SHORELINE CHANGE ANALYSIS OF THE VIZHINJAM COAST USING BEACH PROFILES AND SATELLITE IMAGES

ANNUAL REPORT
(October 2022 to September 2023)

FOR

ADANI VIZHINJAM PORT PVT LIMITED

PREPARED BY

Coastal and Environmental Engineering Division

NATIONAL INSTITUTE OF OCEAN TECHNOLOGY

CHENNAI

February, 2024

NATIONAL INSTITUTE OF OCEAN TECHNOLOGY
(Ministry of Earth Sciences, Government of India)
NIOT Campus, Velachery-Tambaram Road,
Pallikkaranai, Chennai-600 100
Tel: +91 044 66783440,
Fax: +91 044 22460275
Email: postmaster@niot.res.in
Web: www.niot.res.in

Report Summary

<table>
<tr><td colspan="3">Client
Adani Vizhinjam Port Pvt Limited.</td><td colspan="3">Client's representative
Mr. Hebin, Manager- Environment, AVPPL, Trivandrum</td></tr>
<tr><td colspan="3">Project
Shoreline change analysis of the Vizhinjamusing beach profiles and satellite images</td><td colspan="3">Project No.NIOT/CEE/1323</td></tr>
<tr><td>1</td><td>Annual Report-Final</td><td>SSP/ANV</td><td>RAJ</td><td>BKJ</td><td>21-June-2024</td></tr>
<tr><td>0</td><td>Annual Report-Draft</td><td>SSP/ANV</td><td>RAJ</td><td>BKJ</td><td>23-February-2024</td></tr>
<tr><td>Revision</td><td>Description</td><td>By</td><td>Checked</td><td>Approved</td><td>Date</td></tr>
<tr><td colspan="3">Key words</td><td colspan="3">Classification
☐ Open
☐ Internal
☒ Proprietary</td></tr>
<tr><td colspan="4">Distribution
AVPPL</td><td colspan="2">No of copies
1</td></tr>
<tr><td colspan="4">NIOT, Chennai.</td><td colspan="2">1</td></tr>
</table>

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Executive Summary

This report includes a study on shoreline change assessment along the 40-km stretch of the Vizhinjam coast from October 2022 to September 2023, using high-resolution satellite images (0.5m spatial resolution) and field-measured beach profile data.

The shoreline change analysis has been carried out using multi-date satellite images to estimate the rate of change in terms of the distance of the eroded or accreted coast, and the rate of change was calculated using the cross-shore profile in terms of the volume of beach sediment.

From onshore beach profile analysis from October 2022 to September 2023, it was found that beaches exhibited erosion was observed at Shangumugham South (CSP69), Vettucaud (CSP74) and Kochuveli to Valiyaveli (CSP76-78) while accretion at Edappadu Beach (CSP02), Kovalam (CSP42,43), Panathura North (CSP52), Shangumugham North (CSP70-71), Vettucaud (CSP73), Kochuveli (CSP75) and Thumba (CSP80-81).).There is no data from CSP 15 to 41, 44,51, 53, 66, and 72. Due to rough sea conditions, the offshore survey was not carried out in September 2023. Hence, offshore beach profile analysis was not carried out from October 2022 to September 2023.

The overall shoreline changes using satellite images from October 2022 to September 2023 are erosion at Poovar (CSP15), Pulluavila (CSP27), Karumkulam (CSP24), Mullur (CSP36-37), Punthura (CSP56), Valiyathura (CSP65), Shangumugham (CSP69), and Thumba (CSP80); while accretion is noticed at Edapadu beach (CSP02), Poovar (CSP16-18), Karumkulam (CSP25-26), Adimalathura (CSP31-34), Kovalam (CSP43), Punthura (CSP57), Shangumugham north (CSP70), Vettucaud (CSP73), Kochuveli (CSP75), Valliyaveli (CSP76-79) for the period from October 2022 to September 2023.

The erosion and accretion spots identified from satellite images and beach profile analysis for the period from 2015 to 2023 have been compared. The erosion and accretion spots identified from satellite images before and after 2015 using high-resolution satellite images have also been compared. The results of the previous annual reports (2018 to 2022) have been compared with the shoreline changes from the satellite images and the beach volume changes from the beach profile data from 2015 onwards. Shoreline trend analysis was also carried out for six hotspot locations: Valliyathura, Shangumugham, Punthura, Vizhinjam, Adimalathura, and Poovar.

The breakwater of the Port protrudes about 1.5 kilometres into the sea in line with the existing headlands in the north. Coastal erosion at Valliyathura and Shangumugham beaches, which are 13 km and 15 km away from the north of the Vizhinjam port breakwater, may not have much impact due to the construction of the Port. Recently constructed coastal interventions (Groynes and seawall) on the northern side of the port are required to be assessed for their impact on the shoreline change, including the incidence of cyclones, coastal flooding, high wave activities and storm surges.

Based on several inputs (multi-date satellite imagery, multi-date onshore and offshore beach profiles, data on climatic events, wave observation data, port activity, etc.) and the subsequent analysis of shoreline changes, it is contingent that the spots of erosion have not been altered much since the commencement of the port construction.

1 INTRODUCTION

NIOT has been engaged by Adani Vizhinjam Port Private Limited (AVPPL) in the studies on shoreline change analysis along Vizhinjam coast using high resolution satellite images for the period October 2017 to September 2018 (SO No. 5700227001 dated 15/11/2017), October 2018-September 2019 (SO No. 5700262831 dated 07/03/2019), for the year October 2019- September 2020 (SO No. 5700285305 dated 23/03/2020), for the year October 2020-September 2021 (SO No. 5700289439 dated 28/09/2020) and for the year October 2021-September 2022 (SO No. 5702005927 dated 12/04/2022). These reports were submitted by Vizhinjam International Seaport Limited (VISL) for vetting by the NGT-appointed expert committee and shoreline monitoring cell. After incorporating the comments received from both the committees, NIOT submitted the final study reports and the same were forwarded by VISL to the Member Secretary, NGT-appointed expert committee, and they were also uploaded onto the website of Kerala Coastal Zone Management Authority (KCZMA).

Subsequently, with reference to the mail dated 12/10/2022, NIOT has received the work order (SO No. 5702010119 dated 21/03/2023) to carry out the study on shoreline change analysis using beach profiles and high-resolution satellite images for the year October 2022 to September 2023. Accordingly, NIOT procured the high-resolution satellite data (10km on either side of Vizhinjam port) through the National Remote Sensing Centre (NRSC) and obtained field-measured data sets (beach profile) from AVPPL to study the shoreline changes analysis for a 40 km stretch along Vizhinjam coast.

This document reports the analysis and observation of the study on the shoreline change analysis carried out over a 40 km stretch, keeping Vizhinjam Port as a centre, using the available high-resolution satellite images and beach profile data from October 2022 to September 2023.

2 OBJECTIVES

i. To assess the shoreline change over the 20 km coastline on either side of Vizhinjam port using satellite images and beach profile data from October 2022 to September 2023.
ii. To identify the erosion and accretion hotspots using available high-resolution multispectral images acquired by remote sensing satellites and field-measured beach profile data from October 2022 to September 2023.
iii. Vetting of data and modelling reports

3 METHODOLOGY & DATA USED

The methodology flowchart is shown in **Figure 3.1**. The shoreline change analysis has been carried out using multi-date satellite images to estimate the rate of change in terms of the distance of the eroded or accreted coast, and the rate of change was calculated using the cross-shore profile in terms of area and volume of beach sediment. The shoreline has been extracted from the satellite images after rectification and co-registration. The shoreline change rate between October 2022 and September 2023 has been analyzed. Further, the trend has been compared with the beach profile data. Digital Shoreline Change Analysis System (DSAS) is a tool that works within the Geographic Information System (ArcGIS) software. DSAS computes the rate-of-change statistics for a time series of shoreline vector data. It is also helpful for computing the rates of change for other boundary change conditions that incorporate an identified feature position at discrete times. This method of integrating multi-date satellite images and beach profile data is a time-tested approach and has been used worldwide for similar studies on shoreline change (Thieler et al., 2017).

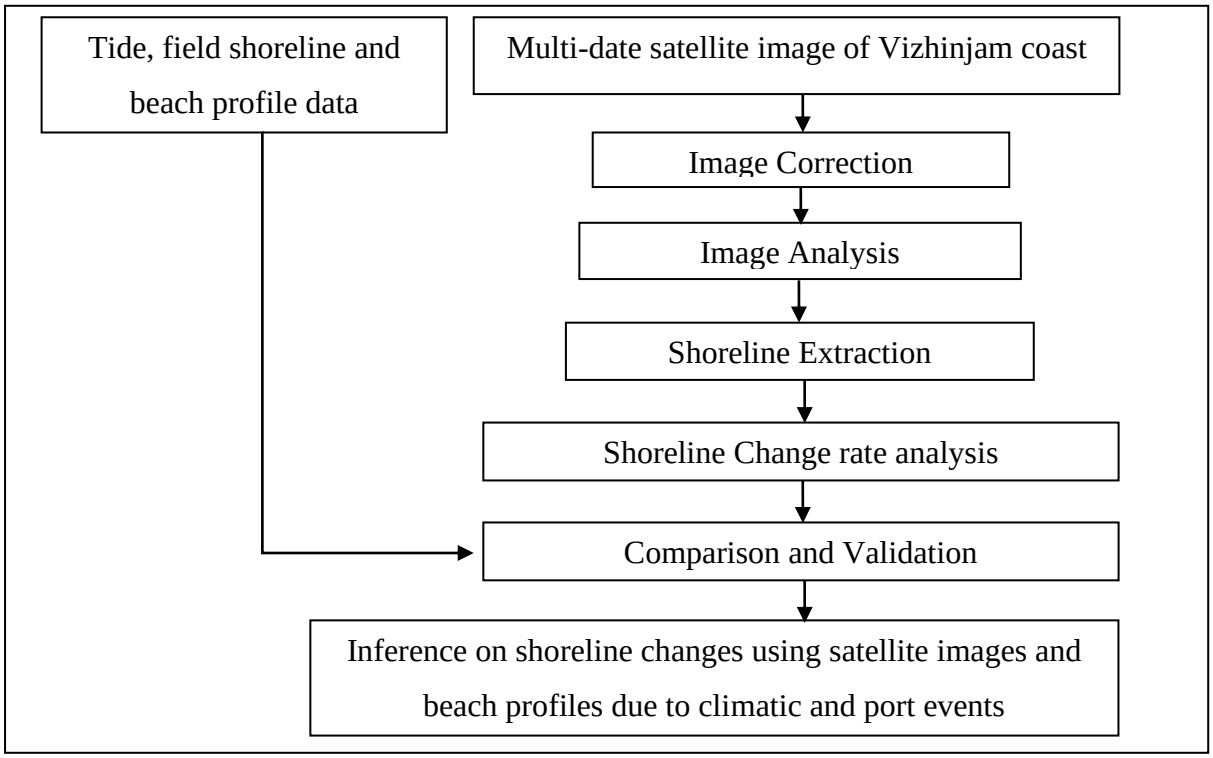


Figure 3.1Flowchart of the methodology adopted

Similarly, the monthly beach profile data perpendicular to the 40Km Vizhinjam shoreline over the period from October 2022 to September 2023 was collected at intervals of 500m, using RTK or total station landward up to 100m distance from the HTL or +2m elevation w.r.t. the HTL and by using shallow draft boats, sledge and other suitable techniques seaward down to 10m CD. The shoreline change analysis using beach profile data has been carried out using SANDS software. The detailed methodology of the shoreline change analysis using satellite images and beach profile analysis has been provided in the Annual Reports of October 2017 to September 2018, October 2018 to September 2019, October 2019 to September 2020, October 2020 to September 2021 and October 2021 to September 2022 submitted to NGT Expert committees through VISL.

3.1 Shoreline change analysis from Satellite images

3.1.1 Short-Term Shoreline Change Analysis

The end point rate (EPR) is estimated by dividing the distance of net shoreline movement by the time elapsed between the oldest and the most recent shoreline (**Figure 3.2**). The significant advantages of the EPR are the ease of computation and the minimal requirement of only two shoreline dates. The major disadvantage is that in cases where more data are available, the additional information is ignored.

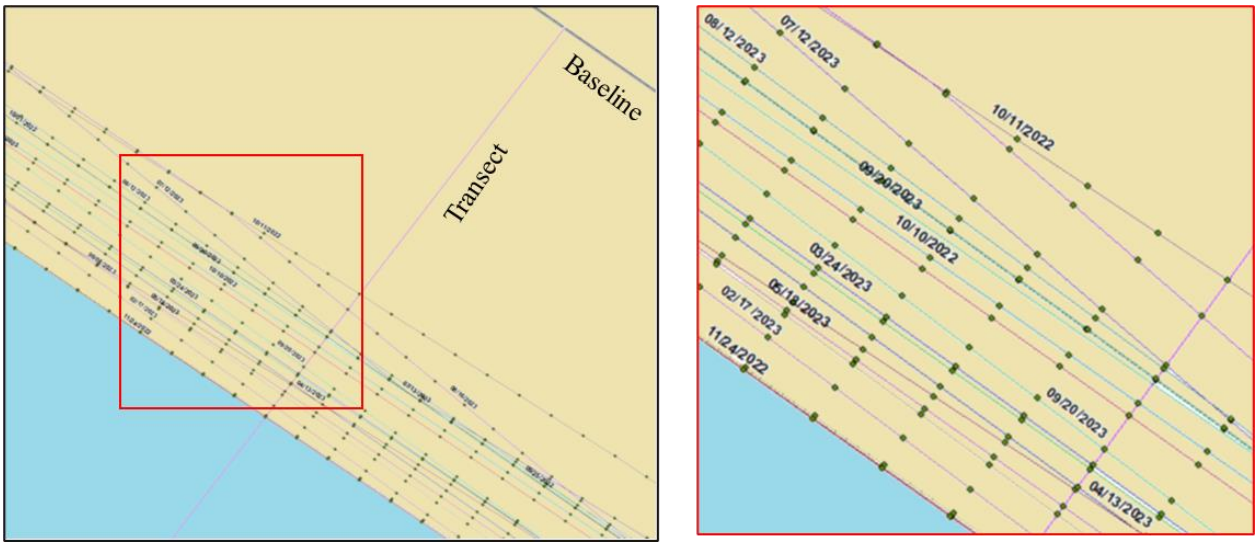


Figure 3.2 Estimation of Short-Term Shoreline Change (EPR)

3.1.2 Long-Term Shoreline Change Analysis

A linear regression rate-of-change (LRR) statistic is determined by fitting a least-squares regression line to all the shoreline points for a particular transect **Figure 3.3**. The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of

each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line.

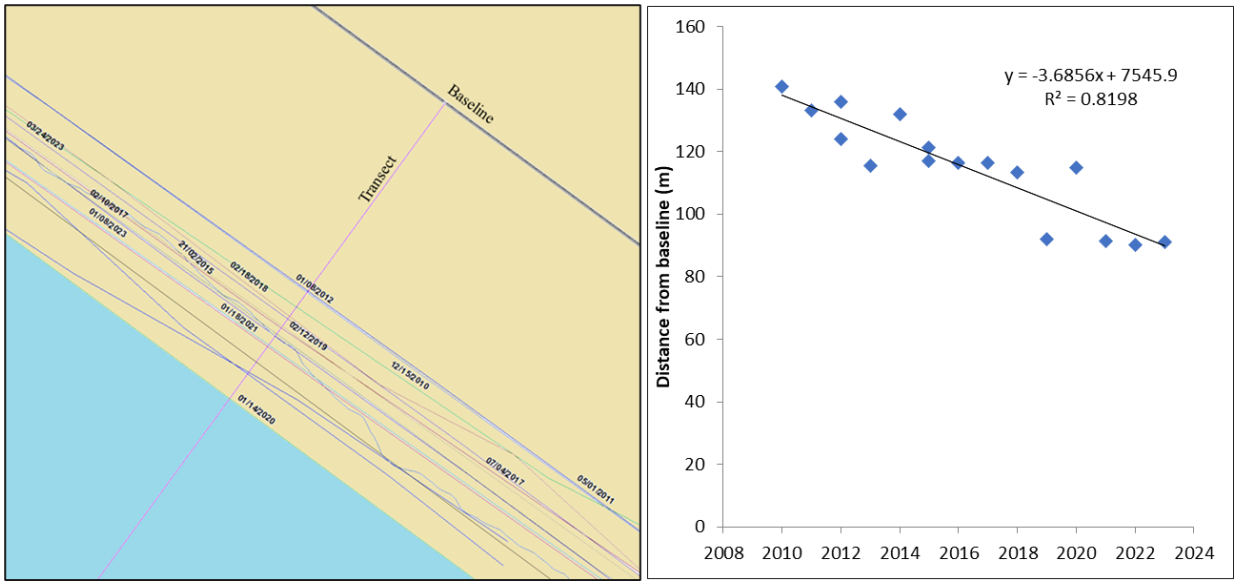


Figure 3.3 Estimation of Long-Term (LRR) Shoreline Change Analysis

3.1.3 Satellite images used

The input high-resolution satellite images (Table 3.1) for the stretch of 10km on either side of Vizhinjam Port have been procured from the vendors listed by the National Remote Sensing Centre. Sentinel 2 images are acquired free of cost from the European Space Agency to study the monthly changes along the shoreline for a 40km stretch from October 2022 to September 2023.

Table 3.1 High-resolution satellite image data used for shoreline change analysis

Satellite	Date	Corresponding Tide (m)	Sensor Bands	Resolution (m)
World View-2	24-01-2012	0.125	VISNIR (Multispectral)	0.5
	26-02-2015	0.289		
	24-10-2021	0.552		
	19-01-2022	0.640		
	01-10-2022	0.498		
	04-11-2022	0.880		
	18-12-2022	0.689		
	04-01-2023	0.663		
	18-02-2023	0.604		
	24-03-2023	0.380		
Satellogic	21-05-2023	0.573	VISNIR (Multispectral)	0.7
	09-06-2023	0.215		
	15-07-2023	0.810		
	11-08-2023	0.661		
	14-09-2023	0.611		
Cartosat 2	12-02-2011	0.283	PAN	1

	30-01-2021	0.600		
Sentinel 2	10-10-2022	0.747	MSI	10
	24-11-2022	0.005		
	29-12-2022	0.459		
	08-01-2023	0.604		
	17-02-2023	0.517		
	16-03-2023	0.388		
	13-04-2023	0.271		
	23-05-2023	0.381		
	22-06-2023	0.301		
	12-07-2023	0.661		
	16-08-2023	0.561		
	09-09-2023	0.607		

3.1.4 Beach Profiles

Shoreline Change analysis using Cross Shore Profile (CSP) has been done as part of the Shoreline Monitoring Programme. CSP data is being collected monthly by the surveying agency engaged by AVPPL every month at 81 profile lines along a stretch of 40 km (From February 2015 to October 2023). The locations of the CSP lines are shown in **Figure 3.4**, and the corresponding landmarks and location names are given in Table 3.2. Due to rough sea conditions along the Vizhinjam coast and agitation by the locals, only an onshore survey was carried out, and the offshore part of the cross-shore profiling was carried out from December 2022 to May 2023.

Figure 3.4 Cross Shore Profiles lines on either side of the Vizhinjam Port

Cross Shore Profile (CSP) surveys have been carried out as two components Viz.:

(1) CSP Surveys (onshore) using RTK (Real Time Kinetic) GPS System landward up to 100m distance from HTL or +2m elevation w.r.t. HTL and

(2) CSP Surveys (offshore) using multi-beam echo sounder system to cover upto10m CD; collected monthly (4 CSP Lines (CSP-02 (Edapadu Beach), CSP-35 (Azhimala), CSP-64 (Valliyathura) and CSP-74 (Vettucaud)) up to a depth of 20 m in January, May, August and October as per the shoreline committee suggestion vide MoM of meeting dated 13th February 2019). The surveying agency combines, processes, and transfers these data sets to NIOT monthly.

Table 3.2 Names of Landmark places and site conditions around each CSP line

CSP NOs.	Region	LANDMARK	LOCATION	SITE CONDITION
CSP-01	SOUTH OF PORT	CATHOLIC CRISMATIC PRAYER CENTER	EDAPPADU BEACH	Seawall
CSP-02				Beach
CSP-03				Seawall
CSP-04		ST.MARYS CHURCH	VALLAVILAY	Seawall
CSP-05				Seawall
CSP-06				Seawall
CSP-07		ST.NICOLAS CHURCH	NEERODY	Seawall
CSP-08				Seawall
CSP-09				Seawall
CSP-10		SREE BHADRAKALI TEMPLE	POZHIYOOR	Seawall
CSP-11				Seawall
CSP-12				Seawall
CSP-13		ST.MATHEWS CHURCH	PARUTHIYOOR	Seawall
CSP-14		CHURCH OF CRIST		Seawall
CSP-15		POOVAR ISLAND RESORT	POOVAR BEACH SOUTH	Beach
CSP-16				Beach
CSP-17				Beach
CSP-18		POZHIKARA BEACH	POOVAR	Beach
CSP-19				Beach
CSP-20		ST.ANTONYS CHAPEL	POOVAR BEACH NORTH	Beach
CSP-21				Beach
CSP-22		ST.ANTONYS CHURH	KARUMKULAM	Beach
CSP-23				Beach
CSP-24				Beach
CSP-25				Beach
CSP-26				Beach
CSP-27		GOTHAMBU ROAD	PULLUVILA	Beach
CSP-28				Beach
CSP-29				Beach
CSP-30				Beach
CSP-31		ADIMALATHURA CATHOLIC CHURCH	ADIMALATHURA	Beach
CSP-32				Beach
CSP-33				Beach
CSP-34				Beach
CSP-35		AZHIMALA TEMPLE	AZHIMALA	Rocky Area
CSP-36		NAGAR BHAGAVATHY TEMPLE	MULLUR	Beach
CSP-37				Beach
CSP-38	PORT	ADANI RECLAMATION AREA	ADANI PORT OFFICE VIZHINJAM	Seawall
CSP-39				Beach
CSP-40				Beach
CSP-41	NORTH OF	VIZHINJAM LIGHT HOUSE	KOVALAM	Beach

CSP-42	PORT			Beach
CSP-43				Beach
CSP-44				Beach
CSP-45				Seawall
CSP-46				Seawall
CSP-47		SAMUDRA BEACH PARK	KOVALAM (NORTH)	Seawall
CSP-48		MOSQUE	PANATHURA (SOUTH)	Seawall
CSP-49				Seawall
CSP-50		PANATHURA TEMPLE	PANATHURA (NORTH)	Seawall
CSP-51				Beach
CSP-52				Beach
CSP-53		PUNTHURA FISH MARKET	PUNTHURA	Beach
CSP-54				Seawall
CSP-55				Seawall
CSP-56				Seawall
CSP-57				Seawall
CSP-58		BEEMA PALLY	BEEMA PALLY	Seawall
CSP-59				Seawall
CSP-60				Seawall
CSP-61		CHERIYATHURA SPORTS GROUND	CHERIYATHURA	Seawall
CSP-62				Seawall
CSP-63		VALLIYATHURA BRIDGE	VALLIYATHURA	Seawall
CSP-64				Seawall
CSP-65				Seawall
CSP-66				Beach
CSP-67				Seawall
CSP-68		SHANGUMUGHAM BEACH	SHANGUMUGHAM (SOUTH)	Seawall
CSP-69				Beach
CSP-70		ST.PETERS CHURCH	SHANGUMUGHAM (NORTH)	Beach
CSP-71				Beach
CSP-72		VETTUCAUD CHURCH	VETTUCAUD	Beach
CSP-73				Beach
CSP-74				Beach
CSP-75		VELI CHILDRENS PARK	KOCHUVELI	Beach
CSP-76				Beach
CSP-77				Beach
CSP-78		ST.THOMAS CHURCH	VALIYA VELI	Beach
CSP-79				Seawall
CSP-80		CHRISTIAN BROTHEREN CHURCH	THUMBA	Beach
CSP-81				Beach

The data received from the surveying agency was analyzed by plotting each profile and by using SANDS software. This exercise aimed to establish a base data to compare profiles with surveyed data from different locations for different seasons. This data shall serve to assess the beach profile after the construction of the Port at Vizhinjam in the future. The difference, if any, shall be investigated further to understand the impact of the Port on the shoreline evolution. The profiles for different months were plotted location-wise. It is accepted that beach profiles can only be of actual use when surveys are carried out, starting at the same place and moving in the same direction (the Origin and Orientation of the profile). SANDS software stores the beach profile

surveys to be viewed graphically and identifies and analyzes the trends in beach levels at a location over time. The 'Beach Profile Graph' allows the user to plot and compare beach profiles from different/multiple locations.

During the analysis of cross-shore profiles, it was observed that some of the profiles appeared distorted, possibly due to some errors during the survey. These profiles are either discarded or manually corrected to the earlier profiles. The profiles corresponding to the Vizhinjam Port area are not considered and mentioned as a development zone.

After qualitative and quantitative reprocessing for shoreline change assessment, the CSP data is directly imported to SANDS. The following flow chart (**Figure 3.5**) explains the process and workflow in SANDS.

Figure 3.5 Work Flow in SANDS

3.2 Analysing Beach Profiles using SANDS

SANDS allows for any number of beach profile survey records to be stored at each profile location over a period. This database has been used to determine beach-level stability and long-term trends. The two main Beach Profile Analyses are Profile Analysis by Level and Profile Analysis by Chainage.

3.2.1 Profile Analysis by Level

Profile analysis 'by Level' analyses the changes in the chainage at which certain levels occur (**Figure 3.6**). In other words, this analysis looks at horizontal strips of the profile.

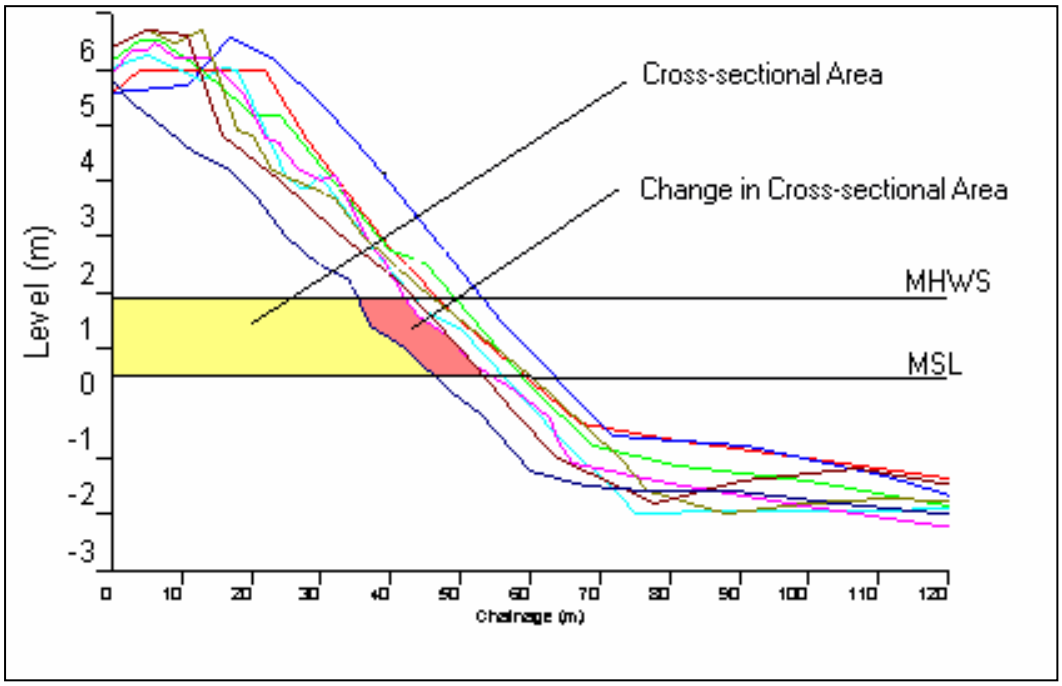


Figure 3.6Profile Analysis by Level

3.2.2 Profile Analysis by Chainage

Profile analysis 'by Chainage' method analyses the changes in level at certain chainages. In other words, this analysis looks at vertical strips of the profile (**Figure 3.7**).

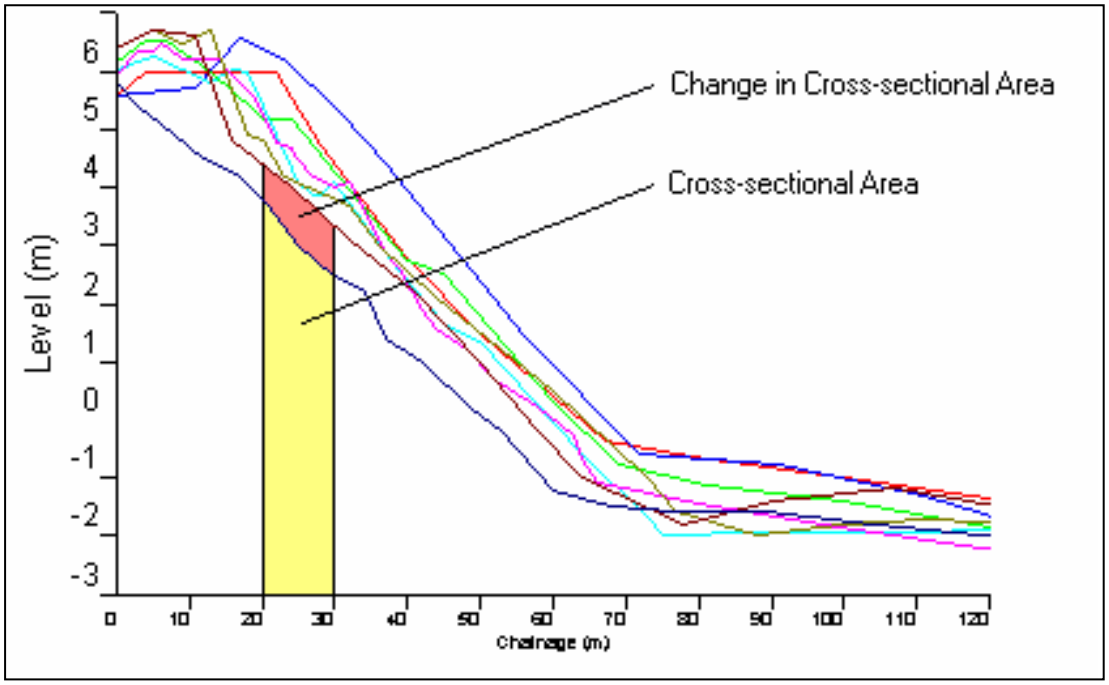


Figure 3.7Profile Analysis by Chainage

SANDS estimates the profile changes and volumes of pre-defined areas based on the above methods. It also enables us to put all beach profile locations together and analyze the volumes of these units. SANDS calculates the profile accretion / Error by directly comparing profiles and displays the results within a GIS-style plan-view format to give striking visual results.

4 RESULTS OF THE ANALYSES

In the present study, the shoreline rate of change statistics from a time series of multiple shoreline positions of a 40 km coastal stretch (20 km either side of Vizhinjam Port) has been taken into account for shoreline change estimation using satellite images. The result of the shoreline change analysis carried out from October 2022 to September 2023 has been examined.

Based on the rate of change over the period being considered, areas of shoreline change have been categorized into five classes. They are high accretion (>5m/year), moderate accretion (5m to 1m/year), stable coast (1m to -1m/year), moderate erosion (-1m to -5m/year), high erosion (<-5m/year).

The observations from the beach profile analysis done using SANDS for the entire 40 km stretch have been presented as monthly changes in the beach volume for a period from October 2022 to September 2023, and beach volume changes between October 2021-October 2022, February 2022- February 2023, May 2022-May 2023 and September 2022-September 2023 also have been worked out and presented in this report. Monthly beach volume changes have been assessed by comparing the month-to-month profiles in **Section 4.1**. The erosion and accretion are highlighted with red and green colour fill in the charts for better understanding. The results shown in the charts are also presented in the tables.

4.1 Results of Beach Profile Analysis

The beach profile data consists of both the onshore and offshore profiles.

No onshore survey was carried out at locations CSP66, 72 in September 2022, CSP15-37, CSP40a-41, CSP53, and CSP64a in October 2022, CSP23-28, CSP29, CSP31-34, CSP35A-37, CSP40A-41, CSP53 in December 2022, and CSP29, CSP30, CSP35, and CSP64A in January 2023. CSP29, CSP35, and CSP64A in March 2023; CSP23-30, CSP35, and CSP64A in April 2023; CSP23-32, CSP35, and CSP64A in May 2023; CSP23-35A,CSP41 in June 2023; July 2023; August 2023; and September 2023.

The onshore and offshore surveys at all these locations could not be carried out in November 2022. No offshore survey was carried out for October 2022, June 2023, and September 2023 due to unfavourable weather conditions. CSP1-16 and 25 offshore lines could not be surveyed in December 2022; CSP02 was not surveyed in February 2023. CSP01-17, CSP20, CSP35-37, CSP59, and CSP69-81 were not surveyed for May 2023.

4.1.1 Monthly Beach Volume variations for October 2022 to September 2023 for the onshore profiles

This report contains the monthly beach volume changes from October 2022 to September 2023 and has been represented graphically in Figures 4.1 to 4.10 and Table 4.1. At CSP44, the data was found to be the to be the same for all months. At CSP51, only a distance of 9m was surveyed. Hence, these profiles were excluded from the analysis for all months.

In September 2022, CSP43 was found to be erroneous. Hence, the profile has not been included in the analysis for October 2022. Accretion is marked at Edappadu Beach (CSP02), Shangumugham South to North (CSP69-70), Vettucaud to Kochuveli (CSP73-CSP75), and Thumba (CSP80-81). Beaches reported erosion at Kovalam (CSP 42), Panathura North (CSP 52), Shangumugham North (CSP 71), and Kochuveli to Valiyaveli (CSP 76–78).

Analysis for December 2022 could not be done since there was no data in November 2022.

At CSP71, the same data was found for December 2022 and January 2023. Hence, the profile was excluded from the January 2023 analysis. Accretion was noted at Poovar (CSP18-19), Panathura North (CSP52), and Valliyathura (CSP66) in January 2023. Erosion was found at Edappadu Beach (CSP02), Poovar South (CSP15–17), Poovar North to Karumkulam (CSP20–22), Kovalam (CSP42–43), Shangumugham South to North (CSP 69–70), Vettucaud to Valiyaveli (CSP72–78), and Thumba (CSP80–81) in January 2023.

In February 2023, beaches exhibited accretion at Edappadu beach (CSP02), Poovar South-Karumkulam (CSP15-24), Karumkulam to Pulluvila (CSP26-28), Adimalathura (CSP31), Adimalathura (CSP33-34), Azhimala to Mullur (CSP35A-37), Kovalam (CSP40A-43), Panathura north (CSP52), Shangumugham south (CSP69), Vettucaud-Valiyaveli (CSP72-78), and Thumba (CSP80-81). Erosion was reported at Karumkulam (CSP25), Adimalathura (CSP32), Punthura (CSP53), Valliyathura (CSP66), and Shangumugham North (CSP70).

In March 2023, accretion was shown at Edappadu Beach (CSP02), Poovar South (CSP16–17), Poovar (CSP20–21), Karumkulam (CSP23–26), Adimalathura (CSP31–34), Azhimala (CSP35A), Kovalam (CSP41), Panathura North to Punthura (CSP52–53), Shangumugham south to Vettucaud (CSP69–73), and Kochuveli to Valiyaveli (CSP77–78). Erosion was displayed at Poovar south (CSP15), Poovar (CSP18–19), Karumkulam (CSP22), Pulluvila (CSP27–28), Pulluvila (CSP30),

Mullur (CSP36–37), Kovalam (CSP40A), Kovalam (CSP42–43), Valliyathura (CSP66), Vettucaud to Kochuveli (CSP74–76), and Thumba (CSP80–81) in March 2023.

At CSP66, only a 5-meter beach has been surveyed. Hence, the profile was excluded from the analysis for April 2023. In April 2023, accretion was observed at Poovar South (CSP15), Poovar South to Poovar North (CSP17–20), Karumkulam (CSP22), Adimalathura (CSP31, CSP33), Mullur (CSP36), Kovalam (CSP42–43), Panathura north (CSP52), Shangumugham south (CSP69), Shangumugham north (CSP71), Vettucaud (CSP74), Kochuveli (CSP76), and Thumba (CSP81). Erosion recorded at Edappadu beach (CSP02), Poovar South (CSP16), Karumkulam (CSP21), Adimalathura (CSP32, CSP34), Azhimala (CSP35A), Mullur (CSP37), Kovalam (CSP40A-41), Punthura (CSP53), Shangumugham north (CSP70), Vettucaud (CSP72-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78), and Thumba (CSP80).

In May 2023, accretion was recorded at Edappadu Beach (CSP02), Poovar South (CSP15), Poovar South (CSP17), Poovar (CSP19), Poovar North (CSP21), Adimalathura (CSP33-34), Azhimalathura to Mullur (CSP35A-36), Kovalam (CSP41), Kovalam (CSP43), Panathura North to Punthura (CSP52-53), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78), and erosion recorded at Poovar south (CSP16), Poovar (CSP18), Poovar north (CSP20), Karumkulam (CSP22), Mullur (CSP37), Kovalam (CSP40A), Kovalam (CSP42), Shangumugham south (CSP69), Vettucaud (CSP74), Kochuveli (CSP76) and Thumba (CSP80-81).

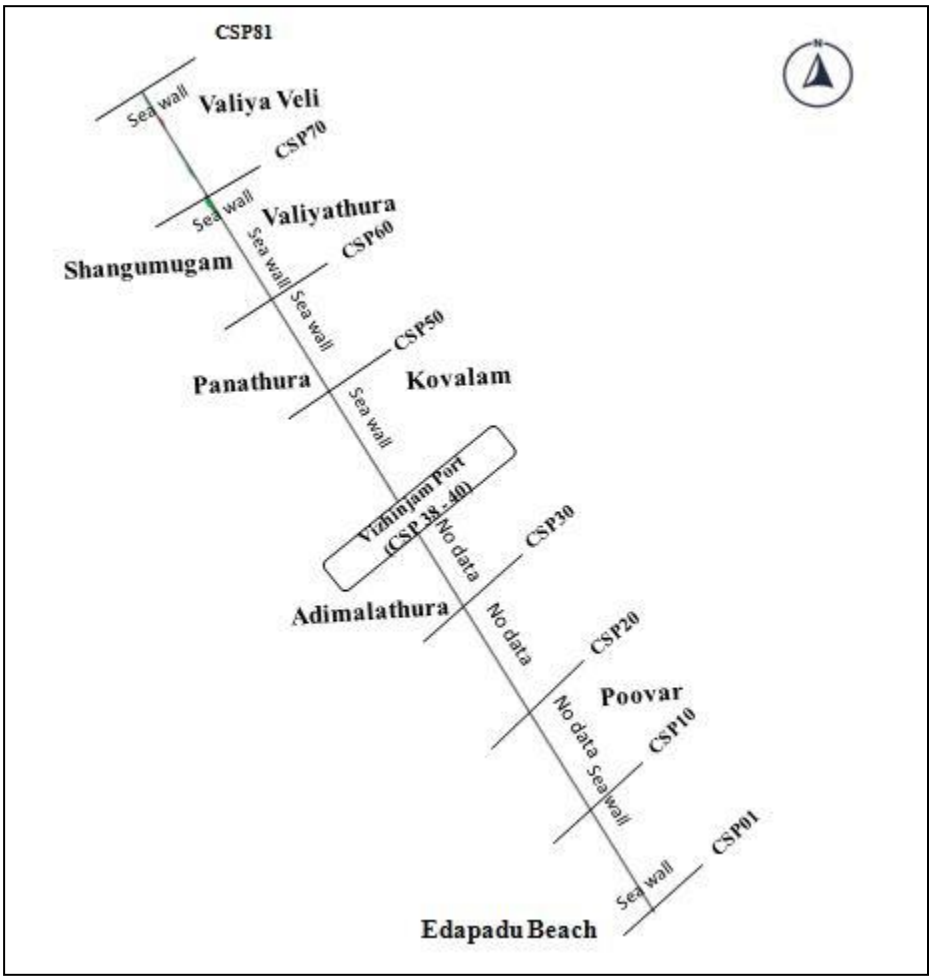
At CSP66, CSP70, CSP72, and CSP73, only a distance of less than 10m was surveyed. Hence, these profiles were excluded from the June 2023 analysis. Accretion noted at Poovar north to Karumkulam (CSP20-22), Kovalam (CSP43), Punthura (CSP53), Shangumugham south (CSP69), Vettucaud to Kochuveli (CSP74-75), Valiyaveli (CSP78), and Thumba (CSP80-81). Erosion observed at Edappadu beach (CSP02), Poovar south to Poovar (CSP15-19), Mullur (CSP36-37), Kovalam (CSP40A), Kovalam (CSP42), Panathura north (CSP52), Shangumugham north (CSP71), and Kochuveli to Valiyaveli (CSP76-77).

At CSP66, CSP70, CSP72, CSP73, CSP74, and CSP80, only a distance of less than 10m was surveyed, and these profiles were excluded from the analysis for July 2023 as they were not suitable. Poovar south to north (CSP15–20), Karumkulam (CSP22), Mullur (CSP36), Kovalam (CSP40A), Kovalam (CSP42), and Punthura (CSP53) beaches recorded accretion in July 2023. Erosion was noted at Edappadu beach (CSP02), Poovar north (CSP21), Mullur (CSP37),

Kovalam (CSP43), Panathura north (CSP52), Valliyathura (CSP64A), Shangumugham south (CSP69), Shangumugham north (CSP71), Kochuveli (CSP75-78), and Thumba (CSP81).

At CSP66, CSP70, CSP72, CSP73, CSP74, and CSP80, only a distance of less than 10m was surveyed in July 2023. Hence, these profiles were excluded from the analysis for August 2023. Beaches showed accretion at Edappadu Beach (CSP02), Poovar South (CSP15), Poovar (CSP19), Mullur (CSP36–37), Panathura North (CSP52), Shangumugham South (CSP69), and Shangumugham North (CSP71) in August 2023. Erosion shown at Poovar south to Poovar (CSP16-18), Poovar north to Karumkulam (CSP20-22), Kovalam (CSP40A), Kovalam (CSP42-43), Punthura (CSP53), Valliyathura (CSP64A), Kochuveli to Valiyaveli (CSP75-78), and Thumba (CSP81).

At CSP66 and CSP72, only a distance of less than 10m was surveyed in August 2023. CSP22 data was found to be erroneous for September 2023. Hence, these profiles were excluded from the analysis for September 2023. Accretion was noticed at Edappadu beach (CSP02), Poovar South (CSP15), Poovar south to Poovar (CSP17–18), Poovar north (CSP21), Kovalam (CSP43), Valliyathura (CSP64A), Shangumugham South to Shanghumugham north (CSP69–71), Vettucaud to Valiyaveli (CSP73–78), and Thumba (CSP80–81) in September 2023. Poovar south (CSP16), Poovar to Poovar north (CSP19-20), Mullur (CSP36-37), Kovalam (CSP40A), Kovalam (CSP42), and Panathura north to Punthura (CSP52-CSP53) exhibited erosion.



