

Cross Shore Profiling and Assessment of Response of Coastal Landforms of Tamil Nadu to Tsunami of 26th December 2004

C. Thanavelu and B. Lakshminarayanan

Abstract

Subsequent to the surprise strike of Tsunami on 26th December 2004, cross shore section measurements and geological studies were taken up along the east coast of Tamil Nadu from Pulicat Lake to Kanyakumari. A total of 45 numbers of profiles across the shore were measured by rapid tacheometric survey to know the extent and elevation of the coastal landforms in conjunction with the run up elevation and inundation distance of the tsunami surge. Based on the type of landforms present in near/back shore area the coast was divided into six categories and their response to the tsunami was assessed. The suggestions on the preparatory measures besides the results are dealt in this paper.

Introduction

Tsunami wave triggered by the world's second largest earthquake of magnitude 9.3 that occurred off Sumatra Coast on 26-12-2004 at about 06.30 hrs, devastated the coasts of Indonesia, Sri Lanka, South India, Thailand, and east coast of Africa. Immediately after the event post tsunami field survey was taken up by the Geologists of Geological Survey of India to study the effects and damages caused and the results were published in the Special Publication No. 89.

In second phase of post tsunami investigation, cross shore section measurements and studies were taken up along the east coast of Tamil Nadu from Pulicat to Kanyakumari. The investigation aimed to measure the parameters of tsunami surge and landforms. Broad lithology, type, extent and elevation of the landforms present in the near and back shore environment are used to categorise the coast. The parameters of the tsunami event like run up elevation, inundation distance and damage in the different coastal categories are considered for assessment of the response.

Geology

The major part of the coastal tract of Tamil Nadu is occupied by coastal sediments, wind blown sand, kankar, calc-tufa, lateritic and calcareous sandstone, limestone and river alluvium of Recent / Quaternary period; sandstone, clay and laterite of Cuddalore Formation of Mio-Pliocene age; hard and compact sandstone, clay, shale, siltstone and shell limestone of Tertiary period. Precambrian rocks of Migmatite, Charnockite and Khondalite Groups and intrusive dykes of dolerite, basalt are occurring in the sectors from Adyar mouth to North of Marakkanam and from Nambiyar mouth to Kanyakumari. Splintery green shales and pebbly, brown sandstone of Lower Gondwana age occur mainly as sub-crops in the stretch between Pulicat and Chennai.

Geomorphology

The coast from Pulicat to Vellar mouth (Parangipettai) in general is indented with two broad bays of North Chennai and Puducherry with a cusped foreland. Where as it is straight in N-S direction from Vellar mouth to

Point Calimere and thereon is E-W direction upto Agniar. Further upto Kanyakumari the coast is embayment coast with two major bays – Palk strait and Gulf of Mannar and a main cusped foreland. A number of small bays with cusped forelands are present within the two major bays.

Younger and older beach, (including teri) dune complex, spits, offshore bars, tidal inlets, estuaries, lagoons, tidal flats, mangrove swamps, salt marshes, strandlines, cheniers, deltas, wave-cut and abrasion platforms and wave-cut terraces etc are the landforms present along the coast.

Cross shore profiling

A total of 45 numbers of profiles across the shore were measured by rapid tachometric survey. Based on the limited level transfers from known permanent / temporary bench marks and data on sea levels published by Survey of India, the coast has been divided into four sectors as Pulicat to Porto Novo, Porto Novo to Nagore, Nagore to Vembar and Vembar to Kanyakumari with the average mean sea level of + 0.74m, + 0.84m, + 0.40m, +0.64m respectively. The profiles were prepared taking these mean sea levels as the reference. The run up elevation was measured based on water marks in trees and plants, buildings and other structures. The outer most limits of the accumulated float deposits on the ground have been taken as inundation distance. The section-wise run up elevation and inundation distance arrived at are given in table - 1.

Response assessment

The run up elevation in general is higher near shore line i.e in the berm area and it gradually reduces towards back shore area. But, in tidal bar island coast the run-up elevation gradually reduces towards the central part and again increases towards the backwater bodies / water ways indicating water surge from all around. The water surge is comparatively more in the coast with steep berm followed by stretches with moderately

sloping and gently sloping berms.

