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

ANNUAL REPORT
(October 2021 to September 2022)

FOR

ADANI VIZHINJAM PORT PVT LIMITED

PREPARED BY

Coastal and Environmental Engineering Division

NATIONAL INSTITUTE OF OCEAN TECHNOLOGY

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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

Client	**Client's representative**
Adani Vizhinjam Port Pvt Limited.	**Mr. Hebin, Manager- Environment, AVPPL, Trivandrum**
Project **Shoreline change analysis study using beach profiles and satellite images**	**Project No.NIOT/CEE/1323**

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Executive Summary

This report includes the study on shoreline change assessment along Vizhinjam coast about 40km stretch for the period from October 2021 to September 2022 using high resolution satellite images (less than 1m spatial resolution) and field measured beach profile data.

During October 2021 to September 2022 on the onshore part using beach profile analysis, 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 Pulluvila to Poovar (CSP 17-29) and Thumba to Shangumugam (CSP 69-72).

Beach profile analysis has not been carried out for offshore part during October 2021 and only few locations were surveyed during November 2021 and January 2022 due to bad weather. Hence, the analysis for the March 2022 has been included in this report for the offshore part during this period.

The overall shoreline changes using satellite images for 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) for the period October 2021 to September 2022.

The high resolution satellite images (less than 1m) has been used for the pre and post port shoreline change analysis from February 2011 to March 2022 and the results has been provided in this annual report.

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). These reports are submitted by Vizhinjam International Seaport Limited (VISL) for vetting by NGT appointed expert committee and shoreline monitoring cell. After incorporating the comments received from both the committees, NIOT had submitted the final study reports and the same is forwarded by VISL to Member Secretary, NGT appointed expert committee and also uploaded to Kerala Coastal Zone Management Authority (KCZMA) website.

Subsequently, with reference to the mail dated 13/04/2022, NIOT has received the work order (SO No. 5702005927 dated 12/04/2022) to carry out the study on shoreline change analysis using beach profiles and high resolution satellite images for the year October 2021 to September 2022. Accordingly, NIOT procured the high resolution satellite data (10km on either side of Vizhinjam port) through National Remote Sensing Centre (NRSC)and obtain field measured data sets (beach profile) from AVPPL to study the shoreline changes analysis for 40 km stretch along Vizhinjam coast.

This report consists of the study on shoreline change analysis carried out over 40 km stretch keeping Vizhinjam Port as center, using available satellite images and beach profile data for the period from October 2021 to September 2022.

2 OBJECTIVES

i) To assess the shoreline change over the 20 km coastline on either side Vizhinjam port using satellite images and beach profile data for the year October2021 to September2022.

ii) To identify the erosion and accretion hotspots using available moderate and high resolution multi spectral images acquired by remote sensing satellites and Field measured beach profile data for the year October 2021 to September2022.

3 METHODOLOGY & DATA USED

The methodology flowchart is shown in **Figure 3.1**. The shoreline change analysis has been carried out using satellite images to estimate the rate of change in terms of distance eroded or accreted and the rate of change estimated using cross shore profile in terms of area and volume. From the satellite images, the shoreline has been extracted after rectification and co-registration. The shoreline change rate from October 2021 to September 2022 has been analysed, and the trend has been compared with beach profile data. Digital shoreline change analysis system (DSAS) is a software application that works within the Geographic Information System (ArcGIS) software. DSAS computes rate-of-change statistics for a time series of shoreline vector data. It is also useful for computing rates of change for other boundary change conditions that incorporate a clearly-identified feature position at discrete times.

Similarly, the beach profile data perpendicular to the shoreline for 40 km stretch at intervals of 500m, using RTK or total station landward up to 100m distance from HTL or +2m elevation w.r.t. HTL and using shallow-draft boats, sled or any other suitable techniques seaward down to 10m CD collected monthly (4 CSP lines (CSP-02 (Edapadu Beach), CSP-35 (Azhimala), CSP-64 (Valliyathura) and CSP-74 (Vettucaud)) carried out unto 20m in the months of October 2020, January 2020, May 2020 and August 2020 as per Shoreline Monitoring Cell MoM dated 13th February 2019). The shoreline change analysis using beach profile data has been carried out using SANDS software/MATLAB. The detailed methodology of the shoreline change analysis using satellite images and beach profile analysis has been provided in this report.

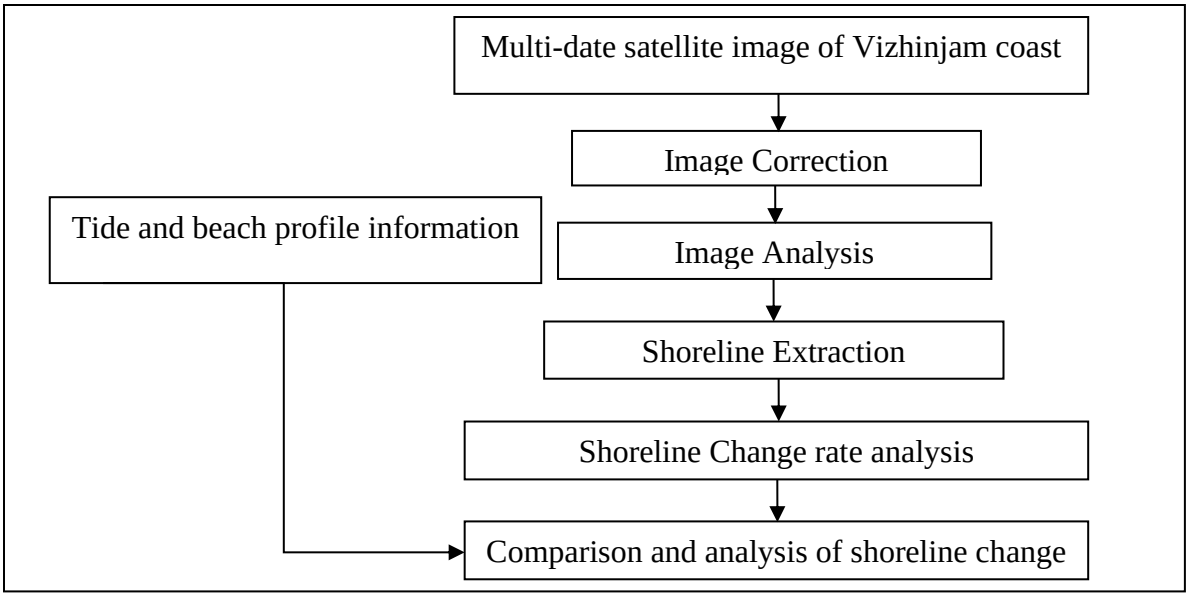


Figure 3.1Flowchart of the methodology adopted

3.1 Shoreline change analysis from Satellite images

3.1.1 Short Term Shoreline change analysis

The end point rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline (**Figure3.2**). The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. The major disadvantage is that in cases where more data are available, the additional information is ignored.

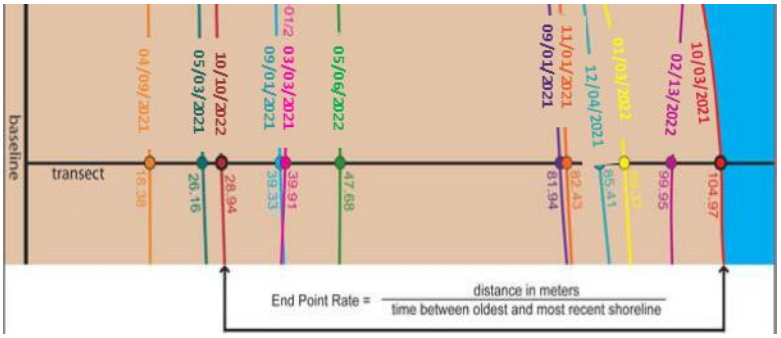


Figure 3.2Calculation of Short Term Shoreline change analysis

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 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. However, the linear regression method is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics.

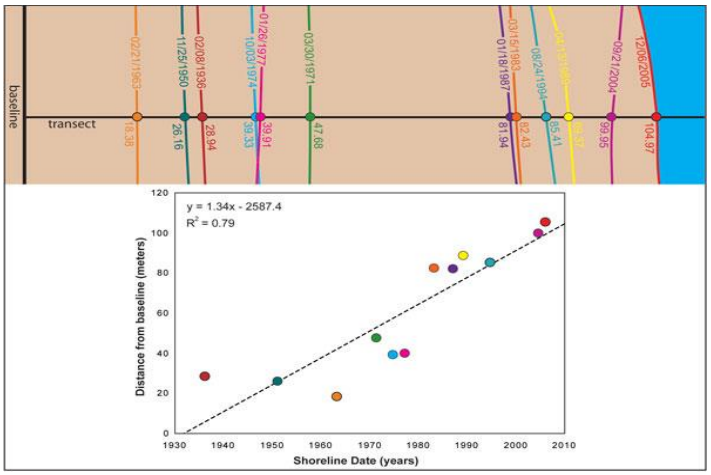


Figure 3.3Calculation of Long Term (LRR) Shoreline change analysis (Sample image source: Thieler et al., 2017)

3.1.3 Satellite images used

The input high resolution satellite images (Table 3.1)10km on either side of Vizhinjam Port have been procured the vendors listed by NRSC to study monthly change in shoreline from October 2021 to September 2022. The high resolution satellite images that are available for the study area have been procured from 2011 to 2022 (yearly changes) and analysis of the same will be included in the subsequent report.

Table 3.1Availablesatellite image data used for shoreline change analysis

Satellite	Date	Sensor Bands	Resolution (m)
World View-2	24-01-2012	RGBNIR	0.5
	18-02-2013		
	14-02-2014		
	26-02-2015		
	26-01-2016		
	27-01-2017		
	26-11-2018		
	29-08-2019		
	08-11-2020		
	24-10-2021		
	05-11-2021		
	19-12-2021		
	19-01-2022		
	14-03-2022		
Cartosat 2	12-02-2011	PAN	1
	30-01-2021		
Resourcesat 2	03-09-2021	LISS4	5
Sentinel 2	25-10-2020	MSI	10
	08-04-2021		
	25-10-2021		
	04-11-2021		
	19-12-2021		
	18-01-2022		
	22-02-2022		
	14-03-2022		
	18-04-2022		
	03-05-2022		
	27-06-2022		
	27-07-2022		
	16-08-2022		
	25-09-2022		

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 every month at 81 profile lines along a stretch of 40 km covering the area of approximately 20 km south and 20 km north of the proposed Vizhinjam port (Since February 2015 to till date). 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. However, due to rough sea condition along the Vizhinjam coast and agitation, only onshore survey was carried out and the offshore part of the cross-shore profiling carried out for the months of February and March 2022. Hence these data have not been considered for the overall beach volume change analysis.

Figure 3.4Beach Profiles lines

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)) to be carried out up to a depth of 20 m in the month

of January, May, August and October as per shoreline committee suggestion vide MoM of meeting dated 13th February 2019). These data sets are combined, processed and transferred to NIOT for analysis by the surveying agency.

Table 3.2 Landmark, places names and site condition around each CSP lines

CSP NOs.		LAND MARK	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 PORT	VIZHINJAM LIGHT HOUSE	KOVALAM	Beach
CSP-42				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 was analyzed by plotting each profile and using SANDS. The aim of this exercise was 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 future. The difference, if any, shall be investigated further to understand impact due to the port on the shoreline evolution. Profiles for different months were plotted location wise.

It is accepted that beach profiles can only be of real use when surveys are taken over a period of time starting at exactly the same place and moving in exactly the same direction (the Origin and Orientation of the profile). SANDS software stores the beach profile surveys, to view them graphically and to analyse them to identify trends in beach levels at a location over time. The 'Beach Profile Graph' feature allows the user to graph and compares beach profiles from different/multiple locations.

It was observed during the analysis of cross shore profiles that some of the profiles appeared distorted, possibly due to some errors during the survey. These profiles are either discarded or manually corrected in respect of the earlier profiles. The profiles corresponding to the Vizhinjam Port area is completely discarded and mentioned as a development zone.

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

Figure 3.5Work Flow in SANDS

3.2 Analyzing Beach Profiles in SANDS

SANDS allow for any number of beach profiles survey records to be stored at each profile location over a period. This database has been used for determining the stability and long term trends in beach levels. 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' method 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.

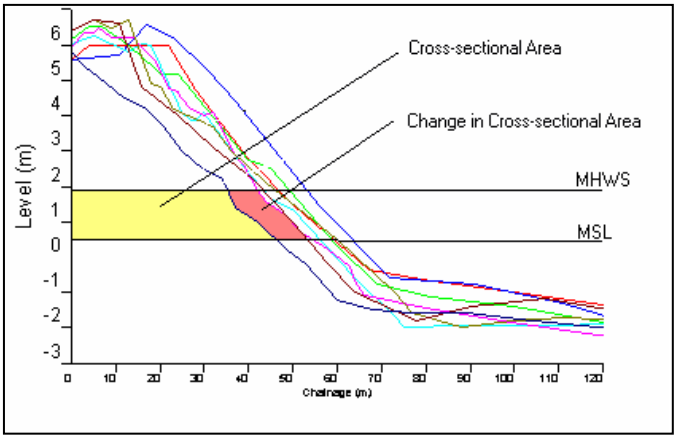


Figure 3.6Profile Analysis by Level

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**).

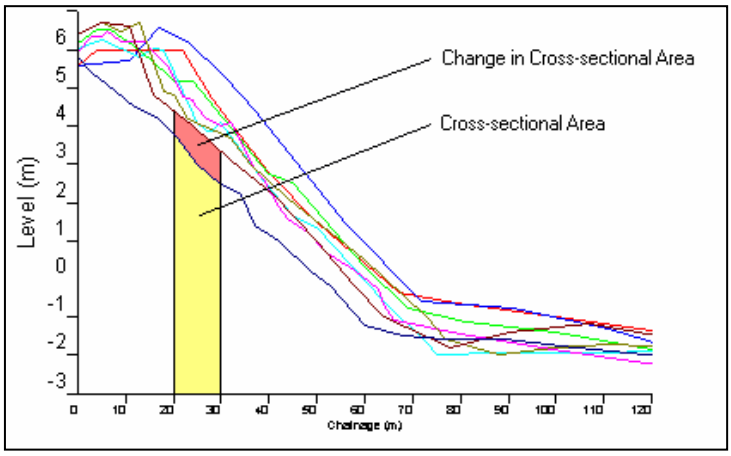


Figure 3.7Profile Analysis by Chainage

Based on the above methods SANDS calculate the profile changes and then it calculates volumes of pre-defined areas. It also enables to group together all beach profile locations and analyze the volumes of these units. SANDS calculate the Profile Accretion / Erosion through a direct comparison between profiles over the period of comparison and allow the results to be displayed within a GIS-style plan-view format to give striking visual results.

4 RESULTS AND ANALYSIS

In the present study, the shoreline rate of change statistics from time series of multiple shoreline positions of 40 km coastal stretch (20 km either side of Vizhinjam Port) has been taken in to account for shoreline calculation using satellite images. The result from the shoreline change analysis carried out for October 2021 to September 2022 has been analysed.

Based on the rate of change over the period, shoreline change has been categorized into 5 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 has been presented as monthly changes in the beach volume for a period from October 2021 to September 2022 and beach volume changes between October 2020-October 2021, February 2021- February 2022, April 2021-April 2022 and September 2021-September 2022 also have been worked out and presented in this report. Monthly beach volume changes have been assessed by comparing month to month profiles in **Section 4.1**. The erosion and accretion are highlighted with red and green color fill in the charts for better understanding. The results shown in the charts are also presented in the tables.

4.1 Results from Beach Profile Analysis

The beach profile data consist of both foreshore and offshore profiles. No offshore survey carried out for October 2021, April 2022 to September 2022 and few locations on the offshore were surveyed in November 2021 and January 2022 due to unfavourable weather conditions. Hence monthly beach volume changes have been assessed by comparing month to month profiles only for onshore part for all months from October 2021 to September 2022 and only for March 2022 on offshore part.

4.1.1 Monthly Beach Volume variations for October 2021 to September 2022 for onshore part

This report contains the monthly beach volume changes during October 2021 to September 2022 and have been represented graphically in **Figures 4.1 to 4.12** and in **Table 4.1.**

During October 2021, the beach was showing accretion at Poovar South (CSP15), Karumkulam (CSP24 & CSP26), Pulluvila (CSP28-30), Adimalathura to Mullur (CSP34-36), Kovalam (CSP43), Punthura (CSP53), Kochuveli (CSP76) and Valliyaveli (CSP78). Erosion found at Edapadu Beach (CSP02), Poovar South to Karumkulam (CSP16-23), Karumkulam (CSP25), Pulluvila (CSP27), Adimalathura (CSP31-33), Mullur (CSP37), Kovalam (CSP44), Pannathura North (CSP51-52), Valliyathura (CSP66), Shangumugam South to Kochuveli (CSP69-75), Kochuveli (CSP77), Thumba (CSP80-81). No onshore survey carried out at location CSP41 during October 2021 as this spot was not accessible by foot and CSP42 was found erroneous. Hence these locations were excluded from the analysis.

In November 2021, the locations Edapadu Beach (CSP02), Poovar South to Pulluvila (CSP15-29), Adimalathura to Azhimala (CSP31-35), Kovalam (CSP44), Pannathura North to Punthura (CSP52-53), Valliyathura (CSP66), Shangumugam South (CSP69), Shangumugam North to Kochuveli (CSP71-77) and Thumba (CSP80-81) shown accretion. Erosion noted at Pulluvila (CSP30), Mullur (CSP36-37), Kovalam (CSP43), Pannathura North (CSP51), Shangumugam North (CSP70) and Valliyaveli (CSP78). No onshore survey carried out at location CSP41 during October 2021 as this spot was not accessible by foot and CSP42 was found erroneous due to data gap in the profile measurement. Hence these locations were excluded from the analysis for November 2021.

In December 2021, accretion found at Edapadu beach (CSP02), Poovar South to Poovar North (CSP15-21), Karumkulam (CSP23-25), Pulluvila to Adimalathura (CSP29-32), Adimalathura to Mullur (CSP34-37), Kovalam (CSP43-44), Shangumugam North (CSP70), Kochuveli (CSP76), Valliyaveli (CSP78) and Thumba (CSP81). Erosion found at Karumkulam (CSP22), Karumkulam to Pulluvila (CSP26-28), Adimalathura (CSP33), Kovalam (CSP41), Pannathura North to Punthura (CSP51-53), Valliyathura (CSP66), Shangumugam South (CSP69), Shangumugam North to Vettucaud (CSP71-72), Vettucaud to Kochuveli (CSP74-75), Kochuveli (CSP77) and Thumba (CSP80). Profile found erroneous at location CSP42 and CSP73.

During January 2022, accretion found at most of the locations except at Poovar South (CSP16), Pulluvila (CSP28-29), Valliyathura (CSP66), Valliyaveli (CSP78).

In February 2022, erosion noted at Poovar South (CSP16), Poovar (CSP18), Karumkulam (CSP23), Mullur (CSP37), Kovalam (CSP43), Pannathura north to Punthura (CSP51-53), Shangumugam North (CSP71), Vettucaud to Kochuveli (CSP74-75), Kochuveli (CSP77) and Thumba (CSP81). Accretion exhibited at Edapadu beach (CSP02), Poovar south (CSP15 & CSP17), Poovar to Karumkulam (CSP19-22), Karumkulam to Mullur (CSP24-36), Kovalam (CSP41& CSP44), Valliyathura (CSP66), Shangumugam North (CSP70), Vettucaud (CSP72-73), Kochuveli (CSP76), Valliyaveli (CSP78) and Thumba (CSP80).

During March 2022, at locations Edapadu beach (CSP02), Poovar South (CSP15&17), Poovar to Poovar North (CSP19-21), Karumkulam to Pulluvila (CSP23-29), Adimalathura to Mullur (CSP 31-36), Kovalam (CSP43-44), Pannathura North to Punthura (CSP51-53), Valliyathura (CSP66), Shangumugam North to Vettucaud (CSP70-72), Kochuveli (CSP75) and Thumba (CSP80) beach found eroded. Beach shown accretion at Poovar South (CSP16), Poovar (CSP18), Karumkulam (CSP22), Pulluvila (CSP30), Mullur (CSP37), Kovalam (CSP41), Shangumugam South (CSP69), Vettucaud (CSP73-74), Kochuveli to Valliyaveli (CSP76-78) and Thumba (CSP81).