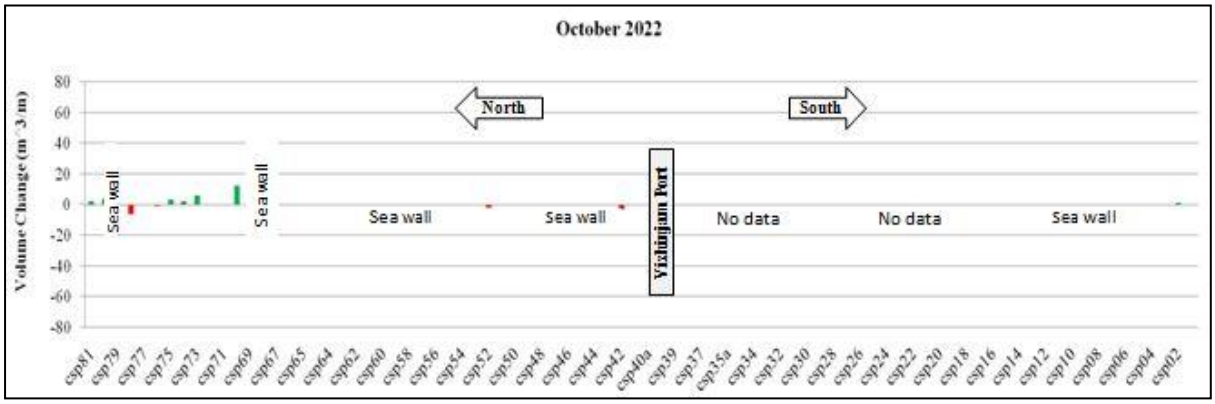
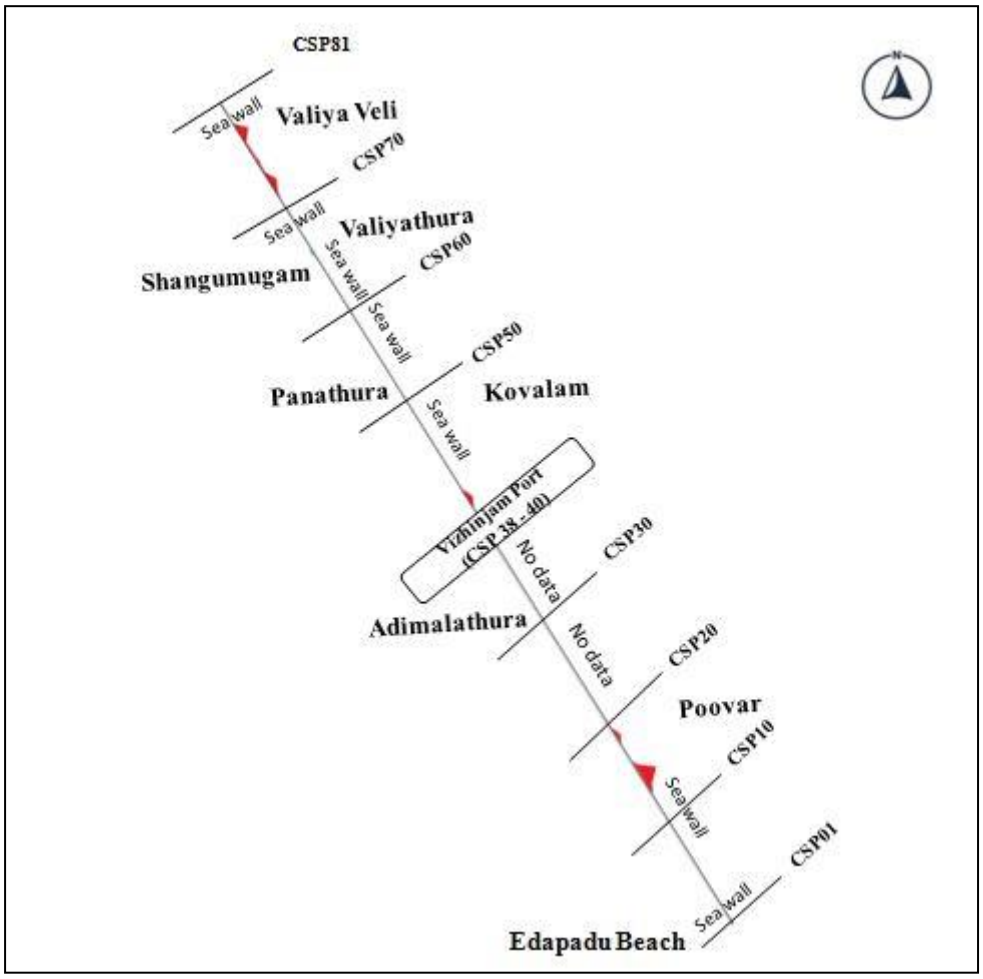


Figure 4.1 Monthly Beach Volume Changes in October 2022 in m^3/m (onshore)



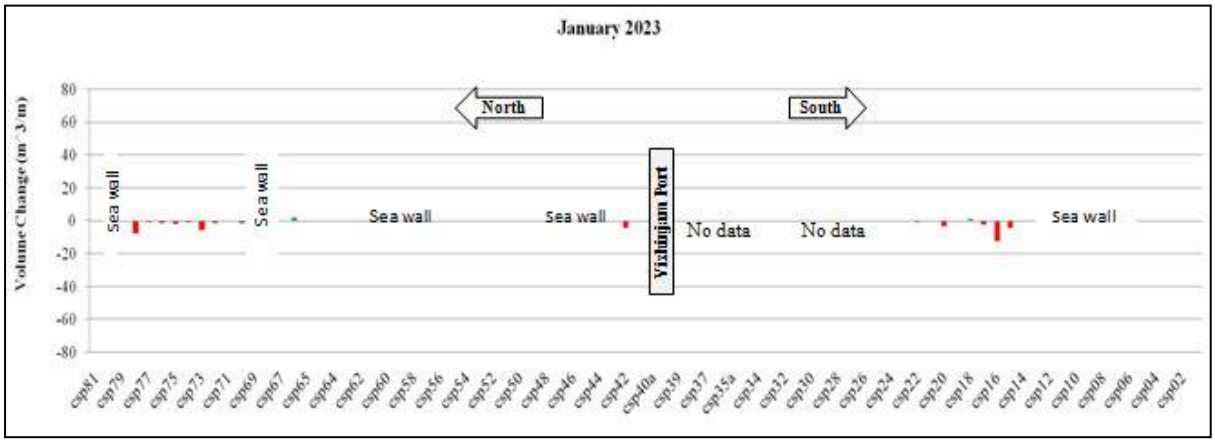
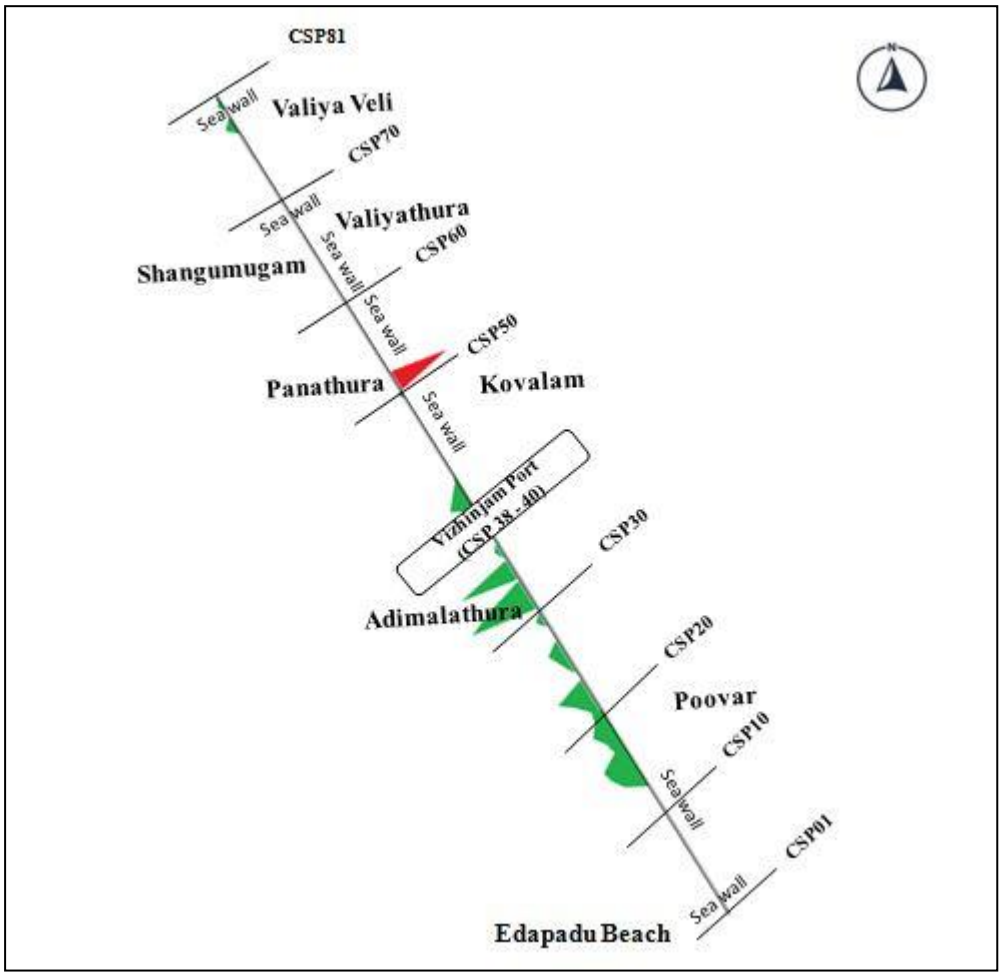


Figure 4.2 Monthly Beach Volume Changes in January 2023 in m^3/m (onshore)



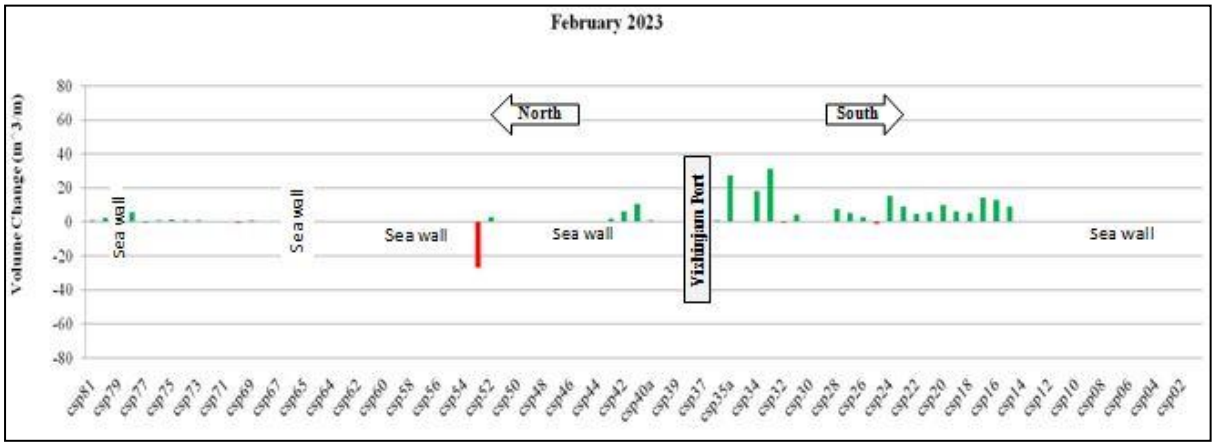
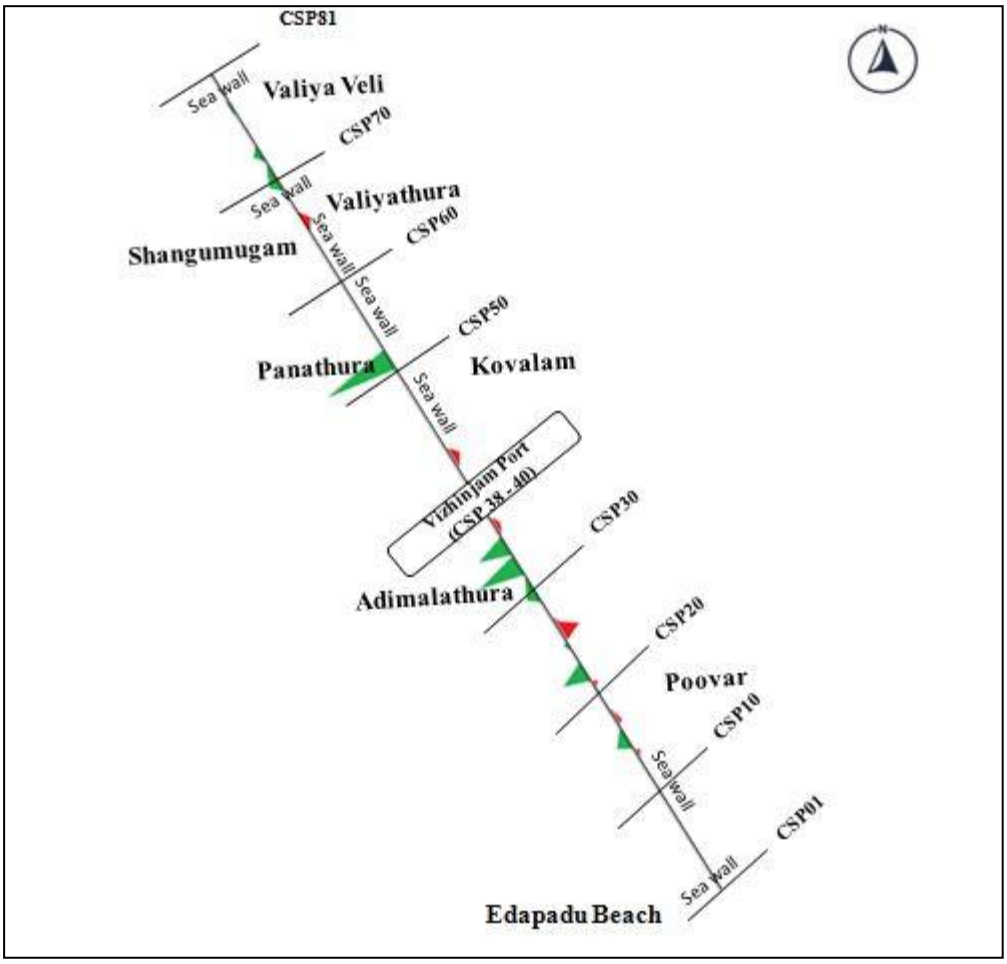


Figure 4.3 Monthly Beach Volume Changes February 2023 in m^3/m (onshore)



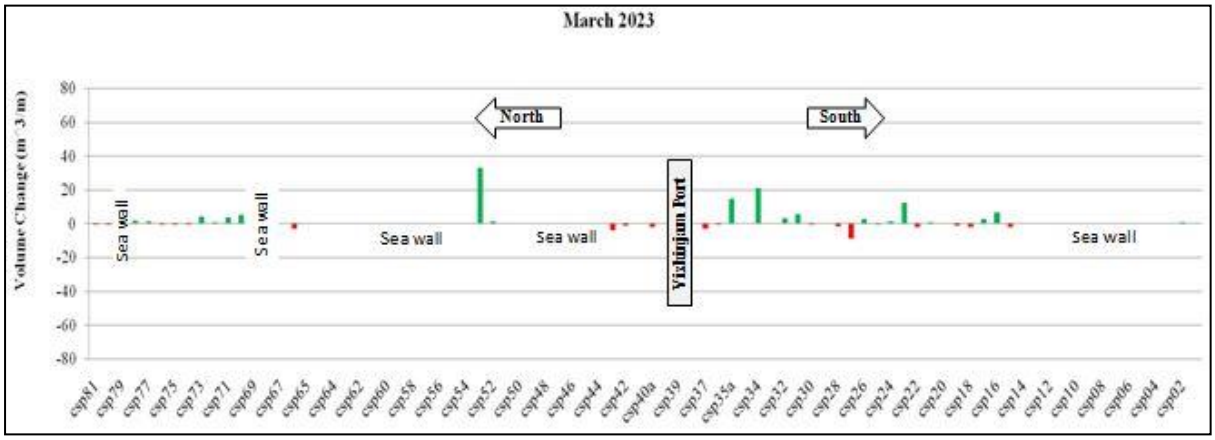
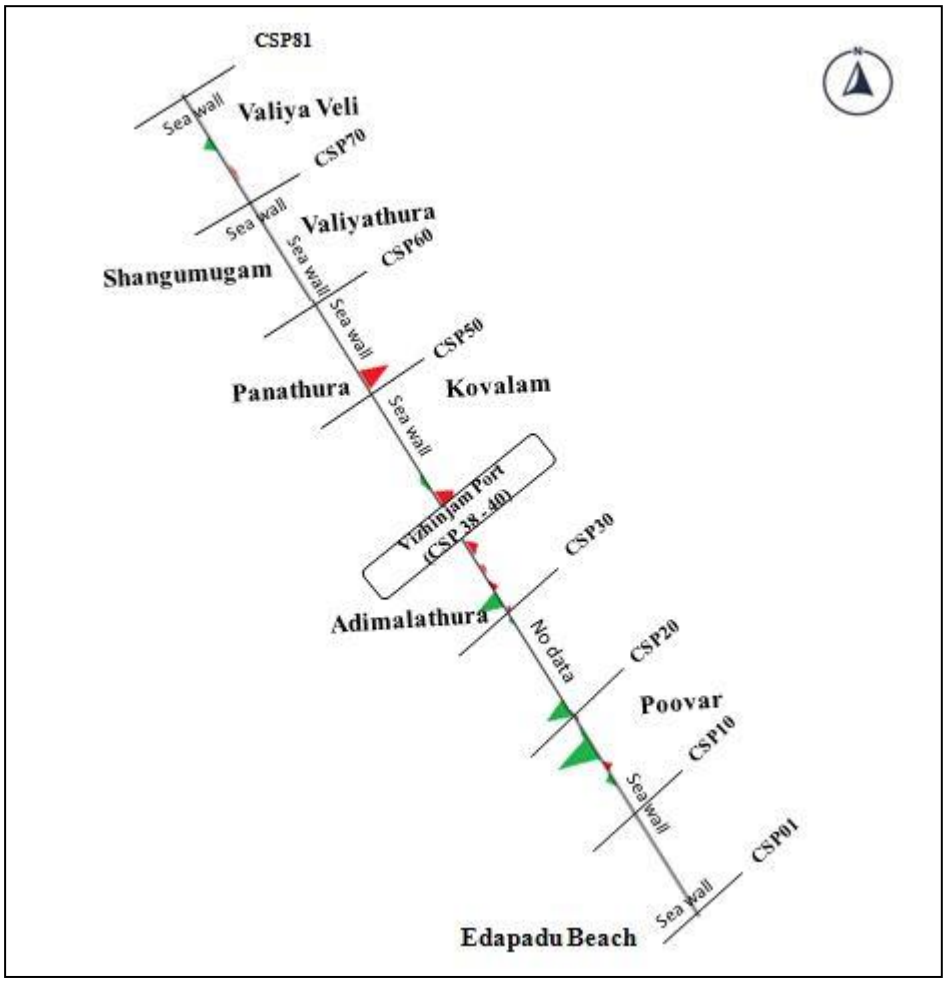


Figure 4.4 Monthly Beach Volume Changes in March 2023 in m^3/m (onshore)



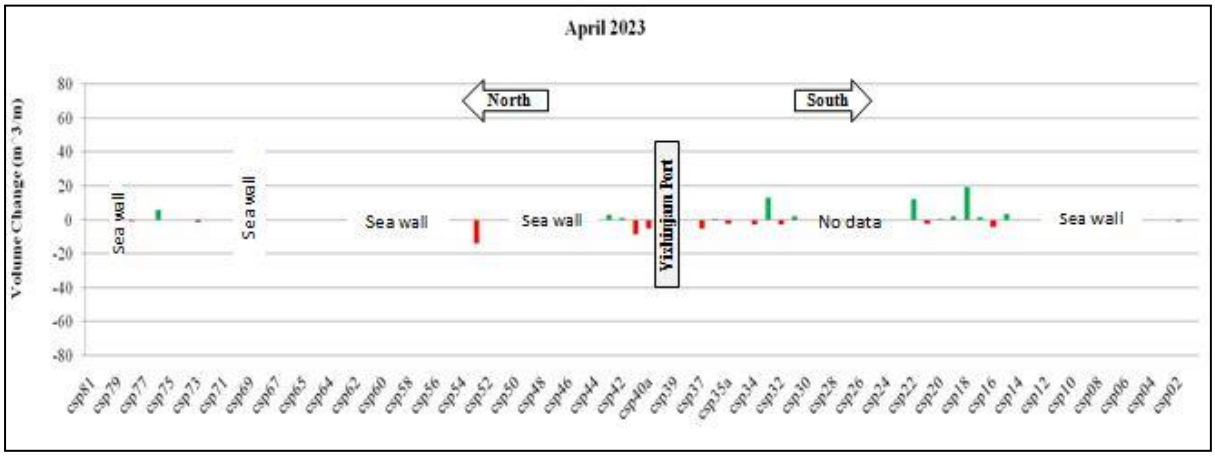
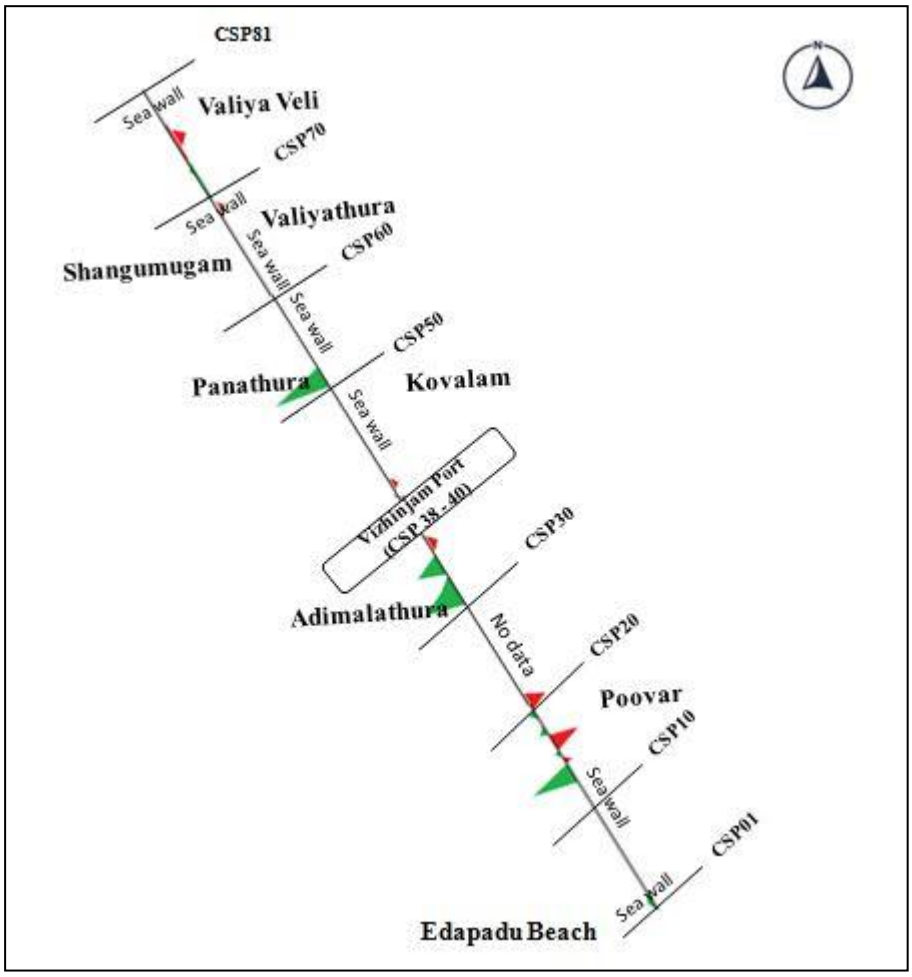


Figure 4.5 Monthly Beach Volume Changes in April 2023 in m^3/m (onshore)



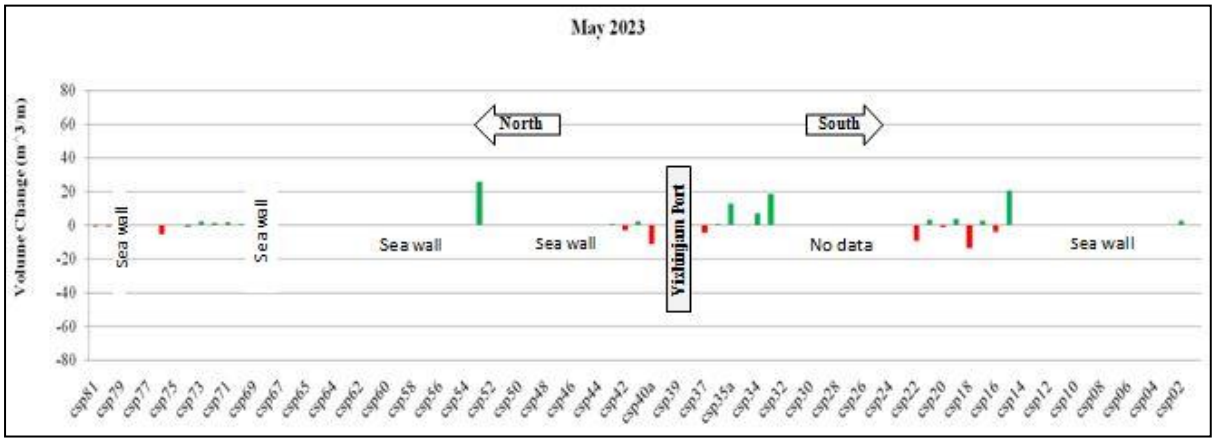
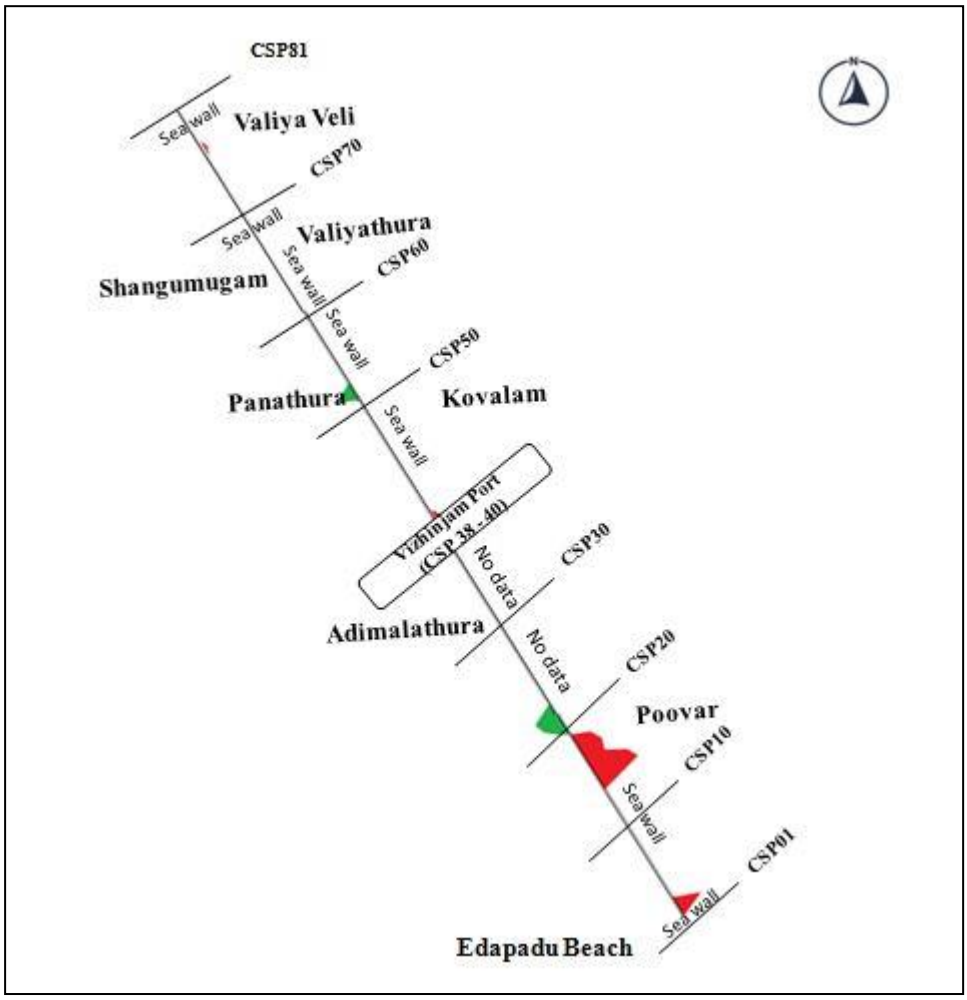


Figure 4.6 Monthly Beach Volume Changes in May 2023 in m^3/m (onshore)



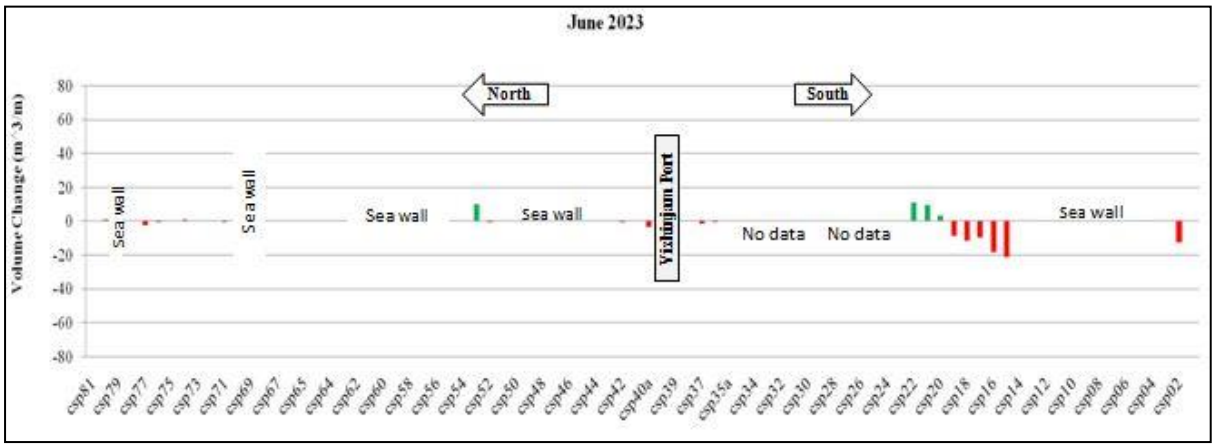
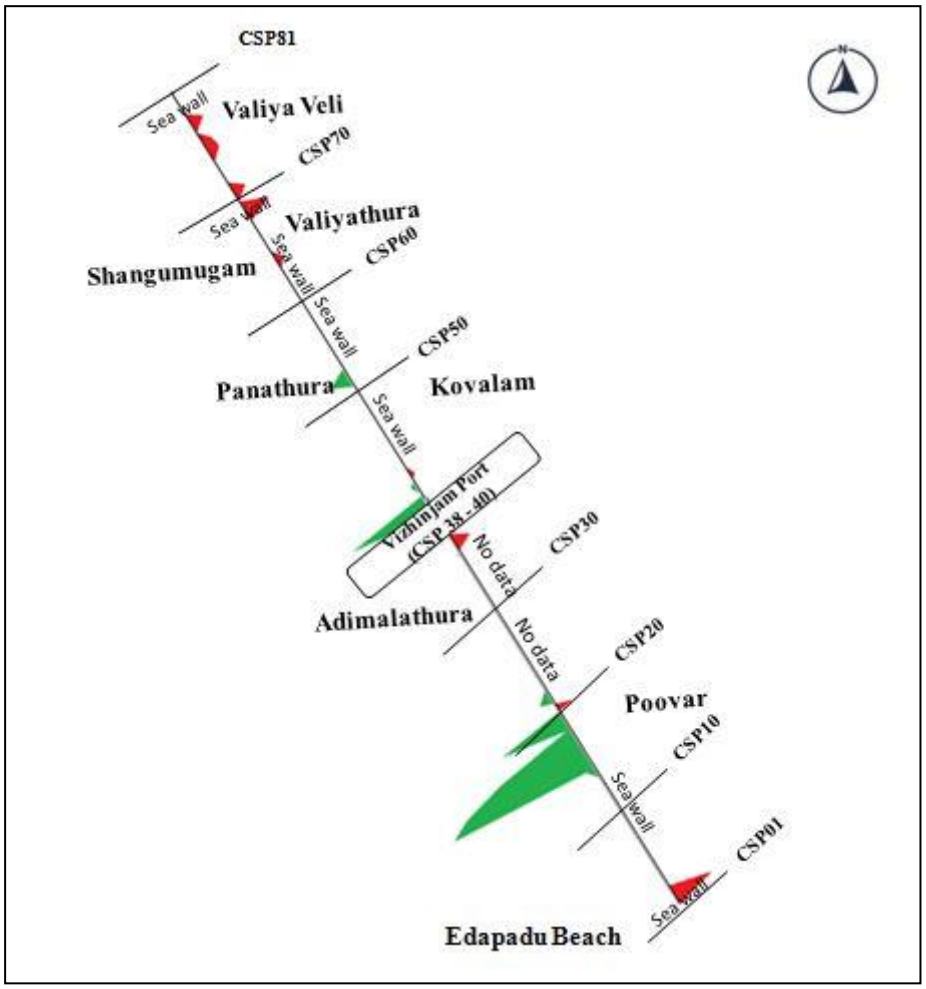


Figure 4.7 Monthly Beach Volume Changes in June 2023 in m^3/m (onshore)



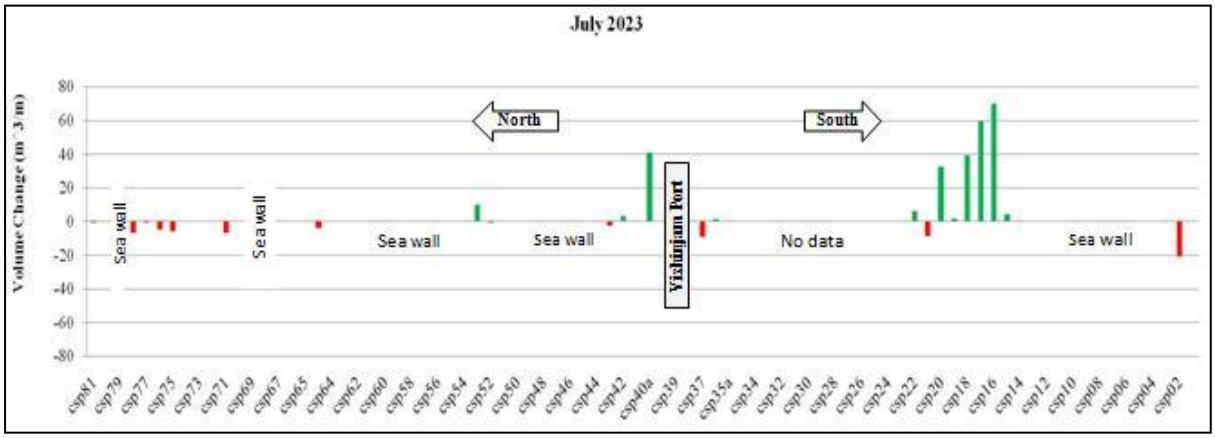
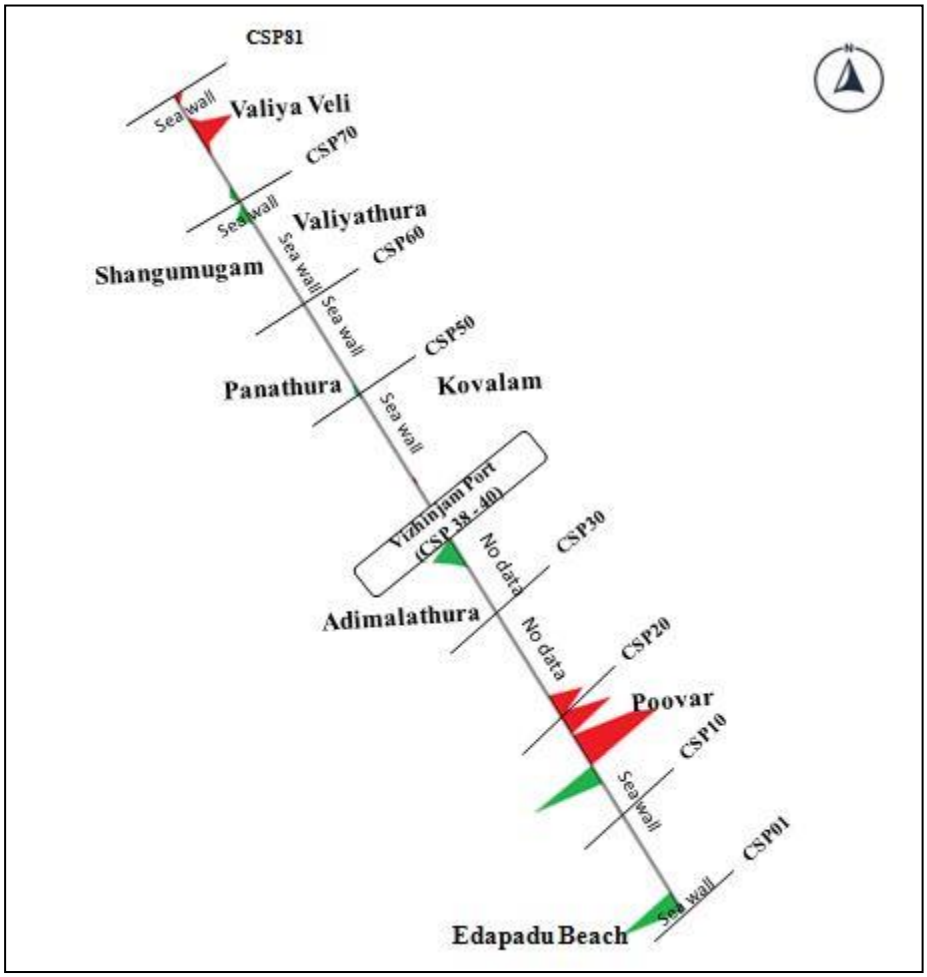


Figure 4.8 Monthly Beach Volume Changes in July 2023 in m^3/m (onshore)



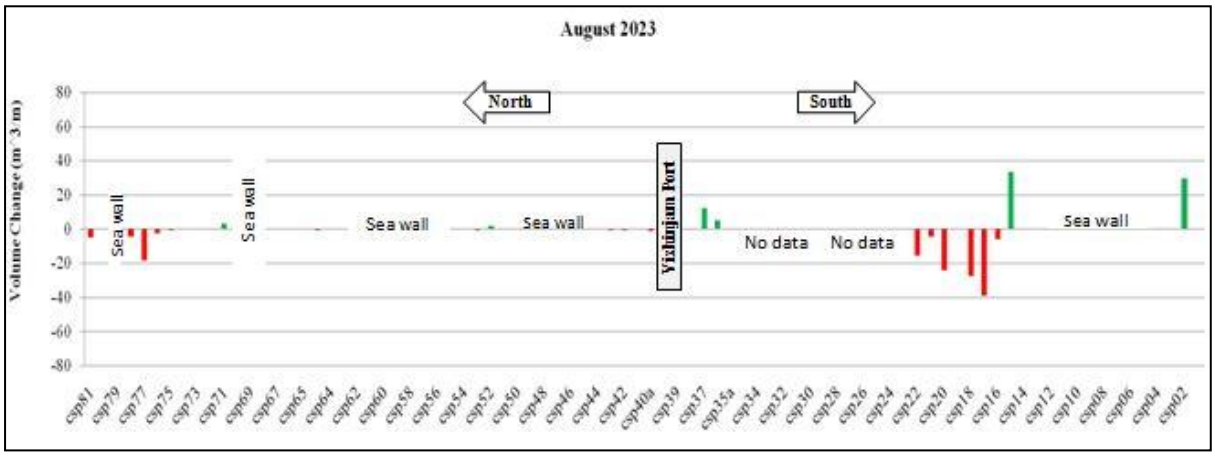
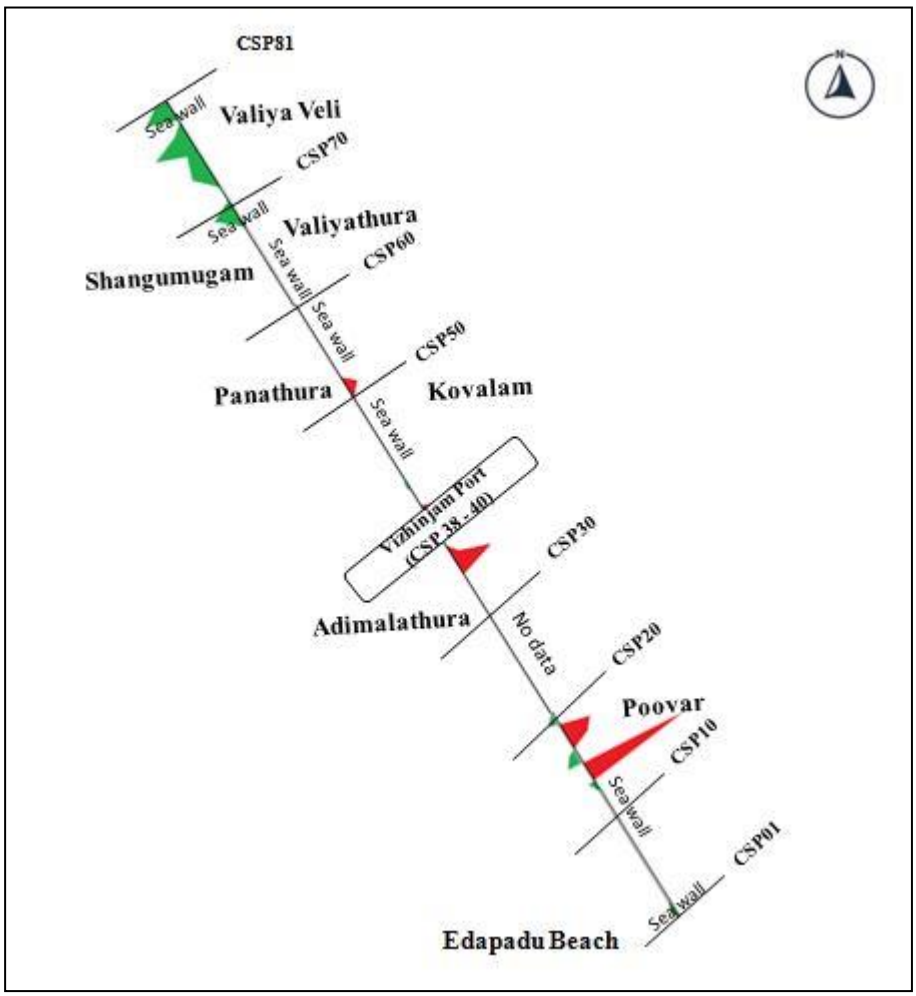


Figure 4.9 Monthly Beach Volume Changes in August 2023 in m^3/m (onshore)



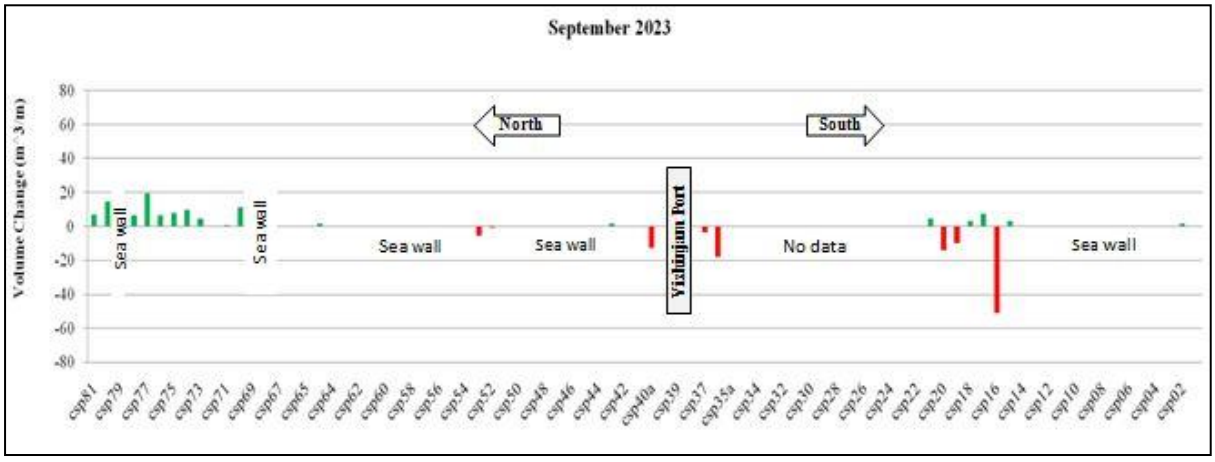


Figure 4.10 Monthly Beach Volume Changes in September 2023 in m^3/m (onshore)

Table 4.1Monthly Beach Volume Changes from October 2022 to September 2023 in m^3/m (onshore)

CSP NOs.	Oct 2022	Nov 2022	Dec 2022	Jan 2023	Feb 2023	Mar 2023	April 2023	May 2023	June 2023	July 2023	Aug 2023	Sept 2023
CSP01	Sea wall											
CSP02	1.07	-	*	-0.61	0.44	0.74	-0.63	2.42	-12.64	-20.99	29.38	1.59
CSP03	Sea wall											
CSP04												
CSP05												
CSP06												
CSP07												
CSP08												
CSP09												
CSP10												
CSP11												
CSP12												
CSP13												
CSP14												
CSP15	-	-	*	-4.10	9.30	-2.15	3.55	20.66	-21.02	3.95	33.30	2.97
CSP16	-	-	*	-12.60	12.79	6.76	-4.03	-4.04	-18.42	69.99	-5.87	-50.97
CSP17	-	-	*	-2.38	14.17	2.64	1.65	2.86	-9.67	59.60	-38.90	7.21
CSP18	-	-	*	1.14	5.25	-2.35	19.48	-13.56	-11.42	39.40	-27.46	3.16
CSP19	-	-	*	0.19	6.38	-1.06	2.00	3.73	-8.59	1.93	0.41	-9.97
CSP20	-	-	*	-3.45	10.02	0.14	0.87	-1.17	3.18	32.56	-24.32	-14.40
CSP21	-	-	*	-0.28	5.77	0.71	-2.20	3.19	9.42	-9.00	-4.41	4.40
CSP22	-	-	*	-0.86	4.50	-2.30	12.03	-9.19	11.24	6.01	-15.74	*
CSP23	-	-	-	*	9.15	12.36	-	-	-	-	-	-
CSP24	-	-	-	*	15.36	1.36	-	-	-	-	-	-
CSP25	-	-	-	*	-1.10	0.04	-	-	-	-	-	-
CSP26	-	-	-	*	2.70	2.62	-	-	-	-	-	-
CSP27	-	-	-	*	5.19	-8.99	-	-	-	-	-	-
CSP28	-	-	-	*	7.66	-1.80	-	-	-	-	-	-
CSP29	-	-	-	-	*	-	-	-	-	-	-	-
CSP30	-	-	*	-	*	-0.68	-	-	-	-	-	-
CSP31	-	-	-	*	4.39	5.74	2.10	-	-	-	-	-
CSP32	-	-	-	*	-0.63	3.12	-2.88	-	-	-	-	-
CSP33	-	-	-	*	31.27	0.40	13.25	18.30	-	-	-	-
CSP34	-	-	-	*	18.24	20.74	-2.83	6.93	-	-	-	-
CSP35	-	-	*	-	*	-	-	*	-	-	-	-
CSP35A	-	-	-	*	27.44	14.85	-2.34	12.80	-	-	-	-
CSP36	-	-	-	*	0.82	-0.78	0.68	0.73	-0.32	1.24	5.24	-17.83
CSP37	-	-	-	*	3.37	-2.87	-5.07	-4.66	-1.45	-9.23	12.39	-3.83
CSP38	Port Area											
CSP39												
CSP40												
CSP40A	-	-	-	*	1.06	-1.93	-5.13	-11.41	-3.29	40.60	-1.29	-12.74
CSP41	-	-	-	*	10.59	0.32	-8.31	2.19	-	-	-	-
CSP42	-3.18	-	*	-4.12	6.06	-1.01	1.24	-3.27	-0.37	3.15	-0.68	-0.18
CSP43	*	-	*	-0.49	1.71	-4.20	3.16	0.50	0.50	-2.57	-0.90	1.51
CSP44	*	-	*	*	*	*	*	*	*	*	*	*
CSP45	Sea wall											

CSP46												
CSP47												
CSP48												
CSP49												
CSP50												
CSP51	*	-	*	*	*	*	*	*	*	*	*	*
CSP52	-1.87	-	*	0.06	2.61	1.30	0.04	0.04	-0.42	-0.79	1.66	-0.90
CSP53	-	-	-	*	-26.87	33.02	-13.84	25.95	9.90	10.09	-0.01	-5.62
CSP54												
CSP55												
CSP56												
CSP57												
CSP58												
CSP59												
CSP60	Sea wall											
CSP61												
CSP62												
CSP63												
CSP64												
CSP64A												
CSP65												
CSP66	*	-	*	2.12	-1.22	-3.29	*	*	*	*	*	*
CSP67	Sea wall											
CSP68												
CSP69	6.46	-	*	-1.11	1.08	0.47	1.95	-3.05	1.61	-12.86	6.20	4.87
CSP70	12.37	-	*	-1.20	-0.77	5.25	-0.39	0.53	*	*	*	11.41
CSP71	-0.34	-	*	*	*	3.44	0.13	1.64	-0.34	-6.68	2.95	0.54
CSP72	*	-	*	-1.62	0.62	0.63	-0.33	1.14	*	*	*	*
CSP73	5.85	-	*	-5.60	0.83	4.35	-1.23	2.34	*	*	*	4.63
CSP74	2.28	-	*	-0.94	0.66	-0.04	0.02	-0.13	0.99	*	*	9.80
CSP75	3.21	-	*	-1.63	1.49	-0.35	-0.13	0.15	0.39	-5.74	-0.91	8.03
CSP76	-1.13	-	*	-1.33	0.89	-0.27	6.13	-5.64	-0.45	-5.08	-2.79	6.34
CSP77	-0.55	-	*	-1.11	0.04	1.36	-0.44	0.02	-2.20	-0.53	-18.36	19.49
CSP78	-6.29	-	*	-7.78	5.55	1.95	-0.60	0.36	0.28	-6.96	-4.50	6.25
CSP79	Sea wall											
CSP80	3.85	-	*	-1.43	2.40	-0.57	-0.22	-0.01	1.07	*	*	14.66
CSP81	2.02	-	*	-0.57	0.91	-0.34	0.32	-0.09	0.42	-0.10	-4.88	7.02

***Data not considered for analysis**
-No data

4.1.2 Monthly Beach Volume variations for October 2022 to September 2023 for the offshore part

No offshore survey was carried out for October 2022, November 2022 to September 2022, June 2023, July 2023, August 2023, and September 2023 due to unfavourable weather conditions. Results are represented graphically in **Figures 4.11 to 4.15** and in **Table 4.2.**

December 2022 analysis could not be done as no survey was conducted in November 2022. In January 2023, erosion was found at Poovar south to Poovar north (CSP17-CSP20), Karumkulam (CSP22-23), Karumkulam to Pulluvila (CSP26-27), Pulluvila (CSP29-30), Adimalthura (CSP33), Azhimala (CSP35), Mullur (CSP36-37), Kovalam to Beemapally (CSP40A-59), Valiyathura (CSP63), and Shangumugham south (CSP68). Accretion noted at Poovar North (CSP21),

Karumkulam (CSP24), Pulluvila (CSP28), Adimalathura (CSP31-32, 34), Azhimala (CSP35A), Valliyathura (CSP64-67), Shanghumugham south to Thumba (CSP69-81).

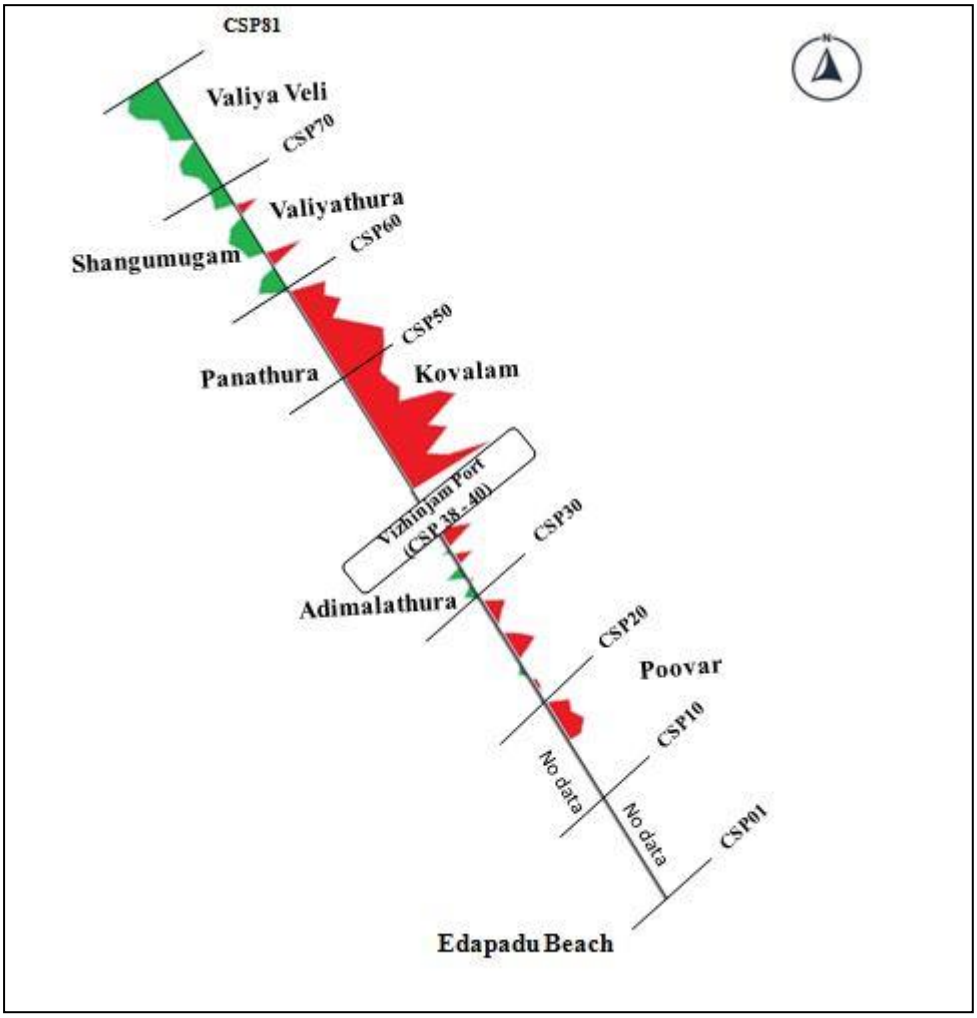
In February 2023, beaches displayed erosion at Edappadu beach (CSP01, CSP03), Vallavilay (CSP05), Adimalathura (CSP32, CSP34), Kovalam (CSP40a), Panathura north to Punthura (CSP52-58), Azhimala (CSP35A), Kovalam (CSP45), Panathura south (CSP49), and Valliyathura (CSP64-67). Beach shown accretion at Vallavilay (CSP04), Vallavilay to Paruthiyoor (CSP06-CSP14), Poovar south to Karumkulam (CSP16-24), Karumkulam to Adimalathura (CSP26-31), Adimalathura (CSP33), Azhimala (CSP35), Mullur (CSP36-37), Kovalam (CSP40A-44), Kovalam to Panathura South (CSP46-48), Panathura north to Valliyathura (CSP50-CSP63), Shangumgham south to Thumba (CSP68-81).