Based on the broad lithology and landforms the coast has been divided into six categories as

1. Tidal bar / Tidal bar island coast
2. Flat coast with low disfigured dunes
3. Coast with barrier dune / dune complex
4. Flat coast with residual dunes
5. Narrow flat coast with dunes
6. Rocky platform coast with dunes

Besides these coastal categories, the response of Tidal inlets and coasts of Pamban Island were assessed.

Tidal bar / Tidal bar island coast

The tidal bars/tidal bar islands were thoroughly inundated from sea overtopping / breaching the recent dunes as well as from the back shore through the sea connected water bodies. Devanampattinam, Sonangkuppam - Singaratoppu, Mulukkuturai -MGR Tittu (South of Parangipettai) and Akkaraipettai were the worst affected villages located in these landforms.

Flat coast with low disfigured dunes

The coastal segment between Ennore and Adyar river (Chennai) mouth is categorised as flat coast with low / disfigured dunes, in which sea water surged to a distance varying from 364 m to 449 m. At the southern end of the Marina beach near light house the sea water surged and joined Buckingham canal in the west.

Coast with barrier dune / dune complex

The coastal stretches from Adyar river mouth, Chennai to Ponnaiyar river mouth, north of Cuddalore; from Upanar (Cuddalore) river mouth to Vellar river mouth (Parangipettai) and from Upanar river mouth (south of Akkaraipettai) to Point Calimere are characterized by dune complexes and called

Table 1: Section wise run up elevation and inundation distance

| Sl. No. | Name of the section | Type of the coast | Average sea level (in m) | Run up Elevation in m | | Inundation (in m) |
|---------|-----------------------|--|--------------------------|-----------------------|------|----------------------|
| | | | | Max. | Min. | |
| 1 | Pulicat | Tidal bar / Tidal bar island coast | 0.74 | 4.2 | 3.72 | Completely inundated |
| 2 | Ennore | Flat coast with low / disfigured dunes | 0.74 | 4.0 | 3.50 | 364 |
| 3 | Marina Beach | Flat coast with low / disfigured dunes | 0.74 | 4.0 | 3.49 | 449 |
| 4 | Besant Nagar | Coast with barrier dune / dune complex | 0.74 | 6.0 | 5.68 | 120 |
| 5 | Tiruvidanthai | Coast with barrier dune / dune complex | 0.74 | 4.4 | 2.19 | 251 |
| 6 | Elanthopu | Coast with barrier dune / dune complex | 0.74 | 4.4 | 2.95 | 439 |
| 7 | Mahabalipuram | Coast with barrier dune / dune complex | 0.74 | 5.0 | 4.44 | 334 |
| 8 | Sadras | Coast with barrier dune / dune complex | 0.74 | 5.0 | 4.78 | 178 |
| 9 | Chinakuppam | Coast with barrier dune / dune complex | 0.74 | 4.2 | 3.48 | 562 |
| 10 | Kaipaniekuppam | Coast with barrier dune / dune complex | 0.74 | 4.2 | 3.82 | 66 |
| 11 | Bommaiyarpalayam | Coast with barrier dune / dune complex | 0.74 | 4.7 | 3.28 | 420 |
| 12 | Veerampattinam | Coast with barrier dune / dune complex | 0.74 | 4.7 | 4.25 | 191 |
| 13 | Talanguda | Flat coast with residual dunes | 0.74 | 4.69 | 2.76 | 792 |
| 14 | Devanampattinam | Tidal bar / Tidal bar island coast | 0.74 | 4.7 | 3.4 | 1250 |
| 15 | Sonangkuppam | Tidal bar / Tidal bar island coast | 0.74 | 4.7 | 2.60 | Completely inundated |
| 16 | Pettai | Coast with barrier dune / dune complex | 0.74 | 4.50 | 3.16 | 468 |
| 17A | Mudasuodai | Tidal bar / Tidal bar island coast | 0.74 | 4.5 | 4.5 | Completely inundated |
| 17B | Parangipettai | Flat coast with residual dunes | 0.74 | 4.5 | 1.5 | 715 |
| 18 | Tirumullaivasal | Flat coast with residual dunes | 0.84 | 5.3 | 2.16 | 1040 |
| 19 | Poombhukar | Flat coast with residual dunes | 0.84 | 5.48 | 1.50 | 922 |
| 20 | Tarangambadi | Flat coast with residual dunes | 0.84 | 6.08 | 1.50 | 583 |
| 21 | Kassakkudimedu | Flat coast with residual dunes | 0.84 | 6.1 | 3.2 | 1666 |
| 22 | Kilvanjorekuppam | Flat coast with residual dunes | 0.84 | 6.02 | 4.44 | 432 |
| 23 | Samanthampettai | Flat coast with residual dunes | 0.40 | 5.43 | 2.28 | 977 |
| 24 | Akkaraipettai | Tidal bar / Tidal bar island coast | 0.40 | 6.02 | 3.79 | Completely inundated |
| 25 | Velankkani | Coast with barrier dune / dune complex | 0.40 | 5.14 | 3.20 | 519 |
| 26 | Vanavanmahadevi | Coast with barrier dune / dune complex | 0.40 | 5.47 | 4.2 | 464 |
| 27 | Kodiyakarai | Coast with barrier dune / dune complex | 0.40 | 2.50 | 1.65 | 186 |
| 28 | Mallipattinam | Narrow flat coast with sand dunes | 0.40 | 1.49 | 1.49 | 48 |
| 29 | Adhipattinam | Narrow flat coast with sand dunes | 0.40 | 1.27 | 1.27 | 18 |
| 30 | Tondi | Narrow flat coast with sand dunes | 0.40 | 1.78 | 1.78 | 54 |
| 31 | Devipattinam | Narrow flat coast with sand dunes | 0.40 | 1.57 | 1.57 | 39 |
| 32 | West of Pamban bridge | Coast with rocky platform and dunes | 0.40 | 1.75 | 1.75 | 10 |
| 33 | Cherankottai | Tidal bar / Tidal bar island coast | 0.40 | 3.40 | 3.40 | 19 |
| 34 | China Erwadi | Coast with rocky platform and dunes | 0.40 | 1.85 | 1.85 | 13 |
| 35 | Mel Mundal | Coast with rocky platform and dunes | 0.40 | 1.84 | 1.84 | 16 |
| 36 | Vembar | Coast with rocky platform and dunes | 0.64 | 3.19 | 3.19 | 48 |
| 37 | Taruvaikulam | Coast with rocky platform and dunes | 0.64 | 3.2 | 1.45 | 165 |
| 38 | Kayalpattinam | Coast with rocky platform and dunes | 0.64 | 3.2 | 2.49 | 183 |
| 39 | Alanthalai | Coast with rocky platform and dunes | 0.64 | 3.2 | 2.51 | 74 |
| 40 | Manapad | Coast with rocky platform and dunes | 0.64 | 3.2 | 2.47 | 142 |
| 41 | Kuttam | Coast with rocky platform and dunes | 0.64 | 3.2 | 2.14 | 114 |
| 42 | Ovari | Coast with rocky platform and dunes | 0.64 | 5.5 | 4.99 | 142 |
| 43 | Kuttankull | Coast with rocky platform and dunes | 0.64 | 3.5 | 1.0 | 206 |
| 44 | Perumanal | Coast with rocky platform and dunes | 0.64 | 4.0 | 2.45 | 64 |
| 45 | Kaluvilai | Coast with rocky platform and dunes | 0.64 | 3.0 | 2.31 | 38 |