During April 2022, erosion occurred at Poovar (CSP16), Karumkulam (CSP22), Pulluvila (CSP28-30), Mullur (CSP36-37), Kovalam (CSP41), Punthura (CSP53), Shangumugham (CSP70-71), Kochuveli (CSP77) and other locations indicates accretion.

In May 2022, most of the locations indicates accretion such as Poovar (CSP16), Punthura (CSP53), Shangumugham (CSP71) while erosion is noticed at Poovar (CSP17), Karumkulam

(CSP25), Pulluvila (CSP30), Adimalathura (CSP33), Mullur (CSP36-37), Kovalam (CSP42-43), Panathura (CSP52) and Shangumugham (CSP69).

In June 2022, the beach volume change indicates accretion trend except for the locations Poovar beach (CSP17), Pulluvila (CSP29), Adimalathura (CSP31-32), Mullur (CSP37) Punthura (CSP51) and Shangumugham (CSP71) exhibits erosion.

During July 2022, most of the locations indicates erosion such as Edapadu beach (CSP2), Poovar to Pulluvila (CSP15-28), Adimalathura (CSP30,32-34), Kovalam (CSP43), Punthura (CSP53), Valliyathura (CSP66), Shangumugham North to Vettucaud (CSP70-74), Kochuveli to Thumba (CSP77-81) while accretion is noticed at Pulluvila (CSP29), Adimalathura (CSP31), Kovalam (CSP42), Shangumugham south (CSP69) and Kochuveli (CSP75-76).

During August 2022, accretion is noticed at Edapadu beach (CSP2), Poovar beach (CSP15-19), Shangumugham north (CSP70-71), Vettucaud (CSP73), Kochuveli (CSP77) and erosion is noticed at Poovar to Pulluvila (CSP20-28), Kovalam (CSP44), Panathura (CSP51-52), Valliyathura (CSP66), Shangumugham south (CSP69), Kochuveli (CSP74-76) and Thumba (CSP80-81).

During September 2022, accretion is noticed at Edapadu beach (CSP2), Poovar to Karumkulam (CSP16-22), Shangumugham North (CSP71), Kochuveli to Thumba (CSP75-81) and erosion is noticed at Poovar beach (CSP15), Kovalam (CSP42), Panathura (CSP51), Shangumugham south (CSP69) and Vettucaud (CSP73).

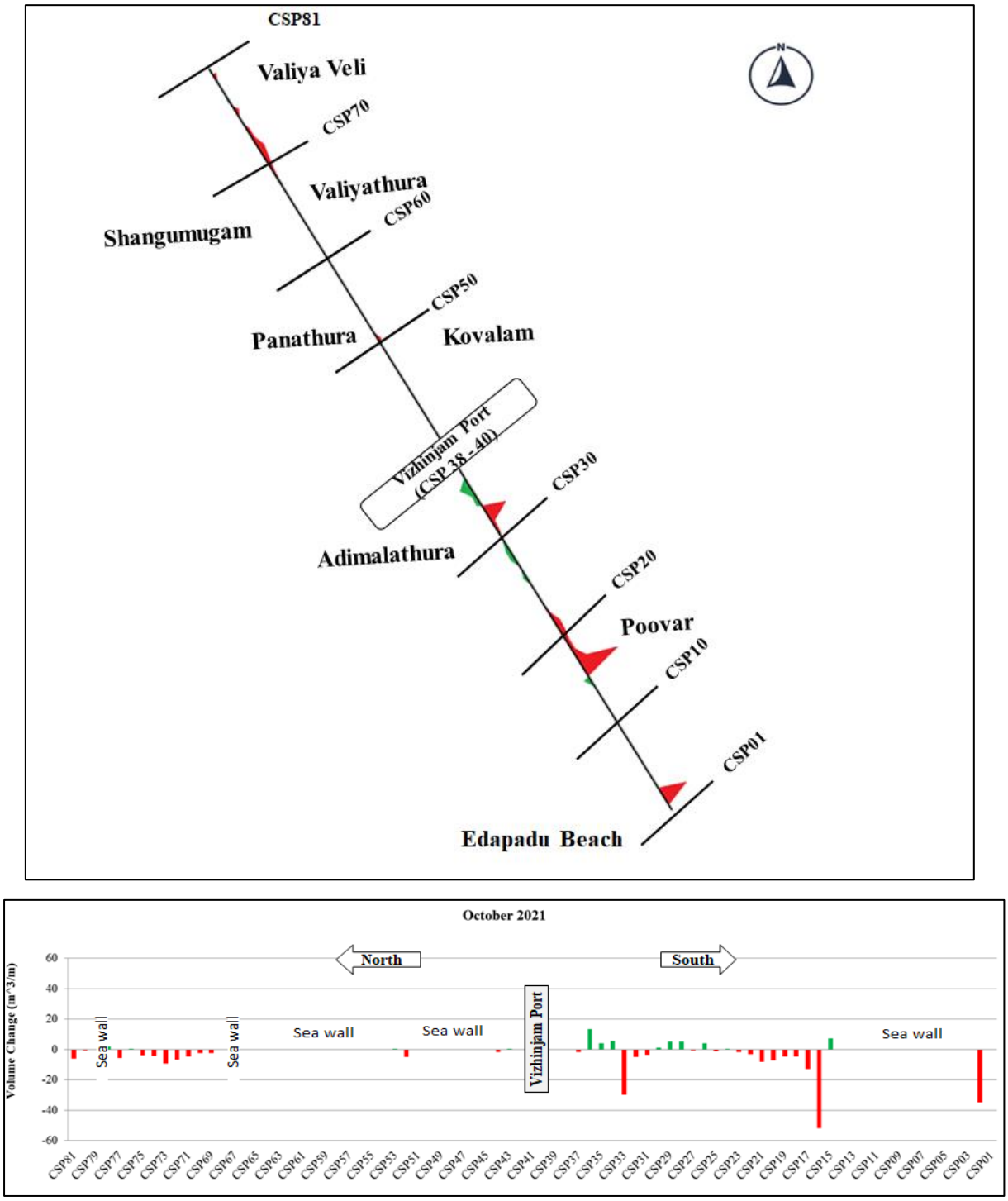
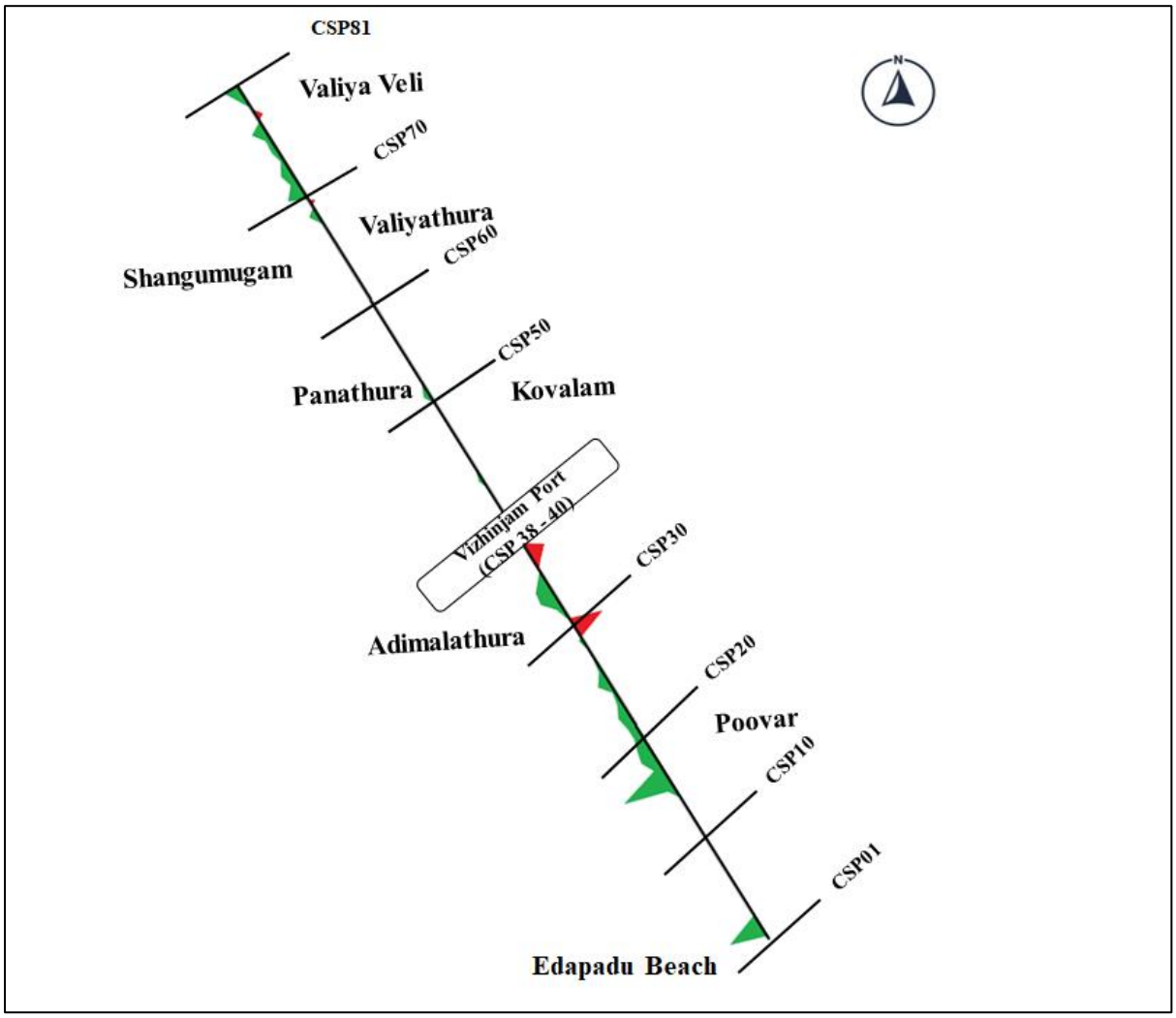


Figure 4.1Monthly Beach Volume Changes in October 2021 in m^3/m (onshore)



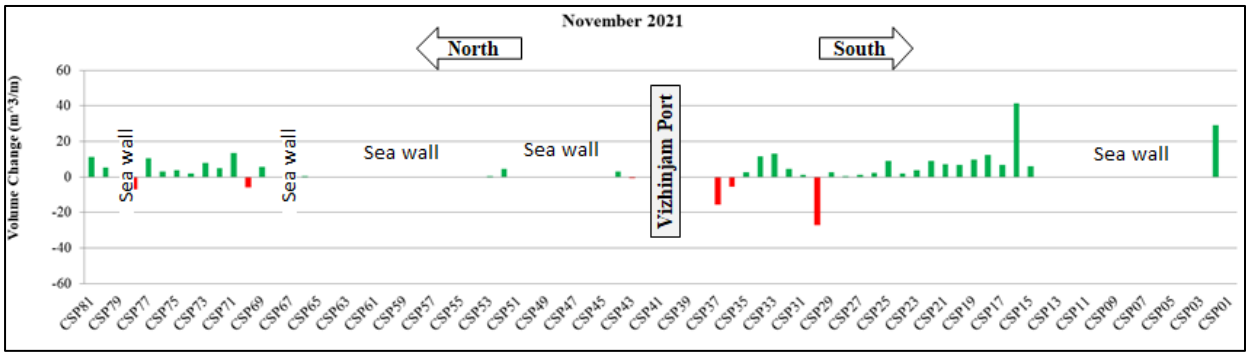
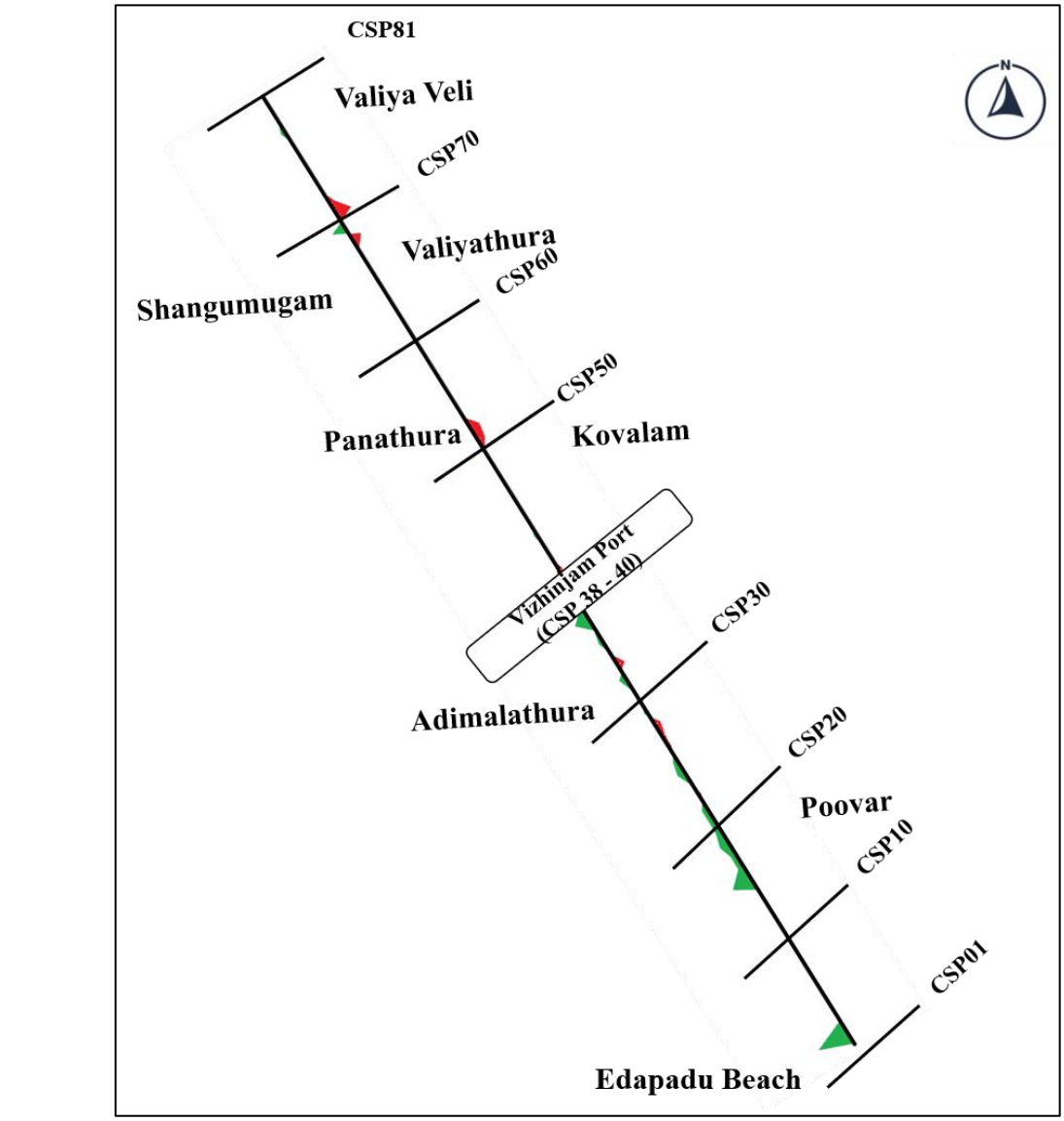


Figure 4.2Monthly Beach Volume Changes in November 2021 in m^3/m (onshore)



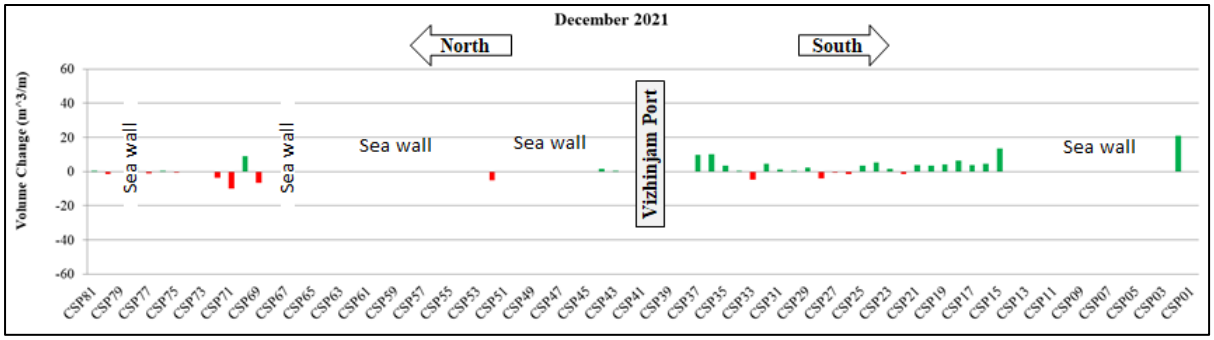


Figure 4.3Monthly Beach Volume Changes in December 2021 in m^3/m (onshore)