Profile CSP05 was found to be erroneous in March 2023. Observed erosion at Edappadu beach (CSP01), Edappadu to Vallavilay (CSP03-04), Vallavilay to Poovar (CSP06-CSP19), Adimalathura (CSP33-34), Kovalam (CSP42), Kovalam north (CSP47), Punthura to Beemapally (CSP56-60), Cheriyathura to Shangumugham south (CSP62-68), Shangumugham north to Vettucaud (CSP70-72,74), and Kochuveli to Thumba (CSP76-81). Accretion reported at Poovar north to Adimalathura (CSP20-32), Azhimala to Mullur (CSP35-37), Kovalam (CSP40a-41, CSP43-46), Panathura south to Punthura (CSP48-55), Cheriyathura (CSP61), Shangumgham south (CSP69), Vettucaud (CSP73), and Kochuveli (CSP75) in March 2023.

Profiles for locations CSP19, CSP70, and CSP71 were found to be the same for March and April 2023. Hence, these profiles were excluded from the analysis for April 2023.Erosion marked at Edappadu Beach (CSP01,03), Poovar north to Karumkulam (CSP21-24), Karumkulam (CSP26), Pulluvila to Adimalathura (CSP29-32), Azhimala to Mullur (CSP35-36), Kovalam to Punthura (CSP40a-54), Cheriyathura (CSP61), Shangumugham south (CSP69), Vettucaud (CSP73), Thumba (CSP81). Accretion recorded at Edappadu Beach (CSP02), Vallavilay (CSP04), Vallavilay to Poovar (CSP06-18), Poovar north (CSP20), Karumkulam (CSP25), Pulluvila (CSP27-28), Adimalathura (CSP33-34), Mullur (CSP37), Punthura to Beemapally (CSP55-60), Cheriyathura to Shanghumugham (CSP62-68), Vettucaud (CSP72), and Vettucaud to Thumba (CSP74-80).

Profile CSP19 found the same for March and April, and CSP58 found the same for April and May 2023. Hence, these profiles were excluded from the analysis for May 2023. Erosion was noted at Adimalathura (CSP 33). Accretion noted at Poovar (CSP18), Poovar north to Adimalathura

(CSP21-32), Adimalathura (CSP34), Kovalm to Punthura (CSP40A-57), and Beemapally to Shangumugham south (CSP60-68).



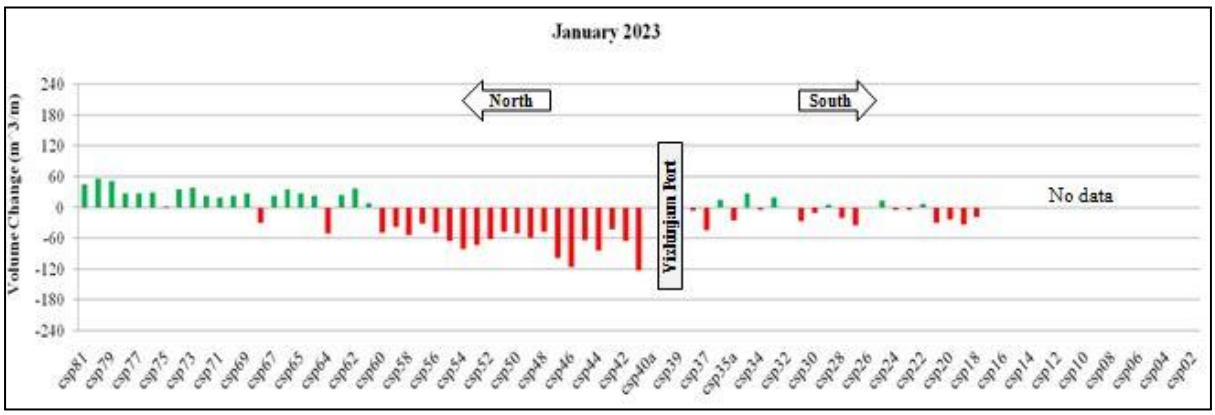
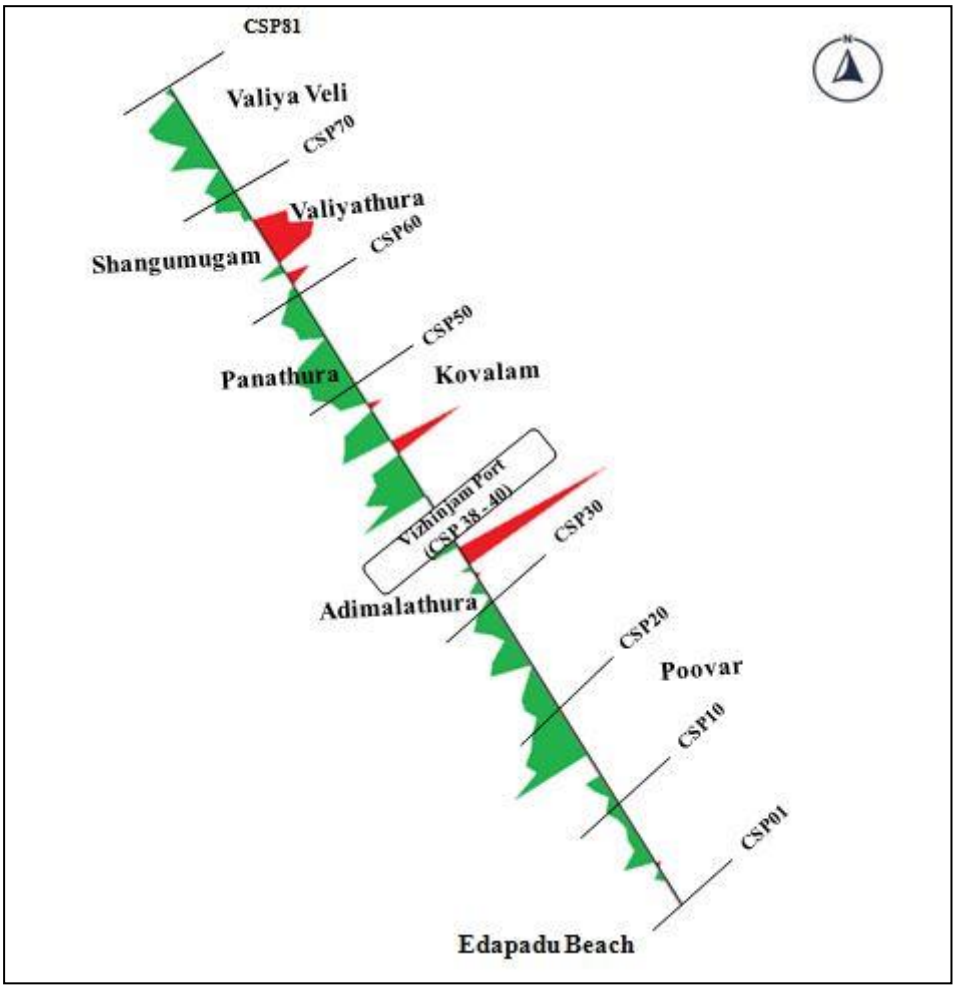


Figure 4.11 Monthly Beach Volume Changes in January 2023 in m^3/m (offshore)



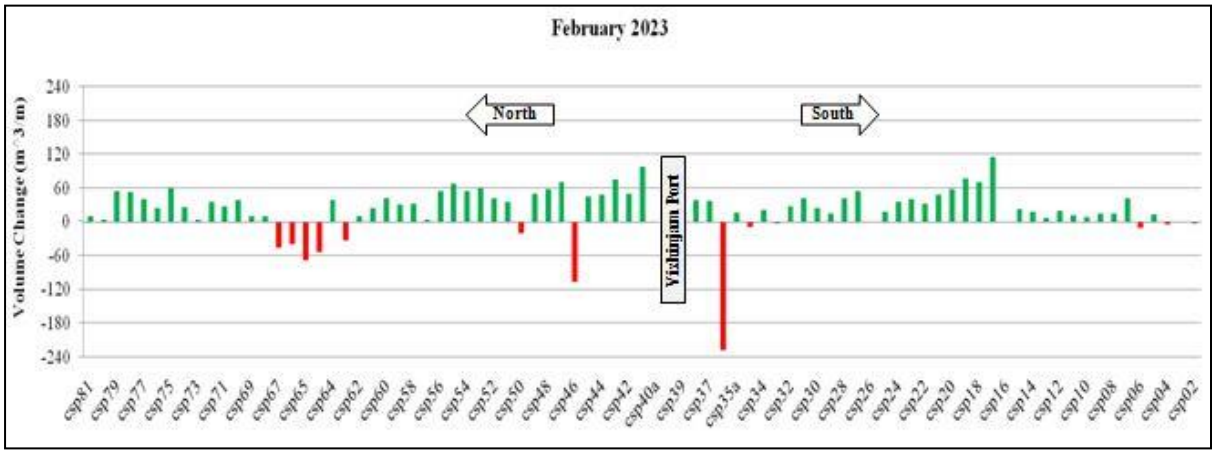
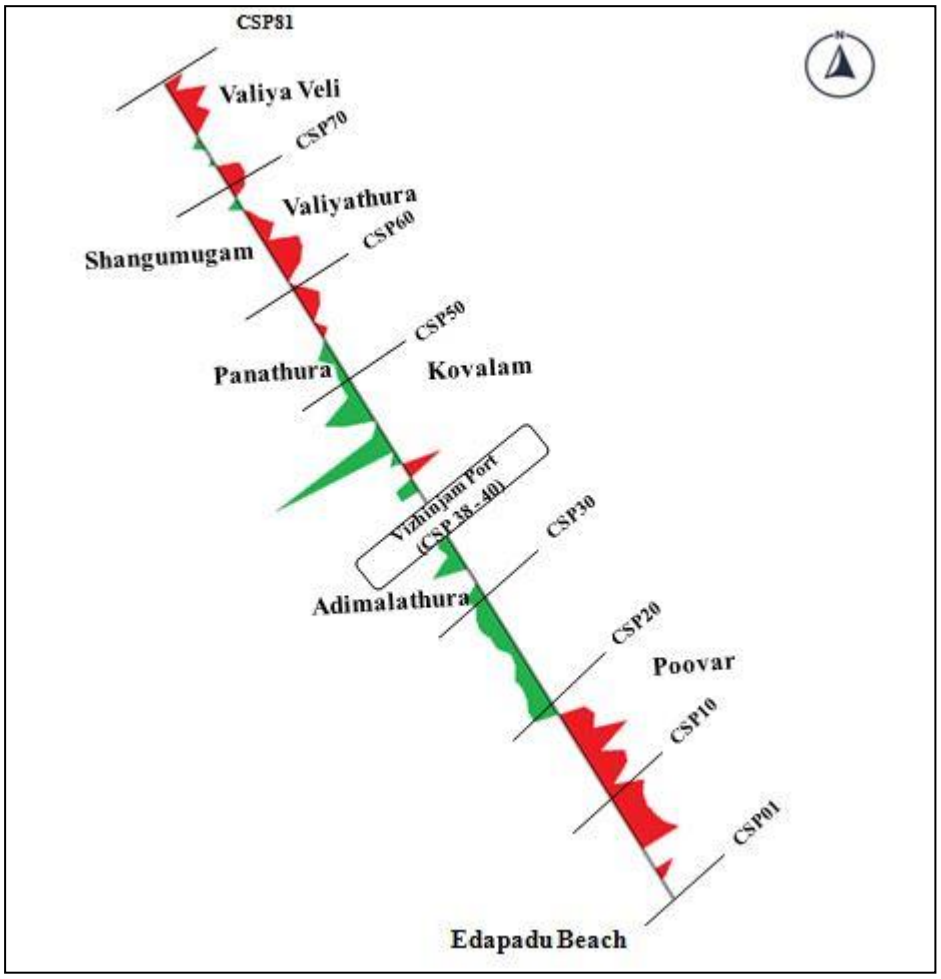


Figure 4.12 Monthly Beach Volume Changes in February 2023 in m^3/m (offshore)



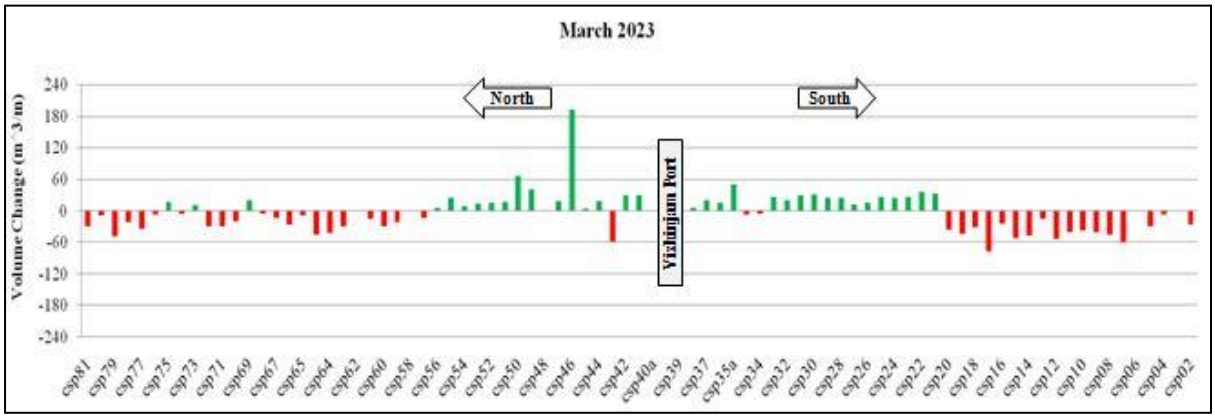
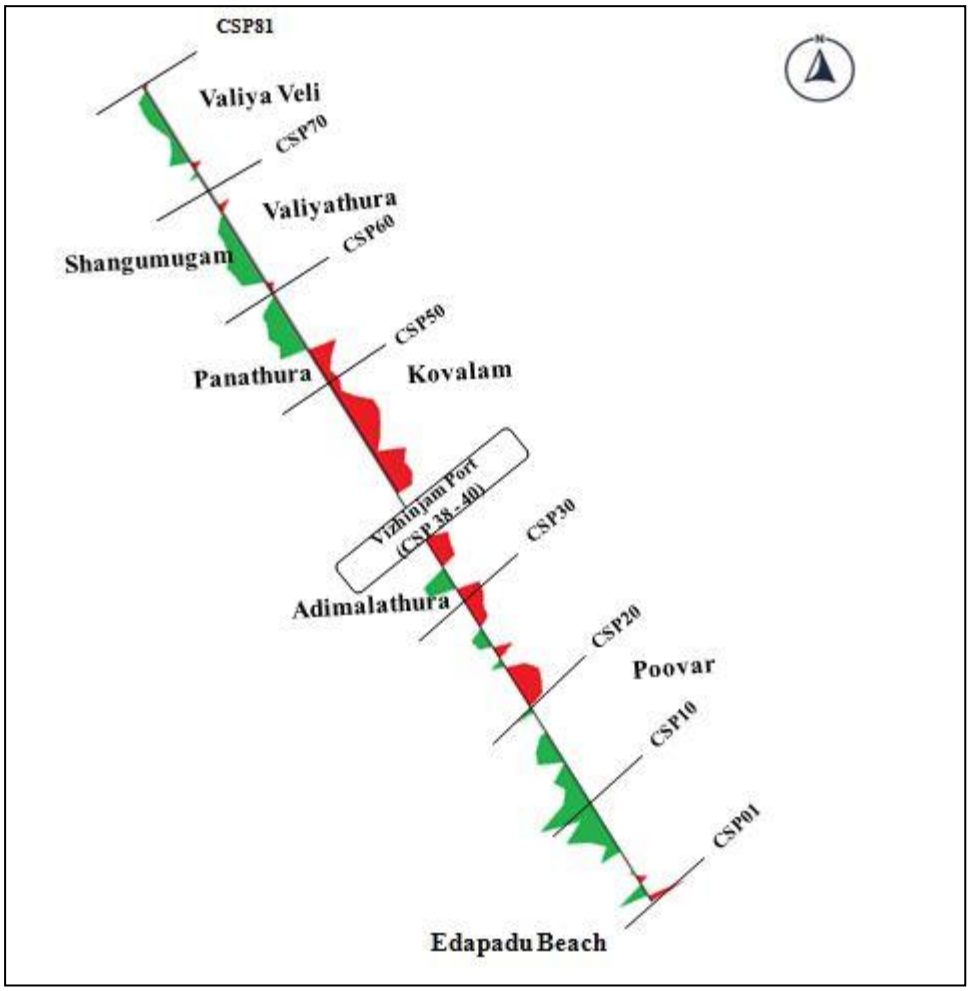


Figure 4.13 Monthly Beach Volume Changes in March 2023 in m^3/m (offshore)



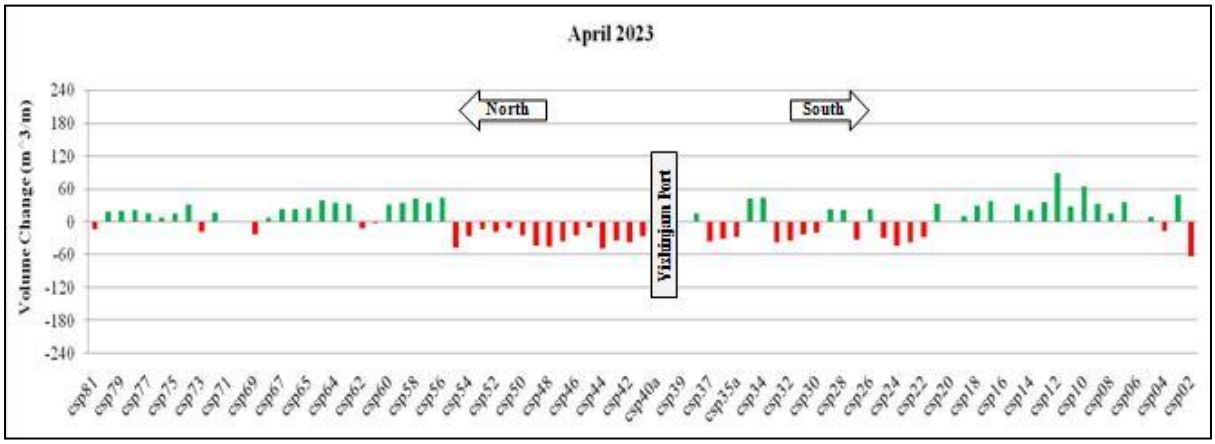
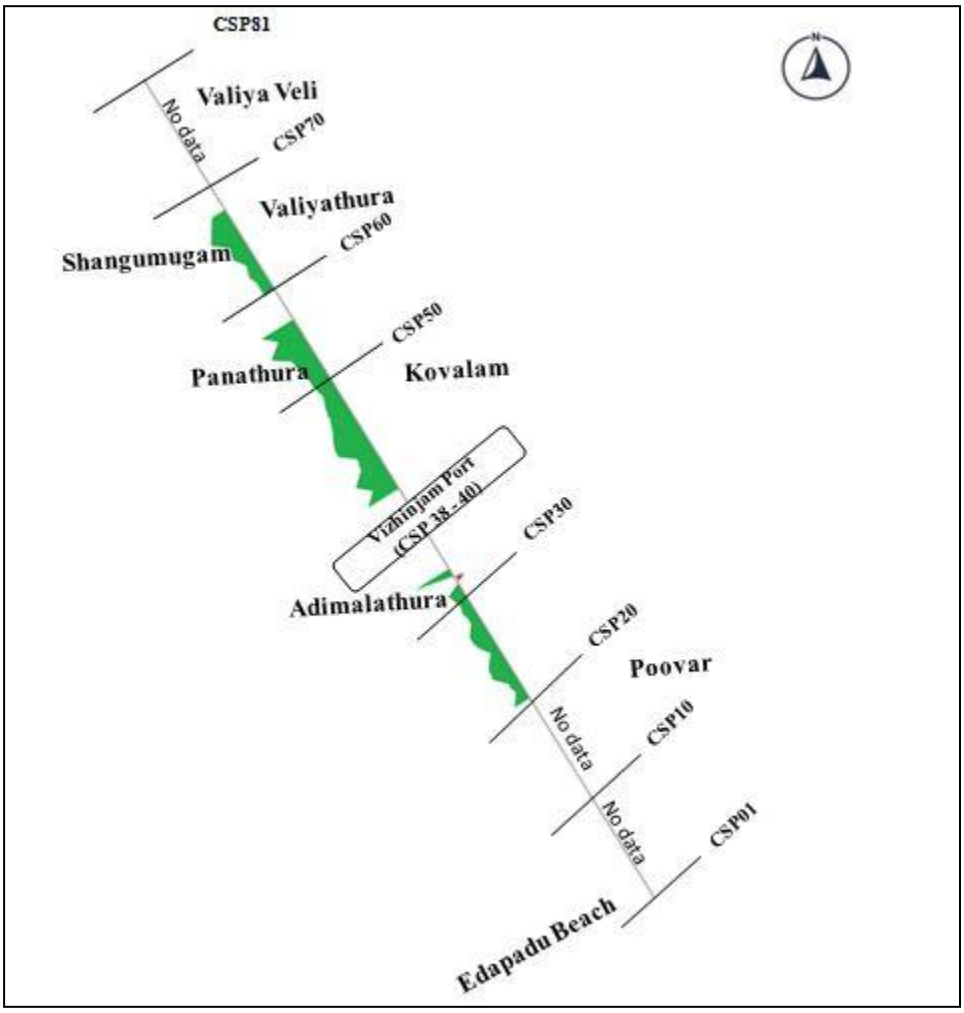


Figure 4.14 Monthly Beach Volume Changes in April 2023 in m^3/m (offshore)



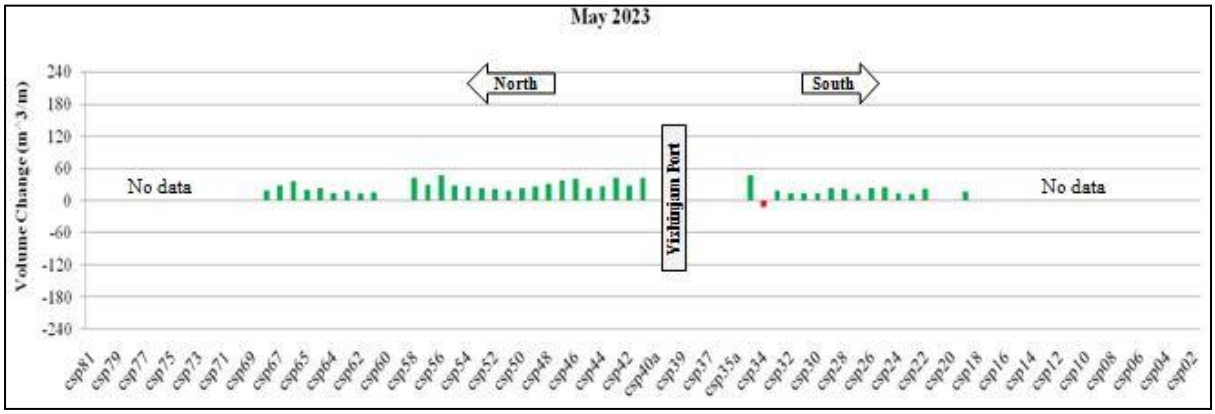


Figure 4.15 Monthly Beach Volume Changes in May 2023 in m^3/m (offshore)

Table 4.2 Monthly Beach Volume Changes fromOctober 2022 to September 2023 in m^3/m (offshore)

CSP NOs.	Oct 2022	Nov 2022	Dec 2022	Jan 2023	Feb 2023	Mar 2023	April 2023	May 2023	June 2023	July 2023	Aug 2023	Sep 2023
CSP01	-	-	-	*	-3.62	-27.09	-63.50	-	-	-	-	-
CSP02	-	-	-	*	-	*	48.53	-	-	-	-	-
CSP03	-	-	-	*	-4.89	-7.93	-16.04	-	-	-	-	-
CSP04	-	-	-	*	12.08	-29.35	8.87	-	-	-	-	-
CSP05	-	-	-	*	-10.74	*	*	-	-	-	-	-
CSP06	-	-	-	*	41.07	-60.16	35.41	-	-	-	-	-
CSP07	-	-	-	*	13.72	-46.27	14.80	-	-	-	-	-
CSP08	-	-	-	*	14.50	-40.79	32.04	-	-	-	-	-
CSP09	-	-	-	*	7.61	-38.15	64.55	-	-	-	-	-
CSP10	-	-	-	*	11.54	-41.56	27.97	-	-	-	-	-
CSP11	-	-	-	*	19.64	-53.10	89.04	-	-	-	-	-
CSP12	-	-	-	*	5.76	-15.02	35.66	-	-	-	-	-
CSP13	-	-	-	*	16.95	-46.72	21.34	-	-	-	-	-
CSP14	-	-	-	*	22.60	-51.85	31.03	-	-	-	-	-
CSP15	-	-	-	*	*	-24.36	0.88	-	-	-	-	-
CSP16	-	-	-	*	115.05	-77.84	37.23	-	-	-	-	-
CSP17	-	-	*	-19.33	69.67	-31.73	29.48	-	-	-	-	-
CSP18	-	-	*	-33.45	77.37	-43.67	10.55	17.57	-	-	-	-
CSP19	-	-	*	-23.75	58.34	-36.56	*	*	-	-	-	-
CSP20	-	-	*	-29.45	47.51	33.29	33.17	-	-	-	-	-
CSP21	-	-	*	6.52	31.35	35.45	-27.85	21.40	-	-	-	-
CSP22	-	-	*	-4.11	39.36	26.73	-37.73	12.01	-	-	-	-
CSP23	-	-	*	-3.53	35.79	24.87	-44.23	13.78	-	-	-	-
CSP24	-	-	*	12.68	17.75	26.59	-29.96	25.55	-	-	-	-
CSP25	-	-	-	*	0	15.69	22.88	23.04	-	-	-	-
CSP26	-	-	*	-35.22	54.31	12.53	-32.32	12.26	-	-	-	-
CSP27	-	-	*	-19.56	42.17	23.98	21.19	21.11	-	-	-	-
CSP28	-	-	*	5.04	13.82	24.30	23.20	23.44	-	-	-	-
CSP29	-	-	*	-10.08	23.65	31.11	-19.45	13.48	-	-	-	-
CSP30	-	-	*	-27.14	42.03	28.92	-22.73	14.26	-	-	-	-
CSP31	-	-	*	0.04	26.63	19.49	-33.48	13.83	-	-	-	-
CSP32	-	-	*	19.75	-3.68	26.10	-37.47	18.51	-	-	-	-
CSP33	-	-	*	-4.67	21.01	-5.55	43.67	-12.21	-	-	-	-
CSP34	-	-	*	27.51	-9.41	-7.14	41.85	48.04	-	-	-	-
CSP35	-	-	*	-25.18	15.89	50.71	-27.27	-	-	-	-	-
CSP35A	-	-	*	14.33	-228.57	14.37	-30.69	-	-	-	-	-
CSP36	-	-	*	-44.09	36.28	20.42	-36.40	-	-	-	-	-
CSP37	-	-	*	-5.85	38.40	5.15	15.71	-	-	-	-	-
CSP38												
CSP39												
CSP40												
CSP40A	-	-	*	-123.00	97.66	29.72	-26.45	41.78	-	-	-	-
CSP41	-	-	*	-64.39	48.88	29.86	-37.68	27.73	-	-	-	-
CSP42	-	-	*	-42.07	74.97	-58.66	-34.88	41.91	-	-	-	-
CSP43	-	-	*	-83.98	48.28	18.23	-48.65	26.84	-	-	-	-
CSP44	-	-	*	-63.36	44.97	3.67	-9.95	23.61	-	-	-	-
CSP45	-	-	*	-116.14	-107.58	192.79	-25.07	40.51	-	-	-	-
CSP46	-	-	*	-98.90	70.68	17.84	-36.51	38.13	-	-	-	-
CSP47	-	-	*	-48.01	57.76	-1.25	-45.64	31.08	-	-	-	-
CSP48	-	-	*	-57.77	49.24	41.31	-43.82	26.29	-	-	-	-
CSP49	-	-	*	-50.38	-21.44	66.08	-25.22	24.06	-	-	-	-
CSP50	-	-	*	-46.70	35.48	16.71	-12.01	19.04	-	-	-	-
CSP51	-	-	*	-62.41	40.93	15.60	-18.71	21.63	-	-	-	-
CSP52	-	-	*	-72.60	58.98	13.20	-13.66	22.88	-	-	-	-
CSP53	-	-	*	-80.90	54.83	8.10	-27.02	25.97	-	-	-	-

CSP54	-	-	*	-65.51	67.91	24.51	-46.20	27.70	-	-	-	-
CSP55	-	-	*	-48.75	54.07	6.08	44.04	46.56	-	-	-	-
CSP56	-	-	*	-31.80	2.84	-13.42	34.17	29.42	-	-	-	-
CSP57	-	-	*	-53.98	32.03	-1.28	42.33	43.00	-	-	-	-
CSP58	-	-	*	-38.01	30.39	-20.90	33.96	*	-	-	-	-
CSP59	-	-	*	-48.41	41.60	-29.71	31.02	-	-	-	-	-
CSP60	-	-	*	8.19	23.31	-15.12	0.05	15.98	-	-	-	-
CSP61	-	-	*	37.70	9.54	1.37	-12.21	14.25	-	-	-	-
CSP62	-	-	*	23.72	-34.11	-29.82	33.32	18.42	-	-	-	-
CSP63	-	-	*	-50.93	38.62	-42.65	34.85	14.46	-	-	-	-
CSP64	-	-	*	22.78	-54.26	-46.13	39.05	23.85	-	-	-	--
CSP64A	-	-	*	*	*	*	*	*	-	-	-	-
CSP65	-	-	*	27.04	-68.34	-8.70	25.46	19.84	-	-	-	-
CSP66	-	-	*	35.22	-39.61	-27.21	22.46	36.20	-	-	-	-
CSP67	-	-	*	23.11	-46.00	-13.89	22.64	27.75	-	-	-	-
CSP68	-	-	*	-30.28	10.12	-6.24	6.70	18.79	-	-	-	-
CSP69	-	-	*	27.50	9.61	20.63	-23.15	-	-	-	-	-
CSP70	-	-	*	22.48	38.04	-19.79	*	-	-	-	-	-
CSP71	-	-	*	19.49	26.84	-29.69	*	-	-	-	-	-
CSP72	-	-	*	23.21	35.04	-29.81	17.60	-	-	-	-	-
CSP73	-	-	*	39.22	3.92	10.42	-17.76	-	-	-	-	-
CSP74	-	-	*	35.06	25.47	-6.11	30.55	-	-	-	-	-
CSP75	-	-	*	1.79	59.23	17.08	15.67	-	-	-	-	-
CSP76	-	-	*	29.17	23.82	-7.23	7.46	-	-	-	-	-
CSP77	-	-	*	27.46	39.45	-34.60	14.55	-	-	-	-	-
CSP78	-	-	*	28.08	52.54	-22.19	21.14	-	-	-	-	-
CSP79	-	-	*	51.11	54.54	-49.32	20.73	-	-	-	-	-
CSP80	-	-	*	56.22	3.11	-9.64	19.21	-	-	-	-	-
CSP81	-	-	*	45.20	9.80	-30.31	-12.81	-	-	-	-	-

***Data not considered for analysis**
-No data

4.1.3 Seasonal and Overall Beach Volume variations from October 2022 to September 2023

Seasonal variation has been analysed as post-monsoon (October 2022 to November 2022), fair weather period (December 2022 to March 2023), pre-monsoon period (April 2023 to May 2023), and monsoon (June 2023 to September 2023) for the period October 2022 to September 2023. The results have been presented to depict the total changes that occur in a particular season by analysing profiles between each month in a season.—shown graphically in **Figures 4.16 to 4.18** and **Table 4.3.**

No survey was carried out in November 2022 at any of the locations. Hence, the analysis for the post-monsoon season (October 2022 to November 2022) could not be carried out.

Beach Volume Change in Fair Weather Period 2023 (December 2022-March 2023)

During the fair weather period of 2023, the beach marked accretion at Edappadu beach (CSP02), Poovar south to Karumkulam (CSP15-22), Kovalam (CSP42), Punthura (CSP52),

Shanghumugham south to Shanghumugham north (CSP69-71), Kochuveli (CSP77), and Thumba (CSP80-81). Erosion was observed at Kovalam (CSP43), Valliyathura (CSP66), and Shangumugham north up to Kochuveli (CSP72–76) and Valiyaveli (CSP78). The results are given in **Figure 4.16.**

On offshore in the fair weather season of 2023, erosion was recorded at Poovar (CSP19), Azhimala (CSP35A), Kovalam (CSP42–46), Panathura South (CSP49), Panathura north to Punthura (CSP51–53), Punthura to Beemapally (CSP56–59), and Cheriyathura to Shanghumugham south (CSP62–68). Accretion noted at Karumkulam to Azhimala (CSP26-CSP35), Mullur (CSP36-37), Kovalam (CSP40A-41), Kovalam north to Panathura south (CSP47-48), Panathura north (CSP50), Punthura (CSP54-55), Beemapally to Cheriyathura (CSP60-61) and Shangumugham south to Thumba (CSP69-81). Results are shown in **Figure 4.17.**

Beach Volume Change in Pre Monsoon 2023 (April 2023-May 2023)

During the pre-monsoon period,the locations indicated on the onshore are: Edappadu beach (CSP02), Poovar south (CSP15), Poovar south (CSP17), Poovar (CSP19), Poovar north (CSP21), Adimalathura (CSP33-34), Azhimala to Mullur (CSP35A-36), Kovalam (CSP41, CSP43), Panathura north to Punthura (CSP52-53), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75), and Kochuveli to Valiyaveli (CSP77-78). Erosion was reported at Poovar south (CSP16), Poovar (CSP18), Poovar north (CSP20), Karumkulam (CSP22), Mullur (CSP37), Kovalam (CSP40A,42), Shangumugham south (CSP69), Vettucaud (CSP74), Kochuveli (CSP76), and Thumba (CSP80-81) on the onshore. Results are shown in **Figure 4.18**.

Offshore, in the pre-monsoon season of 2023, erosion was observed at Adimalathura (CSP 33). Accretion noted at Poovar (CSP18), Poovar north to Adimalathura (CSP21-32), Adimalathura (CSP34), Kovalm to Punthura (CSP40A-57), and Beemapally to Shangumugham south (CSP60-68). Results are shown in **Figure 4.19.**

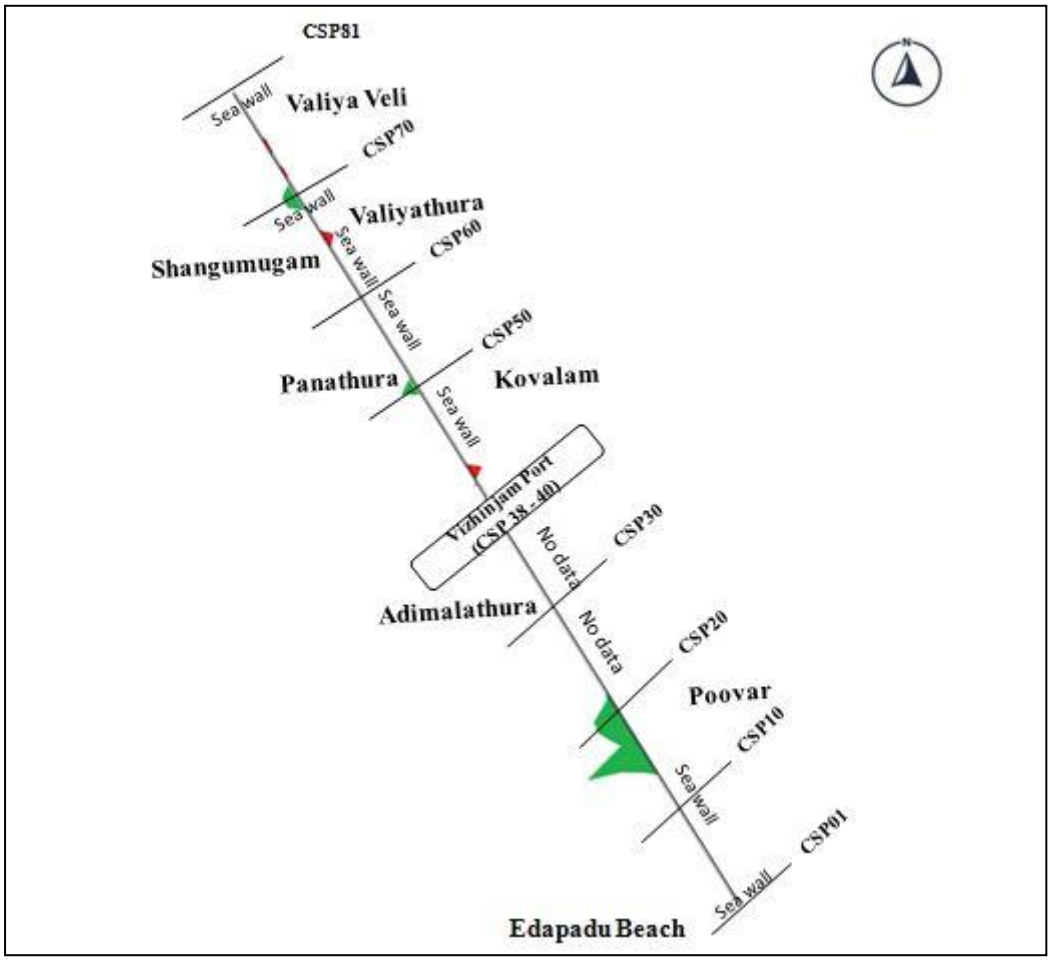
Beach Volume Change in Monsoon 2023 (June 2023-September 2023)

During the monsoon period, beaches exhibit accretion at Edappadu beach (CSP02), Poovar south to Poovar (CSP15-18), Kovalam (CSP40A, 42), Punthura (CSP53), Kochuveli (CSP75, CSP77), and Thumba (CSP81), while erosion at Poovar to Poovar north (CSP19-CSP21), Kovalam (CSP43), Panathura north (CSP52), Valliyathura (CSP64A), Shangumugham south (CSP69), Shangumugham north (CSP71), Vettucaud (CSP74), Kochuveli (CSP76), Valiyaveli (CSP78),

and Thumba (CSP80) on the onshore. No survey was carried out offshore. The results are shown in **Figure 4.20.**

Overall beach volume variation from October 2022 to September 2023 (onshore)

During the year October 2022 to September 2023, beaches exhibited accretion at Edappadu Beach (CSP02), Kovalam (CSP42, 43), Panathura North (CSP52), Shangumugham North (CSP70-71), Vettucaud (CSP73), Kochuveli (CSP75), and Thumba (CSP80-81). Erosion was observed at Shangumugham South (CSP69), Vettucaud (CSP74), and Kochuveli to Valiyaveli (CSP76-78).No offshore survey was carried out during September 2023. The results are shown in **Figure 4.21.**



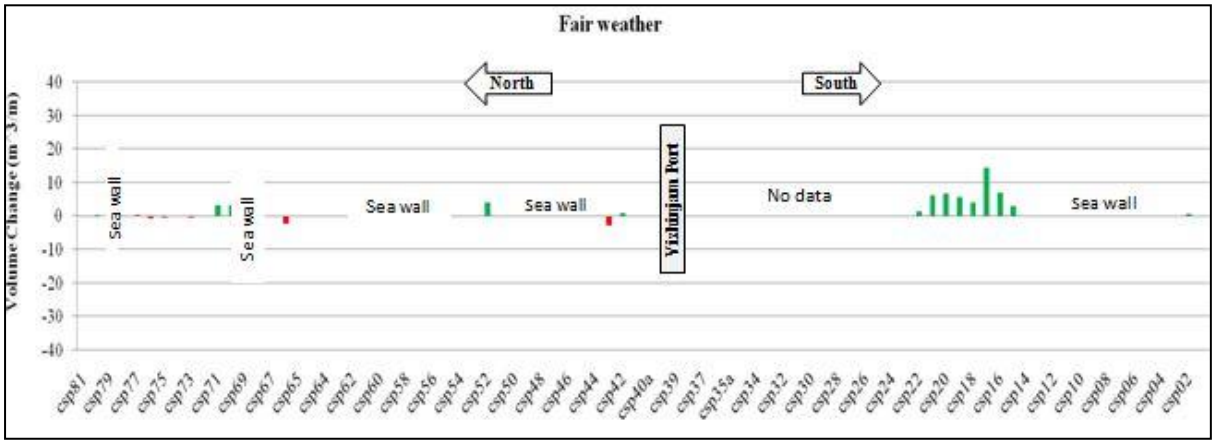
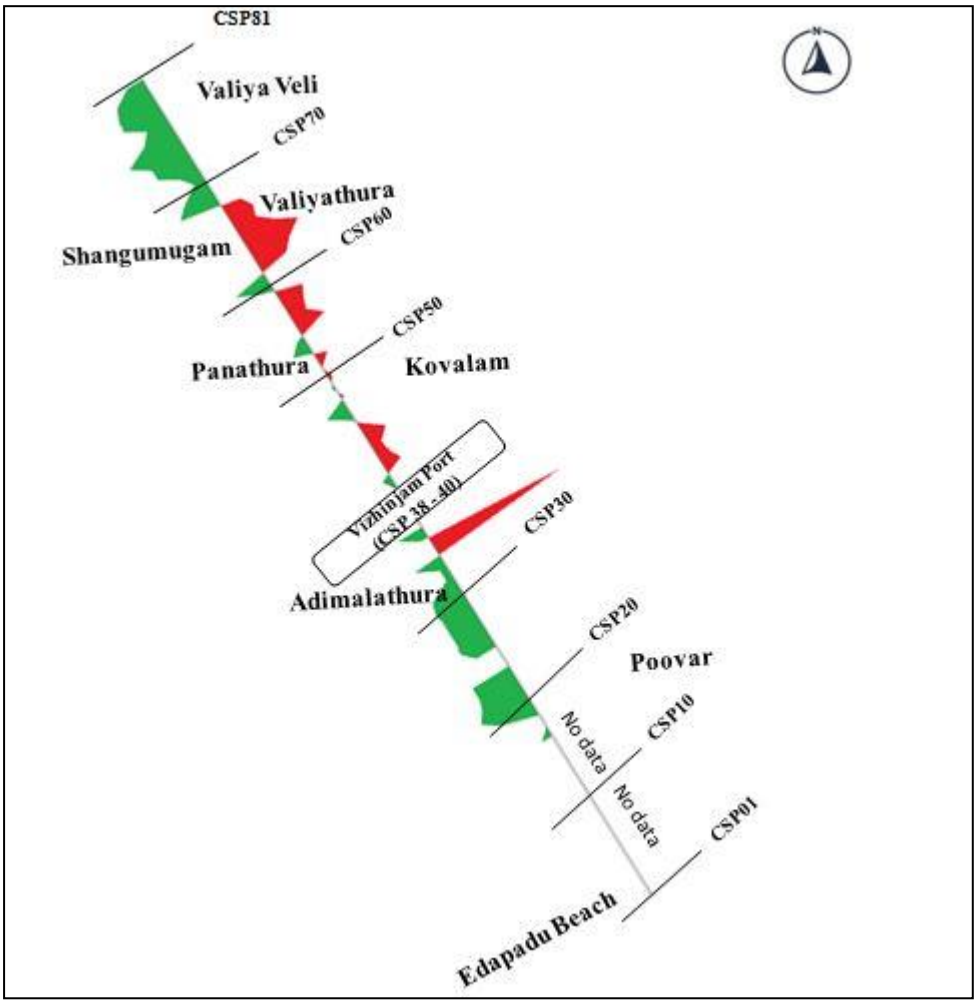


Figure 4.16 Seasonal Beach Volume Changes during Fair Weather Period in m^3/m (onshore)



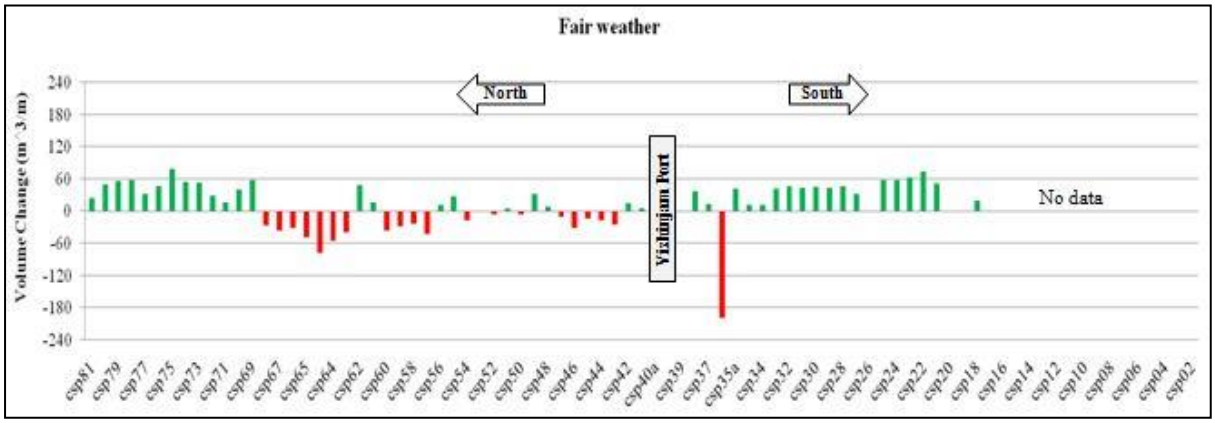
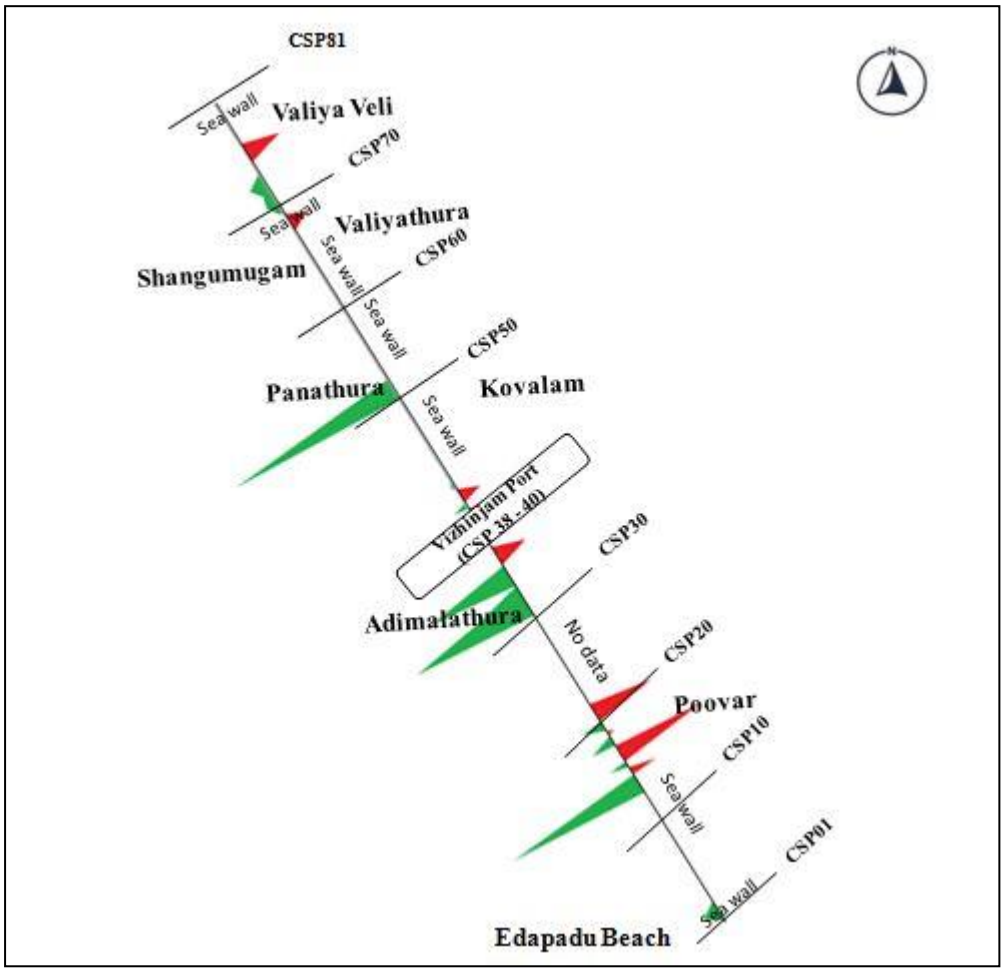