as coast with barrier dune / dune complex. The dune complex is located between beach and tidal flat. Width of the dune complex varies from 100 m to 1.5 km and height ranges from 5 m to 20 m. The area on either sides of tidal inlet / river mouths is flat without the near shore dunal line facilitating the tsunami water surge for longer distance. The inundation in this category was mainly restricted to beach and at places sea water entered and inundated the shore parallel inter-dunal depressions by breaching near shore dune line along cross shore inter-dunal depressions. The inundation distance vary from 66m to 562m.

Flat coast with residual dunes

The segment between Coleroon river mouth and Vettar river mouth (Nagapattinam) is characterized by flat coast with residual dunes. The sea water surge reached a distance varying from 432m to 1666m causing loss of life and damage to properties. The fishermen settlements located on top of the residual dunes escaped from inundation.

Narrow flat coast with dunes

The stretch between Agniar river mouth and Vaigai river mouth is characterized by narrow beach of about 15-20m width with dunes of about 1.5m to 3m height. The inundation distance observed in this segment varies from 18m to 54m.

Rocky platformal coast with dunes

The coast from Vaigai river mouth (Periyapattinam) to Kanyakumari is made up of wave-cut and abrasion platforms. The platforms have formed in marine calcareous sandstone and gneissic rock. Recent and older dune complex are formed over the rock platform. Hence this segment is conotated as rocky paltformal coast with dunes. The width of the beach is narrow ranging from 15m to 25m. The inundation distance in this stretch ranges from 10m to 206m depending on the height of the platform/dune.