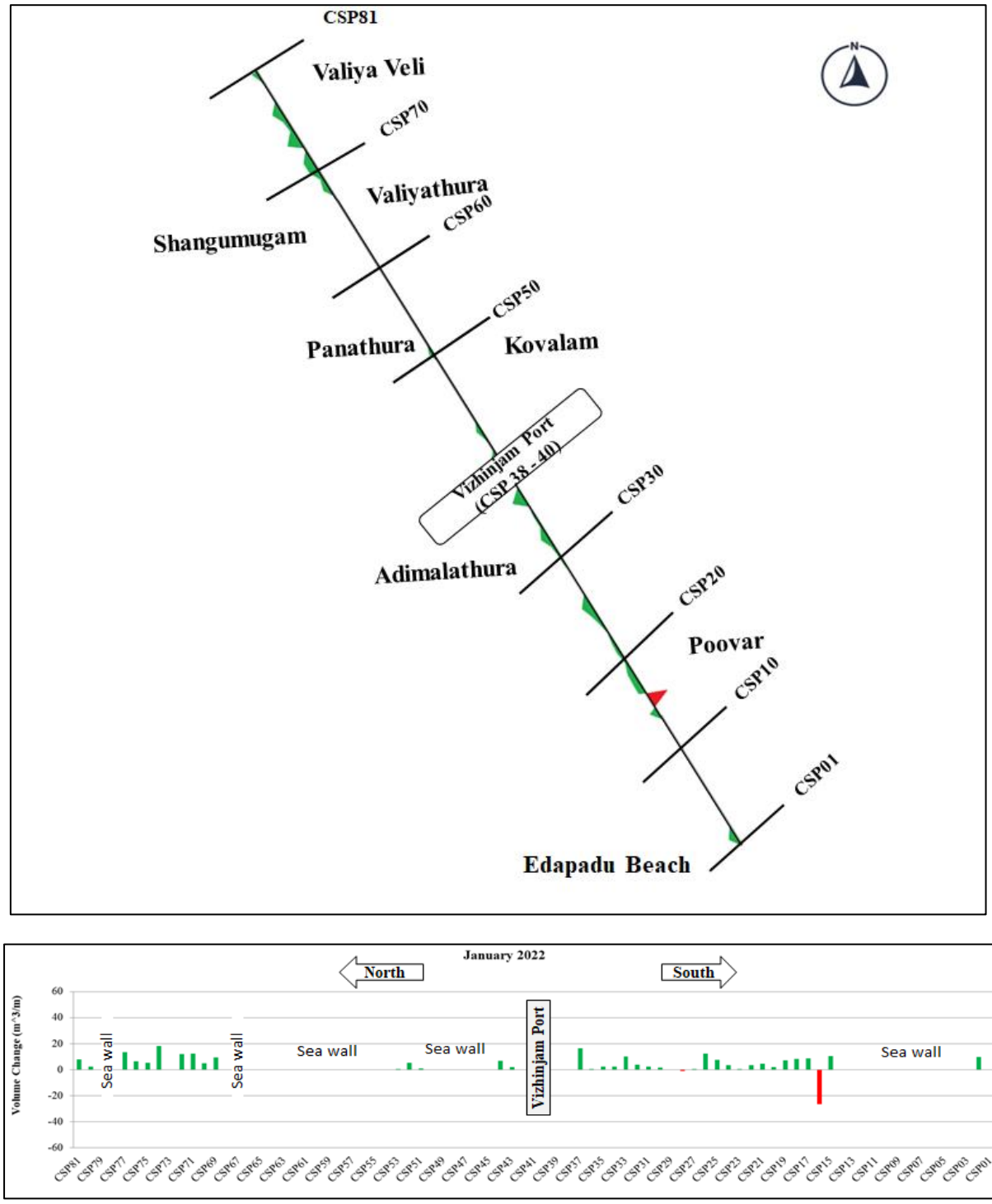
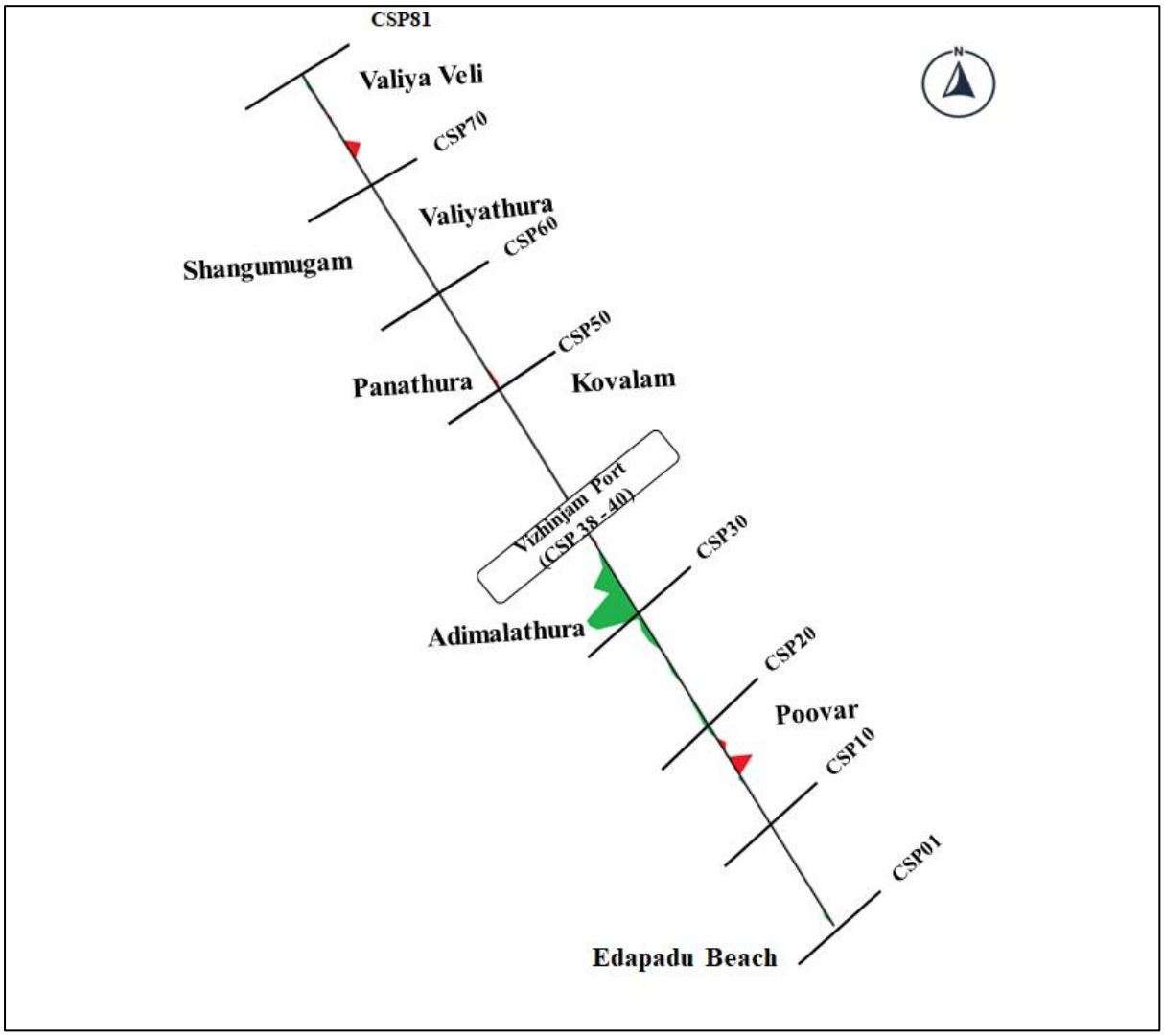


Figure 4.4Monthly Beach Volume Changes in January 2022 in m^3/m (onshore)



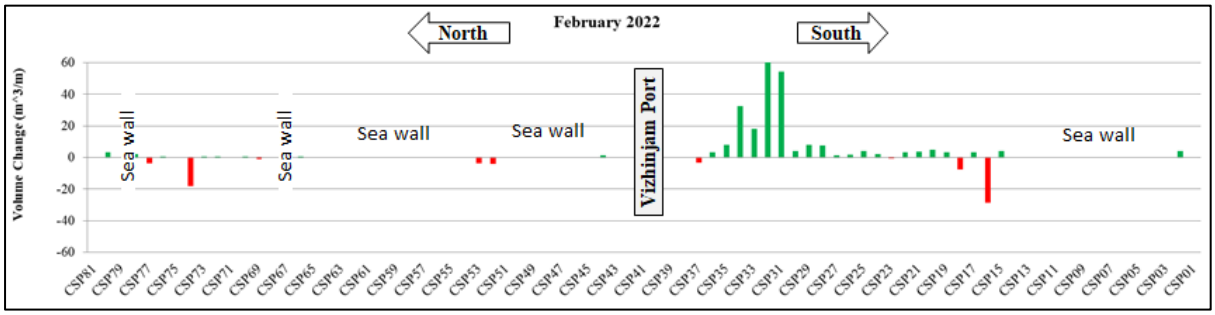
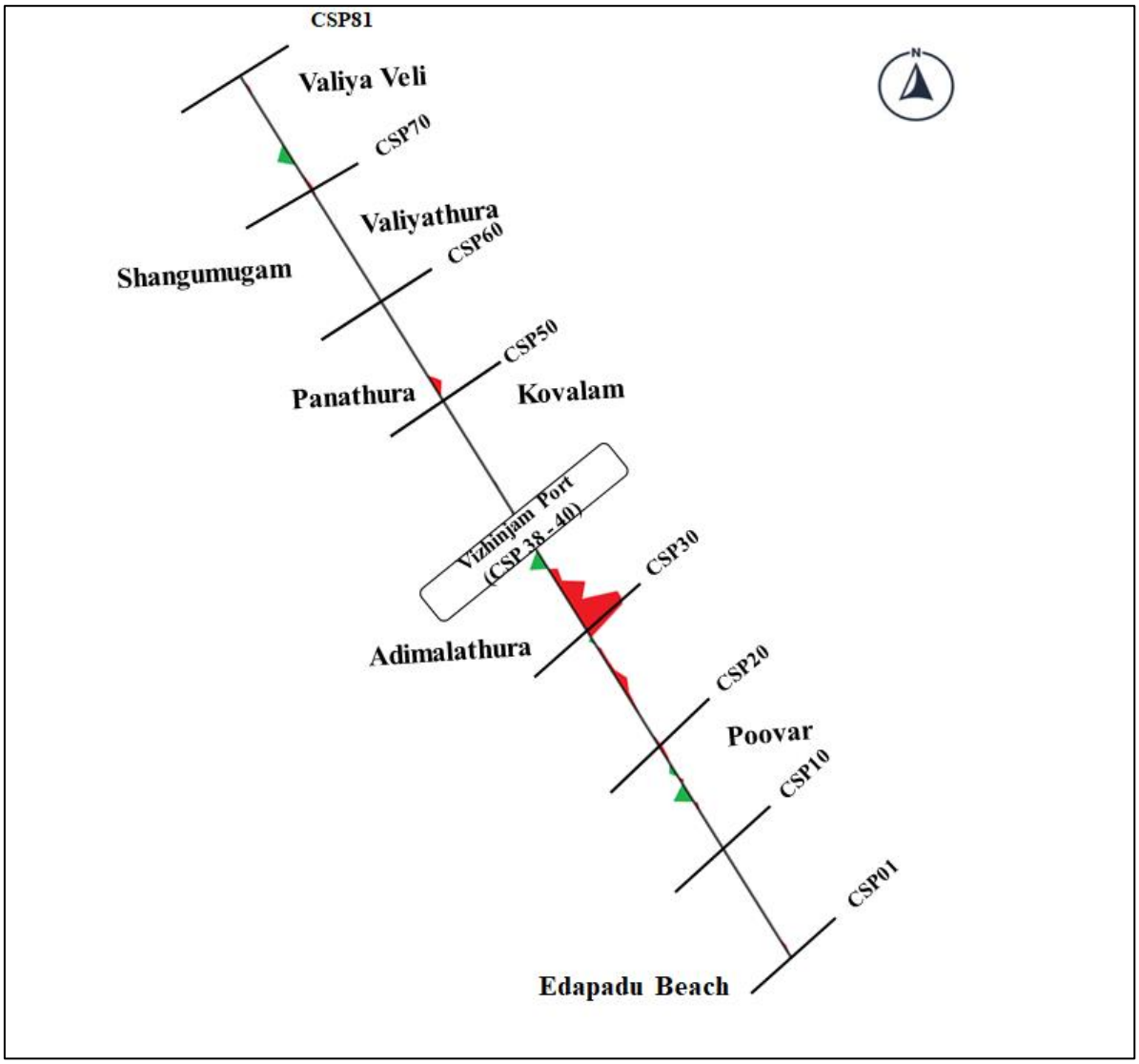


Figure 4.5Monthly Beach Volume Changes in February 2022 in m^3/m (onshore)



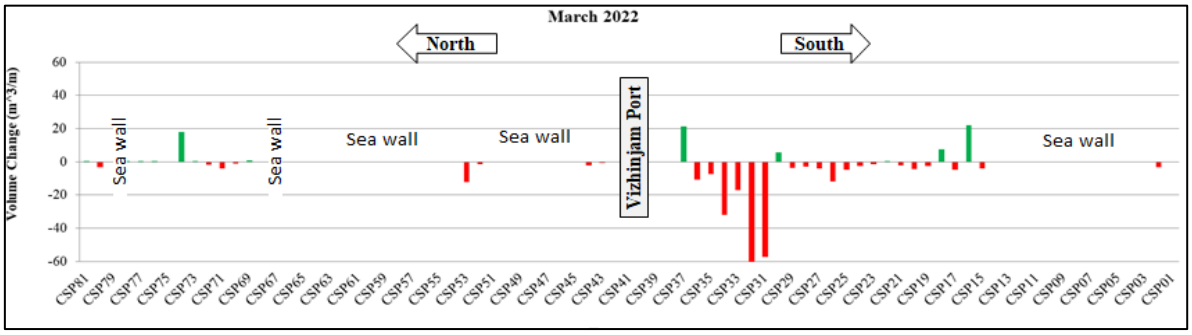


Figure 4.6Monthly Beach Volume Changes in March 2022 in m^3/m (onshore)

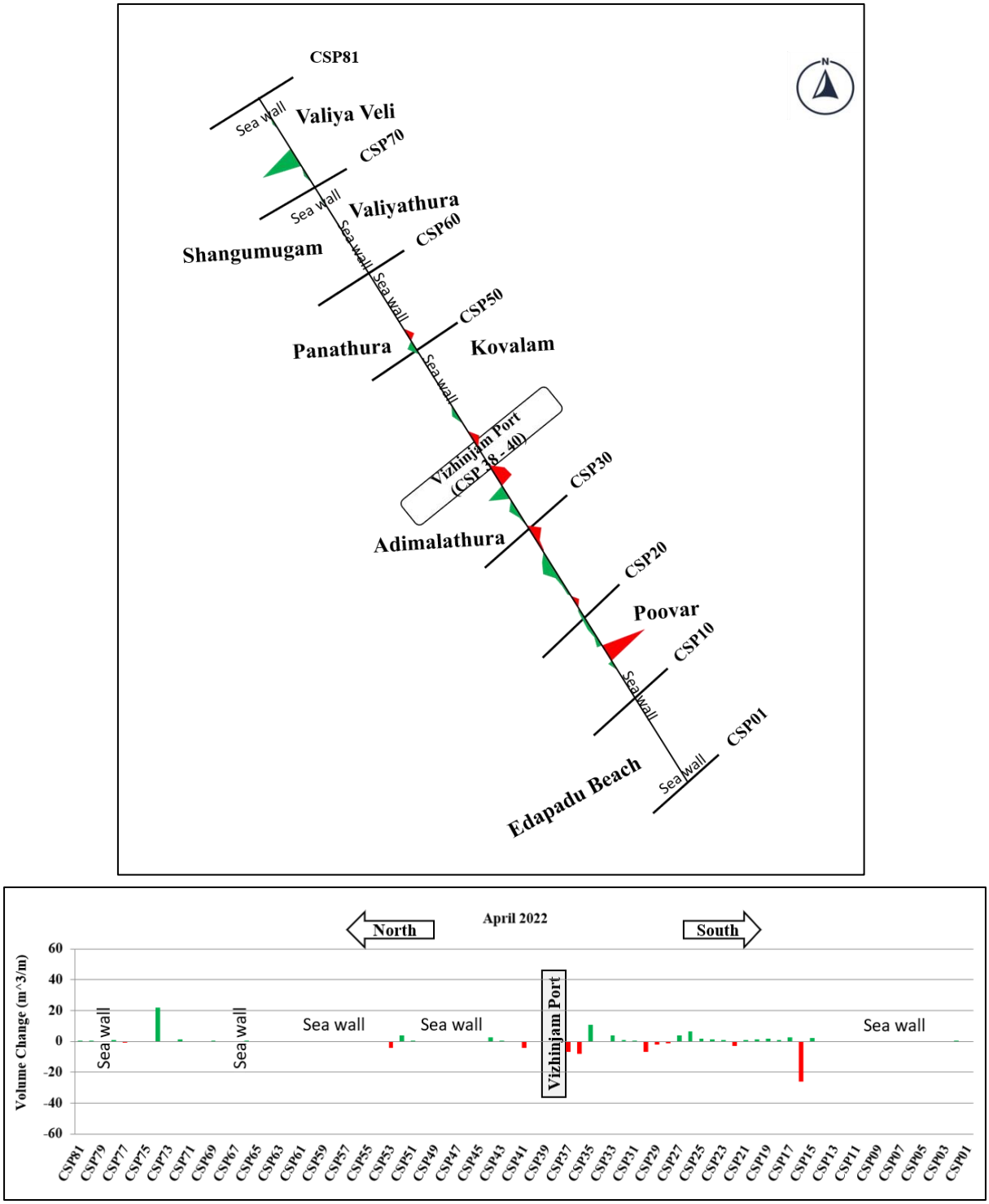
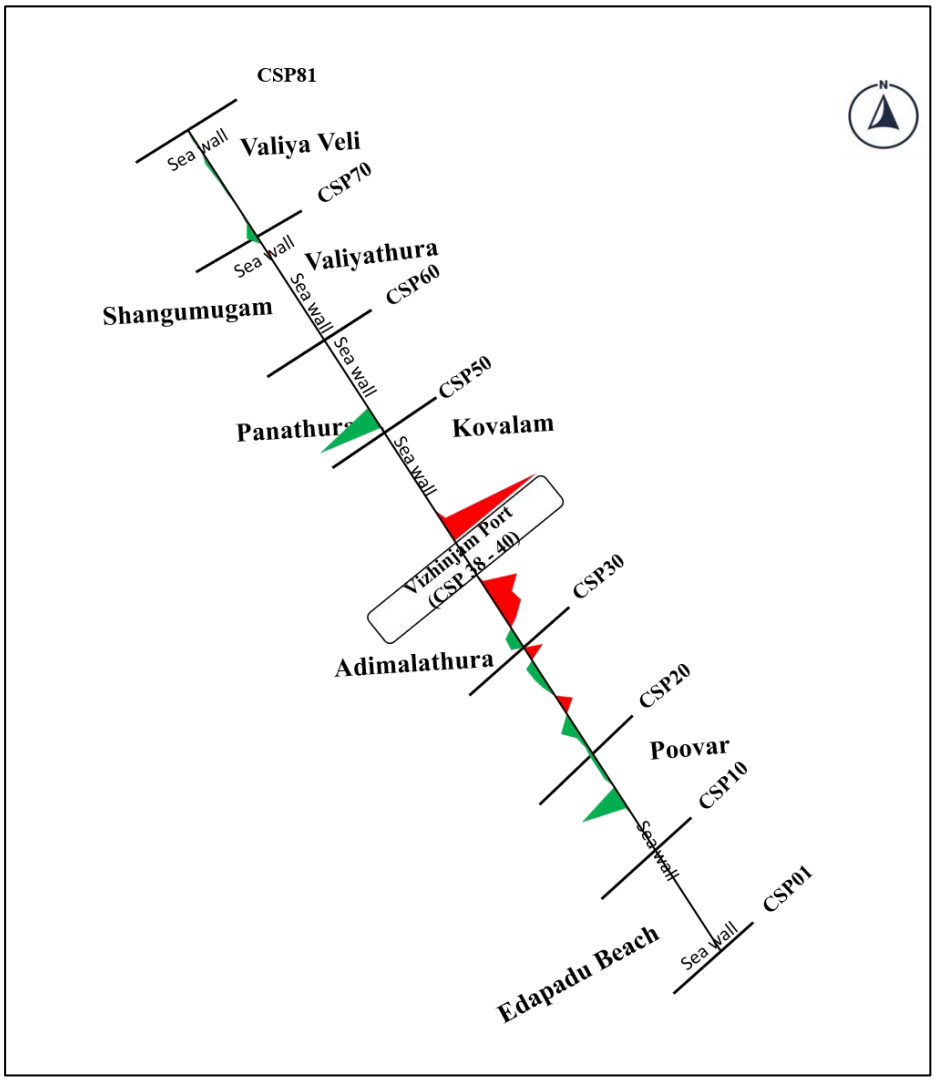


Figure 4.7Monthly Beach Volume Changes in April 2022 in m^3/m (onshore)