Figure 4.17 Seasonal Beach Volume Changes during Fair weather period in m^3/m (offshore)



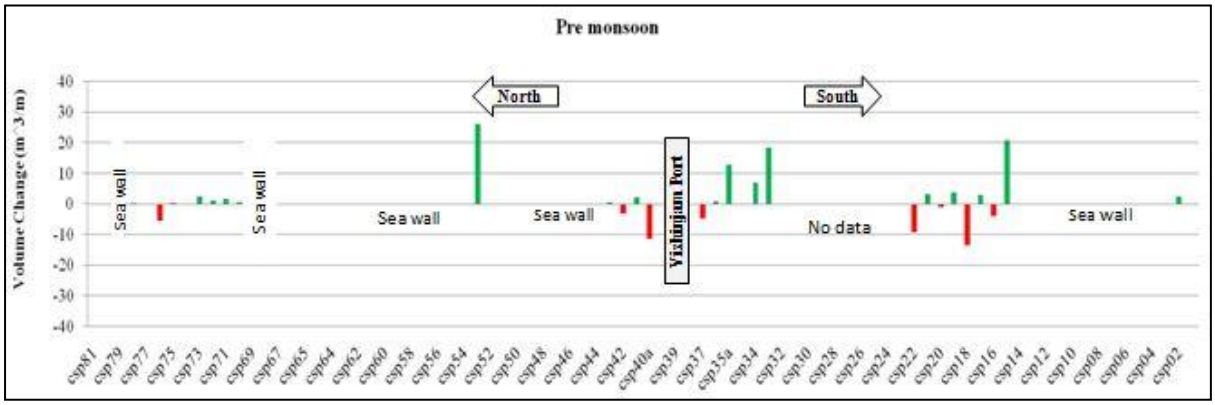
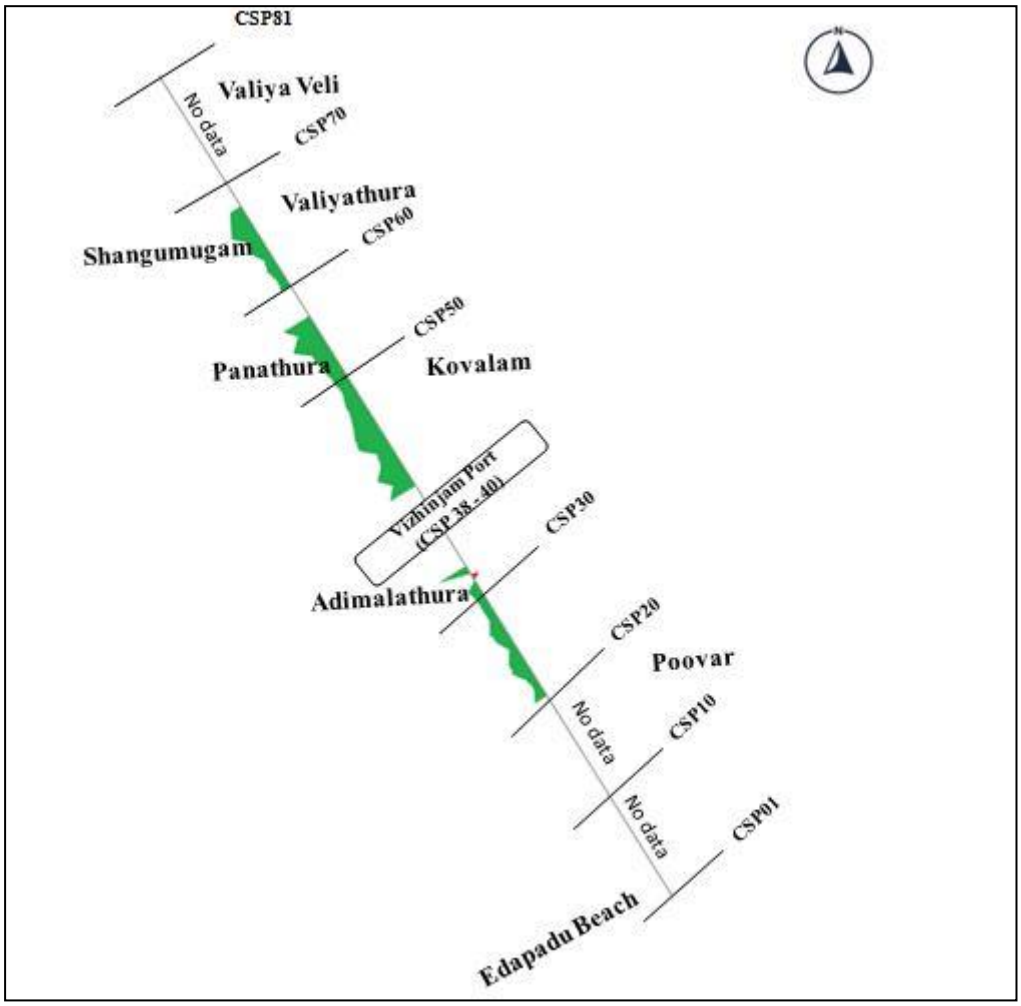


Figure 4.18 Seasonal Beach Volume Changes in Pre-monsoon 2023 in m^3/m (onshore)



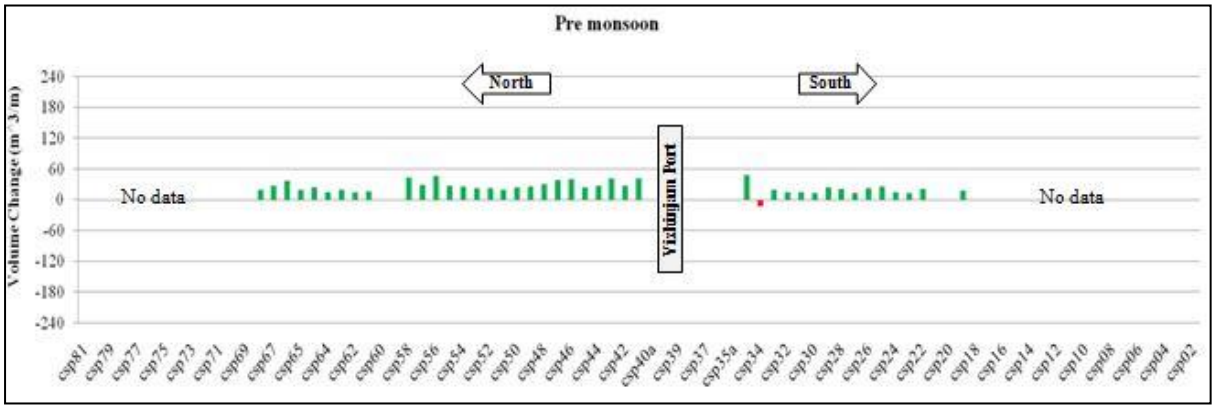
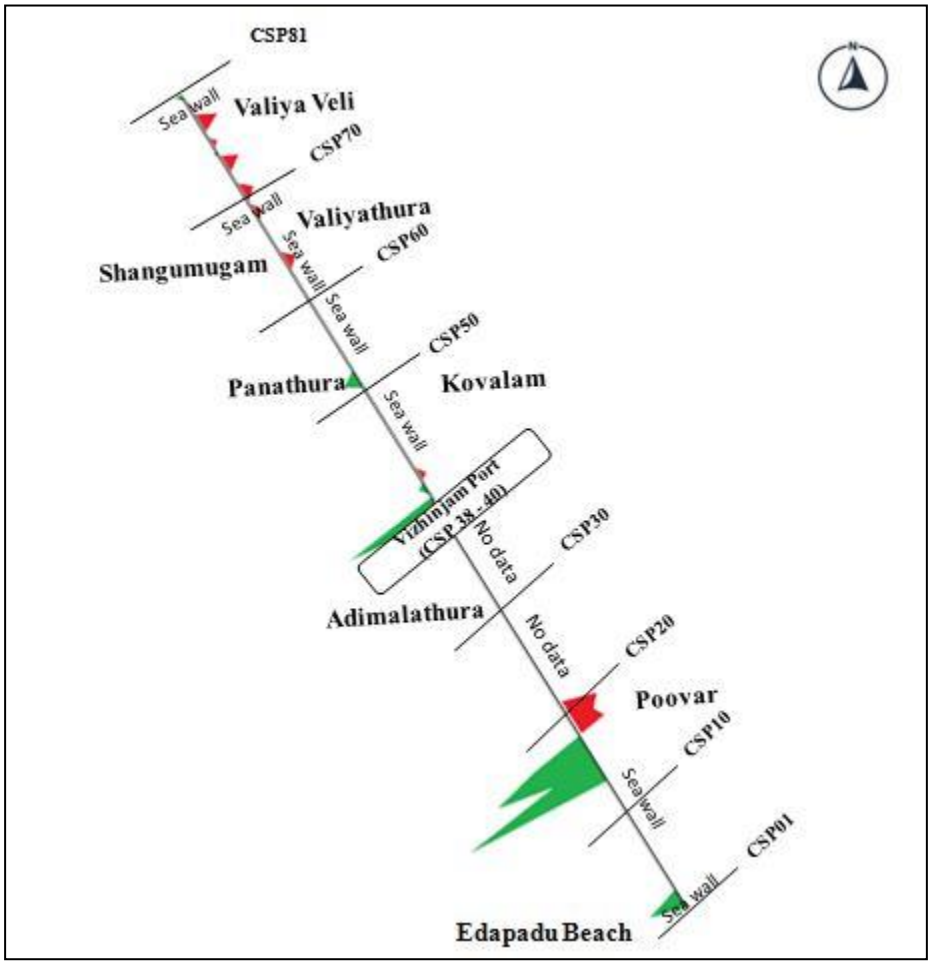


Figure 4.19 Seasonal Beach Volume Changes in Pre-monsoon 2023 in m^3/m (offshore)



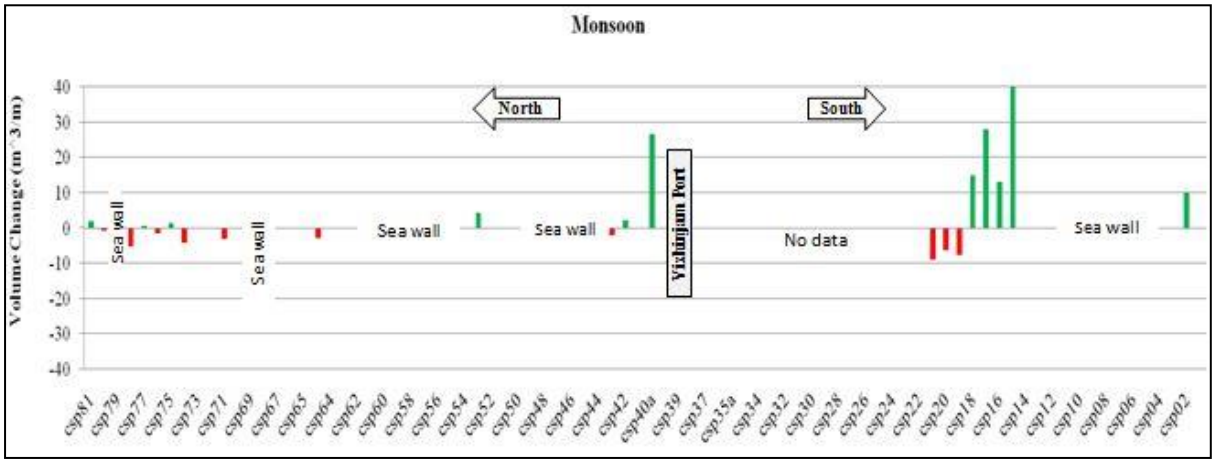
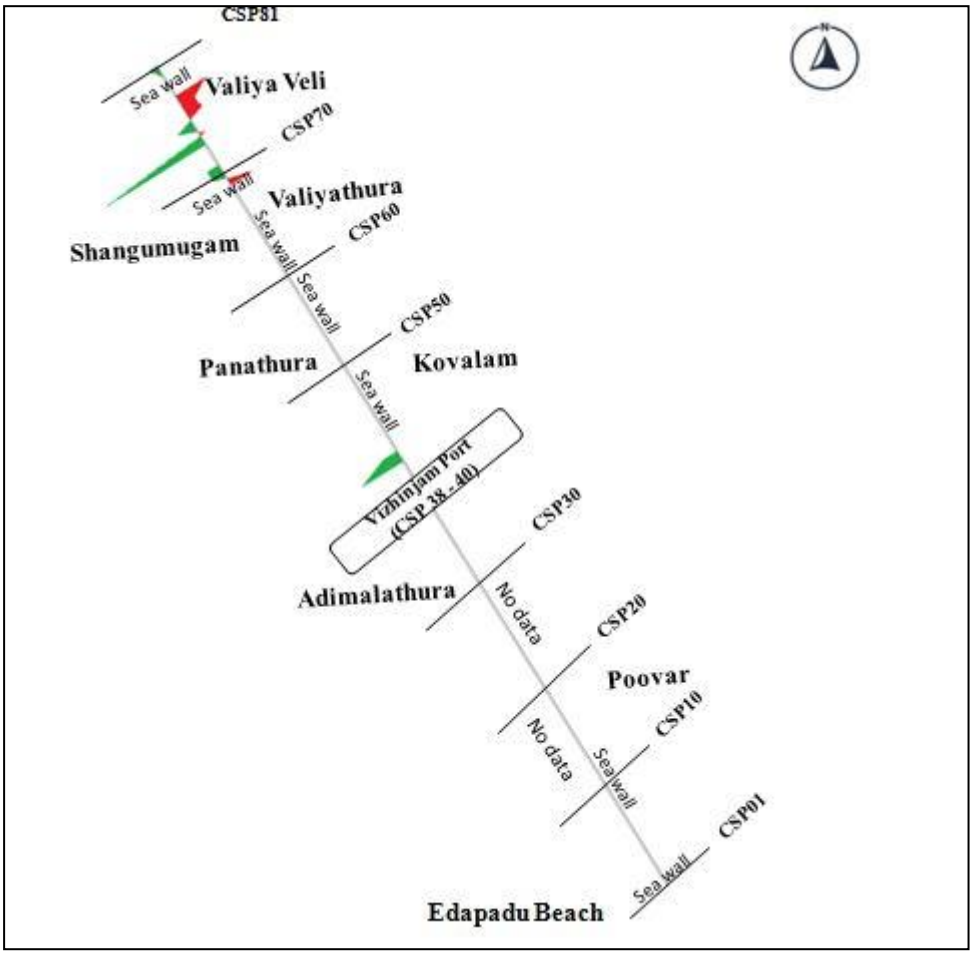


Figure 4.20 Seasonal Beach Volume Changes in Monsoon 2023 in m^3/m (onshore)



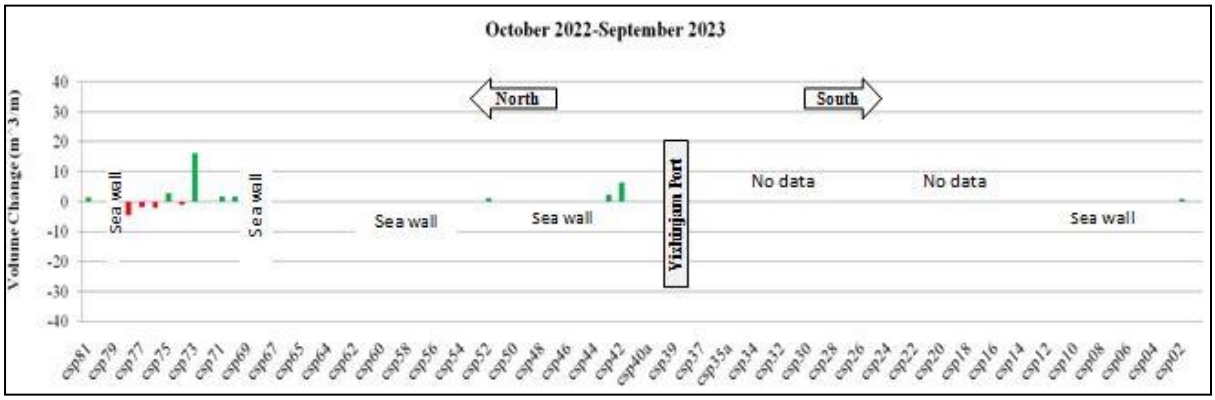


Figure 4.21 Overall Beach Volume Changes for the period of October 2022 to September 2023 in m3/m (onshore)

Table 4.3 Seasonal and Overall Beach Volume Changes in m^3/m (onshore)

CSP NOs.	AREA	October 2022 to November 2022 (Post monsoon Period 2022)	December 2022 to March 2023 (Fair weather Period 2023)	April 2023 to May 2023 (Pre-monsoon Period 2023)	June 2023 to September 2023 (Monsson Period 2023)	October 2022 to September 2023 (overall)
CSP01	SOUTH OF PORT	Sea wall				
CSP02		-	0.58	2.42	9.98	1.01
CSP03		Sea wall				
CSP04						
CSP05						
CSP06						
CSP07						
CSP08						
CSP09						
CSP10						
CSP11						
CSP12						
CSP13						
CSP14						
CSP15		-	3.05	20.66	40.23	-
CSP16		-	6.94	-4.04	13.15	-
CSP17		-	14.43	2.86	27.90	-
CSP18		-	4.04	-13.56	15.10	-
CSP19		-	5.51	3.73	-7.62	-
CSP20		-	6.72	-1.17	-6.17	-
CSP21		-	6.20	3.19	-9.01	-
CSP22		-	1.34	-9.19	-	-
CSP23		-	-	-	-	-
CSP24		-	-	-	-	-
CSP25		-	-	-	-	-
CSP26		-	-	-	-	-
CSP27		-	-	-	-	-
CSP28		-	-	-	-	-
CSP29		-	-	-	-	-
CSP30		-	*	-	-	-
CSP31		-	-	-	-	-
CSP32		-	-	-	-	-
CSP33		-	-	18.30	-	-
CSP34		-	-	6.93	-	-
CSP35		-	-	-	-	-
CSP35 A		-	-	12.80	-	-
CSP36		-	-	0.73	-11.35	-
CSP37		-	-	-4.66	-0.67	-
CSP38						
CSP39						
CSP40						
CSP40 A	NORTH OF PORT	-	-	-11.41	26.57	-
CSP41		-	-	2.19	-	-
CSP42		-	0.93	-3.27	2.30	6.33
CSP43		-	-2.98	0.50	-1.95	2.23
CSP44		-	*	*	*	*
CSP45						
CSP46						
CSP47						
CSP48						

CSP49						
CSP50						
CSP51		-	*	*	*	*
CSP52		-	3.96	0.04	-0.03	1.26
CSP53		-	-	25.95	4.46	-
CSP54						
CSP55						
CSP56						
CSP57						
CSP58						
CSP59						
CSP60						
CSP61						
CSP62						
CSP63						
CSP64						
CSP64 A						
CSP65						
CSP66		-	*	*	*	*
CSP67		Sea wall				
CSP68						
CSP69		-	0.44	-3.05	-1.79	-3.63
CSP70		-	3.27	0.53		1.88
CSP71		-	3.30	1.64	-3.18	1.87
CSP72		-	-0.36	1.14	*	*
CSP73		-	-0.42	2.34	*	16.27
CSP74		-	-0.32	-0.13	-4.21	-1.03
CSP75		-	-0.49	0.15	1.38	2.75
CSP76		-	-0.71	-5.64	-1.54	-2.18
CSP77		-	0.29	0.02	0.60	-1.92
CSP78		-	-0.28	0.36	-5.21	-4.60
CSP79		Sea wall				
CSP80		-	0.40	-0.01	-2.58	0.22
CSP81		-	0.01	-0.09	2.04	1.37

***Data not considered for analysis**

-No data

Table 4.4 Overall beach volume variation from October 2022 to September 2023 (offshore)

CSP NOs.	AREA	October 2022 to November 2022 (Post monsoon Period 2022)	December 2022 to March 2023 (Fairweather Period 2023)	April 2023 to May 2023 (Pre-monsoon Period 2023)	June 2023 to September 2023 (Monsson Period 2023)	October 2022 to September 2023 (overall)
CSP01	SOUTH OF PORT	-	-	-	-	-
CSP02		-	-	-	-	-
CSP03		-	-	-		-
CSP04		-	-	-	-	-
CSP05		-	-	-	-	-
CSP06		-	-	-	-	-
CSP07		-	-	-	-	-
CSP08		-	-	-	-	-
CSP09		-	-	-	-	-
CSP10		-	-	-	-	-
CSP11		-	-	-	-	-
CSP12		-	-	-	-	-

CSP13		-	-	-	-	-
CSP14		-	-	-	-	-
CSP15		-	-	-	-	-
CSP16		-	-	-	-	-
CSP17		-	18.61	-	-	-
CSP18		-	0.25	17.57	-	-
CSP19		-	-1.98	*	-	-
CSP20		-	51.35	-	-	-
CSP21		-	73.32	21.40	-	-
CSP22		-	61.97	12.01	-	-
CSP23		-	57.13	13.78	-	-
CSP24		-	57.01	25.55	-	-
CSP25		-	-	23.04	-	-
CSP26		-	31.63	12.26	-	-
CSP27		-	46.60	21.11	-	-
CSP28		-	43.16	23.44	-	-
CSP29		-	44.67	13.48	-	-
CSP30		-	43.81	14.26	-	-
CSP31		-	46.16	13.83	-	-
CSP32		-	42.17	18.51	-	-
CSP33		-	10.80	-12.21	-	-
CSP34		-	10.96	48.04	-	-
CSP35		-	41.42	-	-	-
CSP35A		-	-199.87	-	-	-
CSP36		-	12.61	-	-	-
CSP37		-	37.70	-	-	-
CSP38	Port Area					
CSP39						
CSP40						
CSP40A	NORTH OF PORT	-	4.37	41.78	-	-
CSP41		-	14.36	27.73	-	-
CSP42		-	-25.76	41.91	-	-
CSP43		-	-17.48	26.84	-	-
CSP44		-	-14.72	23.61	-	-
CSP45		-	-30.93	40.51	-	-
CSP46		-	-10.39	38.13	-	-
CSP47		-	8.50	31.08	-	-
CSP48		-	32.79	26.29	-	-
CSP49		-	-5.74	24.06	-	-
CSP50		-	5.49	19.04	-	-
CSP51		-	-5.88	21.63	-	-
CSP52		-	-0.42	22.88	-	-
CSP53		-	-17.97	25.97	-	-
CSP54		-	26.91	27.70	-	-
CSP55		-	11.39	46.56	-	-
CSP56		-	-42.39	29.42	-	-
CSP57		-	-23.23	43.00	-	-
CSP58		-	-28.52	*	-	-
CSP59		-	-36.52	-	-	-
CSP60		-	16.39	15.98	-	-
CSP61		-	48.61	14.25	-	-
CSP62		-	-40.22	18.42	-	-
CSP63		-	-54.96	14.46	-	-

CSP64		-	-77.61	23.85	-	-
CSP64A		-	*	*	-	-
CSP65		-	-50.00	19.84	-	-
CSP66		-	-31.61	36.20	-	-
CSP67		-	-36.78	27.75	-	-
CSP68		-	-26.40	18.79	-	-
CSP69		-	57.74	-	-	-
CSP70		-	40.74	-	-	-
CSP71		-	16.64	-	-	-
CSP72		-	28.45	-	-	-
CSP73		-	53.55	-	-	-
CSP74		-	54.42	-	-	-
CSP75		-	78.11	-	-	-
CSP76		-	45.75	-	-	-
CSP77		-	32.31	-	-	-
CSP78		-	58.43	-	-	-
CSP79		-	56.34	-	-	-
CSP80		-	49.69	-	-	-
CSP81		-	24.69	-	-	-

***Data not considered for analysis**
-No data

4.1.4 Seasonal Beach Volume comparison between the period October 2021 and October 2022, February 2022 and February 2023, May 2022 and May 2023 and September 2022 and September 2023

Beach Volume comparison between October 2021 and October 2022

No offshore survey was carried out in October 2021 and October 2022. Hence, the comparison of October 2021 beach profiles with October 2022 done only for the onshore part has been presented in **Figure 4.22** and **Table 4.5.** The beach was shown accretion at Edappadu beach (CSP02), Kovalam (CSP42-44), Panathura north (CSP51-52), Valliyathura (CSP66), Shangumugham north (CSP70-71), Vettucaud (CSP74), Kochuveli (CSP76-77), Thumba (CSP80-81) in October 2022 compared to October 2021. The locations Punthura (CSP53), Shangumugam South (CSP69), Vettucaud (CSP72-73), Kochuveli (CSP75) and Valiyaveli (CSP78) showed erosion trend in October 2022 compared to October 2021. The change in volume in percentage during this period was less than 1%.

Beach Volume comparison between February 2022 and February 2023

No offshore survey was carried out for February 2022. Hence, a comparison was made only for the onshore part. On onshore during February 2023, the beach exhibits accretion compared to February 2022 at the locations Poovar to Karumkulam (CSP18-26), Pulluvila (CSP28), Adimalathura (CSP31-33), Mullur (CSP36), Kovalam (CSP42,44), Punthura (CSP53),

Shangumugham south to Shangumugham north (CSP69-71), Vettucaud (CSP73), Kochuveli (CSP75,77) and Thumba (CSP80-81). Erosion noted at Poovar south (CSP15,17), Pulluvila (CSP27,30), Azhimala(CSP35A), Mullur (CSP37), Kovalam(CSP41,43), Panathura north (CSP51-52), Valliyathura (CSP66), Vettucaud (CSP72,74), Kochuveli (CSP76), Valiyaveli (CSP78). The change in volume in percentage during this period was less than 1%. Results have been presented in **Figure 4.23** and **Table 4.5.**

Beach Volume comparison between May 2022 and May 2023

No offshore survey was carried out for May 2022. Hence, a comparison was made only for the onshore part. Erosion was noticed at Edapadu Beach (CSP02), Poovar South (CSP15), Adimalathura (CSP34), Kovalam (CSP40A,44), Panathura North (CSP51), Punthura (CSP53), Kochuveli (CSP75) and Valiyaveli (CSP78) in May 2023 compared to May 2022. Accretion found at Poovar south (CSP16-18), Poovar north (CSP20-22), Adimalathura (CSP33), Azhimala to Mullur (CSP35A-37), Kovalam (CSP41-43), Panathura north (CSP52), Valliyathura (CSP66), Shangumugham south to Vettucaud (CSP69-74), Kochuveli to Valiyaveli (CSP76-77) and Thumba (CSP80-81). However, the volume change in percentage is less than 1% from May 2022 to May 2023. Results have been presented in **Figure 4.24** and **Table 4.5.**

Beach Volume comparison between September 2022 and September 2023

No offshore survey was carried out for September 2022 and September 2023. Hence, the comparison was done only for the onshore part, as shown in **Figure 4.25** and **Table 4.5.** There are no data from CSP22 to CSP41, 43 and 44 onshore. Erosion has occurred at Poovar south (CSP16), Panathura (CSP51-52), Valliyathura (CSP66), Shangumugham north (CSP70), Kochuveli to Valiyaveli (CSP75-78) in September 2023 compared to September 2022. Accretion noticed at Edappadu Beach (CSP02), Poovar South (CSP15), Poovar South to Poovar North (CSP17-21), Kovalam (CSP42), Shangumugham South (CSP69), Shangumugham north to Vettucaud (CSP71-74) and Thumba (CSP80-81). However, the volume change in percentage is less than 1%.

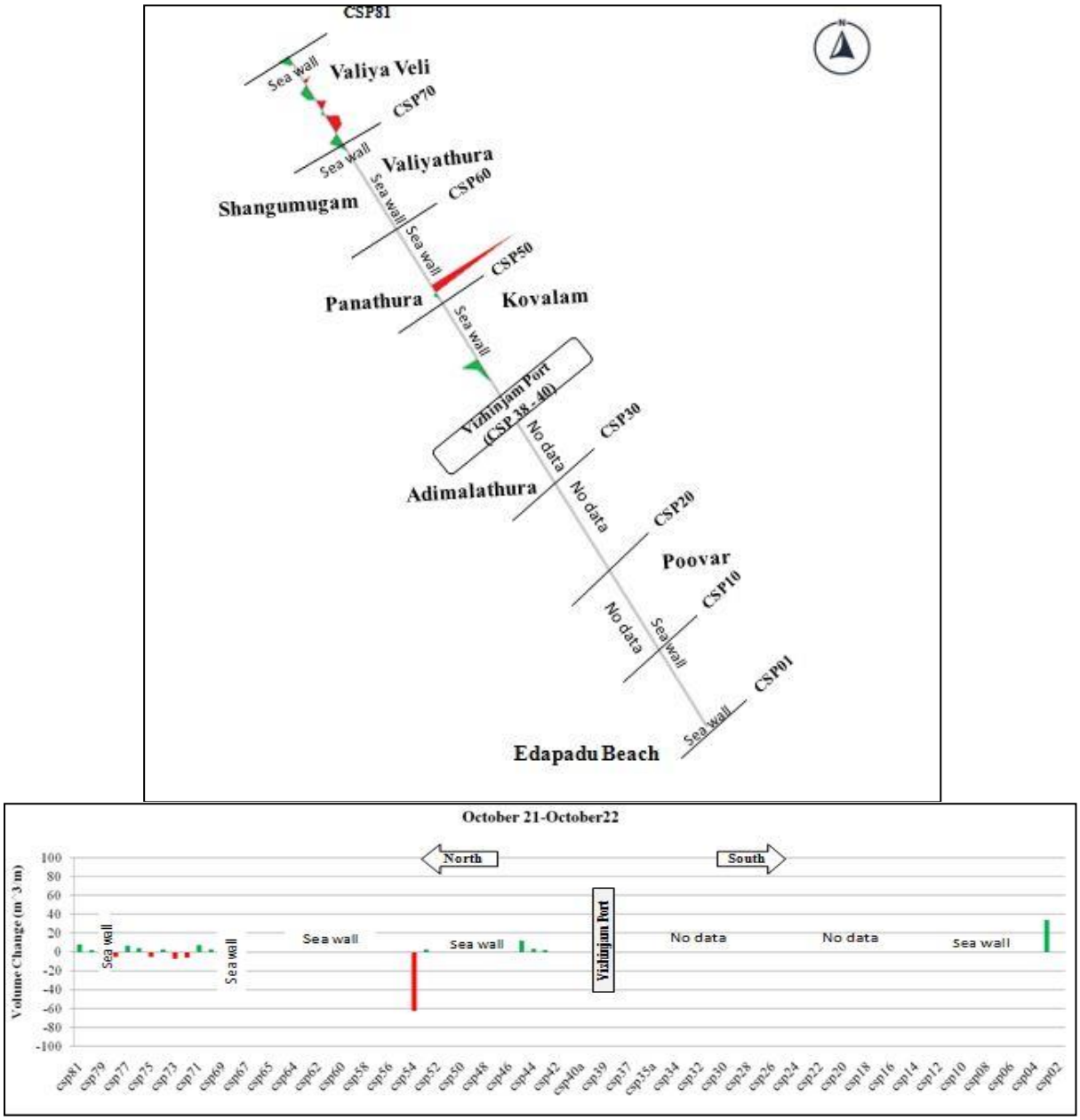
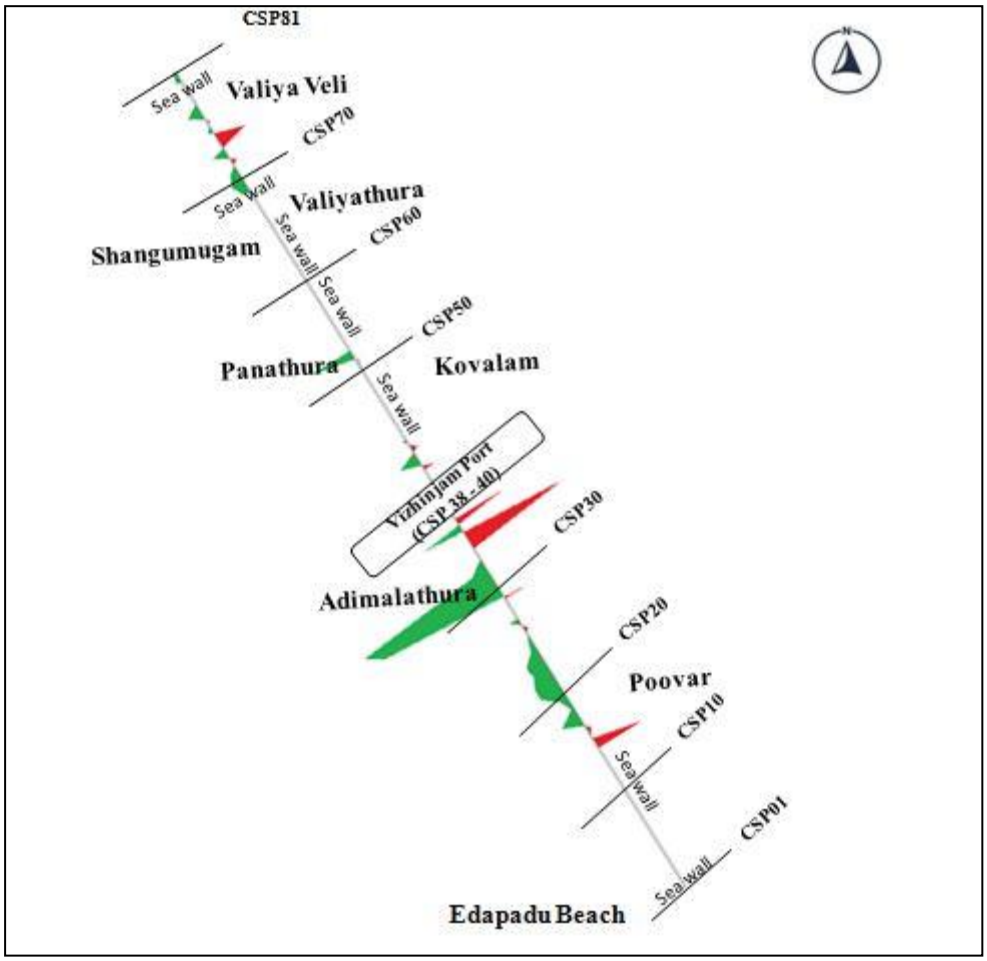


Figure 4.22 Beach Volume Change comparison between October 2021 and October 2022 in m^3/m (onshore)



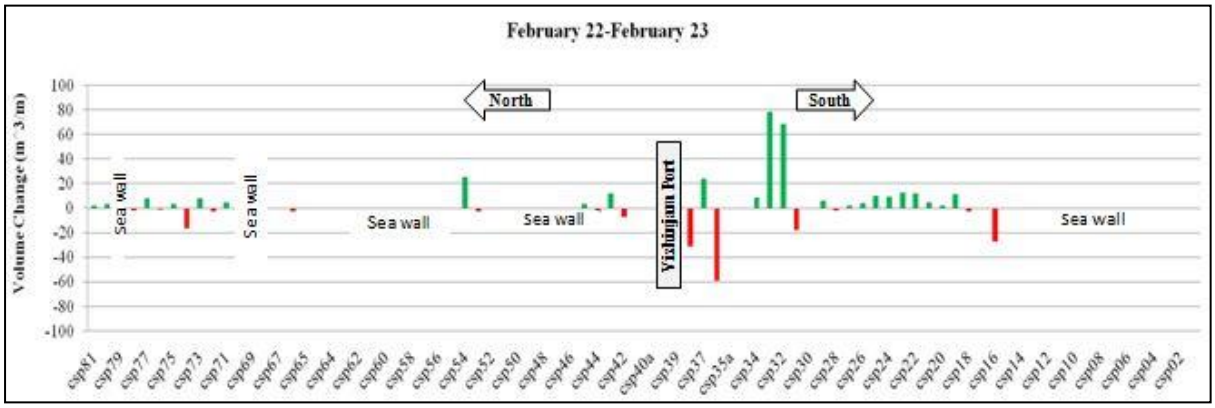
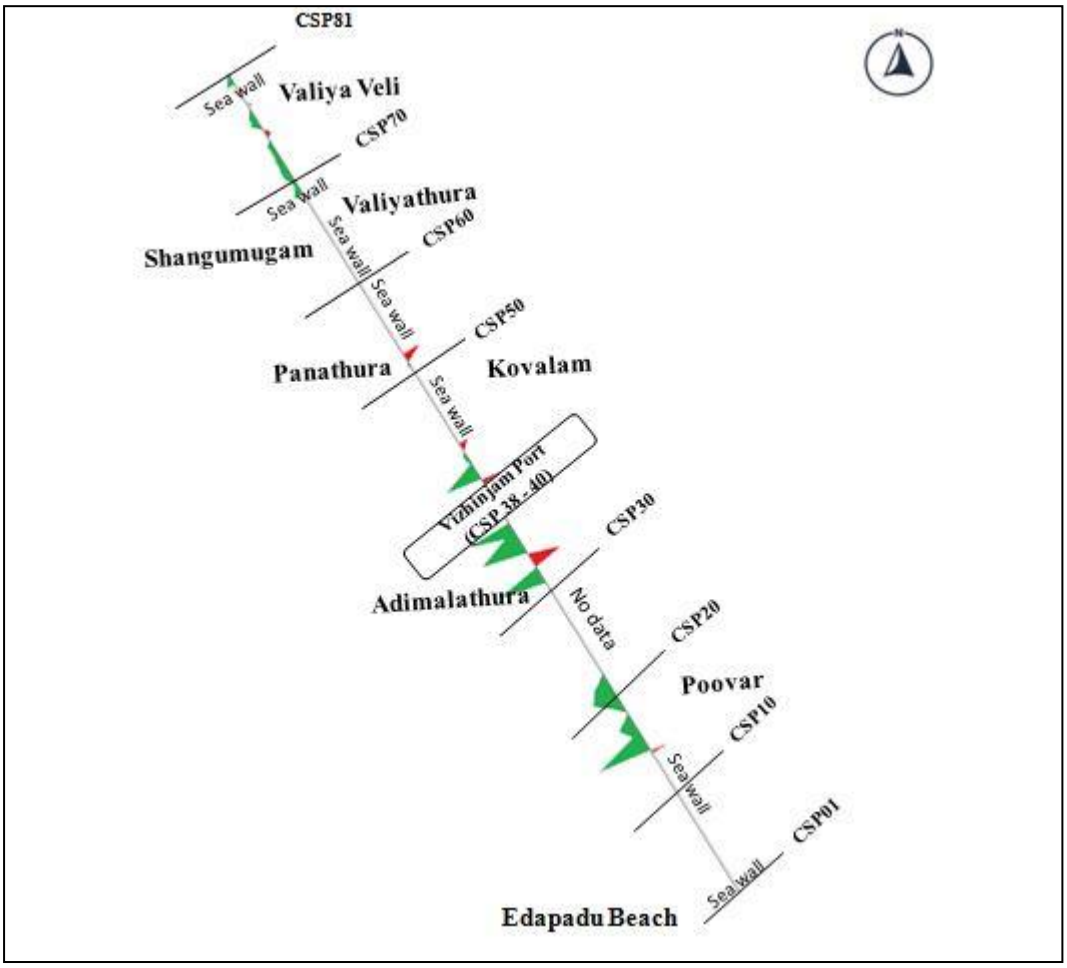


Figure 4.23 Beach Volume Change comparison between February 2022 and February 2023 in m^3/m (onshore)



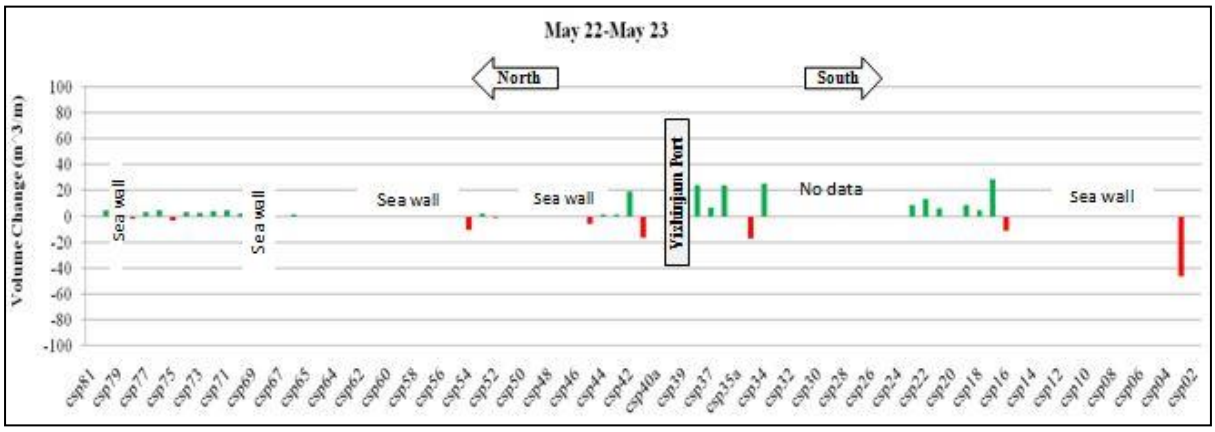
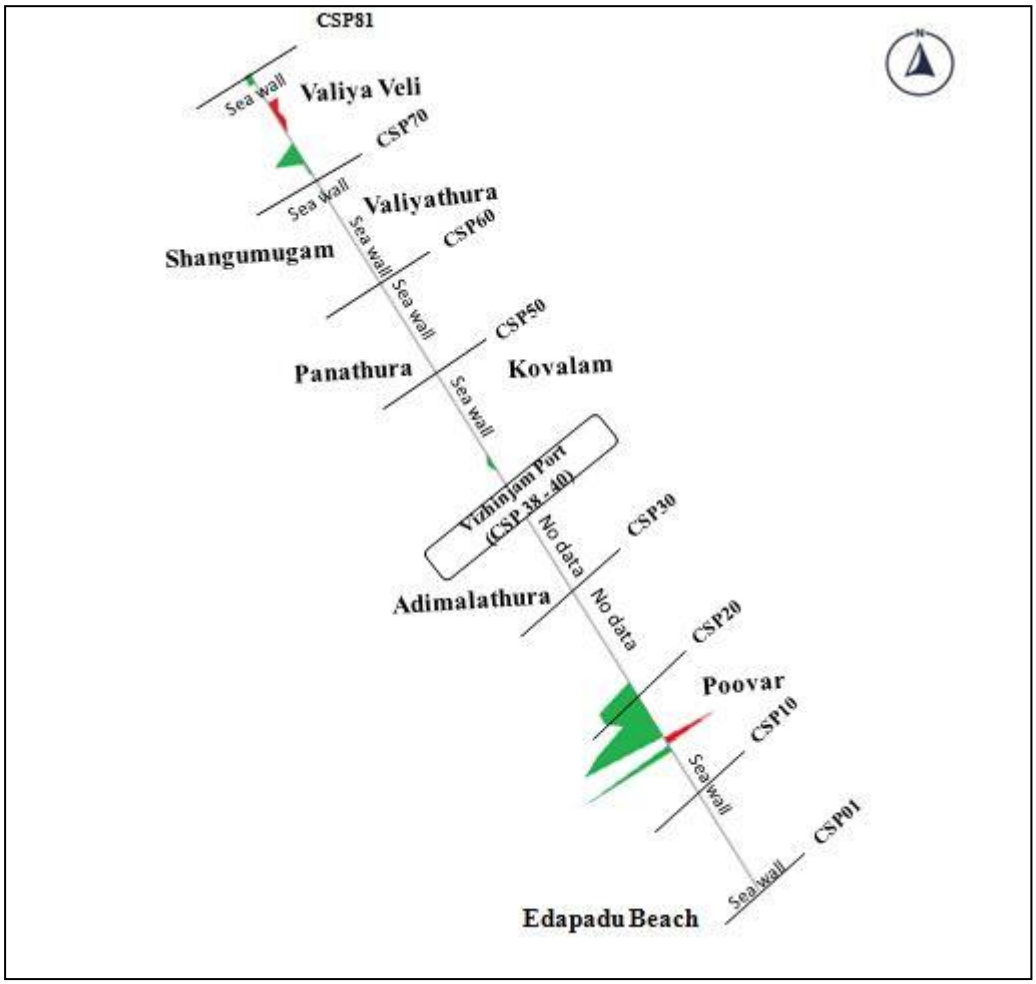


Figure 4.24 Beach Volume Change comparison between May 2022 and May 2023 in m^3/m (onshore)



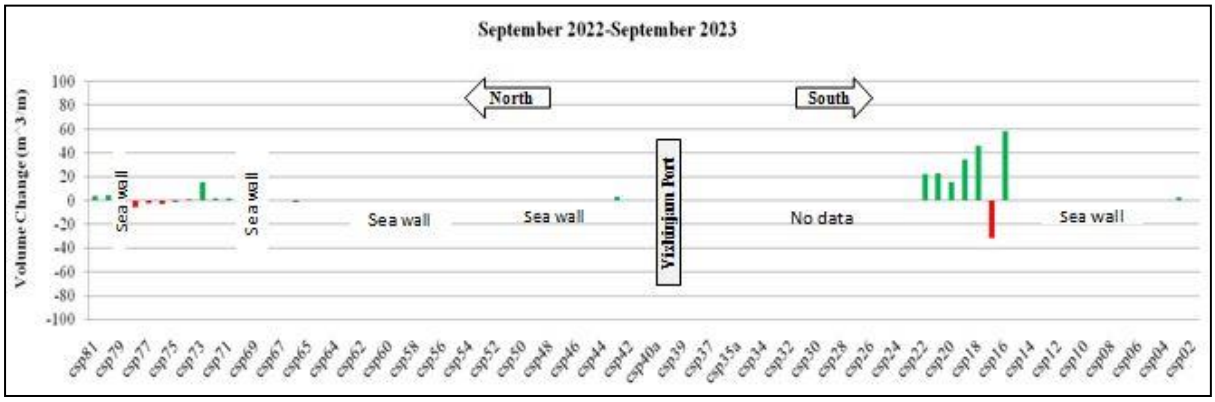


Figure 4.25 Beach Volume Change comparison between September 2022 and September 2023 in m^3/m (onshore)

Table 4.5 Beach Volume Changes comparing the months of October 2021 and October 2022(onshore), February 2022 and February 2023 (onshore), May 2022 and May 2023, September 2022 and September 2023 in m^3/m

