

# **SUSTAINABLE SHORE PROTECTION METHODS FOR TAMIL NADU COAST**

**By**

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## SUMMARY

The coastline is defined as the physical boundary between land and ocean, and it is a dynamic environment that provides economic and social security to coastal communities. Due to disasters, rising urbanization, industrialization, sand and coral mining, and other anthropogenic interventions, Tamil Nadu's coastline, which is 991 km long, facing many challenges. The coastline of Tamil Nadu is subjected to prolonged erosion over decades. The properties of waves and their patterns along the Tamil Nadu coast were investigated since they play a significant impact in the formation of the coastline location. Shorelines are deteriorating in Tuticorin, sections of Chennai, Vedaranyam, and other places. This study deals with reducing the impacts of potential hazard to the coastal system, allowing for the prioritization of actions and a sustainable shore protection measure thereby providing an appropriate adaptive solution to counteract the coastal erosion along the coast of Tamil Nadu.

## 1 INTRODUCTION

Tamil Nadu is located on the peninsular part of India with the Bay of Bengal to the east and the Indian Ocean to the south. The coastline is 991 km long stretching from Neerody - the boundary between Kerala and Tamil Nadu on the west coast: to the mouth of Pulicat Lake - the border between Tamil Nadu and Andhra Pradesh on the east coast. The stretch of the Tamil Nadu coast is unique by its varied morphological formation and a kind of exposure to either Indian ocean, Gulf of Mannar, Palk Bay and Bay of Bengal. The coast comprises of around 57% sandy beach, 38% mudflats, and 5% rocky coast. The various significant parameters defining the stability of Tamil Nadu coastline are estuaries of ecological value, coral islands, seagrass beds, mangrove forests, major and minor ports, presence of fishing harbours, fishermen settlements, archaeological & heritage monuments, tourist destinations, pilgrimage centres, shore temples, beach mining, construction of coastal structures etc.

### 1.1 Coastal morphology

Tamil Nadu coastline takes changes in the orientation i.e., stretching west to east between Neerody and Kanyakumari; southwest to northeast between Kanyakumari and Manappad, south to north from Manappad to Thoothukudi; southwest to northeast from Thoothukudi to Kilakkarai, west to east from Kilakkarai to Dhanushkodi tip, east to west from Mandapam to Devipattinam, southwest to northeast from Devipattinam and Vedaranyam; and south to north from Vedaranyam to Chennai.

Major part of Tamil Nadu coastline is made up of alluvium and beach sands overlying sedimentary formations such as laterite, limestones, clay, and stones. The coastal form is very varied with bed rocks, hill promontories, pocket beaches, long sandy beaches, low and raised sand dunes, deposition of wide sand dune inshore formation, offshore rocks, coral Islands, sand hills, bays, tidal flats, tidal swamps, marshy land, mangrove forests, salt pan, submerged reef, coral islands, seagrass bed, tidal rivers, tidal inlets, estuaries, creeks, and spits. The existence of Sri Lankan Island and the peninsular configuration make the coastline to expose for four separate seas: the Indian Ocean, the Gulf of Mannar, the Palk Bay and the Bay of Bengal leading to wide ecological and morphological diversification.

The stability of the Tamil Nadu is dependent on the variation of littoral drift and the reduction in sediment supply to the littoral system. Due to the proximity of Sri Lankan Island, the coastlines between Vedaranyam and Rameswaram in Palk Bay, and between Rameswaram and Thoothukudi in the Gulf of Mannar, are well protected from monsoon waves. Palk Bay is extremely shallow, with a lot of coral banks and submerged shoals. For the convenience of defining the stability, the Tamil Nadu coastline is classified into 8 stretches as presented below in **Table 1.1**.

**Table 1.1.** Coastal stretches along Tamil Nadu coast

| Stretches | Locations                     | Remarks                                     |
|-----------|-------------------------------|---|
| Stretch 1 | Neerody to Keezhamanakudy     | Exposed to Indian Ocean                     |
| Stretch 2 | Keezhamanakudy to Thoothukudi | Exposed to Indian Ocean                     |
| Stretch 3 | Thoothukudi to Dhanushkodi    | Exposed to Gulf of Mannar                   |
| Stretch 4 | Dhanushkodi to Devipattinam   | Exposed to Palk Bay                         |
| Stretch 5 | Devipattinam to Kodiyakarai   | Exposed to Palk Bay                         |
| Stretch 6 | Kodiyakarai to MGR Thittu     | Exposed to Bay of Bengal (partly protected) |
| Stretch 7 | MGR Thittu to Mahabalipuram   | Exposed to Bay of Bengal                    |
| Stretch 8 | Mahabalipuram to Pulicat      | Exposed to Bay of Bengal                    |

This report provides a more suitable method of protecting Tamil Nadu Coastline by adopting two prongs approach, i.e.,

***Protection of shore without any impact to the adjacent shoreline and form a calm area for fishermen to beach their boats, by reducing the wave energy acting on the shoreline particularly in monsoon.***

***Create a submerged reef at offshore around 5 m water depth which will form as an ideal fish breeding ground and thereby increase the local fisheries.***

## 1.2 Erosion reported along Tamil Nadu coast

The National Centre for Coastal research (NCCR) have done detailed study on shoreline changes based on the satellite imageries along the Indian coast. The details on the erosion, stable and accretion status of Tamil Nadu coastal districts is presented in **Table 1.2**. The shoreline changes and the places of erosion reported by NCCR is shown in **Fig. 1.1**.

**Table 1.2.** Erosion-stable-accretion status of Tamil Nadu coastal districts

| Sl. No. | District       | Coastal length (km) | Coastal length (km) |                  |             |        |               |                    |                |
|---------|----------------|---------------------|---------------------|------------------|-------------|--------|---------------|--------------------|----------------|
|         |                |                     | High Erosion        | Moderate Erosion | Low Erosion | Stable | Low Accretion | Moderate Accretion | High Accretion |
| 1       | Thiruvallur    | 40.97               | 1.66                | 3.12             | 9.22        | 17.22  | 6.54          | 0.61               | 2.60           |
| 2       | Chennai        | 24.87               | 0.00                | 0.00             | 3.08        | 14.31  | 7.13          | 0.35               | 0.00           |
| 3       | Kancheepuram   | 84.41               | 1.30                | 3.54             | 44.56       | 27.74  | 7.27          | 0.00               | 0.00           |
| 4       | Villupuram     | 34.52               | 0.00                | 0.31             | 24.83       | 8.39   | 1.00          | 0.00               | 0.00           |
| 5       | Cuddalore      | 43.35               | 2.47                | 2.21             | 13.06       | 9.93   | 12.08         | 3.60               | 0.00           |
| 6       | Nagapattinam   | 125.65              | 3.48                | 14.46            | 43.84       | 17.70  | 33.92         | 8.65               | 3.60           |
| 7       | Thiruvarur     | 24.39               | 3.08                | 0.99             | 11.01       | 6.84   | 2.38          | 0.06               | 0.02           |
| 8       | Thanjavur      | 52.36               | 0.20                | 0.77             | 16.84       | 20.05  | 13.36         | 1.01               | 0.13           |
| 9       | Pudukottai     | 46.74               | 0.04                | 0.28             | 22.67       | 18.98  | 4.66          | 0.11               | 0.00           |
| 10      | Ramanathapuram | 272.01              | 1.27                | 3.48             | 99.55       | 125.95 | 37.81         | 1.97               | 1.99           |
| 11      | Thothukudi     | 121.43              | 1.05                | 3.27             | 17.48       | 46.99  | 44.05         | 6.33               | 2.26           |
| 12      | Thirunelveli   | 51.70               | 0.00                | 0.00             | 9.40        | 21.60  | 19.26         | 0.41               | 1.03           |
| 13      | Kanyakumari    | 69.06               | 0.12                | 4.24             | 40.20       | 17.86  | 4.79          | 0.85               | 1.00           |
| Total   |                | 991.47              | 14.66               | 36.65            | 355.74      | 353.56 | 194.27        | 23.96              | 12.63          |

**Eroding sites based on field study by Indomer**

The classification of coastal stretches and the places of erosion identified by Indomer along Tamil Nadu coast is shown in **Fig.1.2**. The eroding sites identified by Indomer is presented below in **Table 1.3**.

