats and 10% marshy coast (*Kumar et al., 2006*). The following table gives the types of coastline of different maritime states of India.

Table 6: Nature of India coastline

State	Sandy Beach %	Rocky Coast %	Muddy Flats %	Marshy Coasts %
Gujarat	28	21	29	22
Maharashtra	17	37	46	-
Goa	44	21	35	-
Karnataka	75	11	14	-
Kerala	80	5	15	-
Tamil Nadu	57	5	38	-
Andhra Pradesh	38	3	52	7
Odisha	57	-	33	10
West Bengal	-	-	51	49
Daman & Diu	-	-	-	-
Puducherry	-	-	-	-
Total Mainland	**43**	**11**	**36**	**10**

The continental shelf along the east coast is narrow (about 20 km), whereas along the west coast, the width of the shelf varies from less than 60 km in the south to about 340 km in the north (*Baba and Nayak, 2002*). Further, there is also a clear divide between the west and the east of the Indian coasts due to the reversal of the monsoon winds. The stormy onshore winds during the southwest monsoon (June–September) are more active along the west coast compared to the mild offshore winds during the northeast monsoon (November–January). In the monsoon conditions, the highest waves reach 3-5 m (*Table 2, Black et al., 2006, Kumar et al., 2006, Kurian, 1987, Thomas, 1988*). Wave height of 9 m was measured off Kavaratti in the Lakshadweep Sea by CESS (*Baba et al., 1992*).

The east coast becomes active during the cyclones of the northeast monsoon period. Wave heights of more than 9 m occur under severe tropical cyclones (*Kumar et al 2004*), in the Bay of Bengal. According to the Indian Daily Weather Reports (IDWR), significant wave height (defined as the average height of the one-third highest waves of a given wave group) off Visakhapatnam coast has a range of 1-3 m during May to September, 0.5-2 m during October to December (except during cyclone periods), and generally less than 1.5 m in the remaining period.

The tidal range also varies significantly from south to north. While the southern coasts have a tidal range of less than 1 m, the northwest peaks at 11 m and the northeast reaches 4.5 m (*Baba and Nayak, 2002*).

There are approximately 100 rivers which bring large quantities of sediment to the coast. The major ones are the Ganges, Brahmaputra, Krishna, Godavari and Cauveri on the east coast and Narmada and Tapi on the west coast. Sediment discharge through the rivers into the sea is about 1.2 x 10^{12} kilogram per year (*Chandramohan et al 2001*).

The characteristics of the Indian eastern and western coastline are quite different. The West coast stretches from Rann of Katch to Kanyakumari as a narrow strip between Arabian Sea and Western Ghats. It is divided into coastal plains of Gujarat, Konkan Coast and Malabar Coast. The western coast is a submerging coast and lagoons and estuaries are a common feature of the west coast.

On the contrary, the East Coast stretches from Kanyakumari to Sunderbans as a relatively broader (than western coast) between Eastern Ghats and Bay of Bengal. It is divided into Coromandal Coast and North Sircar coastal plains. It is an emergent coast and deltas are a common feature of the East coast. The frequency of occurrence of cyclones is very high on the East coast.

Eastern Coastal Plain is broader than the West Coast plain. The width varies from 80 to 100 km. But the Western Coastal Plain is narrow with a width of 50 to 65 km. In some places it is so narrow that the Western Ghats touch the Sea water. The Eastern Coast is smooth and unfit for making ports. So, very few ports are developed there. But the Western Coast is broken and indented and suitable for ports. For this, a large number of ports are there. The Eastern Coast is sandy with alluvium and slopes gently towards the sea. Sand dunes and marshy lands are also found. In some Coastal strips lagoons (Chilka, Pulicat) are formed. But the Western Coast is relatively rocky with sand and sand dunes. It slopes abruptly down to the sea. There is no lagoon on the northern part. It has many estuaries on the Konkan Coast. But the southern part especially the Malabar Coast has the beautiful scene of back-water country with a series of lagoons.

Large parts of the coastal plains of India are covered by fertile soils on which different crops are grown. Rice is the main crop of these areas. Coconut trees grow all along the coast. The entire length of the coast is dotted with big and small ports which help in carrying out trade. The sedimentary rocks of these plains are said to contain large deposits of mineral oil (KG Basin).The sands of Kerala coast have large quantity of Monazite which is used for nuclear power. Fishing and salt production in low lying areas are other prime activities of the coastal regions. Beaches and Backwaters are important tourist destinations.

Important features of the Indian coastline have been given below:

Table 7: Characteristics of East Coast vs. West Coast of India

West Coast	East Coast
• Flat sea bed slopes (1:100 to 1:500)	• Steep seabed slopes (1:30 to 1:100)
• Wide continental shelf (60-340 km)	• Narrow continental shelf(≈ 20 km) (except offshore to West Bengal)
• Tidal range : 1 to 11 m	• Tidal range : 1 to 4.5 m
• Strong tidal currents (Especially in the Gulfs).	• Weak tidal currents (except northern coast)
• About 2 storms per year	• Frequent storms (about 5 per year)
• Southwest monsoon (May to Sept) • Receives higher rainfall	• Two monsoons : Southwest (May to Sept) and Northeast (Oct to Jan) • Overall rainfall lesser than west coast
• Littoral drift negligible (except Gujarat)	• Large littoral drift: 0.5 million cum at Chennai to 1.5 million cum at Paradip.
• Only two major rivers meet the Arabian Sea	• Almost all rivers meet the Bay of Bengal : High source of sediment
• Bed material : Clay, Silty-Clay (except in southern portion)	• Bed Material : fine sand (Except in northern portion)

Mub-bank

The mud-banks is a common phenomenon during the south-west monsoons and these are unique in nature and are kind of endemic to Kerala only, as they are not found in other parts of India.

A Mud-bank is a submerged or partly submerged bank of mud along a shore or in a river. In local context, the calm, turbid regions in coastal waters of Kerala are called the mud banks. Formation of mud bank is a phenomenon observed off Kerala coast, especially along the coast of Kochi and Alleppy. During the monsoon, the mud gets churned up and this mud remains in suspended state, making the water highly turbid. These muddy waters are free from surface disturbances, as there are no waves even during the peak monsoon season. Portion of the beach corresponding to mud banks are free from wave action, while the other adjacent beaches undergo severe erosion.

The mud banks work like submerged breakwater protecting the beach behind them from erosion. The mud banks acts as a barrier and save the beach being eroded. Mud bank zones (sea between mud bank and shore line) are potential fishing ground and local fishermen use them as temporary harbours. The lengths of mud banks vary from few hundred metres to about 10 kms and they extend into the sea from 2 to 4 km. Mud

banks keep changing their location, size and duration. They may appear and disappear from a place after a few months or years.

1.5. Coastal Zone Categorization As Suggested By BEB

The general characteristic of the east coast of India has different features from those of West Coast as indicated in pervious section. Broadly, the two coastlines can also be divided into different distinct zone, each having peculiar characteristics, based on factors such as orientation of the coastline, intensity and frequency of storms, types of rivers joining and sediment load brought by them, existence of rock outcrops, mud banks etc. Problems of any reach have, therefore, to be studied with due regard to the special feature of the main coastal zone together with the other peculiar condition, which pertain specifically to the site or the reach under consideration.

In past, taking into account various factors and available data, the erstwhile Beach Erosion Board (BEB), in the year 1978, had suggested a division of coastal zone along Indian-subcontinent. The East coast was sub-divided in 8 major zones and West coast was sub-divided in 5 major zones as described below in Table 8 and Fig 6.

Table 8: Coastal Zone Categorization of Indian sub-continent by BEB

S.N.	East Coast	S.N.	West Coast
1	Kanyakumari to West of Sri Lanka	1	Kanyakumari to Mangalore
2	East of Sri Lanka to Cauveri Outfall	2	Mangalore to Tapi Outfall
3	Cauveri Outfall to Chinnaganjam	3	Tapi Outfall to Veraval
4	Chinnaganjam to Paradip Port	4	Veraval to Okha
5	Paradip Port to Hooghly Mouth	5	Okha to West of Indus Outfall (Pakistan)
6	Hooghly Mouth to Chittagong (Bangladesh)		
7	Chittagong to Akyab (Myanmar**)**		
8	Akyab to Outfall of Irrawadi River		

Source: Proceeding of Beach Erosion Board Meetings

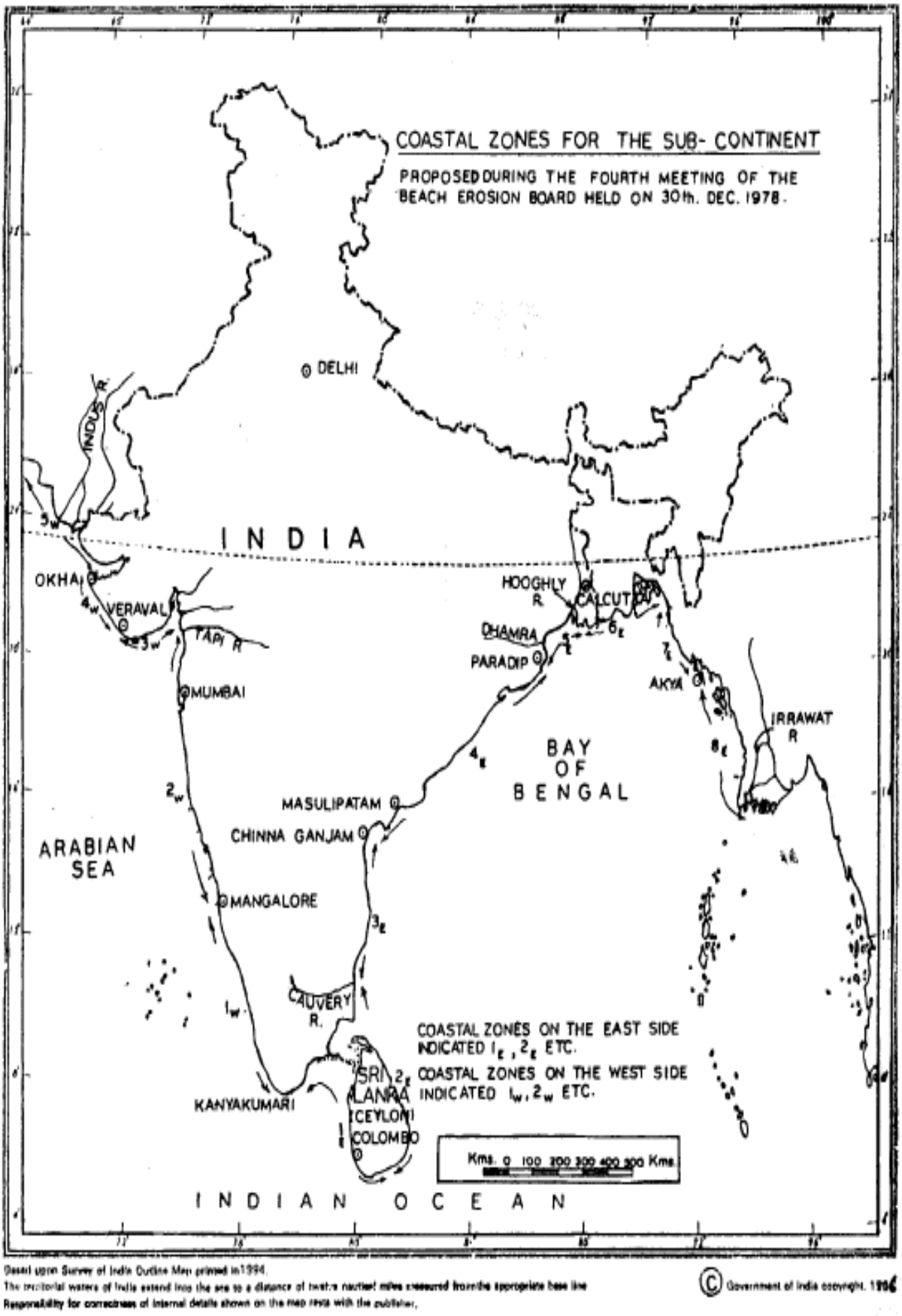

Fig. 3: Coastal Zone Categorization of Indian Sub-continent by BEB

1.6. Sediment Cell Identification by NCSCM, Chennai

The sediment budget and the transport rate play vital roles in determining the stability of the coast and they are chiefly governed by the coastal processes prevalent in the area. Hence there is a need to understand coastal sediment budgets and their inter-relationship with coastal management schemes. As the sediment budget and processes vary from one coastal area to the other, there is a need to demarcate coastal areas based on these properties. For this purpose, the concept of sediment cell is to be adopted and the entire coast of India needs to be divided into a series of coastal sediment cells.

A coastal sediment cell is defined as length of the coastline and associated near-shore areas where movement of sediments is largely self-contained. It is also called littoral cell. Each cell contains a complete cycle of sedimentation including sources, transport paths, and sinks. Common examples are beaches between large headlands. Sediment Cell in realm of Coastal Management can be equated with Basin for Water Resources Management. A sediment cell is a convenient method to sub-divide the coast into zones which are essentially independent with no sediment exchanges between two neighboring cells.

The National Centre for Sustainable Coastal Management (NCSCM), Chennai under MoEF&CC has delineated the entire Indian coastline into 27 primary cells with 10 primary cells on the west coast and 17 primary cells on the east coast. The sediment cells are identified and categorized as primary cell, sub cell and management units based on certain unique key criteria for each type. Primary cell can be based on geomorphology of the coast, sediment source, stores of sediments etc. The 27 primary cells are further delineated into 59 sub cells with 21 sub cells out of 10 PC's in the West coast and 38 sub cells out of 17 pc's on the East coast.

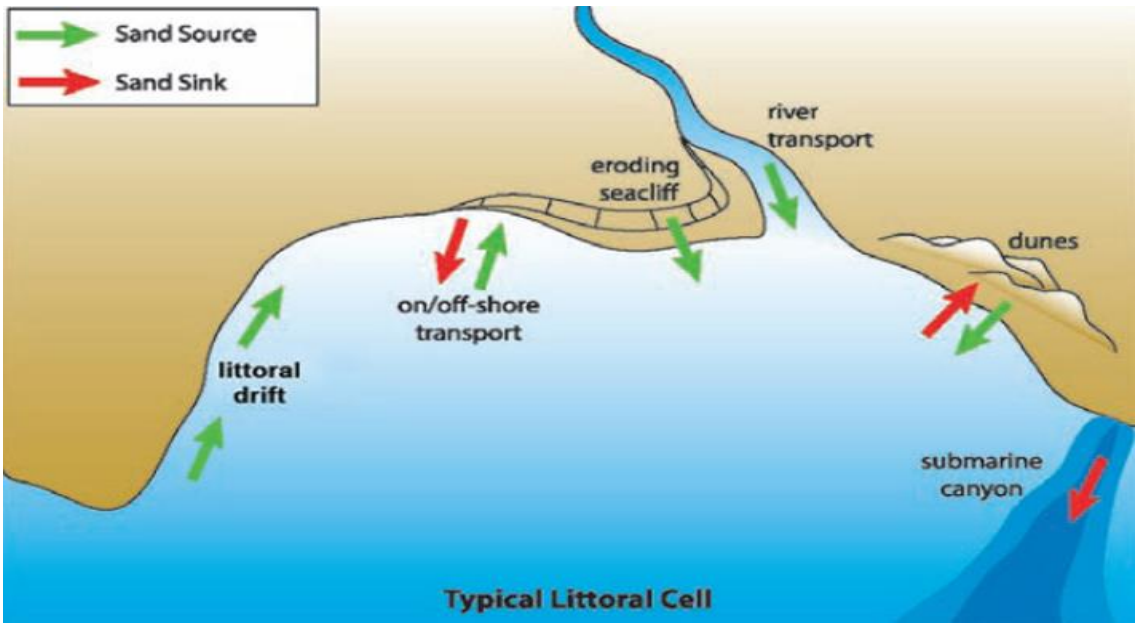

Fig 4: Definition sketch of a Sediment Cell

1.7. Coastal Erosion

Some of the general problems along the Indian coast which requires engineering interventions are:

- Silting up of entrance channels
- Closing of river mouths
- Flooding during storm surge
- Sand bar formation near mouths of inlets, rivers and estuaries
- Erosion of the coast.

While all the problems need to be addressed, coastal erosion is the major concern.

A coastline is a complex series of interlinked physical systems in which both offshore and onshore processes are involved. Coastal Erosion is one of these physical processes, wearing away and redistributing solid elements of the shoreline as well as sediment, normally by such natural forces as waves, tidal and littoral currents and deflation. Erosion occurs when material being removed, for deposition elsewhere, exceeds the rate of supply finally resulting in the landward shifting of the shoreline.

The coastal sediments, together with those arising from inland erosion and transported seaward by rivers, are redistributed along the coast, providing material for dunes, beaches, marshes and reefs. The sand can be moved to another beach, to the deeper ocean bottom, into an ocean trench or onto the landside of a dune. The removal of the sand from the sand sharing system results in permanent changes in beach shape and structure.

Waves are the main cause of coastal erosion. Wave takes birth in the mid ocean and moves towards the coast. Waves bring an enormous amount of energy to the coast that is dissipated through wave breaking, generation of currents, water level changes, and movement of sediment, turbulence and heat. Wave energy is the result of three factors: the speed of the wind blowing over the surface of the sea, the length of fetch (i.e., the distance of sea over which the wind has been blowing) and the length of time that the wind has been blowing for. Incident waves vary spatially and temporally, with their properties changing with movement over the bottom. Waves are the major factor in determining the geometry and composition of the beaches. The action of waves dictates the processes of removal and addition of material/sediment on the coast.

Sometimes, the coastal sediment returns to the visible part of the coast by accretion. The two processes of accretion and erosion play a major role in defining the coastal geography. The shoreline changes induced by coastal erosion and accretion are natural processes that take place over a range of time scales. With respect to temporal scale, these processes may occur in response to both small-scale events, such as storms, regular wave action, tides and winds, and large-scale events such as glaciation or orogenic cycles or tectonic activities that cause coastal land subsidence or emergence.

1.8. History Of Coastal Erosion In India

Kerala is the state which is worst affected by coastal erosion in India. In the original assessment in 1960s, about 57% of the coastline was identified as vulnerable. Although erosion of the coastal land has been experienced in the State since long time and records show of anti-erosion works having been constructed even in the nineteenth century. Assessment made in late 1980s indicated that almost 85% length of Kerala's coastline was in the grip of erosion. Later, it was found that Karnataka and Maharashtra were also affected badly by sea erosion. Problem in other states was found to be in patches/coastal pockets depending on various factors. The first anti-sea erosion measure in Puducherry was initiated by the French in the early 1920's, when a 1.75 km long Retaining wall was constructed along the urban coastline in Puducherry.

1.9. Causes of Coastal Erosion

Shoreline or coastline, the boundary between land and sea, keeps changing its shape and position continuously due to dynamic environmental conditions. Various developmental projects are made in coastal areas, placing great pressure on it, leading to diverse coastal hazards like soil erosion, sea water intrusion, coral bleaching, shoreline change; etc.

The causes of erosion are either natural or man-made. Sometimes, it is a combination of both the natural and man-made factors. While the former is a relentless process which is often impossible to resist, the latter is often due to ill-planned activities and can certainly be contained, or even reversed. Effects of climate change, sea level rise and other long-term causes for the erosion are still unaccounted for.

1.9.1 Natural Reasons:

Natural factors influencing coastal erosion are wave, winds, tides, near-shore currents, storms, sea level rise etc. The combined action of different processes on the coastline like waves and tides maintain the stability of the shoreline. If, for any reason, the sediment supply to a section of beach is reduced due to littoral drift/sea level rise or constant impact of waves, it can cause severe erosion.

Another important factor here is an increasing gradient in transport rate in the direction of the net transport. For e.g. consider the gradient in the wave conditions due to certain relief features or bathymetric conditions. Also, the natural variation in the supply for sediments to the coastline from the river can affect the erosion of the coastline.

Another major factor promoting coastal erosion is the sea level rise. An increasing sea level will promote shoreline setback. This setback is higher in the littoral coasts, consisting of finer sediments, as compared to coasts consisting of coarser sediments.

Another factor is the phenomenon of Subsidence. Subsidence is a regional phenomenon which lowers the surface area in a specific region. It impacts the coastline in a way similar to sea level rise, however the rate may vary as per the factor causing this subsidence.

Also, catastrophic events like severe storms, tidal surges and cyclones cause the sea level to rise to abnormal heights and cause severe erosion. The sudden and furious rush of water causes the bars to move seawards. The high surge also causes an offshore movement of sand due to non-equilibrium in the profile.

1.9.2 Man-induced erosion

Most of the human induced erosion is due to human interventions in the natural transportation process as well as in the sediment load of the rivers.

Human activity may be enumerated as Coastal defense structures, river regulation works, dredging aggregate extraction/ sand mining, oil/gas exploration (in the form of long term subsidence), ports/harbours that impacts sediment transport.

Coastal activities can also directly or indirectly result in beach erosion. The following are some examples:

- Building houses via land reclamation or within sand dune areas has a long term impact on coastal processes and the sediment stability.
- Harbors, meant to provide safe mooring and navigation for the calling vessels, often have shore-perpendicular/inclined solid quays and breakwaters, which obstruct the long shore transport of sand and cause accretion on the up drift side, and erosion down drift.
- Sand removal above replenishable quantities from the coast upsets the long shore sand transport budget and can result in erosion down drift.
- Groynes and jetties and other structures on the coast/shoreline interfere with long shore sand transport and can result in erosion when these are ill-designed. Groynes protect a part of the shoreline by blocking littoral transport by accumulation of the littoral sediments on the upstream side of the groynes. This causes a deficit in the littoral drift budget and this has negative consequences on the downstream as the erosion problem shifts to the downstream area.
- Structures like Seawalls, bulkheads and breakwaters etc. have side effects in terms of erosion of adjacent areas. The protective structures like sea walls lead to enhanced erosion at the end of the structure generate scouring at the toe of seawall and shorten the beach face.
- The mining of sand/gravel along beaches and in the surf-zone will cause erosion by depleting the shore of its sediment resources.
- The maintenance Dredging of harbours, navigational channels and tidal inlets causes loss of sand from the littoral zone and the sand is dumped into the deep sea. This disturbs the dynamic sediment equilibrium of the coast and promotes erosion to re-establish the equilibrium.

- Coral mining and other means of spoiling the protective coral reefs will also cause coastal erosion and beach degradation. The production of carbonate sand stops due to killing of the corals and the protective function of the reef disappears.

- Vegetation is important for maintaining/improving the sediment slope stability and consolidating the sediments by trapping the sediments. The removal of dune vegetation and mangroves due to man interventions causes exposure of the low-energy shorelines to the increased energy and reduced sediment stability. This further promotes erosion of coastal zone.

In most of the cases, coastal erosion would be attributed to cumulative effect of the both natural and human-induced factors.

The phenomenon of Climate Change has recently emerged as a important determinant in the coastal environment. The phenomenon of Climate Change is not new to the scientific and research community. An overwhelming scientific and research consensus maintains that climate change is real.

Coasts are sensitive to sea level rise, changes in the frequency and intensity of storms, increases in precipitation, and warmer ocean temperatures. In addition, rising atmospheric concentrations of carbon dioxide (CO2) are causing the oceans to absorb more of the gas and become more acidic. This rising acidity can have significant impacts on coastal and marine ecosystems. The low lying areas along the coast are likely to be prone to salinization due to sea water intrusion (surface and ground).

Fig 5: Damage due to coastal erosion

Fig 6: Ullal Beach (Karnataka) In 2013

Fig 7: Ullal Beach (Karnataka) in 2014

Before going into detail of the coastal erosion, we need to understand the physical set-up of the coastal zone of the country.

1.10. Coastal Protection Measures

Coastal protection measures moderate the long-term average erosion rate of shoreline change from natural or man-made causes. Reduced erosion means a wider buffer zone between the land and the sea. Nature not only erodes but also protects. Protection of coastline from erosion is provided by nature in the form of a stable beach, capable of dissipating incident wave energy. Unfortunate, such beaches are not available at all places along the coast. Nature's coastal protection is also demonstrated at the headlands, reefs, rocky, shores, dunes etc.

Protection works to prevent erosion should be on long-term basis and must be planned to suit the particular site conditions on the basis of thorough field investigation and available data which obviously require observations over an extended period of time. However, where urgent steps are imperative to stem the onslaught of erosion and to prevent serious damages immediately, short-term measures will become necessary relying on the design and performance of the structures existing elsewhere.

The measures to control erosion include non-structural and structural or their combination. These solutions have at least two hydraulic functions to control waves and littoral sediment transport (*Kawata, 1989*); in applying the solutions, their underlying principles should be well-understood, otherwise they will fail. A combination of hard and soft options has become more popular recently for optimum results because they have weaknesses when used singularly. Many schemes have failed and resulted in environmental and socio-economic problems owing to improper design, construction and maintenance, and were often only implemented locally in specific places or at regional or jurisdictional boundaries, rather than at system boundaries that reflect natural processes (*Kamphuis, 2002*).

Brief description of these measures is given below:

1.10.1 Non-structural measures

The Non-structural measures aim at dissipation of the wave energy by mirroring the natural forces and maintaining the natural topography of the coast.

These measures are also called soft solutions. Some of these are:

- Artificial nourishment of beaches
- Coastal vegetation such as mangrove and Palm plantation
- Sand bypassing at tidal inlets
- Dune reconstruction/rehabilitation

Before opting for the hard structures, non-structural measures like adaptation to natural coastal processes (by using large setback distances, relocating vital structures etc) and moderation of coastal erosion (by stabilizing coastal slopes, tripping the waves etc) should be used.

These measures have limitations. While artificial nourishment of beaches is complicated and costly, mangrove plantation is possible only in marshy land and in semi-tropical or tropical conditions. Brief description of these measures is given below:

1.10.1.1 Artificial Nourishment of Beaches

Beach nourishment is a technique, which is being increasingly adopted in many parts of the world. The basic principle involved is to dredge sand from the sea and deposit it on the beaches subject to erosion. The aim is to create a wider beach by artificially increasing the quantity of sediment on a beach experiencing sediment loss by dredging

operations on the offshore sediments. It also aims at improving the recreational value of the coast and replicating the way that natural beaches dissipate wave energy.

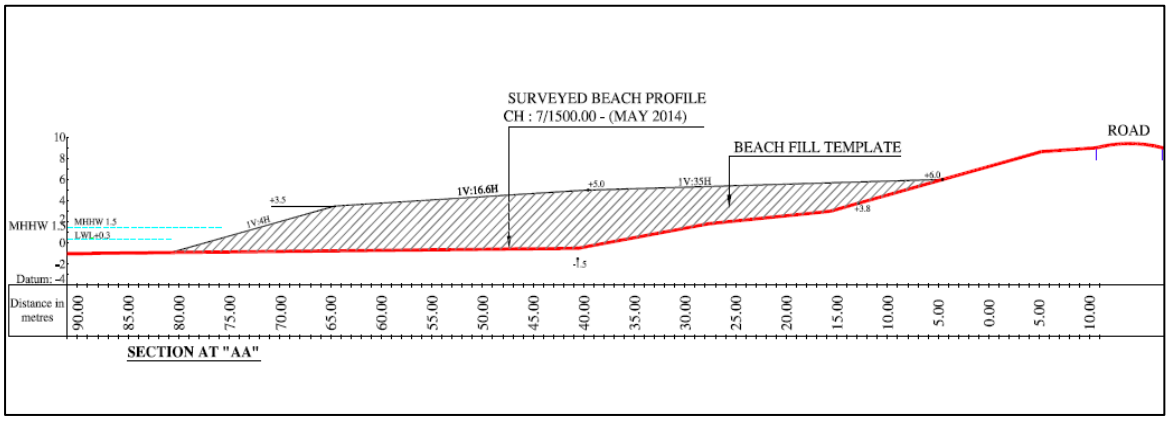

Fig. 8: A beach fill Template

But this is an expensive work and has to be continued throughout the monsoon season. Since the monsoon season also coincides with the rough sea condition, this method may not be successful at all times and in all situations. It can, however, be used as an interim measure to fill up short length of the beaches immediately after monsoon season so that at the beginning of the next monsoon the beaches well-stocked with sandy materials can act as a sacrificial filling, and keep the original profile undisturbed. This will be an annual exercise to be repeated at the end of each monsoon. The cost of filling has to be kept low so as to make such a proposal attractive. Its success will depend upon local factors and the type of equipment used.

This technique of coastal erosion protection is used in combination with the structural measures like offshore breakwaters, headlands and groynes to improve efficiency. It requires regular maintenance and becomes a costly affair at beaches with huge sediment load.

In India, this method has been rarely used. CW&PRS, Pune has recommended Beach Nourishment at INS Hamla in past as one of the pilot schemes. The same is also proposed at Ullal (Karnataka) and Mirya Bay (Maharashtra) under Asian Development Bank (ADB) aided Sustainable Coastal Protection and Management Investment Programme (SCP&MIP) along with other structural measures.

The Beach nourishment at Ullal (Karnataka) is to be placed along the critical beach erosion area. This will supplement the diminishing sand supply of natural sediment delivered by Natravati and Gurupur rivers and Littoral transport. Under the Beach Nourishment activity at Mirya Bay (Maharashtra), it is proposed to provide beach nourishment along a stretch of about 0.9 km. The selected sand will be extracted from the area of sand trapped by the fish harbour as well as sand from the sand heaps.

1.10.1.2 Coastal Vegetation Cover such as Mangrove Plantation

Mangrove is a habitat of a complex group of plant communities, which normally occur above the mean sea level in the inter-tidal zone of marine coastal environment, estuarine

margins and saline marshy land. It can act as the first defense against the cyclone, high tides and waves. It plays a very significant role in land accretion and can resist the sea erosion effectively and economically. The mangrove stabilizes the sea floor, traps sediments and reduces the angle of sea beds slope.

About 80% of the mangroves in India are grown in Sunderbans area of West Bengal and in Andaman and Nicobar Islands. Mangroves are grown in a few places of other States, like Goa, Kerala and Tamil Nadu. Prof. V. Sundar, IIT Madras Chennai presented an experimental study regarding Interaction of Tsunami with vegetation during 12th CPDAC meeting. While discussing the green belt design parameter, he compared the experimental results in respect of Mangrove, Casuarina and Oak and found Mangrove to be the most efficient.