Location	October 2021 and October 2022 (onshore)	Change in percentage (October 2021-October 2022) (onshore)	February 2022 and February 2023 (onshore)	Change in percentage (February 2022 and February 2023) (onshore)	May2022 and May2023 (onshore)	Change in percentage (May 2022-May 2023) (onshore)	September 2022 and September 2023 (onshore)	Change in percentage (September 2022-September 2023) (onshore)
CSP01	Sea wall				Sea wall			
CSP02	33.74	0.03	*	*	-46.46	0.03	2.08	0.00
CSP03	Seawall							
CSP04								
CSP05								
CSP06								
CSP07								
CSP08								
CSP09								
CSP10								
CSP11								
CSP12								
CSP13								
CSP14								
CSP15	-	-	-27.37	0.01	-11.20	0.01	57.95	0.04
CSP16	-	-	*	*	28.64	0.01	-31.49	0.03
CSP17	-	-	-2.41	0.00	4.60	0.00	46.14	0.02
CSP18	-	-	11.36	0.01	8.79	0.00	34.25	0.02
CSP19	-	-	1.95	0.00	*	*	15.33	0.01
CSP20	-	-	4.47	0.00	6.01	0.00	22.55	0.01
CSP21	-	-	12.12	0.01	13.28	0.01	21.80	0.02
CSP22	-	-	12.48	0.01	8.75	0.01	-	-
CSP23	-	-	9.44	0.01	-	-	-	-
CSP24	-	-	10.10	0.00	-	-	-	-
CSP25	-	-	3.76	0.00	-	-	-	-
CSP26	-	-	1.79	0.00	-	-	-	-
CSP27	-	-	-2.06	0.00	-	-	-	-
CSP28	-	-	5.71	0.00	-	-	-	-
CSP29	-	-	*	*	-	-	-	-
CSP30	-	-	-18.22	0.01	-	-	-	-
CSP31	-	-	68.37	0.02	-	-	-	-
CSP32	-	-	78.17	0.02	-	-	-	-
CSP33	-	-	8.82	0.00	25.24	0.01	-	-
CSP34	-	-	*	*	-16.77	0.01	-	-
CSP35	-	-	*	*	-	-	-	-
CSP35A	-	-	-59.33	0.03	23.85	0.01	-	-
CSP36	-	-	23.94	0.02	6.59	0.01	-	-
CSP37	-		-31.10	0.03	24.05	0.03	-	-
CSP38	PORT AREA							
CSP39								
CSP40								
CSP40A	-	-	*	*	-16.19	0.01	-	*
CSP41	-	-	-7.21	0.01	19.54	0.03	-	-
CSP42	2.17	0.00	12.07	0.01	1.60	0.00	3.04	0.01
CSP43	3.63	0.01	-3.41	0.00	1.88	0.00	*	-
CSP44	12.10	0.01	3.18	0.00	-5.62	0.00	-	-
CSP45	Seawall							

CSP46								
CSP47								
CSP48								
CSP49								
CSP50								
CSP51	0.06	0.00	-0.35	0.00	-0.84	0.00	-0.14	0.00
CSP52	2.42	0.00	-2.56	0.00	1.98	0.00	-0.61	0.00
CSP53	-62.57	0.03	25.52	0.03	-10.65	0.01	*	*
CSP54								
CSP55								
CSP56								
CSP57								
CSP58								
CSP59								
CSP60								
CSP61								
CSP62								
CSP63								
CSP64								
CSP65								
CSP66	0.01	0.00	-2.91	0.01	1.34	0.01	-0.37	0.00
CSP67								
CSP68								
CSP69	-0.02	0.00	3.99	0.00	5.58	0.01	2.83	0.01
CSP70	2.65	0.01	7.18	0.01	2.01	0.00	-0.88	0.00
CSP71	7.54	0.01	4.79	0.00	4.79	0.01	1.53	0.00
CSP72	-5.60	0.01	-2.71	0.00	3.93	0.01	1.76	0.01
CSP73	-7.22	0.01	8.08	0.01	3.19	0.01	15.12	0.06
CSP74	2.92	0.01	-16.67	0.02	3.24	0.01	1.25	0.00
CSP75	-5.47	0.01	3.19	0.00	-3.15	0.00	-0.30	0.01
CSP76	4.38	0.01	-1.63	0.00	4.69	0.01	-3.31	0.01
CSP77	6.46	0.01	7.94	0.01	3.25	0.00	-2.46	0.00
CSP78	-5.45	0.01	-1.97	0.00	-1.84	0.00	-5.75	0.02
CSP79								
CSP80	2.35	0.01	3.46	0.00	4.67	0.01	4.07	0.01
CSP81	7.81	0.01	1.88	0.00	0.47	0.00	3.39	0.01

***Data not considered for analysis**
-No data

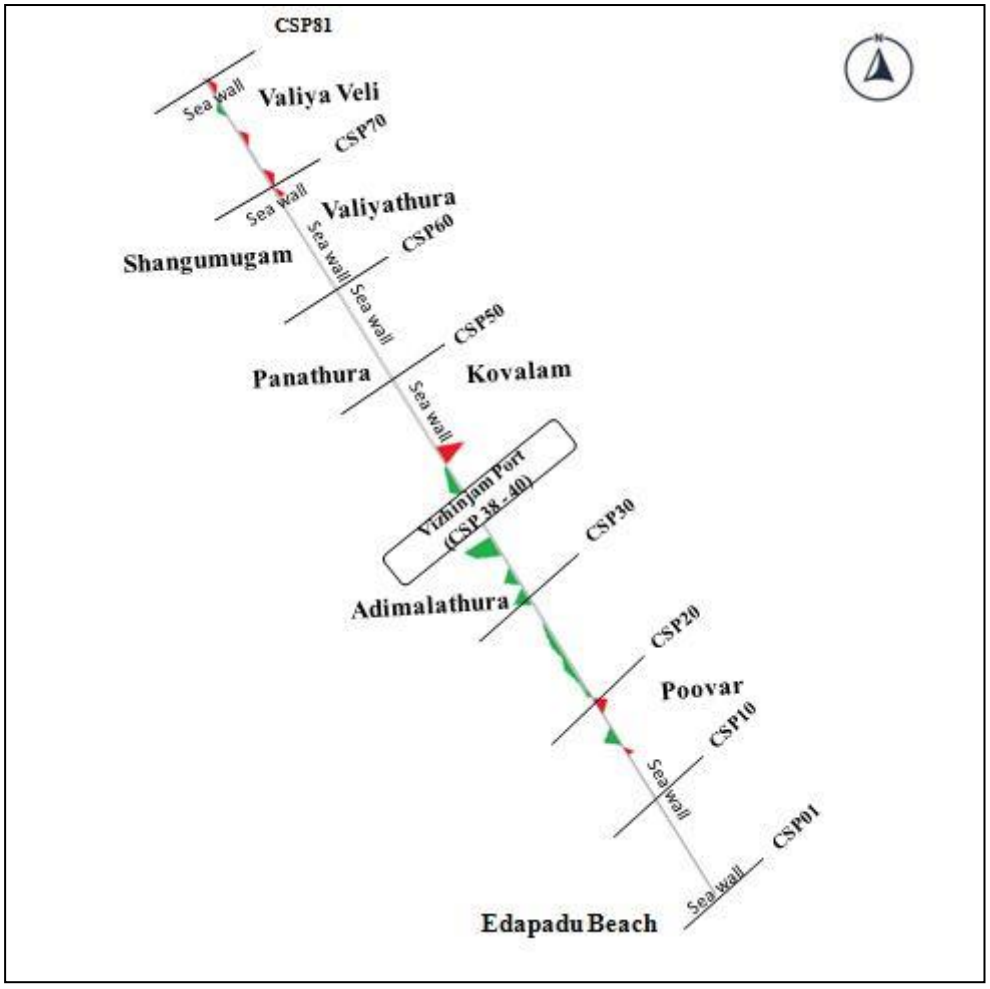
4.1.5 Beach volume variation during February 2015 and February 2023

This analysis has been carried out to identify and compare the beach volume variation before the commencement of the port dredging process with the current scenario. The beach volume changes in February 2015 and February 2023 are given in graphs in **Figure 4.26 & Figure 4.27** and **Table 4.5**.

On the onshore part accretion noticed at Poovar South (CSP17), Poovar north (CSP21-28), Adimalathura (CSP31 & CSP33-34), Mullur (CSP36-37), Kovalam (CSP41-43), Panathura north (CSP51), Valiyathura (CSP66) and Kochuveli to Valiyaveli (CSP76-78). Erosion was noticed at Poovar South (CSP15), Poovar South to Poovar North (CSP18-20), Pulluvila (CSP30), Kovalam (CSP44), Shangumugham South to Kochuveli (CSP69-75) and Thumba (CSP80-81).

Offshore, accretion has taken place at Edappadu beach to Paruthiyoor (CSP03-14), Poovar south to Poovar north (CSP16-21), Pulluvila to Adimalathura (CSP27-34), Panathura south (CSP49),

Punthura (CSP53), Punthura to Beemapally (CSP55-58), Beemapally (CSP60), Valliyathura (CSP63-67), Shangumugham to Vettucaud (CSP68-72), Kochuveli to Valiyaveli (CSP75-78) and Thumba (CSP80-81). Poovar South (CSP15), Karumkulam (CSP22-26), Mullur (CSP36-37), Punthura (CSP54), and Valiyaveli (CSP79) exhibited erosion.



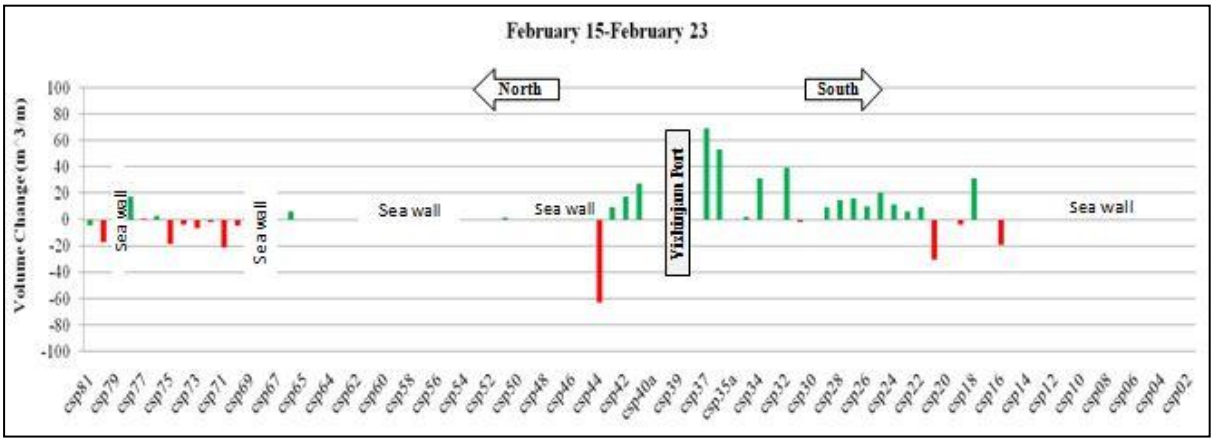
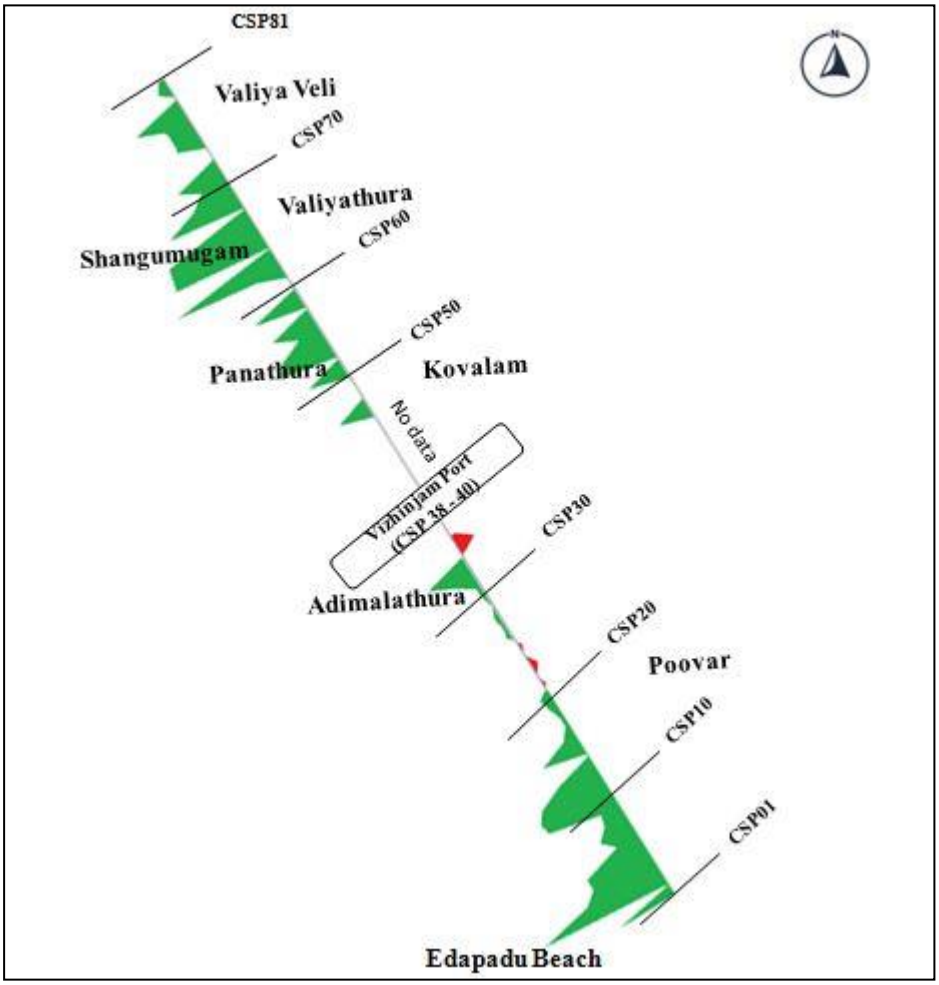


Figure 4.26 Beach Volume Changes - February 2015 and February 2023 in m^3/m (onshore)



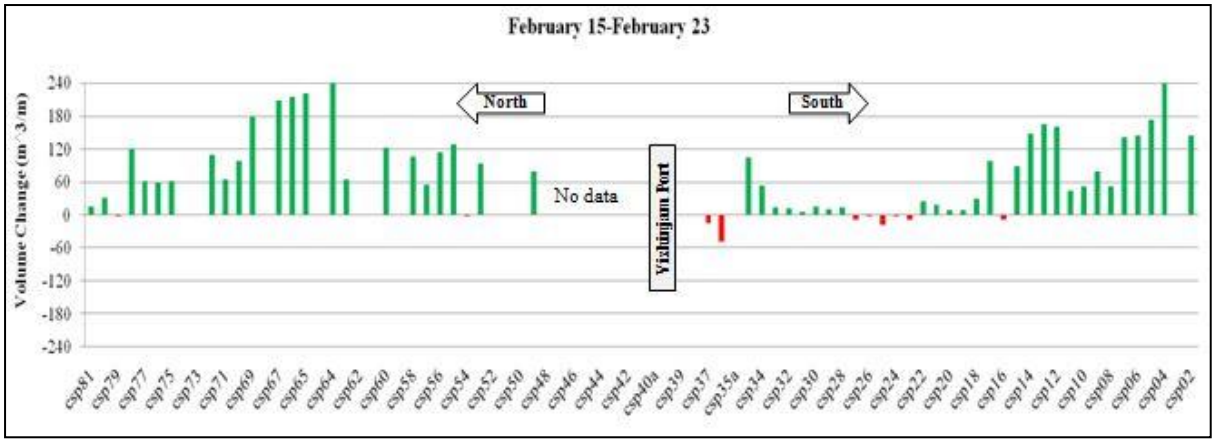


Figure 4.27 Beach Volume Changes - February 2015 and February 2023 in m^3/m (offshore)

Table 4.6 Beach Volume Changes comparing the inter-annual months of February 2015 and February 2023 (onshore and offshore) m^3/m

CSP NOs.	AREA	February 2015 and February 2023 (onshore)	February 2015 and February 2023 (offshore)
CSP01	SOUTH OF PORT	Sea Wall	144.91
CSP02		-	-
CSP03		Sea wall	301.85
CSP04			173.92
CSP05			143.84
CSP06			142.02
CSP07			52.18
CSP08			78.53
CSP09			51.74
CSP10			44.23
CSP11			159.92
CSP12			166.01
CSP13			147.02
CSP14			88.56
CSP15		-19.00	-8.35
CSP16		*	98.61
CSP17		31.56	29.86
CSP18		-4.00	8.26
CSP19		-0.70	9.08
CSP20		-30.27	18.45
CSP21		9.30	25.57
CSP22		6.26	-8.95
CSP23		11.57	-1.37
CSP24		19.86	-18.32
CSP25		10.07	-1.65
CSP26		15.87	-9.32
CSP27		14.75	13.76
CSP28		9.10	10.18
CSP29		*	15.66
CSP30		-2.04	5.00
CSP31		39.02	11.84
CSP32		*	14.17
CSP33		31.50	54.17
CSP34		2.38	105.18
CSP35		*	*
CSP35A		*	*
CSP36		53.06	-48.04
CSP37		69.35	-14.88
CSP38			
CSP39			
CSP40			
CSP40A		*	*
CSP41	NORTH OF PORT	27.39	*
CSP42		17.22	*
CSP43		9.52	*
CSP44		-63.12	*
CSP45		Sea wall	*
CSP46			*
CSP47			*
CSP48			*
CSP49			79.51
CSP50			*
CSP51		1.40	*
CSP52		*	*
CSP53		*	92.72
CSP54		Sea wall	-1.92
CSP55			129.32
CSP56			114.07
CSP57			54.50
CSP58			106.80

CSP59			*
CSP60			121.66
CSP61			*
CSP62			*
CSP63			65.12
CSP64			255.48
CSP64A			*
CSP65			221.45
CSP66		6.23	214.96
CSP67		Sea wall	208.89
CSP68			*
CSP69		-18.31	178.40
CSP70		-4.71	98.87
CSP71		-21.37	65.30
CSP72		-2.11	109.04
CSP73		-6.72	*
CSP74		-3.99	*
CSP75		-18.39	61.04
CSP76		2.71	57.80
CSP77		0.45	60.84
CSP78		17.10	121.39
CSP79		*	-3.02
CSP80		-17.34	31.67
CSP81		-4.71	15.59

***Data not considered for analysis**

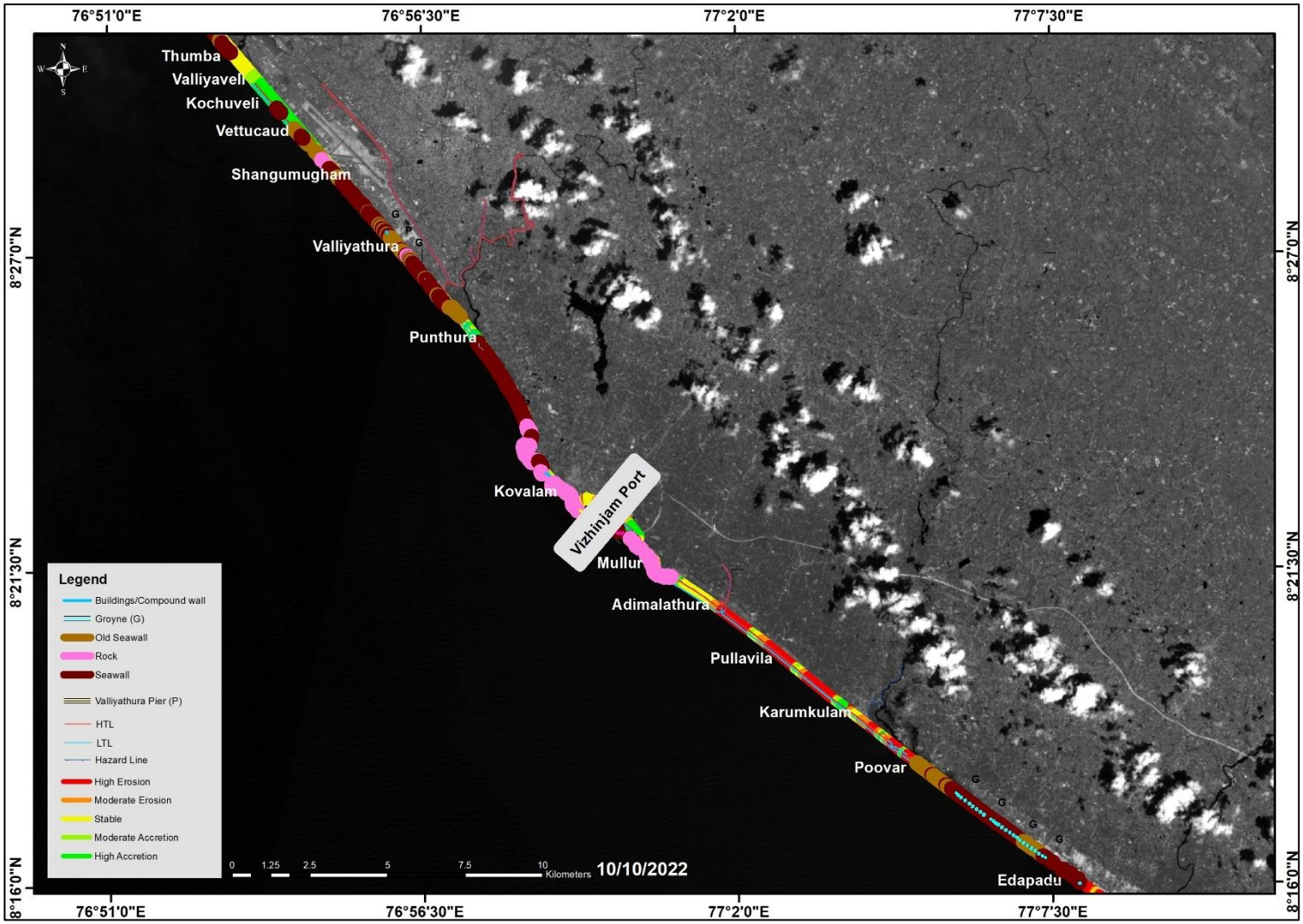
-No data

4.2 Results for Shoreline Change Analysis from Satellite Images

This report provides the shoreline change (monthly, seasonal and annual shoreline change analysis)over the period from October 2022 to September 2023 using satellite images that were carried out and presented.

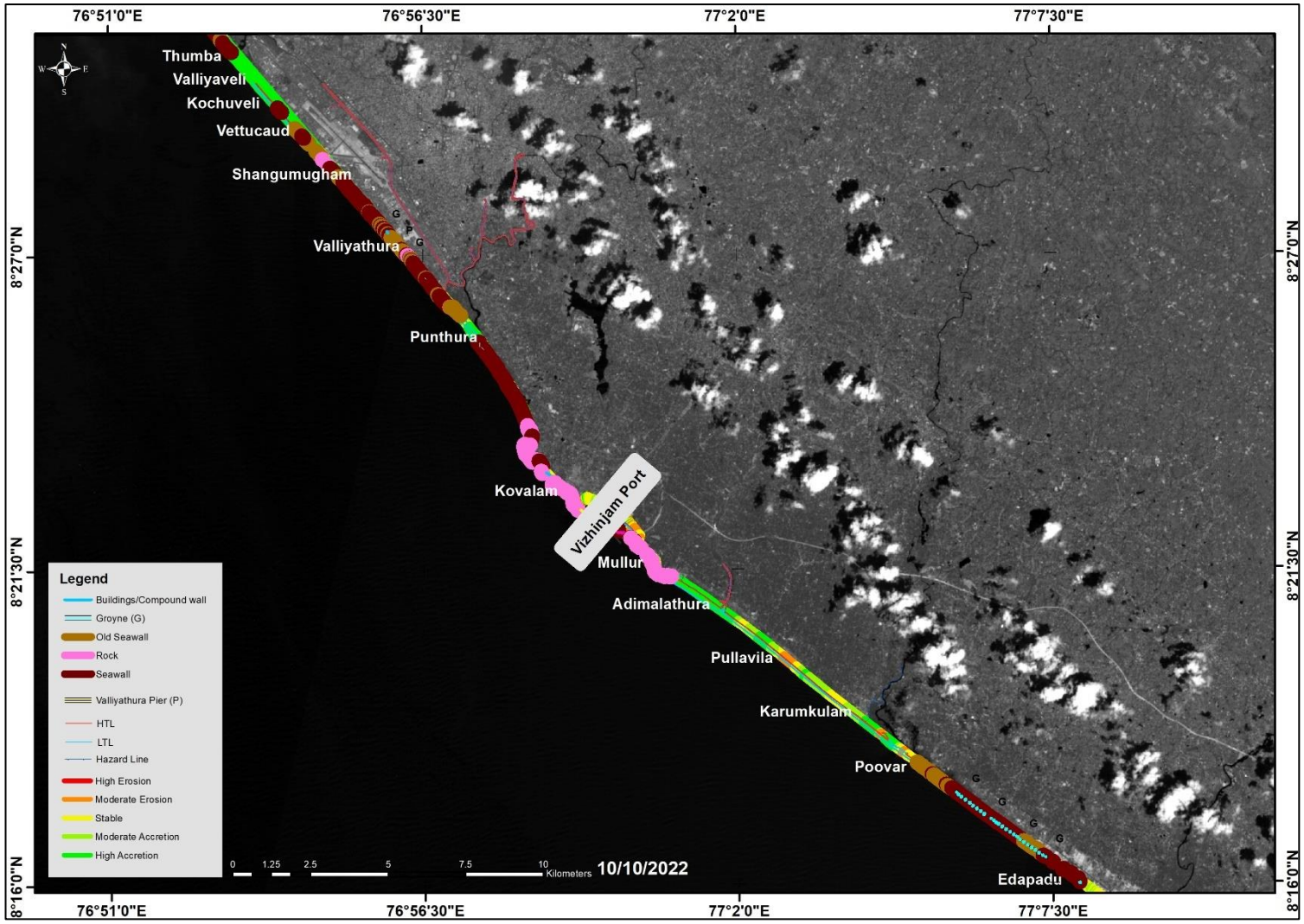
4.2.1 Monthly and overall Shoreline Change from October 2022 to September 2023

The monthly shoreline change analysis from October 2022 to September 2023 has been shown in Figures 4.28 to 4.39.



The monthly shoreline change analysis carried out using satellite images for October 2022 has been presented in Figure 4.26. Edappadu beach (CSP02), Shangumugam (CSP 69), Punthura to Pannathura (CSP 51 -53),Vettucaud (CSP72-74) and Thumba (CSP80-81) indicate accretion, while moderate erosion at Adimalathura to Karumkulam (CSP 22-34), and Valliyathura (CSP 66) for October 2022.

Figure 4.28 Shoreline Change Map -October 2022



The shoreline change analysis map shows accretion at Adimalathura to Poovar (CSP 18-24,26-36), Punthura to Pannathura (CSP51-53), Thumba to Vettucaud (CSP72-81) while erosion noted at few sectors of Poovar (CSP17), Karumkulam (CSP25), Valliyathura (CSP 66) for November 2022.

Figure 4.29 Shoreline Change Map - November 2022

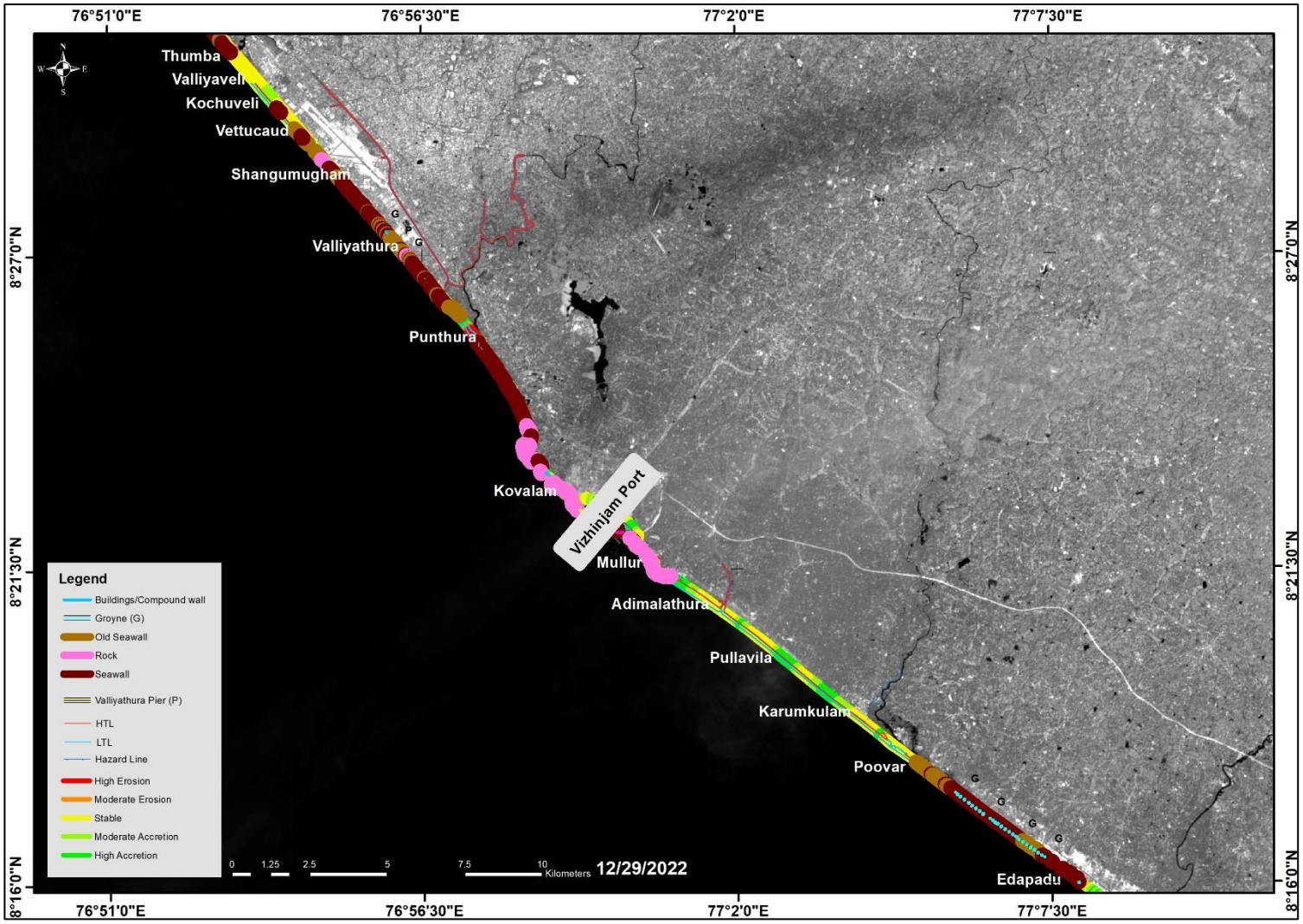


Figure 4.30 Shoreline Change Map - December 2022

The shoreline change analysis map shows that the accretion Adimalathura to Poovar (CSP15-34), Kochuveli to Beemapally (CSP 58-77),while erosion is noticed at Punthura (CSP 53-54), Valiyaveli (CSP78) for December 2022.

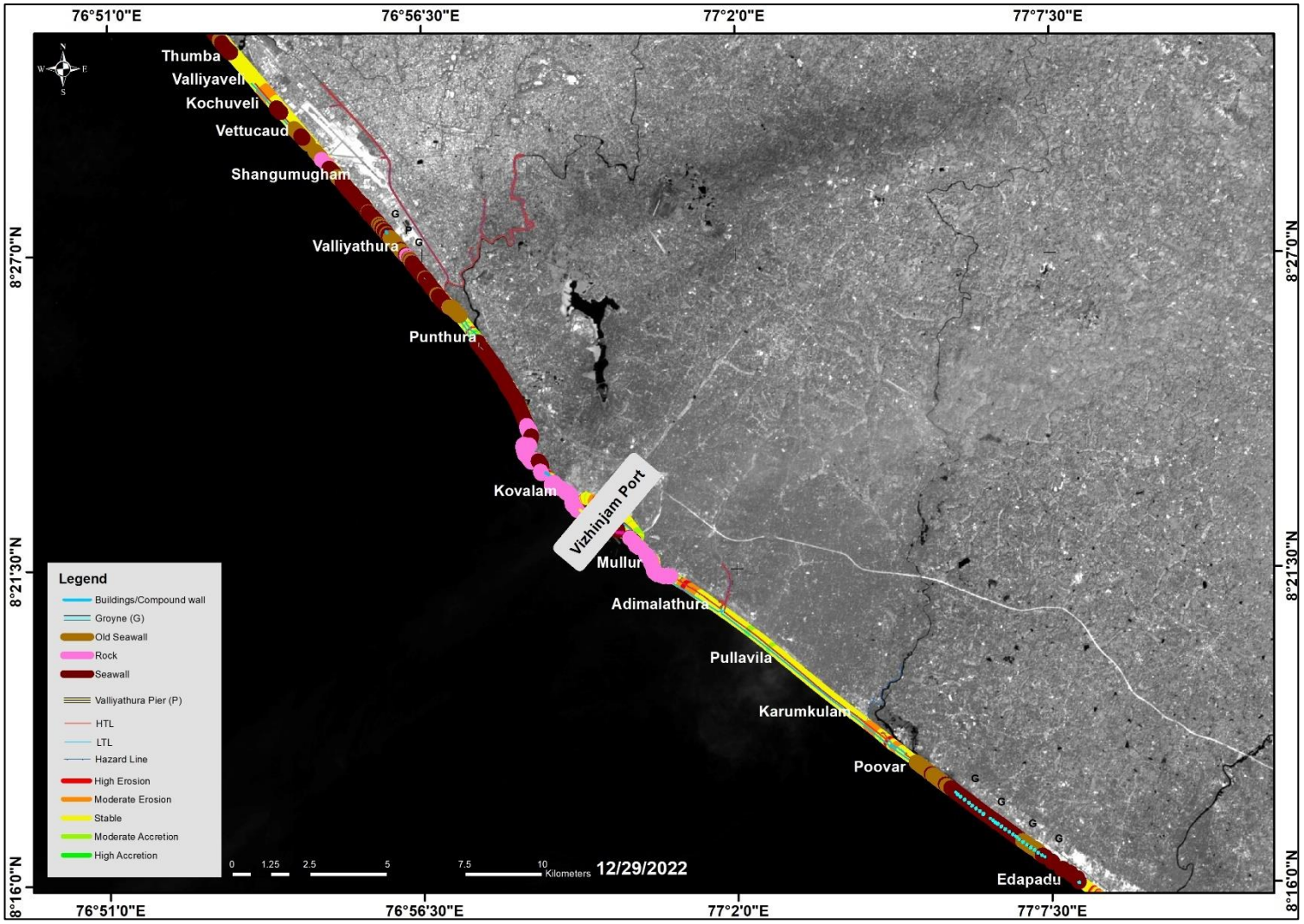
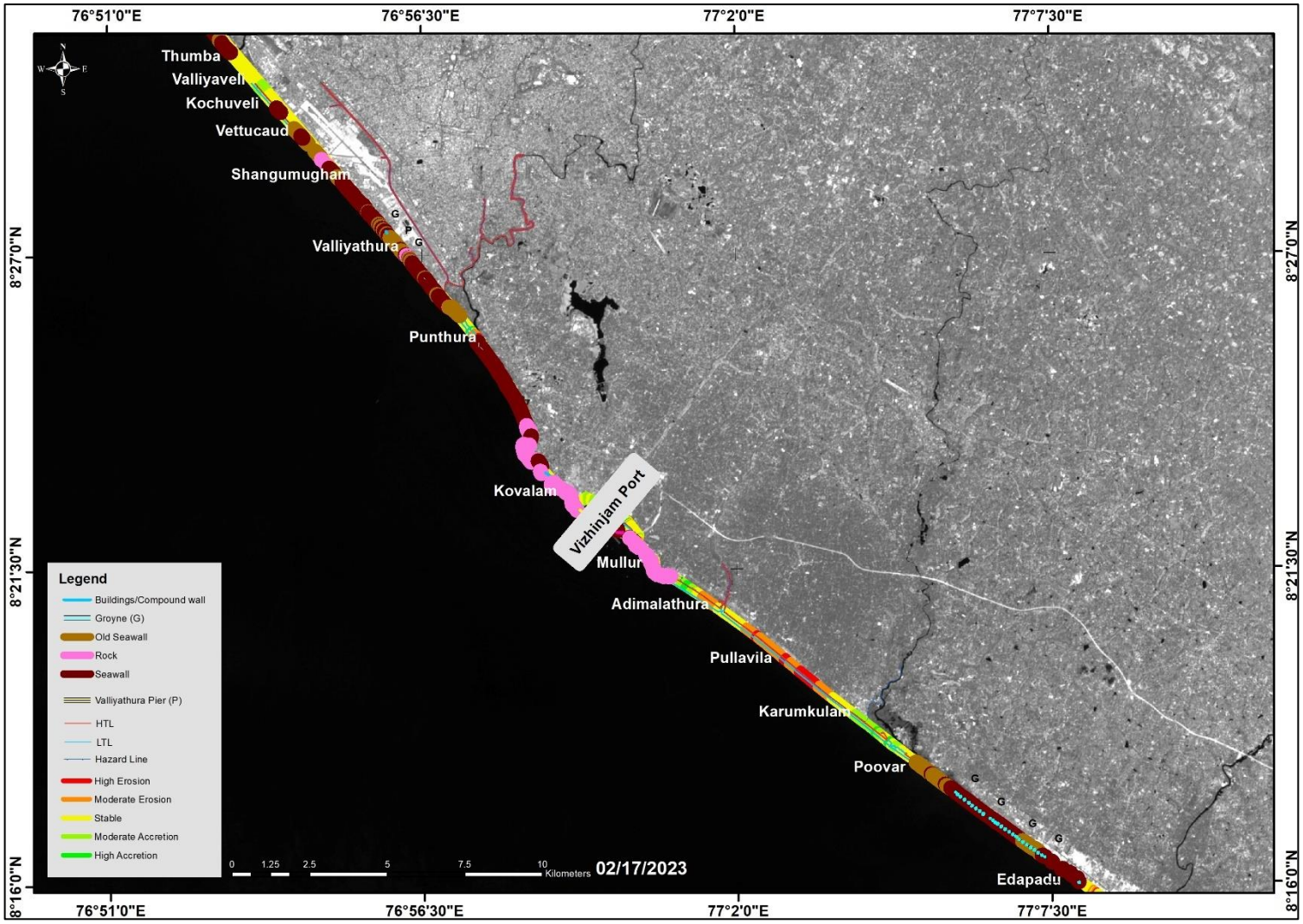


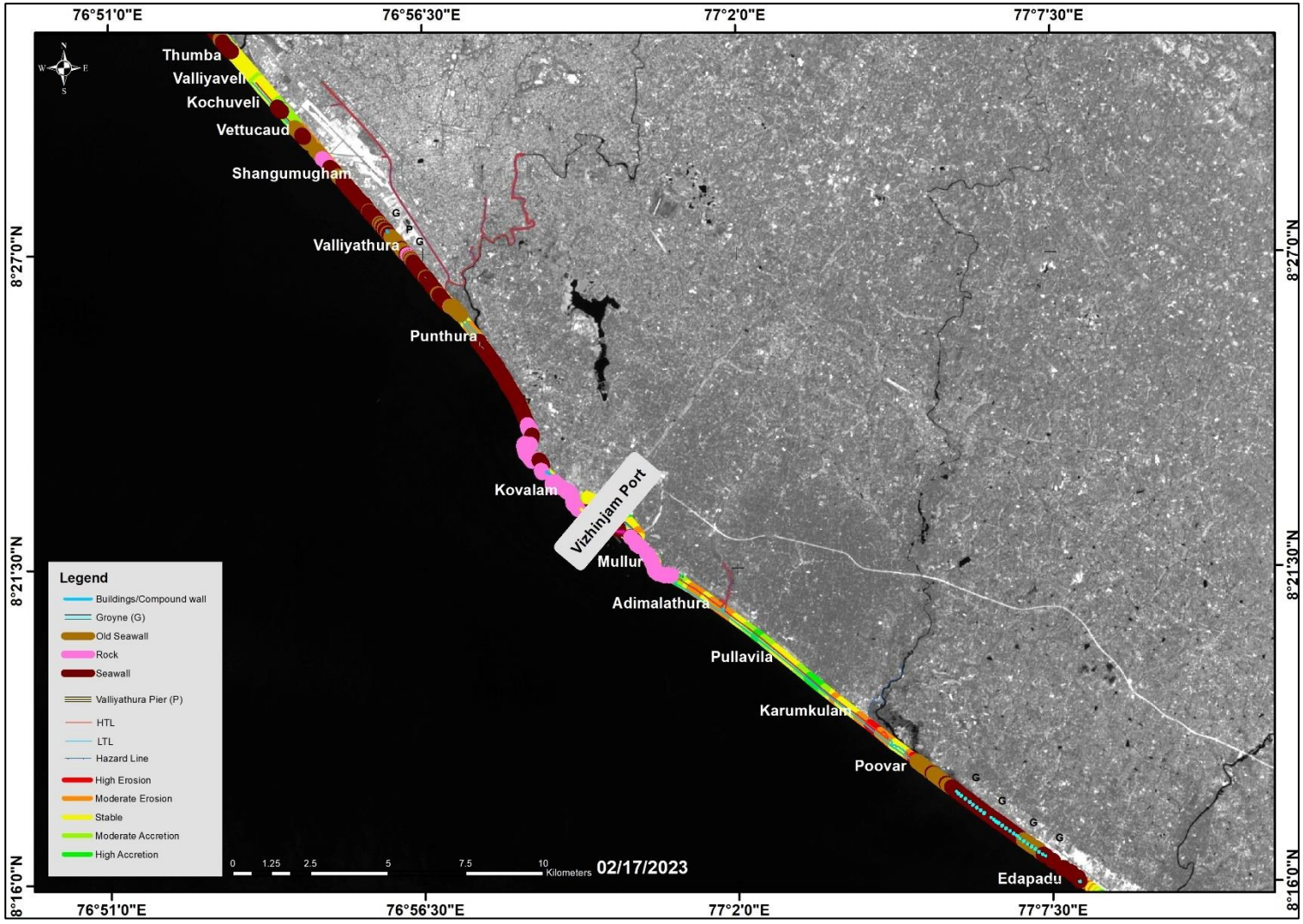
Figure 4.31 Shoreline Change Map - January 2023

The shoreline change analysis map shows accretion from Pullavila (CSP28), Thumba to Valliyaveli (CSP 78,80), while erosion is noticed at Poovar (CSP16-18), Adimalathura (CSP33), Valliyathura (CSP66), Shangumugham beach (CSP69), and Vettucaud (CSP74).



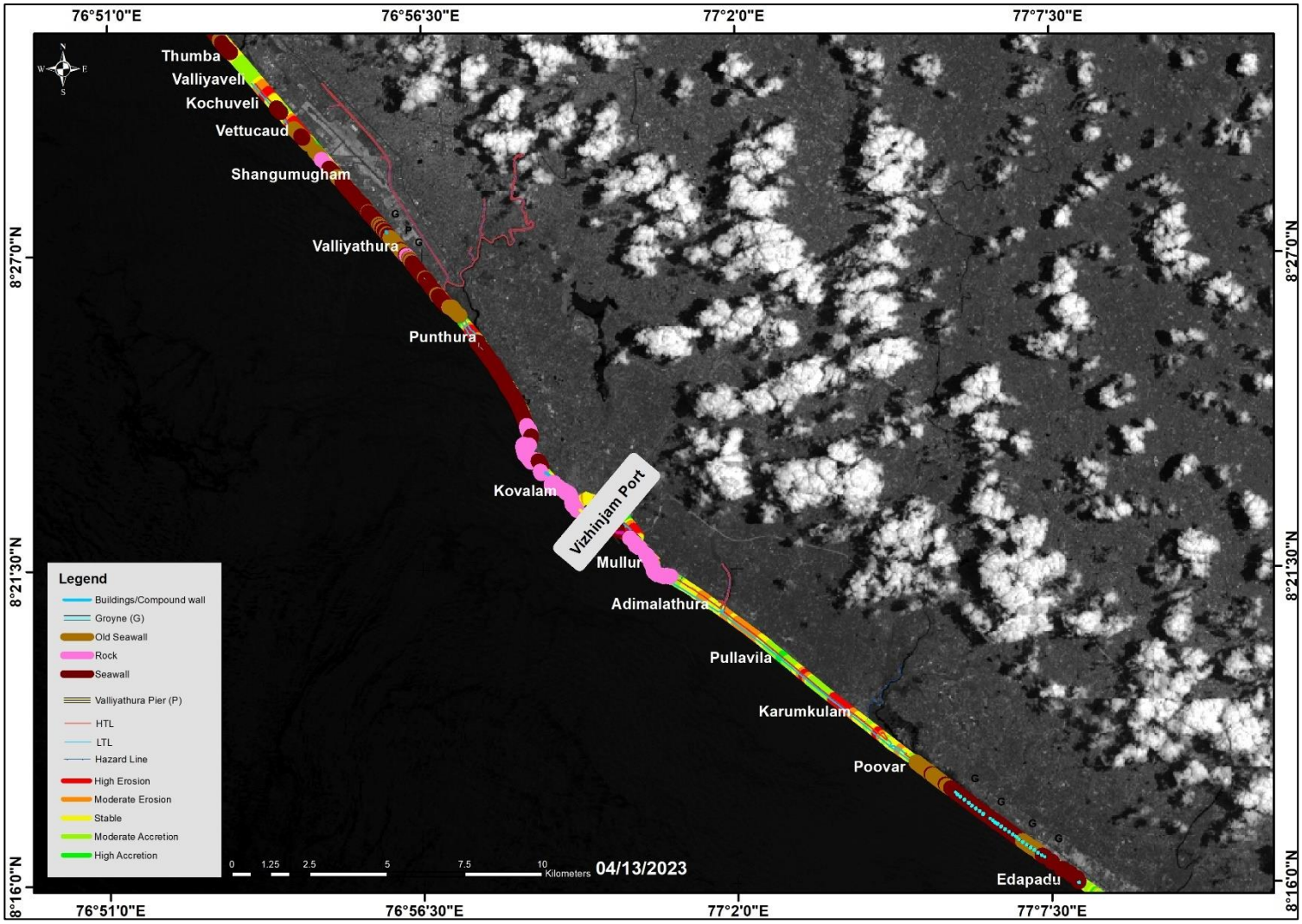
The shoreline change analysis map shows that the accretion from Poovar (CSP16-18), Adimalathura (CSP33), Valliyathura(CSP66), Shangumugham beach (CSP69), and Vettucaud (CSP74), while erosion is noticed at Pullavila to Poovar (CSP21-29), Adimalathura (CSP31), Mullur (CSP37), Punthura(CSP53), Valliyathura (CSP66) and Valiyaveli (CSP78).

Figure 4.32 Shoreline Change Map - February 2023



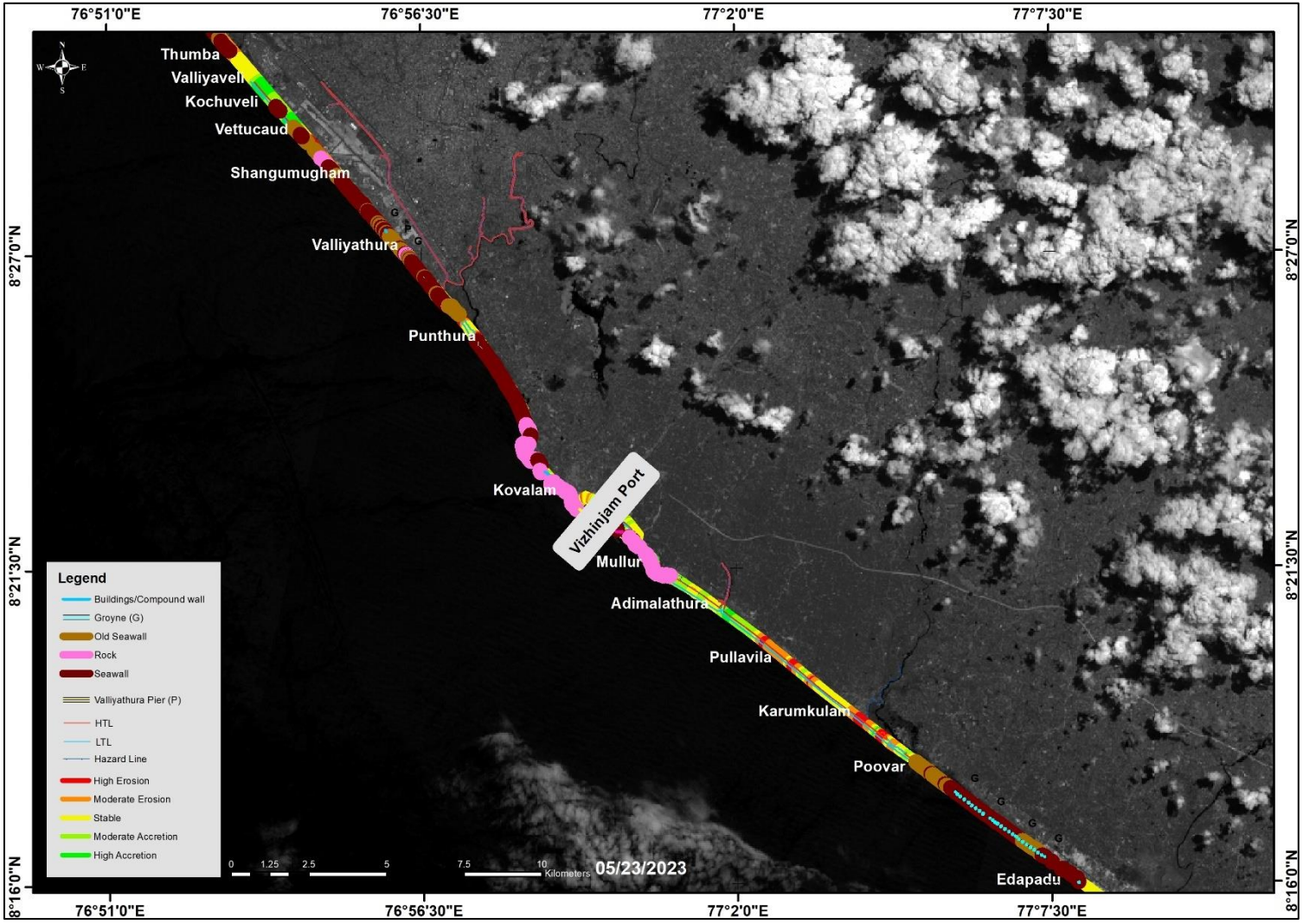
The shoreline change analysis map shows that the accretion from Adimalathura (CSP33-34), Thumba to Vettucaud (CSP72- 81),while erosion is noticed at Pullavila to Adimalathura (CSP29-32), Punthura (CSP 53-54), and Shangumugham to Valliyathura (CSP64-70).