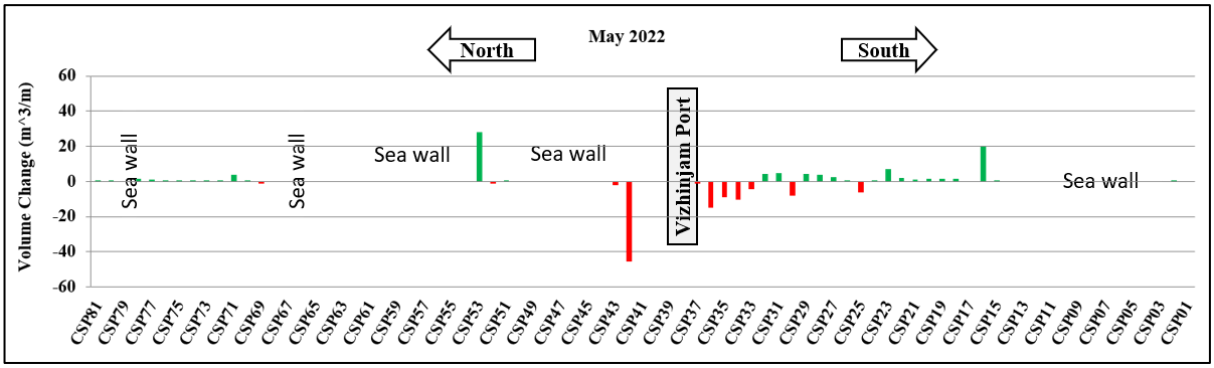
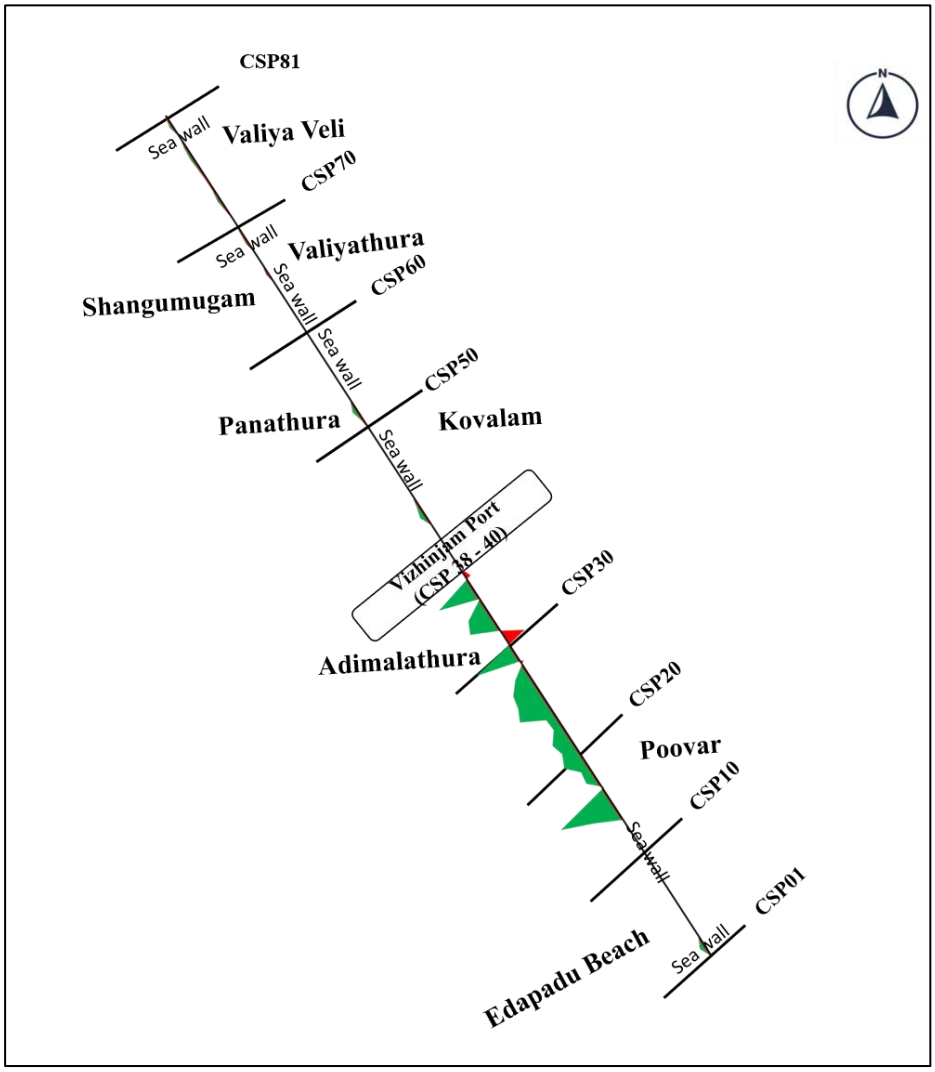


Figure 4.8Monthly Beach Volume Changes in May 2022 in m^3/m (onshore)



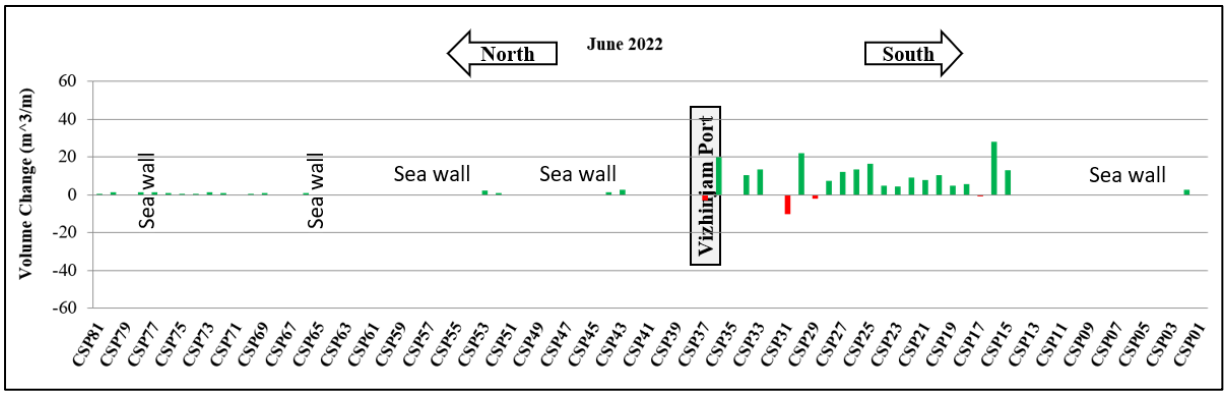
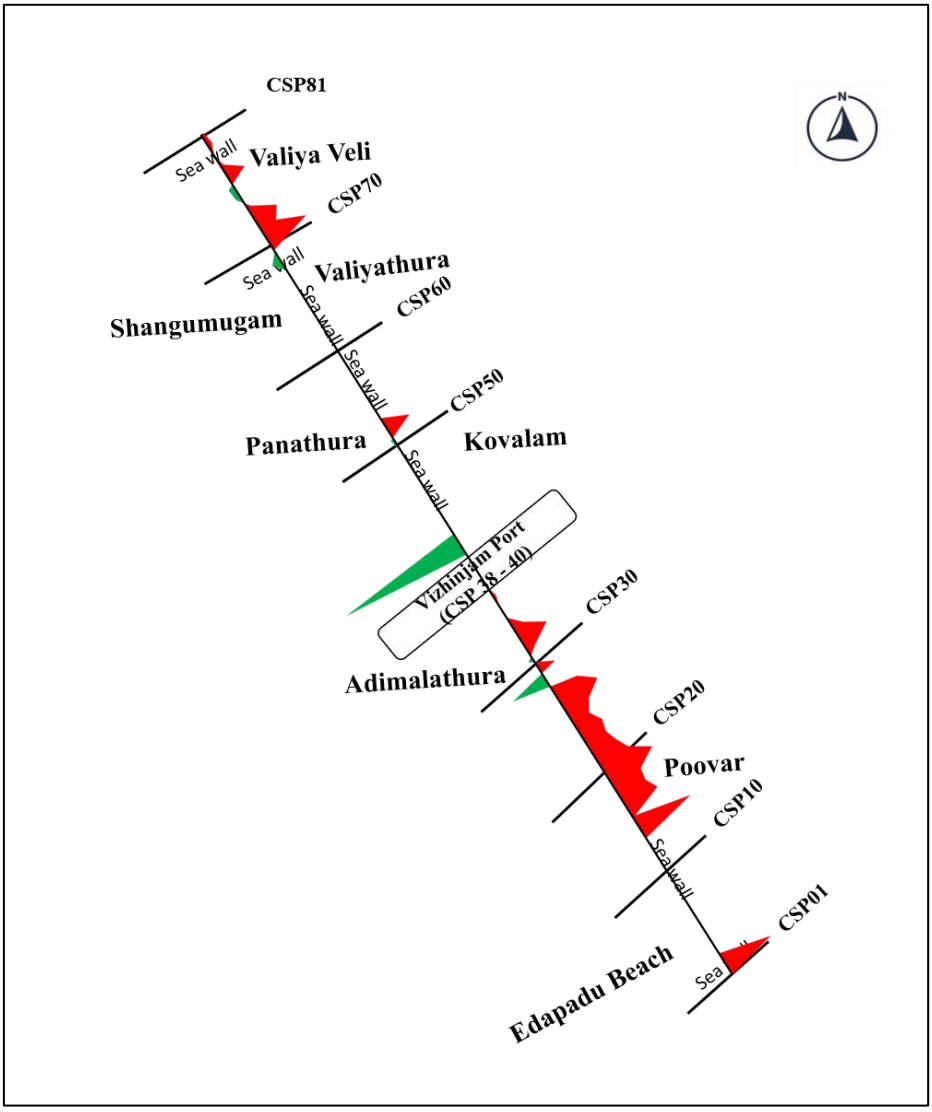


Figure 4.9Monthly Beach Volume Changes in June 2022 in m^3/m (onshore)



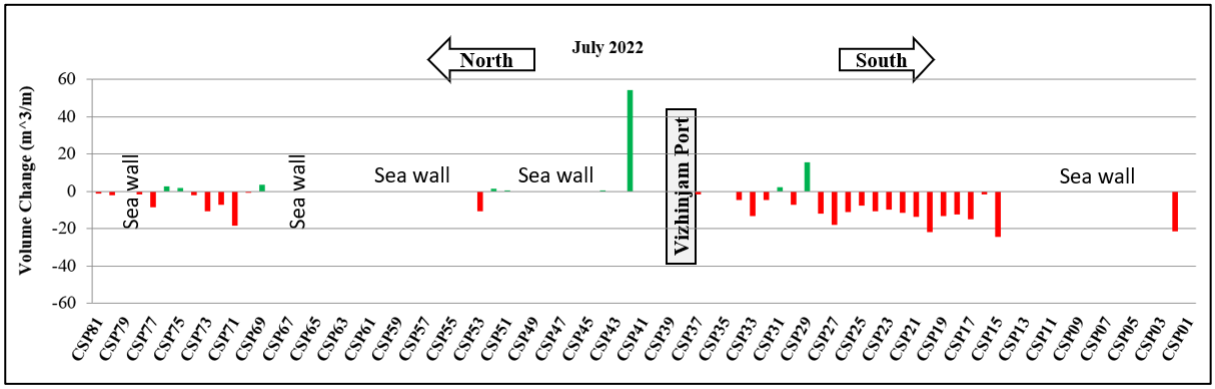


Figure 4.10Monthly Beach Volume Changes in July 2022 in m^3/m (onshore)

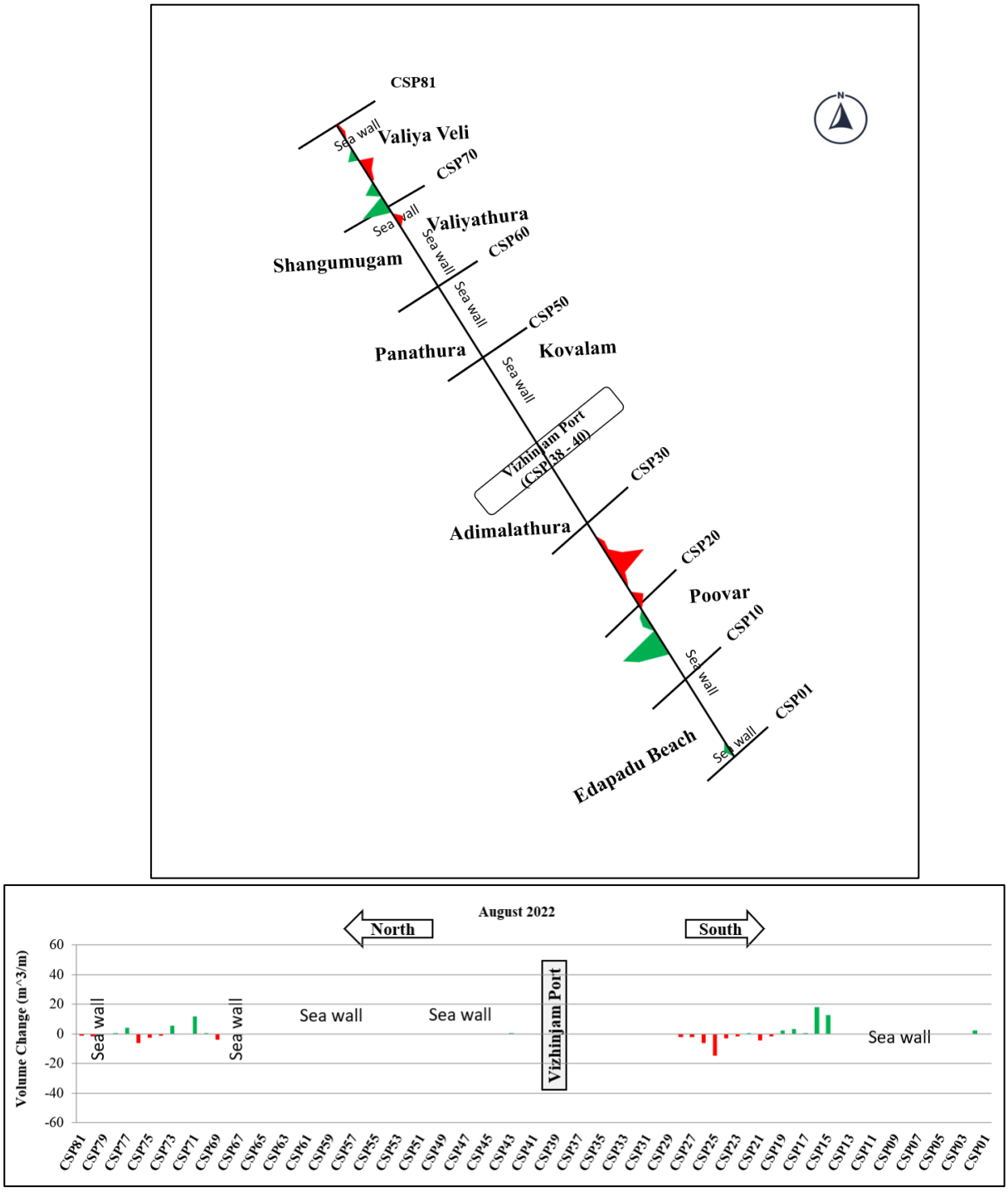


Figure 4.11Monthly Beach Volume Changes in August 2022 in m^3/m (onshore)

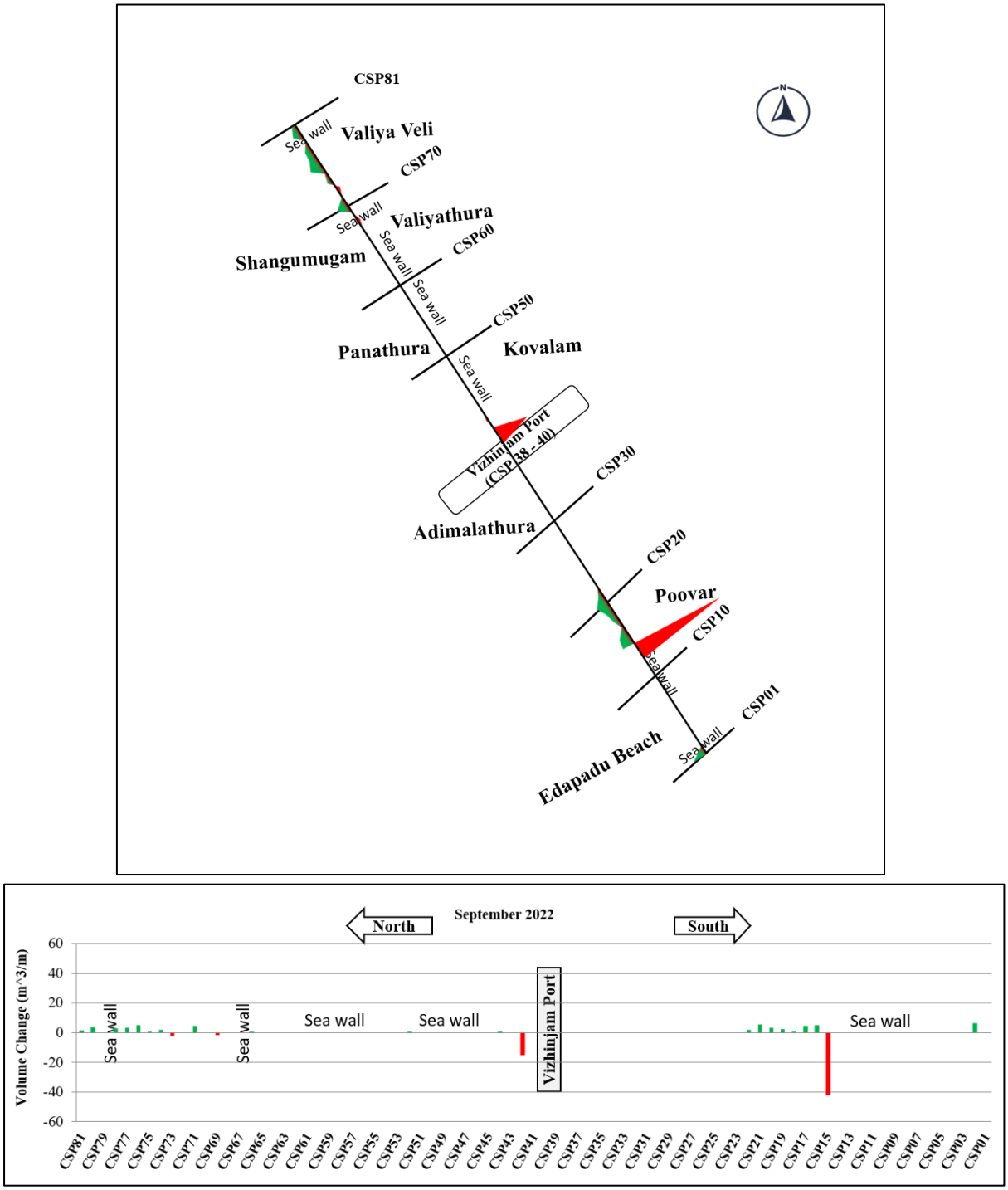


Figure 4.12Monthly Beach Volume Changes in September 2022 in m^3/m (onshore)

Table 4.1Monthly Beach Volume Changes during October 2021 to September 2022in m^3/m (onshore)

CSP NOs.	Oct 2021	Nov2021	Dec 2021	Jan 2022	Feb 2022	Mar 2022	April 2022	May 2022	June 2022	July 2022	Aug 2022	Sept 2022
CSP01	**Sea wall**											
CSP02	-34.89	29.26	21.09	9.60	4.20	-3.20	0.09	0.12	2.73	-21.50	2.49	6.45
CSP03	**Sea wall**											
CSP04												
CSP05												
CSP06												
CSP07												
CSP08												
CSP09												
CSP10												
CSP11												
CSP12												
CSP13												
CSP14												
CSP15	7.43	6.00	13.58	10.54	4.13	-4.17	2.21	0.80	12.84	-24.45	12.54	-42.24
CSP16	-51.65	41.32	4.40	-26.49	-28.62	22.07	-25.91	19.69	28.11	-1.52	18.07	5.14
CSP17	-12.65	6.76	3.87	8.52	3.44	-4.94	2.64	-0.29	-0.92	-14.99	0.35	4.42
CSP18	-4.71	12.29	6.58	8.15	-7.72	7.43	1.07	1.41	5.43	-12.53	3.33	0.44
CSP19	-4.71	9.90	4.14	7.07	3.23	-2.62	1.81	1.47	4.66	-13.25	2.52	2.38
CSP20	-7.14	6.69	3.55	2.05	5.03	-4.31	1.34	1.30	10.27	-22.01	-1.49	3.25
CSP21	-8.26	7.06	3.86	4.61	3.78	-2.27	0.97	1.27	7.61	-13.64	-4.55	5.53
CSP22	-2.93	8.89	-1.33	3.59	3.28	0.52	-3.07	1.83	9.13	-11.36	0.35	1.88
CSP23	-1.78	3.75	1.53	0.57	-0.47	-1.59	1.11	6.80	4.33	-9.76	-1.58	*
CSP24	0.49	1.83	5.21	3.49	2.06	-2.71	1.24	0.50	4.97	-10.71	-2.98	*
CSP25	-0.77	9.18	3.48	7.39	4.02	-4.83	1.79	-6.12	16.19	-7.69	-14.75	*
CSP26	4.23	2.13	-1.30	12.39	1.81	-11.86	6.62	0.27	13.26	-11.03	-5.97	*
CSP27	-0.68	1.06	-0.79	0.24	1.18	-4.07	3.72	2.35	12.14	-18.12	-2.06	*
CSP28	5.12	0.55	-3.94	-1.00	7.59	-3.04	-1.26	3.75	7.20	-11.89	-2.24	*
CSP29	5.08	2.77	2.29	-0.36	8.14	-3.64	-1.91	4.08	-1.92	15.43	*	*
CSP30	1.19	-27.01	0.46	1.69	3.96	5.72	-6.60	-8.07	21.87	-7.40	*	*