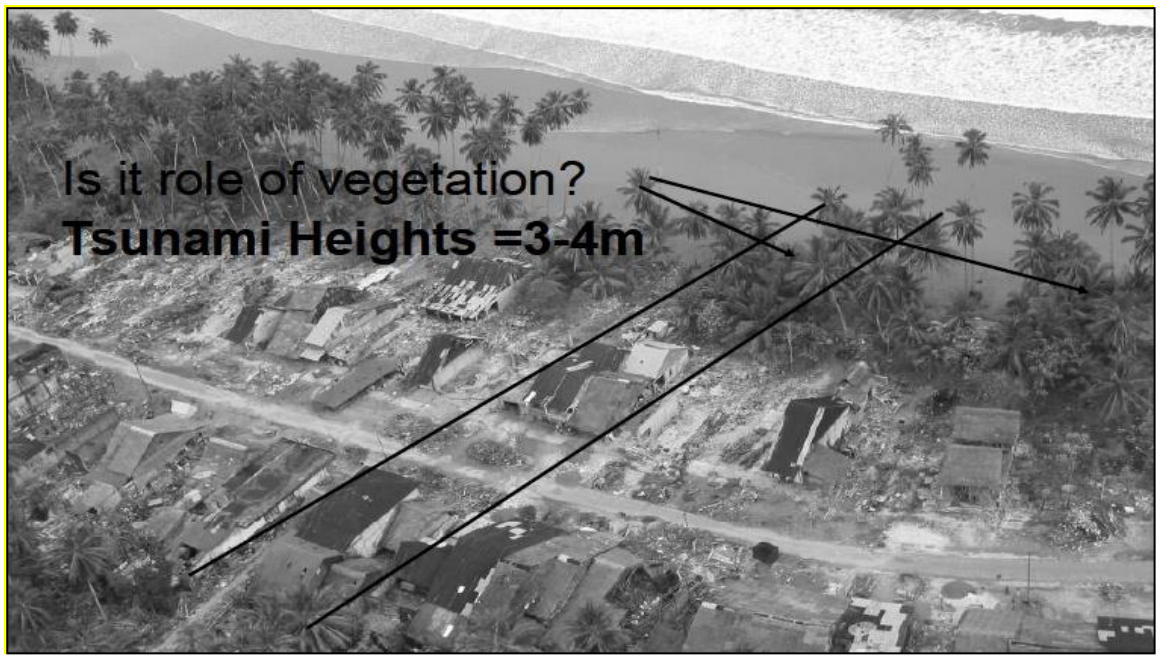

Fig. 9: Role of Vegetation in protection from Coastal Hazards

Studies have globally showed that the presence of vegetation in coastal areas helps in sediment consolidation, improves slope stability and promotes dissipation of the wave energy moving onshore. However, it may be more successful in estuarine conditions (low energy environment), but less successful on the open coast (high energy environment).

In some cases, Revegetation fails because environmental conditions do not favour the growth of species at the particular site or there is ignorance as to how to plant properly given the same conditions. It is also possible that anthropogenic influences have completely altered the natural processes in the area. The most obvious indicator of site suitability for particular vegetation is the presence of vegetation already growing. This can be extended by other factors such as the slope, elevation, tidal range, salinity, substrate and hydrology (*Clark, 1995; French, 2001*).

1.10.1.3 Bypassing of Material at Tidal Inlets

India has experienced severe erosion problems due to improvements of many inlets by jetties and/or dredged channels. This problem can only be solved by bypassing of material from the up-drift side of the inlet to the down-drift side. Improvement of the tidal inlets in India has some special features. In many cases, improvements have given more adverse effects on the shore stability than similar improvements elsewhere in the world. This is due to the skewness of the flow occurring during the rainy (monsoon) season. The ebb flow becomes very predominant over the flood flow and the result is that material being transported as bed load as well as suspended load is jetted far out into the sea where it gets lost as it never returns to the shore. This effect is very obvious when during the monsoon the high flood discharges of a river break through a barrier, which largely remains closed during the non-monsoon period. It also occurs when the ebb flow during the monsoon produces a deep cut through or pushes out an existing offshore bar or a shoal further offshore. An example of the former is found at Ponnani and of the latter at Neendakara, both in the Kerala State on the west coast. On the Bay of Bengal side, corresponding cases are found at numerous places in Andhra Pradesh, e.g., at Biminipatnam and in many monsoon estuaries of Orissa.

Jetty improved inlets are, therefore, even more dangerous for conditions prevailing in India than elsewhere. The bypassing procedure, which could prove to be most successful for Indian conditions, is trap-dredging by which drift material is accumulated in dredged traps located at a convenient place from where it can be removed by hydraulic pipeline dredge at regular intervals. Moderate wave action on the Indian shores makes it generally possible to operate hydraulic pipeline dredges in the open sea for at least during a major part of the non-monsoon season.

1.10.1.4 Dune Reconstruction/Rehabilitation

Sand dunes are unique category of coastal landforms as they are formed by the direct action of wind and not waves. They are a storehouse of sand/sediment above the landward limits of normal high tides. Dunes naturally occur along the most undeveloped, sandy coastlines. They work like a barrier between the sea and land and they are an effective defence against coastal erosion and flooding. The winds counter the action of the waves, by bring back and stacking the sediments back to the dune after it is eroded by the waves during a storm.

Presence of vegetation is an critical factor for the life of a dune as it is the roots of the vegetations that keeps the sediments of the dune binded together. Dune Rehabilitation refers to the restoration of natural or artificial dunes from a highly impaired, to a less impaired state, in terms of functionality. In reconstruction, sand fences and mesh matting in combination with vegetation planting have successfully regenerated dunes via sediment entrapment and vegetation colonization.

Artificial dune construction is also an innovative solution towards coastal zone protection. The sediments from the dredged sources are placed and then these deposits

are reshaped into dune. Many a times, artificial dune construction is carried out parallely to beach nourishment as per avialablity of sand.

1.10.2 Structural Measures

The structural measures, also known as the hard structural/engineering measures use physical structures constructed near the coast to prevent or restrict water from reaching the potential damage areas. These solutions influence the coastal processes to stop/reduce the rate of coastal erosion.

The Structural measures used for coastal erosion prevention are as follows:

- Seawall
- Revetment
- Off-shore breakwater
- Groins/groynes/spurs
- Offshore-Reefs
- Artificial Headland

Out of the above measures, Seawall is popular and generally used in almost all maritime States in varying proportions. Brief description of the above structural measures is given in subsequent sections:

1.10.2.1 Seawall

Seawall is commonly used to control coastal erosion. This structure is constructed along the coast and separates the land from the sea. It is constructed parallel to the coastline that shelters the shore from wave action. It is primarily designed to prevent wave attack on the coast. Seawall works by reflecting the incident wave energy back into the sea, thus reducing the energy available to cause erosion of the coast. Seawalls also help in improving the slope stability.

Seawalls have different design-types and the three main types of seawalls are vertical, curved/ stepped, and mounds. The appropriate design and type of seawall for a specific site depends on aspects specific to the location, including the surrounding erosion processes.

In India , generally seawall consists of heavy stones in the cover or armour layers placed over secondary layer of smaller stones. The secondary layer is placed over core mound consisting of very small stones. The size of stone in secondary layer and that in core is generally 1/10 to 1/15th and 1/100 to 1/200th respectively of the stones used in armour layer. The size of stone used in armour layer is generally worked out on the basis of Hudson formulae. The armour layer is supported by toe having a berm of suitable width. Berm width of 2 m to 5 m is generally provided. Size of stones in the toe varies from 1/2 to 1/10th of the stone used in the armour layer. The provision of toe also ensures that the damage profile attains an S-shaped profile which is most suitable.

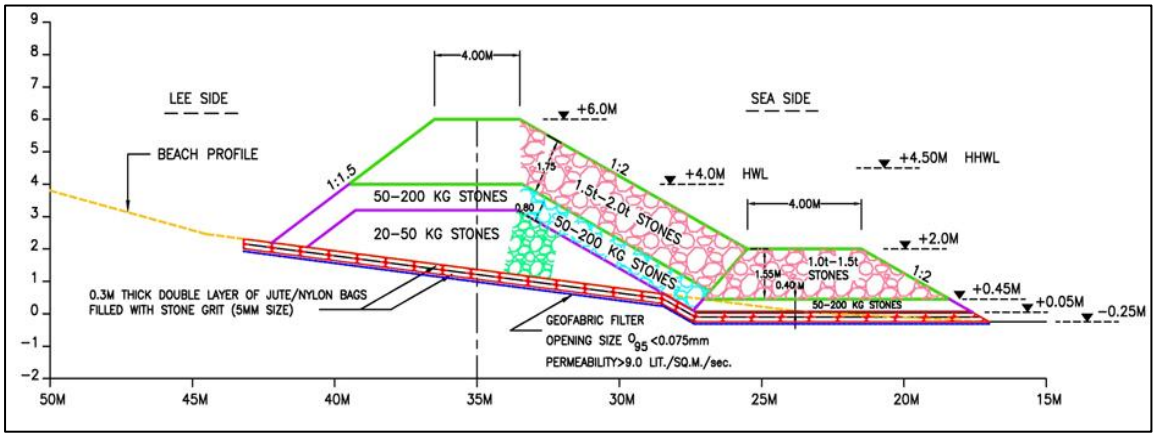

Fig 10: A sample Seawall's cross section

Provision of filter layer below the sea wall is very essential to prevent upward leaching of sand and thereby destabilizing the structure. The filter layer consists of either graded stones or a geo-fabric type of filter.

The crest of sea wall should be sufficiently above the highest water level to prevent any eventuality of overtopping and thereby damage of property on the lee-side. Generally, crest level is kept one wave height above the highest water level. If for some reasons, it is not possible to keep the crest at that level than adequate stones of suitable size should be provided on lee-side slope. The alternatives are selected considering the degree of severity of damage and funds available for construction.

Despite being the most popular measure for coastal protection, Seawalls have the following disadvantages:

- Erection of seawalls creates wave reflections which promotes scouring or sediment transport offshore and subsequent lowering of the sediment levels. Scour occurs at the toes of eroded beaches.
- It does not promote beach stability.
- Seawalls affect the littoral drift process. They promote erosion of the adjacent coastline or unprotected areas.

1.10.2.2 Revetment

It is an inclined facing of stones, concrete, etc., built to protect embankment, or shore structure against erosion by wave action or currents. These are placed in a manner that they absorb the energy of the incoming water.

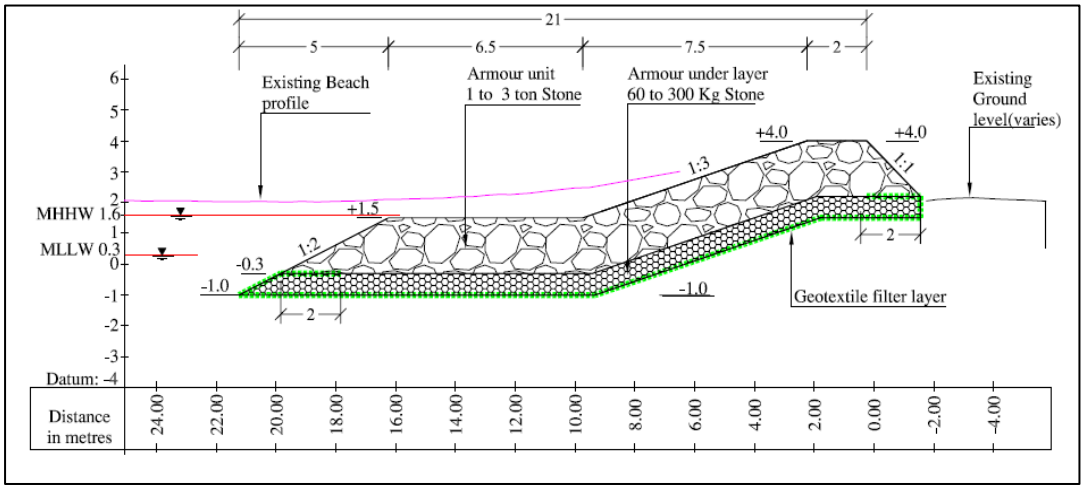

Fig 11 : A sample Revetment's cross section

1.10.2.3 Offshore Breakwater

Breakwater is a structure protecting a shore area, harbour, anchorage from waves. These may be either off-shore breakwaters or shore-connected breakwaters. Off-shore breakwaters are employed as a solution to coastal problem in favorable situations. The (submerged) parallel bars function as (submerged) shore parallel off-shore breakwaters. It reduces wave energy in its lee and creates a salient or tombolo behind the structure that influences long-shore transport of sediment. The wave dampening action in the shadow region of these breakwaters is likely to minimize erosion and sometimes build up a beach in the shadow region. Their likely adverse effects on neighboring shores need to be very carefully examined.

Following are the disadvantages of breakwater solutions:

- They need special design and are large structures.
- The structure is vulnerable to strong wave action.

Fig 12: Breakwater works

1.10.2.4 Groynes/Spurs

It interrupts water flow and also the movement of sediments. Groins can also be in the form of 'T'. The selection of groins as a coastal protection measure should be evaluated very carefully because overall effect of a group of groins could easily become harmful than beneficial. Groins may, however, be beneficial to specific areas where a protection is definitely wanting regardless of the possible adverse effects on the adjoining shores. In such cases, T-groins are most effective because they compartmentalize the beach more effectively. If groins are built at the end of the beach, e.g., on a barrier spit they will only have a beneficial effect partly by holding the beach at the spit and partly by decreasing the shoaling effect at the end of the spit, which could also be beneficial to navigation. Long and high groins can be used to act as artificial headlands, if it is desirable to completely trap the littoral drift. Such groins may be constructed as terminal groins at the up-drift side of a tidal inlet, a harbour entrance or a submarine canyon. Long groins in conjunction with beach nourishment have been used to provide a stable beach and reduce adverse effects on the down-drift beaches.

In general, the head of the groin located at the seaward end is more vulnerable to the attack of waves and scour. It is, therefore, important to design this portion with a gradual slope having energy absorbing characteristics and a suitable apron placed on a mattress. Groins should be extended landward to provide sufficient anchoring into the dune or backshore to prevent flanking during severe wave conditions. Proper maintenance particularly their seaward ends is essential to prolong the life and functional effectiveness of groins.

Fig 13: Groynes

Groins field alternative for shore protection and sand management should be considered as follows.

- At divergent, nodal points for littoral drift
- On the downdrift side of a harbour breakwater or jetty
- At the updrift side of an inlet entrance where intruding sand is to be managed
- To reduce the loss of beach fill, but provide material to downdrift beaches in a controlled manner
- Along the banks at inlets, where tidal currents alongshore are strong.

Groynes are easy to construct from a wide variety of materials like wood, bamboo, rock etc. However, groynes have the following disadvantages:

- Groynes cause erosion downdrift and regular maintenance.
- Induces local scour at the toes of the structures.
- Typically more than one structure is required.

Groins may not function well and should not be considered under the following conditions:

- Where a large tidal range permits too much bypassing at low tide and overpassing at high tide
- Where cross-shore sediment transport is dominant
- When constructed too long or impermeable, causing sand to be jetted seaward
- When strong rip currents are created to cause potentially dangerous swimming conditions

1.10.2.5 Offshore Reef

It is a human-made underwater structure. Enormous concrete blocks, natural boulders, rubble, tires, or construction debris are sunk offshore to alter wave direction and to dissipate the energy of waves and tides. This type of structure serves several functions like promotion of marine life, blocking the passage of ships and improving hydrodynamics for surfing or to control beach erosion.

These reefs also provide surfaces where algae and invertebrates such as barnacles, corals, and oysters attach. This accumulation of attached marine life in turn provides intricate structure and food for assemblages of fish, thus promoting marine life.

Advantages:

- Allows the build-up of sand due to the reduction in wave energy
- Waves break further off shore and therefore reduce their erosive power

Disadvantages:

- May be removed by heavy storms
- Difficult to install

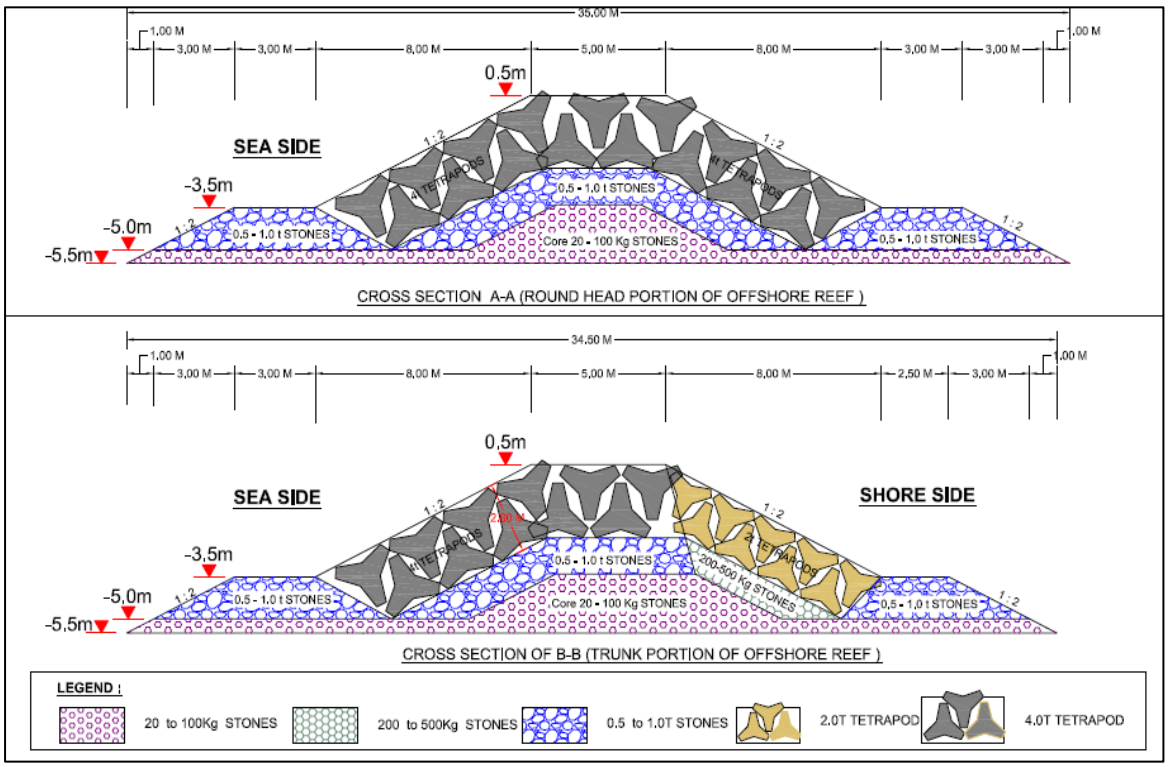

Fig 14 : A sample Offshore Reef's cross section

India's first artificial reef was constructed in Kovlam, Kerala. Currently, the Asian Development Bank (ADB) aided Sustainable Coastal Protection and Management Investment Programme (SCP&MIP) is under progress in the states of Karnataka and Maharashtra. Two projects namely **Ullal Coastal Erosion & Inlet Improvement Project in Karnataka** and **Mirya Bay Coastal Erosion and Protection Project in Maharashtra** are under implementation with loan from ADB.

The **Ullal Coastal Erosion and Inlet Improvement Project (Karnataka)** propose a hybrid solution, comprising of several components like beach nourishment, offshore reefs, near shore berms etc. Two submerged offshore reefs are being constructed to dissipate incoming wave energy and stabilize the beach nourishment placed on shore.

Under the **Mirya Bay Coastal Erosion and Protection Project in Maharashtra**, the proposed submerged headland "Cup Reef', will break wave energy and protect the most critical northern part of the bay. The reef has been constructed of sand filled geotextile containers. The individual container units will be oriented in a shore perpendicular fashion.

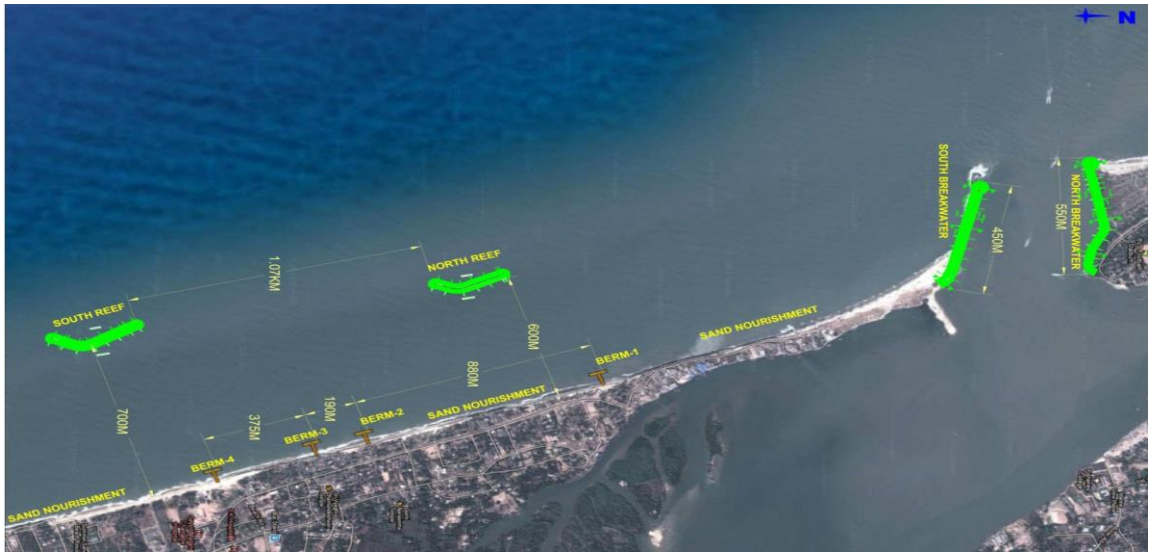

Fig 15: Layout of works at Ullal (Karnataka)

1.10.2.6 Artificial Headlands

A headland is a coastal landform, a point of land usually high and often with a sheer drop that extends out into a body of water. Headlands are characterized by high, breaking waves, rocky shores, intense erosion, and steep sea cliffs.

Artificial headlands are rock structures built along the toe of eroding dunes to protect strategic points. Temporary headlands can be formed of gabions or sand bags. These stabilize discrete lengths of the dune face while allowing the intervening stretches to erode naturally, forming an increasingly embayed shoreline.

Advantages:

- Relatively easy to construct
- It is significantly cheaper than protecting a whole frontage
- Little maintenance is required

Disadvantages:

- It can cause erosion downdrift of the protected length of coastline.
- Has poor stability against large waves.

1.10.3 Combination of the Structural and Non-Structural Measures:

It has already been stated that using a combination of the structural and non-structural measures helps in providing better efficacy and efficiency. The combination gives synergetic outcomes and provides an environmentally and economically acceptable coastal protection system. The hard solutions offer a wide variety of disadvantages like causing erosion and unnecessary accretion at various points, being expensive and also, at times, spoil the economic value of the site by making its look less beautiful. In terms of the soft solutions, it may be noted that these are not quick-fix solutions and they take time to be effective and these are effective only in a medium to long term perspective.

In view of aforesaid aspects and also to optimize the long-term positive impact of soft solutions, many combinations of soft and hard solutions can be selected. These combinations act as interim hard structures and some of the common approaches of combinations are:

- combining beach nourishment with artificial headlands/groynes
- Revegetation with temporary offshore breakwaters/artificial reefs and are commonly used.

Using a combination of beach nourishment and groynes/artificial headlands promotes the trapping of the downdrift movement of the sediment, thus reducing downdrift erosion. This also reduces the frequency of re-nourishment.

We realize that coastal erosion is an extensive and multi-dimensional problem for a vast country like ours. Efforts are being made to counter the menace of coastal erosion and to protect our coasts, using both the traditional approaches (using hard structures like Seawall etc) and also using the new, innovative soft measures like dune rehabilitation.

The protection works are prioritized, planned and designed as per the graveness and extent of the problem. This also helps in deciding the resources-input needed for executing a particular solution. In view of this, it is of immense importance to accurately gauge the extent and graveness of coastal erosion as a problem.

2.0 STATUS OF COASTAL EROSION IN INDIA

All the maritime States/UTs are facing problem of coastal erosion in varying magnitude. The latest national-level data in this regard is obtained from the Shoreline Change Atlas of Indian Coast.

2.1 Shoreline Change Atlas of Indian Coast

Coastal Protection and Development Advisory Committee (CPDAC) constituted by Ministry of Water Resources, River Development & Ganga Rejuvenation (Govt. of India) recommended the need for preparation of a Coastal Atlas showing information related to coastal erosion derived from satellite data and protection measures undertaken by all maritime states of India. Accordingly, at the behest of Coastal Erosion Directorate, Central Water Commission, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India, New Delhi, a project entitled, "Shoreline Change Atlas of the Indian Coast", was initiated by Space Applications Centre (ISRO), Ahmedabad, in collaboration with Central Water Commission. The activity was funded by CWC.

The major objective of this activity was to prepare a digital shoreline change atlas in GIS environment on 1:25, 000 scale using satellite data (1989-91 and 2004-06). The detailed objectives are:

i) To quantify and classify the shoreline as shoreline under erosion, stable and accretion for all the maritime states by integrating shoreline using existing database of 1989-91 and 2004-06 period.

ii) To integrate the field collected information on coastal erosion and shoreline protection measures of all the maritime states of India in GIS environment.

iii) To analyse high resolution satellite data of 2009-2010 period for selected hotspot areas (areas showing large shoreline changes) and understand coastal processes responsible for such changes.

The entire Indian coast was covered by around 1000 maps on 1:25, 000 scales. The highest High Tide Line was used as shoreline and in quantifying the erosion, accretion because it is easily detectable on satellite image due to tonal discontinuity.

The publication of the Shoreline Change Atlas of Indian Coast was accepted by the CPDAC in its 14th Meeting (February, 2014). Further, the Shoreline Change Atlas was published in the Brain-Storming Workshop on "Implementation of Coastal Management Information System" held at CWC, New Delhi in May, 2015.

Primarily, landuse/landcover maps on 1:25,000 prepared using IRS-P6 LISS IV data of 2004-06 period and SPOT-1 & 2 Multispectral and IRS-1A & IRS-1B LISS-II data of 1989-91 periods available at Space Applications Centre, Ahmedabad have been utilized. Shoreline changes with respect to Highest High Tide Line have been taken up for the Atlas. The Status of shoreline protection measures have also been depicted in the Atlas

as per the information provided by the maritime State/UT agencies through Central Water Commission.

The maps show eroding, stable and accreting coast for the maritime States/UTs. The shoreline has been quantified and classified as shoreline under erosion, stable and accretion for all the maritime states by integrating shoreline using existing database of 1989-91 and 2004-06 periods.

2.1.1 Results of the Shoreline Change Atlas of Indian Coast

The Shoreline Change Atlas of the Indian Coast shows that around 45.5% of the total Indian coastline is under erosion, around 35.7% of coastline is under accretion and rest (18.79%) is under stable category. It also shows that the Indian Coast has lost a net area of about 73 sq. km during 1989-91 and 2004-06 timeframe. The findings of the Shoreline Change Atlas have been summarized in Tables 7 and 8 below:

Table 9: Coastline Length Erosion/Accretion as per Shoreline Change Atlas

State	Erosion Length* (km)	Accretion Length* (km)	Stable Length*	Total Length* (km)
Gujarat, Daman & Diu	486.43	297.99	697.71	1482.13
Maharashtra	449.5	244.47	48.29	742.26
Goa	27.03	46.98	81.38	155.39
Karnataka	106.12	118.65	73.31	298.08
Kerala	218	294	73.6	585.6
Tamil Nadu & Puducherry	281.56	514.11	29.25	824.92
Andhra Pradesh	443.88	186.94	340.45	971.27
Odisha	199	205	32.1	436.1
West Bengal	115.06	19.46	147.68	282.2
Lakshadweep Islands	72.03	63.24	1.01	136.28
Andaman Islands	740.37	944.84	36.83	1722.04
Nicobar Islands	690.1	68.3	19.23	777.63
Total	**3829.1**	**3004**	**1580.8**	**8413.9**
%	**45.51%**	**35.70%**	**18.79%**	
**Length does not include river mouth, creeks etc.*				

Table 10: Coastal Area under Erosion/Accretion as per Shoreline Change Atlas

State/UT*	Area Under Accretion (Sq. km)	Area Under Erosion (Sq. km)	Net gain/loss (Sq. km)
Gujarat, Daman & Diu *	43.45	27.28	16.17
Maharashtra	5.08	7.83	-2.75
Goa	1.53	0.771	0.759
Karnataka	6.26	5.16	1.1
Kerala	9.54	5.31	4.23
Tamil Nadu & Puducherry *	42.64	17.19	25.45
Andhra Pradesh	25.14	46.89	-21.75
Odisha	13.3	13.8	-0.5
West Bengal	1.52	11.63	-10.11
Lakshadweep Islands*	0.83	1.7	-0.87
Andaman Islands*	27.09	17.93	9.16
Nicobar Islands*	0.77	94.72	-93.95
Total	**177.15**	**250.211**	**-73.061**

From the above, it may be noted that the highest percentage of the shoreline under erosion is in Nicobar Islands (88.7%), while percentage of accreting coastline is the highest for Tamil Nadu (62.3%). The state of Goa has the highest percentage of stable shoreline (52.4%). The analysis shows that the Indian coast has lost a net area of about 73 km^2 during time frame of 1989-91 and 2004-06. In Tamil Nadu, a net area of about 25.45 km^2 has increased due to accretion, while along Nicobar Island about 93.95 km^2 is lost due to erosion.

During the 14th CPDAC Meeting, it was also envisaged that the Shoreline Change Atlas of Indian Coast will be updated at regular intervals of five years and for undertaking the first updating based upon data of 2012-13. In view of this, CWC has requested Space Application Center (SAC), Ahmedabad to update the shoreline change data for the 2012-13 time-frame. Accordingly, all the maritime States/UTs have also been requested to provide details of Coastal protection works other than those which have already been incorporated in the Atlas for further incorporation into the updated Atlas.