Figure 4.33 Shoreline Change Map - March 2023



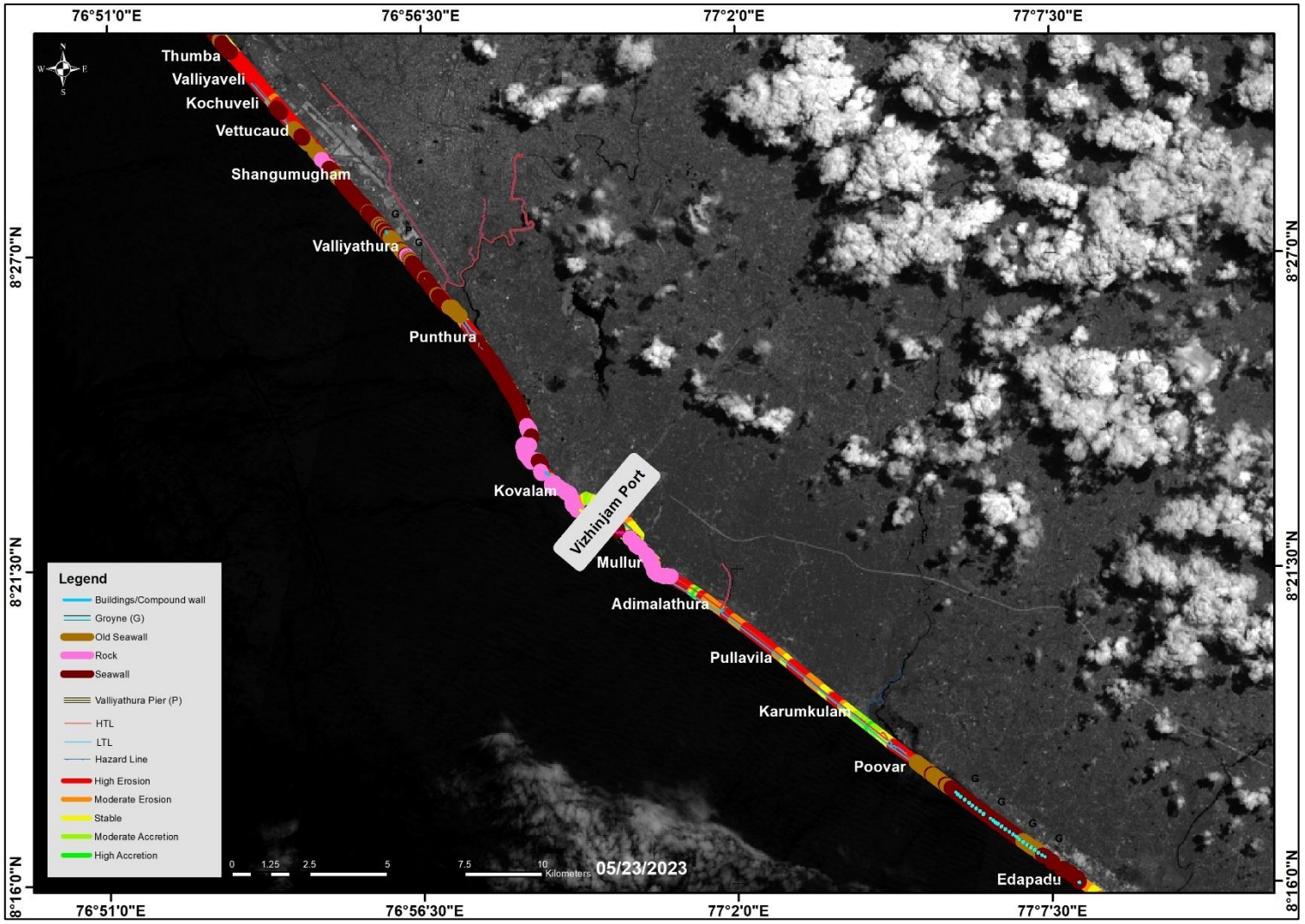
The monthly shoreline change analysis for April 2023 indicates erosion at Edappadu beach (CSP02), Poovar South (CSP16), Karumkulam (CSP21), Adimalathura (CSP32), Mullur (CSP37), Kovalam (CSP40A-41), Punthura (CSP53), Valiyathura (CSP66), Shangumugham north (CSP70), Vettucaud (CSP72-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78) and CSP80(Thumba), while accretion at Poovar (CSP17-20), Karumkulam (CSP22), Adimalathura (CSP31), Mullur (CSP36), Kovalam (CSP42-43), Shangumugham south (CSP69), Shangumugham north (CSP71), Thumba to Vettucaud (CSP74-81).

Figure 4.34 Shoreline Change Map - April 2023



The monthly shoreline change analysis for May 2023 exhibits erosion at Edappadu beach (CSP02), Poovar south (CSP16), Poovar (CSP18), Poovar north (CSP20), Karumkulam (CSP22), Mullur (CSP37), Panathura north (CSP51), Punthura (CSP53), Shangumugham south (CSP69), and Thumba (CSP80-81), while accretion at Poovar north (CSP21), Adimalathura (CSP33-34), Kovalam (CSP43), Punthura (CSP52-53), Valiyathura (CSP66), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78).

Figure 4.35 Shoreline Change Map - May 2023



For June 2023, the shoreline change analysis shows accretion from Poovar (CSP20), Punthura (CSP53), and Thumba (CSP80-81), while erosion occurs at Edappadu beach (CSP02), Poovar south to Poovar (CSP15-18), Karumkulam (CSP21-24), Adimalathura (CSP33-34), Mullur (CSP36-37), Kovalam (CSP40A), Kovalam (CSP42), Panathura north (CSP52), Valiyathura to Kochuveli (CSP66-78).

Figure 4.36 Shoreline Change Map - June 2023

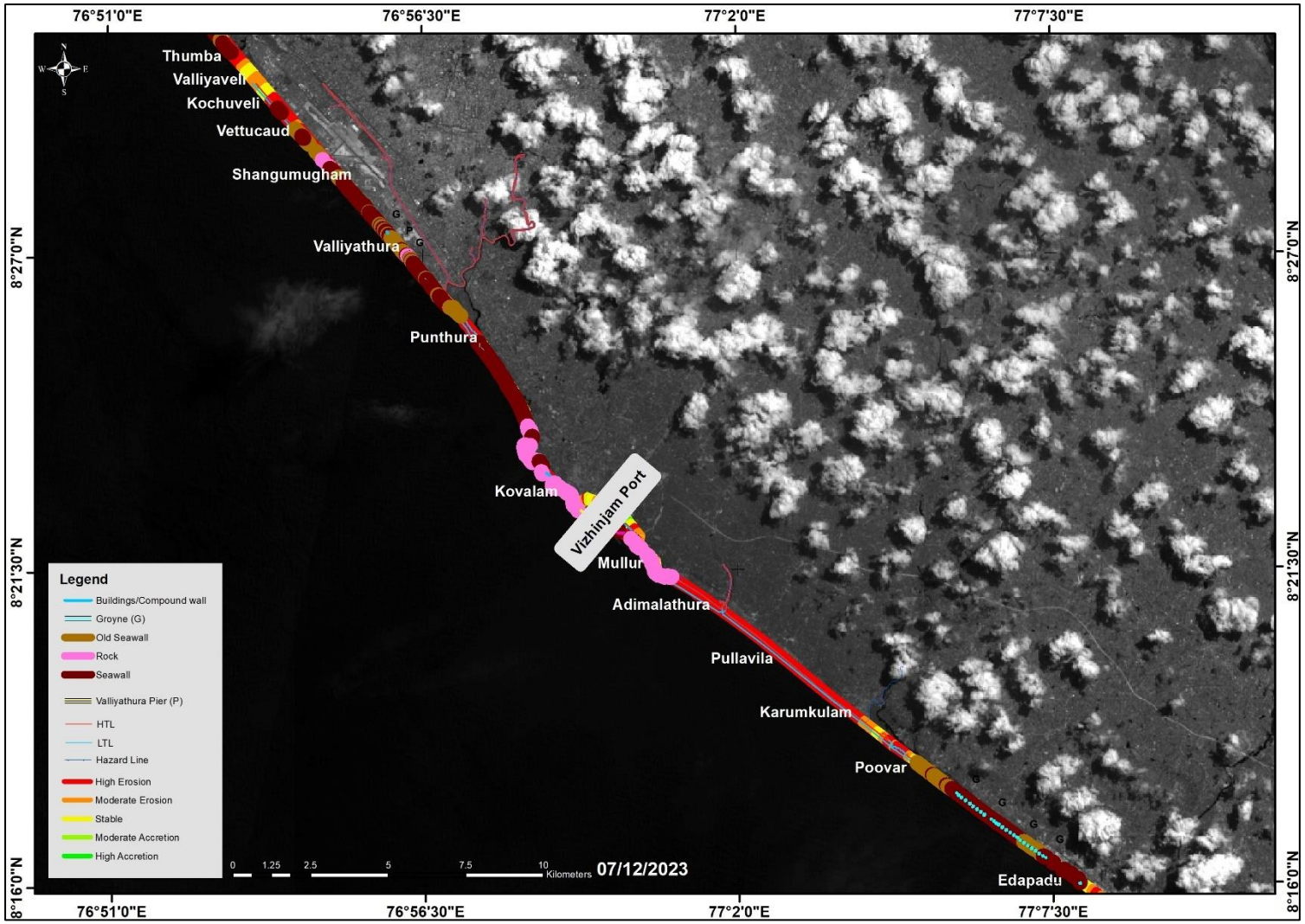


Figure 4.37 Shoreline Change Map - July 2023

For July 2023, the shoreline change analysis shows erosion at Edappadu beach (CSP02), Poovar north (CSP21), Mullur (CSP37), Kovalam (CSP43), Panathura north (CSP51-52), Punthura (CSP53), Valliyathura (CSP64A), Shangumugham south to Shangumugham north (CSP69-71), Kochuveli (CSP75-77) and Thumba (CSP81) while accretion at Poovar (CSP15), Mullur (CSP36), and Valiyaveli (CSP78).

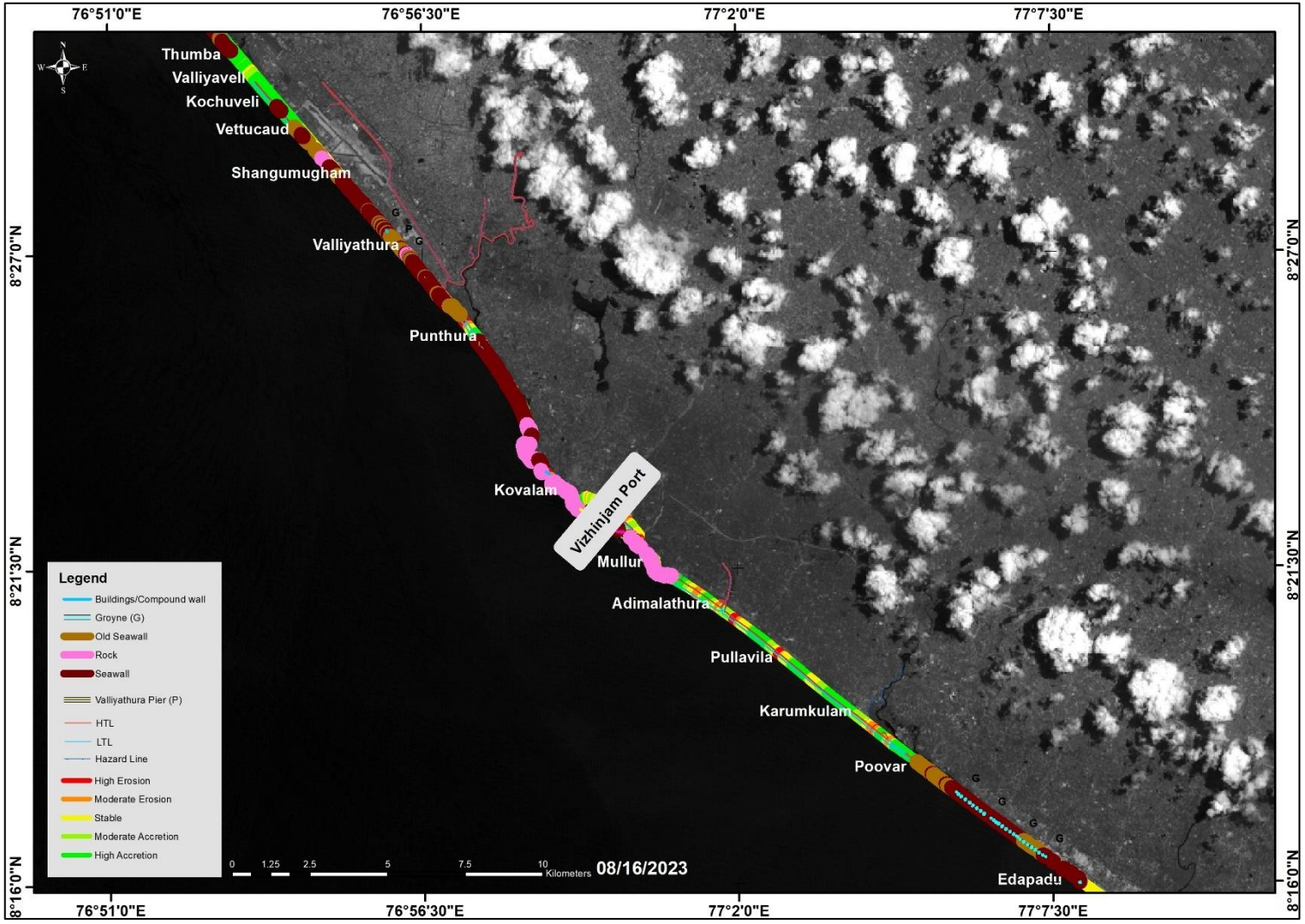
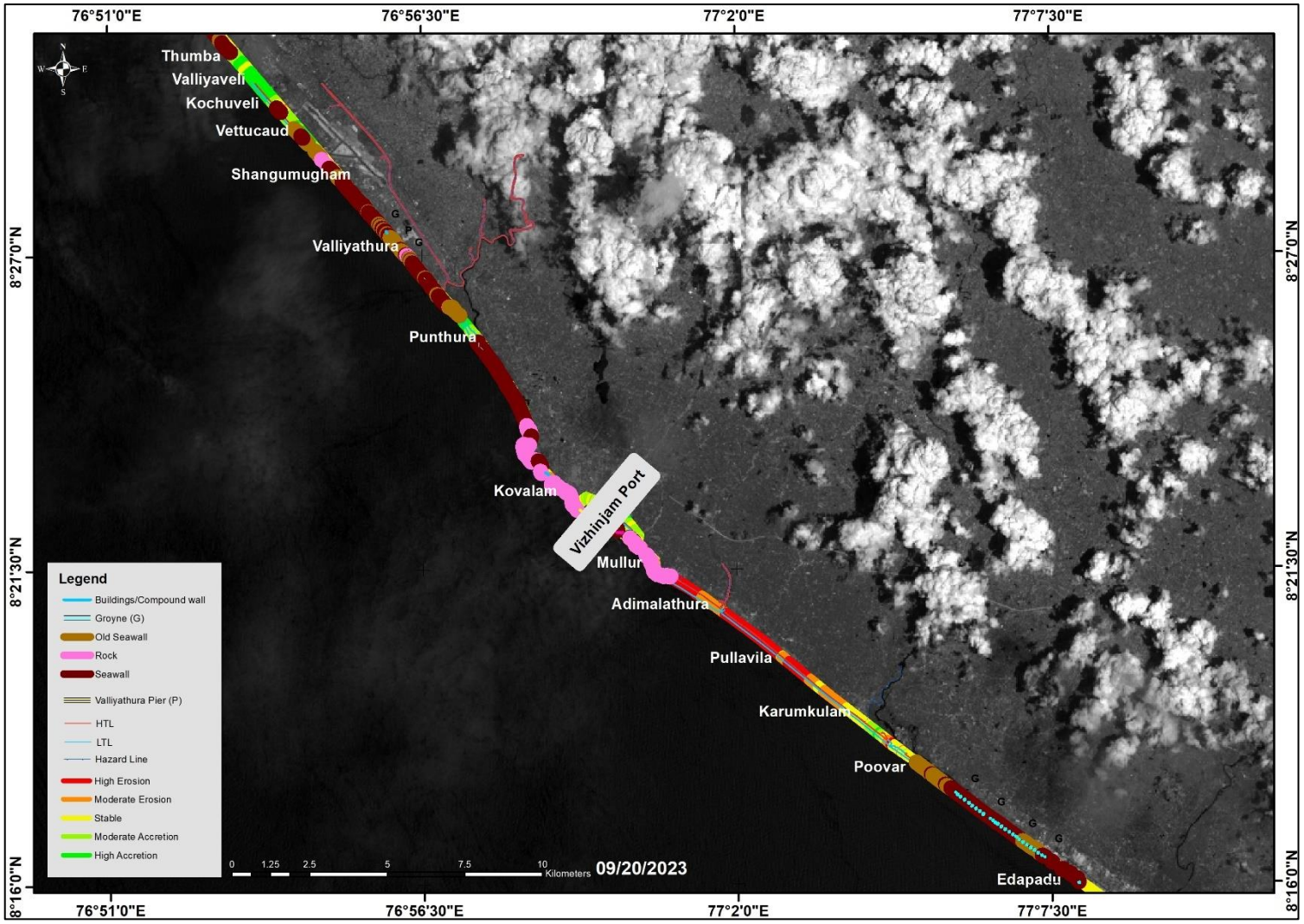


Figure 4.38 Shoreline Change Map - August 2023

The monthly shoreline change analysis for August 2023 indicates accretion at Edappadu Beach (CSP02), Poovar South (CSP15), Poovar (CSP19), Mullur (CSP36-37), Panathura North (CSP52), Shangumugham South (CSP69) and Shangumugham north (CSP71), Kochuveli to Valiyaveli (CSP75-78) and Thumba (CSP81). while erosion at Poovar south (CSP16), Poovar north (CSP20), Kovalam (CSP40A), Kovalam (CSP42-43), Panathura north (CSP51), Punthura CSP53), Valliyathura (CSP64A), Shangumugham (CSP69).



The monthly shoreline change analysis for September 2023 indicates erosion at Poovar south (CSP16), Adimalathura to Karumkulam (CSP), Mullur (CSP36-37), Kovalam (CSP40A), Valliyathura (CSP64A), Shangumugham north (CSP70), while accretion at Edappadu beach (CSP02), Poovar South (CSP15), Poovar south to Poovar (CSP17-18), Poovar north (CSP21), Kovalam (CSP43), Panathura north (CSP51), Shangumugham South (CSP69), Shangumugham north to Kochuveli (CSP71-77) and Thumba (CSP80-81).

Figure 4.39 Shoreline Change Map –September 2023

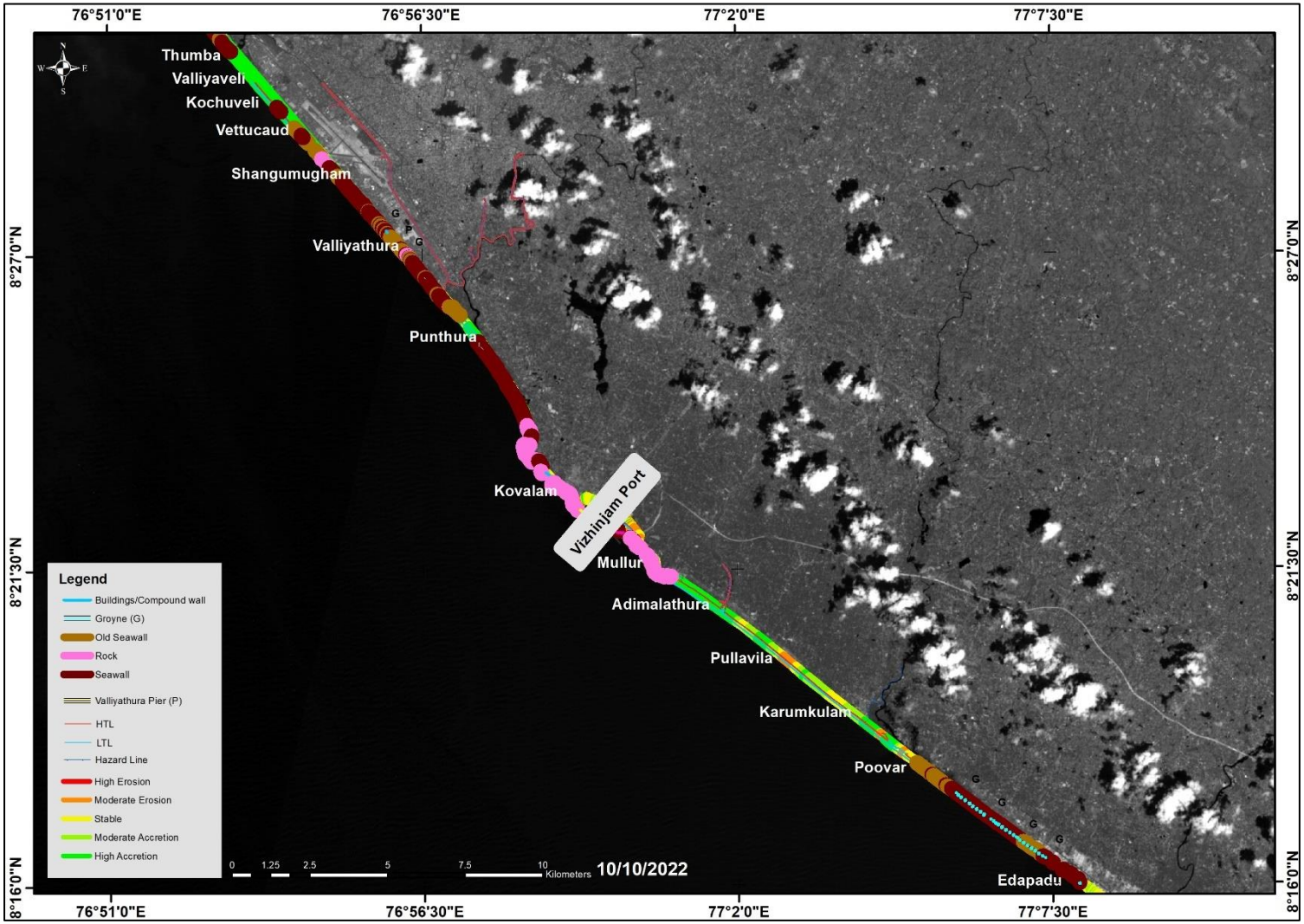


Figure 4.40 Shoreline Change Analysis - Post Monsoon Period (October 2022 – November 2022)

4.2.2 Seasonal and Overall Shoreline Change Analysis from October 2022 to September 2023

The shoreline change analysis map shows accretion at Adimalathura to Poovar (CSP 18-24,26-36), Punthura to Pannathura (CSP51-53), Thumba to Vettucaud (CSP72-81) while erosion noted at Poovar (CSP17), Karumkulam (CSP25), Valliyathura (CSP 66)for the post-monsoon period (October 2022 to November 2022).

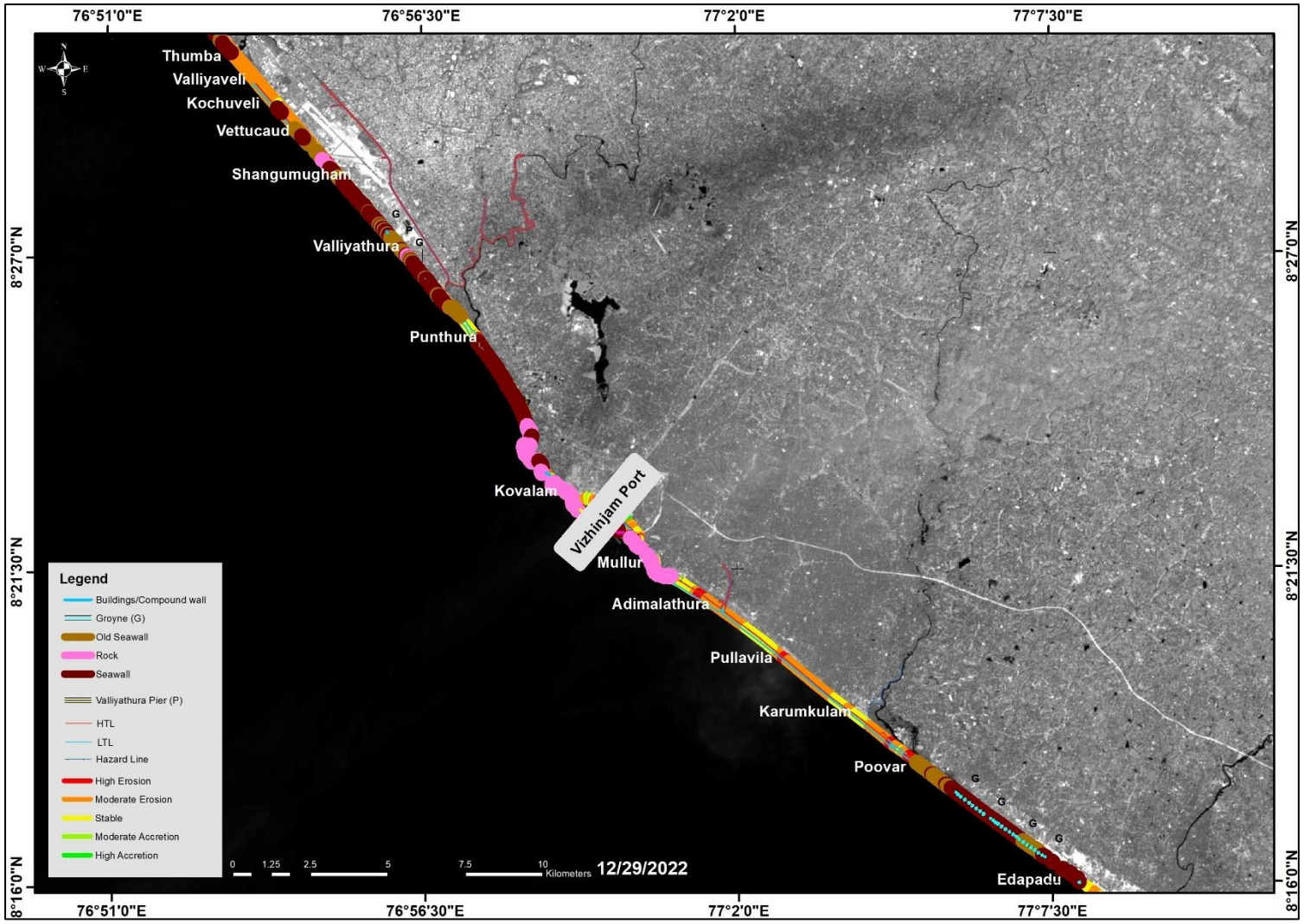
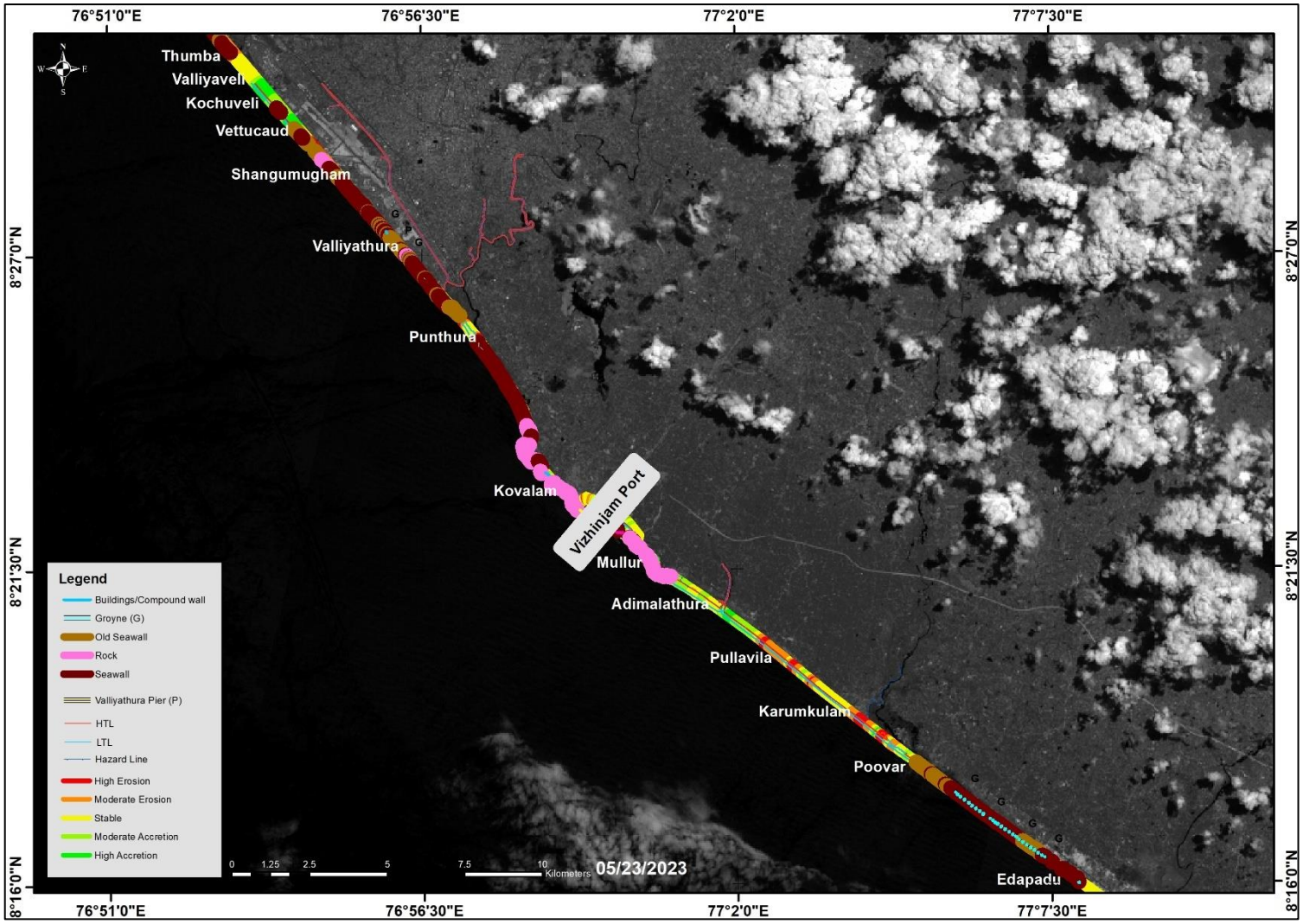


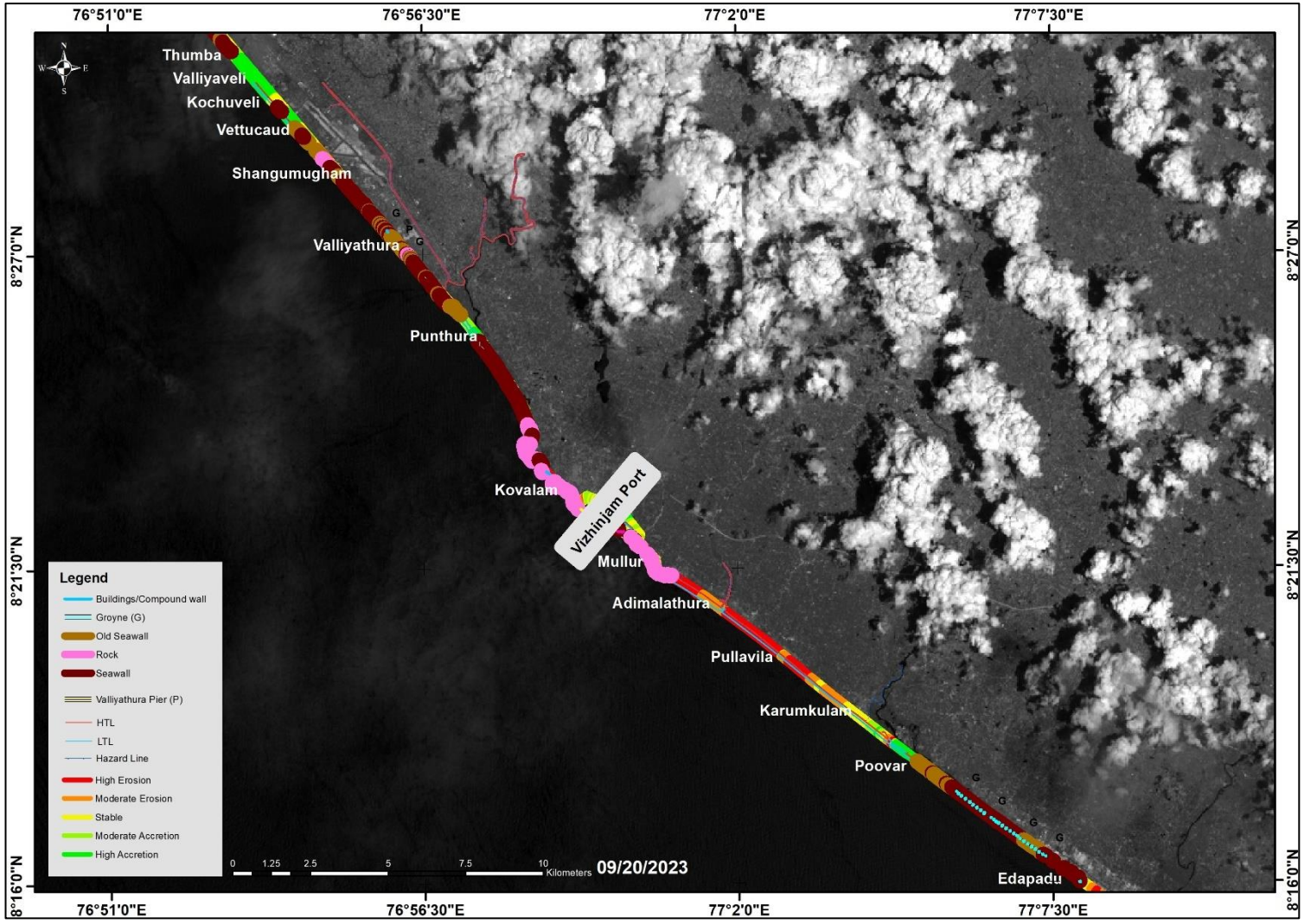
Figure 4.41 Shoreline Change Analysis - Fair Weather Period (December 2022 - March 2023)

The shoreline change analysis map shows accretion at Pullavila(CSP28-29), Thumba to Vettucaud (CSP72-81), Adimalathura(CSP33-34), while erosion noted at few sectors of Paruthiyoor to Karumkulam (CSP13-26), Adimalathura (CSP31-32), Mullur (CSP37), Punthura (CSP 53), and Shangumugamto Valliyathura (CSP63-71) for the fair weather period (December 2022 to March 2023).



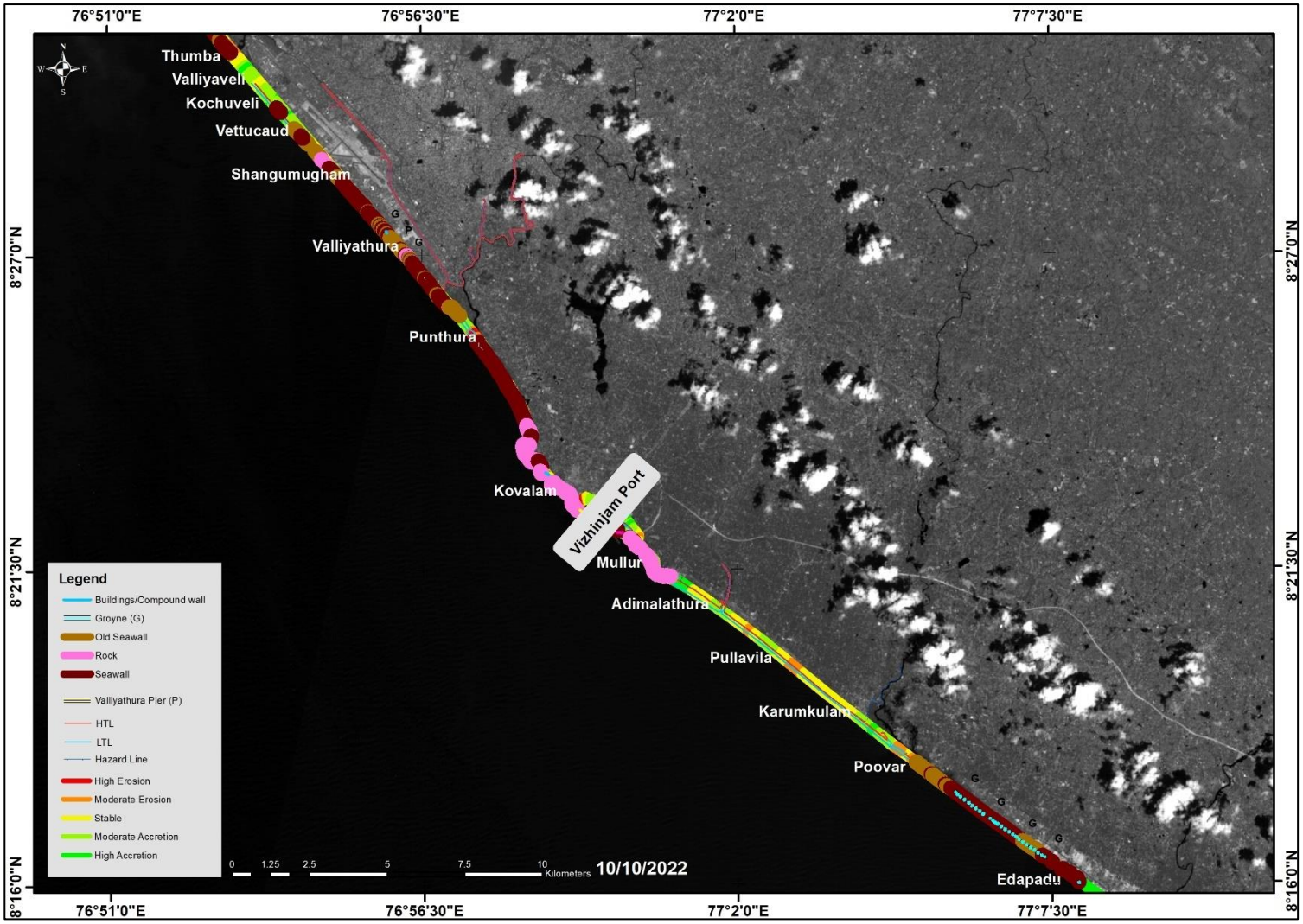
Pre monsoon period (April 2023 to May 2023) exhibits erosion at Edappadu beach (CSP02), Poovar south (CSP16), Poovar (CSP18), Poovar north (CSP20), Karumkulam (CSP22), Mullur (CSP37), Panathura north (CSP51), Punthura (CSP53), Shangumugham south (CSP69), and Thumba (CSP80-81), while accretion at Poovar north (CSP21), Adimalathura (CSP33-34), Kovalam (CSP43), Punthura (CSP52-53), Valiyathura (CSP66), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78).

Figure 4.42 Shoreline Change Analysis – Pre-Monsoon Period (April 2023-May 2023)



Monsoon period for 2023 indicates erosion along the coast at Adimalathura to Poovar (CSP20-34, 16), Kovalam (CSP45), Valliyathura (CSP63-67), Shangumugham (68-71), while accretion is noticed at Edapadu beach (CSP02), Poovar (CSP14-15), Mullur (CSP37), Punthura (CSP 53), Thumba to Vettucaud (CSP 72-81).

Figure 4.43 Shoreline Change Analysis - Monsoon Period (June 2023 – September 2023)



Erosion is noticed at Poovar (CSP15), Pulluavila (CSP27), Karumkulam (CSP24), Mullur (CSP36-37), Punthura (CSP56), Valiyathura (CSP65), Shangumugham (CSP69), and Thumba (CSP80), while accretion is noticed at Edapadu beach (CSP02), Poovar (CSP16-18), Karumkulam (CSP25-26), Adimalathura (CSP31-34), Kovalam (CSP43), Punthura (CSP57), Shangumugham north (CSP70), Vettucaud (CSP73), Kochuveli (CSP75), Valliyaveli (CSP76-79)for the period October 2022 to September 2023.

Figure 4.44 Overall Shoreline Change Map for October 2022- September 2023

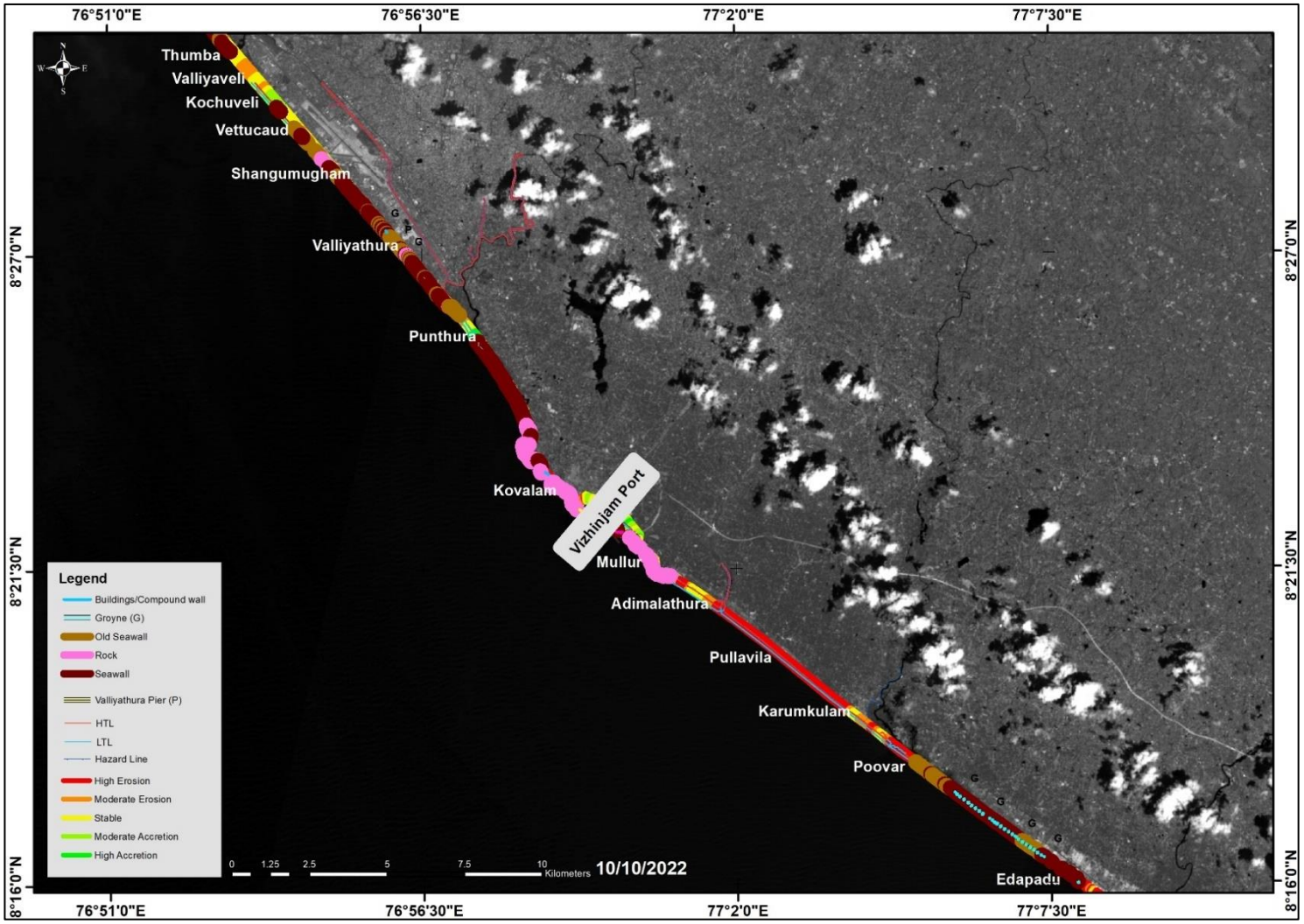


Figure 4.45 Shoreline Change Map –October 2021 and October 2022

4.2.3 Shoreline comparison for the period October 2021-September 2022 and October 2022- September 2023

Shoreline comparison between October 2021 and October 2022

Accretion is noticed at Kovalam(CSP42-44), Panathura north (CSP51-52),Valliyathura (CSP66), Shangumugham north(CSP70-71), Vettucaud (CSP74), Kochuveli (CSP76-77), while erosion is noticed at Edappadu beach(CSP02), Pullavila to Karumkulam (CSP) Punthura (CSP53), Shangumugam South (CSP69), Vettucaud (CSP72-73), Kochuveli (CSP75) Valiyaveli (CSP78), Thumba(CSP81).