CSP31	-3.39	1.19	1.29	2.29	54.16	-57.29	0.07	4.70	-10.29	2.05	*	*
CSP32	-4.92	4.68	4.62	3.64	65.33	-63.97	1.01	4.40	-0.26	-4.49	*	*
CSP33	-29.67	13.06	-4.64	9.94	18.24	-17.07	3.91	-4.44	13.56	-13.15	*	*
CSP34	5.53	11.72	0.37	2.17	32.43	-32.03	-0.44	-10.39	10.40	-4.85	*	*
CSP35	4.26	2.66	3.47	2.44	7.88	-7.21	10.89	-9.11			*	*
CSP36	13.33	-5.38	10.26	0.18	3.32	-10.64	-8.12	-15.04	19.67	-0.24	*	*
CSP37	-1.59	-15.50	9.64	16.36	-3.45	21.34	-6.93	-1.18	-2.87	-1.59	*	*
CSP38	**PORT AREA**											
CSP39												
CSP40												
CSP41	*	*	-2.80	12.21	2.26	3.12	-4.33	*	*	*	*	*
CSP42	*	*	*	*	*	*	*	-45.68	0.00	54.02	*	-15.11
CSP43	0.33	-0.56	0.20	2.14	-0.04	-0.57	0.21	-2.19	2.74	-0.52	0.09	0.00
CSP44	-1.54	2.99	1.63	6.85	1.21	-2.35	2.59	0.00	1.14	0.03	-0.49	0.71
CSP45	**Sea wall**											
CSP46												
CSP47												
CSP48												
CSP49												
CSP50												
CSP51	-0.07	-0.34	-0.26	0.82	-0.28	-0.22	0.25	0.23	-0.32	0.39	-0.01	-0.05
CSP52	-4.83	4.41	-5.15	5.38	-3.94	-1.27	3.94	-1.16	0.72	1.21	-0.13	0.33
CSP53	0.45	0.24	-0.01	0.07	-3.85	-12.41	-4.15	27.83	2.26	-10.72	*	*
CSP54	**Sea wall**											
CSP55												
CSP56												
CSP57												
CSP58												
CSP59												
CSP60												
CSP61												
CSP62												
CSP63												
CSP64												
CSP65												
CSP66	-0.16	0.20	-0.12	-0.39	0.55	-0.41	0.05	-0.41	0.97	-0.40	-0.03	0.16
CSP67	**Sea wall**											
CSP68												
CSP69	-2.31	5.83	-6.78	9.32	-0.84	0.76	0.51	-1.00	1.00	3.47	-3.80	-1.67
CSP70	-2.54	-5.98	8.88	4.88	0.33	-0.96	-0.11	0.29	0.62	-0.80	0.14	-0.37
CSP71	-4.57	13.35	-9.98	12.14	-0.15	-4.13	-0.07	3.88	-0.33	-18.53	11.63	4.78
CSP72	-6.81	5.03	-3.61	11.95	0.56	-1.90	1.39	0.55	0.79	-7.32	*	*

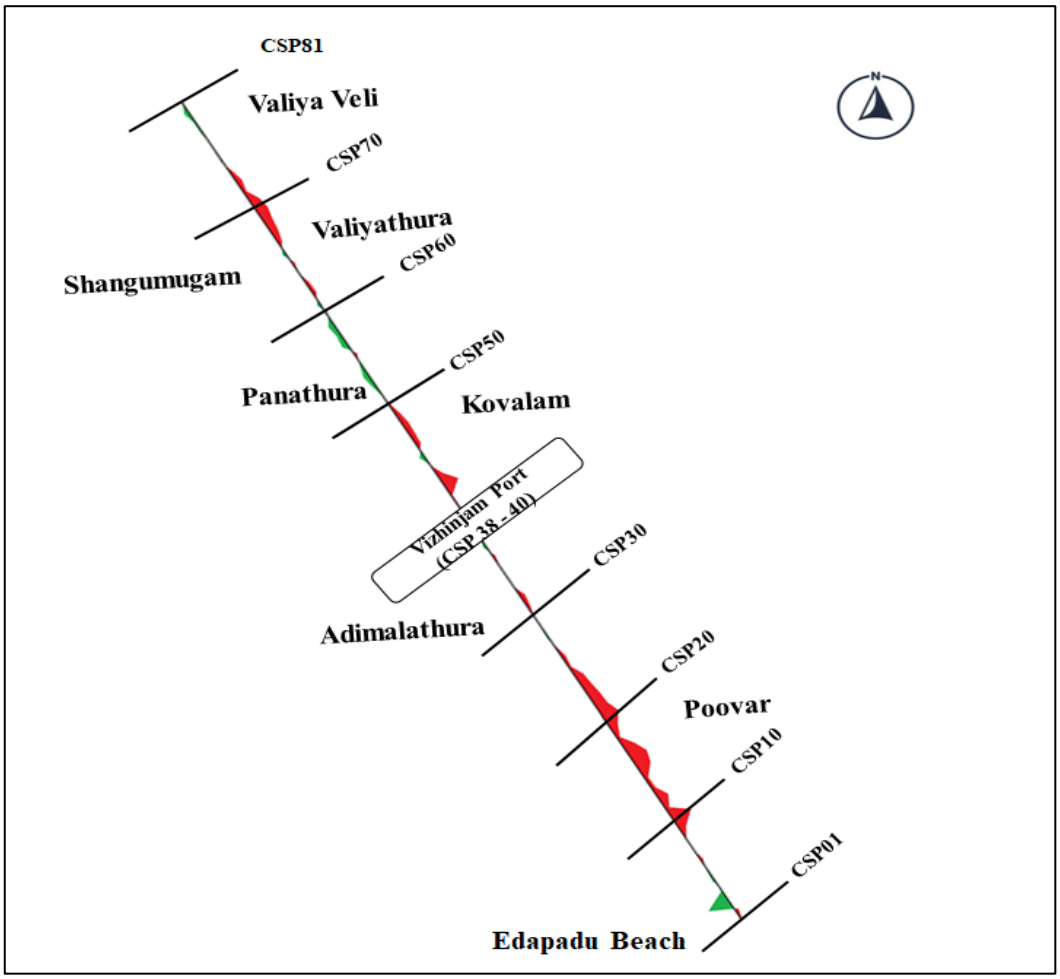
CSP73	-9.04	7.86	*	*	0.16	0.21	-0.18	0.23	1.33	-10.67	5.37	-1.94
CSP74	-4.33	1.94	-0.28	18.06	-18.06	18.03	22.11	0.41	0.68	-1.88	-1.42	1.74
CSP75	-3.96	3.96	-0.58	5.15	-0.21	-0.25	-0.24	0.56	0.53	1.75	-2.59	0.54
CSP76	0.67	3.19	0.07	6.56	0.44	0.28	-0.10	0.81	0.92	2.47	-6.15	5.17
CSP77	-5.65	10.39	-1.07	13.43	-3.70	0.15	-0.65	0.98	1.52	-8.46	4.10	3.32
CSP78	1.87	-7.05	2.97	-0.22	2.30	0.25	0.91	1.41	1.17	-1.65	0.17	2.70
CSP79	**Sea wall**											
CSP80	-0.74	5.45	-1.50	2.45	3.38	-3.16	0.12	0.67	1.55	-2.13	-1.75	3.60
CSP81	-5.97	11.17	0.63	7.99	-0.25	0.38	0.03	0.12	0.39	-1.34	-1.26	1.54

*Data not considered for analysis

4.1.2 Monthly Beach Volume variations for March 2022 offshore part

No offshore survey carried out for October 2021, April 2022 to September 2022 and few locations on the offshore were surveyed in November 2021 and January 2022 due to unfavourable weather conditions. Hence this session contains only the analysis of March 2022 offshore profiles. Results are represented graphically in **Figures 4.13**and in **Table 4.2**

During March 2022, accretion noted at Edapadu beach (CSP02), Vallavilay (CSP4-5), Neerody (CSP7-8), Pulluvila (CSP28-30), Adimalathura (CSP34), Mullur (CSP37), Kovalam (CSP46), Pannathura North to Punthura (CSP52-55), Punthura to Beemapally (CSP57-59), Cheriyathura (CSP61), Valliyathura (CSP66), Kochuveli (CSP75-76) and Valliyaveli to Thumba (CSP78-80). Erosion found at Edapadu beach (CSP01&03), Vallavilay (CSP06), Neerody to Pulluvila (CSP9-27), Adimalathura (CSP31-32), Mullur (CSP36), Kovalam (CSP41-44), Kovalam North to Pannathura North (CSP47-51), Punthura (CSP56), Beemapally (CSP60), Cheriyathura to Valliyathura (CSP62-65), Valliyathura to Vettucaud (CSP67-74), Kochuveli (CSP77) and Thumba (CSP81). CSP33, CSP35 and CSP45 profiles found erroneous due to data gap in profile measurement hence excluded from the analysis.



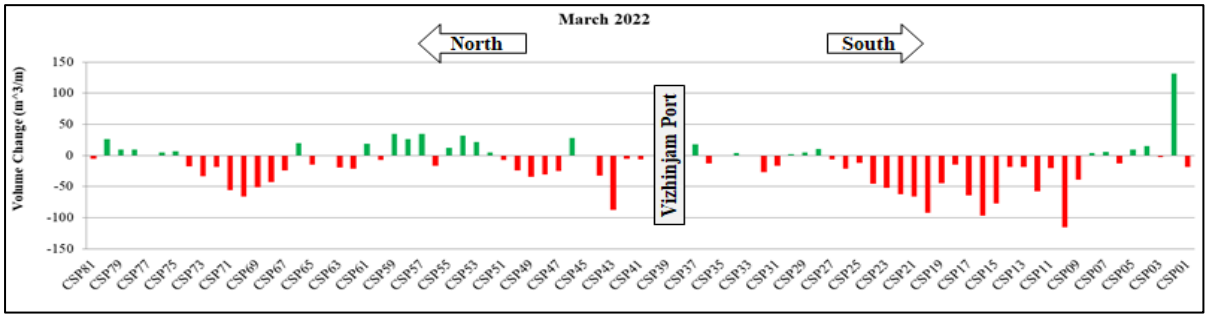


Figure 4.13Monthly Beach Volume Changes in March 2022 in m^3/m (offshore)

Table 4.2Monthly Beach Volume Changes during March 2022in m^3/m (offshore)

CSP NOs.	March 2022
CSP01	-18.94
CSP02	131.43
CSP03	-2.82
CSP04	15.30
CSP05	9.28
CSP06	-12.77
CSP07	5.35
CSP08	3.52

CSP09	-38.52
CSP10	-114.93
CSP11	-20.63
CSP12	-57.30
CSP13	-18.93
CSP14	-18.22
CSP15	-77.41
CSP16	-96.47
CSP17	-63.91
CSP18	-15.14
CSP19	-44.91
CSP20	-91.81
CSP21	-66.24
CSP22	-62.67
CSP23	-52.42
CSP24	-45.77
CSP25	-11.91
CSP26	-21.40
CSP27	-5.91
CSP28	10.64
CSP29	5.18
CSP30	1.92
CSP31	-16.21
CSP32	-27.32
CSP33	*
CSP34	4.26
CSP35	*
CSP36	-13.34
CSP37	17.86
CSP38	**PORT AREA**
CSP39	
CSP40	
CSP41	-6.10
CSP42	-5.40
CSP43	-87.51
CSP44	-32.30
CSP45	*
CSP46	28.28
CSP47	-25.30
CSP48	-30.43
CSP49	-34.31
CSP50	-24.49
CSP51	-7.39
CSP52	4.98

CSP53	21.82
CSP54	31.99
CSP55	11.90
CSP56	-16.19
CSP57	34.75
CSP58	25.89
CSP59	34.90
CSP60	-7.32
CSP61	18.34
CSP62	-21.71
CSP63	-19.36
CSP64	-0.36
CSP65	-14.84
CSP66	19.76
CSP67	-24.05
CSP68	-42.50
CSP69	-51.14
CSP70	-66.37
CSP71	-55.86
CSP72	-18.42
CSP73	-32.92
CSP74	-17.40
CSP75	6.43
CSP76	4.83
CSP77	-0.89
CSP78	9.66
CSP79	9.13
CSP80	26.44
CSP81	-5.25

4.1.3 Seasonal and Overall Beach Volume variations from October 2021 to September 2022

Seasonal variation has been analyzed as post monsoon (October 2021 to November 2021), fair weather period (December 2021 to March 2022), pre monsoon period (April 2022 to May 2022) and Monsoon (June 2022 to September 2022) for the period October 2021 to September 2022. The results have been presented to depict the total changes that occur in a particular season by analyzing profiles between each month in a season. Shown graphically in **Figures 4.14 to 4.18** and in **Table 4.3.**

There was no offshore data for October 2021 for any of the 81 locations and only few locations surveyed on the offshore part during February 2022 and March 2022. Hence overall and seasonal analysis was done only for onshore part.

Beach Volume Change in Post Monsoon 2021 (October-November 2021)

The locations Edapadu Beach (CSP02), Poovar South to Pulluvila (CSP15-29), Adimalathura to Azhimala (CSP31-35), Kovalam (CSP44), Pannathura North to Punthura (CSP52-53), Valliyathura (CSP66), Shangumugam South (CSP69), Shangumugam North to Kochuveli (CSP71-77) and Thumba (CSP80-81) shown accretion. Erosion noted at Pulluvila (CSP30), Mullur (CSP36-37), Kovalam (CSP43), Pannathura North (CSP51), Shangumugam North (CSP70) and Valliyaveli (CSP78). Profile found erroneous at CSP41 and CSP45 due to data gap in profile measurement hence excluded from the analysis. Results shown in **Figure 4.14**.

Beach Volume Change in Fair Weather Period 2021 (December 2021-March 2022)

During the fair weather period the beach exhibits accretion along most of the beaches except Poovar South (CSP16), Pulluvila (CSP27-28), Pannathura North to Punthura (CSP52-53), Valliyathura (CSP66) and Shangumugam North (CSP71) shown in **Figure 4.15**. Profile found erroneous at CSP73due to data gap in profile measurement for December 2021 hence excluded from the analysis.

Beach Volume Change in Pre Monsoon 2022 (April 2022-May 2022)

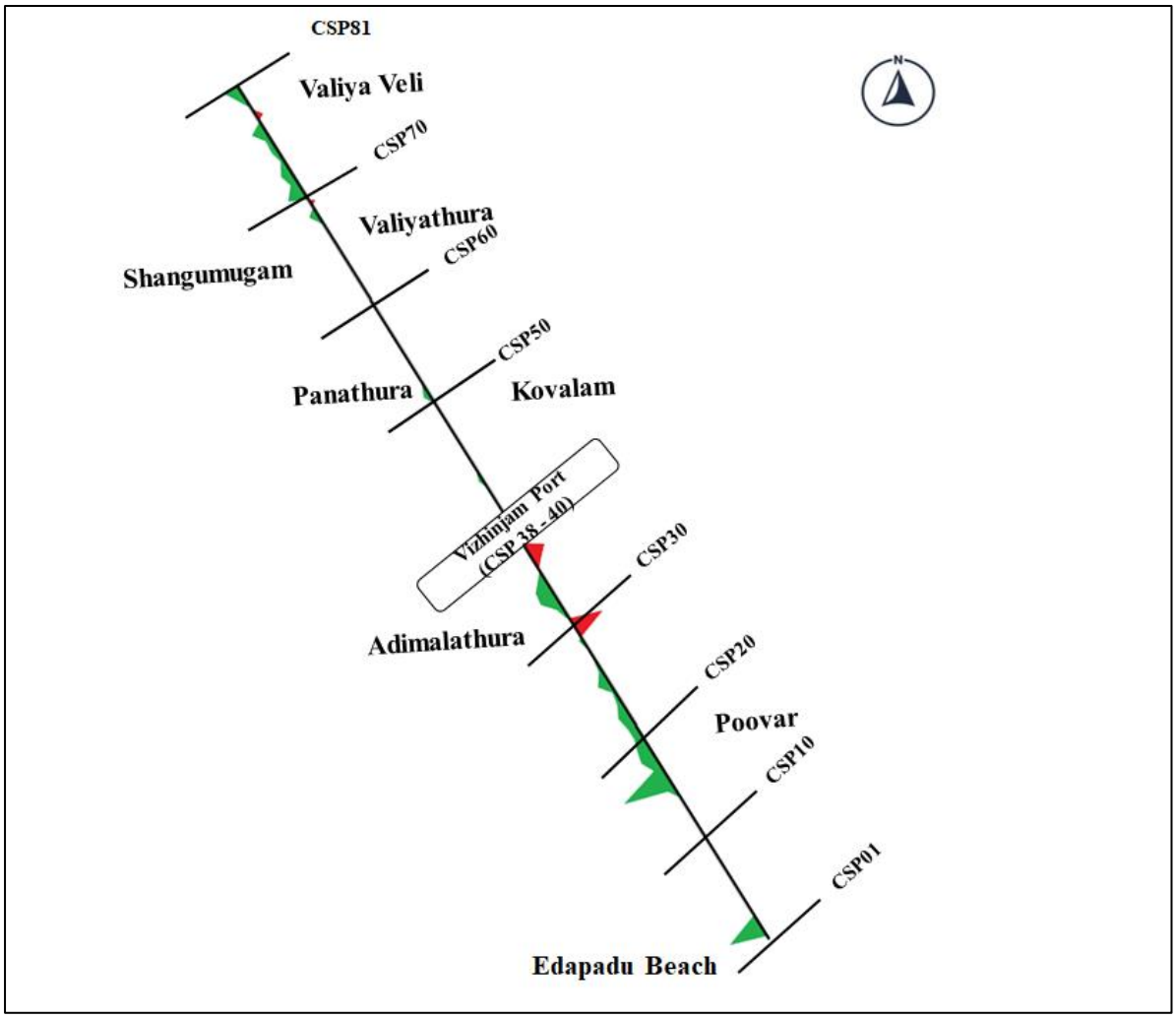
During pre-monsoon period, most of the locations indicates accretion such as Poovar south (CSP16), Punthura (CSP53), Shangumugham (CSP71) while erosion is noticed at Poovar (CSP17), Karumkulam (CSP25), Pulluvila (CSP30), Adimalathura (CSP33), Mullur (CSP36-37), Kovalam (CSP42-43), Panathura (CSP52) and Shangumugham (CSP69). shown in **Figure 4.16**.