The state-wise Shoreline Change maps and the status of the respective coastlines, as taken from the Shoreline Change Atlas of Indian Coast, are given below from Fig 11 to Fig 34.

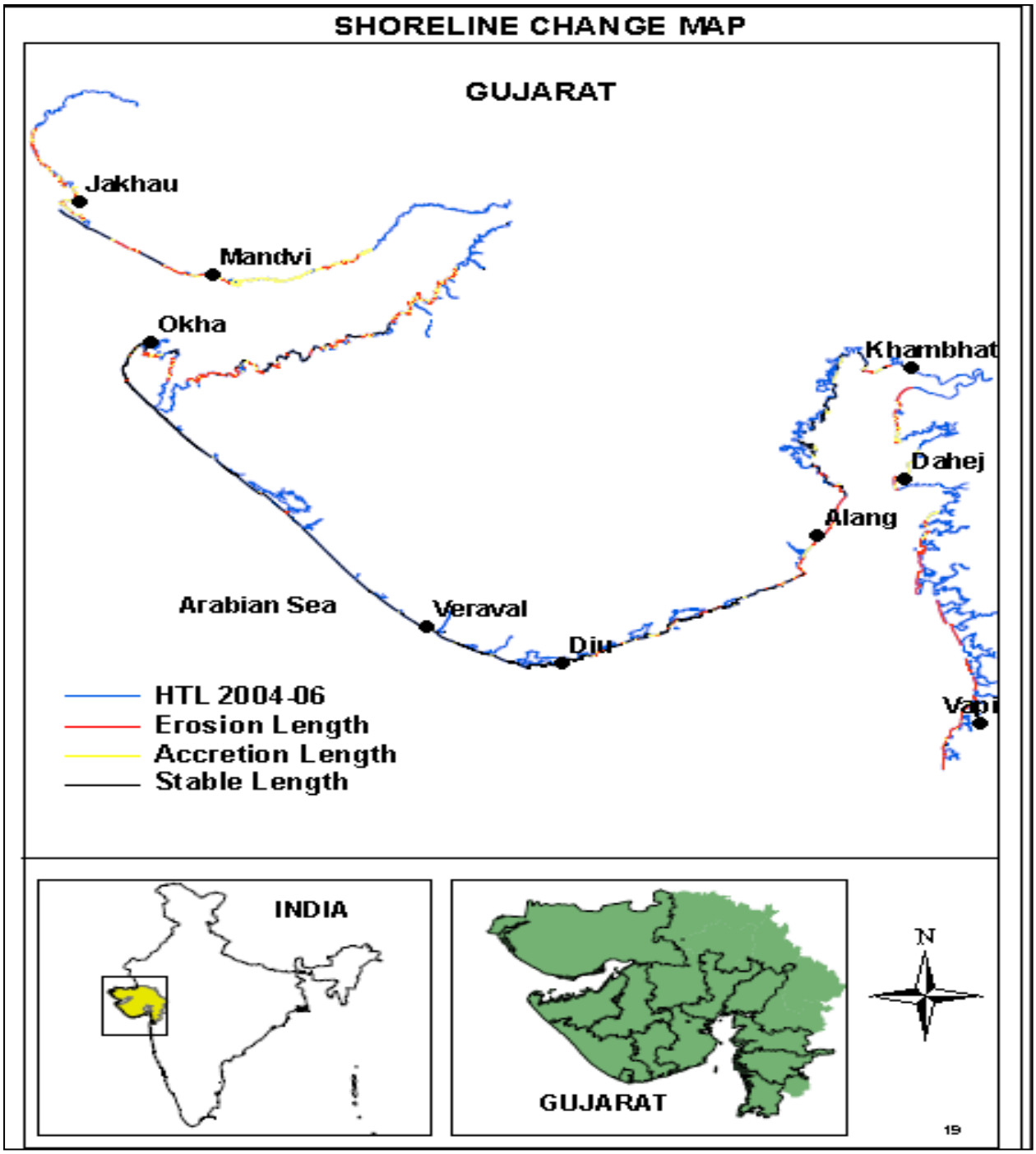

Fig 16: Shoreline change map: Gujarat and Daman & Diu

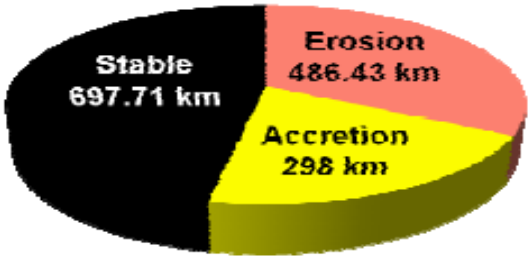

Fig 17: Status of Shoreline of Gujarat and Daman & Diu

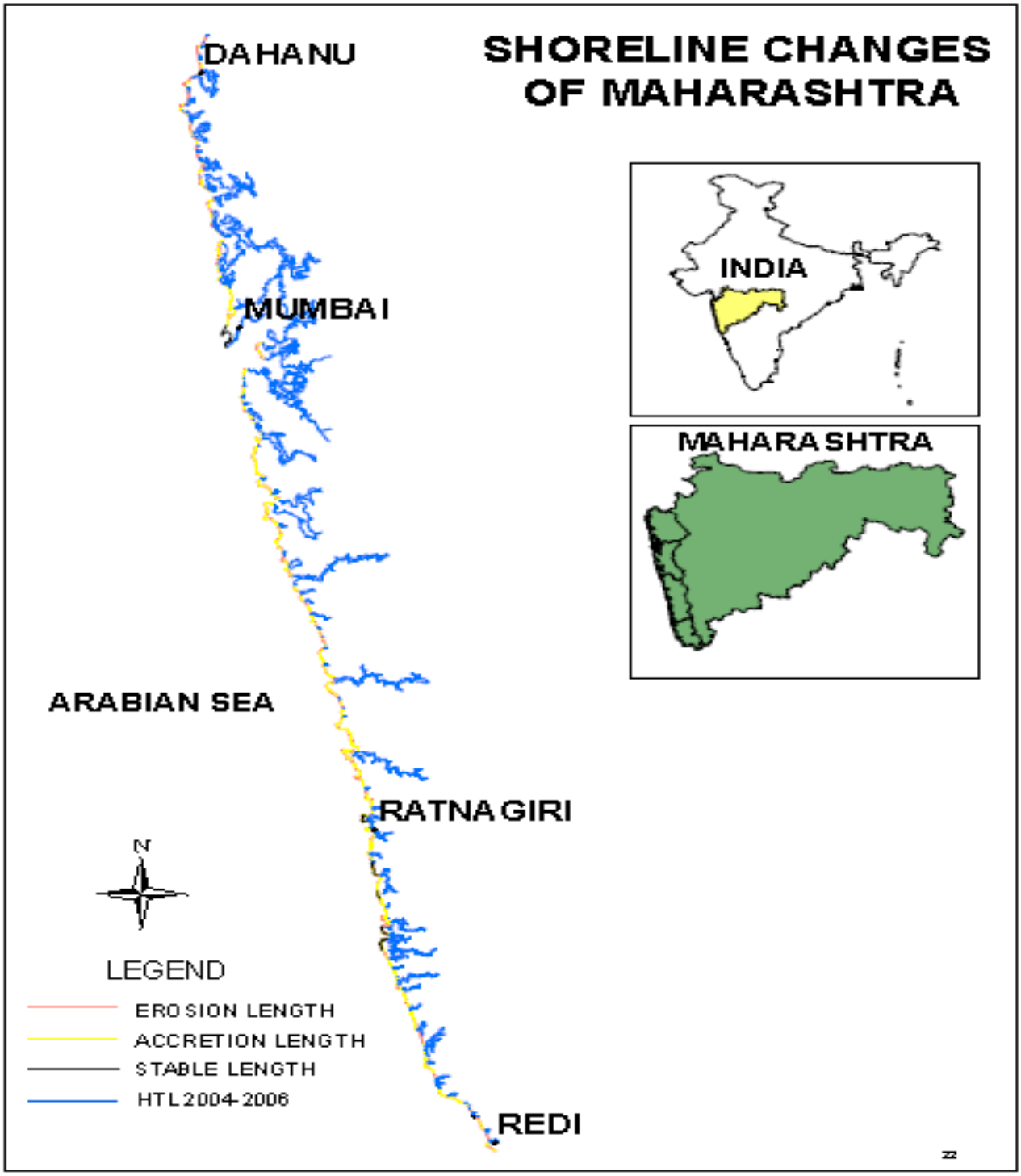

Fig 18: Shoreline change map: Maharashtra

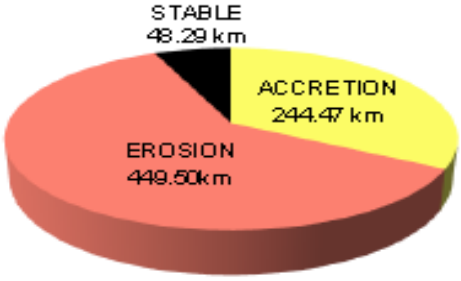

Fig 19: Status of Shoreline of Maharashtra

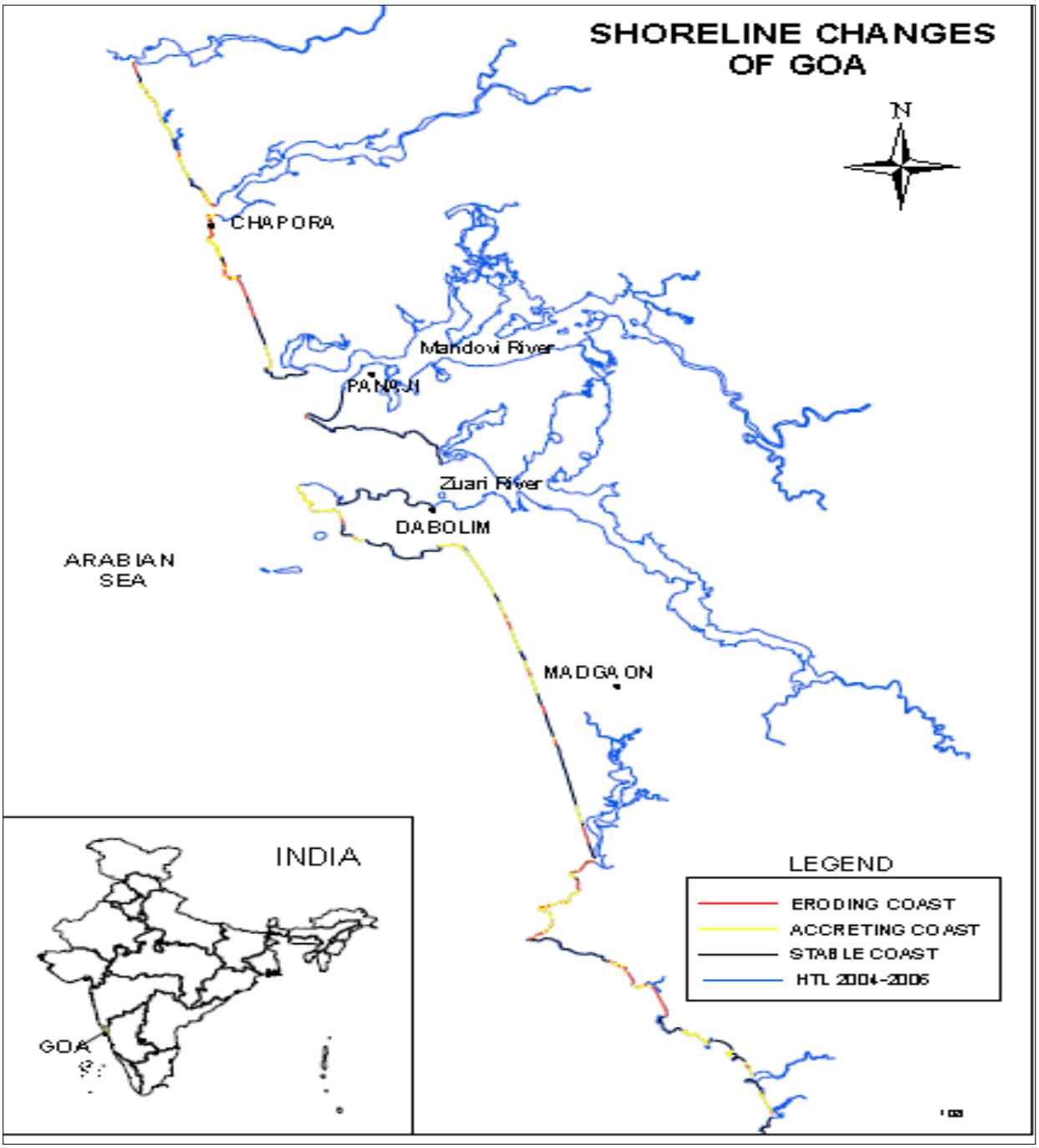

Fig 20: Shoreline change map: Goa

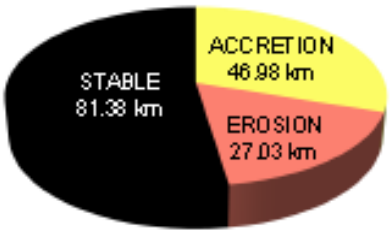

Fig 21: Status of Shoreline of Goa

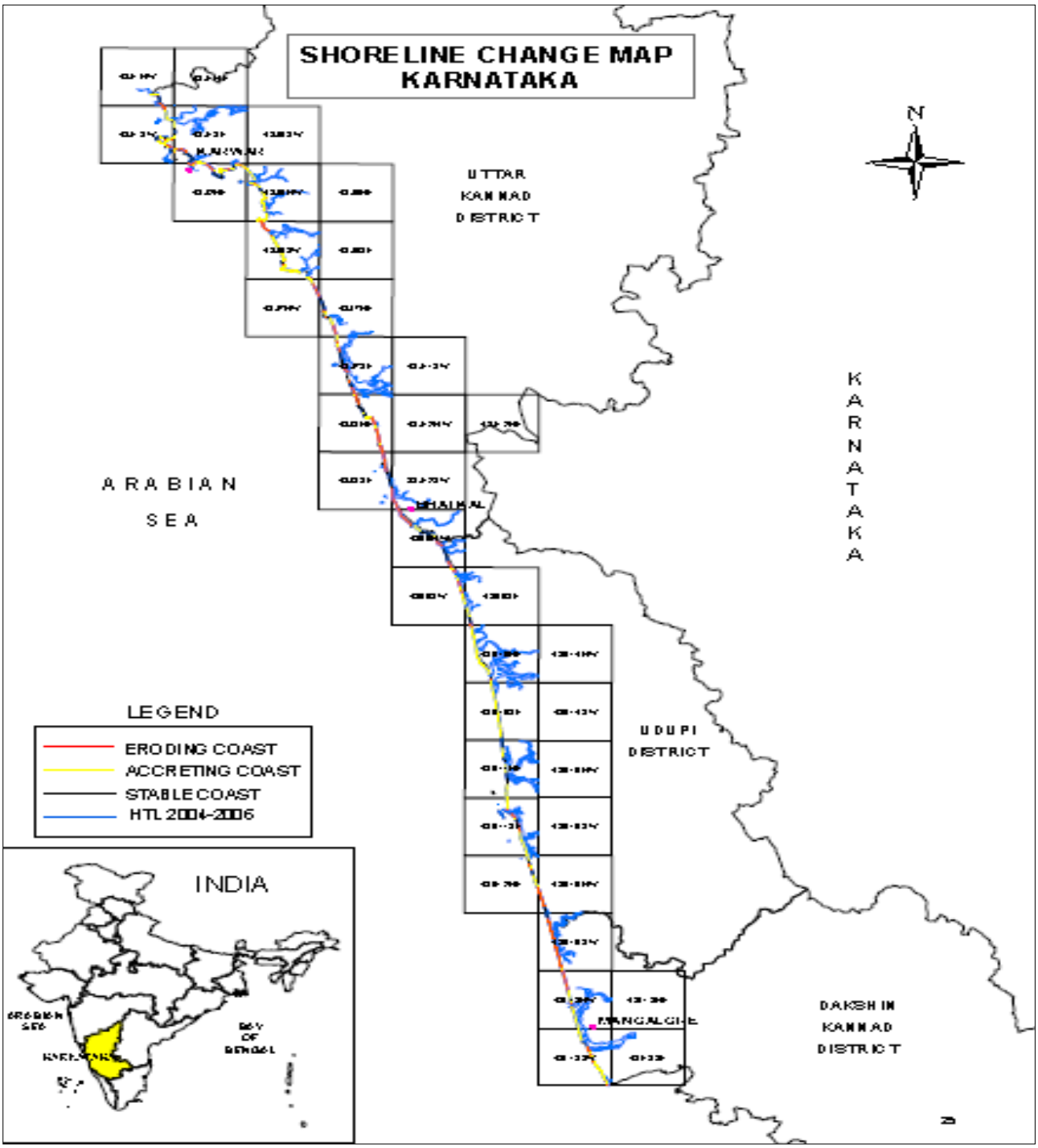

Fig 22: Shoreline change map: Karnataka

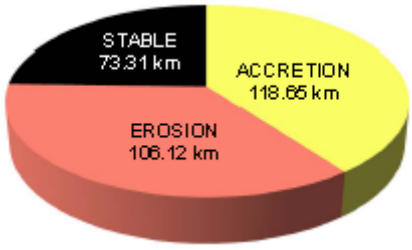

Fig 23: Status of Shoreline of Karnataka

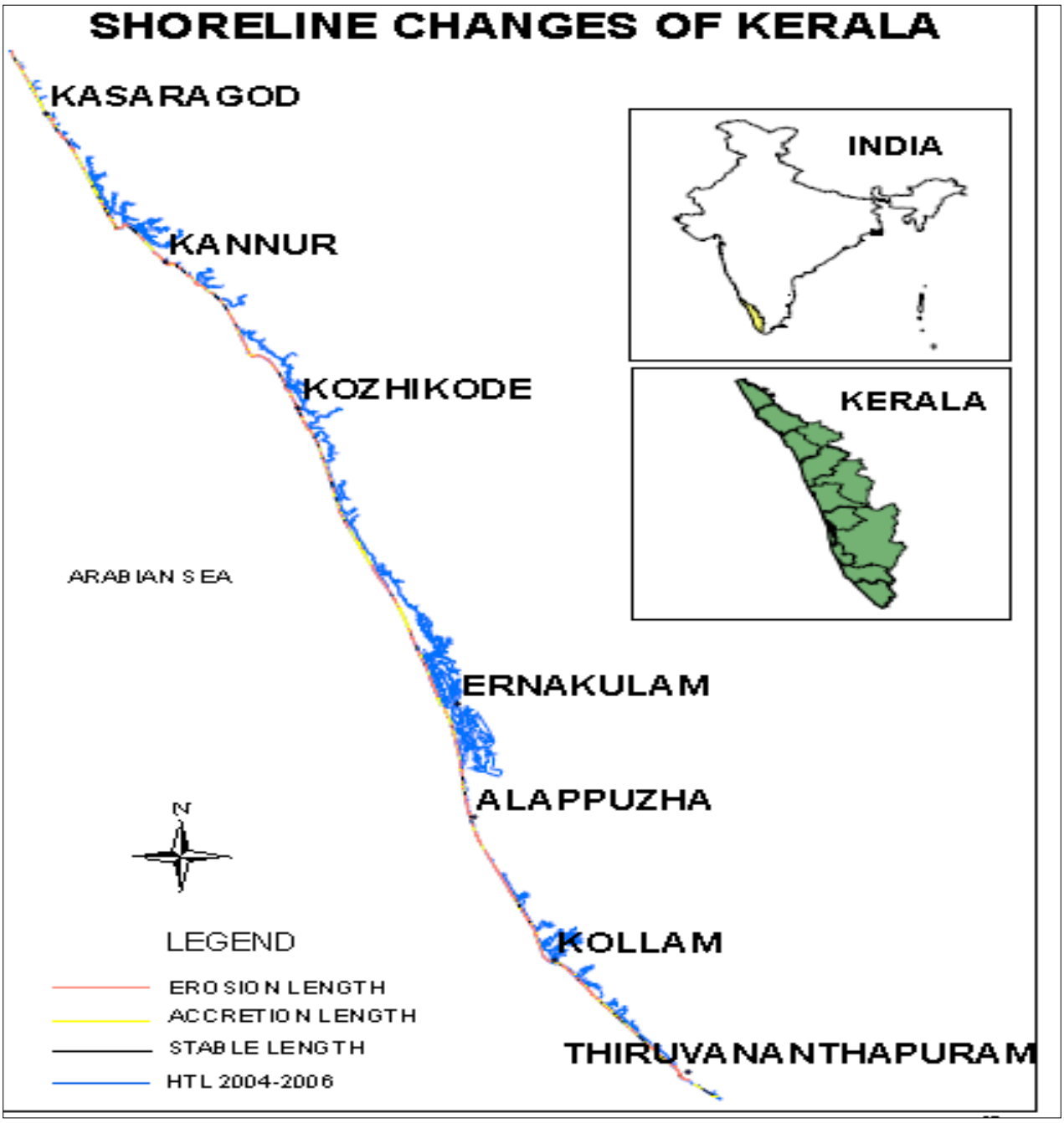

Fig 24: Shoreline change map: Kerala

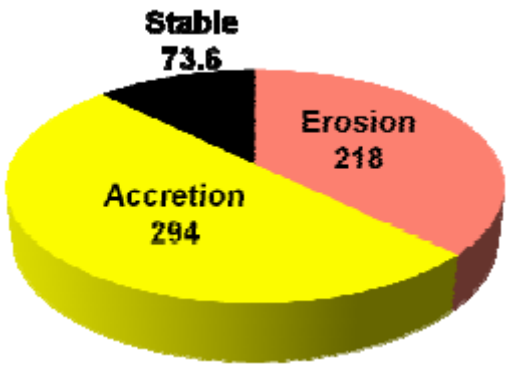

Fig 25: Status of Shoreline of Kerala

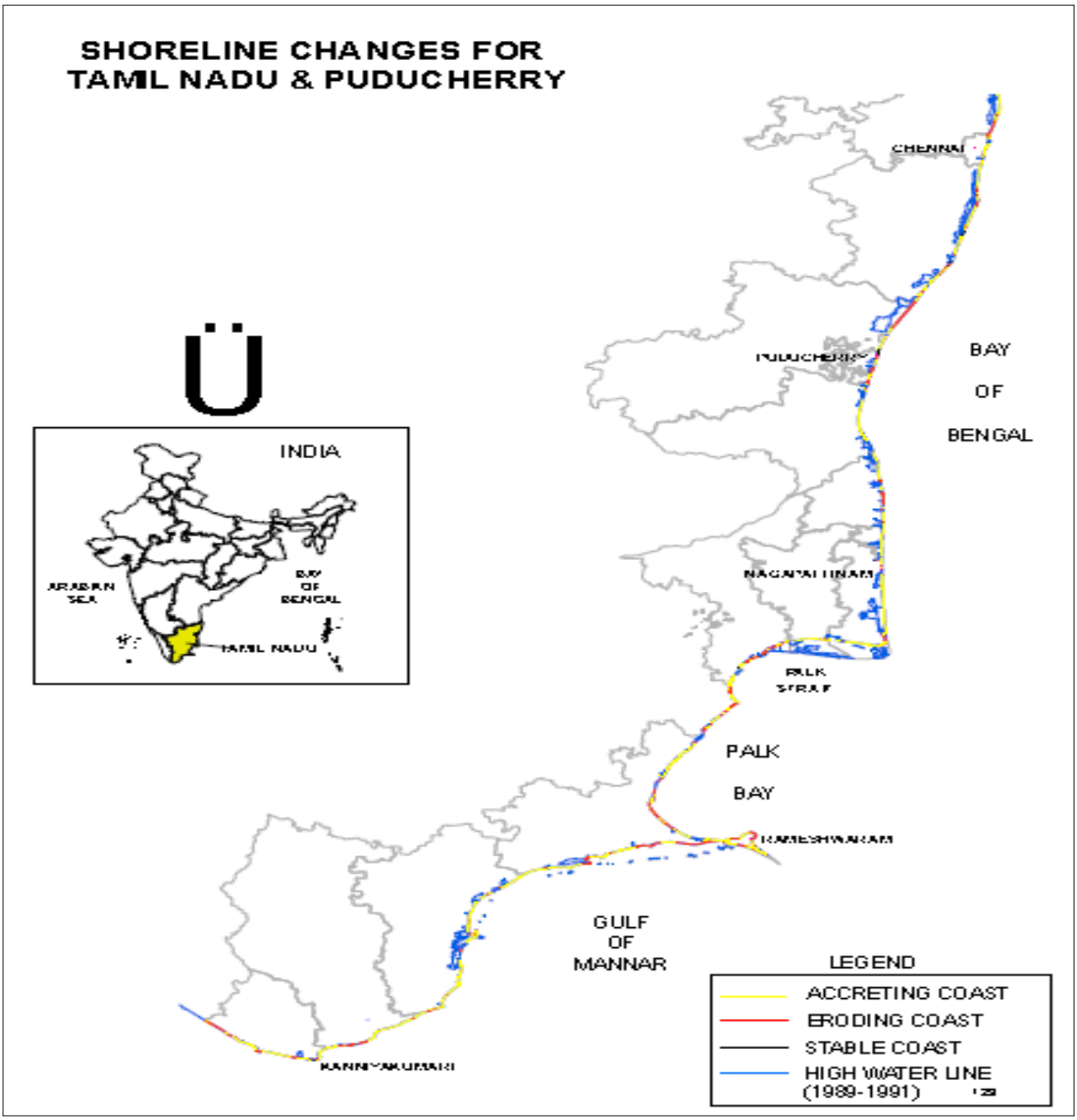

Fig 26: Shoreline change map: Tamil Nadu & Puducherry

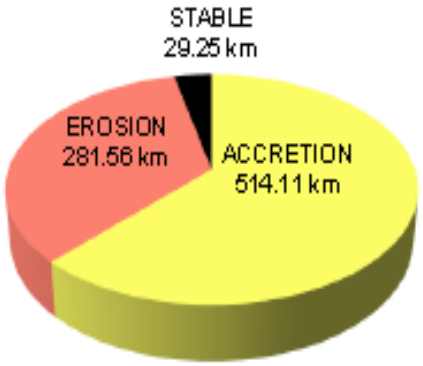

Fig 27: Status of Shoreline of Tamil Nadu and Puducherry Coast

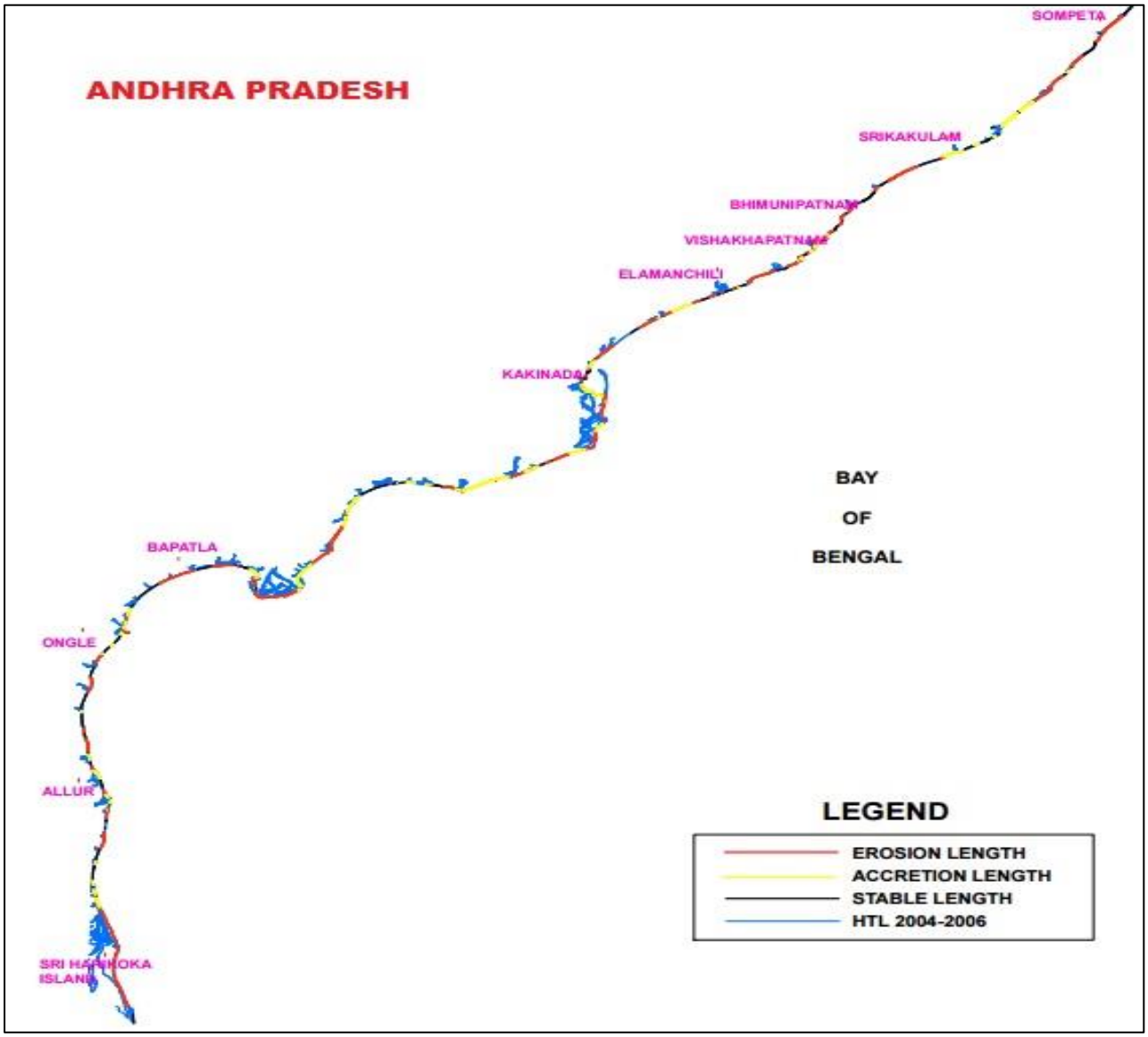

Fig 28: Shoreline change map: Andhra Pradesh

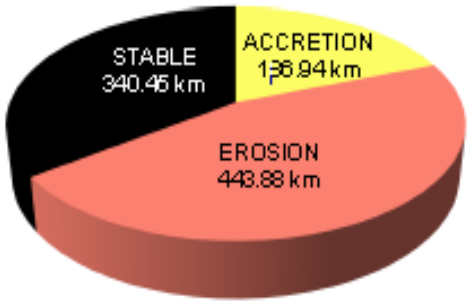

Fig 29: Status of Shoreline of Andhra Pradesh

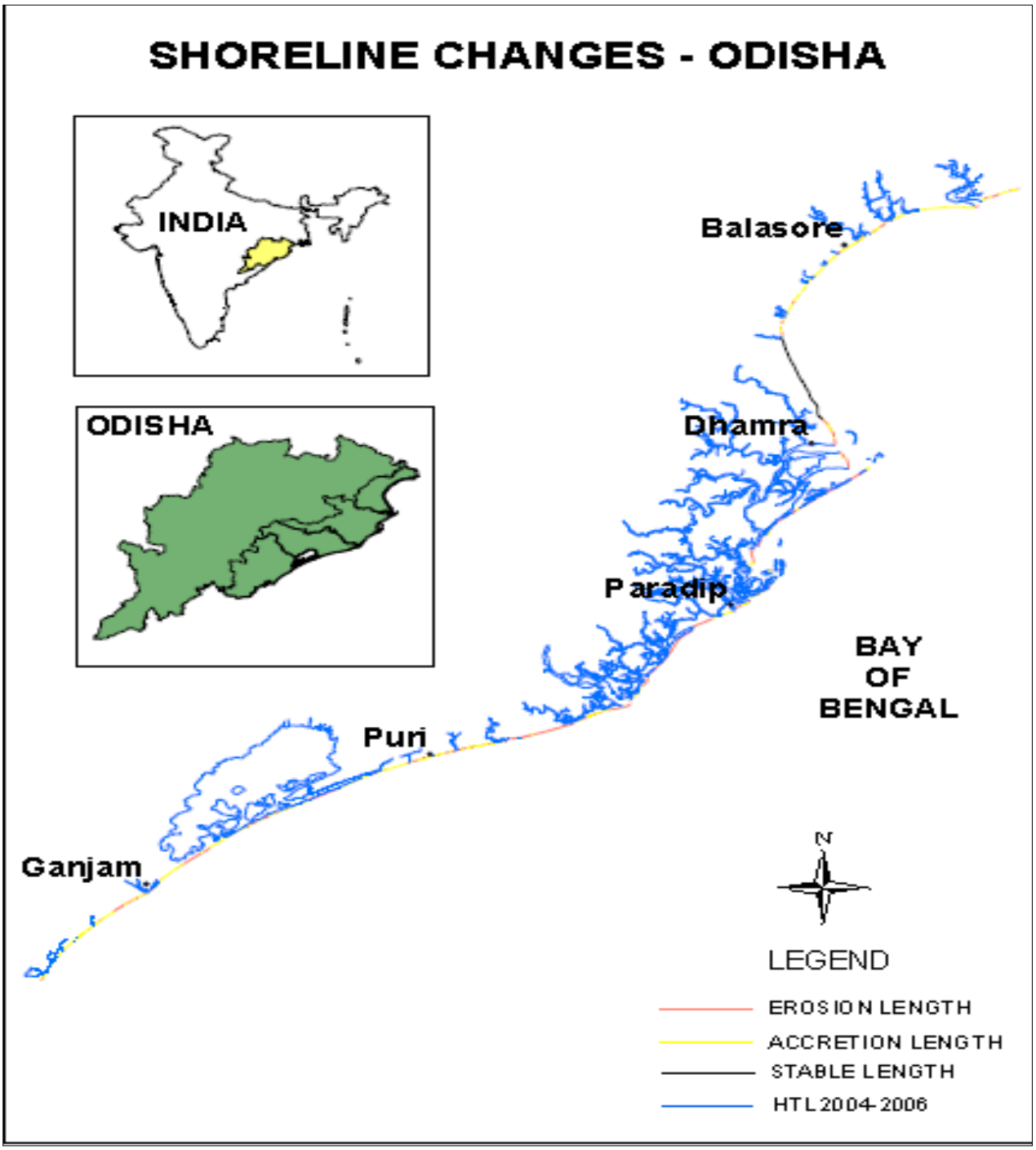

Fig 30: Shoreline change map: Odisha

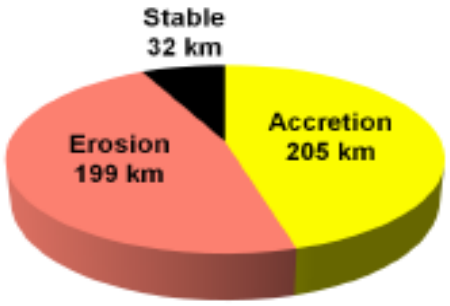

Fig 31: Status of Shoreline of Odisha

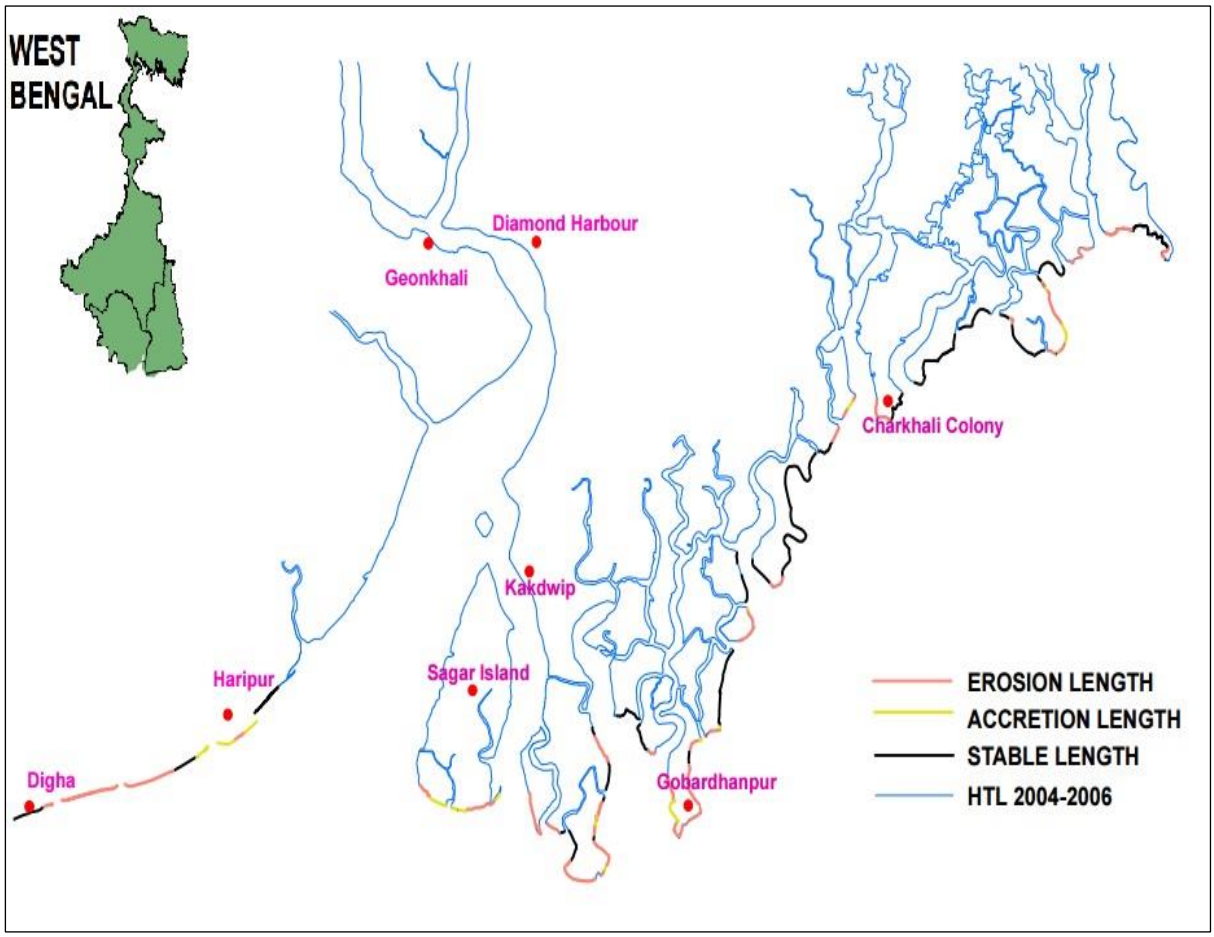

Fig 32: Shoreline change map: West Bengal

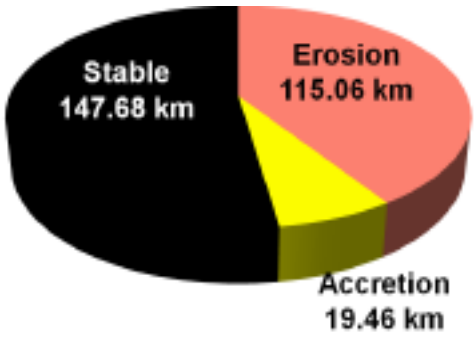

Fig 33: Status of Shoreline of West Bengal

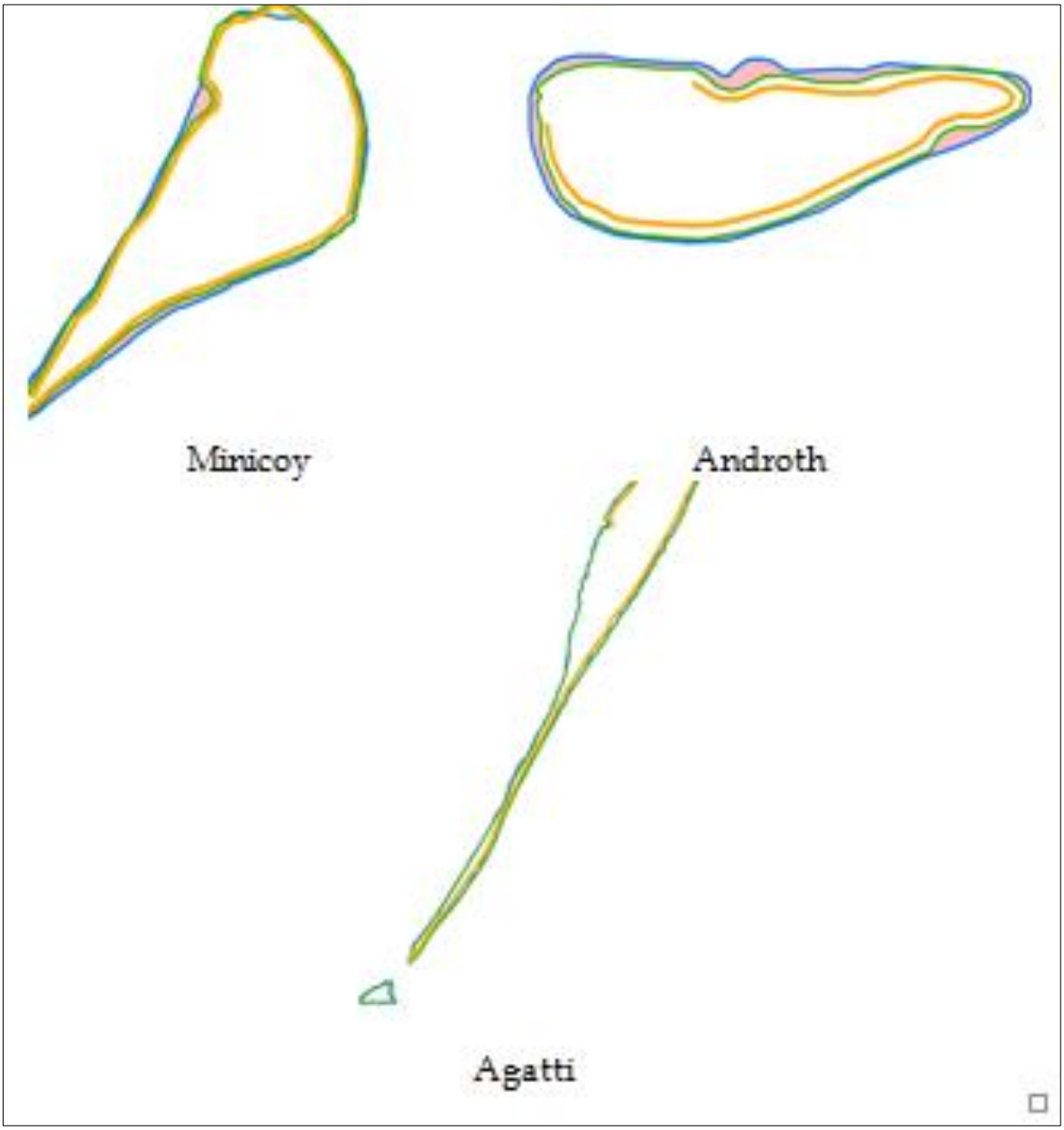

Fig 34: Shoreline change map for selected Islands: Lakshadweep

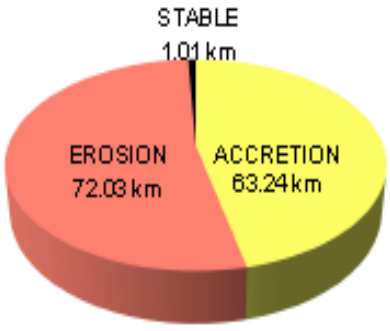

Fig 35: Status of Shoreline of Lakshadweep

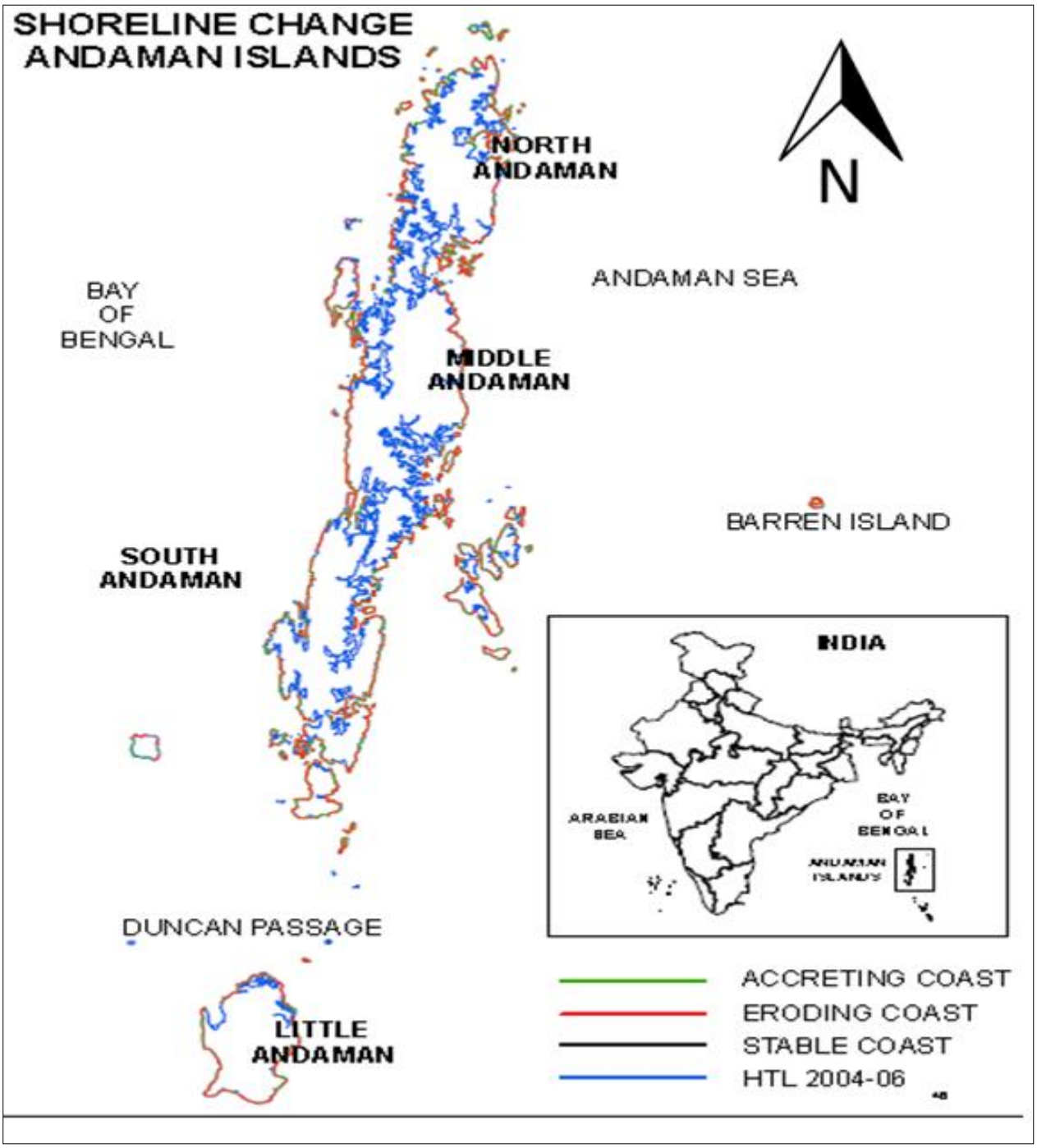

Fig 36: Shoreline change map: Andaman Islands

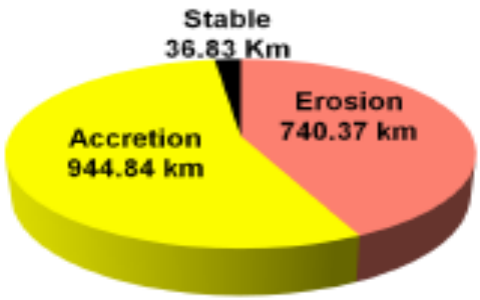

Fig 37: Status of Shoreline of Andaman

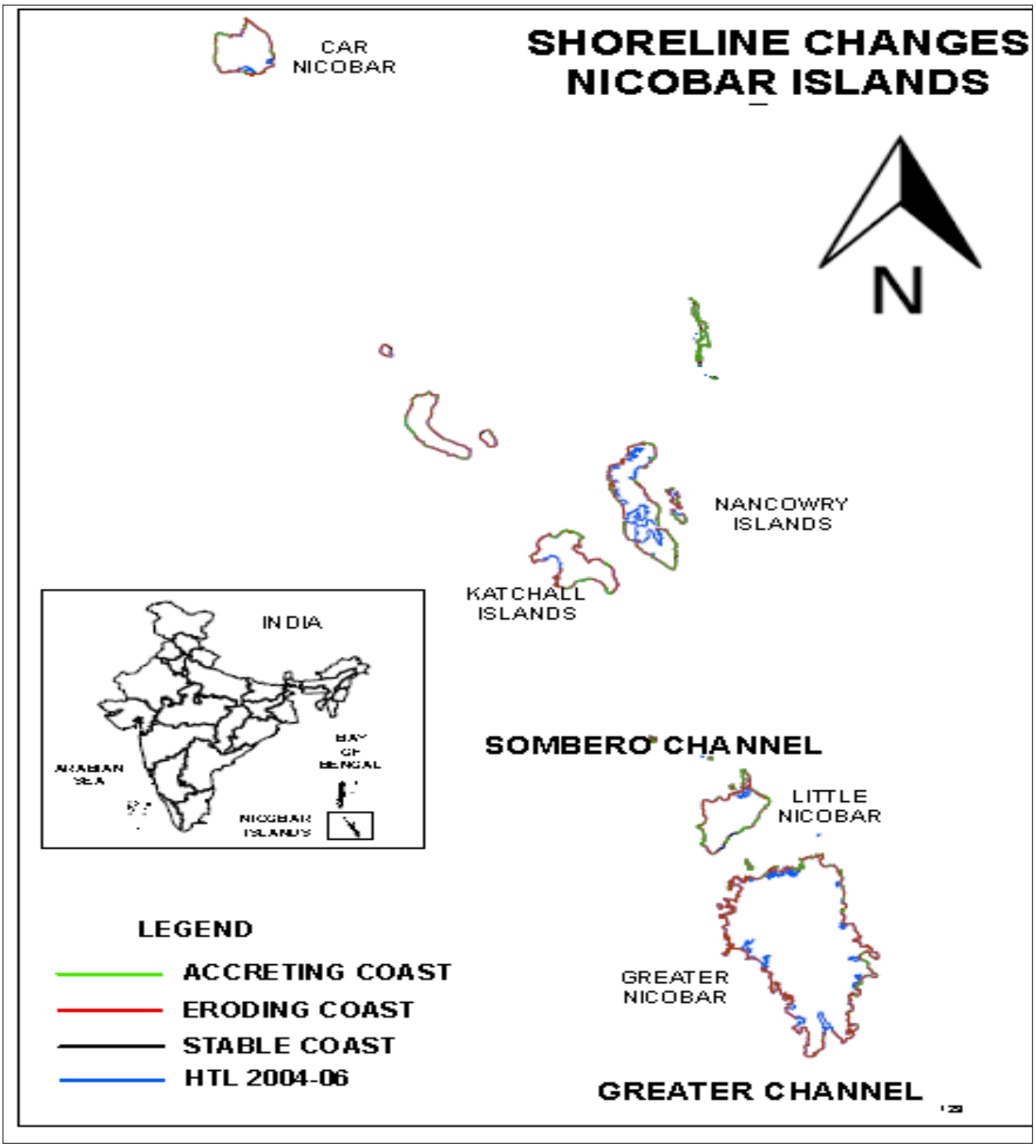

Fig 38: Shoreline change map: Nicobar Islands

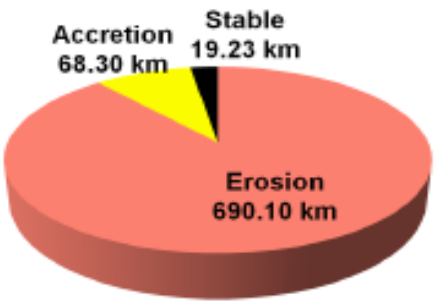

Fig 39: Status of Shoreline length of Nicobar

3.0. INSTITUTIONAL SET-UP

3.1 Ministry of Water Resources, River Development & Ganga Rejuvenation

As per the Government of India (Allocation of Business) Rules, 1961 (amended from time to time) Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD& GR) has been entrusted with General Policy, technical assistance, research and development , training and all matters relating to **sea erosion problems**. Following setup under the Ministry deals with the above matter.

3.1.1 CPDAC (erstwhile Beach Erosion Board)

(http://cwc.gov.in/CPDAC-Website/index.html)

Realizing the need of overall planning and cost effective solution to the coastal problems, the Govt. of India constituted **Beach Erosion Board** (BEB) in the year 1966 under the Chairmanship of Chairman, CWC (erstwhile CW&PC) initially, to guide and implement the programme of anti-sea erosion works in Kerala only. Chief Engineer In-charge of anti-sea erosion works of Kerala was appointed as Member-Secretary. Besides the Chairman and Member-Secretary, the Board comprised three Members, including Director, CW&PRS, Pune. Govt. of India reconstituted the Board in 1971 and further in 1989 extending its jurisdiction to the entire coastline of the country. The Board held 24 meetings in all.

With the objective of the development in the protected coastal zone and the pressure of population in the densely populated areas in the coastal zone, the Beach Erosion Board was reconstituted and renamed as "Coastal Protection and Development Advisory Committee" (CPDAC) in April, 1995 with its secretariat in the Central Water Commission to identify and develop the various resource potential available behind the protected areas.

Coastal Protection and Development Advisory Committee (CPDAC) is a high level body of experts in the field of coastal engineering, which is regularly approached by the maritime States/UTs and other concerned agencies for specific advice on the problems of coastal erosion. CPDAC is headed by Member (RM), Central Water Commission and the representatives of Coastal States and the related Central Departments as its members. Coastal Protection and Development Advisory Committee provides a common platform to all maritime States/UTs to discuss and solve their coastal erosion problems. The Committee has given its recommendations in the past on various coastal related issues.

CPDAC (erstwhile BEB) has taken various initiatives in past in respect of following:

I. Formulation of National Coastal Protection Project (NCPP)
II. NCDC (National Coastal Data Centre) at CWPRS, Pune
III. Guideline for collection of Coastal Field Data through CWPRS, Pune
IV. Performance Evaluation of existing coastal protection works
V. Training Programme & Institutional Strengthening
VI. Updating/preparation of relevant Manual

VII. Guidelines for Design of Sea Wall and recommendation for modification based on experimental results
VIII. Criteria for assessing the economic viability of beach protection schemes
IX. Outline for Constitution of Coastal Zone/Land Management Authority before CRZ Notification,1991
X. Inspection of various erosion sites and recommendations
XI. Effort to Study of Phenomenon of Mud Bank in Kerala
XII. Overview /Status Report of Coastal Erosion Problem at National/State level
XIII. Broad Zoning of coastal zone of Great Indian sub-continent
XIV. Shoreline Change Atlas of the Indian Coast
XV. Acceptance of the new Methodology and new Coastal Length Data as provided by NHO, Dehradun.
XVI. Standard coastal data collection framework
XVII. Team to study coastal erosion in Lakshadweep
XVIII. Technical Memoranda on Guidelines for Design, Construction of Seawalls by CW&PRS, Pune (May, 2010)