**Table 1.3.** Eroding sites identified by Indomer

| Stretches | Eroding sites  |
|-----------|--|
| Stretch 1 | Neerody to Kanyakumari   |
| Stretch 2 | Vattakottai to Periyathalai  |
| Stretch 3 | No Erosion   |
| Stretch 4 |  |
| Stretch 5 |  |
| Stretch 6 | Tharangambadi to Thirumullaivasal                                  |
| Stretch 7 | Villages covering northern and southern stretches of Parangipettai |
|           | Manjakuppam to Paramankeni   |
|           | Kalpakkam to Mahabalipuram   |
| Stretch 8 | Nemmeli to Muttukadu   |
|           | Chennai Port to Ennore Port  |
|           | Kattupalli to Pulicat Lake   |

### 1.3 Reasons for erosion along Tamil Nadu coast

The main reasons for the erosion along the Tamil Nadu coast are attributed to one or the combination of following factors.

- ***Deficit in sediment supply to littoral system***
- ***reduction of sediment supply through flood discharge into the sea***
- ***total stoppage of littoral drift from Kerala coast***
- ***No beach building up in fair weather season from offshore***
- ***Breaking of high waves during monsoon on the beach having less sediment reserve***
- ***Construction of port breakwaters and interfering with littoral drift***
- ***Construction of shore protection seawalls & groynes and interfering with littoral drift***
- ***Beach mining***
- ***Encroachment of hutments close to High Tide Line of the sea***



## Littoral drift

Littoral drift implies the transport of sediments within the wave breaking zone by the breaking waves. The volume and direction of littoral drift are characterized by i) breaking wave characteristics defined by wave height, wave period and wave direction, ii) particle size of the seabed sediments in the surf zone and iii) Slope of seabed across the surf zone. When the beach is exposed to monsoon waves, the sediments on the beach foreshore will be eroded and partly transported offshore and get deposited as an offshore bar behind the surf zone. The inner part of the shoreface as well as the foreshore will become steeper in this process, and the shoreline will get eroded. *But, during the ensuing fair-weather period, the sediments formed as offshore bar should drift back to the shore and rebuild the beach to the original shape, which is not happening along the eroding stretch of Tamil Nadu.*

More details and the complete science on littoral drift along Tamil Nadu has been presented in the book 'Littoral Drift along East coast of India, P. Chandramohan et.al., 2022, Indomer Inhouse publication "<https://www.indomer.com/books/littoraldrift>". The annual gross and net littoral drift for Tamil Nadu coast are shown in **Fig. 1.3. and Fig.1.4.**