The inundation was much less in the coast of Pamban Island as it is a wave cut platformal coast with high dunes. Slight rise in water level was reported in the Vedaranyam swamp area in the stretch between Point Calimere to Agniyar river mouth so also in the lagoons. Beach part of the coast of all the categories were completely inundated and caused maximum damage to boats, dwelling units and properties and loss of life

The inundation is maximum (3-5 km) along the tidal inlets and estuaries. Sea water surged and entered through these landforms breach opening the silt / sediment deposits in the creek mouths and traveled longer distance. Piling up of silt and float materials in these channels while receding resulted in bed level increase. The water surged above the banks mainly near the mouth area causing inundation, damage and increase in salinity of soil and ground water.

In general, the near shore run up and damage are maximum in the sector from Ponnaiyar river mouth to Point Calimere followed by the northern sector up to Pulicat, which were hit by direct waves at around 8.30 hrs. Only slight rise in sea water level reported during this time in the southern coast from Agniyar river mouth to Kalluvilai (north of Kanyakumari). The maximum water surge reported around 11.00 hrs in this sector. Recession of sea prior to the main water surge reported from Vembar to Kanyakumari. The water surge and damage are comparatively much less. The reason for this could be the presence of Srilankan Island in the wave front which acted as barrier and bore the brunt of the tsunami waves. Part of the west ward traveling waves from the source area got reflected by Kori Comorin Ridge and traveled back towards east resulting in sea water recession. Part of these waves again got reflected back after hitting the west coast of Srilanka and traveled towards west which was responsible for the maximum and delayed surge.

Preparatory measures

Based on the statistical analysis of the source parameters like magnitude, type of rupture and focal depth of the causative earthquake in conjunction with the historical and recorded earthquake events in the nearest seismo tectonic belts and the parameters of the resultant tsunamis, the magnitude of the 26th December 2004 tsunami can be taken as **maximum**

considered tsunami for the Tamil Nadu coast. Accordingly the inundation limit of this event with some cushion may be taken as **“Set back line”**. The preparatory measures suggested to face such type of hazards include

1. Ban / restriction of new settlements within the set back line
2. Relocation of the existing settlements well beyond the set back line