CPDAC has various Sub-committees to look into different functions assigned to it. Few of them are detailed as under:

3.1.1.1. Sub-Committee on Coastal Atlas

In pursuance of the decision taken in the 11th Meeting of CPDAC held in January 2010 and to facilitate the preparation of the Coastal Atlas, a Sub-Committee of CPDAC on Coastal Atlas was reconstituted in January, 2010. Since then, the reconstituted Sub-Committee on Coastal Atlas has had 2 meetings. The first meeting of this Sub-committee was held in May 2010 and the second meeting was held in September 2011.

The sub-committee confirmed the proposal of SAC, Ahmedabad for preparation of the Shoreline Change Atlas of Indian Coast during and reviewed the progress of the work.

3.1.1.2. Sub-Committee on Coastal Data Collection, Compilation & Publication

The Sub-Committee of CPDAC on Coastal Data Collection, Compilation and Publication was constituted in pursuance of the decision taken in the 13th Meeting of CPDAC held in February, 2012.

The First Meeting of Sub-Committee was held in October, 2013 to discuss various issues on coastal data collection. The sub-committee discussed and finalized the list of parameters, frequency, methodology & schedule of observations for coastal data to be collected and format for compilation of selected parameters. The sub-committee also discussed and identified the Lead Agencies for various activities in respect of coastal data collection/protection.

3.1.1.3. Sub-Committee on Performance Evaluation of Coastal Protection Measures

In pursuance of the CPDAC function regarding ''review the performance of the work carried out by the States and evolve improved design techniques based on such

experience from time to time'', the Sub-Committee of CPDAC on Performance Evaluation of Coastal Protection Measures was constituted. The Sub-committee is actively involved in the effective and timely monitoring of the coastal protection and development projects.

The Sub-Committee has held various Meetings to review the performance of the coastal protection works visa-a-vis first at Kerala (July 2004), second at Karnataka (May 2005), third at Goa (October 2005), fourth at Lakshadweep (January 2011), fifth at Tamil Nadu (June 2011) and sixth at Gujarat (June, 2015).

3.1.2 Central Water Commission (CWC)

One of the major functions of CWC is to carry out morphological studies to assess river behavior, bank erosion/coastal erosion problems and advise the Central and State Governments on all such matters. CWC is responsible for overall co-ordination, monitoring and techno-economic appraisal of anti-sea-erosion schemes in respect of the maritime States/UTs, monitoring of the progress of centrally sponsored/externally aided schemes for coastal protection works, interaction with the Research Stations in the maritime States and CW&PRS, Pune on the studies relating to coastal protection and coastal erosion control schemes. It also works as secretariat to CPDAC (Coastal Protection and Development Advisory Committee) constituted by Government of India.

3.1.3 Central Water & Power Research Station (CWPRS), Pune

CWPRS is the national level research organization under MoWR, RD&GR and it has been playing a major role in design development for coastal protection projects for different States/UTs. CWPRS as a subordinate office of the MoWR, RD&GR is one of the foremost organizations in the field of hydraulics and allied research. CWPRS provides specialized services through physical and mathematical model studies and field investigations in various fields including Coastal and Offshore Engineering. The institution has well developed technical capacities and has also provided sustainable, soft solutions like beach nourishment and protection by geo-tubes at low water level, application of geo-textiles in Gujarat, Maharashtra and West Bengal as well as detached offshore bunds in Gujarat and Maharashtra. The Coastal Engineering Research Centre (CERC) within the institute was developed under United Nation Development Programme (UNDP). The institute undertakes studies for ports and harbours development, design of coastal structures, coastal processes, tidal inlets, intake and outfall systems of thermal/nuclear power plants using physical as well as mathematical modelling techniques. CWPRS is also actively engaged in disseminating research findings amongst hydraulic research fraternity by way of publications and training programmes.

3.2 Other Ministries/ Institutions/Agencies

Apart from above, the related aspects to Coastal Protection and Development are also dealt through other organizations at National level and state level. A brief overview of the core activities of the said institutions is given in the following text:

3.2.1. Ministry of Earth Sciences (MoES)

3.2.1.1. Integrated Coastal & Marine Area Management, Project Directorate (ICMAM-PD)

The Ministry of Earth Sciences (erstwhile Department of Ocean Development) which is responsible for preservation and conservation of marine environment in India, established the ICMAM Project Directorate in January, 1998 at Chennai (Madras) with the objective of:

(i). Developing capacity towards accomplishing the coastal and ocean related objectives of UNCED and

(ii). To carry out R&D on application of scientific tools and techniques that are helpful in the development of integrated management solutions to address the issues and problems prevalent in the coastal marine areas.

Given below is the mission of ICMAM Project Directorate:

- Developing and improving capability to understand the critical coastal parameters, processes and phenomena, which have significant societal, economic and environmental benefits.
- Providing scientific and technical support for coastal states for implementing the ICMAM concept and ecosystem-based management for sustainable use of resources.