FIG. 1.1. PLACES OF EROSION IDENTIFIED BY NCSCM

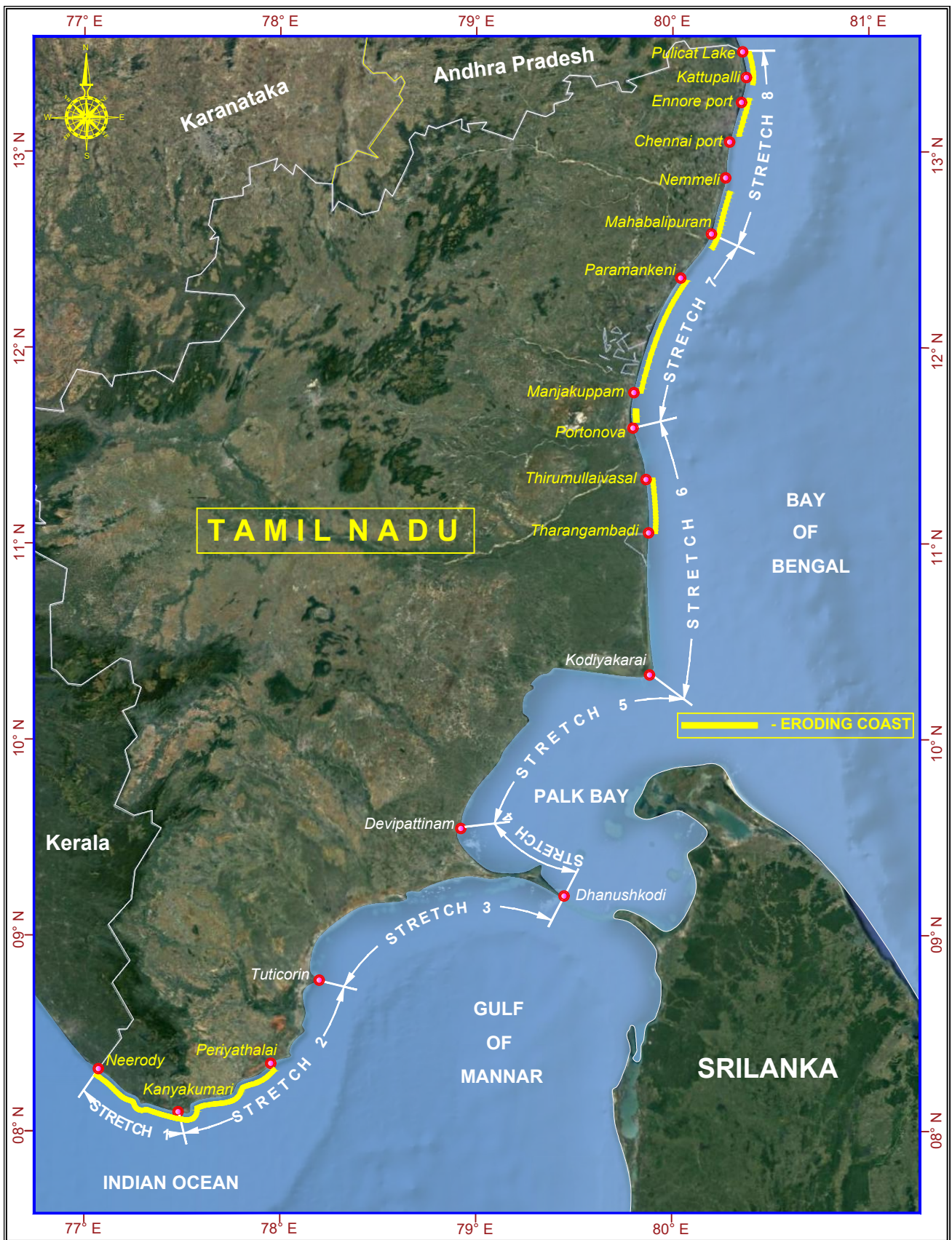


FIG. 1.2 .PLACES OF EROSION ALONG TAMILNADU COAST - IDENTIFIED BY INODMER

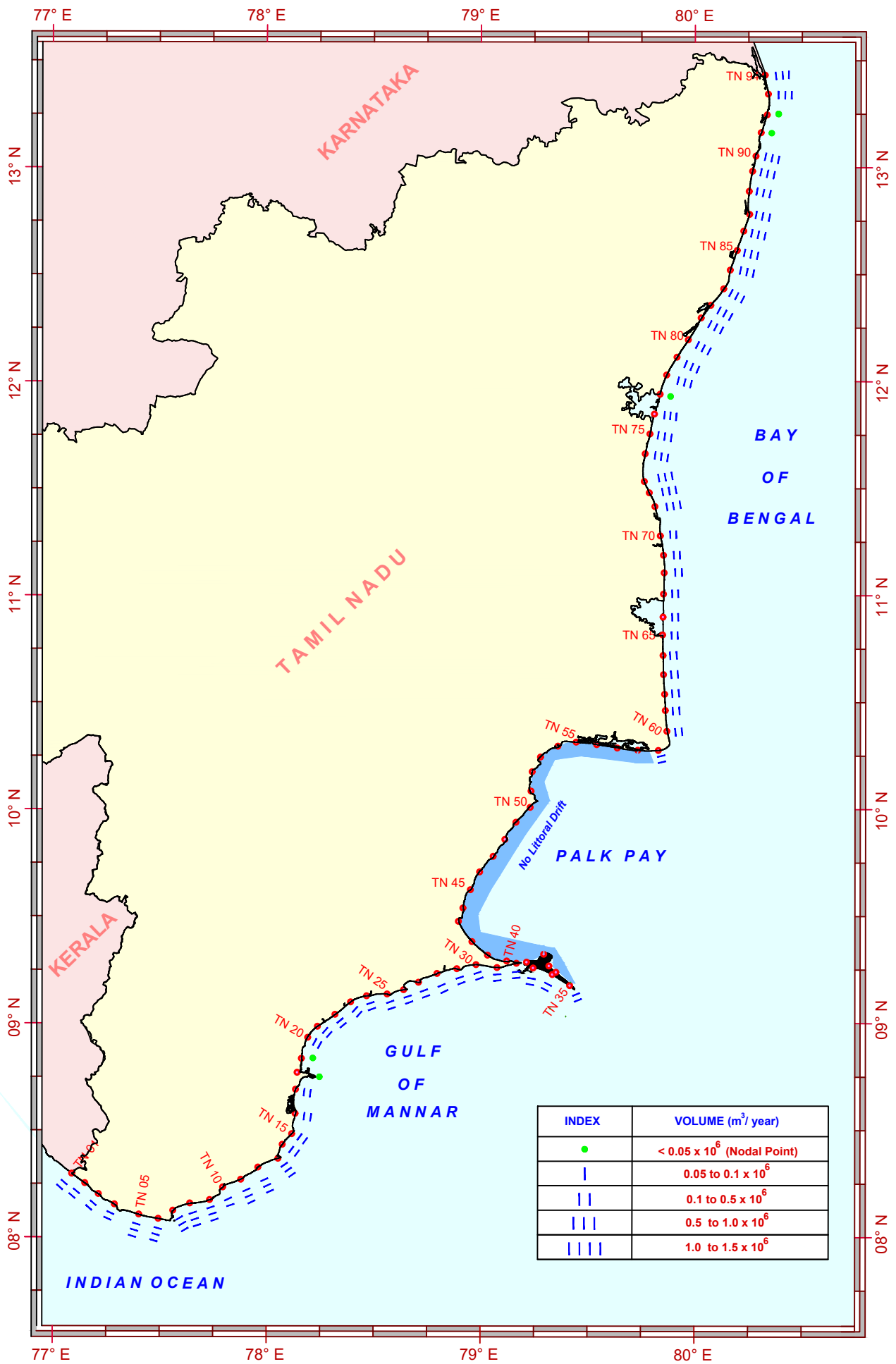


FIG. 1.3. ANNUAL GROSS LITTORAL DRIFT ALONG TAMIL NADU COAST

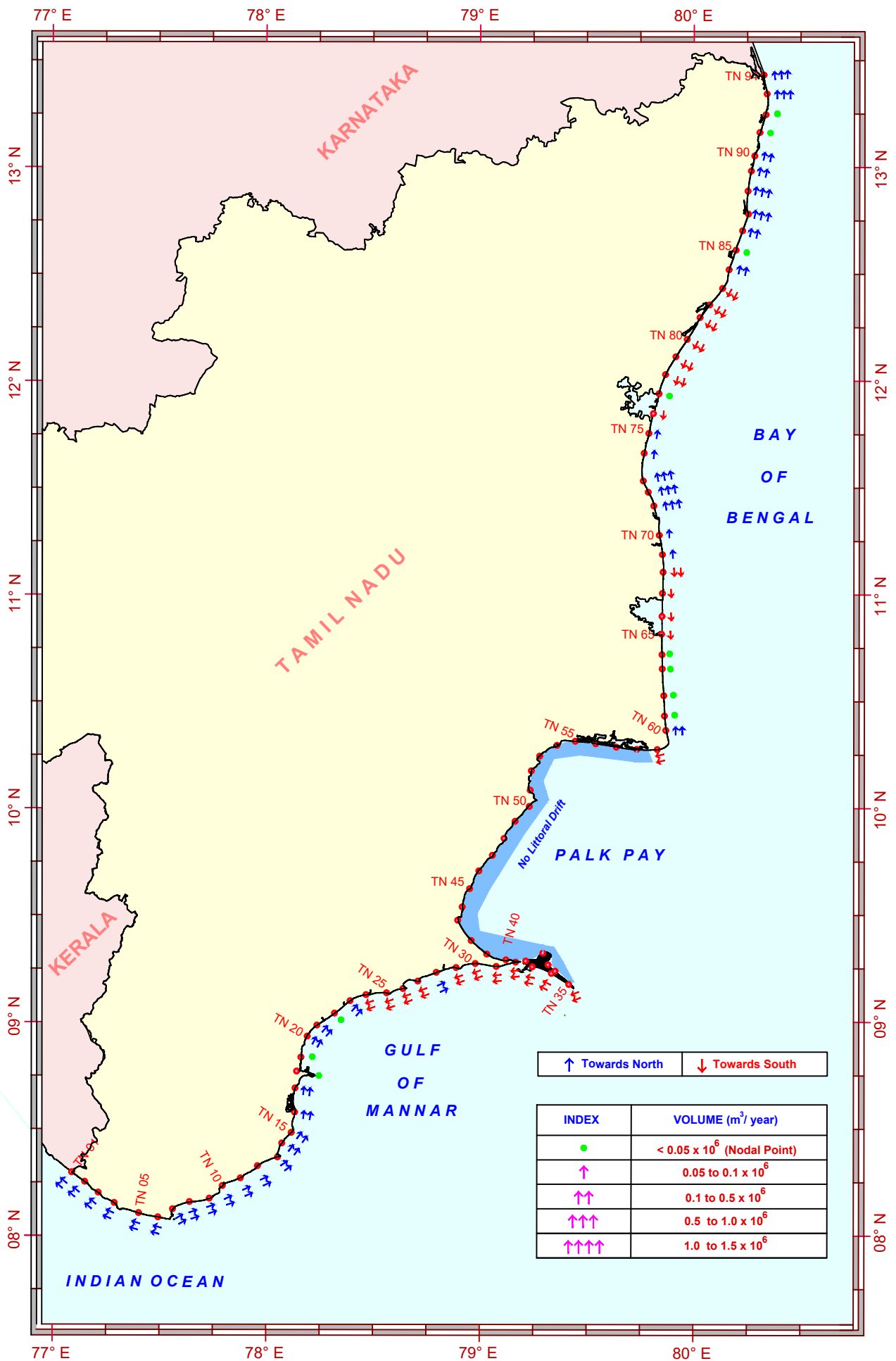


FIG. 1.4. ANNUAL NET LITTORAL DRIFT ALONG TAMIL NADU COAST



## 2 PRESENT SHORE PROTECTION MEASURES

In order to protect the shoreline from coastal erosion, shore protection measures are widely carried out along Tamil Nadu coast. Mostly *hard measures like shore perpendicular groynes were constructed which made to shift the erosion to further north*. The series of construction of groins had shifted erosion to neighbouring places.

Mainly there are two types of approaches towards coastal protection i.e., hard measures and soft measures.

Hard measures: Hard measures are designed to resist the energy of the breaking waves thereby protecting the coast. The type of shore protection structures includes groynes and seawalls and they are designed to resist wave energy. But they totally stop the movement of littoral drift and cause erosion on the downdrift side.

Soft measures: This approach has economic benefits while minimizing the environmental impact than hard type construction of engineering structures. The methods include artificial beach nourishment by placing sand on the beach face, plantations of coastal vegetations, sand dune vegetation and mangroves.

### **Seawalls**

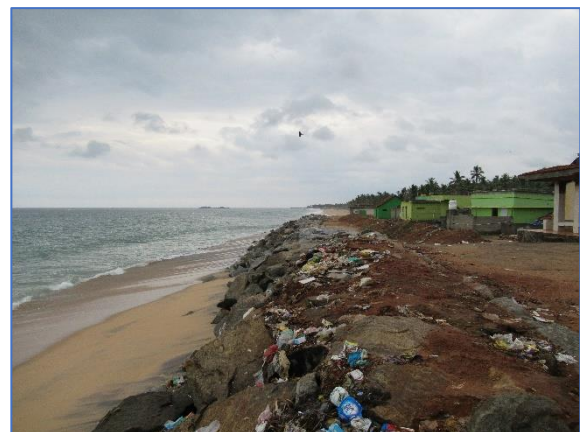
Seawalls are sloping structures built on the face of the shoreline to protect the shore from high breaking waves against the removal of sand. Seawalls in Tamil Nadu are generally constructed using boulders and broken construction debris. The seawall functions by dissipating the wave energy. Similarly, though the seawall protects the beach face, it will lead to toe erosion. The beach in front of the seawall disappears and it requires frequent repairs by strengthening the foot of the seawall with additional rubble revetments after every monsoon. The typical seawalls constructed elsewhere are shown in Photos below.