Beach Volume Change in Monsoon 2022 (June 2022-September 2022)

During monsoon period, beach exhibits erosion at Poovar south (CSP15), Adimalathura (CSP31), Kovalam (CSP43) while accretion at Edapadu beach (CSP02), Poovar south (CSP16), Pulluvila (CSP30), Valliyathura (CSP66), Thumba (CSP81). The results are shown in **Figure 4.17.**

Overall beach volume variation during October 2021 to September 2022

During October 2021 to September 2022, beach shown erosion at Vettucaud (CSP73), Valliyathura (CSP66), Pannathura to Punthura (CSP51-53), Kovalam (CSP42-43), Adimalathura (CSP31,33), Pulluvila (CSP27,30), Poovar (CSP15), and Edapadu beach (CSP 2) except accretion at most of the locations such as Thumba to Shangumugam (CSP 69-72), Pulluvila to Poovar (CSP 17-29). Results shown in **Figure 4.18**



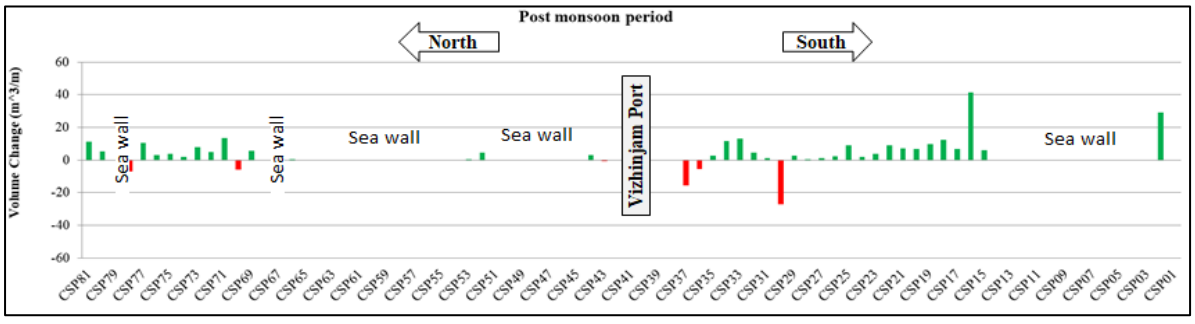
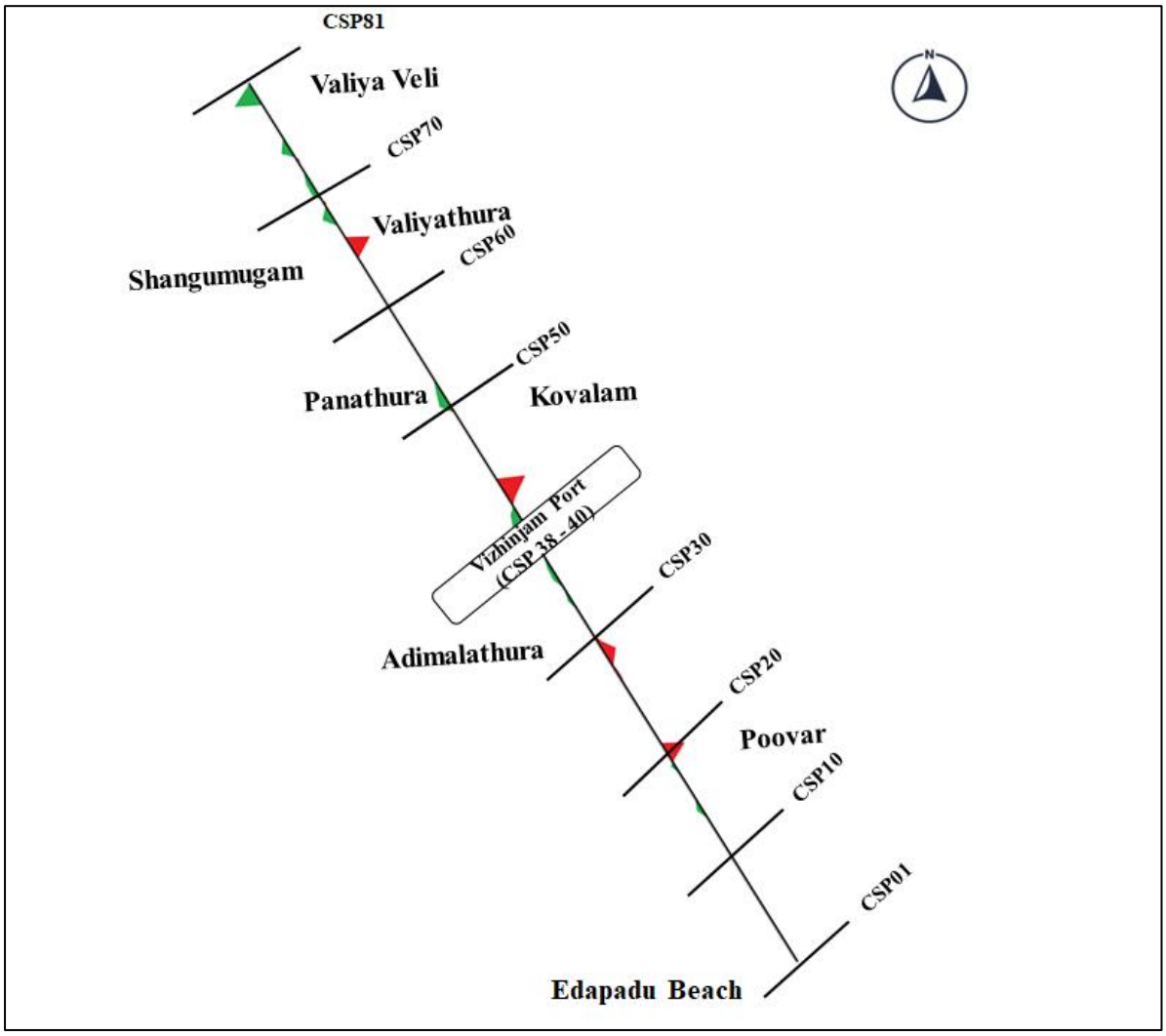


Figure 4.14Seasonal Beach Volume Changes during Post monsoon period in m³/m



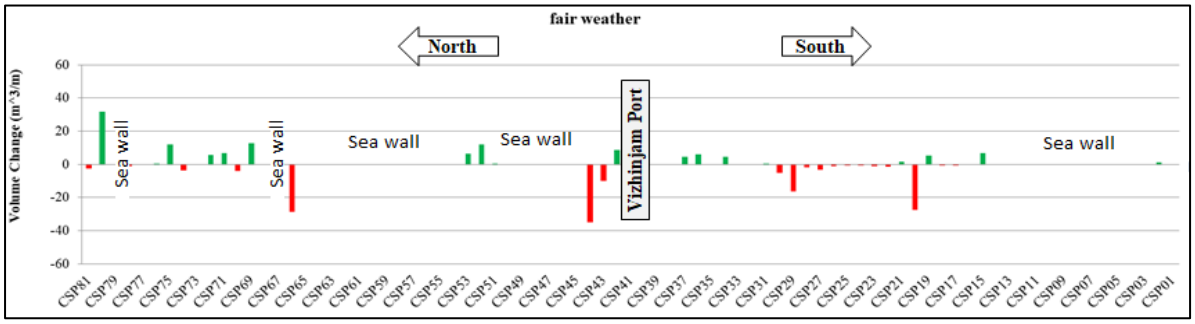
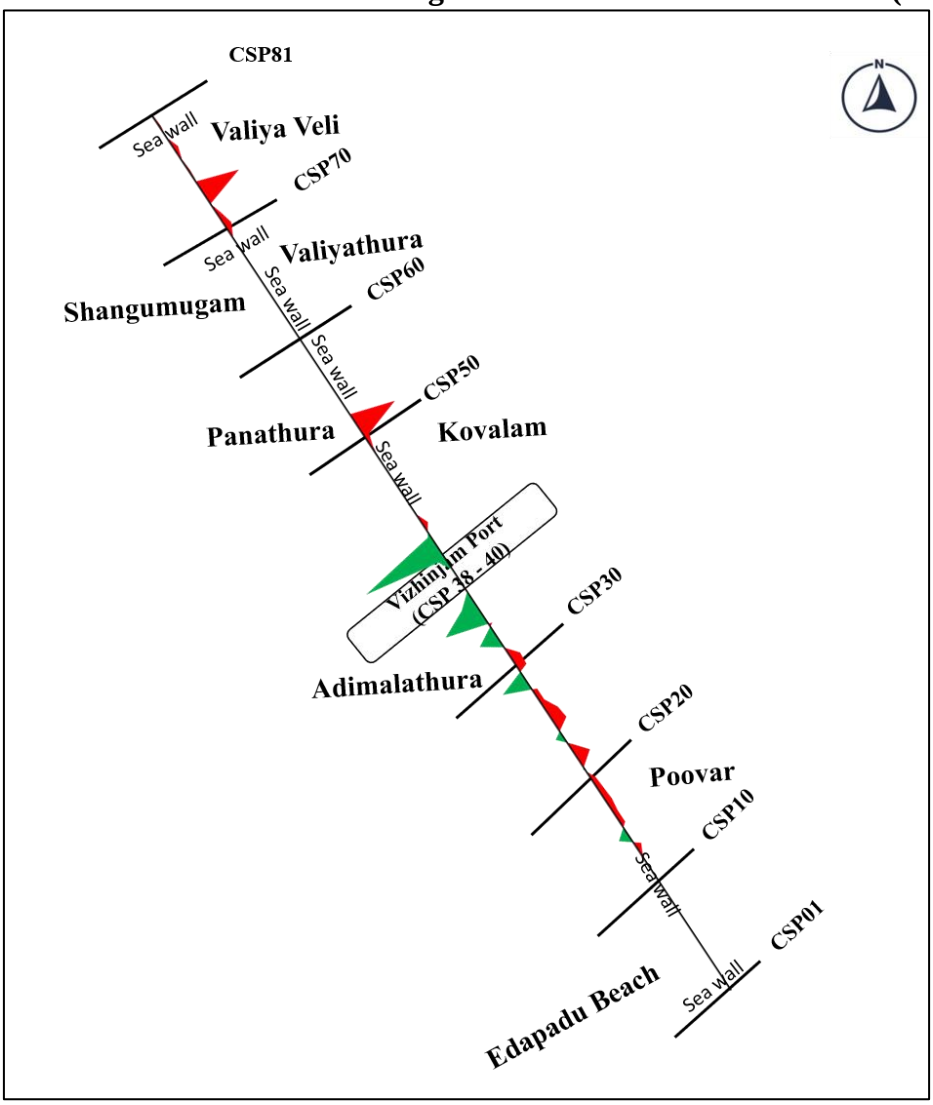
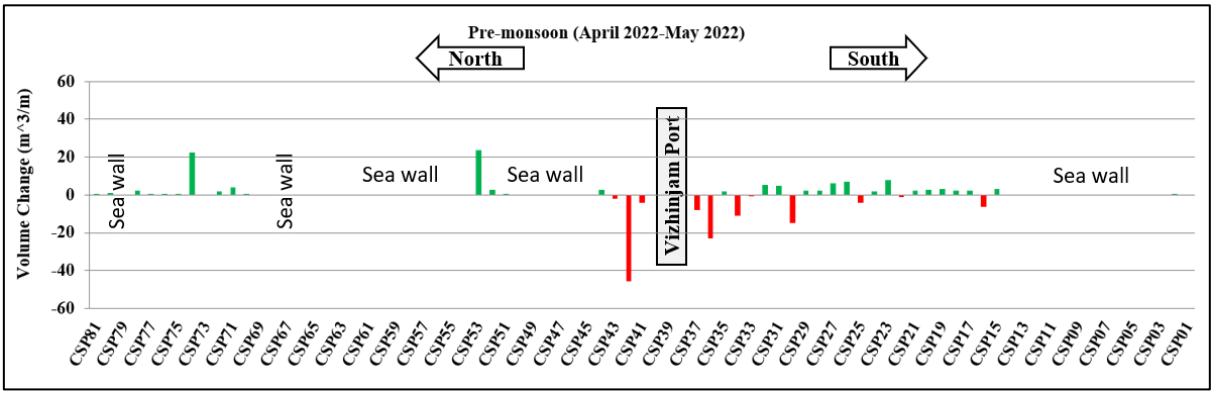
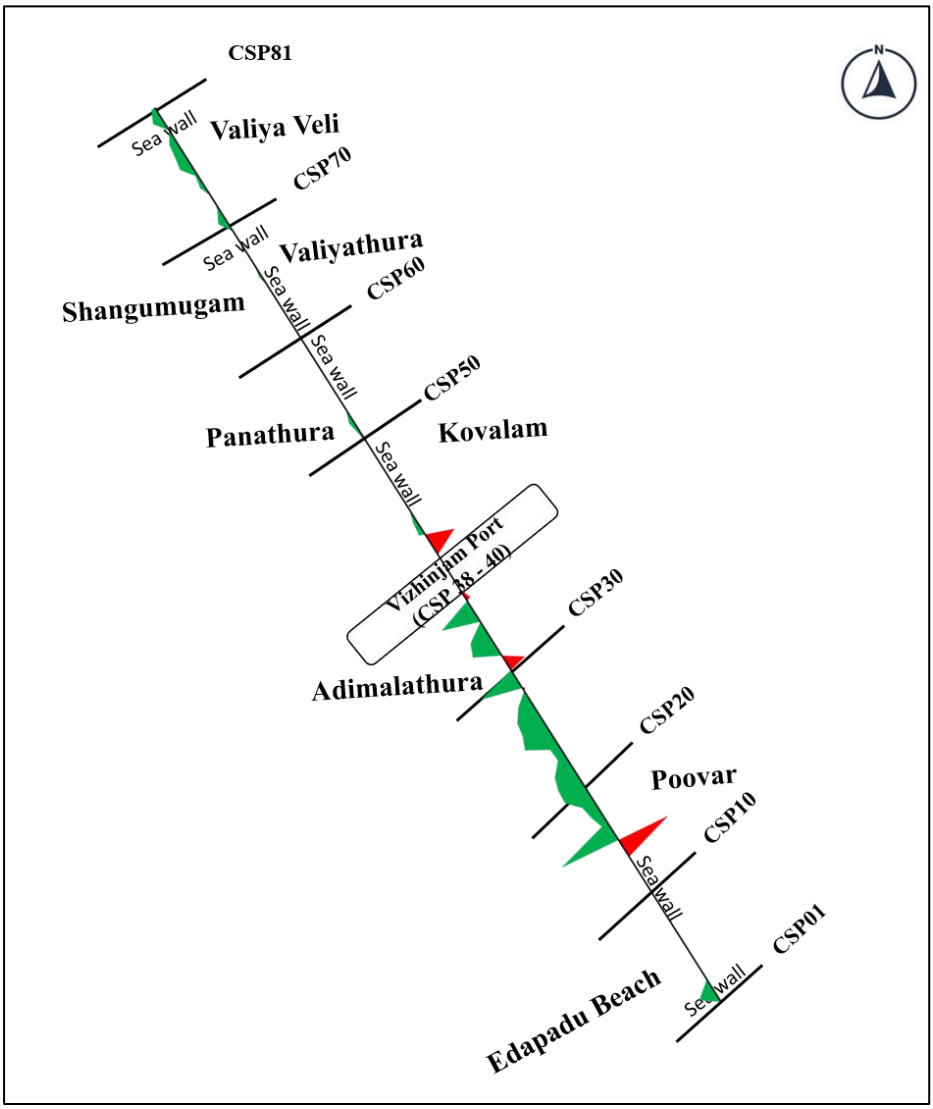


Figure 4.15Seasonal Beach Volume Changes during Fair weather period in m^3/m

Figure 4.16Seasonal Beach Volume Changes in Pre-monsoon 2022 in m^3/m (onshore)







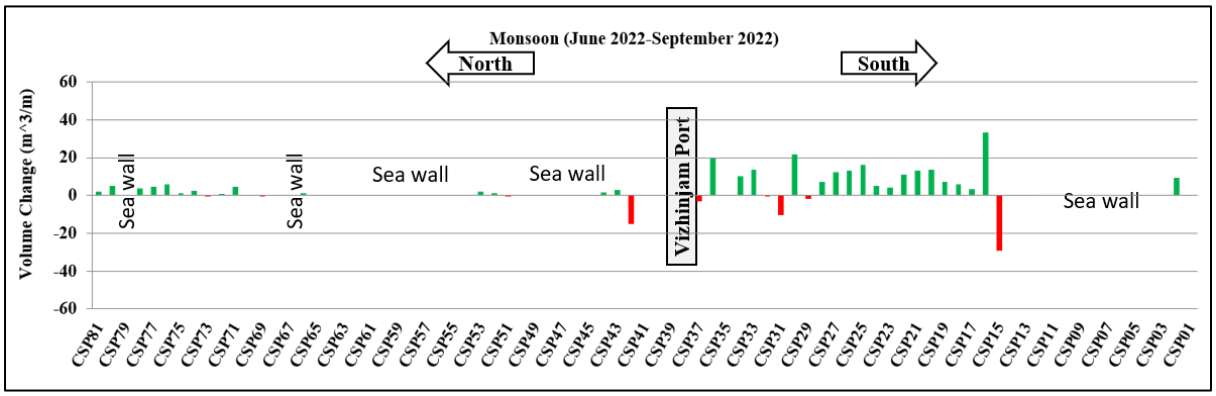


Figure 4.17Seasonal Beach Volume Changes in Monsoon 2022 in m^3/m (onshore)

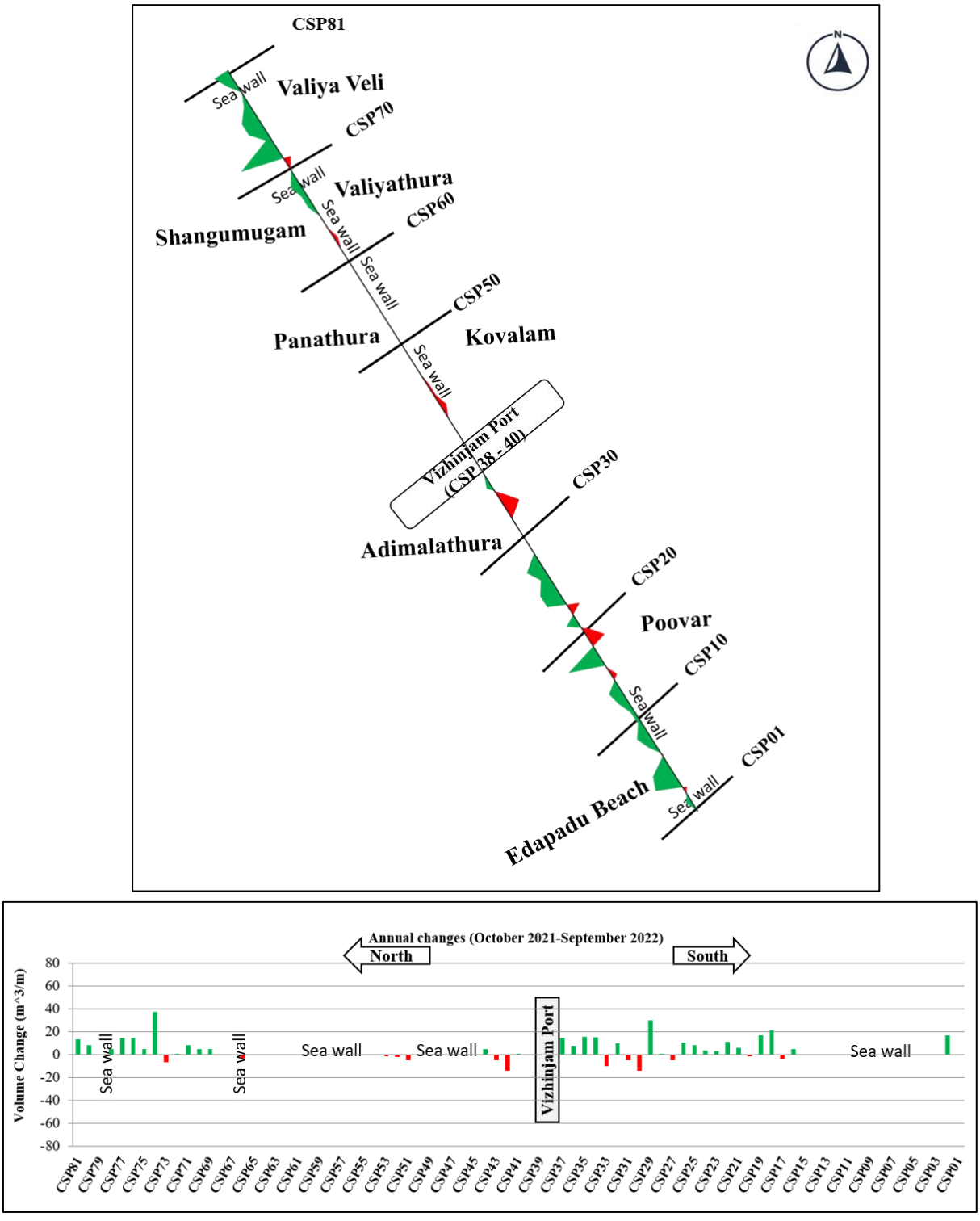


Figure 4.18Overall Beach Volume Changes for the period of October 2021 to September 2022 in m3/m