ICMAM Project Directorate, an attached office of Ministry of Earth Sciences, has collected numerous data on coastal processes viz., waves, tides, currents, bathymetry, shoreline position, beach profiles, and sediment size as a part of shoreline management plan during the X and XI five year plan periods. The sites that have been extensively studied through field data and mathematical modelling are Ennore and tidal inlet of Vellar estuary (Tamilnadu), Munambam to Kayamkula, 4 locations in Kozhikode, Trissur District (Kerala), Ullal beaches in Manglore (Karnataka), locations in Uttar Kannada (Devbhag, Pavinkurve, Kundapur kodi, Uliargoli Padukere) of Karnataka, Gopalpur (Orissa), Gangavaram (AP) by involving local universities and /or research institutions such as NCESS and NIO. The data collected under all these programs are submitted to the data repository of INCOIS, Hyderabad. The ICMAM Project Directorate operates from NIOT Chennai which has a well-developed research base in ocean technology including imagery interpretations of shoreline changes.

3.2.1.2. Indian National Centre For Ocean Information Services (INCOIS)

INCOIS, Hyderabad was established as an autonomous body in 1999 under the Ministry of Earth Sciences (MoES) and is a unit of the Earth System Science Organization (ESSO). ESSO- INCOIS is mandated to provide the best possible ocean information and advisory services to society, industry, government agencies and the scientific community through sustained ocean observations and constant improvements through systematic and focused research. INCOIS has been identified by the Ministry of Earth Sciences as the central repository of oceanographic data in the country and also designated as the National Oceanographic Data Centre (NODC) by the International Oceanographic Data Exchange Programme (IODE) of Intergovernmental Oceanographic Commission (IOC/UNESCO). Further, INCOIS serves as the National Argo Data Centre and Regional Argo Data Centre for the Indian Ocean region.

ESSO-INCOIS has a prominent international presence, being a permanent member of the Indian delegation to IOC of UNESCO and a founding member of the Indian Ocean Global Ocean Observing System (IOGOOS) and the Partnership for Observing the Oceans (POGO) which is actively engaged in capacity building. ESSO-INCOIS houses the IOGOOS secretariat and the Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) International Programme Office. Through the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), ESSO-INCOIS provides ocean information and forecasts to member countries. ESSO-INCOIS is also a member of the Global Ocean Data Assimilation Experiment (GODAE) Ocean View Science Team (GOVST) and Patrons Group.

INCOIS deploys and maintains a suite of Ocean Observing Systems in the Indian Ocean to collect data on various oceanic parameters to understand the processes in the ocean and to predict their changes. INCOIS receives the oceanographic & surface meteorological data in real-time from in-situ ocean observing system (viz. Argo Floats, Moored Buoys, Drifting Buoys, Coastal HF Radars, Automatic Weather Stations, Wave Rider Buoys, Wave Height Meters, Tide Gauges, Bottom Pressure Recorders in real time and XBT, Current meters, ADCP - in delayed mode) and also from the ocean remote sensing data from various satellites (NOAA series, METOP, Terra, Aqua and Oceansat-2). The data center at INCOIS receives the data, process, quality control as per the internationally adopted standards and disseminates to the users as per the data policy. Further, INCOIS developed the Ocean Data and Information System (ODIS), a one-stop-shop for providing oceanographic data services online which facilitates on the fly visualization and downloading in user defined formats. It has developed online web-application for Coastal Ocean Monitoring and Prediction System (COMAPS). It has set up the Tsunami Early Warning Centre in 2007 and has identified tsunamigenic zones along the country's coastline. Under Tsunami Warning System programme, various HF radars have been installed which are located in coast of Tamil Nadu, Andhra Pradesh, Orissa, Gujarat and A&N Islands. Some of the locations are Gopal Pur, Puri (Orissa),

Machhalipattanam, Nagipattanam, Kalpakkam , Cuddalore etc. Data from HF radars are sourced to INCOIS and NIOT both.

INCOIS provides round-the-clock monitoring and warning services for the coastal population on tsunamis, storm surges, high waves, etc. through the in-house Indian Tsunami Early Warning Centre (ITWEC). The IOC of UNESCO designated ITWEC as a Regional Tsunami Service Provider (RTSP) to provide tsunami warnings to countries on the Indian Ocean Rim. INCOIS has established a national network (Indian Seismic and GNSS Network (ISGN)) that integrates Seismic and GNSS stations and provides high quality data for research and operational use. It has also established a VSAT aided Emergency Communication System (VECS) (a fail-safe satellite-based communication system) to provide tsunami warnings with the least possible time delay even when there is a failure in conventional communication systems.

3.2.1.3. National Institute of Ocean Technology (NIOT), Chennai

NIOT, based in Chennai, was established in 1993 as an autonomous society under the Ministry of Earth Sciences, Government of India. The major aim of starting NIOT under the MoES was to develop reliable indigenous technology to solve the various engineering problems associated with harvesting of non-living and living resources in the Indian Exclusive Economic Zone (EEZ), which is about two-third of the land area of India.

The Coastal and Environment Engineering group of NIOT functions with a mandate to develop application-oriented technology in ocean (Coastal & Environmental) related areas. The Ocean Electronics group has a mandate to develop ocean observation systems and demonstrate for applications in the ocean. The group is involved in the development of Deep Ocean Bottom Pressure Recorder (DOPR) & surface buoy data logger for Tsunami Early Warning Systems, Autonomous Underwater Profiling Drifter (AUPD).

Storm Surge Models, Tidal Propagation model are being developed by the institute. It is engaged in developing the Tidal Propagation model which can be used for giving information on Coastal circulation currents which is very important for understanding the coastal processes and causes of erosion and deposition along the shoreline. Sediment Transport and annual budget along the Indian Coast is also being investigated for preparation of countrywide Sediment Transport Atlas. NIOT, in 2014, published a Wave Atlas for the Indian coast which will help design marine structure and serve as a major resource point to protect beaches and coastal environment in the country. The atlas is a reference for basic wave related information like wave height, wave approach and period.

3.2.1.4. India Meteorological Department (IMD)

IMD is the principal agency responsible for meteorological observations, weather forecasting and seismology. It is the custodian of data related to rainfall, Wind, Tropical Cyclone and visually observed wave data from Ships.

IMD is one of the 6 worldwide Regional Specialised Meteorological Centres of the Tropical Cyclone Programme of the World Weather Watch of the World Meteorological Organization. It is regional nodal agency for forecasting, naming and disseminating warnings about tropical cyclone in the Indian Ocean north of the Equator.

3.2.1.5. National Centre for Earth Sciences Studies (NCESS)

Centre for Earth Science Studies (CESS- currently NCESS) was conceived in 1978 by the State Govt. of Kerala. CESS was the earliest institute in the country to embrace the concept of Earth System Science (ESS). For a long time, it served as an institution under the Kerala State Council for Science, Technology and Environment and CESS got established as a research base and expertise on shoreline management and coastal zone studies. The institution has undertaken research projects for the west coast of India for sustainable development of natural resources, conservation of environment and management of natural hazards including the States of Kerala and Lakshadweep. It carried out studies in river basin evaluation, ground water management, coastal erosion, and other special problems. Its work included research in earth system, micro-level watershed planning, natural hazards management, chemical analysis, CRZ mapping, and studies of air, water, land, noise pollution environmental impact assessment, coastal and estuarine management, terrain analysis, natural resources management etc.

In view of the growth potential of the institute, CESS was brought under the MoES and rechristened as NCESS. NCESS pursues problems related to land, sea and atmosphere. It is a premier institute in India that has strong linkages to researches and studies related to the Earth System. The major two areas are Earth System Dynamics and Earth Science Applications.

3.2.2. Ministry of Science and Technology (MoST) -CSIR

3.2.2.1 National Institute of Oceanography (NIO), Goa

The National Institute of Oceanography (NIO), Goa, a research institution of the Council of Scientific and Industrial Research (CSIR) under Ministry of Science and Technology (MoST) was established in January, 1966 following the International Indian Ocean Expedition (IIOE) in the 1960s. Since then, NIO has developed core competence in the fields of oceanography and provides support to industries, Government and non-Government organizations through consultancy and contract research. NIO also operates two research vessels RV Sindhu Sankalp (56 m) and RV Sindhu Sadhana (80 m) that are equipped for multidisciplinary oceanographic observations. NIO has published a manual on 'Protection and Control of Coastal Erosion in India'.

In addition to the above, the Natural Resources Data Management System (NRDMS) under the MoST, undertakes research programmes for the coastal and off-shore areas of the country for providing spatial support to local level planning.

3.2.3. Ministry of Defence (MoD)

The Naval Hydrographic Department (under the Chief Naval Hydrographer to GoI), Dehradun under Indian Navy undertakes surveys in the coastal/inland waters and in the deep seas for navigational safety, coastal zone management, environmental protection and scientific oceanic investigations. It undertakes surveys and research for development of natural resources / projects of economic importance.

The Indian Coast Guard protects structures in the maritime zone and fishermen in distress, oversees preservation of the maritime environment including prevention and control of marine pollution.

The Coastal Guard Organization is the central coordinating agency for combating of Oil-pollution in the coastal and marine environment of various maritime zones. It also undertakes oil spill prevention and control, inspection of ships and offshore platforms in the country.

3.2.4. Ministry of Home Affairs (MoHA)

MoHA/NDMA is the implementing authority of the Disaster Management Act, 2005 for effective management of disasters including environmental degradation in the coastal areas which are beyond the coping capacity of the communities of the affected area.

3.2.5. Ministry of Agriculture and Farmers Welfare (MoA&FW)

3.2.5.1. Central Institute of Coastal Engineering for Fisheries (CICEF)

The Central Institute of Coastal Engineering for Fisheries (CICEF), Bangalore, an institution under the MoA&FW undertakes techno-economic feasibility studies, preparation of Detailed Project Report (DPR), design development and other coastal engineering studies for development of fishing harbours, fish landing centres and related facilities in the maritime States in India for all centrally assisted projects.

3.2.5.2. Central Marine Fisheries Research Institute(CMFRI)

The Central Marine Fisheries Research Institute (CMFRI), Kochi is a national level institution for research and development for ensuring sustainability in fisheries resource, eco-system and livelihoods of the coastal communities. CMFRI has a comprehensive data base on fisheries and marine eco-system of the Indian coast.

3.2.6. Ministry of Shipping (MoS)

Ministry of Shipping is mandated for development of Major Ports, located in east and west coasts and the policy issues of entire Port sector. Maritime State Governments are responsible for development of Minor Ports located in the territory.

3.2.7. Ministry of Environment, Forests & Climate Change (MoEF&CC)

As per the demarcation of responsibilities in GoI, the MoEF&CC has been given the responsibility for 'Environment and Ecology', including environment in coastal waters, in mangroves and coral reefs but excluding marine environment on the high seas.

Under the National Coastal Zone Management Programme, the MoEF&CC is implementing a reengineered Coastal Regulation Zone (CRZ) Notification 2011 to ensure livelihood security to fishing and other local community, to conserve and protect coastal stretches and to promote development based on scientific principles. Another Notification on Island Protection Zone(IPZ) is also being implemented for similar purposes for the island of Andaman & Nicobar and the Lakshadweep. Ministry is also implementing a World Bank Assisted Integrated Coastal Zone Management Project (ICZMP).

To protect and conserve the coastal environment the MoEF&CC has issued Coastal Regulation Zone (CRZ) Notification on 19/02/1991 under Environment (Protection) Act, 1986. Now the MoEF&CC has replaced the Coastal Regulation Zone (CRZ) Notification, 1991 with two Notifications namely;

- Coastal Regulation Zone (CRZ) Notification, 2011 issued vide S.O. No. 19 (E) dated the 6th Jan, 2011 and applicable for Mainland India and
- Islands Protection Zone Notification, 2011 issued vide S.O. No. 20 (E) dated the 6th Jan, 2011 and applicable for A&N islands and Lakshadweep.

The CRZ area has been classified as CRZ-I (ecological sensitive), CRZ-II (built-up area), CRZ-III (Rural area), CRZ-IV which includes the water areas up to the territorial waters and the tidal influenced water bodies. The National Coastal Zone Management Authority (NCZMA) at national level and CZMAs at State level have been constituted for effectively monitoring and enforcing the notification.

Under the regulatory measures, the Coastal Regulation Zone Notification, 2011 and Island Protection Zone Notification, 2011 provide, for appraisal of proposals with due consideration to protection of mangroves and also to prevent ecological imbalances and recognize, the mangrove areas as ecologically sensitive and categorize, them as Coastal Regulation Zone (CRZ)-I which implies that these areas are afforded protection of the highest order.

Also, under the Conservation of Natural Resources and Eco-systems programme, MoEF&CC is working to conserve the natural resources and eco-system in areas like, corals, mangroves, Bio-spheres, wetland and lakes.

3.2.7.1 National Centre for Sustainable Coastal Management (NCSCM)

NCSCM, Chennai is an autonomous centre of the Ministry of Environment, Forests and Climate Change, Government of India, aiming to be a world-class institution for

coastal and marine area management. The Centre is established within the Anna University Campus, Chennai.

Vision:

Promote sustainable coasts through increased partnerships, conservation practices, scientific research and knowledge management for the benefit and well being of current and future generations.

Mission and Role:

Support integrated management of coastal and marine environment for livelihood security, sustainable development and hazard risk management by enhancing:

- Knowledge
- Research and Advisory Support
- Partnerships and Network
- Coastal Community Interface

Objectives:

- Strive to become and remain a World Class knowledge institution pertaining to understanding coastal zones and coastal processes, and pertaining to integrated planning and management of coastal and marine areas.
- Promote integrated and sustainable management of the coastal and marine areas in India for the benefit and well being of the traditional coastal and island communities.
- Advise the Union and State Governments and other associated stakeholder(s) on policy and scientific matters related to ICZM.

3.2.8. Ministry of Mines

3.2.8.1 Geological Survey of India(GSI)

The GSI, established in 1851, is an attached office to the Ministry of Mines and is primarily responsible for conducting geological surveys and studies. The main functions of GSI relate to creation and updation of national geoscientific information and mineral resource assessment, including marine resources. These objectives are achieved through ground surveys, air-borne and marine surveys, mineral prospecting and investigations etc.

The Marine Wing of GSI has marine geoscientists, well equipped ocean-going research vessel and coastal launches which are capable of conducting seabed survey. It has surveyed over 95% of the 2,012 million sq km EEZ, including about 1,05,000 sq km of territorial waters of India on reconnoitory scale. The Marine Data Centre at Kolkata is a well equipped laboratory which acts as the central data bank on ocean

related geological parameters. The following services are provided by the Marine wing, GSI:

- Sea bed geological mapping with subsurface data up to 30 m depth along with preparation of geological, geophysical, geochemical and other thematic maps.
- Survey for off-shore structures like single Buoy Mooring Systems (SBM), drilling platforms, jetties, etc.
- Survey for development of ports & harbours, under-water works etc.
- Survey in the estuary and coastal areas for non-conventional energy resources.
- Pollution studies and evaluation of environmental hazards in near-coastal domains.

3.3 Institutions in Coastal Zone/Coastal Engineering

3.3.1 Indian Institute of Technology (IIT) Madras, Chennai

Department of Ocean Engineering under IIT Madras (IITM), Chennai undertakes research projects on ocean engineering and related disciplines including coastal protection works. The Department has hydrodynamic test facilities. It has successfully completed the Master Plan for Planning of Coastal protection Measures along Kerala Coast and Tamil Nadu Coast. It has also been providing design, consultancy services to the maritime States/UTs especially Tamil Nadu, Kerala, Odisha etc. for the coastal protection works.

In 2016, IIT Madras, Chennai was assigned the responsibility for the implementation of the Coastal Management Information System (CMIS) by CWC in the states of Kerala and Tamil Nadu and the UT of Puducherry.

3.3.2 National Institutes of Technology Karnataka (NITK), Surathkal

The Department of Applied Mechanics and Hydraulics under the Institute was established in 1960. It deals with academic courses on various aspects including Marine Structures and Coastal Engineering. It also offers various consultancy services to State Govt. and other organization such as MoES, MoST etc. in related field.

3.3.3 Karnataka Engineering Research Station(KERS)

The Karnataka Engineering Research Station (KERS) was established in the year 1944 and is under the administrative control of Water Resources Department of Govt. of Karnataka. The Coastal Engineering Division of KERS, investigates the cause of coastal erosion along the coastline of Karnataka and suggests remedial measures to contain coastal erosion. It also undertakes the monitoring of coastal protection projects.

3.3.4 Institute of Hydraulics and Hydrology (IHH), Poondi

The IHH is under the administrative control of the Water Resources Orgnziation of PWD , Tamil Nadu . It has facilities for conducting model studies on coastal problems, data collection etc. Field investigations and data collection on coastal changes and erosion in selected sites are done by IHH since 1978 onwards. The institute also compiles Annual Reports on Shoreline Change in the State based on the manual observations.

3.3.5 Maharashtra Engineering Research Institute (MERI), Nashik

MERI is under State Govt. of Maharashtra and it provides design solution for coastal protection works to Maharashtra Maritime Board and Public Works Department which are mandated to execute them.

3.4 State/UT Department dealing with Coastal Protection

The coastal protection works are executed through State Govt./UT agencies. The Nodal department to deal with such matter varies from the State to State. List of State/UT agencies dealing with the coastal protection works is as under.

Table 11: **State/UT Departments dealing with Coastal Protection**

S.N.	Maritime State/UT	Nodal Department dealing with Coastal Protection
1	Gujarat	Narmada, Water Resources, Water Supply and Kalpsar Department
2	Daman and Diu	Public Works Department
3	Maharashtra	Maharashtra Maritime Board and Public Works Department
4	Goa	Water Resources Department
5	Karnataka	Public Works, Ports & Inland Water Transport Department
6	Kerala	Water Resources Department
7	Tamil Nadu	Water Resources Organization under PWD
8	Puducherry	Public Works Department
9	Andhra Pradesh	Irrigation & Command Area Development
10	Odisha	Water Resources Department
11	West Bengal	Irrigation & Waterways Department
12	A&N Islands	Public Works Department
13	Lakshadweep	Public Works Department

4.0. COASTAL DATA PARAMETERS

4.1 Introduction

The availability of reliable coastal data is crucial from the following aspects:

- Economical Design of Coastal Protection Measures
- Calibration and Validation of Numerical / Physical Models
- Performance Evaluation of Coastal Protection Measures

In coastal environment, waves, tides, currents and winds are the important parameters, which need to be considered for any planning and developments. The effect of these environmental parameters varies over space and time. The knowledge of these parameters is essential in design and planning of harbor work, shore protection, maintenance of waterways and disposal of dredged spoil etc.

The parameters on which data is to be collected are grouped as follows:

4.1.1. Oceanographic Parameters

i. Waves – Height, Period, Direction

ii. Currents - Magnitude, Direction

iii. Tides - Water level at specified time interval

iv. Silt charge – Concentration, Particle size distribution

v. Bed material - Particle size, composition

vi. Salinity

vii. Water temperature

viii. Storm Surge

4.1.1.1. Waves

Information on wave climate is required for design of harbor layouts, for design of shore protection measures, estimation of sediment transport etc. Wave climate refers to the general condition of sea state at a particular location. The important wave parameters are wave height, period and direction.

The wave statistics is generally classified as a short term, long term and extreme wave statistics (*Goda, 1990*). The short term statistics deals with the statistical properties of individual waves over a short duration (about 20 minute's record). The long term statistics deals with data of about one year(total no. of significant wave heights (H_S) about 3000) while extreme value analysis deals with 30 to 50 years of storm wave data. The short term/long term wave statistics is more useful for operational condition of any structure, while extreme value statistics is applicable for design of marine

structures. The common wave data source are visually observed data, instrumentally measured data and hindcast storm wave data.

The wave climate or sources of wave data can be classified as:

- Visually observed wave data
- Measured wave data

(i) Visually observed wave data

Visually observed wave data is measured by ships which are unlikely ply through pre-warned storms. The data is recorded by visual observation and is not much accurate as the measured wave height and it is going to differ from person to person. This data is available with India Meteorological Department (IMD) and is published in Daily Weather Report.

(ii) Measured wave data

The various governments as well as non-governmental organizations are measuring the wave data in the ocean on long term basis or for a particular project for a limited duration of time by deploying Wave Rider Buoy . The quality and duration of data measured period various from site to site. This system consists of 70 or 90 cm diameter wave rider buoy and the wave recorder. The buoy transmits signals up to a distance of 50 km along the line of sight. Wave heights up to 20m and wave periods from 2 to 16 sec could be measured.

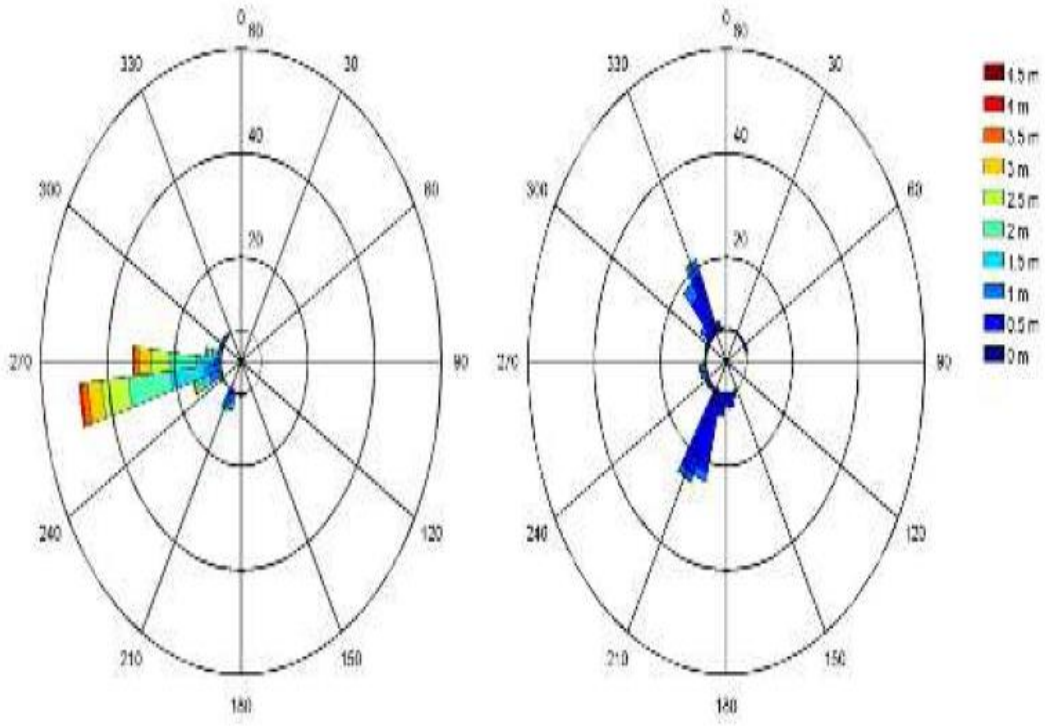

Fig. 40: Typical Wave Rose Diagram for West Coast during Monsoon & Non-Monsoon

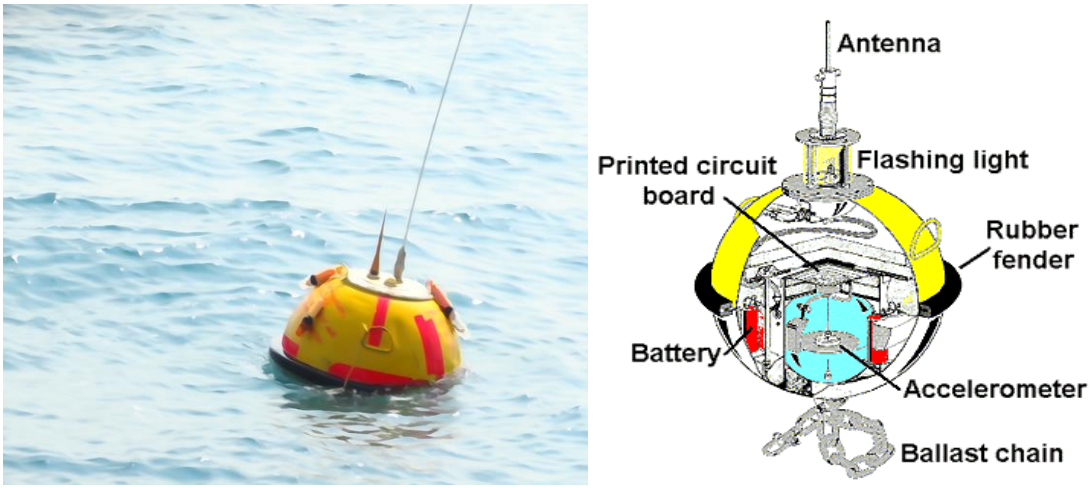

Fig 31: Wave Rider Buoy System

4.1.1.2. Currents

In coastal environment, the currents vary spatially and temporally in both magnitude and direction. Knowledge of currents is essential in assessing siltation in channels and harbour area, aligning coastal structures, in understanding geomorphologic changes taking place etc.

Fig 42: Acoustic Doppler Current Profiler (ADCP)

4.1.1.3. Tides

The rhythmic rise and fall of sea level over a period of tidal day (24 Hrs 50min) is referred as tide. The rising of water level is referred as flood tide while lowering of water level is termed as ebb tide. When the moon, sun and earth are in same line then tides produced are called spring tides, whereas when moon, sun are at quadrature to earth then tides produced are neap tides. The tides occurring in Indian Ocean are semi-diurnal means there will be two high water levels and two low water level during one tidal day.

Water level measurements recorded by gauges are to be related to an established datum such as Mean Sea Level (MSL) or Chart Datum (CD). In India, Survey of India, NHO and INCOIS are engaged in collection of data on Tides.

4.1.1.4. Silt charge

Simultaneous measurements of silt charges, currents and wave climate are essential for estimation of siltation in harbour waters and navigation channels. The silt charge can be measured by collecting water samples at various depths or by in-situ measurements by deploying a suspended solids monitor (Turbidity recorder) which after initial calibration reads silt charge directly. The concentration of suspended material is measured up to 0-5000 mg/l. The equipment uses photocell as a sensor.

4.1.1.5. Bed material

Seabed sediments in coastal areas show great spatial and temporal variation. The sediments may provide information on long-term processes and movement of materials etc. Bed surface sediments are collected with grab samples and analysed using standard laboratory procedures. The samples collected are analysed for sediment properties such as grain size, shape, density, mineralogy and heavy mineral type and content.

Coastal sediments reflect the relative importance of various source areas. Gravels and larger particles require more energy to be transported; hence they are typically found close to their source. In contrast, silt and clay once entrained may be transported long distances. Heavy minerals can provide information regarding source and process and other aspects of geomorphic variability in coastal zone.

4.1.1.6. Salinity

Salinity measurements are required in estuaries where saline and fresh water flows are mixing. The salinity measurements indicate type of mixing which is very important from siltation point of view. The salinity is measured by a salinometer or by a Salinity Temperature Depth (STD) Unit. It can also be obtained by collecting water samples and chemically analysing it. The portable salinometers are used to measures salinity in the range 0-35 ppt. The equipment uses conductivity cell as sensor. Since salinity is a function of temperature, the temperature is also measured simultaneously.

4.1.1.7. Temperature

In locating intake and outfall structures, the measurement of temperature at site is a must. Temperature profiles over vertical and along the coast are required to avoid re-circulation of hot water. The temperature measurements can be carried out by STD units.

4.1.1.8. Storm Surge

Storm surge is the abnormal rise of sea level which occurs when the cyclone moves from ocean to continent. It is a disastrous and destructive feature of cyclone, which could cause massive destruction in the coastal region and misery to the coastal human population and livestock.

The crucial inputs for preparation of vulnerability atlases are the Probable Maximum Storm Surge (PMSS) over the various coastal areas. Infrastructure development over coastal regions has to take into consideration the respective PMSS values. The "Probable maximum storm surge heights for the maritime districts of India" by *Kalsi et al, 2007* is an extensive work on computation of PMSS and the values obtained by them for the Indian coastal districts are given in Fig.38 .