Concrete seawall



Steel pile seawall



Rubble mound seawall



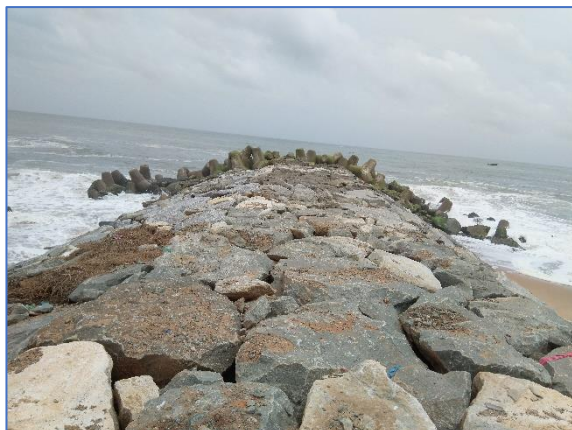
Precast concrete boxes



Gabion boxes

## Groynes

Groynes are shore protection structures constructed perpendicular to shore to arrest the littoral drift and make them to deposit on the updrift side. Construction of groynes will alter the sediment transport and induce accretion on the updrift side and erosion on the down drift side. To reduce erosion on the down drift side, series of short groynes are being built along the Tamil Nadu coast.



Groynes

### 3 WAVE CLIMATE ALONG ERODING SITES

The stretch of the coastline from Pulicat to Vedaranyam receives relatively more wave energy during northeast monsoon (November to January). On the other hand, the coastline from Manapad to Neerody is more influenced during southwest monsoon (June to August). The stretch of coastlines in Palk Bay and Gulf of Mannar, i.e., from Vedaranyam to Tuticorin is relatively protected for both the monsoons. The frequent occurrence of cyclones along the coast of Tamil Nadu particularly between Nagapattinam and Cuddalore causes high waves to break for few days and erode the foreshore of the beach. Such increase in wave heights in monsoons and cyclonic days make significant influence on the littoral drift moving along the Tamil Nadu coast. Out of eight coastal stretches referred in **Table 1.1**. Stretches 1,2,6,7 and 8 are severely affected by wave climate. The wave characteristics for the eroding sites of various coastal stretches is indicated in **Table 1.3** are given below.

#### Stretch 1

The wave characteristics in the region between Neerody to Kanyakumari is exposed to Indian ocean but predominantly affected by wave climate of Arabian sea. The Arabian Sea have high wave activity especially during monsoon where the wave height reaches maximum upto 3 m. The monthly wave characteristics for the eroding sites of Stretch 1 is given as follows.

**Table 3.1.** Month wise wave characteristics - Stretch 1

| Months | Significant Wave Height $H_s$ (m) | Zero – crossing Wave Period, $T_z$ (s) | Wave Direction, $\theta_P$ (deg.) |
|--------|-----------------------------------|--|-----------------------------------|
| Jan    | 0.5 - 1.0                         | 7 - 9                                  | 180.0 - 202.5                     |
| Feb    | 0.5 - 1.0                         | 4 - 6                                  | 180.0 - 225.0                     |
| Mar    | 0.5 - 1.0                         | 7 - 8                                  | 180.0 - 202.5                     |
| Apr    | 0.5 - 1.5                         | 7 - 9                                  | 180.0 - 225.0                     |
| May    | 1.0 - 1.5                         | 6 - 8                                  | 180.0 - 202.5                     |
| Jun    | 0.5 - 2.0                         | 6 - 8                                  | 157.5 - 180                       |
| Jul    | 0.5 - 2.5                         | 8 - 9                                  | 180.0 - 202.5                     |
| Aug    | 0.5 - 2.0                         | 7 - 8                                  | 180.0 - 202.5                     |
| Sep    | 1.0 - 1.5                         | 7 - 8                                  | 180.0 - 202.5                     |
| Oct    | 0.5 - 1.5                         | 7 - 8                                  | 180.0 - 225.0                     |
| Nov    | 0.5 - 1.0                         | 7 - 8                                  | 180.0 - 202.5                     |
| Dec    | 0.5 - 1.0                         | 7 - 8                                  | 180.0 - 202.5                     |

## Stretch 2

The eroding sites of Stretch 2 from Kanyakumari to Periyathalai bordered by Bay of Bengal have moderate wave characteristics than the former one. However, during monsoons extreme waves approaching the shore is obvious. The Month wise predominant wave characteristics of is presented below.

**Table 3.2.** Month wise wave characteristics - Stretch 2

| Months | Significant Wave Height, $H_s$ (m) | Zero – crossing Wave Period, $T_z$ (s) | Wave Direction, $\theta$ (deg.) |
|--------|------------------------------------|--|---------------------------------|
| Jan    | 0.5 - 1.0                          | 3 - 5                                  | 135.0 - 157.5                   |
| Feb    | 0.5 - 1.0                          | 4 - 5                                  | 135.0 - 180.0                   |
| Mar    | 0.5 - 1.0                          | 4 - 5                                  | 135.0 - 180.0                   |
| Apr    | 0.5 - 1.0                          | 4 - 5                                  | 135.0 - 157.5                   |
| May    | 0.5 - 1.0                          | 4 - 5                                  | 135.0 - 180.0                   |
| Jun    | 0.5 - 1.5                          | 5 - 6                                  | 135.0 - 157.5                   |
| Jul    | 0.5 - 1.5                          | 4 - 6                                  | 135.0 - 157.5                   |
| Aug    | 0.5 - 1.5                          | 5 - 6                                  | 135.0 - 157.5                   |
| Sep    | 0.5 - 1.5                          | 5 - 6                                  | 135.0 - 157.5                   |
| Oct    | 0.5 - 1.0                          | 4 - 6                                  | 135.0 - 180.0                   |
| Nov    | 0.5 - 1.0                          | 4 - 5                                  | 135.0 - 180.0                   |
| Dec    | 0.5 - 1.0                          | 3 - 5                                  | 135.0 - 157.5                   |

## Stretch 6

The coastal stretch covering the region between Kodyakarai to Porto Novo has a gradually increasing wave characteristics moving from South to North. This is also evident that the shallow to steep transition of seabed depth twitches after Kodyakarai coast as the coastal stretches covering the Palk Bay always remain as shallow calm region. The monthly wave characteristics for the eroding sites of Stretch 2 is presented in **Table 3.2.**

**Table 3.3.** Month wise wave characteristics - Stretch 6

| Months | Significant Wave Height, $H_s$ (m) | Zero – crossing Wave Period, $T_z$ (s) | Wave Direction, $\theta$ (deg.) |
|--------|------------------------------------|--|---------------------------------|
| Jan    | 0.5 - 1.5                          | 3 - 5                                  | 67.5 - 112.5                    |
| Feb    | 0.5 - 1.0                          | 3 - 5                                  | 67.5 - 112.5                    |
| Mar    | < 1.0                              | 3 - 4                                  | 67.5 - 112.5                    |
| Apr    | < 1.0                              | 3 - 4                                  | 90.0 - 112.5                    |
| May    | 0.5 - 1.0                          | 3 - 4                                  | 90.0 - 112.5                    |
| Jun    | 0.5 - 1.0                          | 3 - 4                                  | 90.0 - 112.5                    |
| Jul    | 0.5 - 1.0                          | 3 - 4                                  | 90.0 - 112.5                    |
| Aug    | 0.5 - 1.0                          | 3 - 4                                  | 90.0 - 112.5                    |
| Sep    | 0.5 - 1.0                          | 3 - 5                                  | 90.0 - 112.5                    |
| Oct    | 0.5 - 1.0                          | 3 - 5                                  | 90.0 - 112.5                    |
| Nov    | 0.5 - 1.0                          | 3 - 5                                  | 45.0 - 67.5                     |
| Dec    | 1.0 - 1.5                          | 4 - 5                                  | 67.5 - 90.0                     |

### Stretch 7

The coastal stretch between Porto Novo to Paramankeni is vulnerable to high erosion as the wave characteristics gets amplified when compared to southern stretches of Tamil Nadu coast. The region covering Pondicherry Territory and North - South stretches of Cuddalore are partly protected with shore protection measures. However, the stretch extending north from Pondicherry to Paramankeni is prone for erosion. The monthly wave characteristics for the eroding sites of Stretch 7 is given below.