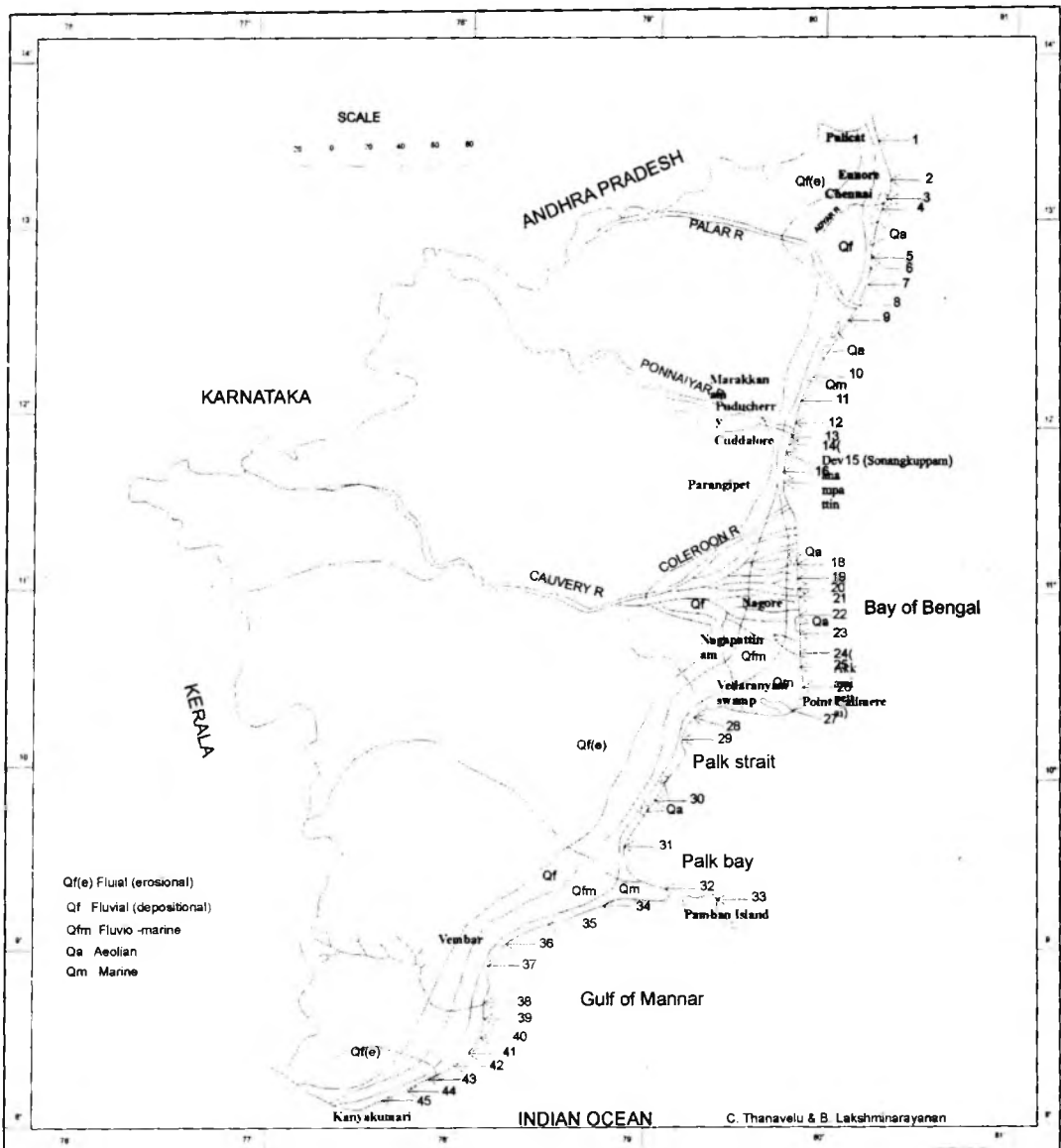


Fig.1: Map showing location of cross shore profiles along east coast, Tamil Nadu

3. Stabilisation of existing dunes particularly the dune complex nearest to the shoreline
4. Growing of sand dunes by artificial methods particularly in the cross shore depressions in the segments of the coast with barrier dune / dune complex.
5. Construction of curved sea walls/ formation of stone revetment in conjunction with earth embankment in the stretches of flat coast with residual dunes, flat coast with low / disfigured dunes and in sand flats without the near shore dunal line on either sides of tidal inlet / river mouths within the coast with barrier dune / dune complex.
6. Relocation of the settlements in tidal bar / tidal bar island coast. Alternatively construction of curved sea walls/ formation of stone revetment in conjunction with earth embankment all around or only on the seaward side with breast wall gate structures in the mouth of back water bodies.

The above preparatory measures can be provided individually or in combination.

Conclusion

Cross shore section measurements and assessment subsequent to the tsunami disaster of 26th December 2004 along the east coast of Tamil Nadu indicate that the inundation and damage were dependent on the landforms in the near and back shore area. The tidal bars / tidal bar islands were thoroughly inundated resulting in to severe damages. The stretches from Ennore creek to Adyar mouth and Coleroon mouth to Nagapattinam (Cauvery delta) belonging to flat coast with low / disfigured dunes and flat coast with residual dunes categories bore the brunt of the tsunami. Water surge and damage was minimum in rocky paltformal coast with dunes / dune complex and in the segment of narrow beach with dunes.

The magnitude of this tsunami can be taken

as **maximum considered tsunami** for the Tamil Nadu coast and the inundation limit of this event with some cushion may be taken as "**Set back line**". The inundation distance varied from 10 m to 142 m in the coasts with rocky platform and dunes, from 18 m to 78 m in the narrow coast with sand dunes, from 66 m to 562 m in the coast with barrier dunes / dune complex and from 449 m to 1666 m in the stretches of flat coast with low / disfigured dunes and flat coast with residual dunes.

In nutshell, the inundation distance and damage by the tsunami are varied vastly depending on the type of the coast and the landforms present in the near shore environment. The present Coastal Regulation Zone Act which prohibits construction activity of any sort within an uniform 500 m may not hold good and needs modification. Hence, it is recommended that a new "**Coastal regulation zone**" may be arrived at according to the landform(s). In order to refine the coastal categories and arrive at an accurate set back line further detailed investigation at closer intervals is to be carried out necessarily. In addition, the data generated by other branches of science and engineering may have to be considered while finalising a new "**Coastal regulation zone**".

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