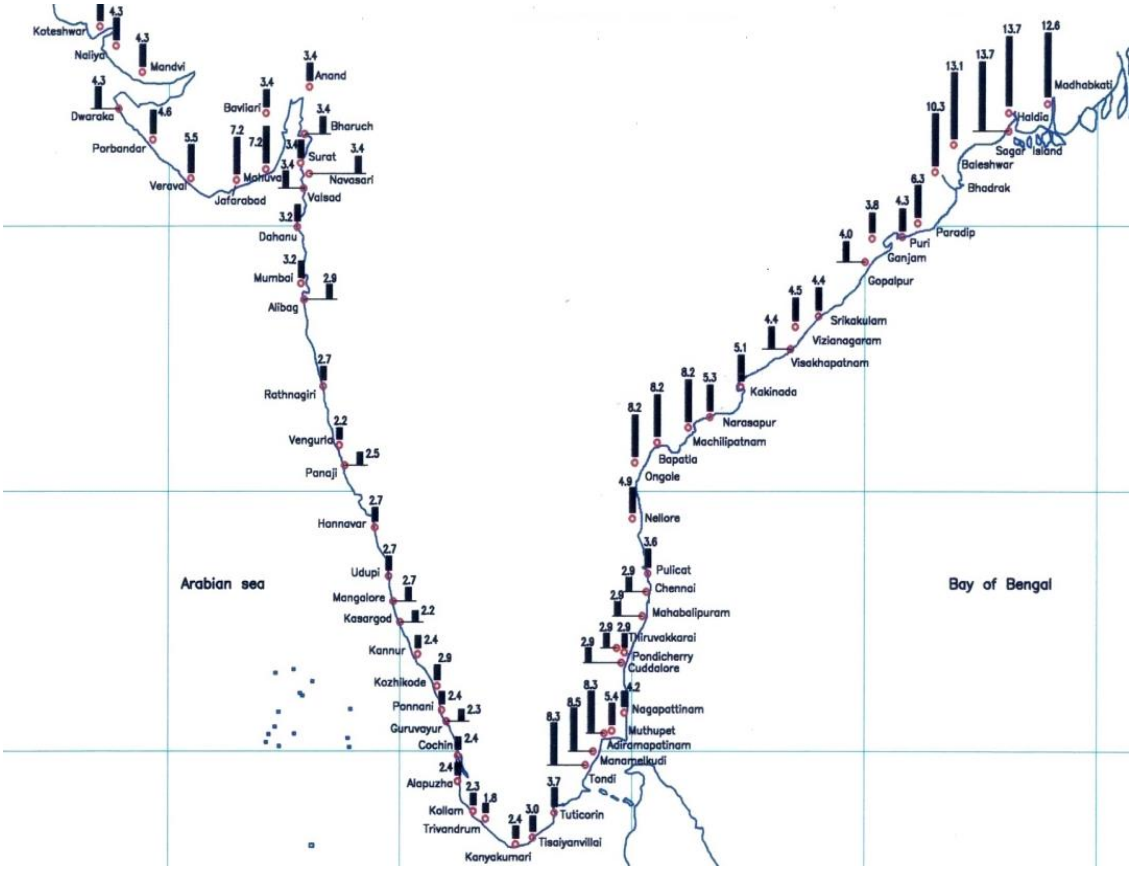

Fig.-43: Maritime District-wise PMSS Value in meters above tide level

4.1.2. Meteorological Parameters

The data on wind (speed and direction), pressure distribution, air temperature and humidity are required for the design of structures. The information on these parameters is normally available from the observations and daily weather reports published by the India Meteorological Department (IMD). The wind rose diagram gives information about percentage of occurrence of wind speed, direction as well as percentage of calm period

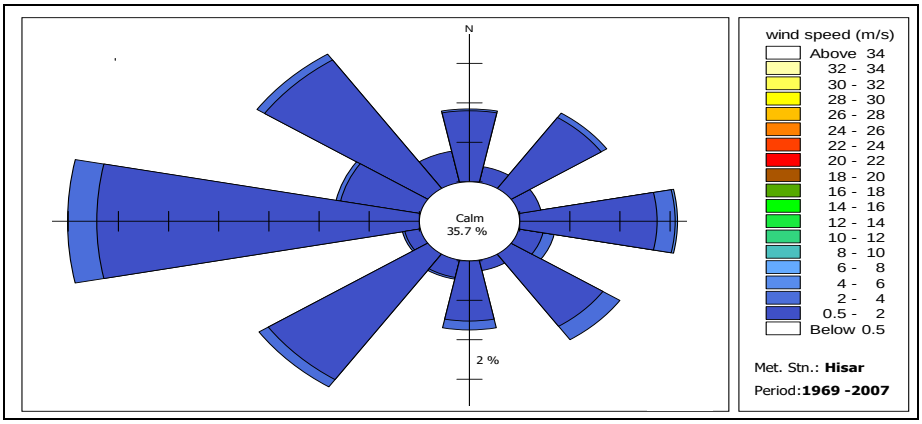

Fig.-44: Typical wind rose diagram

4.1.3. Other Parameters

4.1.3.1. Topographic and Bathymetric surveys

Topographic maps are available from Survey of India. They are available in 15 minute series with 1/50,000 scale and 7.5 minute series with 1/25,000 scale. Now a days satellite imageries are also available and very useful along with Toposheets. The bathymetric surveys are available from National Hydrographic Office, Dehradun. But many a times the resolution of these maps are inadequate for a particular project and hence bathymetric survey is required to be carried out in more details. They are carried out by Government or Private Agencies.

4.1.3.2. Geologic and Geomorphic data

Periodic topographic and nearshore bathymetric surveys constitute the most direct and accurate means of assessing geologic and geomorphic changes over modern time scale. Time series data such as repeated beach profiles; allow the assessment of erosion and accretion in the littoral zone. The preferred surveying technique involves collecting a series of shore normal profile lines. These must extend land ward of the zone that can be inundated by storms usually behind the frontal dunes. Establishment of permanent or semi-permanent benchmarks is required for doing profiles over successive months or years.

4.2 CPDAC's intitatives for Coastal Data

One of the prime functions of CPDAC is to organise a co-ordinated programme of collection, compilation, evaluation and publication of coastal data relating to various natural phenomena in coastal environments. In view of this function, the Sub-Committee of CPDAC on Coastal Data Collection, Compilation and Publication was constituted in January, 2013.

The Sub-Committee, during its first meeting, discussed and finalized the list of parameters, frequency, methodology & schedule of observations for coastal data to be collected and format for compilation of selected parameters.

The Sub-Committee finalised the measurement of the following 9 coastal data parameters for the design of Coastal Protection Structures:

a. Wave
b. Current
c. Tide
d. Riverine Data
e. Wind
f. Coastal Sediment
g. Beach Profile
h. Bathymetry
i. Shoreline Changes

a. Wave

The sub-committee accepted that Offshore Wave Data (at 20-30 m water depths) and near-shore wave data (at 5-12 m water depth) should be collected. The parameters to be collected are Wave Height, Time Period, Direction and Wave-length. It was also agreed that hourly data should be collected and such programme should be planned for 2-3 years.

b. Current

The sub-committee discussed that hourly current data (at 20-30 m water depths and at 5-12 m water depth) should be collected and such collection programme should be planned hourly for 2-3 years' time-span. It was also discussed that point data should be collected at 0.4 d (d is the depth) at 15-30 minutes time interval for Research & Development point of view, but at the same time it may increase the volume of data which may be looked from data storage, process, transfer & retrieval point of view. Therefore hourly data may serve the basic needs of data collection's objectives. In case there is requirement of data observations even having a time unit smaller than hour, it may be taken specifically R&D purpose. The same was discussed and accepted by the sub-committee.

c. Tide

It was discussed and accepted that hourly Sea Water Level should be observed for 5 years or more based on the specific project requirement. It was informed that all Major Ports are collecting Tidal data continuously.

d. Riverine Data

The sub-committee informed that daily gauge, discharge and sediment data are collected by CWC based on the type of site maintained. During Monsoon season, the hourly gauge data is collected. It was also discussed that Salinity should also be

measured wherever there is tidal influence, which is one of water quality data which would be very useful in study related to salinity ingress along the coast as well as in fresh riverine water. Thus the riverine data included gauge, discharge, sediment and salinity as per CWC standard.

e. Wind

It was discussed and accepted that Wind Speed and direction should be measured in the coastal areas. Such data collection should be done as per the IMD standards.

f. Coastal Sediments

It was proposed that Bed Load and Suspended Load should be measured up to 20 m water depth. The difficulty in carrying out such measurements at 20 m water depth was discussed at length and it was concluded that such decision can be taken only upon the requirements of project/study/research. It was also elaborated that sampling can be done at 2-3 m depth intervals across the shore. The frequency of the measurements was discussed and it was concluded that at sites where river is there, the measurement during Monsoon season can be done twice a day; once corresponding to flood tide and once corresponding to ebb tide. The beach sample should be collected both alongshore and across the shore from HTL to LTL at 50 cm depth at least. It was also discussed that Suspended Sediment Concentration data is extremely useful for understanding regional sediment dynamics and is being used as one of the input in numerical models to simulate sediment transport. Regional sediment dynamics is useful in understanding coastal processes responsible for causing shoreline changes at local level. It was also informed that Sediment Movement is maximum during the Monsoon season and use of satellite data during this time is limited due to clouds. While discussing the difficulties of measurement in surf zone, it was also stated that due to hazardous nature of surf zone direct measurement of sediment load is not possible, hence Sediment Sampler (frame) could be used in these conditions with a support of movement boat, which can provide average value over a period of 15-30 days.

g. Beach Profile

It was accepted that the beach profile is one of the important parameter required to assess the physical changes in beach over a period. It was decided that beach profile may be taken twice a year i.e. pre-monsoon (preferably in April-May) and post-monsoon (preferably in November-December). This parameter needs a long term programme for assessing the beach profile trend based on the requirements, but duration may be decided based on the objective, but a minimum of 5 years data is recommended for beach profile.

Due to dynamic nature of coast, bench marks should be established permanently and to establish the trend of beach line movement, each time during surveys these established bench marks must be covered. This parameter can sustain minimum of 5 years and the spatial frequency should be such that any abrupt changes in the profiles must be covered during survey. It was accepted that for long sandy beaches

undergoing erosion, the profile should be done along three lines i.e. both extremes i.e. (HTL & LTL) and in the mid position preferably at 50 m interval along the beach.

h. Bathymetry

The Sub-Committee accepted that the collection of Bathymetry data and its resolution should be based on the requirements of the objective and accordingly it may be carried out. Echo sounders work at depth more than 4 m and for measurements of bottom variation in 0-4 m water depth, Sled can be used which can be pulled across the surf zone for carrying out the measurement of water depth manually.

i. Shoreline Change

It was discussed that the Shoreline Change Atlas of Indian Atlas should be updated at every 5 years, with the first update to be done for the time-frame 2012-13. It was also deliberated that higher resolution maps (preferably 1:10,000) should be prepared for specific sites which are identified as hot-spots (great erosion prone). The Sub-Committee also decided that first of all identification of critical coastal line (erosion prone) may be carried out based on Shoreline Change Atlas, and accordingly new sites as well as establishment of new sites for coastal data collection may be done. While finalising the new sites, sediment cell approach may be given due consideration in addition to Shoreline changes detected based on remote sensing technology.

The Sub-committee also discussed and accepted the formats for compilation of Wave, current and Tidal Data compilation. The Sub-Committee also discussed and identified the Lead Agencies for various activities in respect of coastal data collection/protection.

Table 12: Lead Agencies for coastal data collection

Data	Lead Agency
Oceanographic Data	NIO, Goa (in association with INCOIS, NIOT etc.)
Tidal Data	Survey of India (in association with INCOIS, NIOT)
Meteorological Data (Wind)	IMD
Beach Profiling	Respective State Agencies
Coastal Sediment	GSI
Bathymetry	NHO, Port Organization
Shoreline Change	SAC, Ahmedabad
Riverine Data	CWC
Design/Modelling of Coastal Protection	CW&PRS in association with NIOT, ICMAM-PD, CESS etc.

4.2.1. Coastal data collection under Coastal Management Information System (CMIS)

Considering the importance of collection of data on coastal processes relevant for evolving long term plans and coastal protection measures, a new component in the 12th Five Year Plan (Period 2012-17) for the establishment of Coastal Management Information System (CMIS) has been approved by the GoI under the Plan Scheme of MoWR, RD&GR namely "Development of Water Resource information System (DWRIS)". For the implementation of CMIS, suitable vulnerable coastal site would be selected for the collection of coastal data parameters. The parameters to be observed and their frequency, duration etc. as accepted by Coastal Protection and Development Advisory Committee (CPDAC) is given in table below:

Table 13: Coastal data to be collected for CMIS as accepted by CPDAC

S.N	Data-type	Location	Span	Parameter	Frequency
1	Wave	Offshore Wave Data (at 20-30m water depths) & Near-shore wave data (at 5-12 m water depth)	2-3 years	Wave Height, Time period, Direction & Wave Length	Hourly Data
2	Current	Same as above	Same as above	Velocity	Same as above or at 15-30 minutes
3	Tide	n/a	5 years or more	Water Level	Hourly Data
4	Riverine Data	As per CWC Standards		Gauge, Discharge, Sediment, Salinity	As per CWC Standards
5	Wind	As per IMD Standards	As per IMD Standards	Wind Speed & Direction	As per IMD Standards
6	Coastal Sediment	Project Specific (Max. up to 20m depth)	Project Specific	Bed Load & Suspended load	At each 2-3 m depth intervals
7	Beach Profile	Eroding Stretches Along three lines (HTL, LTL and midway)	Project Specific (min 5 years)		Twice Pre-monsoon & Post-monsoon
8	Bathymetry	Project Specific	Project Specific		Project Specific

9	Shoreline Change				Needs to be updated at every 5 years

4.3 Coastal Data Collection Programmes

Details of some of the past data collection initiatives by various institutes under different programmes is given below:

4.3.1 NCESS (erstwhile CESS), Kerala

The Centre for Earth Science Studies, Thiruvananthapuram (now NCESS under MoES) has collected nearshore wave, current, beach data under different study programmes. Numerical model studies on coastal processes are being undertaken with the above data in addition to various studies on coastal processes, coastal erosion and coastal protection measures. The major initiatives undertaken by CESS in the past are given below:

1. **Spot observation at Thiruvananthapuram, Alappuzha, Kozhikode and Thalassery** (under institutional programme)**:**

   - Waves (at 3.5 to 5 m depth): Analogue records using pressure gauge – non directional during 1980-85 (period & height); Wave rider buoy observations (analogue records – period, height & direction) at Vizhinjam, Trivandrum for 8 months
   - Breakers: Observations from pier - Manual
   - Surf zone width: Observations from pier - Manual
   - Longshore currents: Observations using floats – Manual methods
   - Beach profiles: 1 km stretch at Thiruvananthapuram, Alappuzha, Kozhikode and Thalassery on either side of pier – using dumpy level & staff
   - Sediment characteristics: Size distribution – Observation stations at Thiruvananthapuram, Alappuzha, Kozhikode and Thalassery

2. **Data along Neendakara- Kayamkulam coastal zone during 1999-2001** (Under IREL sponsored programme in collaboration with ASR Ltd, New Zealand)

   Detailed observations at different locations in the nearshore of waves, currents, beach characteristics & sediments during 1999-2001.

   - Waves using Dobie wave gauge (period, height), Wave rider buoy (period, height & direction)
   - Currents using, S4 current meter, ADP, FSI current meter

- Breaker characteristic: Manual – visual observations
- Longshore currents: Floats (manual)
- Sediment (nearshore) characteristics: Sediment traps, Hydrocamel sediment sampler
- Sediment (beach): Sediment samples along beach profile
- Bathymetry: Nearshore bathymetry including that of surf zone (Echosounder and sled profiles)

3. **Data off Muthalapozhi and Kayamkulam harbor during 2002-03**
(Under DST sponsored project)

- Wave data: Off Kyamkulam harbor at a depth of 8 m seasonally for 3 weeks in each season
- Current data: Off Kyamkulam harbor at a depth of 8 m seasonally for 3 weeks in each season
- Beach data (Kayamkulam): 15 km stretch of coast flanking the harbor on monthly basis in the year 2002
- Beach data (Muthalapozhi): 10 km stretch of coast flanking the harbor on monthly basis from Jan to May 2003

4. **Nearshore wave, current and beach observations during 2002-07**
(Under MoES-ICMAM programmes)

- Limited nearshore wave and current observations (2 weeks) during 2004-05 off Poonthura, Thiruvananthapuram
- Nearshore waves and currents for premonsoon, monsoon & post monsoon seasons for 1 year at selected locations between Kayamkulam and Munambam using Valeport pressure wave gauges and RCM current meters, ADP.
- Shoreline mapping using GPS
- Beach profiles at selected locations
- Sediment characteristics at profiling stations
- Nearshore bathymetry using echosounders

5. **Nearshore wave, current and beach observations during 2007-11**
(Under MoES-ICMAM programmes)

- Nearshore waves and currents for premonsoon, monsoon & post monsoon seasons for 1 year at selected locations between Veli-Varkala, Munambam-Chettuwa and Beypore-Elathur using Valeport pressure wave gauges and RCM current meters, ADP.
- Shoreline mapping using GPS along Veli-Varkala, Munambam-Chettuwa and Beypore-Elathur
- Beach profiles at selected locations along Veli-Varkala, Munambam-Chettuwa and Beypore-Elathur

- Sediment characteristics at profiling stations along Veli-Varkala, Munambam-Chettuwa and Beypore-Elathur
- Nearshore bathymetry using echosounders off Veli-Varkala, Munambam-Chettuwa and Beypore-Elathur

6. Long term wave observations
(MoES-INCOIS programme being implemented by CESS along the Kerala coast)

- Initiated in October 2011 with a Wave Rider Buoy for Thiruvananthapuram – Kollam coastal waters: Observations at 30 m depth.

4.3.2 NIO Goa (CSIR, MoST)

NIO, Goa has established an Integrated Coastal Observation Network (ICON) of in-house designed and developed Internet-accessible real/near-real time reporting cellular based sea-level, sea-state, and surface meteorological (Met) stations at several locations on the Indian coasts and Islands.

Table 14: Real-time data collection (by NIO, Goa)

Location	Weather Stations	Sea Level Gauges	Wave Rider Buoys
West Coast	Ratnagiri, Maharashtra	Ratnagiri , Maharashtra	Ratnagiri , Maharashtra
	Dona Paula, Goa	Dona Paula Radar Gauge, Goa	Okha, Gujarat
	Karwar, Karnataka	Karwar Radar Gauge, Karnataka	Karwar, Karnataka
	Trivandrum, Kerala		
East Coast	Gopalpur, Odisha	Gangavaram Radar Gauge, Andhra Pradesh	Gopalpur, Odisha
	Paradip, Odisha	Kakinada Radar Gauge, Andhra Pradesh	Vizag, Andhra Pradesh
	Vizag, Andhra Pradesh	Machilipatnam Radar Gauge, Andhra Pradesh	Pondicherry, UT of Pondicherry
	Gangavaram, Andhra Pradesh	Tuticorin Radar Gauge, Tamil Nadu	Tuticorin, Tamil Nadu
	Kakinada, Andhra Pradesh		

	Pondicherry, UT of Pondicherry		
	Tuticorin, Tamil Nadu		
Islands	Kavaratti, UT of Lakshadweep	Kavaratti Radar Gauge, UT of Lakshadweep	
	Port Blair, Andaman & Nicobar	Port Blair Radar Gauge, Andaman & Nicobar	

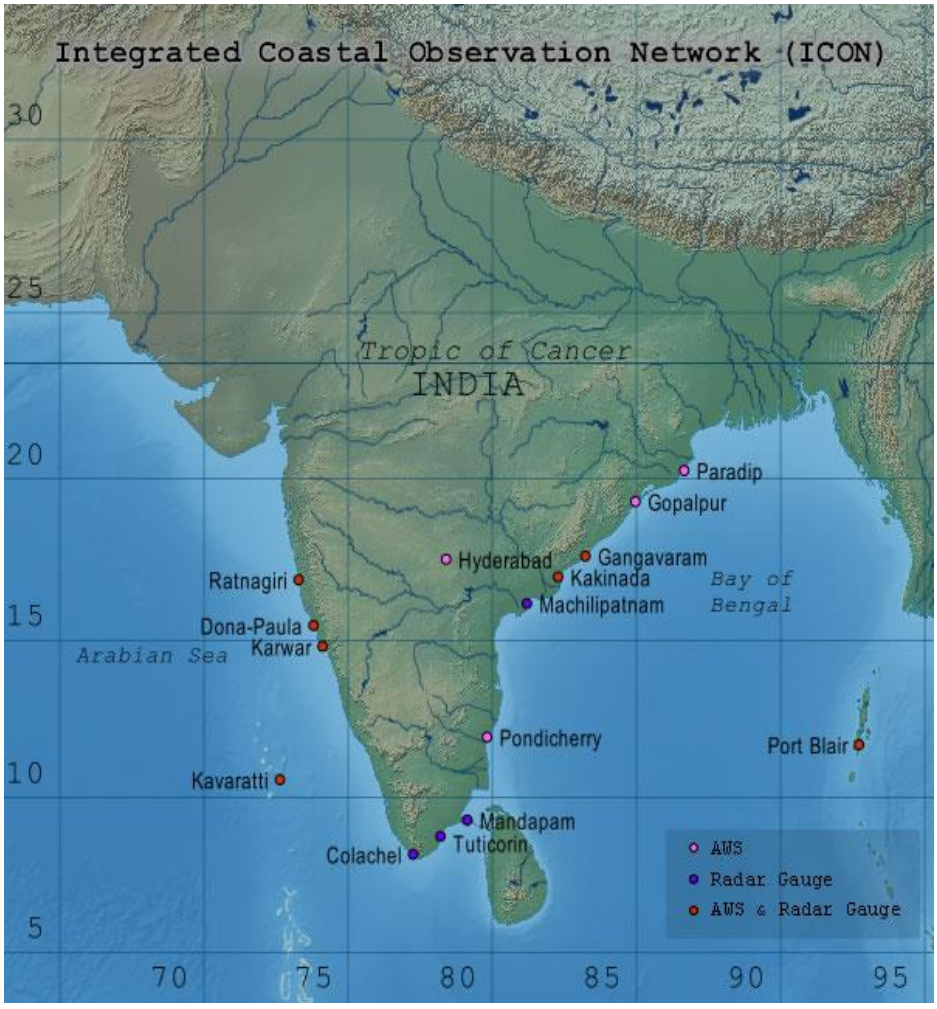

Fig 45: Integrated Coastal Observation Network (NIO, Goa)

4.3.3 Institute of Hydraulics and Hydrology (IHH), Poondi (Tamil Nadu)

In Tamil Nadu, total 39 sited were identified for observation of coastal behaviour of which 32 sites are situated on the East Coast and balance 7 sites on the West Coast. The

length of each site varies from 500 m to 7 km and total length covered under all the sites is about 90 km throughout the state. The manual observations on Coastline changes are conducted twice i.e. on Full Moon day and New Moon (No moon) day and monthly and annual reports are recorded in IHH, Poondi and the same are sent to the CW&PRS for records.

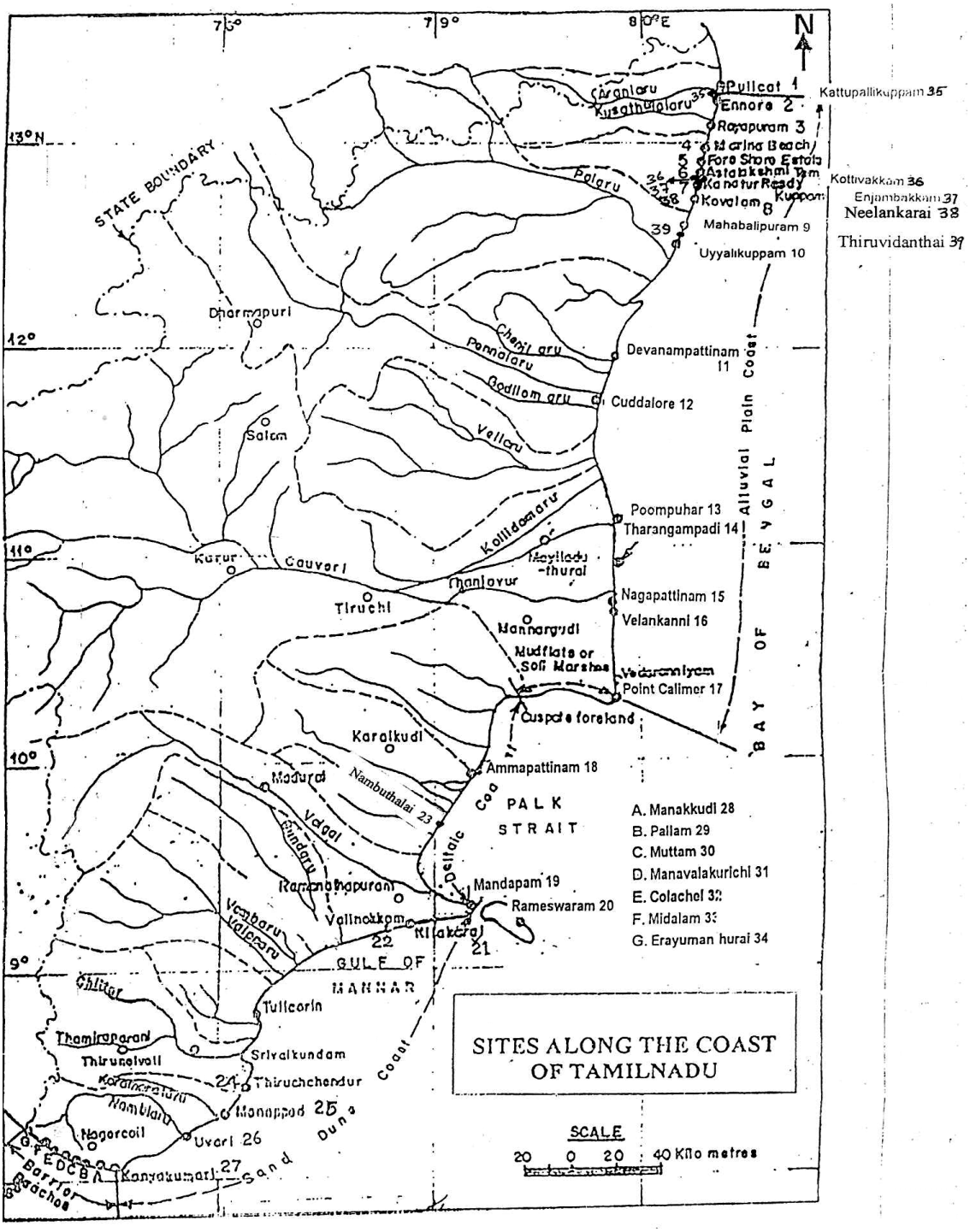

Fig. 46: Data Collection sites along Tamil Nadu Coast

4.3.4 Data Compilation/collection by CW&PRS (Pune)

Based on the decision taken in the 1st CPDAC meeting, a National Coastal Data Bank (NCDB) was established at CW&PRS, Pune and data in respect of various erosion sites were collected, digitized and stored in the same. Additionally CW&PRS is also engaged in providing consultancy services to various projects in coastal sector eg. Port etc. CW&PRS has reported that short period data were received from following states.

Table 15: Coastal Data Inventory at CW&PRS, Pune

S. No.	State	Received from	Period	Data For	Contents
1	Kerala	KERI, Peechi in June, 2007	2001-2005	Kerala Coast	Beach Width
2	Tamil Nadu	IHH, Poondi in March,2008	2004-2006	Tamil Nadu Coast	Beach Width (Monthly)
3	Gujarat	CDO, Gandhinagar in July, 2008	Site Specific	Sites of Nargol, Tithal, Survada, Magod Dugri	Tide, Current, Wave Height, Bed Slope and beach profile etc.
4	Karnataka	KERS, Bangalore in August, 2007	2005-06	Uttara Kannada, Dakshina Kannada & Udupi	Monitoring of Coastal Protection after monsoon in 2005-2006
5	Maharashtra	MMB	Site Specific	More than 50 sites	Beach profiles, tide, wave etc.
6	Goa	PWD	Site Specific	More than 10 sites	Beach profiles, tide, wave etc.

4.3.5 Ministry of Earth Sciences (MoES)- ESSO

MoES has provided details to CWC regarding the coastal data information collected by the ESSO-MoES as on July, 2014. The details fo the coastal data collected by the organizations under ESSO-MoES is given in **Annexure-I**.

4.3.6 Ministry of Environment Forest and Climate Change (MoEF&CC)

Under World Bank aided Integrated Coastal Zone Management Project (ICZMP) in Odisha, coastal data has been collected. Inventory of the same is summarized in **Annexure-II.**

5.0. COASTAL PROTECTION & DEVELOPMENT PROJECTS

5.1. Past initiatives

5.1.1 Assistance from the GOI

The Govt. of India had been providing Central Loan Assistance to the Kerala State for anti-sea erosion works since 1970-71. The amount provided till March, 1992 was around Rs. 52 crore. During the year 1991-92, an amount of Rs. 0.93 crore was also provided to Govt. of Karnataka. The Central Loan Assistance was discontinued beyond 1991-92 as a process of decentralisation as per the decision taken in the 43rd meeting of National Development Council held in December, 1991. During 1995, the Govt. of Kerala submitted a proposal for special Central Assistance for urgent anti sea erosion works. The Govt. of India sanctioned Rs. 3.00 crore, as special Central Assistance, as one time measure for completing anti-sea erosion works in Kerala by June, 1996.

5.1.2 National Coastal Protection Project (NCPP)

With the discontinuation of Central Loan Assistance, the State Govts/Union Territories started facing financial difficulties in funding the anti-sea erosion works. The beach protection works suffered serious setback due to paucity of funds with the State Govts. The State Govts. approached the Govt. of India for locating source of funding for anti-sea erosion works. Realizing the setback received in the progress of coastal protection works in the maritime States, the Beach Erosion Board, in its 23rd meeting, held in July, 1994, requested the maritime States to formulate the proposals for protection of coastal reaches from sea erosion at vulnerable reaches in their respective states and send the proposals to Central Water Commission who will coordinate and prepare a consolidated National Coastal Protection Project (NCPP) based on their proposals, for posing the same for external Assistance.

5.1.3 Assistance from GoI under X Plan

A Centrally Sponsored Scheme, "Critical anti-erosion works in coastal and other than Ganga basin States", estimated to cost Rs. 20.64 crore, for implementation during X Plan, was approved in March 2004. The proposals of the States of Karnataka, Kerala, Maharashtra, Orissa, Pondicherry, Tamil Nadu, pilot project on beach nourishment and preparation of Coastal Atlas were included in the scheme. The scheme was later transferred to State Sector under the Central Plan.

Subsequently, the scheme was revised to Rs. 46.17 crore in November, 2006 in view of the inclusion of the anti erosion scheme, "Drainage improvement and enhancing flood channel capacity at critical reaches of Jhelum, Chenab and Tawi rivers in J & K (estimated cost –Rs. 23 crore)" in the above State Sector Scheme.

The estimated cost of the anti sea erosion scheme of Karnataka State was increased from Rs. 3.21 crore to Rs. 5.74 crore, thereby, enhancing the total cost of the scheme by Rs. 2.53 crore. Out of total estimated cost of Rs. 46.17 crore, the central share is Rs. 38.57 crore and State share is Rs. 7.60 crore. Central share of Rs. 33.87 crore have been released up to March 2009. The above scheme was subsumed in the "Flood Management Programme" for implementation during XI Plan

5.1.4 Flood Management Programme (under XI & XII Plans)

Specific anti-sea erosion problems are now being addressed under State Sector – Flood Management Programme of MoWR, RD&GR. The state Govt. of Gujarat submitted the proposals amounting to about Rs. 85.00 crore for undertaking anit-sea erosion works under FMP. During the XI plan, Central Assistance Rs. 200.00 lakh was released to State Govt. of Gujarat in FY-2010-11 for undertaking the coastal protection work from Sangam Narayan temple to Gayatri Mandir at Dwarka , Dist. Jamnagar.