**Table 3.4.** Month wise wave characteristics - Stretch 7

| Months | Significant Wave Height, $H_s$ (m) | Zero – crossing Wave Period, $T_z$ (s) | Wave Direction, $\theta$ (deg.) |
|--------|------------------------------------|--|---------------------------------|
| Jan    | 0.5 - 1.0                          | 5 - 6                                  | 67.5 - 90.0                     |
| Feb    | 0.5 - 1.0                          | 4 - 5                                  | 90.0 - 112.5                    |
| Mar    | 0.5 - 1.0                          | 4 - 5                                  | 90.0 - 135.0                    |
| Apr    | 0.5 - 1.0                          | 4 - 5                                  | 112.5 - 157.0                   |
| May    | 0.5 - 1.0                          | 4 - 6                                  | 135.0 - 157.5                   |
| Jun    | 0.5 - 1.0                          | 4 - 6                                  | 135.0 - 157.5                   |
| Jul    | 0.5 - 1.0                          | 6 - 7                                  | 112.5 - 135.0                   |
| Aug    | 0.5 - 1.5                          | 6 - 7                                  | 112.5 - 135.0                   |
| Sep    | 0.5 - 1.0                          | 5 - 7                                  | 112.5 - 135.0                   |
| Oct    | 0.5 - 1.0                          | 5 - 7                                  | 112.5 - 135.0                   |
| Nov    | 0.5 - 1.0                          | 5 - 7                                  | 67.5 - 90.0                     |
| Dec    | 1.0 - 1.5                          | 5 - 6                                  | 67.5 - 112.5                    |

## Stretch 8

The wave characteristics of eroding sites of stretch 8 i.e., from Mahabalipuram to Pulicat Lake is predominantly high, however the shore protection measures along the coast of Chennai and Ennore makes them less vulnerable to erosion. Especially the south side of Chennai is accreting due to the breakwaters constructed along the coast and the northern stretches extending upto pullicat lake is highly subjected to erosion. The monthly wave characteristics for the eroding sites of Stretch 8 is given in **Table 3.5**.

**Table 3.5.** Month wise wave characteristics - Stretch 8

| Months | Significant Wave Height, $H_s$ (m) | Zero – crossing Wave Period, $T_z$ (s) | Wave Direction, $\theta$ (deg.) |
|--------|------------------------------------|--|---------------------------------|
| Jan    | 0.5 - 1.0                          | 4 - 5                                  | 67.5 - 90.0                     |
| Feb    | 0.5 - 1.0                          | 4 - 5                                  | 90.0 - 112.5                    |
| Mar    | 0.5 - 1.0                          | 4 - 5                                  | 112.5 - 135.0                   |
| Apr    | 0.5 - 1.0                          | 4 - 5                                  | 112.5 - 135.0                   |
| May    | 0.5 - 1.0                          | 4 - 5                                  | 112.5 - 157.0                   |
| Jun    | 0.5 - 1.5                          | 5 - 6                                  | 135.0 - 157.5                   |
| Jul    | 0.5 - 1.5                          | 5 - 6                                  | 135.0 - 157.5                   |
| Aug    | 0.5 - 1.5                          | 6 - 7                                  | 112.5 - 157.5                   |
| Sep    | 0.5 - 1.0                          | 5 - 6                                  | 112.5 - 157.5                   |
| Oct    | 0.5 - 1.0                          | 4 - 6                                  | 90.0 - 112.5                    |
| Nov    | 0.5 - 1.0                          | 4 - 5                                  | 90.0 - 112.5                    |
| Dec    | 0.5 - 1.5                          | 4 - 5                                  | 67.5 - 112.5                    |

*From the observations we can infer that the eroding sites of Stretch 1 & Stretch 2 bordering Arabian sea and the eroding sites of Stretch 8 are subjected to rigorous wave climate and receives high erosion. However, the coastal Stretches 6,7 and 8 covering the regions between Tharangambadi to pullicat lake is prone to cyclonic events. So, it is evident that a sustainable shore protection measure is required thereby providing an ergonomically best solution to control erosion all along the coast of Tamil Nadu.*

## 4 PROPOSED METHOD OF SHORE PROTECTION FOR TAMIL NADU COAST

**Approach:** One of the best approaches to protect the shoreline is reducing the height of monsoon waves breaking on the shoreline. The main advantage is that, it will not stop the littoral drift moving along the shore. It would form a calm zone ideal for anchoring / beaching the boats. Fishermen with fibre boats can sail into the sea on any day at any time in a year irrespective of the offshore wave climate. To meet these criteria, it has been suggested to place artificial armour reef at offshore, say at 5 m CD depth to a height of 4 m from the bed to a bottom width of 27 m with 1:2 slope. The waves of more than 0.8 m will break beyond the reef inside the sea. Only waves of less than 0.8 m will propagate and break on the shoreline. On the other hand, during non-monsoon months, the waves breaking on the shoreline will be less than 0.5 m. Such low wave height will help in maintain a calm wave breaking zone, low littoral drift and reduction on offshore transport. So, the beach erosion can be totally avoided.

### 4.1 Seabed depth off eroding sites

The locations subjected to erosion along Tamil Nadu Coast are already shown in **Fig. 1.2**. As per the previous discussions, placement of artificial reef at offshore will enact and reduce the impact of high monsoon waves breaking the shoreline. To identify and analyse the placement of reefs at offshore, the bathymetry of eroding sites along the TN coast depicting the seabed depth is mandatory.

Based on the available information derived from Naval Hydrographic Chart (NHC), C-MAP data obtained from Danish Hydraulic Institute (DHI) and in situ survey data with Indomer, the preliminary information of water depth vs distance has been compiled. Referring to the eroding sites along the Tamil Nadu coast in **Table 1.3**, the distance of 5 m water depth from the High Tide Line (HTL) for the eroding sites are presented in **Table 4.1**.

**Table 4.1.** Approximate distance of 5 m depth contour from HTL

| Stretches | Eroding coast of various stretches                                 | Distance of 5 m depth contour from HTL   |
|-----------|--|--|
| Stretch 1 | Neerody to Kanyakumari   | 200 - 300                                |
| Stretch 2 | Vattakottai to Periyathalai  | 400 - 800                                |
| Stretch 3 | No Erosion   |  |
| Stretch 4 |  |  |
| Stretch 5 |  |  |
| Stretch 6 | Tharangambadi to Thirumullai Vasal                                 | 50 - 75                                  |
| Stretch 7 | Villages covering northern and southern stretches of Parangipettai | 100                                      |
|           | Manjakuppam to Paramankeni   | 40 - 110                                 |
|           | Kalpakkam to Mahabalipuram   | 75 - 165                                 |
| Stretch 8 | Nemmeli to Muttukadu   | 90 - 130                                 |
|           | Chennai Port to Ennore Port  | 80 - 120<br>(Already groins constructed) |
|           | Kattupalli to Pulicat Lake   | 100 - 110                                |

#### 4.2 Use of Artificial Reef – Sustainable beach protection

Artificial reefs are benthic structures constructed of natural or man-made materials that are placed in the ocean to protect, improve, or restore ecosystem components. Their ecological configuration and function, vertical relief, and irregular surfaces differ depending on their location, construction, and degree of resemblance to natural ecosystems like coral reefs. Humans have long exploited the habit of some creatures to seek shelter near submerged objects by placing structures in shallow waters where biological communities can emerge and fish can be captured. Artificial reefs are currently used for a variety of purposes, including improving the efficiency of commercial, and recreational fisheries, producing new biomass in fisheries and aquaculture, increasing underwater recreation and ecotourism opportunities, preserving, and renewing coastal habitats and biodiversity, and furthering research. Tamil Nadu government has put forth an idea to revive traditional fishing grounds of small fishermen and create a cluster of artificial reefs, which act as natural breakwaters by reducing wave energy, along the coast with the focus on fragile coastal stretches as Tamil Nadu is experiencing increasing recurrence of extreme weather events and erosion of beaches.



The artificial reef can be placed in different patterns depending on their usage and purpose of laying. Prior to that, experimental modules are to be constructed to test and manifest whether it is suitable for the purpose. Several studies including the water turbulence behaviour and the hydraulic conditions, post the deployment of reef must be analyzed and the type of configuration i.e., whether to deploy them as single unit or as group prototype model must be decided. The wide application of Artificial Reef are as follows.

- Protection of sensitive habitats from fishing activities
- Restoration of depleted habitats
- Mitigating habitat loss
- Enhancement of biodiversity
- Professional and recreational fisheries Enhancement
- Creating suitable areas for diving
- Monitoring and management of coastal activities and to reduce conflicts
- Research and educational activities
- Creating potential networks of Marine Protected Areas to manage the life cycles of fish and connectivity.