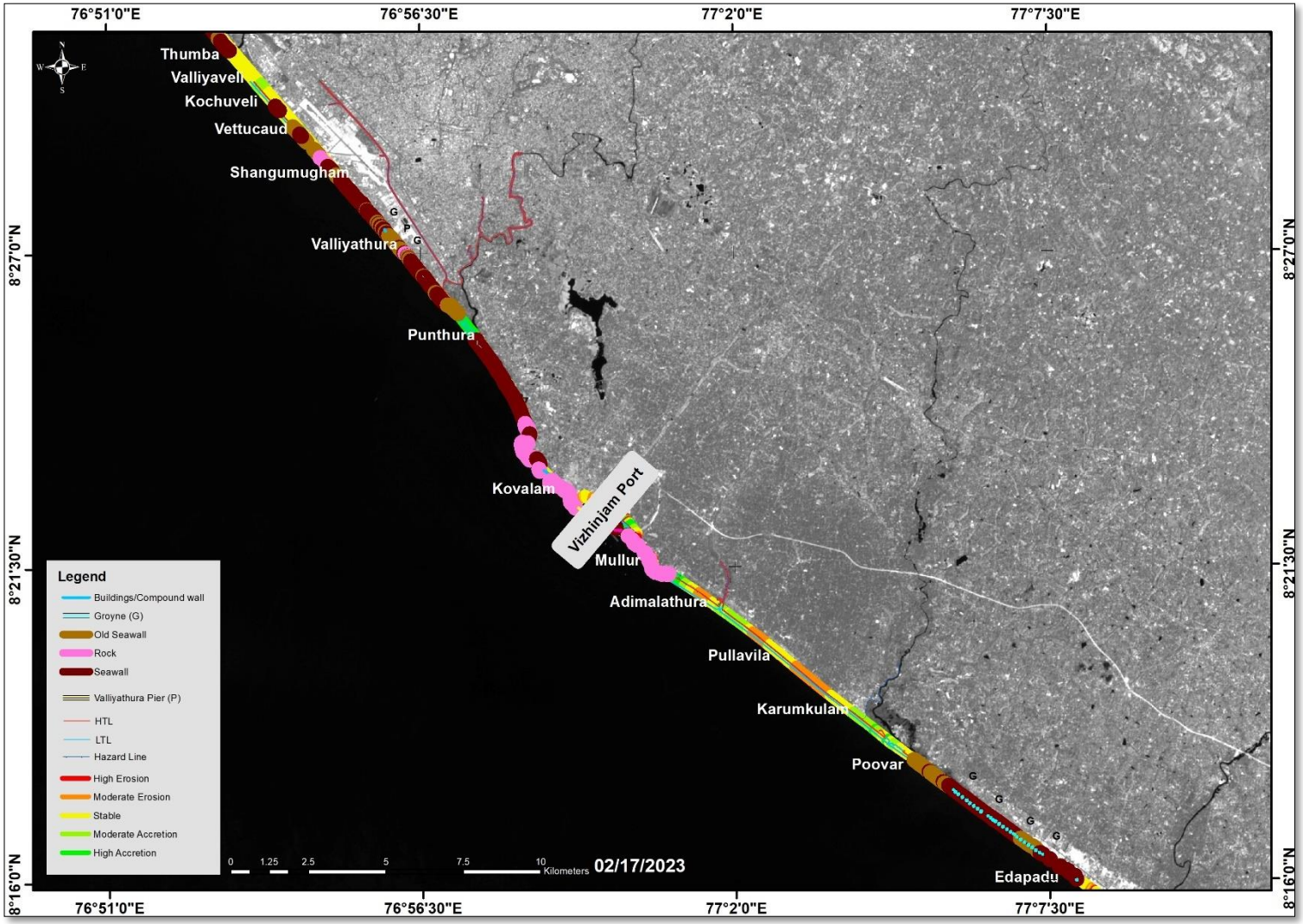
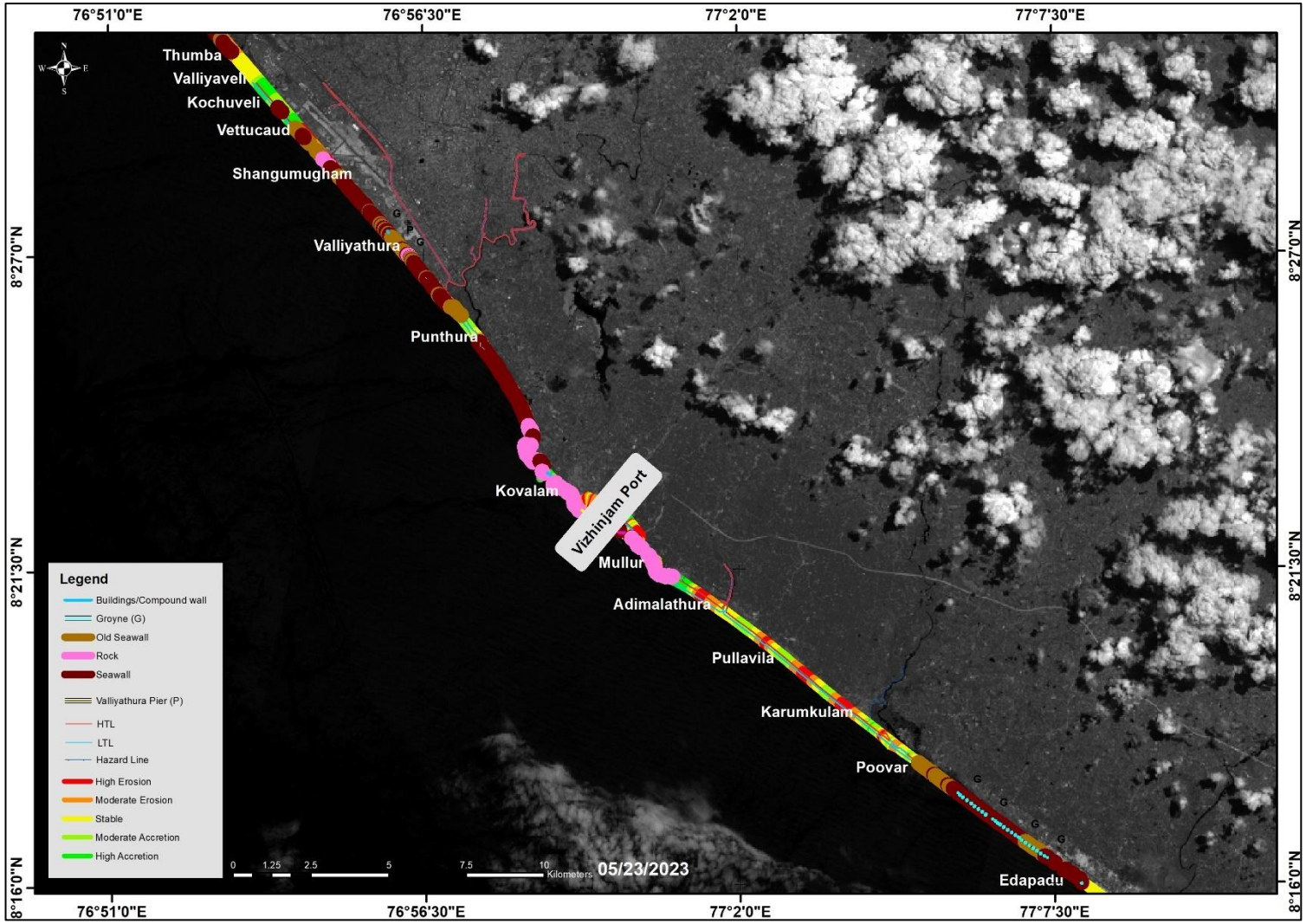


Figure 4.46 Shoreline Change Map –February 2022 and February 2023

Shoreline comparison between February 2022 and February 2023

Accretion is noticed at Poovar (CSP16-18), Adimalathura (CSP33), Valliyathura (CSP66), Shangumugham beach (CSP69), Vettucaud (CSP74), while erosion is noticed at Pullavila to Poovar (CSP21-29), Adimalathura (CSP31), Mullur (CSP37), Punthura (CSP53), Valliyathura (CSP66), Valiyaveli (CSP78).



Shoreline comparison between May 2022 and May 2023

Accretion is noticed at Poovar south (CSP16), Poovar north (CSP20), Adimalathura (CSP33), Kovalam (CSP41-43), Panathura north (CSP52), Shangumugham south to Vettucaud (CSP70-74), Kochuveli to Valiyaveli (CSP76-77), while erosion is noticed at Edapadu beach (CSP02), Poovar (CSP15, 18), Pullavila (CSP27), Adimalathura (CSP34), Kovalam (CSP40A,44), Valliyathura (CSP66), Shangumugham south (CSP69)and Thumba (CSP80-81).

Figure 4.47 Shoreline Change Map –May 2022 and May 2023

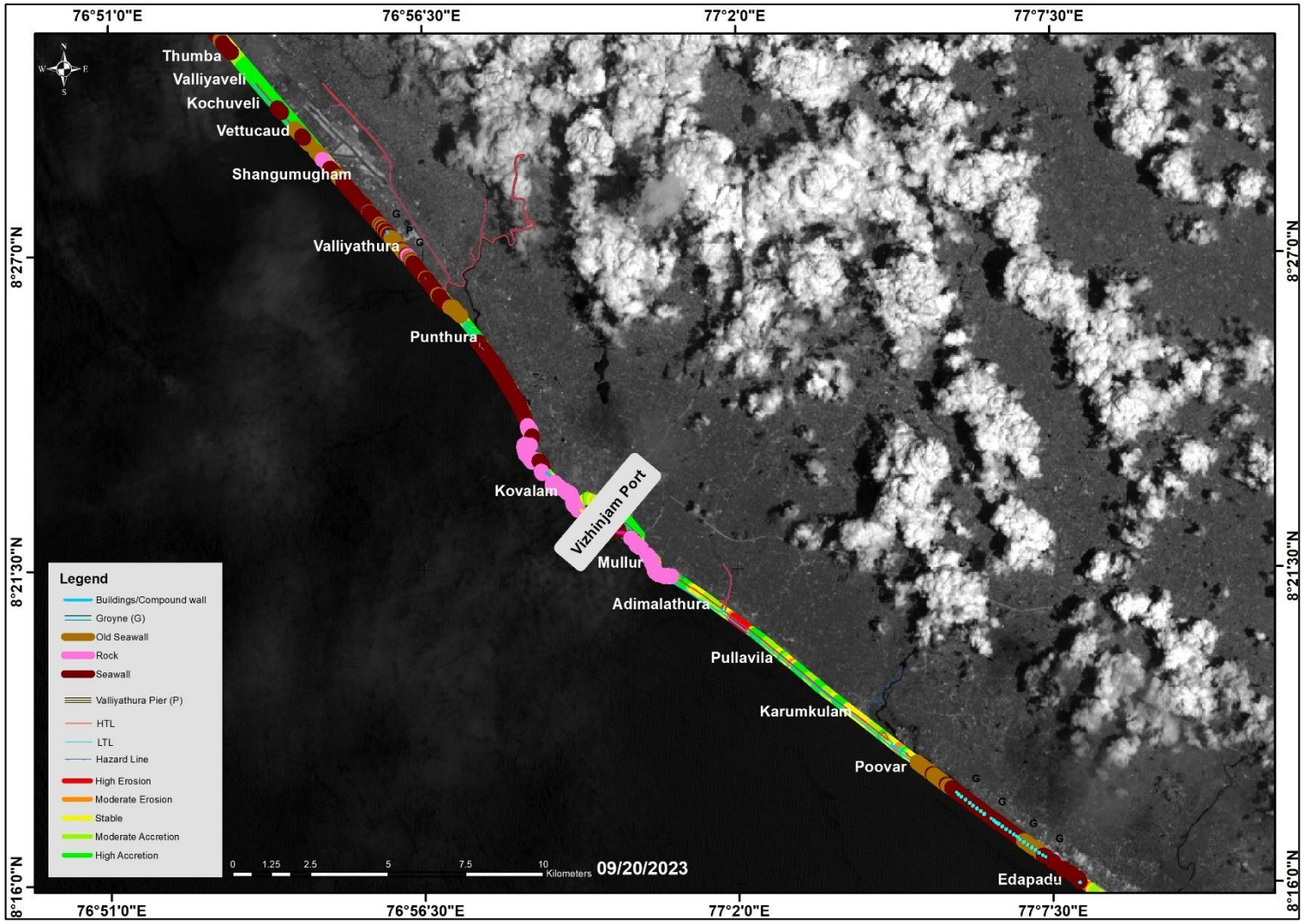


Figure 4.48 Shoreline Change Map –September 2022 and September 2023

Shoreline comparison between September 2022 and September 2023

Accretion is noticed at Edappadu Beach (CSP02), Poovar South (CSP15), Poovar South to Poovar North (CSP17-21), Kovalam (CSP42), Shangumugham South (CSP69), Shangumugham north to Vettucaud (CSP71-74), Kochuveli to Valiyaveli (CSP75-78), and Thumba (CSP80-81), while erosion at Poovar south(CSP16), Pullavila (CSP27-28), Valliyathura (CSP66), Shangumugham north (CSP70).

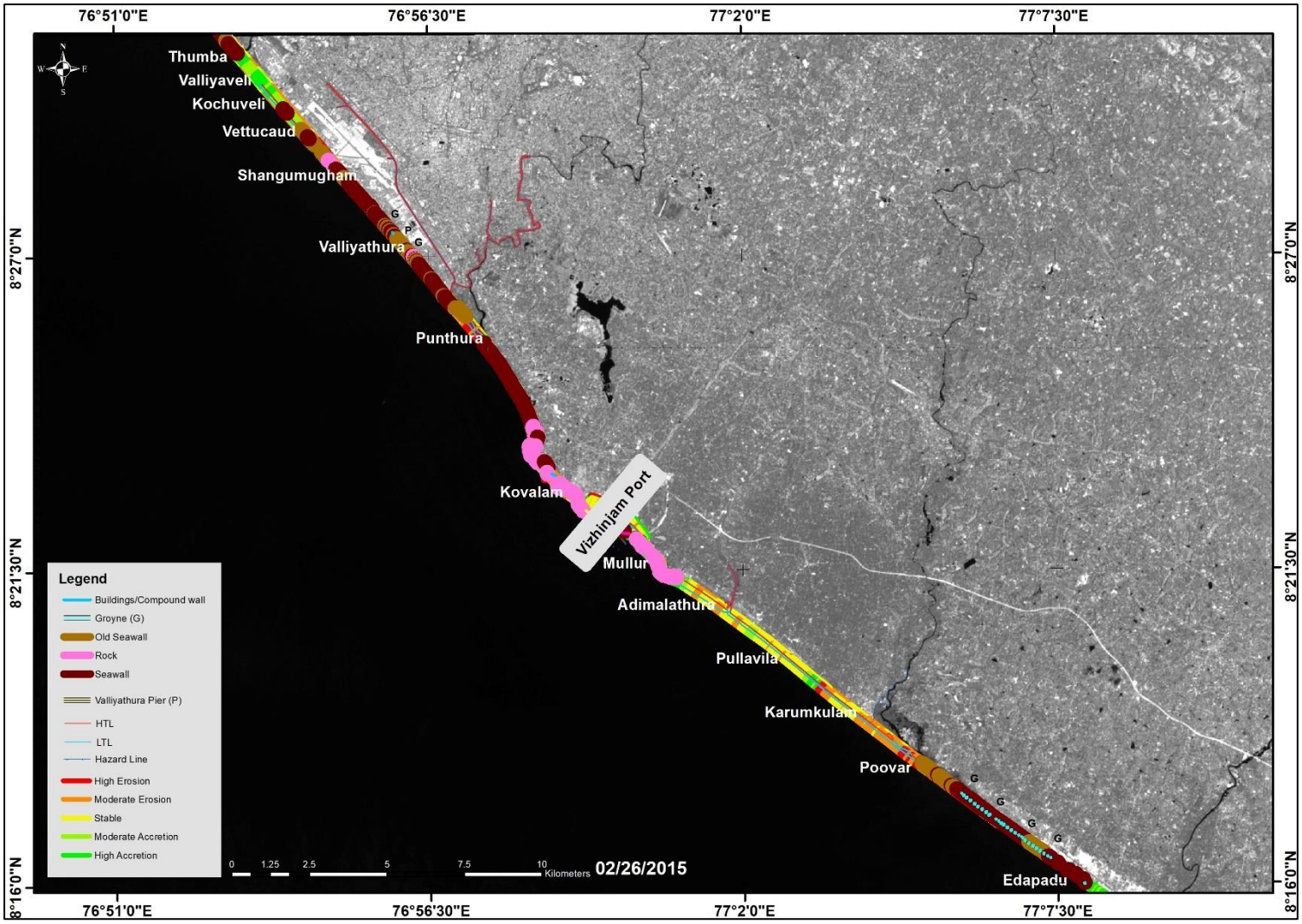


Figure 4.49 Shoreline Change Comparison- 2011 to 2015

4.2.4 Shoreline Change comparison before and after 2015

The result from the analysis indicates erosion at Poovar South (CSP14-15), Poovar North (CSP18-20), Karumkulam (CSP 22), Pullavila (CSP30), Punthura (CSP53), Valliyathura (CSP66) and Shangumugham (CSP69) while accretion at Karumkulam (CSP 25), Pullavila (CSP27), Adimalathura (CSP33) and Vettucaud to Valiyaveli (CSP 75-81).

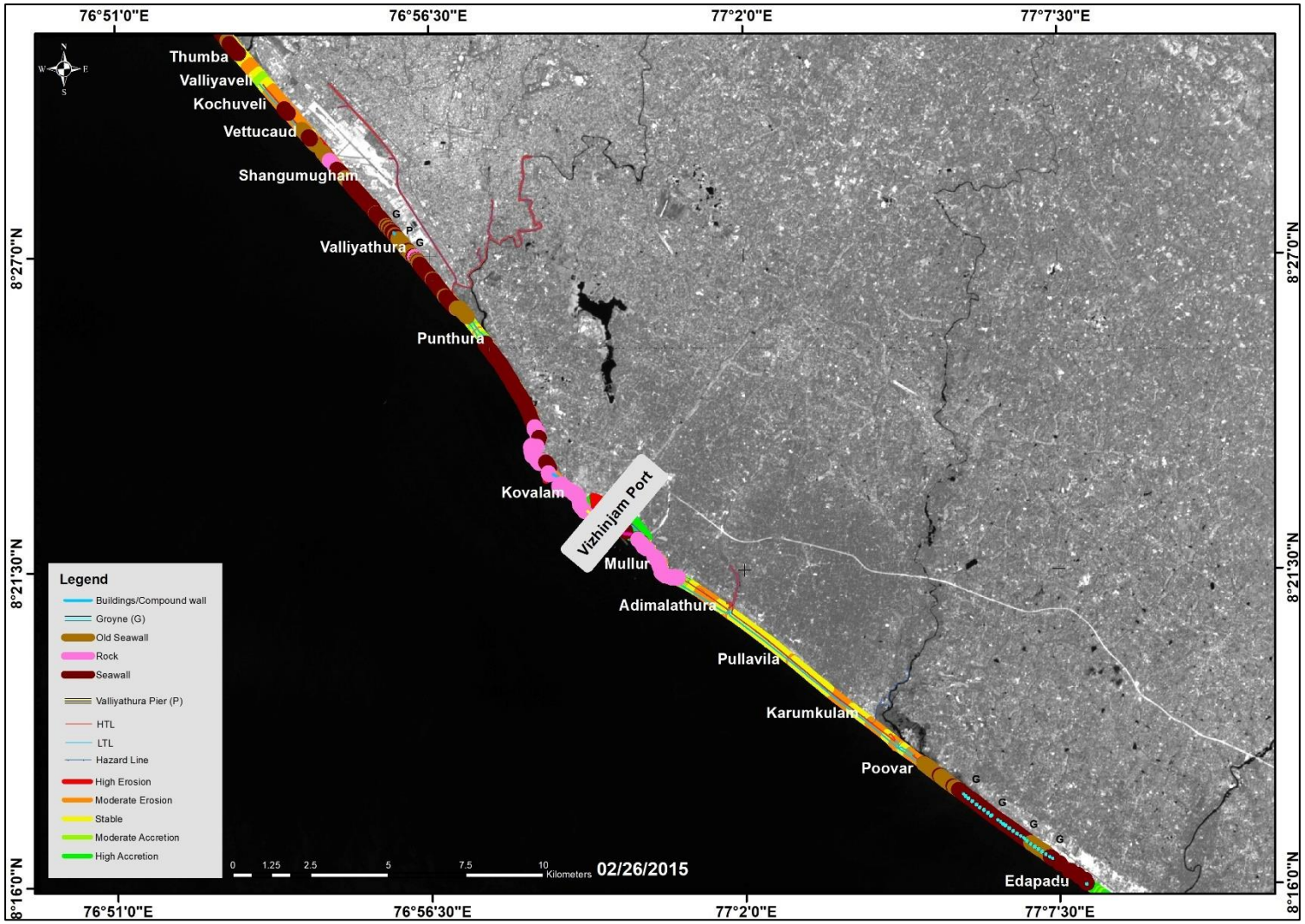


Figure 4.50 Shoreline Change Map- 2015 to 2023

The comparison of the February 2015 shoreline with February 2023 using satellite images has been presented in Figure 4.50. The comparison shows erosion at Poovar South (CSP14-15), Poovar South to Poovar North (CSP18-20), Pulluvila (CSP30), Kovalam (CSP44), Shangumugham South to Thumba (CSP69-81) while Poovar South (CSP17), Karumkulam (CSP22), Pullavila (CSP28), Adimalathura (CSP31, CSP33-34), Mullur (CSP36-37), Kovalam (CSP41-43), Panathura north (CSP51), Valiyathura (CSP66) shows accretion.

5 VALIDATION AND COMPARISON

The shoreline extracted from the high-resolution satellite images and the shoreline extracted from the beach profile data at 500m intervals have been compared, as shown in Figure 5.1, and the correlation between the location of the points from the satellite image and beach profile at 500 m interval with respect to the baseline has been correlated as shown in Figure 5.2. It shows a correlation of 0.872 between the shoreline extracted from the satellite images and beach profiles.

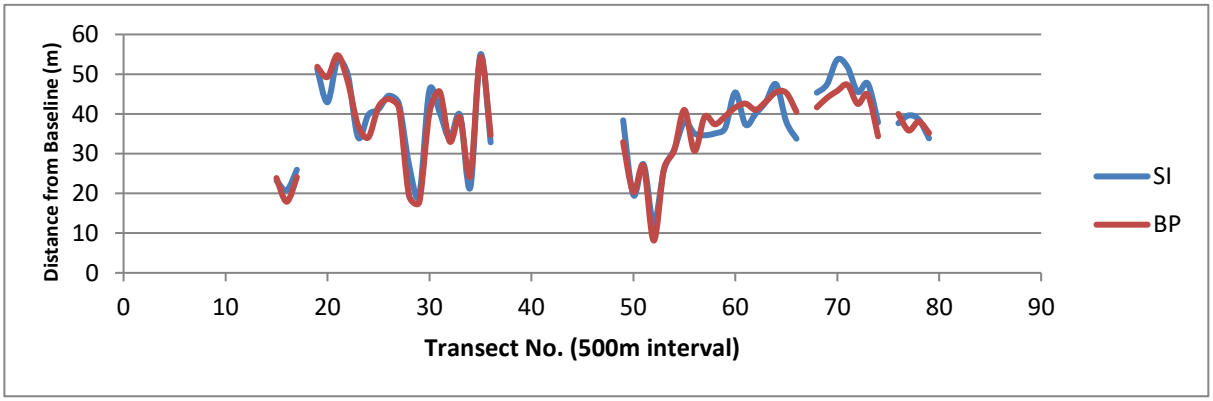


Figure 5.1 Comparison of shoreline extracted from the satellite images and beach profiles at 500m intervals.

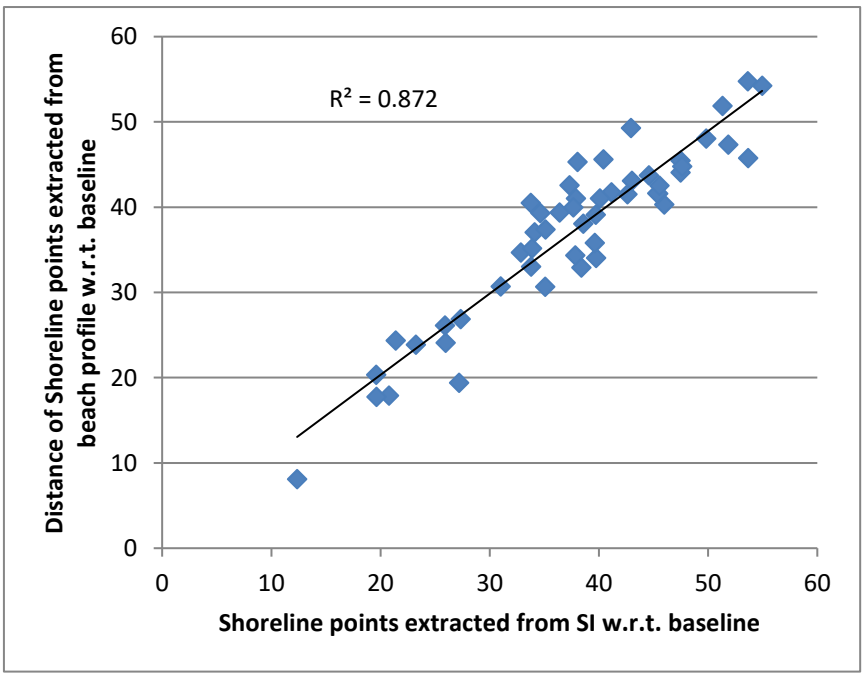


Figure 5.2 Correlation of shoreline extracted from satellite image and beach profiles.

The trend of the shoreline analysis using satellite images shows the trend before and after 2015, as shown in Figure 5.3. It shows that erosion spots like Valliyathura, Shangumugham and Punthura have been eroding before and after the commencement of the Port (December 2015). The timeline of climatic events and port activities along the Vizhinjam coast is listed in Table 5.1.

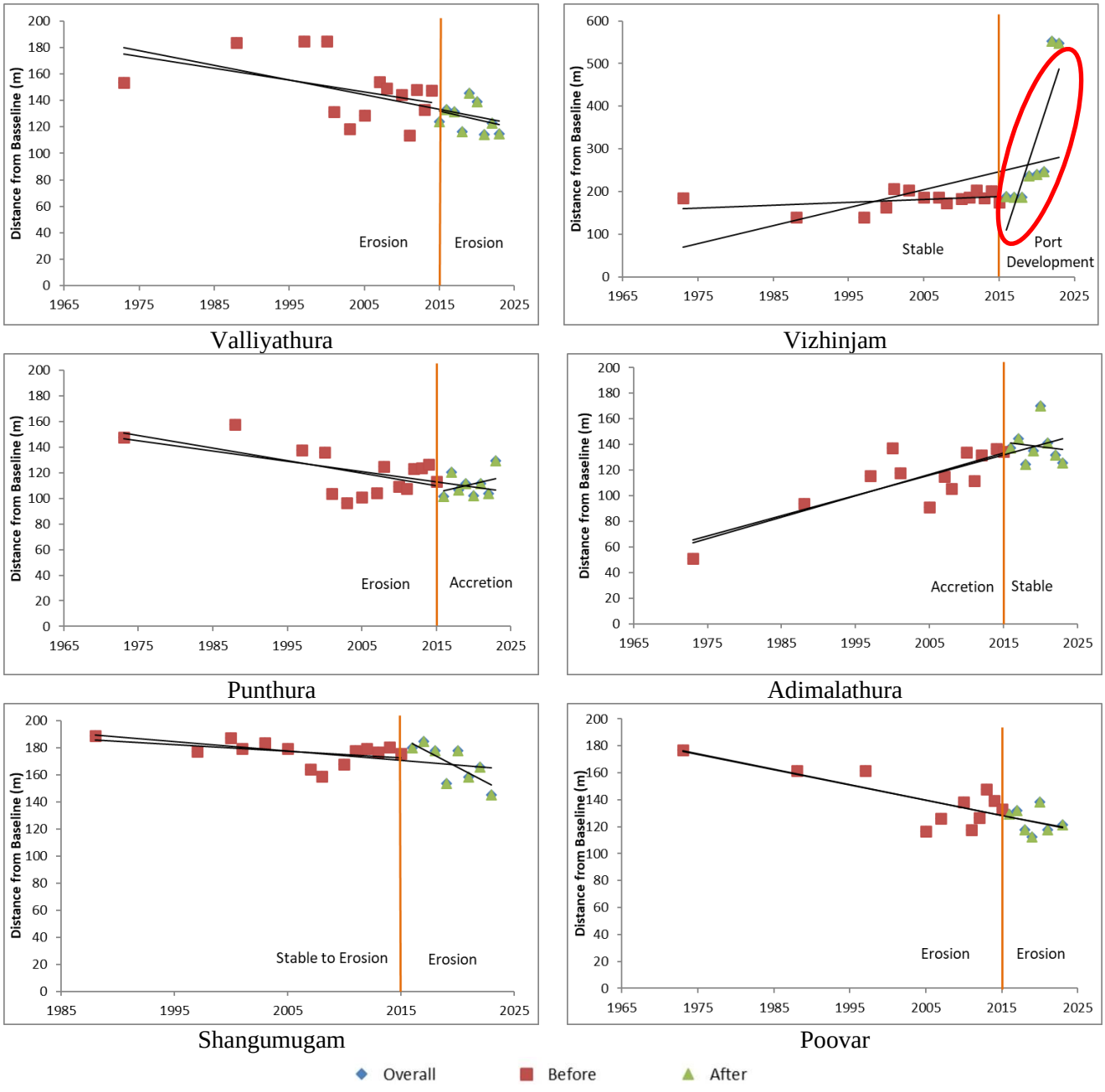


Figure 5.3Trend analysis of shoreline change distance from baseline from 1973 to 2022 and trends before and after 2015.

Table 5.1. Timeline of climatic and Port events along Vizhinjam coast and corresponding wave measurements

Date	Month	Climatic events	Wave observations captured in WRB	Port activity
October 9-October 12	Oct-15	Deep Depression ARB03		
	Dec-15			Dredging &Reclamation (0.2Mm^3)
	Apr-16			Breakwater construction of initial 676m
	Nov-16			Dredging (0.25Mm^3)
December 17-December 18	Dec-16	Depression ARB02	Maximum Hs-1.53m, Maximum Hmax-2.56m, Maximum Tp-18.18s	Dredging (0.25Mm^3)
	Jan-17			Dredging (0.2Mm^3) Reclamation (0.3Mm^3)
	Feb-17			
	Mar-17			Jetty construction Dredging (0.2Mm^3) Reclamation (0.3Mm^3)
	Apr-17			Dredging (0.2Mm^3) Reclamation (0.4Mm^3)
29th November-6th December	Dec-17	Cyclone Ockhi	Maximum Hs-4.05m, Maximum Hmax-7.29m, Maximum Tp-20s	Some portion of reclaimed areas washed away due to Cyclone Okhi, which passed the Kerala coast on 30.11.2017. The dredged material till 31.03.2019 amounting to 2.90 Mm^3 has been utilized for reclamation of 0.36 Mm^3 area.
	Jan-18			Backup yard and buildings
March 13-March 14	Mar-18	Depression ARB01	Maximum Hs-1.62m, Maximum Hmax-6.2m, Maximum Tp-18.18s	
6th October to 15th October	Oct-18	Cyclone Luban	Maximum Hs-2.17m, Maximum Hmax-3.62m, Maximum Tp-16.7s	
November 10-November 19	Nov-18	Cyclone Gaja	Maximum Hs-1.19m, Maximum Hmax-2.21m, Maximum Tp-16.7s	
June 10-17	Jun-19	Cycline Vayu	Maximum Hs-3.49m, Maximum Hmax-6.13m, Maximum Tp-16.7s	
	Nov-19			Breakwater construction beyond 676 m
October 30-November 7	Nov-19	Cyclone Maha	Maximum Hs-1.36m, Maximum Hmax-6.13m, Maximum Tp-16.7s(No Data During Cyclone Time)	No dredging and Reclamation
2nd December to 5th December	Dec-19	Deep Depression ARB07	Maximum Hs-1.49m, Maximum Hmax-2.52m, Maximum Tp-18.2s	
16th to 22nd May 2020	May-20	Cyclone Amphan	Maximum Hs-2.55m, Maximum Hmax-4.99m, Maximum Tp-20s	

31st May to 4th June 2020	Jun-20	Cyclone Nisarga	Maximum Hs-2.44m, Maximum Hmax-4.5m, Maximum Tp-20s	
17th to 19th June 2020	Jun-20	Monsoon		
20th July 2020	Jul-20	Monsoon	Maximum Hs-3.15m, Maximum Hmax-6.28m, Maximum Tp-20s	
8th August 2020	Aug-20	Monsoon	Maximum Hs-3.03m, Maximum Hmax-5.2m, Maximum Tp-16.67s	
6th to 9th September 2020	Sep-20	The low-pressure area formed under the influence of cyclonic circulation	Maximum Hs-3.98m, Maximum Hmax-8.84m, Maximum Tp-18.2s	
20th to 22nd September 2020	Sep-20	Low-pressure area North East Bay of Bengal		
13th to 14th October 2020	Oct-20	Deep depression over East Central Bay of Bengal	Maximum Hs-2.36m, Maximum Hmax-4.5m, Maximum Tp-20s	
17th November 2020	Nov-20	Cyclone Gati	Maximum Hs-1.68m, Maximum Hmax-2.92m, Maximum Tp-22.22s	
14th May to 19th May 2021	May-21	Cyclone Tauktae	Maximum Hs-4.12m, Maximum Hmax-9.44m, Maximum Tp-18.2s	
10th July 2021	Jul-21	Monsoon	Maximum Hs- 3.38m Maximum Hmax–5.74m Maximum Tp- 10.53s	
26th July 2021	Jul-21	Monsson	Maximum Hs- 2.60m Maximum Hmax–4.43m Maximum Tp- 14.29s	
3rd August 2021	Aug-21	Monsson	Maximum Hs- 2.41m Maximum Hmax–3.79m Maximum Tp- 16.67s	
7th August 2021	Aug-21	Monsson	Maximum Hs- 2.51m Maximum Hmax–4.37m Maximum Tp- 10.53s	
26th to 28th September 2021	Sep-21	Cyclonic storm Gulab	Maximum Hs- 2.99m Maximum Hmax–5.86m Maximum Tp- 7.69s	
15th to 17th October 2021	Oct-21	No associated extreme events in NIO	Maximum Hs- 3.62m Maximum Hmax–6.66m Maximum Tp- 7.69s	
12th to 15th November 2021	Nov-21	Depression BoB 05	Maximum Hs- 2.87m Maximum Hmax–5.66m Maximum Tp- 10.0s	
19th to 20th November 2021	Nov-21	Depression BoB 06	Maximum Hs- 1.86m Maximum Hmax–3.33m Maximum Tp- 6.67s	
2nd to	Dec-21	Cyclonic storm	No Data	

6thDecember 2021		Jawad		
14th to 15th May 2022	May-22	Severe cyclonic storm Asani	Maximum Hs- 3.03m Maximum Hmax–5.04m Maximum Tp- 8.33s	
5th July 2022	Jul-22	Monsoon	Maximum Hs- 3.01m Maximum Hmax–5.26m Maximum Tp- 11.76s	
1st August 2022	Aug-22	Monsoon	Maximum Hs- 3.51m Maximum Hmax–5.96m Maximum Tp- 9.09s	
5th September 2022	Sep-22	No associated extreme events	Maximum Hs- 3.57m Maximum Hmax–6.87m Maximum Tp- 10.0s	
3rd October 2022	Oct-22	No associated extreme events	Maximum Hs- 2.12 m Maximum Hmax–3.55 m Maximum Tp- 18.2s	
5th November 2022	Nov-22	Depression BOB 08	Maximum Hs- 1.51 m Maximum Hmax–2.73 m Maximum Tp- 18.18s	
11th December 2022	Dec-22	Severe Cyclonic StormMandous over the Bay ofBengal	Maximum Hs- 1.45 m Maximum Hmax–2.57 m Maximum Tp- 20.0 s	Dredging works at Vizhinjam resumed in December 2022 and continued till May 2023
25th January 2023	Jan-23	No associated extreme events	Maximum Hs- 1.28 m Maximum Hmax–2.06 m Maximum Tp- 18.18 s	0.03Mm^3 Reclaimed
16th February 2023	Feb-23	No associated extreme events	Maximum Hs- 1.5 m Maximum Hmax–2.31 m Maximum Tp- 20.0 s	0.23Mm^3 Reclaimed
30th March 2023	Mar-23	No associated extreme events	Maximum Hs- 1.23 m Maximum Hmax–2.59 m Maximum Tp- 20.0 s	0.12 Mm^3 Reclaimed
13th June 2023	Jun-23	Extremely severe cyclonic storm Biparjoy over southeast Arabian sea	Maximum Hs- 2.49 m Maximum Hmax– 4.98 m Maximum Tp- 18.2 s	0.7893 Mm^3 Reclaimed
4th July 2023	July-23	No associated extreme events	Maximum Hs- 4.84 m Maximum Hmax–5.96m Maximum Tp- 25.0 s	
6th August 2023	Aug-23	No associated extreme events	Maximum Hs- 2.97 m Maximum Hmax–5.42 m Maximum Tp- 18.18 s	
30th September 2023	Sep-23	Depression over the east-central Arabian Sea	Maximum Hs- 2.29 m Maximum Hmax–3.03 m Maximum Tp- 20.0 s	

The natural factor that induces/promotes coastal erosion is the incidence of cyclones and storm surges. It is well known that this factor is dominant on the eastern coast of south India compared to the western coast. However, cyclones formed in the Bay of Bengal have

impacted the Vizinjam coast. Though Cyclone Okchi formed in the southwest Bay of Bengal in 2017, it changed its course to the Arabian Sea and significantly impacted the Vizhinjam coast. It can be noticed from the frequency of cyclones trend since 1997 (Source: IMD) that the occurrence of cyclonic activity in the Arabian Sea and the Bay of Bengal has increased. This is also attributed to the sea roughness and erosion. The total number of Cyclones from 2016 to 2023 is 89, while the number of cyclones from 2008 to 2015 is 71, as shown in Figure 5.4.

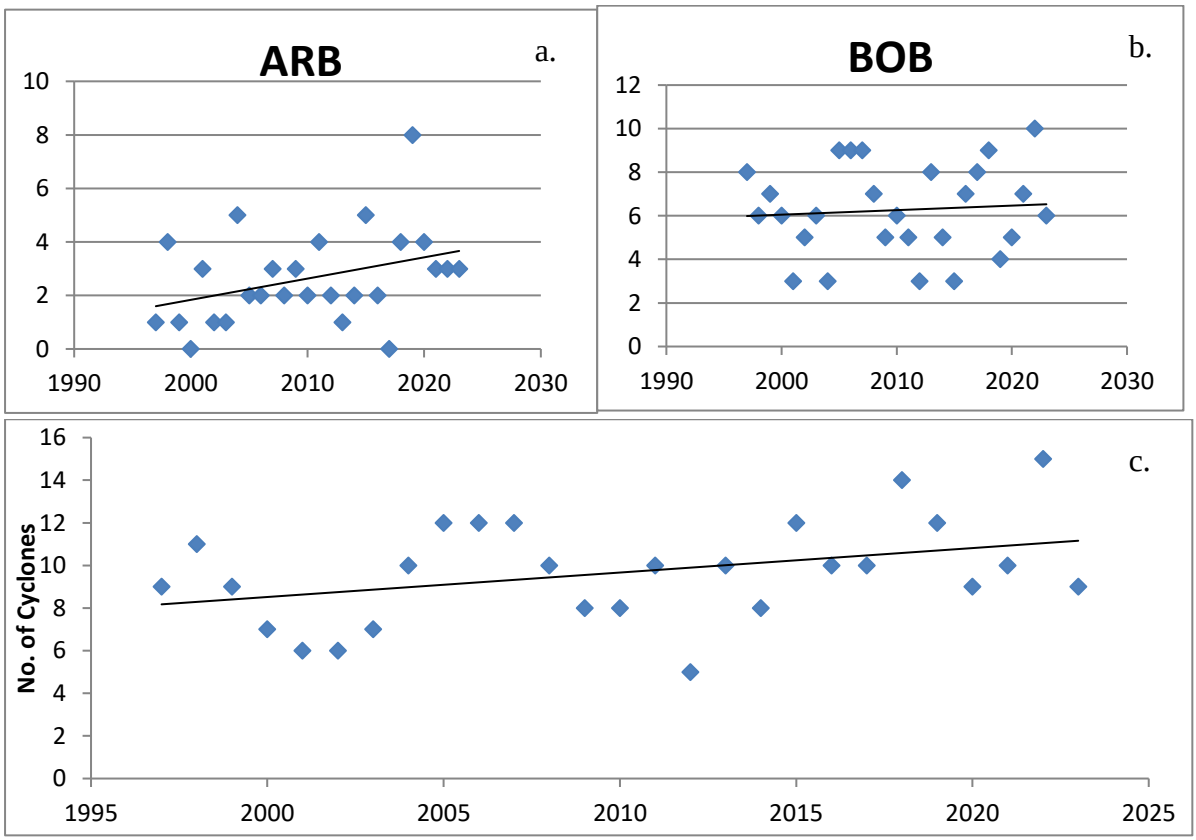


Figure 5.4 Incidence of cyclone activities a. Arabian Sea (ARB) b. Bay of Bengal (BoB) c. Total (BoB&ARB)

Table 5.2 Erosion and Accretion spots identified from satellite image and Beach profile analysis (onshore) during each month, seasonsfrom October 2022 to September 2023

		From Satellite image analysis	From Beach profile analysis-Onshore
October 2022	Erosion spots	Punthura to Pannathura (CSP 51 -53) Valliyathura (CSP 66) and Shangumugam (CSP 68)	Kovalam (CSP42), Panathura North (CSP52), Shangumugham North (CSP71) and Kochuveli to Valiyaveli (CSP76-78).
	Accretion spots	Edappadu beach(CSP02),Adimalathura to Karumkulam (CSP 22-34)	Edappadu beach (CSP02), Shangumugham South to North (CSP69-70), Vettucaud to Kochuveli (CSP73-CSP75) and Thumba (CSP80-81).
November 2022	Erosion spots	Poovar (CSP17), Karumkulam (CSP25), Valliyathura (CSP 66)	No data
	Accretion spots	Adimalathura to Poovar (CSP 18-24,26-36),PunthuratoPannathura(CSP51-53),ThumbatoVettucaud(CSP72-81)	No data
December 2022	Erosion	Punthura(CSP 53-54), Valiyaveli(CSP78)	No data
	Accretion spots	Adimalathura to Poovar (CSP15-34), Kochuveli to Beemapally (CSP 58-77)	No data
January 2023	Erosion spots	Poovar(CSP16-18), Adimalathura (CSP33), Valliyathura (CSP66), Shangumugham beach (CSP69), Vettucaud (CSP74),	Edappadu beach (CSP02), Poovar south (CSP15-17), Poovar north to Karumkulam (CSP20-22), Kovalam (CSP42-43), Shangumugham South to North (CSP 69-70), Vettucaud to Valiyaveli (CSP72-78) and Thumba (CSP80-81).
	Accretion spots	Pullavila (CSP28), Thumba to Valliyaveli (CSP 78,80)	Poovar (CSP18-19), Panathura North (CSP52) and Valliyathura (CSP66).
February 2023	Erosion spots	Pullavila to Poovar(CSP21-29), Adimalathura(CSP31), Mullur(CSP37), Punthura(CSP53), Valliyathura(CSP66), Valiyaveli(CSP78)	Karumkulam (CSP25), Adimalathura (CSP32), Punthura (CSP53), Valliyathura (CSP66) and Shangumugham North (CSP70).
	Accretion spots	Poovar(CSP16-18), Adimalathura(CSP33), Valliyathura(CSP66), Shangumugham beach(CSP69), Vettucaud (CSP74),	Edappadu beach(CSP02), Poovar South-Karumkulam (CSP15-24), Karumkulam to Pulluvila (CSP26-28), Adimalathura (CSP31), Adimalathura (CSP33-34), Azhimala to Mullur (CSP35A-37), Kovalam (CSP40A-43), Panathura north (CSP52), Shangumugham south (CSP69), Vettucaud-Valiyaveli (CSP72-78) and Thumba (CSP80-81).
March 2023	Erosion spots	Pullavila to Adimalathura (CSP29-32), Punthura (CSP 53-54), Shangumugham to Valliyathura (CSP64-70),	Poovar south (CSP15), Poovar (CSP18-19), Karumkulam (CSP22), Pulluvila (CSP27-28), Pulluvila (CSP30), Mullur (CSP36-37), Kovalam (CSP40A), Kovalam (CSP42-43), Valliyathura (CSP66), Vettucaud to

			Kochuveli (CSP74-76) and Thumba (CSP80-81).
	Accretion spots	Adimalathura (CSP33-34), Thumba to Vettucaud (CSP72- 81)	Edappadu beach (CSP02), Poovar South (CSP16-17), Poovar (CSP20-21), Karumkulam (CSP23-26), Adimalathura (CSP31-34), Azhimala (CSP35A), Kovalam (CSP41), Panathura North to Punthura (CSP52-53), Shangumugham south to Vettucaud (CSP69-73) and Kochuveli to Valiyaveli (CSP77-78).
April 2023	Erosion spots	Edappadu beach (CSP02), Poovar South (CSP16), Karumkulam (CSP21),Adimalathura (CSP32), Mullur (CSP37), Kovalam (CSP40A-41), Punthura (CSP53), Valiyathura (CSP66), Shangumugham north (CSP70), Vettucaud (CSP72-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78) and CSP80(Thumba).	Edappadu beach (CSP02), Poovar South (CSP16), Karumkulam (CSP21), Adimalathura (CSP32,CSP34), Azhimala (CSP35A), Mullur (CSP37), Kovalam (CSP40A-41), Punthura (CSP53), Shangumugham north (CSP70), Vettucaud (CSP72-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78) and Thumba (CSP80).
	Accretion spots	Poovar (CSP17-20), Karumkulam (CSP22), Adimalathura (CSP31), Mullur (CSP36), Kovalam (CSP42-43), Shangumugham south (CSP69), Shangumugham north (CSP71), Thumba to Vettucaud (CSP74-81).	Poovar south (CSP15), Poovar south to Poovar north (CSP17-20), Karumkulam (CSP22), Adimalathura (CSP31,CSP33), Mullur (CSP36), Kovalam (CSP42-43), Panathura north (CSP52), Shangumugham south (CSP69), Shangumugham north (CSP71), Vettucaud (CSP74), Kochuveli (CSP76) and Thumba (CSP81).
May 2023	Erosion spots	Edappadu beach (CSP02), Poovar south (CSP16), Poovar (CSP18), Poovar north (CSP20), Karumkulam (CSP22), Mullur (CSP37), Panathura north (CSP51),Punthura (CSP53), Shangumugham south (CSP69), and Thumba (CSP80-81).	Poovar south (CSP16), Poovar (CSP18), Poovar north (CSP20), Karumkulam (CSP22), Mullur (CSP37), Kovalam (CSP40A), Kovalam (CSP42), Shangumugham south (CSP69), Vettucaud (CSP74), Kochuveli (CSP76) and Thumba (CSP80-81).
	Accretion spots	Poovar north (CSP21), Adimalathura (CSP33-34), Kovalam (CSP43), Punthura (CSP52-53), Valiyathura (CSP66), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78).	Edappadu beach (CSP02), Poovar south (CSP15), Poovar South (CSP17), Poovar (CSP19), Poovar north (CSP21), Adimalathura (CSP33-34), Azhimalathura to Mullur (CSP35A-36), Kovalam (CSP41), Kovalam (CSP43), Panathura North to Punthura (CSP52-53), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78).
June 2023	Erosion spots	Edappadu beach (CSP02), Poovar south to Poovar (CSP15-18), Karumkulam (CSP21-24), Adimalathura (CSP33-34), Mullur (CSP36-37), Kovalam (CSP40A), Kovalam (CSP42), Panathura north (CSP52), Valiyathura to Kochuveli (CSP66-78),	Edappadu beach (CSP02), Poovar south to Poovar (CSP15-19), Mullur (CSP36-37), Kovalam (CSP40A), Kovalam (CSP42), Panathura north (CSP52), Shangumugham north (CSP71) and Kochuveli to Valiyaveli (CSP76-77).
	Accretion spots	Poovar (CSP20), Punthura (CSP53), and Thumba (CSP80-81).	Poovar north to Karumkulam (CSP20-22),Kovalam (CSP43),Punthura (CSP53),Shangumugham south (CSP69), Vettucaud to Kochuveli (CSP74-75), Valiyaveli (CSP78) and Thumba (CSP80-81).