5.1.5 Recommendation of the Finance Commission

The 12th Finance Commission recommended Rs. 175 crore to Kerala and Rs. 50 crore to Tamil Nadu for undertaking Coastal Protection Works. Summary of the financial recommendation made by 13th Finance commission for coastal areas is as under.

Table 16: 13th Finance Commission Recommendation for Coastal Areas

State	Activity	Amount
Gujarat	To address the problem of 10.69 lakh hectares of land in more than 600 coastal villages which have been affected due to ingress of salinity. To tackle the menace of coastal erosion Rs.150 crore, faced by about 450 fishing villages	Rs.150 crore Rs.150 crore
Maharashtra	For taking up 110 anti-sea erosion bund works in six districts	Rs. 205 crore
Tamil Nadu	To protect the long coastline of the state Rs.200 crore from sea erosion	Rs. 200 crore

Source: 13th Finance Commission Report

5.2. On-going initiatives under the MoWR, RD&GR

5.2.1. Sustainable Coastal Protection and Management Investment Programme (SCPMIP)

Though coastal protection is planned and executed by the State Govts, MoWR, RD&GR considering the severity of erosion in some areas, initiated the collection of details/information with a view to explore the formulation of National Coastal Protection Project (NCPP) and taking up the same for external assistance. After discussion between GoI and Asian Development Bank (ADB) for funding on coastal protection works, ADB approved grant for Project Preparatory Technical

Assistance (PPTA). The PPTA was used to prepare an investment programme for Sustainable Coastal Protection and Management Project in the States of Goa, Maharashtra and Karnataka. Under PPTA, an investment programme estimating to $404.6 Million including ADB loan of $250 Million was signed between the GoI and the ADB. Loan from ADB to states will be in the form of back-to-back loan (multiple tranches). After loan negotiation, the multi-tranche facility (MFF) for project was approved by ADB in September, 2010 for amount of 250 Million USD to be implemented over a period of 8 years. The Terms of Reference (ToR) of PPTA also included preparation of one or two projects in each participating state for immediate implementation based on state's priority. Mirya Bay (Maharashtra), Coco and Colva Beach (Goa) and Ullal (Karnataka) projects were selected for implementation in first tranche and Feasibility Study and Design report for these projects were completed under PPTA. However, Goa was not included under Tranche-1 as State Govt. of Goa did not pursue the TAC approval for its projects.

Further to above, the Government of India and the Asian Development Bank (ADB) signed an agreement for the first tranche ($51.555 Million loan - LN-2679-IND) under the $250 Million Sustainable Coastal Protection and Management Investment Programme on 17.08.2011. The first tranche loan will focus on heavily eroded coast in Karnataka (Ullal) and Maharashtra (Mirya Bay). Under the Tranche-1 of SCPMIP, two projects namely **Ullal Coastal Erosion & Inlet Improvement Project in Karnataka** and **Mirya Bay Coastal Erosion and Protection Project in Maharashtra** are under implementation with loan from ADB.

The Ullal Coastal Erosion and Inlet Improvement Project (Karnataka) propose a hybrid solution, comprising of several components like Beach nourishment, two offshore reefs, near shore berms etc. Two submerged offshore reefs are being constructed to dissipate incoming wave energy and stabilize the beach nourishment placed on shore.

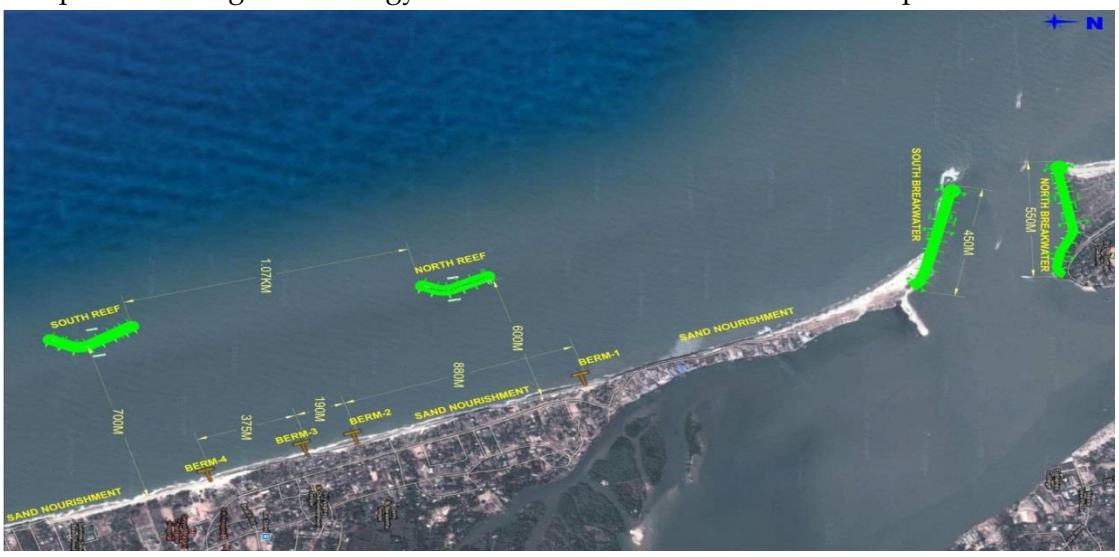

Fig 47: Layout of Tranche-1 sub-project at Ullal (Karnataka)

Under **Mirya Bay Coastal Erosion and Protection Project in Maharashtra,** it is envisaged to construct offshore submerged cup shaped Geotextile Reef at Mirya bay and carrying out Beach Nourishment in the Northern side of the Bay. The proposed

submerged head land "Cup Reef' will break wave energy and protect the most critical northern part of the bay. The reef is to be constructed of sand filled geotextile containers. The individual container units will be oriented in a shore perpendicular fashion.

Fig 47: Coastal erosion problem in Mirya Bay (Maharashtra)

Fig 48: Solution to tackle erosion problem in Mirya Bay

The summarized details of the financing and the output aspects of the Tranche-1 of SCPMIP is given in table below:

Table 17: SCPMIP Tranche-1: Outputs and Financing details

Sl No.	Outputs	Sub-outputs
1	Sustainable Plan and Management for Shoreline	Shoreline Management Plans (**SMP**)
		State specific Coastal Management Information System(**CMIS**)
		Planning and Design of protection projects
2	Reduction of Coastal Erosion , salinity and instability	Implementation of projects
3	Capacity/Institution Development	**PMU** under State Executing Agency (SEA)
		Coastal Information Management Unit (**CIMU**)

Amount in Million $

State	ADB Loan	State's Contribution	Other/ Pvt. Sector	Total
Maharashtra	96.03	51.2	16.23	163.46
Goa	27.07	13.69	2.3	43.06
Karnataka	126.9	54.94	16.3	198.14
Total	**250**	119.83	34.83	**404.6**

Total Financing

First Tranche

State	ADB Loan	State's Contribution	Total
Maharashtra	10.535	3.59	14.125
Karnataka	41.02	7.53	48.55
Total	**51.555**	11.12	62.675

Under the Tranche-2 of SCPMIP in Karnataka, the Detailed Project Report (DPR) at estimated cost of **Rs. 379.04 crore** was considered and accepted by the Advisory Committee of MoWR, RD&GR on Major & Medium Irrigation, Flood Control and, Multi-purpose project proposals in its 129th Meeting held in New Delhi on 08.07.2016. The Tranche-2 of SCPMIP in Karnataka has 6 sub-project and 2 community protection sub-projects.

The protection measures proposed for Tranche - II subprojects include the following:

a) Offshore reef
b) Rock revetments
c) Sand-filled geotextile bag revetment
d) Groynes with beach nourishment
e) Beach Nourishment
f) Sand bypassing
g) Dune stabilization through planting

5.2.2. Climate Resilient Coastal Protection and Management Project (CRCP&MP)

During the year 2014, an agreement was signed by the GoI with ADB for Technical Assistance (TA) programme namely TA 8652-IND: Climate Resilient Coastal Protection and Management Project (CRCP&MP) to support mainstreaming of climate change consideration into coastal protection and management at the national level and in the two focal states (of Karnataka and Maharashtra) where the Sustainable Coastal Protection and Management Investment Programme (SCP&MIP) is already operational under external assistance from ADB. This TA is being financed by grant amounting to **Two Million USD ($)** from Global Environment Facility (GEF) & administered by Asian Development Bank (ADB). The MoWR, RD&GR is the Executing Agency. Four components are proposed for the CRCP&MP. Components two, three and four link to the components of the baseline project (SCPMIP); component 1 is a new additional component. Component 1 & 4 are focused on National Level whereas the component 3 & 4 are specific to focal states only. Following table shows the 4 components under the CRCP&MP:

Table 18: Components of CRCP&MP

Component 1	Analysis of Climate Change Impacts in Coastal Areas and Preparation **of Guidelines for Climate Change Adaptation for the Indian coast.**
Component 2	Climate Resilient Shoreline Planning and Management in Two Focal States
Component 3	Climate Resilient Coastal Investments in Two Focal States
Component 4	Institutional Strengthening, Capacity Building and Enhanced Awareness for Climate Resilient Coastal Protection and Management.

National component are being Implemented through CW&PRS whereas State specific components are being implemented through the concerned State Govt. Three specific studies have been given to National research institutes for analyzing the Climate Change Impacts in Coastal Areas. The details are given below:

Table 19: Studies assigned to the institutes under CRCP&MP

National research institutes	Climate Change Impact study
National Institute of Oceanography (NIO), Goa	Sea Level Rise, Wave
Indian Institute of Technology (IIT), Delhi	Storm Surge
Indian Institute of Technology (IIT), Bombay	Wind, Precipitation, Sea Level Pressure

5.2.3. Coastal Management Information System (CMIS)

For proper Coastal Protection, understanding of various coastal processes and cause of erosion need to be identified first. Vast set of data on Sediment transport, wave, tides, bathymetry, geological data, satellite imageries etc. is required to analyze the problem. Hence, need for a comprehensive Coastal Management Information System (CMIS) is keenly felt. It should have all the consolidated coastal data on national level, including updated shoreline, effects of climate change, already protected areas, vulnerable areas, geological /geomorphological characteristics of shoreline etc.

Considering the importance of collection of data on coastal processes relevant for evolving plans towards coastal protection measures, a new component in the XII-Plan (2012-17) period for creation of "Coastal Management Information System (CMIS)" has been approved by Govt. of India under the Plan Scheme "Development of Water Resources Information System (DWRIS)", which is to be implemented by CWC. In this regard, it is proposed to set up sites along the coast of the maritime states/UTs of India for collecting data of relevant coastal processes.

Objectives of CMIS:-

- To create an integrated data bank to tackle coastal erosion in a scientific manner keeping in view the long-term perspective and
- Collection of data on coastal processes relevant for evolving long term plans and coastal protection measures.

In this regard, it is proposed to set up sites along the coast of the maritime states/UTs of India for collecting data of relevance in this regard. The prime objective of CMIS is to collect near shore parameters which will be used in the design, construction and maintenance of site specific coastal protection structures. Integration of relevant data into India-WRIS (Water Resources Information System) portal is also included under this activity.

The preferred implementation model for CMIS was decided to be through signing of a Memorandum of Understanding (MoU) by CWC with the concerned expert agencies and respective maritime States/UTs wherein, CWC would be the 'Project Implementer', the expert agency as the 'Project Executor' and the concerned State/ UT Government would be the 'Project Facilitator'.

Consequently in 2016, the IIT Madras Chennai has been assigned the responsibility of execution of CMIS in the states of Kerala, Tamil Nadu & UT of Puducherry through tri-partite MoU. Similar exercise is likely to come up with National Institute of Oceanography **(NIO) Goa** etc. for implementation of CMIS in the state of Goa and states/UTs.

5.3. On-going initiatives under other Ministries

5.3.1. Coastal Regulation Zone (CRZ) – MoEF&CC

The Coastal Regulation Zone (CRZ) Notification was issued by the MoEF&CC on February 19, 1991, under the Environment (Protection) Act, 1986, with the aim to provide comprehensive measures for the protection and conservation of the coastal environment. In view of the requests made by various State Governments, Central Ministries, NGOs etc, the original Notification has been amended several times. Relevant Office orders have also been issued by MoEF&CC from time to time clarifying certain provisions. The recent CRZ Notification of 2011 is a consolidation of the changes made to the 1991 Notification.

The recent CRZ Notification (2011) aims at the following:

- To ensure livelihood security to the fishing communities and other local communities living in the coastal areas;
- To conserve and protect coastal stretches, its unique environment and its marine area, and;
- To promote development in a sustainable manner based on scientific principles taking into account the dangers of natural hazards in the coastal areas and sea level rise due to global warming.

The jurisdiction of the CRZ Notification is:-

a. 500 m from HTL to 12 nautical mile (limit of territorial waters)
b. Land area between HTL and Low Tide Line (LTL)
c. 100 m (or width of creek) from HTL on landward side along tidal-influenced water body and the distance upto which the tidal effects are experienced which shall be determined based on salinity concentration of 5 parts per thousand measured during in driest period of the year.
d. The landward side of the hazard line even beyond 500/100 m.

The 2011 Notification restricts the setting up and expansion of any industry, operations or processes and manufacture or handling or storage or disposal of hazardous substances in the CRZ area. For the purpose of conserving and protecting the coastal areas and marine waters, the CRZ area is classified as follows:

1. CRZ-I

It includes the ecologically sensitive areas and the geomorphological features that play a primary role in maintaining the integrity of the coast such as mangroves, coral reefs and associated biodiversity, sand dunes, mudflats which are biologically active; national parks, marine parks, sanctuaries, reserve forests, wildlife habitats and other protected areas under the provisions of Wild Life (Protection) Act, 1972 (53 of 1972), the Forest (Conservation) Act, 1980 (69 of 1980) or Environment (Protection) Act, 1986

(29 of 1986) including biosphere reserves encompassing salt marshes, turtle nesting grounds, horse shoe crabs habitats, sea grass beds, nesting grounds of birds; areas or structures of archaeological importance and heritage sites; and, the area between Low Tide Line (LTL) and High Tide Line (HTL) i.e. the inter-tidal zone.

2. CRZ-II

It includes the areas which are developed upto or close to the shoreline and falling within municipal limits.

3. CRZ-III

It includes the areas that are relatively undisturbed and those do not belong to either CRZ-I or II which include coastal zone in the rural areas (developed and undeveloped) and also areas within municipal limits or in other legally designated urban areas, which are not substantially built up.

4. CRZ-IV

It includes (a) the water area from LTL to the limit of territorial waters of India (12 nautical miles on the seaward side), and (b) the water area of the tidal influenced water body from the mouth of the water body at the sea to the distance upto which the tidal effects are experienced which shall be determined based on salinity concentration of five parts per thousand (ppt) measured during the driest period of the year (here the term 'tidal influenced water bodies' implies the water bodies influenced by tidal effects from sea, in the bays, estuaries, rivers, creeks, backwaters, lagoons, ponds connected to the sea or creeks and the like).

5. Areas requiring special consideration for the purpose of protecting the critical coastal environment and difficulties faced by local communities:

(a) (i) CRZ area falling within municipal limits of Greater Mumbai;

(ii) the CRZ areas of Kerala including the backwaters and backwater islands;

(iii) CRZ areas of Goa.

(b) Critically Vulnerable Coastal Areas (CVCA) such as Sunderbans region of West Bengal and other ecologically sensitive areas identified as under Environment (Protection) Act, 1986 and managed with the involvement of coastal communities including fisher folk.

A separate Island Protection Zone (IPZ) Notification (2011) has also been issued for protection of the islands of Andaman & Nicobar, and Lakshadweep under Environment (Protection) Act, 1986.

Jurisdiction of the Island Protection Zone Notification 2011:

The IPZ Notification covers the entire islands of A and N (except for four large islands) and Lakshadweep and the coastal waters upto territorial limits. For

conserving and managing the fragile environment of the islands and protecting the island communities from hazards emerging from the sea, the Notification prescribes preparation of Integrated Island Management Plan (IIMPs) for each of the islands. The IIMPs shall take into consideration the ESAs such as mangroves; coral reefs; sand Beaches and Sand Dunes; mudflats; protected areas under the Wild Life (Protection) Act, 1972 (53 of I972), the Forest (Conservation) Act, l98O (69 of T980) or Environment (Protection) Act, T986 (29 of I986); salt Marshes; turtle nesting grounds; horse shoe crabs habitats; sea grass beds; sea weed beds; nesting grounds of birds; fishing villages and areas of traditional rights and the area between Low Tide Line and High Tide Line. Further the built up areas including the proposed settlement areas are to be indicated in the IIMPs. The undisturbed rural areas which have potential for tourism facilities and other infrastructure as permitted in the Notification are to be indicated in the IIMP.

The CRZ notification brings out the activities permissible under the above mentioned classes. Besides a detailed list of prohibited activities within CRZ, the following are declared as prohibited activities within the CRZ pertaining to water resources etc.:

(a) Land reclamation, bunding or disturbing the natural course of seawater except those:
- required for setting up, construction or modernisation or expansion of foreshore facilities like ports, harbours, jetties, wharves, quays, slipways, bridges, sealink, road on stilts, and such as meant for defence and security purpose and for other facilities that are essential for activities permissible under the notification;
- Measures for control of erosion, based on scientific including Environmental Impact Assessment (EIA) studies
- Maintenance or clearing of waterways, channels and ports, based on EIA studies;
- Measures to prevent sand bars, installation of tidal regulators, laying of storm water drains or for structures for prevention of salinity ingress and freshwater recharge based on studies carried out by any agency to be specified by MoEF&CC.

(b) Mining of sand, rocks and other sub-strata materials except,
- Those rare minerals not available outside the CRZ area,
- Exploration and exploitation of Oil and Natural Gas.

(c) Withdrawal of groundwater and construction related thereto, within 200 m of HTL; except the following:
- In the areas which are inhabited by the local communities and only for their use.
- In the area between 200-500 m zone, withdrawal of groundwater shall be permitted only when done manually through ordinary wells for drinking, horticulture, agriculture and fisheries and where no other source of water is available. Restrictions for such withdrawals may be imposed by the

authority designated by the State Government and Union territory Administration in the areas affected by sea water intrusion.

5.3.2. Integrated Coastal Zone Management Project (ICZMP)-MoEF&CC

To assist the MoEF&CC to implement the various provisions of the CRZ Notification and IPZ Notification, 2011 which include hazard line mapping, conservation and protection of ESAs, mapping of coastal areas, understanding and mapping of coastal dynamics such as sediment cell, shoreline changes, environmental impacts due to pollution including addressing alternative livelihood for coastal communities, the Government of India has initiated the ICZM Project with the assistance of US$220 million from the World Bank in March, 2010 with an overall revised cost of Rs.1580.10 crore upto the project period of December, 2017.

ICZM is defined by as 'a process that brings together all those involved in the development, management and use of the coast within a framework that facilitates the integration of their interests and responsibilities.

Objectives of ICZM Project:

a. To develop the capacity and establish institutions to implement the Coastal Regulation Zone Notification, 1991 and achieve the objectives of-integrated and sustainable coastal management as per the National Environmental Policy, 2006.
b. To address the issues relating to climate change which have a major implication on the coastal areas and coastal communities especially with respect to sea level rise and increased frequency of cyclones and storm surges. Under the programme, an exercise of hazard mapping will be carried out to protect the coastal people and infrastructure located in the coastal regions.
c. To develop an institution to carry out studies and research in the area of coastal and marine management.
d. To conserve and protect the fragile coastal ecosystems such as the mangroves, brackish water wetlands, coral reefs, etc.
e. To control pollution of coastal waters from land-based sources.
f. To demonstrate and pilot improved livelihood options of coastal communities threatened by coastal hazard and pollution.
g. To develop Integrated Coastal Zone Management Plans for better Management of coastal areas.

ICZMP is being implemented through Society of Integrated Coastal Management (SICOM) of MoEF&CC. The ICZMP Phase-I with a cost outlay of Rs 1580.10 crore (revised) that is being implemented by MoEF&CC address most of the issues relevant to impact of Climate Change in coastal areas especially in 3 states viz, Gujarat, Odisha and West Bengal. Further the Phase-II of the Integrated Coastal Zone Management Project that is in the initial process will take into consideration the coastal issues at the remaining 10 maritime States/UTs.

The project is working at the national level and in three states: Gujarat, Odisha, and West Bengal. At the national level, the project is working to expand the knowledge base and build institutional capacity for the integrated management of coastal zones. This will include the mapping, delineation and demarcation of hazard lines and ecologically sensitive areas along the mainland coast of India, in addition to setting up a new National Center for Sustainable Coastal Management (NCSCM).

Investments in the three coastal states – which were chosen for their varying levels of development and their unique set of challenges – will pilot ICZM approaches with a view to replicating them in all the coastal states in future.

In the three states, complementary pilot investments will be carried in small coastal stretches (on 3% of India's coastline) to support capacity building. Each of these pilots was selected on the basis of wide stakeholder consultations.

5.3.3. National Coastal Mission (NCM)-MoEF&CC

The National Coastal Mission (NCM) has been proposed to be initiated by the GoI to ensure that the coastal areas are managed to respond to the threats of climate change. This would be possible by building in appropriate adaptive responses and mitigation strategies and by bridging socioeconomic and scientific gaps. With a high concentration of population in coastal zones, the NCM identifies sustainable coastal development as a top priority. The key focus areas include livelihood security of coastal communities in the face of climate change and conservation of coastal ecosystems to protect against climate induced hazards, erosion and sea level rise. The mission would demonstrate that integrated coastal management and biodiversity conservation can play key roles in reducing the human and natural vulnerabilities to the multiple threats of climate change. The mission would provide for effective planning of utilisation of resources present along the coast and the islands, and mitigate the impacts (e.g. flooding, and extreme weather events) that are likely to be exacerbated due to climate change.

NCM shall contribute to achieve sustainable development by:

- Ensuring Integrated Management of Coastal Spaces,
- Reducing Coastal Vulnerability,
- Enhancing Food Security,
- Ameliorating Climate (C Sequestration) especially by mangroves, salt marshes and seagrass beds
- Securing Livelihoods of Coastal Communities.

The Mission would add value to ongoing programmes of Integrated Coastal Zone Management by including climate sensitivity and adaptation components. The National Coastal Mission will assist the nine coastal states and four Union Territories, other allied central Ministries and coastal communities, to address some of lndia's most pressing coastal issues, planning including climate change, conservation, spatial and coastal development. It would primarily assess current vulnerabilities (physical,

ecological and socio-economic) and build scenarios to use this knowledge in protecting people, property and the environment under changing climate.

The five objectives of the proposed NCM are as follows:

1. Scientifically map the cumulative vulnerability of coastal environment to climate change and consequent threats to ecology, lives and livelihoods.
2. Develop vulnerability-based environment & adaptive management plans for key sectors by (i) Mainstreaming climate sensitivity and readiness into all coastal developmental projects and (ii) Promoting development taking into account the threats due to natural hazards in the coastal areas and SLR
3. Build resilience of coastal communities (e.g. fishers, agriculture etc.), infrastructure and settlements in urban and rural areas
4. Conserve and protect coastal stretches, its unique environment and its marine area by enhancing mitigation (e.g. Blue carbon)
5. Build institutional capacity both sector-wise and for community

The given figure shows the conceptual framework of the National Coastal Mission.

Fig 50: Conceptual Framework of the NCM

A brief description of the various activities under the NCM is given below:

Key Activity 1: Coastal Vulnerability will be assed as a function of physical hazards, socio-ecological senility and the adaptive capacity of the coastal stretch. A national framework shall be developed for the assessment by the MoEF&CC, MoES and SoI partnering with relevant line departments and expert agencies.

Key Activity 2: Based on the Vulnerability Assessment, development plans will be made comprising of sectoral response plans, vulnerability reduction plans and

prioritized intervention plans for different stretches of the coast. An inter-ministerial expert team shall plan, and implement the planned tasks and sub-tasks through the respective coastal states.

Key Activity 3: The Mission recognizes that resilience has to be built at the level of the community and for the coastal infrastructure comprising urban and rural segments. Emphasis is laid on the development of Holistic villages. These tasks are to be undertaken by various state and central government agencies, concerned Ministries/Departments of State/ UT Governments shall incorporate the above issues in their ongoing plans.

Key Activity 4: Coastal ecosystems are known for their carbon sequestration potential and hence, the Mission envisages implementing a multi-pronged strategy for conservation of the existing ecosystems, implementation of schemes for expanding their extent and undertaking systematic studies for assessing their sequestration potential. The Union Ministry of Environment, Forest and Climate Change shall strive to strengthen the Policy and regulatory frameworks and create national knowledge networks in partnership with the coastal states to aid in evidence-based conservation planning.

Key Activity 5: Capacity Building is a cross cutting activity for mitigating the causes and strengthening the adaptive capacity. The Mission aims at addressing the issue at every level from the coastal community to the policy maker, with tailor-made content and communication strategy. The tasks shall be conceived and coordinated by MoEF&CC and State Forest Departments and implemented through various state agencies, NGOs, and community organizations.

5.3.4. National Cyclone Risk Mitigation Project (NCRMP)- NDMA (MoHA)

GoI has initiated the National Cyclone Risk Mitigation Project (NCRMP) with a view to address cyclone risks in the country. The overall objective of the Project is to undertake suitable structural and non-structural measures to mitigate the effects of cyclones in the coastal states and UT's of India. The National Disaster Management Authority (NDMA) under the aegis of Ministry of Home Affairs (MoHA) will implement the Project in coordination with participating State Governments and the National Institute for Disaster Management (NIDM).

The Project has identified 13 cyclone-prone States and Union Territories (UTs), with varying levels of vulnerability. These States/UTs have further been classified into two categories, based on the frequency of occurrence of cyclone, size of population and the existing institutional mechanism for disaster management. These categories are:

Category I: Higher vulnerability States i.e. Andhra Pradesh, Gujarat, Odisha, Tamil Nadu and West Bengal.

Category II: Lower vulnerability States i.e. Maharashtra, Goa, Karnataka, Kerala, Daman & Diu, Puducherry, Lakshadweep and Andaman & Nicobar Islands.

The Project will progress in phases with focus on AP & Odisha in Phase-1.

NCRMP consists of following 4 components:

A. **Early warning and dissemination system (EWDS) and capacity building of coastal communities (Rs 72.75 crores):** This component will help in reducing the vulnerability of coastal communities by tackling the existing gap in dissemination of warning to communities.
B. **Cyclone Risk Mitigation Infrastructure (Rs 1164 crores):** The purpose of this component is to improve the access to emergency shelters, evacuation and protection against cyclones and other hydro meteorological hazards in high risk areas. This will be done through investment in multipurpose cyclone shelters, up-gradation of existing roads helping in connecting the habituations and Cyclone shelters, construction of bridges suitable for evacuation, mangrove regeneration/plantation, drainage improvement measures and **repair and up-gradation of existing embankments**.
C. **Technical Assistance for Cyclone Hazard Risk Mitigation, Capacity Building and Knowledge Creation (Rs 29.10 crores):** this component will help improve the understanding of natural disaster risks and vulnerabilities, and strengthen the institutional capacity to address such risks and vulnerabilities.
D. **Project Management and Implementation Support (Rs 95.06 crores):** The office equipment, training and exposure visits and consulting services for specialist activities will be under taken under it.

The components A, C and D will be fully financed by the Central Government through World Bank assistance. The component-B will be financed by Central and State Governments in the ratio of 75:25.

The table below gives the component-wise financing arrangement for Phase-I of NCRMP:

Table 20: Component-wise financing arrangement for NCRMP Phase-I

Table (Cost in Rs. Crore)

Component	Andhra Pradesh	Orissa	PMU (NDMA)	NIDM	Total
A. – Early Warning System	33.95	38.80			72.75
B. - Cyclone Risk Mitigation Infrastructure	645.05	518.95			1164.00
C. - Technical Assistance for Capacity Buliding on Disaster Risk Management	2.43	2.43	12.13	12.13	29.10
D.-Implementation Assistance	37.83	35.41	19.40	2.43	95.06
Unallocated and Contingency @ 10% of overall cost	72.75	58.20	3.40	1.46	135.80
Total	**792.00**	**653.78**	**34.93**	**16.00**	**1496.71**

Phase-1 of the project was to be implemented over a period of five years up from 2009-10 to 2014-15 by NDMA in co-ordination with the Govt. of Andhra Pradesh and Odisha and National Institute of Disaster Management (NIDM) as a Centrally Sponsored Scheme at the cost of Rs. 1496.71 crore. To this regard, World Bank will be providing an International Development Association (IDA) credit under Adaptation Programme Loan (APL) amounting to Rs. 1198.44 crore. The remaining amount of Rs. 298.27 crore will be contributed by Governments of Andhra Pradesh and Orissa (Under Component B only). Other components will be funded 100% by the Central Government.

Further, the GoI has approved Phase-II of NCRMP in July, 2015 for five years up to March, 2020 covering States of Goa, Gujarat, Karnataka, Kerala, Maharashtra and West Bengal at an Outlay of Rs 2361.35Cr with the World Bank funding amounting to Rs1881.20Cr. The remaining amount of Rs480.15 Cr. is being contributed by State Governments as their share. The sub-component of underground cabling has been included under NCRMP Phase-II (under Component-B).

In 2007, NDMA constituted a National Steering Committee (NSC) consisting of subject-matter specialists drawn up from various Ministries/Agencies/Institutions, to scrutinize the Investment proposals received from the various implementing agencies and advise NDM to ensure smooth and proper implementation of the project. Later in 2012, the NSC was rechristened as Project Steering Committee (PSC).

5.3.5. Holistic development of the Islands -MoHA

India has a total of about 1382 offshore islands, which includes two major island territories- Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep group of Island in the Arabian Sea. Islands hold a prime position with respect to ecosystem services, flora-fauna biodiversity, natural resources, sustainable environmental development, human settlements and tourism, coastal security etc.

The National Committee on Strengthening Maritime & Coastal Security (NCSMCS), under chairmanship of Cabinet Secretary, in its 10th Meeting in February, 2015 decided to constitute a Task Force for holistic development of the inhabited/uninhabited Islands. The Committee is headed by the by Joint Secretary (Dept. of Border Management, MoHA) & have representatives from various ministries/ departments/ agencies.