#### 4.3 Offshore submerged artificial reefs

There have been numerous field trials and implementations of artificial reefs operating as submerged breakwaters, which contribute to shore protection and beach stabilisation, hence benefiting the biological life in the sea (Armono et al.,2004). Submerged artificial reefs aid in the stabilisation of eroding beaches while reducing the negative effects on nearby beaches. The principal mechanism through which submerged artificial reefs aid in coastal stabilisation is wave attenuation. The wave transmission coefficient, which is the ratio of the transmitted wave height to the incident wave height, is used to measure wave attenuation. Physical and numerical model tests are used to establish the wave transmission coefficients for various structural configurations due to the difficulties of wave breaking.

#### 4.4 Proposed geometry of Artificial reefs

There are different types of geometry adopted for design of artificial reef. Presently the Tamil Nadu government has deployed the reef structure for the sustainable development. The Department of Fisheries has deployed artificial reefs in 35 coastal sites spread across eight districts and later in

2014, the International Funding for Agricultural Development (IFAD) assisted the Post Tsunami Sustainable Livelihoods Programme of Department of Rural Development and Panchayat Raj to deploy reefs in six coastal sites, both with technical assistance of the Central Marine Fisheries Research Institute (CMFRI). The reefs deployed by TNFD are designed in ecological perspective and were placed approximately 5 - 6 km offshore where the water depth is about 8 - 10 m. The practical artificial reef design followed by the state of Tamil Nadu for the deployment of artificial reef is shown in **Fig. 4.1**.

The material used can affect the establishment of the artificial substrates by benthic organisms and, consequently, the composition of the fish assemblage that will inhabit the reef. The materials should be inert to avoid pollution and bioaccumulation of contaminants in the environment and in the aquatic organisms. The choice of the material should also consider the resistance to the chemical and physical forces in constant action in the marine waters, the time-life, and the suitability for immigration by benthic communities.

#### **Arrangement of reefs at offshore**

To attain a sustainable shore protection measure, we Indomer has put forth an idea of placing the artificial reefs at offshore all along the eroding coast at 5 m contour. The main intention to place the reefs at 5 m water depth is that the waves experienced by the coast of Tamil Nadu during extreme event is approximately 2 m to 3 m. So, the impact of wave energy will be reduced, thereby when the waves reach the shore will always have a significant height of less than 1 m. The schematic representation arrangement of reefs along the eroding coast is shown in **Fig. 4.2**. The reef can be a continuous one for 200 m long with a gap of 100 m in between in order to allow navigation. The cross section of the beach profile depicting the placement of artificial reef is shown in **Fig. 4.3**.

The approximate length of placement of reefs along the coast of Tamil Nadu for the proposed 8 stretches is presented below.

**Table 4.2.** Approximate length for placement of reefs

| Stretches | Locations                     | Length (km) |
|-----------|-------------------------------|-------------|
| Stretch 1 | Neerody to Keezhamanakudy     | 60          |
| Stretch 2 | Keezhamanakudy to Thoothukudi | 75          |
| Stretch 3 | Thoothukudi to Spit South     | Nil         |
| Stretch 4 | Spit South to Devipattinam    |             |
| Stretch 5 | Devipattinam to Kodyakarai    |             |
| Stretch 6 | Kodyakarai to MGR Thittu      | 35          |
| Stretch 7 | MGR Thittu to Mahabalipuram   | 105         |
| Stretch 8 | Mahabalipuram to Pulicat      | 50          |

### Frustum cone reef

The frustum cone reef is designed in such a way that each unit having a height of 4 m arranged as 4 rows for a length of 200 m arranged as one entity (refer **Fig.3.10**). The plan, elevation and 3D view of the frustum cone reef is shown in **Fig.4.4**. The approximate weight of one unit of frustum cone reef is **43.95 tonnes**. Each unit having a height of 4 m can be directly placed at 5 m water depth and can be arranged as like the configuration referred in **Fig. 4.2**

### Truncated square pyramid reef

The truncated square pyramid is designed in such a way that each unit have height of 1.5 m, so that they serve the ecological purpose of reviving the corals. The plan, elevation and 3D view of the Truncated square pyramid reef is shown in **Fig.4.5**. The approximate weight of one unit of truncated square pyramid is **4.8 tonnes**. Each unit has a height of 1.5 m can be stacked one over other and can be placed at offshore.

### Experimental reef module

As a preliminary study we Indomer had experimentally arrived a concrete reef module in a smaller scale. The pictures depicting the experimental reef module is represented below.