Table 4.3Seasonal and Overall Beach Volume Changes in m3/m

CSP NOs.	AREA	October 2021 to November 2021 (Post monsoon Period 2021)	December 2021 to March 2022 (Fair weather Period 2022)	April 2022 to May 2022 (Pre-monsoon Period 2022)	June 2022 to September 2022 (Monsson Period 2022)	October 2021 to September 2022 (overall)
CSP01	SOUTH OF PORT	Sea wall				
CSP02		29.26	31.69	0.21	9.17	16.44
CSP03		Sea wall				
CSP04						
CSP05						
CSP06						
CSP07						
CSP08						
CSP09						
CSP10						
CSP11						
CSP12						
CSP13						
CSP14						
CSP15		6.00	24.09	3.01	-29.40	-0.77
CSP16		41.32	-28.64	-6.22	33.25	4.62
CSP17		6.76	10.89	2.35	3.50	-3.79
CSP18		12.29	14.44	2.48	5.87	21.17
CSP19		9.90	11.82	3.27	7.04	16.59
CSP20		6.69	6.33	2.64	13.51	-1.47
CSP21		7.06	9.98	2.23	13.14	5.97
CSP22		8.89	6.06	-1.24	11.01	10.78
CSP23		3.75	0.04	7.91	4.33	2.91
CSP24		1.83	8.04	1.74	4.97	3.38
CSP25		9.18	10.05	-4.33	16.19	7.88
CSP26		2.13	1.04	6.89	13.26	10.53
CSP27		1.06	-3.45	6.06	12.14	-5.04
CSP28		0.55	-0.39	2.49	7.20	0.83
CSP29		2.77	6.43	2.17	-1.92	29.96
CSP30		-27.01	11.82	-14.66	21.87	-14.19
CSP31		1.19	0.46	4.77	-10.29	-5.22
CSP32		4.68	9.61	5.41	-0.26	10.04
CSP33		13.06	6.47	-0.53	13.56	-10.27
CSP34		11.72	2.94	-10.82	10.40	14.91
CSP35		2.66	6.59	1.78	*	15.28
CSP36		-5.38	3.13	-23.16	19.67	7.34
CSP37		-15.50	43.88	-8.11	-2.87	14.23
CSP38		Port Area				
CSP39						
CSP40						
CSP41	NORTH OF PORT	*	14.79	-4.33	*	0.72
CSP42		*	*	-45.68	-15.11	-14.07
CSP43		-0.56	1.73	-1.98	2.74	-5.26
CSP44		2.99	7.34	2.59	1.85	4.62

CSP45		**Sea wall**				
CSP46						
CSP47						
CSP48						
CSP49						
CSP50						
CSP51		-0.34	0.05	0.49	-0.37	-5.23
CSP52		4.41	-4.99	2.77	1.05	-2.04
CSP53		0.24	-16.21	23.68	2.26	-1.74
CSP54		**Sea wall**				
CSP55						
CSP56						
CSP57						
CSP58						
CSP59						
CSP60						
CSP61						
CSP62						
CSP63						
CSP64						
CSP65						
CSP66		0.20	-0.37	-0.36	1.13	-3.45
CSP67		**Sea wall**				
CSP68						
CSP69		5.83	2.47	-0.48	-0.67	4.50
CSP70		-5.98	13.13	0.18	0.25	4.38
CSP71		13.35	-2.11	3.81	4.45	8.03
CSP72		5.03	6.99	1.94	0.79	0.63
CSP73		7.86	*	*	-0.61	-6.67
CSP74		1.94	17.75	22.52	2.42	36.99
CSP75		3.96	4.11	0.32	1.07	4.66
CSP76		3.19	7.35	0.72	6.09	14.34
CSP77		10.39	8.82	0.33	4.84	14.36
CSP78		-7.05	5.30	2.33	3.87	4.84
CSP79		**Sea wall**				
CSP80		5.45	1.17	0.79	5.15	7.94
CSP81		11.17	8.76	0.14	1.93	13.44

4.1.4 Seasonal Beach Volume comparison between the period October 2020 and October 2021 and February 2021 & February 2022

Beach Volume comparison between October 2020 and October 2021

No offshore survey was carried out in October 2020 and October 2021, hence the comparison of October 2020 beach profiles with October 2021 done only for onshore part has been presented in the **Figure 4.19** and in the **Table 4.4**

The beach was shown accretion at Pulluvila to Adimalathura (CSP30-31), Mullur (CSP36), Kovalam (CSP43-44), Pannathura North (CSP51), Punthura (CSP53), Valliyathura (CSP66), Kochuveli (CSP75-76), Valliyaveli (CSP78), and Thumba (CSP80)in October 2021 compared to October 2020.The locations Edapadu Beach (CSP02), Poovar South to Pulluvila (CSP15-29),Adimalathura (CSP33-34), Mullur (CSP37), Pannathura North (CSP52), Shangumugam South to Vettucaud (CSP69-74), Kochuveli (CSP77) and Thumba (CSP81) shown erosion trend in October 2021 compared to October 2020.The change in volume in percentage during this period was less than 10% (Refer Table 4.4).

Beach Volume comparison between February 2021 and February 2022

On onshore during February 2022, the beach exhibits accretion compared to February 2021 at most of the locations except at Poovar to Karumkulam (CSP18-25), Pulluvila (CSP30), Azhimala (CSP35), Punthura (CSP53), Shangumugham South (CSP69), Vettucaud (CSP74) and Kochuveli (CSP76). The change in volume in percentage during this period was less than 10%. Results has been presented in the **Figure 4.20** and in the **Table 4.4**

On offshore except at Edapadu (CSP02) and Pulluvila (CSP29) all other locations shown accretion in February 2022 compared to February 2021.Results has been presented in the **Figure 4.21** and in the **Table 4.4**

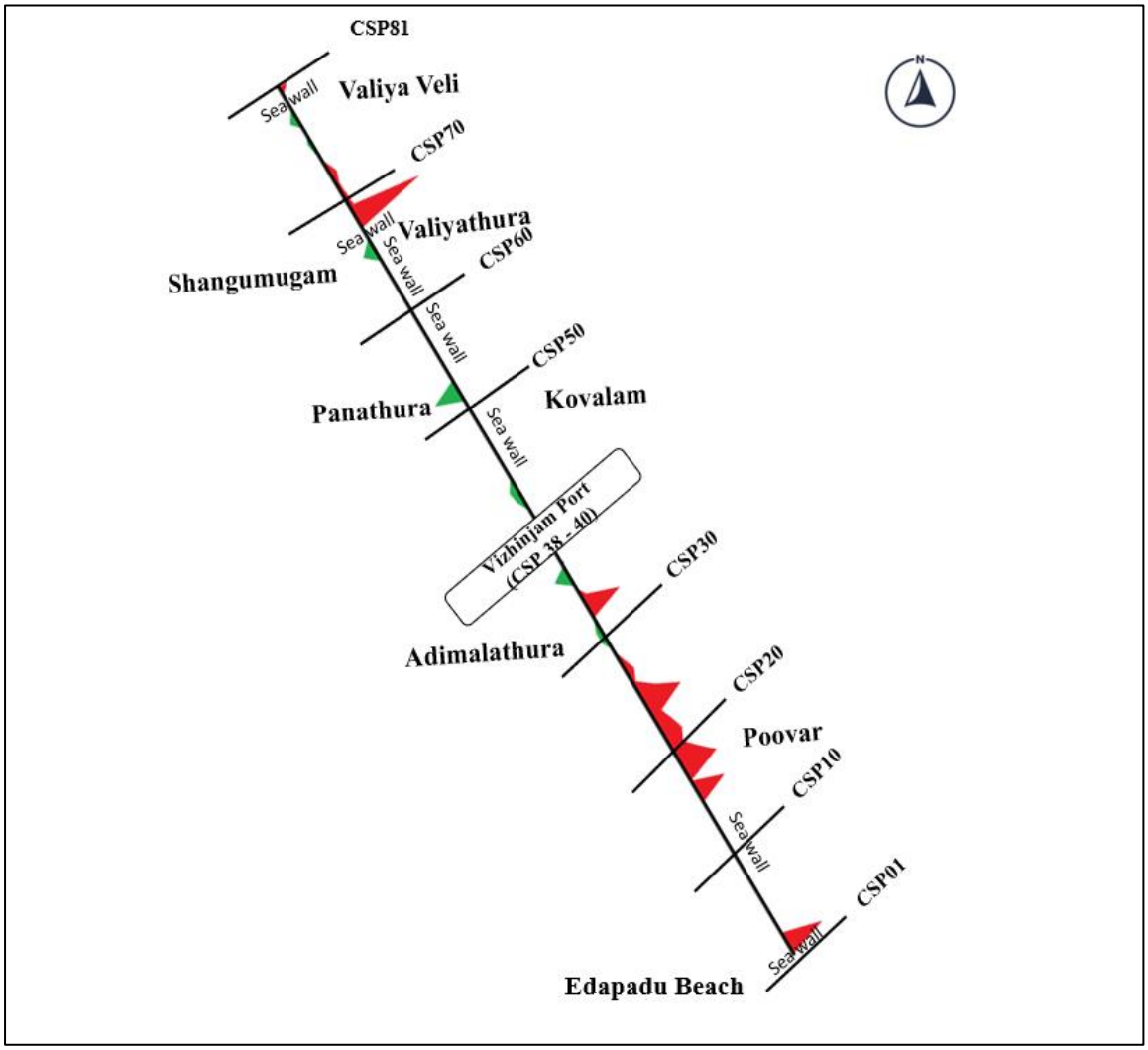
Beach Volume comparison between April 2021 and April 2022

Only Onshore survey for the month of April 2022 have been carried out. Hence the offshore data for the month of April 2022 has been compared with April 2021. It can be noticed from the **Figure 4.22** and the **Table 4.4,** the erosion has been noticed at Edapadu beach (CSP1-2), Vallavilay (CSP5-6), Neerody (CSP9), Pozhiyoor (CSP11-12), Paruthiyoor (CSP13), Poovar (CSP16), Pulluvila (CSP29), Pannathura to Punthura (CSP51-57), Beemapally (CSP57), Cheriyathura to Valliyathura (CSP61-66). However, the volume change in percentage is less than 10% from April 2021 to April 2022.

Beach Volume comparison between September 2021 and September 2022

Offshore survey could not be carried out for the month of September 2022. The comparison of the onshore data between September 2021 and September 2022 has been shown in the **Figure 4.23** and in the **Table 4.4.** Erosion has occurred at Poovar beach (CSP15-20), Kovalam (CSP42-44), Pannathura (CSP51), Valliyathura (CSP66), Shangumugham (CSP69), Vettucaud

(CSP72-73), Kochuveli (CSP75,77-78), Thumba (CSP81). However, the volume change in percentage is less than 5%.



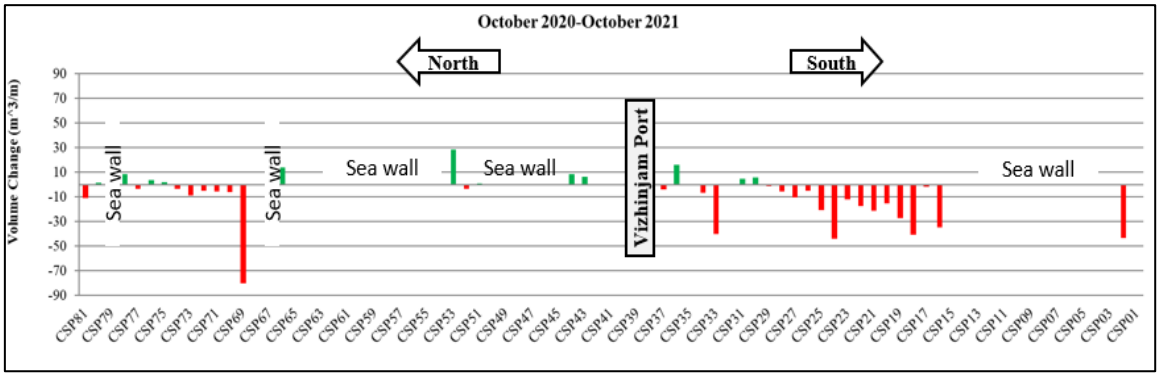
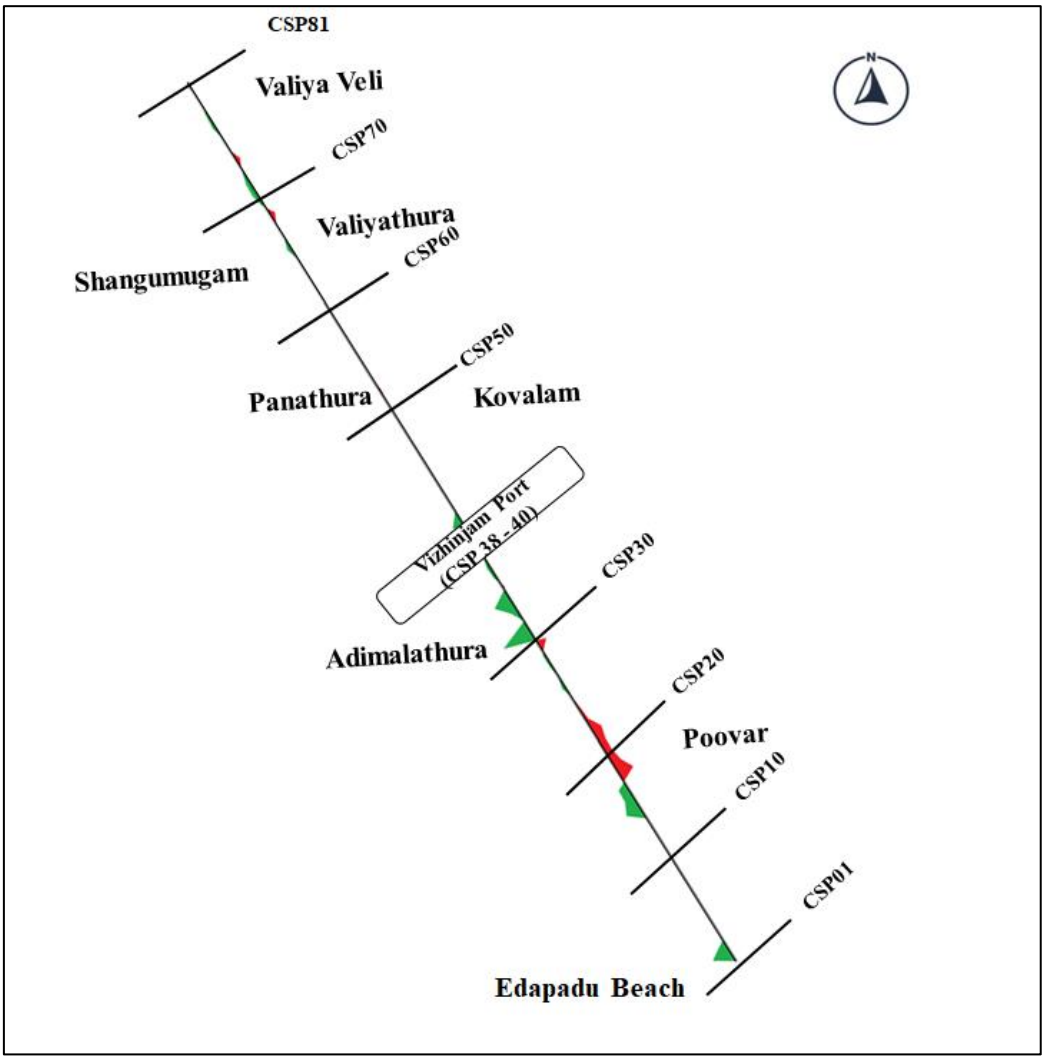


Figure 4.19 Beach Volume Change comparison between October 2020 and October 2021 in m^3/m (onshore)



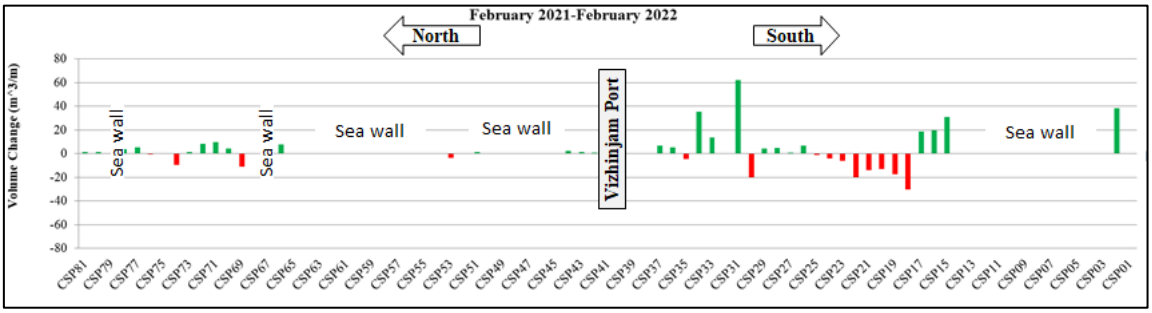
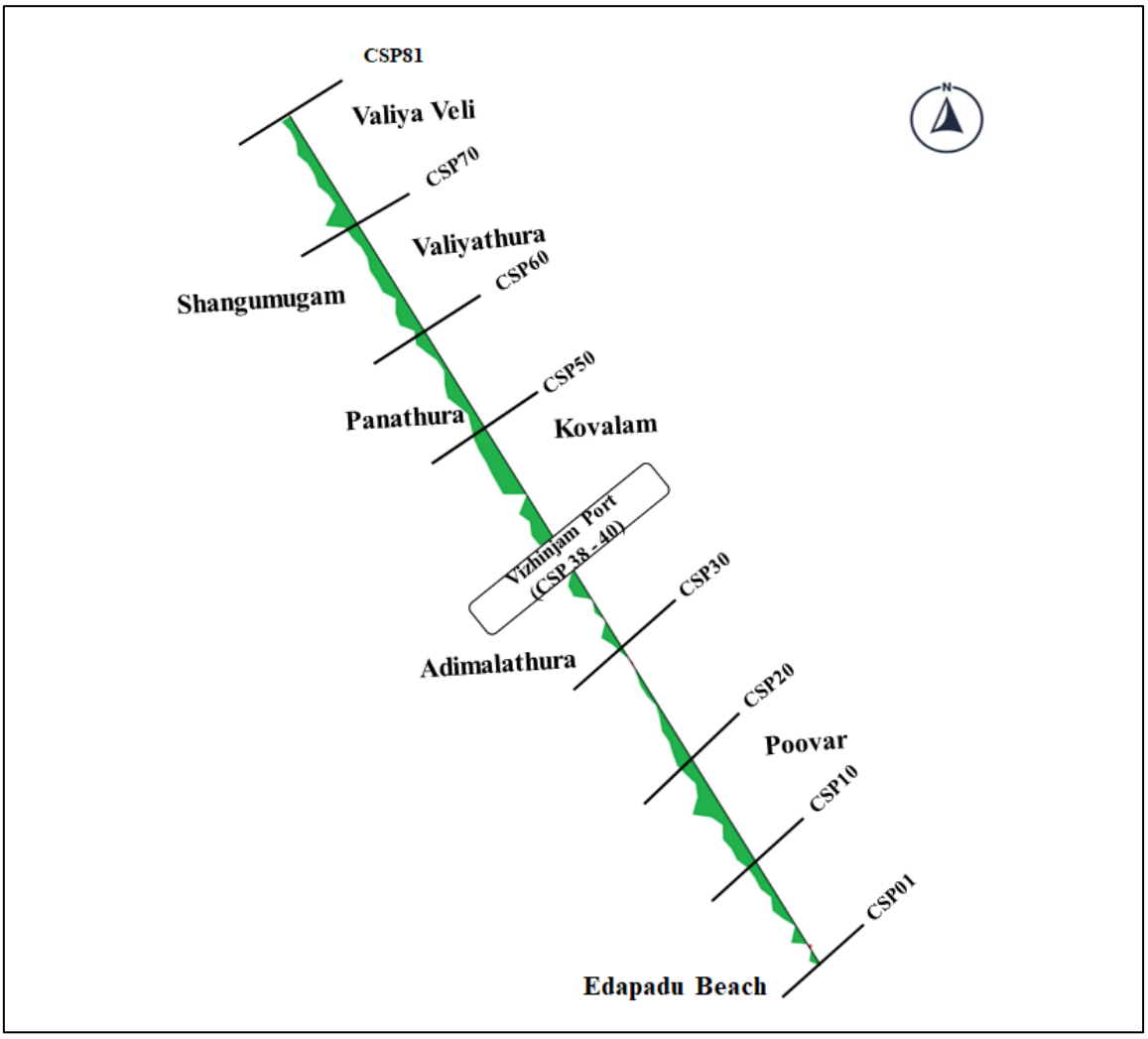