July 2023	Erosion spots	Edappadu beach (CSP02), Poovar north (CSP21), Mullur (CSP37), Kovalam (CSP43),Panathura north (CSP51-52), Punthura (CSP53), Valliyathura (CSP64A), Shangumugham south to Shangumugham north (CSP69-71), Kochuveli (CSP75-77) and Thumba (CSP81).	Edappadu beach (CSP02), Poovar north (CSP21), Mullur (CSP37), Kovalam (CSP43), Panathura north (CSP52), Valliyathura (CSP64A), Shangumugham south (CSP69), Shangumugham north (CSP71), Kochuveli (CSP75-78) and Thumba (CSP81).
	Accretion spots	Poovar (CSP15), Mullur (CSP36), and Valiyaveli (CSP78).	Poovar south to north (CSP15-20), Karumkulam (CSP22), Mullur (CSP36), Kovalam (CSP40A), Kovalam (CSP42) and Punthura (CSP53).
August 2023	Erosion spots	Poovar south (CSP16), Poovar north (CSP20), Kovalam (CSP40A), Kovalam (CSP42-43),Panathura north (CSP51), Punthura CSP53), Valliyathura (CSP64A), Shangumugham (CSP69).	Poovar south to Poovar (CSP16-18), Poovar north to Karumkulam (CSP20-22), Kovalam (CSP40A), Kovalam (CSP42-43),Punthura (CSP53), Valliyathura (CSP64A), Kochuveli to Valiyaveli (CSP75-78) and Thumba (CSP81).
	Accretion spots	Edappadu beach (CSP02), Poovar South (CSP15), Poovar (CSP19), Mullur (CSP36-37), Panathura north (CSP52), Shangumugham South (CSP69) and Shangumugham north (CSP71), Kochuveli to Valiyaveli (CSP75-78) and Thumba (CSP81).	Edappadu beach (CSP02), Poovar South (CSP15), Poovar (CSP19), Mullur (CSP36-37), Panathura north (CSP52), Shangumugham South (CSP69) and Shangumugham north (CSP71).
September 2023	Erosion spots	Poovar south (CSP16), Adimalathura to Karumkulam (CSP), Mullur (CSP36-37), Kovalam (CSP40A), Valliyathura (CSP64A), Shangumugham north (CSP70).	Poovar south (CSP16), Poovar to Poovar north (CSP19-20), Mullur (CSP36-37), Kovalam (CSP40A), Kovalam (CSP42) and Panathura north to Punthura (CSP52-CSP53).
	Accretion spots	Edappadu Beach (CSP02), Poovar South (CSP15), Poovar South to Poovar (CSP17-18), Poovar North (CSP21), Kovalam (CSP43), Panathura North (CSP51), Shangumugham South (CSP69), Shangumugham north to Kochuveli (CSP71-77) and Thumba (CSP80-81).	Edappadu Beach (CSP02), Poovar South (CSP15), Poovar South to Poovar (CSP17-18), Poovar North (CSP21), Kovalam (CSP43), Valliyathura (CSP64A), Shangumugham Southto Shanghumugham north (CSP69-71), Vettucaud to Valiyaveli (CSP73-78) and Thumba (CSP80-81).
Post monsoon (October 2022-November2022)	Erosion spots	Poovar (CSP17), Karumkulam (CSP25), Valliyathura (CSP 66)	No data in November 2022
	Accretion spots	Adimalathura to Poovar (CSP 18-24,26-36),PunthuratoPannathura(CSP51-53),ThumbatoVettucaud(CSP72-81)	No data in November 2022
Fair weather (Dec 2022	Erosion spots	Paruthiyoor to Karumkulam (CSP13-26), Adimalathura (CSP31-32), Mullur (CSP37), Punthura (CSP 53), and Shangumugam to Valliyathura (CSP63-71)	Kovalam (CSP43), Valliyathura (CSP66), Shangumugham north to Kochuveli (CSP72-76)and Valiyaveli (CSP78).

to March 2023)	Accretion spots	Pullavila (CSP28-29), Thumba to Vettucaud(CSP72-81), Adimalathura(CSP33-34),	Edappadu beach (CSP02), Poovar South to Karumkulam (CSP15-22), Kovalam (CSP42), Punthura (CSP52), Shanghumugham south to Shanghumugham north (CSP69-71), Kochuveli (CSP77) and Thumba (CSP80-81).
Pre - Monsoon (April 2023-May 2023)	Erosion spots	Edappadu Beach (CSP02), Poovar South (CSP16), Poovar (CSP18), Poovar North (CSP20), Karumkulam (CSP22), Mullur (CSP37), Panathura North (CSP51),Punthura (CSP53), Shangumugham south (CSP69), and Thumba (CSP80-81).	Poovar south (CSP16), Poovar (CSP18), Poovar north (CSP20), Karumkulam (CSP22), Mullur (CSP37), Kovalam (CSP40A,42), Shangumugham south (CSP69), Vettucaud (CSP74), Kochuveli (CSP76) and Thumba (CSP80-81).
	Accretion spots	Poovar north (CSP21), Adimalathura (CSP33-34), Kovalam (CSP43), Punthura (CSP52-53), Valiyathura (CSP66), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78).	Edappdu beach (CSP02), Poovar south (CSP15), Poovar South (CSP17), Poovar (CSP19), Poovar north (CSP21), Adimalathura(CSP33-34), Azhimala to Mullur (CSP35A-36), Kovalam (CSP41,CSP43), Panathura north to Punthura (CSP52-53), Shangumugham north to Vettucaud (CSP70-73), Kochuveli (CSP75) and Kochuveli to Valiyaveli (CSP77-78).
Monsoon (June2023-September 2023)	Erosion spots	Adimalathura to Poovar (CSP20-34, 16), Kovalam (CSP45), Valliyathura (CSP63-67), Shangumugham (68-71)	Poovar to Poovar north (CSP19-CSP21), Kovalam (CSP43), Panathura north (CSP52), Valliyathura (CSP64A), Shangumugham south (CSP69), Shangumugham north (CSP71) `, Vettucaud (CSP74), Kochuveli (CSP76), Valiyaveli (CSP78) and Thumba (CSP80).
	Accretion spots	Edapadu beach (CSP02), Poovar (CSP14-15), Mullur (CSP37), Punthura (CSP 53), Thumba to Vettucaud (CSP 72-81)	Edappadu beach (CSP02), Poovar south to Poovar (CSP15-18), Kovalam (CSP40A,42), Punthura (CSP53), Kochuveli (CSP75,CSP77) and Thumba (CSP81).
Overall change (October 2022-September 2023)	Erosion spots	Poovar (CSP15), Pulluavila (CSP27), Karumkulam (CSP24), Mullur (CSP36-37), Punthura (CSP56), Valiyathura (CSP65), Shangumugham (CSP69), and Thumba (CSP80).	There is no data from CSP 03 to 41, 44 to 51, 53, 66, and 72. Shangumugham (CSP69), Vettucaud (CSP74) and Kochuveli to Valiyaveli (CSP76-78).
	Accretion spots	Edapadu beach (CSP02), Poovar (CSP16-18), Karumkulam (CSP25-26),Adimalathura (CSP31-34), Kovalam (CSP43), Punthura (CSP57), Shangumugham north (CSP70), Vettucaud (CSP73), Kochuveli (CSP75), Valliyaveli (CSP76-79)	Edappadu beach (CSP02), Kovalam (CSP42,43), Panathura north (CSP52), Shangumugham north (CSP70-71), Vettucaud (CSP73), Kochuveli (CSP75) and Thumba (CSP80-81). There is no data from CSP 15 to 41, 44 to 51, 53, 66, and 72.
October 2021-October	Erosion spots	Edappadu Beach(CSP02), Pullavila to Karumkulam (CSP), Punthura (CSP53), Shangumugam South (CSP69), Vettucaud (CSP72-73), Kochuveli (CSP75) Valiyaveli (CSP78), Thumba (CSP81).	Punthura (CSP53), Shangumugam South (CSP69), Vettucaud (CSP72-73), Kochuveli (CSP75) and Valiyaveli (CSP78).
	Accretion	Kovalam(CSP42-44), Panathura north (CSP51-52), Valliyathura	Edappadu beach(CSP02), Kovalam (CSP42-44), Panathura north

2022	spots	(CSP66), Shangumugham north(CSP70-71), Vettucaud (CSP74), Kochuveli (CSP76-77),	(CSP51-52),Valliyathura (CSP66), Shangumugham north(CSP70-71), Vettucaud (CSP74), Kochuveli (CSP76-77), Thumba(CSP80-81).
February 2022-February 2023	Erosion spots	PullavilatoPoovar(CSP21-29), Adimalathura(CSP31),Mullur(CSP37),Punthura(CSP53), Valliyathura(CSP66),Valiyaveli(CSP78)	Poovar south (CSP15,17), Pulluvila (CSP27,30), Azhimala(CSP35A), Mullur (CSP37), Kovalam (CSP41,43), Panathura north (CSP51-52),Valliyathura (CSP66), Vettucaud (CSP72,74), Kochuveli (CSP76), Valiyaveli (CSP78).
	Accretion spots	Poovar(CSP16-18), Adimalathura (CSP33),Valliyathura(CSP66),Shangumugham beach(CSP69),Vettucaud (CSP74),	Poovar to Karumkulam (CSP18-26), Pulluvila (CSP28), Adimalathura (CSP31-33), Mullur (CSP36), Kovalam (CSP42,44), Punthura (CSP53), Shangumugham south to Shangumugham north (CSP69-71), Vettucaud (CSP73), Kochuveli (CSP75,77) and Thumba (CSP80-81).
May 2022-May 2023	Erosion spots	Edapadu beach (CSP02), Poovar(CSP15, 18),Pullavila (CSP27), Adimalathura (CSP34), Kovalam(CSP40A,44),Valliyathura (CSP66), Shangumugham south (CSP69)and Thumba (CSP80-81).	Edapadu beach (CSP02), Poovar south (CSP15), Adimalathura (CSP34), Kovalam(CSP40A,44), Panathura north (CSP51), Punthura (CSP53), Kochuveli(CSP75) and Valiyaveli(CSP78).
	Accretion spots	Poovar south (CSP16), Poovar north (CSP20), Adimalathura (CSP33), Kovalam (CSP41-43), Panathura north (CSP52), Shangumugham south to Vettucaud (CSP70-74), Kochuveli to Valiyaveli (CSP76-77)	Poovar south (CSP16-18), Poovar north (CSP20-22), Adimalathura (CSP33), Azhimala to Mullur (CSP35A-37), Kovalam (CSP41-43), Panathura north (CSP52), Valliyathura (CSP66), Shangumugham south to Vettucaud (CSP69-74), Kochuveli to Valiyaveli (CSP76-77) and Thumba (CSP80-81).
September 2022-September 2023	Erosion spots	Poovar south(CSP16), Pullavila (CSP27-28), Valliyathura (CSP66), Shangumugham north (CSP70),	Poovar south(CSP16), Panathura (CSP51-52), Valliyathura (CSP66), Shangumugham north (CSP70), Kochuveli to Valiyaveli (CSP75-78).
	Accretion spots	Edappadu beach (CSP02), Poovar south (CSP15), Poovar south to Poovar north (CSP17-21), Kovalam (CSP42), Shangumugham south (CSP69), Shangumugham north to Vettucaud (CSP71-74), Kochuveli to Valiyaveli (CSP75-78), and Thumba (CSP80-81).	Edappadu beach (CSP02),Poovar south (CSP15), Poovar south to Poovar north (CSP17-21), Kovalam (CSP42), Shangumugham south (CSP69), Shangumugham north to Vettucaud (CSP71-74) and Thumba (CSP80-81).

6 VETTING OF REPORTS/ DATA

Periodical (monthly, seasonal and half-yearly) reports on field data quality checks and data on water quality, sediments, shoreline monitoring, etc., are scrutinized by NIOT. The Oceanographic and bathymetric data received from AVPPL and reviewed for the period from October 2022 to September 2023 are listed in Table 6.1. Sediment samples were collected seasonally at the cross-shore profile locations. Water quality (Turbidity and TSS carried out at 4 locations for March 2023). Vetting of Reports on data analysis and model studies for Vizhinjam Port using data collected by AVPPL (October 2022 to September 2023) by LnTIEL during November 2023 and vetting of monthly data reports on water quality, oceanographic and bathymetric data collection (by Shankar & Co) for assessment of Shoreline changes has been completed till September 2023 and periodic review and suggestions are being provided to the survey agency appointed by AVPPL. On February 8, 2024, the survey conducted by the designated survey agency underwent verification by engineers from the National Institute of Ocean Technology (NIOT). After the examination, recommendations were provided to the surveyors, emphasizing the imperative adherence to the Standard Operating Procedures (SOP) governing profile and Leo surveys and the field report was submitted by NIOT to AVPPL (mail dated 12th February 2024). It is suggested that the monthly offshore profile survey be completed within two weeks and the seasonal offshore surveys be completed within a month. The survey agency will conduct periodic quality checks of water samples in the testing laboratory for quality control (measurement uncertainty).

6.1 The methodology adopted for verifying various monitored data

The calibrated pressure sensor was installed at Vizhinjam port for tide measurement. The Vizhinjam tide gauge data was connected to a benchmark near the jetty, and the data was observed with respect to the chart datum. NIOT has checked the consistency of the water level by installing a radar level sensor near the existing tide gauge. The periodic check by manual measurement logs is also verified, and the difference matched well within the acceptable limit. The observed tide data are checked thoroughly, and flagged/suspicious data like spikes are removed.

The beach profile data quality check was carried out based on the quantity of the data received against the temporary benchmark and beach profile comparison with the earlier data sets. The data set has been discarded from the analysis based on the following criteria:

Table 6.1Data Status October 2022 to September 2023

Sl no.	Parameters	Post monsoon (October 2022 - January 2023)				Pre monsoon (Feb 2023-May 2023)				SW Monsoon (June 2023-September 2023)			
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	August	Sept
1	Wave (1 location)	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓
2	Tide (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Met (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	ADCP (4 locations) at 20 m water depth	✓(Mar)				✓(Mar)				x			
5	Bathymetry	✓(Mar)				✓(June)				x			
6	Beach Profile (81 locations at 500 m distance)	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	Turbidity	×	×	×	×	×	×	×	×	×	×	×	×
8	Water sample (TSS, Salinity and temp)	✓(Mar)				x				x			
9	Grain size(81 locations at 500 m distance)	✓(Feb)				✓(May)				✓(Sep)			
10	LEO (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	Shoreline monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12	Photo documentation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

1. No simultaneous offshore profile data with onshore profile was observed with a contour less than +1 m.
2. More than 50% spatial profile deviation from the previous month's data with respective to x and y coordinates
3. A data set which has less than 4 data points
4. The cross-sectional profiles survey has been carried out using the RTK method. The NIOT team members visited the site during the RTK survey and checked the base station and rover setup during the survey. The consistency of position and level before starting the survey and after finishing the survey has been checked.

Initial data quality analysis has been done based on the above criteria. When two of the above points are noticed in all the profile data in a month, the data of that particular month has been discarded.

Sudden unrealistic changes/spikes observed in the profile level that arise for some reason are carefully examined and removed before the analysis. Further, to normalize the gaps in a single profile, bilinear interpolation was carried out to fill the data gaps, and uniform 1-meter interval profile data was generated. The shoreline and nearshore data system (SANDS) that was used in the analysis has its own data quality procedure, which will not allow the system to proceed and analyze the data, but it ends up with an error. All profiles are manually checked before entering the data into SANDS.

The calibration of a multi-beam echo sounder is commonly referred to as a patch test. It is required to identify the offsets that would be applied to the data to compensate for any misalignment in various sensors used. The offsets from the vessel reference point, DGPS antenna, and transducer were measured and entered into the acquisition software with an in-situ measurement of the sound velocity profiler. NIOT has instructed SAC to carry out the crossline survey as per the IHO standards for multi-beam surveys. The NIOT team has checked the patch test and other offsets for the bathymetry survey.

TSS data provided was analyzed and verified using the protocol prescribed by the American Public Health Association (APHA) 21st Edition 2540 D and validated using available data. Turbidity was measured using a turbidity meter as per APHA protocol. The instrument was calibrated using formazin / factory calibrated standard.

The ADCP's current data was analyzed using standard oceanographic methods and analysis techniques using the software used by the surveying agency. These include standard visualization techniques, pre- and post-calibration at the lab, time series, statistical methods, and numerical analysis. The ADCP quality control checks, correlation test, false target rejection test and error velocity test.

The data copied at buoy internal memory was downloaded at the end of retrieval and verified against the real-time data for any missing part. Wave data was processed using the manufacturer’s software package after downloading to the field PC. Wave parameters like Significant wave height, period, maximum wave height and wave direction were tabulated against time. Data gaps, Spikes or improbable data were verified and removed. As the present directional wave rider buoy works based on the GPS principle, the calibration of the buoy is not required.

Grab samples analysis report checked whether i) Grain size analysis is carried out as per IS 2720 PART IV, ii) Grain size distribution chart and table are provided as per IS 2720 PART IV, Appendix A, iii) Soil classification is carried out as per IS 1498 and iv) D50 values and location are provided for each sample. Also, a duplicate set of a few samples is collected and analyzed at the NIOT Geotechnical laboratory for cross-verification of results submitted.

6.2 Tidal observations

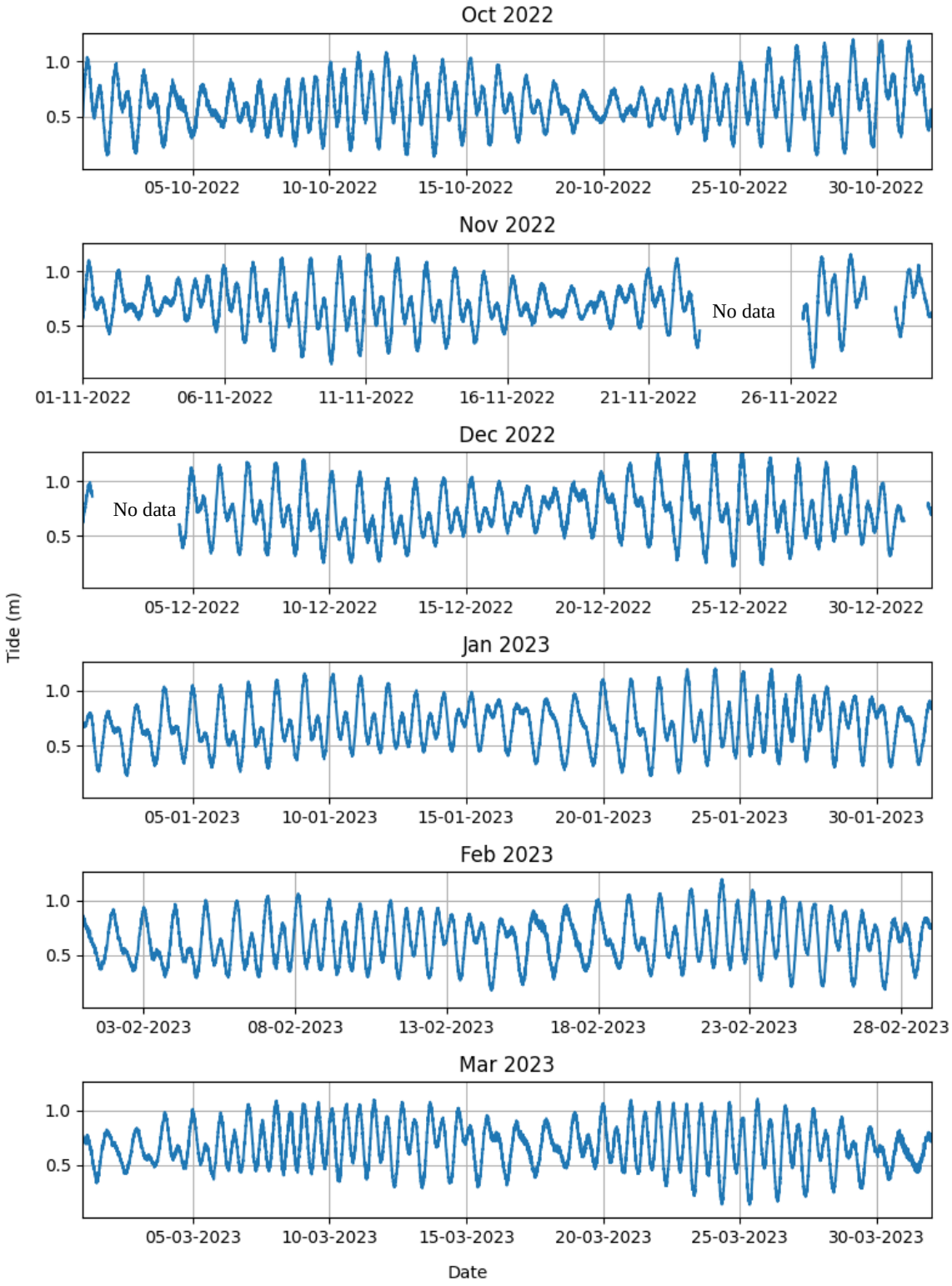
The Valeport Tidemaster Automatic Tide Gauge (ATG) was installed at the CoastGuard jetty inside the fishing harbour to measure the tides. The tide gauge is a pressure-sensor-based instrument that measures the water level due to changes in pressure on the sensor's surface.

The sensor was installed in a 6m long pipe to ensure that the zero of the sensor is always in water, irrespective of the phases of the tide.This was levelled to the jetty top, whose value is 2.711m above CD. The tide station was programmed to measure the tide at 6-minute intervals throughout the project. The sensor is placed at 2.349m below the CD.

The tides observed are mixed semi-diurnal. The tide observation from October 2022 to September 2023 is presented below. The minimum and maximum tide observed at this location from Oct-2022 to Sep-2023 is 0.023m (02-sep-2023) and a maximum of 1.261m (24-Dec-2022).

6.3 Wave observations

Time series for the different wave parameters- Hs, Tp and Dir, during the observation period from October 2022 to September 2023 are given in Figure 6.2. There are major gaps in the observation period, particularly from 1st April 2023 to 31st May 2023, due to the deployment of WRB by INCOIS and from 10th August 2023 to 22nd September 2023, the buoy drifted away from the deployed location and the data acquisition resumed after 22nd September 2023. Hence, the total observation period includes three seasons viz, post-monsoon season (October - November), Fairweather season (December - March) and Monsoon season (June - September). The sea state is relatively calm during the fair-weather season, with an average H_s of 0.75m and a maximum H_s of 1.40 m observed on 16th February 2023 during the fair-weather season. The H_s during monsoon seasons is higher compared to other seasons, with an average H_s of 1.70 m and the post-monsoon season is characterized by an average Hs of 1.0m. The Hs ranges between 3.23 m (on 5th July 2023) and 0.38m (on 5th December 2023) during the observation period. The average T_p is consistent around 12 seconds, and the maximum T_p ranges between 18.18 s to 20.0 s during the different seasons. The predominant wave direction ranged from 180° to 220° during the post-monsoon season, and during the monsoon season, it was between 180^o to 260^o.


Oct 2022
1.0
0.5
05-10-2022
10-10-2022
15-10-2022
20-10-2022
25-10-2022
30-10-2022
Nov 2022
No data
01-11-2022
06-11-2022
11-11-2022
16-11-2022
21-11-2022
26-11-2022
Dec 2022
No data
05-12-2022
10-12-2022
15-12-2022
20-12-2022
25-12-2022
30-12-2022
Tide (m)
Jan 2023
05-01-2023
10-01-2023
15-01-2023
20-01-2023
25-01-2023
30-01-2023
Feb 2023
03-02-2023
08-02-2023
13-02-2023
18-02-2023
23-02-2023
28-02-2023
Mar 2023
05-03-2023
10-03-2023
15-03-2023
20-03-2023
25-03-2023
30-03-2023
Date

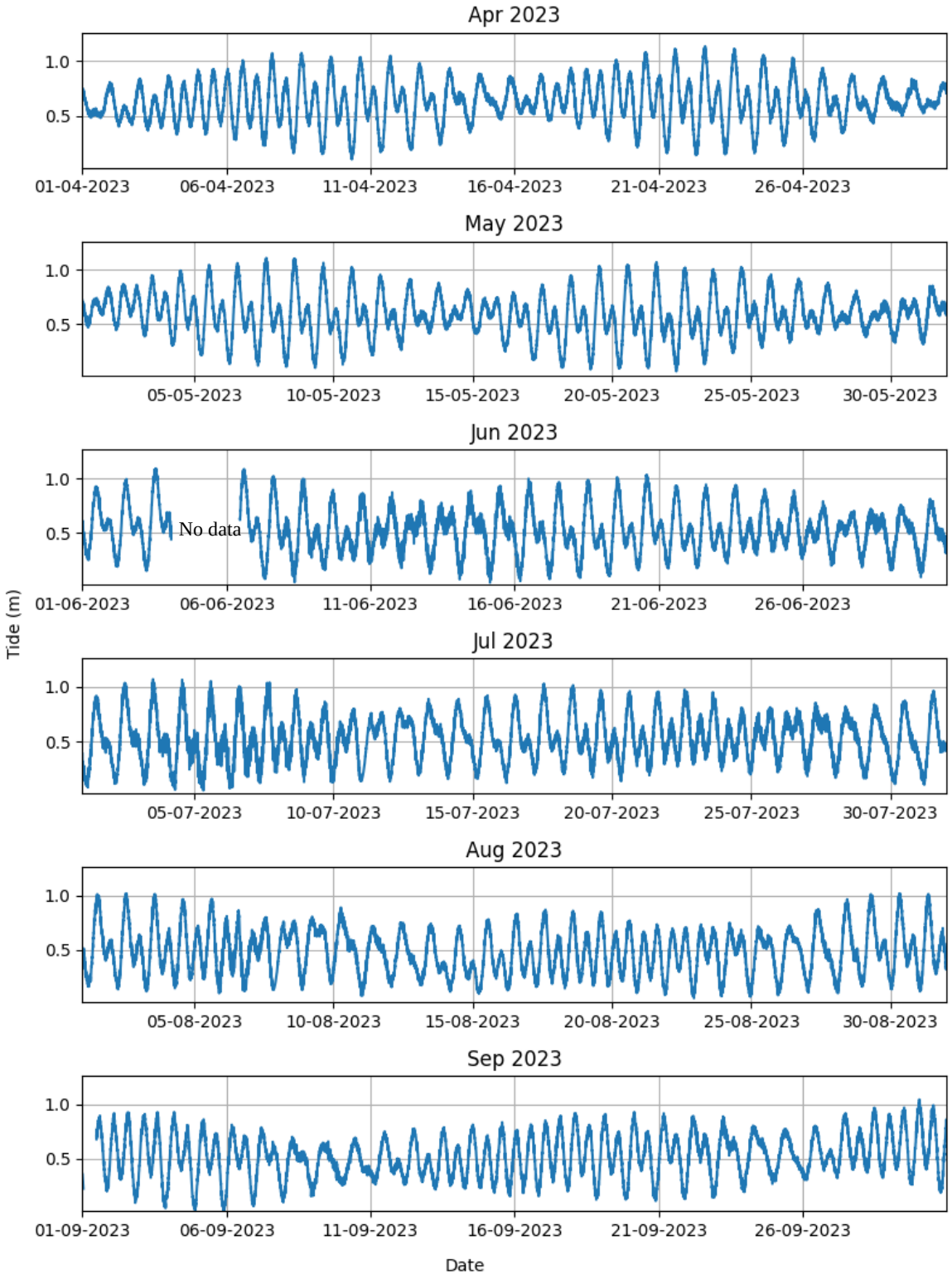
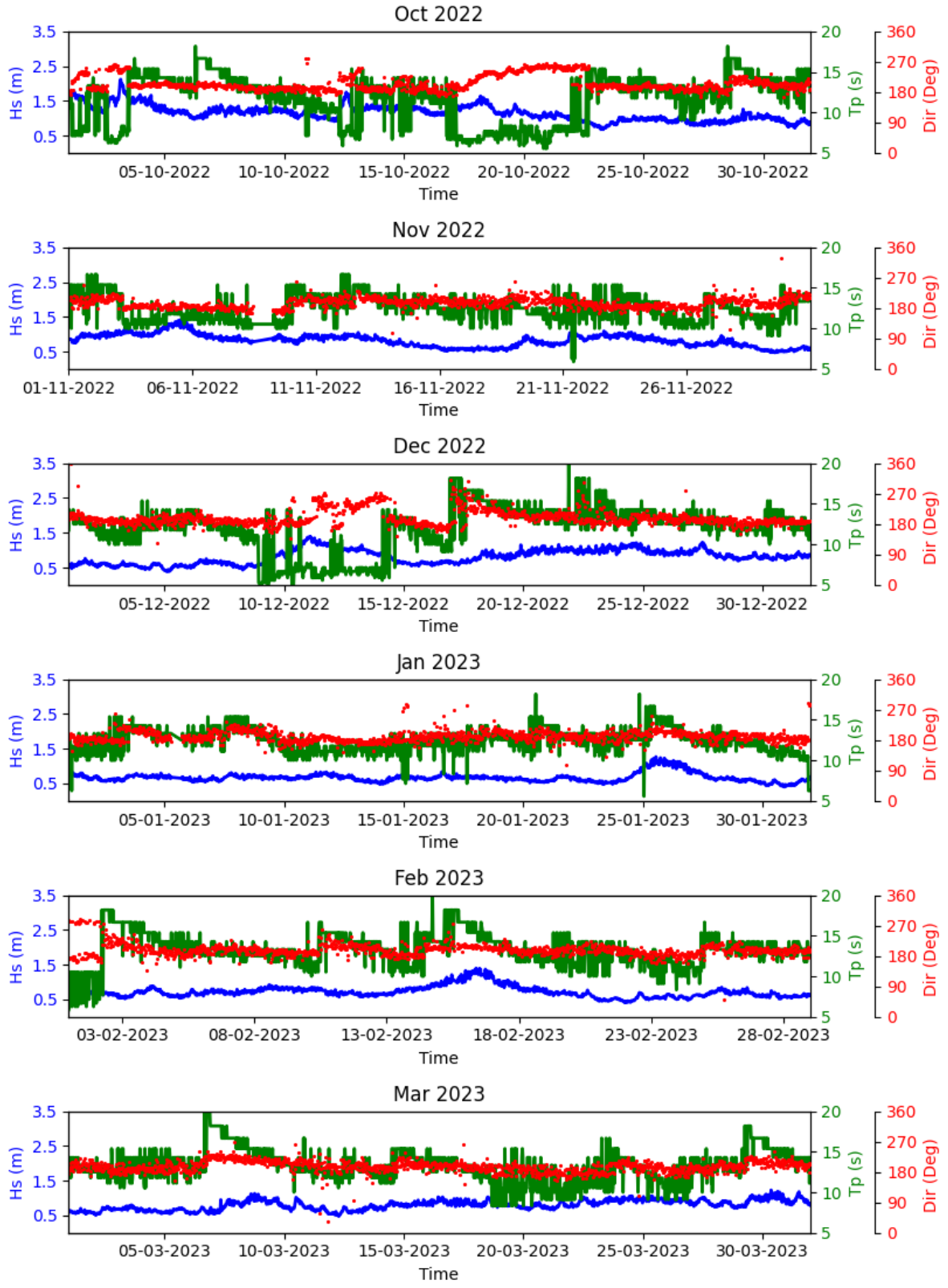


Figure 6.1 Tide observation from October 2022 to September 2023.


Oct 2022
Hs (m)
Tp (s)
Dir (Deg)
05-10-2022
10-10-2022
15-10-2022
20-10-2022
25-10-2022
30-10-2022
Time
Nov 2022
01-11-2022
06-11-2022
11-11-2022
16-11-2022
21-11-2022
26-11-2022
Time
Dec 2022
05-12-2022
10-12-2022
15-12-2022
20-12-2022
25-12-2022
30-12-2022
Time
Jan 2023
05-01-2023
10-01-2023
15-01-2023
20-01-2023
25-01-2023
30-01-2023
Time
Feb 2023
03-02-2023
08-02-2023
13-02-2023
18-02-2023
23-02-2023
28-02-2023
Time
Mar 2023
05-03-2023
10-03-2023
15-03-2023
20-03-2023
25-03-2023
30-03-2023
Time

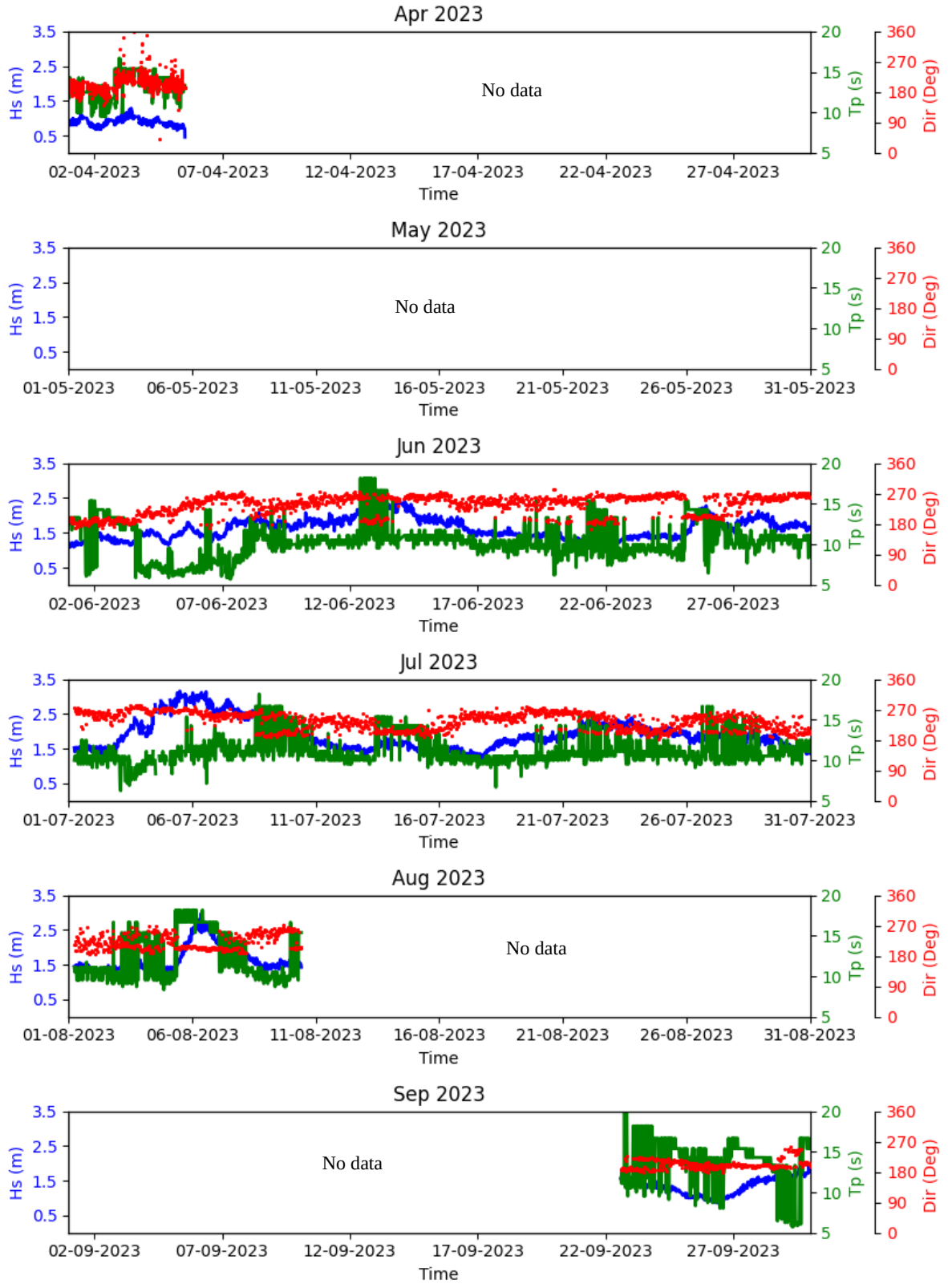


Figure 6.2 Wave observation from October 2022 to September 2023.

7 SUMMARY AND CONCLUSIONS

The littoral sediment transport processes along the coast generally involve the dynamic interactions between waves, currents, and coastline orientation. These processes depend on the coastline's shape and influence the deposition and erosion of sediments along the coast. Accordingly, on the Vizhinjam coast, the coastal currents, wave action, and sediment transport have played vital roles in shaping its morphology over time.

Normally, human activities such as constructing a port jetty or a groin may impact the coastal dynamics by altering sediment transport, leading to accretion and erosion. Consequently, there may be an alteration of the configuration of the coast.

Periodic monitoring of the coast to look for such changes, if any, will help manage these changes, mitigate potential environmental consequences, and maintain the overall coastal equilibrium. Dredging and modifications to coastal morphology can cause sediment deposition, resulting in the build-up of material in specific locations. This accretion may have both positive and negative effects, affecting ecosystems and navigation channels. In the context of the Vizhinjam coast, it is pertinent to mention that the coastline is characterised by longshore sediment transport, which is the dominant cause of beach profile changes.

A detailed analysis of the 40km coastal stretch (20km on either side of the port) and a comprehensive study of the factors mentioned above were carried out and presented in this report to understand the consequences of the port's construction on the shoreline change. Pre- and post-port construction dates have also been considered in the analysis.

This report discusses the monthly shoreline changes (in terms of distance eroded/accreted) using satellite images and the monthly shoreline changes (in terms of volume) using beach profile data.

From onshore beach profile analysis from October 2022 to September 2023, it was found that beaches exhibited erosion was observed at Shangumugham South (CSP69), Vettucaud (CSP74) and Kochuveli to Valiyaveli (CSP76-78) while accretion at Edappadu Beach (CSP02), Kovalam (CSP42,43), Panathura North (CSP52), Shangumugham North (CSP70-71), Vettucaud (CSP73), Kochuveli (CSP75) and Thumba (CSP80-81).). There is no data from CSP 15 to 41, 44 to 51, 53, 66, and 72. Due to rough sea conditions, the offshore survey was not carried out in September 2023. Hence, offshore beach profile analysis was not carried out from October 2022 to September 2023.

The overall shoreline changes using satellite images from October 2022 to September 2023 are erosion at Poovar (CSP15), Pulluvila (CSP27), Karumkulam (CSP24), Mullur (CSP36-37), Punthura (CSP56), Valiyathura (CSP65), Shangumugham (CSP69), and Thumba (CSP80); while accretion is noticed at Edapadu beach (CSP02), Poovar (CSP16-18), Karumkulam (CSP25-26), Adimalathura (CSP31-34), Kovalam (CSP43), Punthura (CSP57), Shangumugham north (CSP70), Vettucaud (CSP73), Kochuveli (CSP75), Valliyaveli (CSP76-79) for the period from October 2022 to September 2023.

As regards the net littoral drift along the Kerala coast, it is known that the net littoral drift is towards the North direction (Sheela Nair et al. 2015), with erosion of beaches taking place during Monsoon periods followed by accretion during pre- and post-SW monsoon months. With specific reference to the southern shore of the Vizhinjam region, sand is transported, mainly in the breaker zone, from south to north during most of the year. However, sand transport also occurs from north to south in the monsoon season. Thus, it is a fact that sediment transport will occur in both directions along the Vizhinjam coast.

The erosion and accretion spots identified from satellite images and beach profile analysis for the period from 2015 to 2023 are listed in Table 7.1, and the erosion and accretion spots identified from satellite images before and after 2015 using high-resolution satellite images are listed in Table 7.2. All the annual reports submitted compare the shoreline change from the satellite images with the beach volume changes from the beach profile data from 2015 onwards, and the erosion and accretion spots are listed in Tables 7.3 &7.4.

Table 7.1 Erosion and accretion spots were identified from the beach profile and satellite image analysis for the period 2015 to 2023.

	From Satellite image analysis	From Beach profile analysis-Onshore	From Beach Profile Analysis - Offshore
Erosion spots	Poovar South (CSP14-15),Poovar South to Poovar North (CSP18-20), Pulluvila (CSP30),Kovalam (CSP44), ShangumughamSouth to Thumba(CSP69-81)	Poovar South (CSP15), Poovar South to Poovar North (CSP18-20), Pulluvila (CSP30), Kovalam (CSP44), Shangumugham South to Kochuveli (CSP69-75) and Thumba (CSP80-81).	Poovar South (CSP15), Karumkulam (CSP22-26), Mullur (CSP36-37), Punthura (CSP54), Valiyaveli (CSP79).
Accretion spots	Poovar South (CSP17), Poovar north (CSP22,28), Adimalathura (CSP31,CSP33-34), Mullur (CSP36-37), Kovalam (CSP41-43), Panathura north (CSP51), Valiyathura (CSP66)	Poovar South (CSP17), Poovar North (CSP21-28), Adimalathura (CSP31, CSP33-34), Mullur (CSP36-37), Kovalam (CSP41-43), Panathura North (CSP51), Valiyathura (CSP66) and Kochuveli to Valiyaveli (CSP76-78).	Edappadu beach to Paruthiyoor (CSP03-14), Poovar south to Poovar north (CSP16-21), Pulluvila to Adimalathura (CSP27-34), Panathura south (CSP49), Punthura (CSP53), Punthura to Beemapally (CSP55-58), Beemapally (CSP60), Valliyathura (CSP63-67), Shangumugham to Vettucaud (CSP68-72), Kochuveli to Valiyaveli (CSP75-78) and Thumba (CSP80-81).

Table 7.2. Comparison of Erosion spots before and after 2015 (Port commencement) using high-resolution satellite images

	2011-2015	2015-2023
Erosion spots	Poovar South (CSP14-15),Poovar North (CSP18-20), Karumkulam (CSP 22), Pullavila (CSP30), Kovalam (CSP44), Punthura (CSP53), Valliyathura (CSP66) and Shangumugham (CSP69)	Poovar South (CSP14-15), Poovar South to Poovar North (CSP18-20), Pulluvila (CSP30), Shangumugham South to Thumba (CSP69-81)
Accretion spots	Karumkulam (CSP25), Pullavila (CSP27), Adimalathura (CSP33) and Vettucaud to Valiyaveli (CSP 75-81).	Poovar South (CSP17), Karumkulam (CSP22), Pullavila (CSP28), Adimalathura (CSP31,CSP33-34), Mullur (CSP36-37), Kovalam (CSP41-43), Panathura north (CSP51), Valiyathura (CSP66)

Table 7.3. Comparison of Erosion spots since 2000 using high-resolution satellite images

	2000-2005	2005-2010	2010-2015	2015-2023	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Erosion spots	No data to the north of Shangumugham			Thumba to Kochuveli	Kochuveli	Thumba to Vettucaud	Kochuveli Cheriyathura	Thumba to Kochuveli	Thumba to Kochuveli
	Shangumugham	Valliyathura	Shangumugham	Shangumugham	Shangumugham	Shangumugham	Shangumugham	-	Shangumugham
	Valliyathura		Valliyathura	Valliyathura	Valliyathura	Valliyathura	Valliyathura	Valliyathura	-
	Punthura		Punthura	Punthura	Punthura	Punthura	Punthura	Punthura	-
	Pulluvila		Pannathura	Pullivila	Pulluvila to Edapadu	Karumkulam to Edapadu	Pulluvila	-	
			Poovar	Poovar				-	Poovar

*****Red colour indicates the places that are continuously appearing in erosion spots

Table 7.4Summary and significant findings of Annual reports submitted

Reports	Period	Significant finding
Annual Report 2018	October 2017 to September 2018	• The shoreline change analysis using available high-resolution satellite images was carried out for 2000-2018 and annual variation for the years 2015-2016, 2016-2017, and 2017-18. • Erosion spots are Valliyathura, Punthura,and Neerody toEdapadu beach. Table 6.4 indicates that these sites were facing erosion even before the start of port activities. • The study has been compared with other available data and reports (NCCR, NCSCM, SAC), which show that these sites along the Vizhinjam coast have undergone erosion for a long time.
Annual Report 2019	October 2018 to September 2019	• The overall shoreline analysis for the period October 2018 to September 2019 shows accretion at a few transects of Cheriyathura and Mullur. It is stable at Pannathura and Adimalathura, whereas erosion is noticed at Kochuveli, Shangumugam, Valliyathura, Punthura, Pulluvila, and Edapadu Beach. • The overall beach volume change shows net accretion at CSP 22-23 (Karumkulam), CSP 32-33 (Adimalathura), CSP 35-38 (Mullur), CSP 61 (Cheriyathura) and net erosion at other locations. • It was noted that the spots of erosion, such as Valliyathura, Shangumugham and Punthura, remained the same before and after the commencement of the Port in December 2015 (Table 6.4).
Annual Report 2020	October 2019 to September 2020	• Thumba to Valliyathura, Punthura and Edapadu have been identified as zones of erosion, whereas Kovalam, Poovar and Karumkulam regions are identified as zones of accretion.

		• The spots of erosion, such as Valliyathura, Shangumugham and Punthura, remained the same before and after the commencement of the Port (December 2015). However, spots such as Thumba to Vettucaud to the north of Valliyathura show erosion during the period October 2019- September 2020.
Annual Report 2021	October 2020 to September 2021	• Erosion is noticed at Kochuveli, Shangumugham, Valliyathura, Cheriyathura, Punthura, Mullur, Pulluvila and accretion at Thumba, Vettucaud and Shangumugham, Punthura, Adimalathura, Karumkulam, Poovar and Edapadu beach. • From October 2020 to September 2021, the beach showed erosion at Thumba, Vettucaud to Kochuveli, Valliyathura, Pannathura to Punthura, Kovalam, Mullur, Pulluvila to Adimalathura, Karumkulam and Poovar. • Accretions are found at Edapadu Beach, Poovar, Karumkulam to Pulluvila, Adimalathura, Shangumugham and Valiyaveli. • It is inferred that the spots of erosion, such as Valliyathura, Shangumugham and Punthura, remained the same before and after the commencement of the Port in December 2015 (Table 6.4). • Trend analysis comparison of beach volume change (onshore) and shoreline change using satellite images (February to February) from 2015 to 2021 has been presented in the report. It was noticed that high erosion occurred during the Ockhi cyclone along the Vizhinjam, and the original profile has not recovered.
Annual Report 2022	October 2021 to September 2022	• Erosion is noticed at few sectors north of Adimalathura (CSP 35), Mullur (CSP 37), Punthura (CSP51-53), Valliyathura (CSP 64,66), Thumba to Kochuveli (CSP 75-81), while accretion is noticed at Adimalathura to Poovar (CSP 22-34) and Shangumugam (CSP 69-71). • From beach profile analysis for October 2021 to September 2022,it is found that beach shown erosion at Poovar (CSP15,17), Pulluvila (CSP27,30), Adimalathura (CSP31,33), Kovalam (CSP42-43) Pannathura to Punthura (CSP51-53) and Valliyathura (CSP66) and Vettucaud (CSP73) except accretion at most of the locations such as Pulluvila to Poovar (CSP 17-29) and Thumba to Shangumugam (CSP 69-72).

Based on several inputs (multi-date satellite imagery, multi-date onshore and offshore beach profiles, data on climatic events, wave observation data, port activity, etc.) and the subsequent analysis of shoreline changes, it is contingent that the spots of erosion have not been altered much since the commencement of the port construction.

It is noticed from the long-term analysis of shoreline changes of the high resolution of satellite images that accretion at Poovar (CSP17), Adimalathura (CSP31), Mullur (CSP36, 37), and Panathura north (CSP51) and erosion at Poovar (CSP15), Pulluvila (CSP30), Kovalam (CSP44), Valiyathura (CSP66), and Shangumugham South to Thumba (CSP69-81) for the period from February 2015 – February 2023.

As iterated in the 2018 Annual Report, it can be noted that the study carried out by Thomas (1988) discussed the cyclic trend of erosion and accretion cycle at Valliyathura. This analysis shows that the beach undergoes alternative phases of erosion and accretion, which are utterly dependent on incoming waves concerning seasons and weather events. Periodic long swells with high-energy waves and coastal flooding create beach erosion at these sites. Sanil Kumar et al., 2018 have discussed the increase in the significant wave height on the western shelf seas (~1.2m) compared to the eastern shelf seas (~1.0m) due to the more substantial influence of summer monsoon in the Arabian Sea compared to the Bay of Bengal, in the last decade which plays a vital role in the beach sediment transport.

The breakwater of the Port protrudes about 1.5 kilometres into the sea in line with the existing headlands in the north. Coastal erosion at Valliyathura and Shangumugham beaches, which are 13 km and 15 km away from the north of the Vizhinjam port breakwater, may not have much impact due to the construction of the Port. Recently constructed coastal interventions (Groynes and seawall) on the northern side of the port are required to be assessed for their impact on the shoreline change, including the incidence of cyclones, coastal flooding, high wave activities and storm surges.

References:

1. Annual report on shoreline change analysis using high-resolution satellite images October 2017 to September 2018, National Institute of Ocean Technology 09-April 2019.
2. Annual report on shoreline change analysis using beach profiles and satellite images. October 2018 to September 2019, National Institute of Ocean Technology.
3. Annual report on shoreline change analysis using beach profiles and satellite images. October 2019 to September 2020, National Institute of Ocean Technology.
4. Annual report on shoreline change analysis using beach profiles and satellite images. October 2020 to September 2021, National Institute of Ocean Technology.
5. Annual report on shoreline change analysis using beach profiles and satellite images. October 2021 to September 2022, National Institute of Ocean Technology.
6. Sheela Nair, V. Sundar, and N.P. Kurian 2015., Longshore sediment transport along the coast of Kerala in Southwest India Procedia Engineering, 116 (1): 40-46.
7. Theiler, E.R., Himmelstoss, E.A., Zichichi, J.L., and Ergul, Ayhan, (2017). Digital Shoreline Analysis System (DSAS) version 4.0—An ArcGIS extension for calculating shoreline change (ver. 4.4): U.S. Geological Survey Open-File Report 2008-1278, https://pubs.er.usgs.gov/publication/ofr20081278.
8. Thomas, K.V., (1988). Waves and nearshore processes in relation to beach development at Valliyathura. In: Ocean waves and Beach processes of the Southwest coast of India and their prediction, (Eds: Baba, M, and Kurian, N.P.), NCESS, 47-66.
9. Sanil Kumar V, Jossia Joseph, M.M. Amrutha, B.K. Jena, K.M. Sivakholundu, K.K.Dubhashi., (2018). Seasonal and interannual changes of significant wave height in shelf seas around India during 1998–2012 based on wave hindcast, Ocean Engineering 151, 127-140.