**Specially designed reef for good fishing ground**

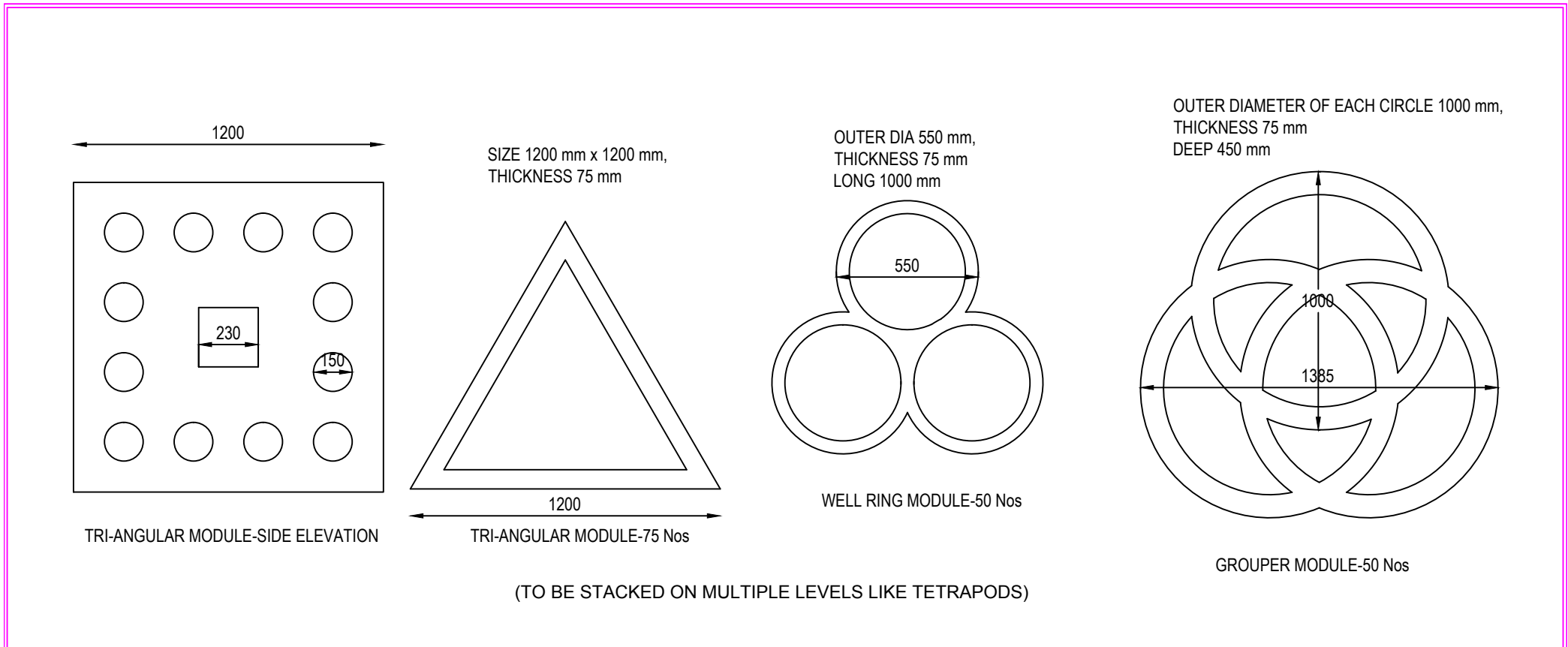


FIG. 4.1. TYPES OF GEOMETRY BEING USED BY TNFD

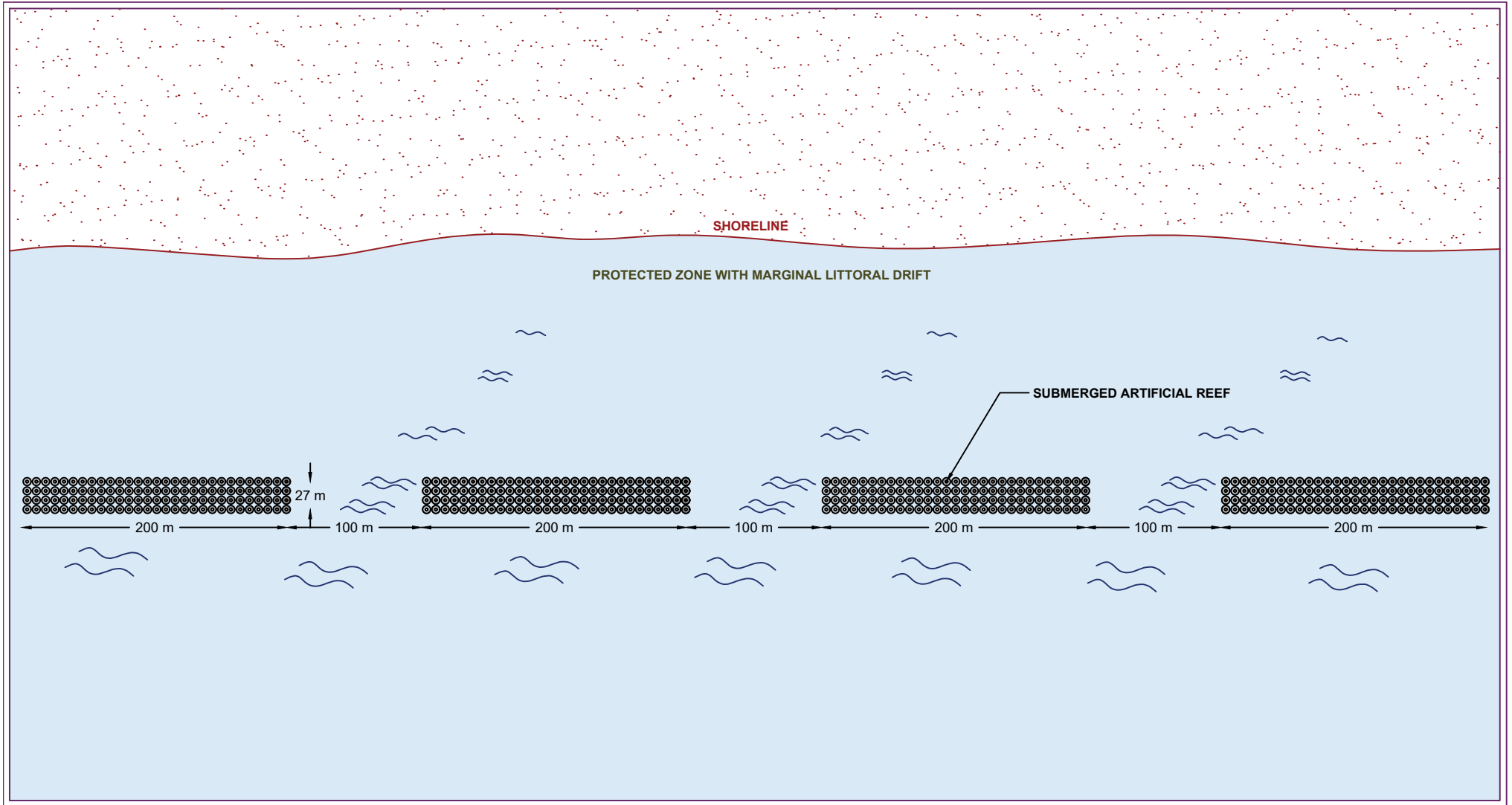


FIG. 4.2. SCHEMATIC REPRESENTATION OF ARRANGEMENT OF REEFS ALONG ERODING COAST

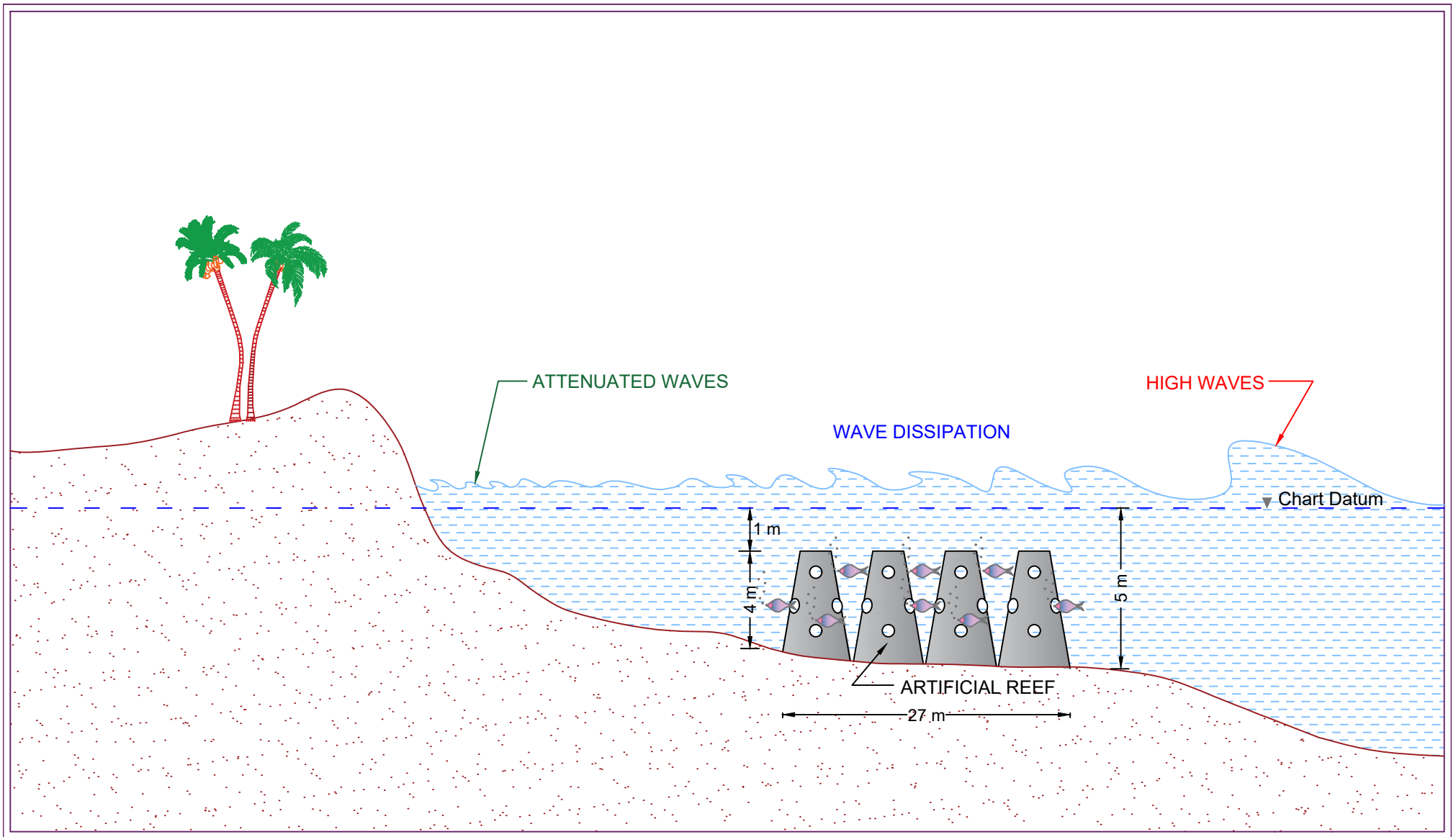
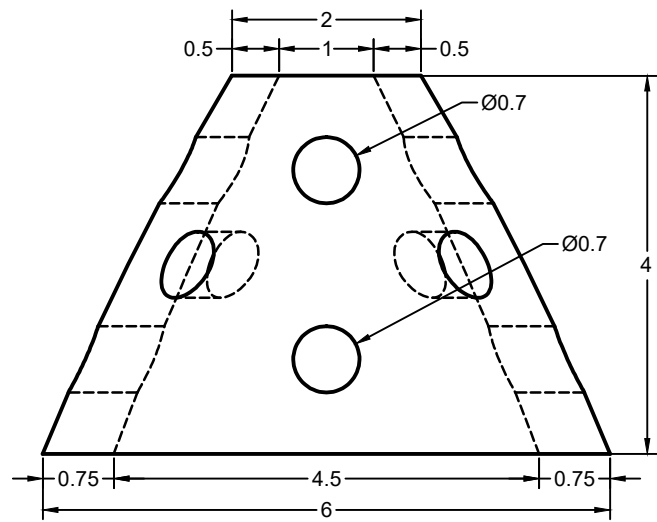
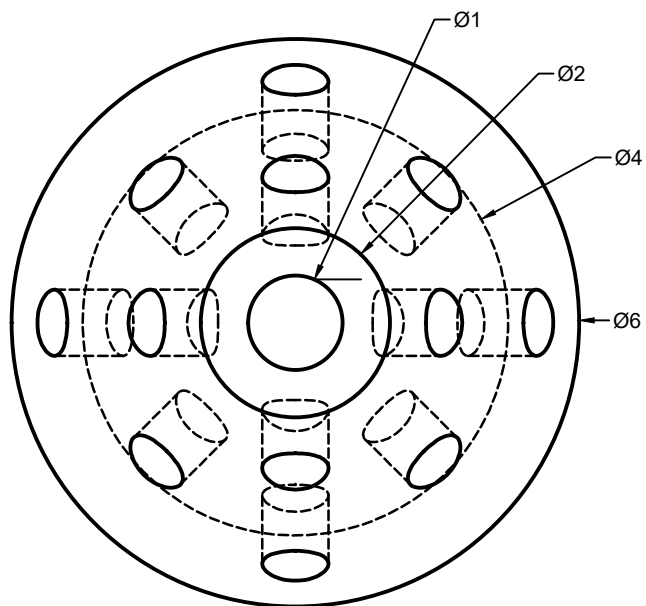