The Terms of Reference (ToR) of the task Force are given below:

- To ascertain the exact number of inhabited/uninhabited islands in all the coastal states/UTs.
- To ascertain the flora and fauna of the above islands.
- To identify the herbs of medicinal values in the islands.
- To identify the islands to be developed for tourism activities.
- To identify the possible commercial and developmental activities in the islands.
- To go into security related issued concerning the above islands.

In view of above, MoWR, RD&GR is required to prepare details of water bodies, including rivers, rivulets, waterfalls, lakes, ponds etc. located in Islands. After ascertaining the existing relevant data in the INDIA-WRIS system, NRSC (ISRO) Hyderabad was approached to take up special study using geo-spatial approach to mark/digitalize all fresh water resources. NRSC has mapped the water bodies using 2.5 m satellite data available on the BHUVAN-Island Information System. There are about 356 water bodies delineated in various islands and the water body layer is hosted in the island information system in BHUVAN and is also being hosted into the INDIA-WRIS Portal.

NITI Aayog has been mandated to steer the initiatives for holistic and sustainable development of Islands. 10 Islands, 5 in Andaman & Nicobar and 5 in Lakshadweep have been shortlisted for development on priority in the first phase.

5.3.6. Sagarmala Project - Ministry of Shipping (MoS)

It is a Ministry of Shipping initiative. The prime objective of the Sagarmala project is to promote port-led direct and indirect development and to provide infrastructure to transport goods to and from ports quickly, efficiently and cost-effectively. Therefore, the Sagarmala Project shall, inter alia, aim to develop access to new development regions with intermodal solutions and promotion of the optimum modal split, enhanced connectivity with main economic centers. It also includes establishment of rail / road linkages with the port terminals, thus providing last mile connectivity to ports; development of linkages with new regions, enhanced multi-modal connectivity including rail, inland water, coastal and road services.

The programme aims to promote port-led development in the country by harnessing India's long coastline, 14,500-km of potentially navigable waterways and strategic location on key international maritime trade routes. Indian coastline will be developed as Coastal Economic Regions (CER).

The project aims at holistic port infrastructure development along the Indian coastline through modernization, mechanization and computerization. Under this port-led development framework government hopes to increase its cargo traffic. It will benefit around 14 per cent of country's overall population from at least 13 States and Union Territories. If inland waterways programme is included in it will benefit at least 55 per cent of all population.

Three Pillars of Sagarmala Project:

The Sagarmala initiative focuses on three pillars of development as follows:

- Supporting and enabling Port-led Development
- Port Infrastructure Enhancement, including modernization and setting up of new ports
- Efficient Evacuation to and from hinterland.

The Sagarmala Project therefore intends to achieve the broad objectives of enhancing the capacity of major and non-major ports and modernizing them to make them

efficient, thereby enabling them to become drivers of port-led economic development, optimizing the use of existing and future transport assets and developing new lines/linkages for transport (including roads, rail, inland waterways and coastal routes), setting up of logistics hubs, and establishment of industries and manufacturing centres to be served by ports in EXIM and domestic trade. In addition to strengthening port and evacuation infrastructure, it also aims at simplifying procedures used at ports for cargo movement and promotes usage of electronic channels for information exchange leading to quick, efficient, hassle-free and seamless cargo movement.

For a comprehensive and integrated planning for "Sagarmala", a National Perspective Plan (NPP) for the entire coastline shall be prepared within six months which will identify potential geographical regions to be called Coastal Economic Zones (CEZs). While preparing the NPP, synergy and integration with planned Industrial Corridors, Dedicated Freight Corridors, National Highway Development Programme, Industrial Clusters and SEZs would be ensured. Detailed Master Plans will be prepared for identified Coastal Economic Zones leading to identification of projects and preparation of their detailed project reports.

The Sagarmala initiative would also strive to ensure sustainable development of the population living in the Coastal Economic Zone (CEZ). This would be done by synergising and coordinating with State Governments and line Ministries of Central Government through their existing schemes and programmes such as those related to community and rural development, tribal development and employment generation, fisheries, skill development, tourism promotion etc. In order to provide funding for such projects and activities that may be covered by departmental schemes a separate fund by the name 'Community Development Fund' would be created.

An illustrative list of the kind of development projects that could be undertaken in Sagarmala initiative are :

a. Port-led industrialization
b. Port based urbanization
c. Port based and coastal tourism and recreational activities
d. Short-sea shipping coastal shipping and Inland Waterways Transportation
e. Ship building, ship repair and ship recycling
f. Logistics parks, warehousing, maritime zones/services
g. Integration with hinterland hubs
h. Offshore storage, drilling platforms
i. Specialization of ports in certain economic activities such as energy, containers, chemicals, coal, agro products, etc.
j. Offshore Renewable Energy Projects with base ports for installations
k. Modernizing the existing ports and development of new ports. This strategy incorporates both aspects of port-led development viz. port-led direct development and port-led indirect development.

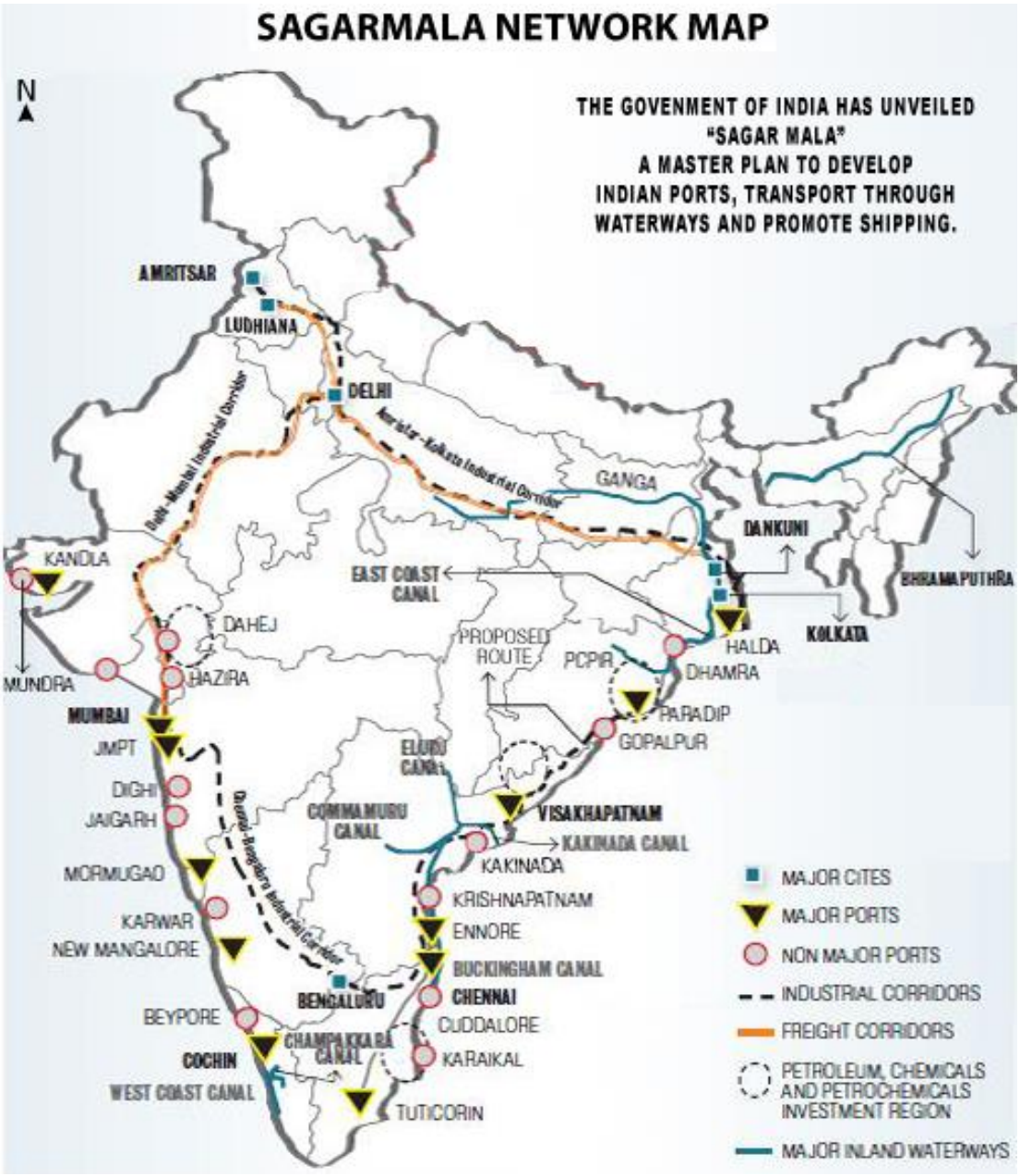

Fig 51: Sagarmala Network Map: India

Total of 173 projects have been initially identified under four projects archetypes of Sagarmala in National Perspective Plan, April 2016. The Project archetype and the number of projects identified are given in table below:

Table 21: Sagarmala Project Archetypes

Sr. No.	Project Archetype	No of Projects
1.	Port Modernization	53
2.	Port Connectivity	83
3.	Port led Industrialization	29
4.	Coastal Community Development	8

Source: Press Information Bureau, GoI (July 2016))

6.0. REFERENCES

1. Proceedings of Beach Erosion Board Meetings, November, 1996
2. Proceeding/Minutes of CPDAC meetings and presentations made during meeting
3. National Coastal Protection Project (NCPP) Report
4. Rashtriya Barh Ayog Report (1980)
5. Shoreline Change Atlas of the Indian Coast, Vol-I to Vol-VI, Space Application Centre (ISRO), Ahmedabad and Coastal Erosion Directorate, CWC, New Delhi (2014)
6. Training Programme on Coastal Erosion and Protection at NWA, Pune
7. MARITIME AGENDA: 2010-2020, Ministry of Shipping, Government of India
8. Presentation made during the first meeting of HLSC
9. Climate Profile Of India, IMD, Oct, 2010
10. Draft Mission Document for the National Coastal Mission (NCM), MoEF&CC
11. CWC Guidelines for Preparation of Coastal Protection Projects, 2003.
12. Ramesh, R. and Ramachandran, S (2003) Coastal Zone Management in India- An Overview. Coastal Urban Environment (eds. R Ramesh and S. Ramachandran) Capital Publ. New Delhi
13. Draft Report on "Problems of Salination of Land in the Coastal States/ Union Territories" (CWC)
14. Approved TAC Notes for SCP&MIP.
15. Inception Report, CRCPMP
16. MoU for implementation of CMIS (CWC)
17. NIO, Goa website: (http://inet.nio.org)
18. CRZ Notification on MoEF&CC website: http://www.moef.nic.in/downloads/public-information/CRZ-Notification-2011.pdf
19. MoEF&CC Website: (http://envfor.nic.in/)
20. Press Information Bureau, Govt of India website- Sagarmala: Concept and implementation towards Blue Revolution (http://pib.nic.in/newsite/PrintRelease.aspx?relid=117691)
21. NCESS, Kerala Website(http://www.ncess.gov.in/)

22. NCSCM, Chennai Website: (http://www.ncscm.res.in/)

23. Geological Survey of India website: (https://www.gsi.gov.in/)

24. CWPRS, Pune website: (http://cwprs.gov.in/)

25. NCRMP website: (http://ncrmp.gov.in/)

26. State ICZMP Websites (Odisha- http://www.iczmpodisha.org/#) (West Bengal - http://www.iczmpwb.org/main/) (Gujarat- http://www.geciczmp.com/)

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Earth System Science Organization (ESSO)
Ministry of Earth Sciences

Coastal Data Information

Platform / Sensor	Parameters	Locations	Frequency	Mode of reception	Availability	Accessibility	Remarks
1. Atmospheric Observations							
Automatic Weather Station along the coast	*Atmospheric Pressure, Air Temperature, Relative Humidity, Wind Speed, Wind Direction, Rainfall, Duration of bright sunshine, soil temperature (at agro-AWS), soil moisture(at agro-AWS)*	64 AWS along the coast	hourly	Near Real-time (satellite telemetry)	2009 - till date (from date of commissioning of stations)	Date receiving Earth Station, GTS, ESSO-IMD website, retrieval of data from field station	Data are being disseminated to end users through GTS
Automatic Rain Gauges	*Rainfall, Air temperature and relative humidity (at selected stations)*	120 ARG stations along the coast	hourly	Near Real-time (satellite telemetry)	2009 - till date (from date of commissioning of stations)	Date receiving Earth Station, GTS, ESSO-IMD website, retrieval of data from field station	Data are being disseminated to end users through GTS
Doppler Weather Radar	*Three base parameters: Reflectivity, Radial velocity and spectral width. Number of various products are derived based on the above three basic products.*	*Kolkata. Visakhapatnam, Machilipatnam, Chennai, Shriharikota, Mumbai*	*Data collection at 10 minutes interval at 24x7 mode .*	*Real time via VPN*	*Since commissioning of the systems at respective stations*	*Six products (images)are available in near real time at ESSO- IMD website . Raw data is available at respective station.*	*Shriharikota data is not available in real time. DWRs at Paradip, Karaikal, Goa are in the process of installation.*

RS/ RW stations	*Measurement of Pressure, Temperature, Relative Humidity, Wind Speed and Wind Direction at different heights in the atmosphere.*	*Kolkata, Chennai, Thiruvanantapuram, Mumbai, Goa, Bhubaneshwar, Minicoy, Aminidivi, Visakhapatnam, Machilipatnam, Karaikal, Kochi, Portblair*	*Twice daily at 00 UTC and 12 UTC*	*Real Time*	*Since commissioning of the systems data available at ADGM(R) Pune office.*	*Data is available at ADGM (R) Pune.*	
2. Ocean Observations – in situ							
Moored Buoy	*Atmospheric Pressure, Atmospheric Temperature, Humidity, Wind Parameters, Currents, SST, Conductivity, Wave parameters, Rainfall, Net Radiation, Irradiance. Profiles of Temperature, Salinity up to 500 m and Currents up to 100m*	*Gulf of Khambhat, Off Mumbai, Off Goa, Off Mangalore, Gulf of Mannar, Off Chennai, Off Krishnapatnam, Off Paradeep, Andaman, Kavarathi* *Active Buoys as on 22/07/14: Andaman, Kavarathi, Off Krishnapatnam*	*1 hr / 3 hr*	*Real-time*	*1997 - till date*	*ODIS - Public Access with only visualisation option.* *No download option.*	*Data is provided on submission of undertaking as data charges are applicable. Surface meteorological and oceanographic data are disseminated in real-time by e-mail to ESSO-IMD, Navy, Coast Guard, A&N Forest Dept, SAC as well as AP, AT, RH, Wind, SST on GTS*
Wave Rider Buoy	*Wave parameters*	*Gopalpur (Odisha), Visakhapatnam (Andhra Pradesh), Puduchery, Tutucorion (Tamil Nadu), Kollam (Kerala), Kozhikode(Kerala), Karwa r (Karnataka), Rathanagiri (Maharashtra), Agatti, (Lakshadweep),Prortblair (A& N)*	*30 minutes*	*Real-time*	*2008 - till date*	*ODIS - Public Access with visualisation option.* *No download option.*	*Data is being supplied on submission of undertaking.*

HF Radar	*Current Vector*	*Andaman coast, Andhra Pradesh coast, Gujarat coast, Odisha coast, Tamilnadu coast*	*60 minutes*	*Real-time*	*2008 - till date*	*Registered access through ODIS*	
Coastal ACDP	*Current Vector*	*Bhatkal, Jaigarh, Goa, Kollam, Mumbai*		*Delayed mode*	*2008 - 2010*		
Tide Gauges	*Sea level data*	*Aerial Bay, Campbell Bay, Chennai, Cochin, Ennore, Garden Reach, JNPT, Kakinada, Kandla, Karwar, Kavaratti, Krishnapatnam, Minicoy, Nagapattinam, Nancowry, New Mangalore, Okha, Paradeep, Port Blair, Tuticorin, Visakhapatnam*		*Real-time*	*2007 - till date*	*Tsunami Early Warning Centre Website Visualization No download facility*	*Data is being supplied on submission of undertaking. Data from selected stations are shared with international agencies.*
Radiometer	Upward and Downward irradiance etc.,			Delayed mode	2008 – till date	Registered access through ODIS	Database is being generated.
Seawater Quality parameters	*dissolved oxygen(DO), nutrients, pH, Biological Oxygen Demand (BOD), plankton, benthos and pathogenic bacteria*	*20 locations Vadinar, Veraval, Hazira ,Thane (Mumbai), Worli, Ratnagiri, Malvan, Mandovi, Mangalore, Kochi, Kavaratti, Sandheads, Hooghly, Paradip, Visakhapatnam, Kakinada Ennore (Chennai), Pondicherry, Tuticorin, Port Blair*	*1/2/3/4 time in a year*	*Delayed mode*	*1992-2010 83 stations 2010 -onward 20 locations*	*Registered access through ODIS with visualisation and download options*	*Through ESSO-INCOIS*
Nearshore Wave Data Pressure gauge:	 Wave parameters (Height, period & direction)	Thiruvananthapuram Thiruvananthapuram Thrissur Kozhikode Alappuzha Ernakulam	Continuous since 2014 2008-09 2009-10 2010-11 2004 2005	 Stored in memory cards and hard disk Stored in	 Archived in ESSO-NCESS	Archived at ESSO-NCESS as hard copy Seasonal *(pre and post monsoon and monsoon*	Available in ESSO-NCESS Available in ESSO-NCESS

	Wave parameters (Height & period)	Chavara (Kollam) Chavara (Kollam) Thiruvananthapuram Thiruvananthapuram, Alappuzha, Kozhikode and Thalasserry.	2010-12 1999-2001 2007-13 1980-85	memory cards and hard disk		Archived at ESSO-NCESS as hard copy	Hard copy
Littoral Environment Observations (LEO)	Breaker waves, Longshore currents	Thiruvananthapuram, Alappuzha, Kozhikode and Thalasserry. Kollam Thrissur Kozhikode Thiruvananthapuram	1980-85 (Weekly 1999-2001; Since 2010 (Monthly) 2009-10 (Monthly) Since 2010 (Monthly) Since 2000 (Monthly)	Manually Recorded field measurement	Archived at ESSO-NCESS	Archived at ESSO-NCESS	Hard copy
Wave Rider Buoy	*Wave parameters*	*Kochi* *Vizhinajm* (Thiruvananthapuram) *Kavaratti (Lakshadweep)* Thiruvananthapuram *Kollam & Kozhikode at 20*	*1983* *1984 (May-June)* *1991-92*	*Continuous for 1 yr* *Continuous for 2 months* *Continuous for 1 yr*	Archived at ESSO-NCESS as hard copy Archived at ESSO-NCESS as hard copy	Archived at ESSO-NCESS as hard copy Archived in ESSO-NCESS *At ESSO-INCOIS*	Hard copy *As part of ESSO-*

		m depth		*2011 - till date at Kozhikode (real time data)*	*At ESSO-INCOIS*		*INCOIS programme of coastal observation system*
Coastal currents RCM/ACDP/ADP/S4	*Current Vector*	Thiruvananthapuram Thrissur Kozhikode Alappuzha Ernakulam Chavara (Kollam) Chavara (Kollam)	2008-09 2009-10 2010-11 2004 2005 2010-12 *1999-2001*	Stored in memory cards and hard disk	Archived in ESSO-NCESS	Archived in ESSO-NCESS	*Seasonal (pre and post monsoon and monsoon)* *Monthly*
3. Geological /Seismic Observations							
Beach & offshore sediment characteristics (Beach samples/Grab /corer/sediment trap)	Sedimentological parameters & minerology Suspended sediment Sedimentological parameters	Kerala coast and innershelf Kollam Lakshadweep	One time observation during different years 1999-2001 & 2010-12	Manually recorded Field measurement Sediment traps	Archived in ESSO-NCESS	Archived in ESSO-NCESS	Hard copy
Beach profiles		Thiruvananthapuram Thrissur Kozhikode Alappuzha Ernakulam Chavara (Kollam) Chavara (Kollam) Thiruvananthapuram	2008-09 2009-10 2010-11 2004 2005 2010-12 1999-2001 Seasonal	Manually recorded Field measurement		Archived in ESSO-NCESS	*pre and post monsoon and monsoon*

		Thiruvananthapuram, Alappuzha, Kozhikode and Thalasserry. Lakshadweep - Inhabited islands	2007-13 1980-85 In three phases during 1990-2005				Monthly Seasonal
Coastal Seismic Stations	Seismic Data			Real-time	2007 - till date	Tsunami Early Warning Centre Website Visualisation No download facility	--
4. Ocean Observations - Satellite Data							
AVHRR - NOAA	AVHRR Raw Data	Entire Coast of India		Real-time	1986 - till date	Non-Sensitive	
AVHRR -SST Archives	SST	Entire Coast of India		Real-time	2001 - till date	Non-Sensitive	
OCM - 1	Chlorophyll, Suspended particles	Entire Coast of India		--	2000 - 2006	Restricted; as per DoS guidelines	
MODIS	Chlorophyll	Entire Coast of India		Real-time	2007 - till date		
Bloom indices	Bloom	Entire Coast of India		Delayed mode	Mar 2010 – till date		
CDOM Index	CDOM	Entire Coast of India		Delayed mode	Mar 2010 – till date		
5. Derived Satellite Products							
Potential Fishing Zone Advisories - PFZ	PFZ Advisories	Entire Coast of India		Near Real-time mode	2003 - till date		
NOAA High resolution SST (AVHRR only and AVHRR+AMSR)	Daily SST and anomalies	Entire Coast of India			1982 - till date		
Ocean Reanalysis (GODAS-MOM)	SST Near Real Time data (older than 5 days) QuikScat forced model	Entire Coast of India			2012 - till date		

	output Real Time data (Daily averaged) Daily SST anomalies						
OCM-1 data sets	Chlorophyll				Weekly composites		
INCOIS Ground station AVHRR data sets	Sea Surface Temperature				2004 to present		
6. Ocean Atmospheric Model Outputs							
Regional Ocean Model System (ROMS)	SST, MLD, D20, Currents	Entire Coast of India		Near Real-time mode	2010 - till date		
Ocean State Forecast	SIgnificant Wave Hight, Wave Direction and Wave Period Swell Wave Height, Director and Period	Entire Coast of India	3 hrs	Ocean State Forecast	SIgnificant Wave Hight, Wave Direction and Wave Period Swell Wave Height, Director and Period		
Tsunami Model	Water levels at Coastal Forecast Points and arrival times	Entire Coast of India	Event based	Tsunami Model	Water levels at Coastal Forecast Points and arrival times		
Storm Surge model	Surge Height	Entire Coast of India	Event based	Storm Surge model	Surge Height		

Tidal predictions	Sea Level	136 locations along the Indian coast		Tidal predictions	Sea Level		
7. Coastal Maps							
Topographic map	(1:25000 Scale)	Topography - Nellore to Machilipatnam ;			156 Maps		
Land use maps	*; (1:25,000 Scale)*	*Orissa, West Bengal, Goa, Tamilnadu, Kerala, Karnataka, Maharashtra*	-		*442 Maps*		
Land use maps	*;(1:50,000 Scale)*	*Andaman & Nicobar*	-		*62 Maps*		
Land use maps	*(1:25,000 Scale)*	*Gujarat ;*	-		*01 Map*		
Land use maps	*(1:50,000 Scale)*	*Gujarat, Orissa, Goa, Maharashtra, Karnataka, West Bengal, Kerala, Tamilnadu, Andhra Pradesh, Andaman & Nicobar ;*	-		*399 Maps*		
Coral Reef Maps	*(1:50,000 Scale)*	*Andaman & Nicobar Islands, Gujarat, Lakshadweep, Tamilnadu;*			*71 Maps*		
Shore line change maps	*(1:50,000 Scale)*	*Maharashtra, Tamilnadu, Goa, Karnataka, Orissa, Kerala;*			*130 Maps*		
Shoreline change maps	*(Varying Scale)*	*Maharashtra, Karnataka, Goa, Tamilnadu, Orissa, Kerala, Krishnapatnam Port, Bhavanapadu Harbour ;*			--		
Topography ALTM	*(Varying Scale)*	*- Cuddalore to Nagapattinam;*			--		
Topography Carto DTM	*- (Varying Scale)*	*Indian coast mainland;*			--		
Coral Reef Eco-	*; (Varying Scale)*	*Andaman and Nicobar,*			--		

morphology		*GOM, GOK and Malvan*					
Coastal Vulnerability Indices (CVI)	*(Varying Scale)*	*Orissa, Andhra Pradesh, Tamil Nadu ;*			--		
Shoreline change maps		*Kerala*	*Long term erosion accretion (1969-90)*	*Map*	Archived in NCESS	Archived in ESSO-NCESS	Hard copy
Integrated Island Management Plans	*coastal and lagoonal characteristic; Spatial plans*	*Lakshadweep for 10 inhabited islands*	*One time*		10 maps in different scale; Maps for different themes	Archived in ESSO-NCESS	One time; Prepared in 2012-13
Integrated Coastal Zone Management Plans	*Coastal and lagoonal characteristic; Spatial plans*	*Lakshadweep for 10 inhabited islands*	*One time*		10 maps in different scale; Maps for different themes	Archived in ESSO-NCESS	One time; Prepared in 2002-05
High Tide Line	*Demarcation of High Tide line (High Tide Line, Low Tide Line, CRZ, coastal ecosystems)*	*Kerala coast, Coastal zone of Thane and Sindhudurg districts of Maharashtra and the entire islands of Lakshadweep.*		*Maps*		Archived in ESSO-NCESS	Hard copy
Coastal Regulation Information System.	*Cadastral level information on High Tide Line, coastal morphology, coastal ecosystems and CRZ categories*	*Kollam in Kerala Islands of Lakshadweep*		*Digital*		Archived in ESSO-NCESS	
Coastal Erosion and Shoreline Management (SLM)	*Site specific erosion, nearshore measurements, modelling, monitoring and mapping at local scale covering 5-10*	*Mumambam-Kayamkulam, Panathura, Muthalapozhi, Vatanappilly, Kozhikode (Kerala)*					*As part of ICMAM programme on Shoreline Management Plan*

	km						
Coastal Erosion and Shoreline Management (SLM) related parameters	specific erosion, nearshore time series measurements on wave, tide, current, modelling, monitoring of shoreline variation , sediment characteristics, and numerical models	Gopalpur (Odisha), Gangavaram (AP) Ennore, Chennai, Vellar inlet (TN), Mumambam-Kayamkulam, Panathura, Muthalapozhi, Vatanappilly, Kozhikode (Kerala), Ullal-Bengre, Karwar, Malpe, Honnavar and Kundapur (Karnataka) Rantagiri-Venurala(South Mah)	2-3 season data for Each site, Monitoring for 3-5 years	Project mode	A site wide composite information needed for shoreline management and coastal protection work	Available to CWC and State Govt as per request for management of coastal erosion	Available at ESSO-ICMAM
Nearshore Hydrodynamic data	Waves, tide and current	Kanyakumari, Chennai, kakinada, Vishakhapattnam, Chilika, Sundarban, Kochin, Dahanu,	1-2 nearshore locations	2-3 seasons data	A site specific to understand the nearshore hydrodynamics	Available to CWC and State Govt as per request for coastal management	Available at ESSO-ICMAM
Tsunami inundation maps	1:25000 scale	Entire Indian mainland coastline	--	--	~600 maps	- part of IOTWC project	Available at ESSO-ICMAM
Shoreline changes along Indian coast	Change rate, identification of accreting and eroding locations in 1:25000 scales	Tamil Nadu, Puducherry, Andhra Pradesh and Karnataka coast	1990, 1999, 2006, 2012	--	~200 maps 1990-2012	visualization option shall be provided for public for awareness and information	Available at ESSO-ICMAM

Inventory of the coastal data collected by SPMU, ICZMP, Odisha for the period from May, 2012 to April, 2013 is given below:

Coastal Energy:

- Wave - Wave measurement data continuously for 12 months at two locations (Paradeep and Balasore), wave transportation, and sediment transport.
- Wind - Wind data measured for 12 months at two locations (Paradeep and Balasore).
- Tide - Tide data for 5 locations (Gopalpur, Jetty, Chilika Lake near Sipakuda village, Paradeep, Dhamra, Budhabalanga River) for the period of 12 months.
- Current - Data on current measurement at 10 locations (near shore and offshore stations of Gopalpur, Chilika, Paradeep, Dhamra and Balasore) continuously for 12 months.

Coastal Sediments:

- Suspended Sediment Concentration (SSC) – Suspended sediment concentration from (i) 8 nos of rivers (surface and mid-depth) at 1 km interval up to 5 ppt salinity (dry season) for four seasons
  (ii) Sea at two locations (surf zone and 250 m distance at 10 km interval for two seasons (Monsoon and Fair weather).
- Bed Sediments - Grain size parameters of bed sediments samples of
  (i) 8 nos of rivers (2 seasons),
  (ii) seabed at five locations covering between LTL and 5 km offshore at 10 km interval for two seasons (Monsoon and Fair weather).
- River Discharge Measurements – Flow and Discharge measurements of six rivers (Subarnarekha, Budhabalanga, Dhamra, Mahanadi, Devi and Rushikulya) for three seasons, i.e. Monsoon (September, 2012 to November, 2012), Post-monsoon (December, 2012 to February, 2013) and Fair weather (March, 2013 to May, 2013).

Coastal Morphology:

- River & Sea Bathymetry – Bathymetry in right rivers up to 5 ppt salinity and in the sea spacing with 250m water depth or 15 km offshore, whichever is closer to shore.
- Bench mark - Permanent Bench Marks at 46 locations at 10 km interval.
- Thematic Mapping – Mapping stretching from LTL to (+) 5 km MSL or 15 Km inland whichever is closer to the sea for the period 2012-2013 on Land use, Wet land, Geomorphology for pre-monsoon and Post-monsoon season, Shoreline change maps (1972,1990,2000,2012) and mapping of erosion/accretion.
- Terrain Survey - At 250m interval for two seasons (Monsoon and Fair weather).
- LEO- Daily LEO observations at Gopalpur, Puri and Paradeep, and LEO at beach profile stations (10 km interval) for four seasons.