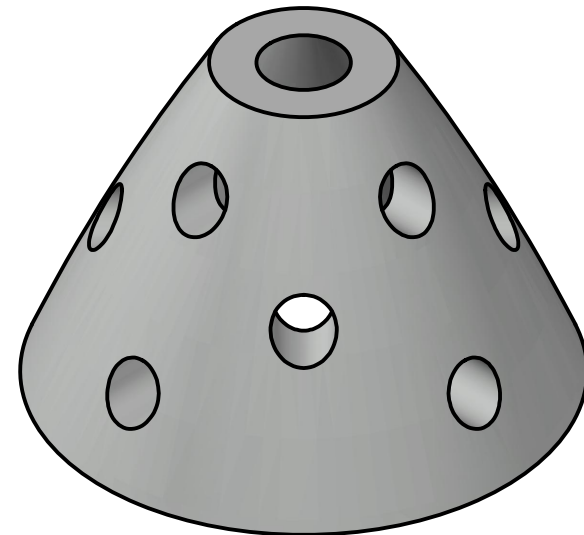
FIG. 4.3. PLACEMENT OF SUBMERGED ARTIFICIAL REEF



ELEVATION



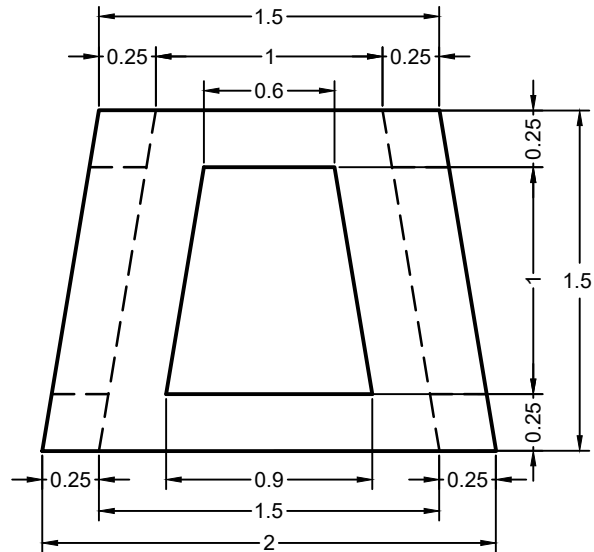
PLAN



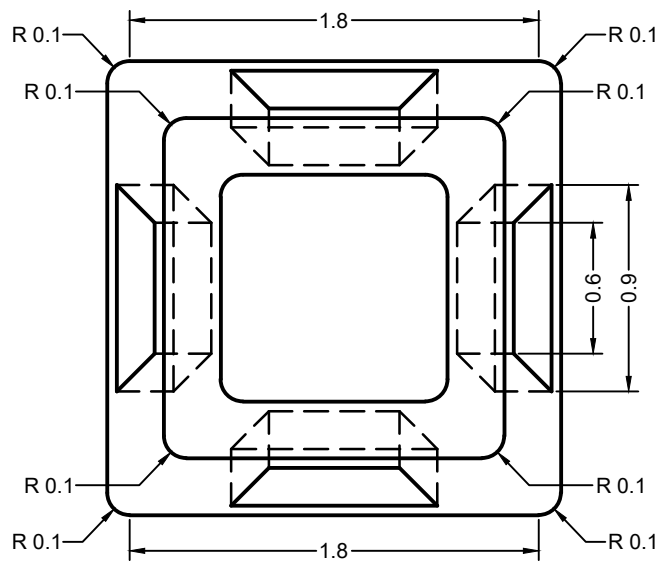
3D VIEW

FIG. 4.4. FRUSTUM CONE REEF

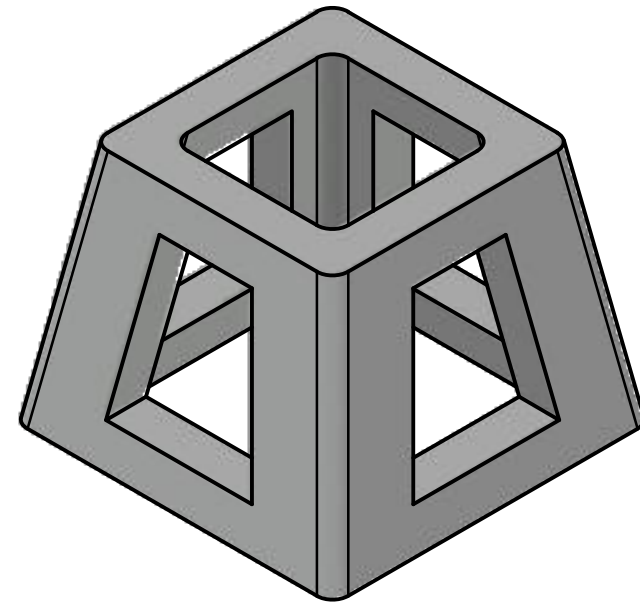
ALL DIMENSIONS ARE IN METERS



ELEVATION



PLAN



3D VIEW

(TO BE PLACED IN MULTIPLE LEVELS LIKE TETRAPODS)

FIG.4.5.TRUNCATED SQUARE PYRAMID REEF

ALL DIMENSIONS ARE IN METERS



## 5 CONCLUSIONS

In order to mainframe the climate change resilience into coastal protection and shoreline management through scientific intervention, the sustainable method of protecting the shore thereby minimizing the adverse effects to the adjacent sites is the placement of artificial reefs at offshore. The reef will be placed at 5 m water depth placed parallel to the shore, implying the arrangement of reefs with 200 m long and 100 m gap between each unit as shown in **Fig.4.2**. The 100 m gap is required to maintain the dynamics of shore as there should be no zero littoral drift and as a socio-economic perspective to help fishermen to sail to shore. The submerged artificial reefs force the high waves to break, which in turn reduce the wave energy reaching the shore.

As a result, out of 991 km of the Tamil Nadu coastline approximately 325 km will be protected in such a manner, so that the eroding sites will be restored and littoral process along the Tamil Nadu coast will remain unaffected. One such study on shoreline stabilization by submerged reef was previously explored by Lee E. Harris in 2006.



## 6 WAY FORWARD

- A) It is suggested to form an expert committee consisting of following members to study and give recommendation.
- i. Prof. R. Sundaravadivelu, Institute Chair Professor, Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai.
  - ii. Mr. M. D. Kudale, Retd. Additional Director, Central Water & Power Research Station, Pune and Member of Maharashtra Coastal Zone Management Authority
  - iii. Dr. P. Chandramohan, Former Scientist of CSIR-National Institute of Oceanography, Goa and presently the Managing Director, Indomer Coastal Hydraulics (P) Ltd., Chennai.
- B) Carryout the flume modelling study on the stability of the submerged artificial reef block size either from IITM, Chennai or CWPRS, Pune.
- C) Involve CMFRI / ZSI / TNFD in finalizing the shape of the submerged artificial block to be more environmental friendly for the marine organisms.



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- <http://www.coastalwiki.org/>