Figure 4.20 Beach Volume Change comparison between February 2021 and February 2022 in m^3/m (onshore)



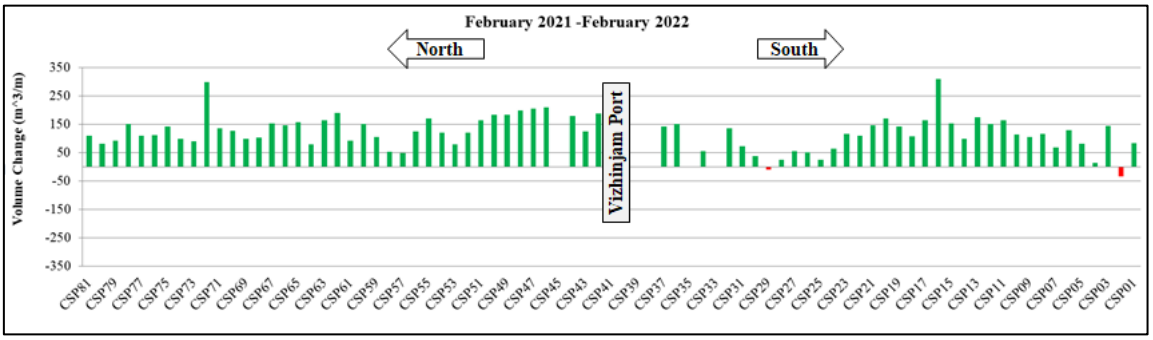


Figure 4.21Beach Volume Change comparison between February 2021 and February 2022 in m^3/m (offshore)

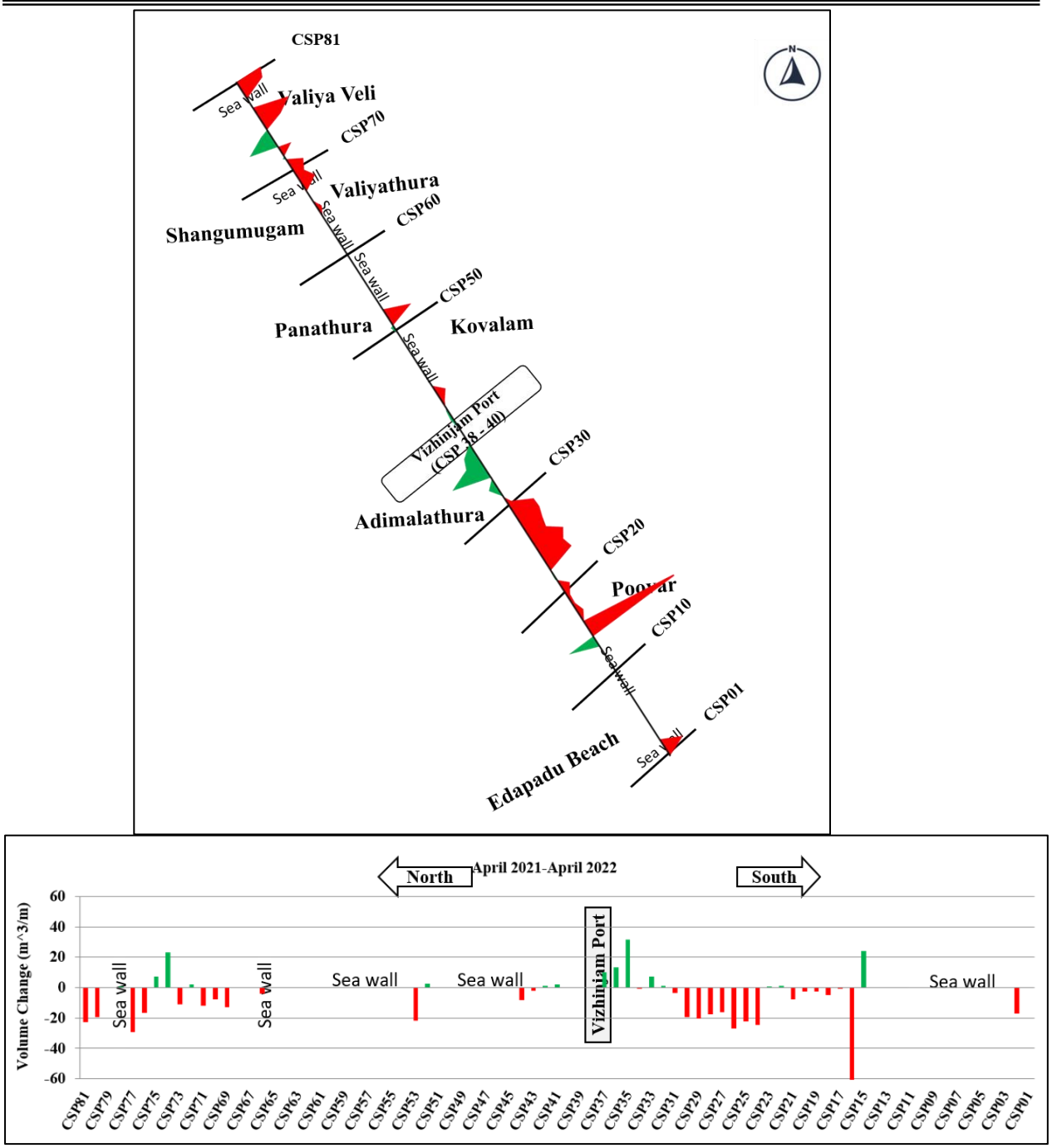
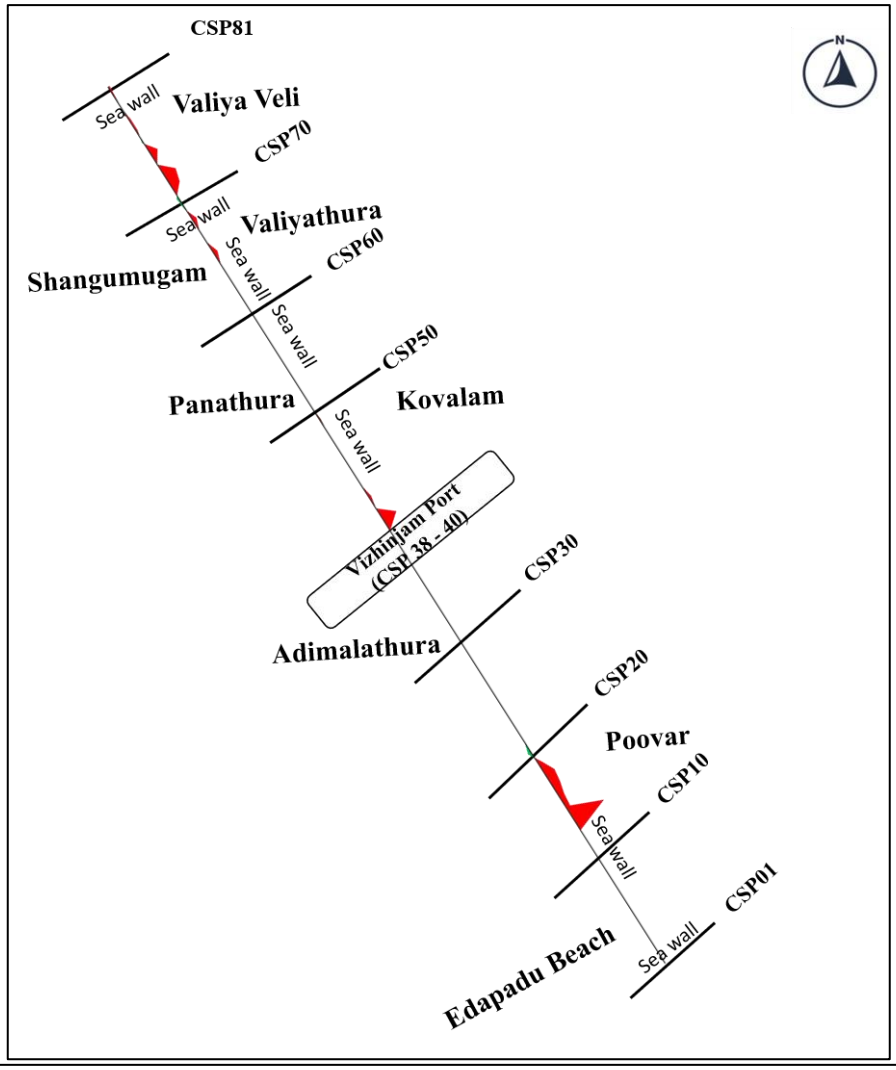


Figure 4.22Beach Volume Change comparison between April 2021 and April 2022 in m^3/m (onshore)



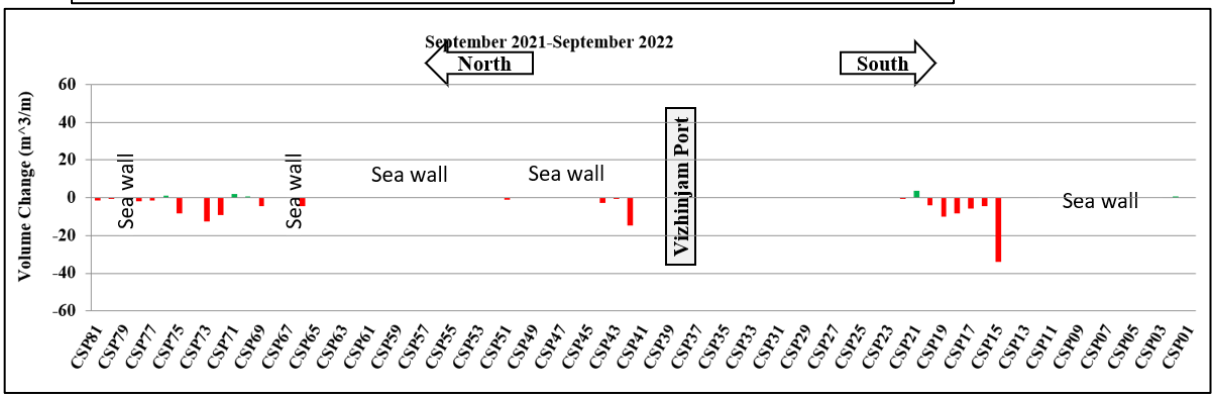


Figure 4.23Beach Volume Change comparison between September 2021 and September 2022 in m^3/m (onshore)

Table 4.4Beach Volume Changes comparing the months of October 2020 and October 2021(onshore) and February 2021 and February 2022 (onshore and offshore) in m^3/m

Location	October 2020 and October 2021 (onshore)	Change in percentage (October 2020-october 2021) (onshore)	February 2021 and February 2022 (onshore)	Change in percentage (February 2021 and February 2022) (onshore)	February 2021 and February 2022 (offshore)	Change in percentage (February 2021 and February 2022) (offshore)	April 2021 and April 2022 (onshore)	Change in percentage (April 2021-April 2022) (onshore)	September 2021 and September 2022 (onshore)	Change in percentage (September 2021-September 2022) (onshore)
CSP01	**Sea wall**				82.66	0.04	**Sea wall**			
CSP02	-43.70	0.04	38.52	0.18	-33.93	-0.01	-17.06	-0.17	0.65	0.01
CSP03	**Sea wall**				144.10	0.08	**Sea wall**			
CSP04					14.05	0.01				
CSP05					80.76	0.04				
CSP06					129.60	0.07				
CSP07					67.43	0.04				
CSP08					115.53	0.07				
CSP09					104.65	0.06				
CSP10					112.55	0.07				
CSP11					163.02	0.10				
CSP12					151.09	0.10				
CSP13					173.23	0.10				
CSP14					97.57	0.08				
CSP15	-0.30	0.00	31.24	0.12	153.46	0.08	12.99	0.24	*	*
CSP16	-34.72	0.01	19.65	0.22	308.58	0.10	-87.64	-0.88	-33.88	0.34
CSP17	-1.92	0.00	18.69	0.06	163.19	0.20	-0.68	-0.01	-4.36	-0.04
CSP18	-40.62	0.02	-30.46	-0.09	107.38	0.10	-5.07	-0.05	-5.64	-0.06
CSP19	-27.34	0.02	-17.45	-0.06	142.33	0.08	-2.35	-0.02	-8.45	-0.08
CSP20	-15.29	0.01	-12.97	-0.03	170.33	0.07	-2.80	-0.03	-9.95	-0.10
CSP21	-21.24	0.02	-14.01	-0.06	144.97	0.10	-7.62	-0.08	-3.89	-0.04
CSP22	-17.65	0.02	-20.02	-0.07	109.19	0.10	0.93	0.01	3.59	0.04
CSP23	-12.32	0.01	-5.99	-0.02	116.06	0.08	0.49	0.00	-0.22	0.00
CSP24	-44.01	0.03	-3.97	-0.01	62.88	0.07	-24.56	-0.25	*	*
CSP25	-20.89	0.01	-0.87	0.00	24.59	0.02	-22.15	-0.22	*	*
CSP26	-4.87	0.00	6.80	0.02	50.48	0.05	-27.12	-0.27	*	*
CSP27	-10.46	0.00	0.96	0.01	54.34	0.05	-15.98	-0.16	*	*
CSP28	-5.84	0.00	4.79	0.01	24.32	0.02	-17.49	-0.17	*	*
CSP29	-1.32	0.00	4.17	0.01	-11.46	-0.01	-20.25	-0.20	*	*
CSP30	5.90	0.00	-19.77	-0.06	36.65	0.04	-19.45	-0.19	*	*
CSP31	4.75	0.00	62.00	0.13	72.38	0.07	-3.47	-0.03	*	*
CSP32	*	*	*	*	136.12	0.09	1.01	0.01	*	*
CSP33	-40.12	0.03	13.49	0.05	*	*	7.09	-0.01	*	*
CSP34	-6.70	0.00	35.25	0.15	54.67	0.03	-0.92	0.07	*	*
CSP35	*	*	-4.62	-0.02	*	*	31.60	0.32	*	*
CSP36	15.80	0.02	5.25	0.03	149.72	0.10	13.23	0.13	*	*
CSP37	-3.98	0.00	6.71	0.05	140.81	0.07	10.04	0.10	*	*
CSP38	**PORT AREA**									
CSP39										
CSP40										
CSP41	*	*	21.12	0.18	170.53	0.07	2.13	0.02	*	*
CSP42	*	*	0.74	0.01	186.39	0.07	1.34	0.01	-2.65	-0.03
CSP43	6.20	0.03	1.16	0.03	125.25	0.08	-2.09	-0.02	-0.05	0.00
CSP44	8.18	0.01	2.12	0.01	177.62	0.10	-8.18	-0.08	-14.80	-0.15
CSP45	**Sea wall**				*	*	**Sea wall**			
CSP46					208.67	0.08				
CSP47					204.01	0.08				
CSP48					197.30	0.09				
CSP49					182.72	0.08				
CSP50					182.03	0.09				
CSP51	1.11	0.01	1.30	0.04	163.10	0.09	-0.08	0.00	0.25	0.00
CSP52	-3.57	0.01	0.35	0.00	119.89	0.06	2.71	0.03	-1.13	-0.01
CSP53	28.61	0.02	-3.45	-0.06	77.65	0.04	-21.85	-0.22	*	*
CSP54	**Sea wall**				120.39	0.05	**Sea wall**			

CSP55					169.42	0.07				
CSP56					123.39	0.07				
CSP57					48.08	0.02				
CSP58					53.13	0.03				
CSP59					103.84	0.06				
CSP60					150.49	0.08				
CSP61					90.98	0.05				
CSP62					189.35	0.10				
CSP63					162.79	0.09				
CSP64					79.41	0.04				
CSP65					156.55	0.10				
CSP66	13.85	0.07	7.80	0.47	145.19	0.10	-4.11	-0.04	-4.34	-0.04
CSP67	**Sea wall**				151.66	0.09	**Sea wall**			
CSP68					103.51	0.07				
CSP69	-79.97	0.10	-10.88	-0.08	97.79	0.06	-12.83	-0.13	-4.27	-0.04
CSP70	-6.33	0.01	4.38	0.04	126.04	0.08	-7.70	-0.08	0.72	0.01
CSP71	-5.84	0.01	9.57	0.07	134.91	0.09	-12.07	-0.12	2.05	0.02
CSP72	-5.12	0.01	8.22	0.10	298.48	0.22	2.11	0.02	-9.12	-0.09
CSP73	-9.03	0.02	1.43	0.01	89.66	0.07	-11.03	-0.11	-12.76	-0.13
CSP74	-3.63	0.01	-9.48	-0.10	98.16	0.07	23.15	0.23	0.24	0.00
CSP75	1.73	0.00	0.44	0.02	141.50	0.09	7.03	0.07	-8.15	-0.08
CSP76	3.64	0.01	-0.57	-0.02	110.99	0.07	-16.45	-0.16	1.33	0.01
CSP77	-3.52	0.00	5.41	0.10	109.62	0.08	-29.28	-0.29	-1.59	-0.02
CSP78	8.67	0.01	3.67	0.05	150.97	0.09	0.78	0.01	-1.67	-0.02
CSP79	**Sea wall**				92.01	0.06	**Sea wall**			
CSP80	1.16	0.00	1.28	0.06	81.66	0.05	-19.57	-0.20	-0.59	-0.01
CSP81	-11.26	0.02	1.60	0.08	108.05	0.07	-22.91	-0.23	-1.49	-0.01

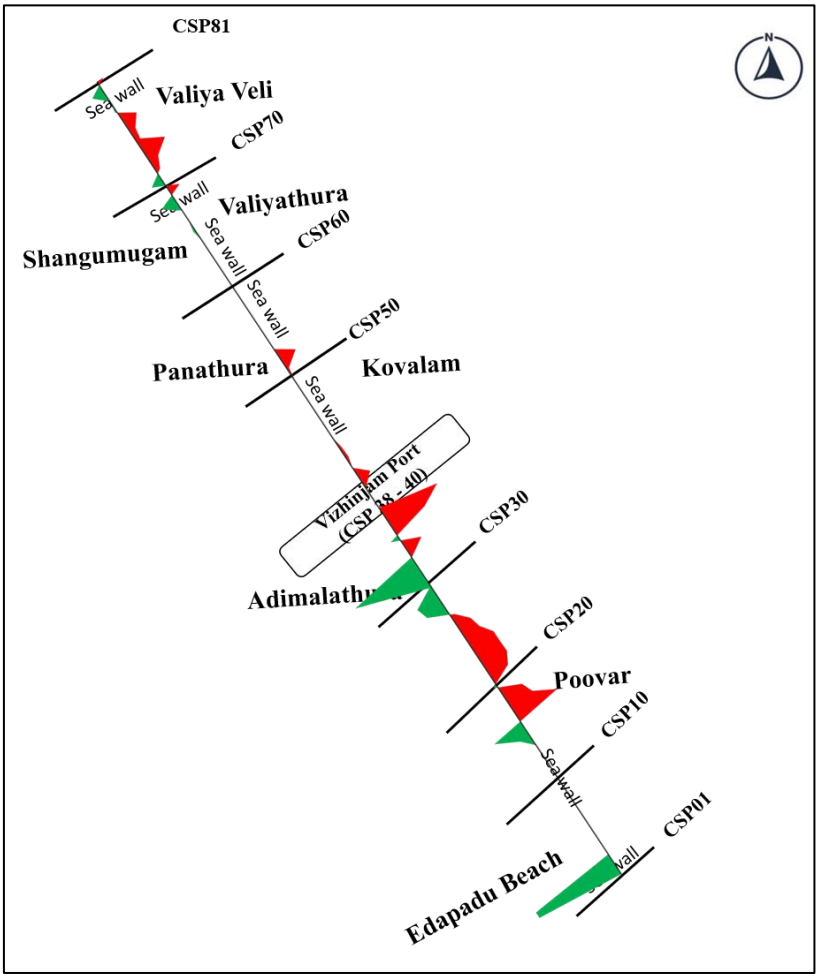
*Data not considered for analysis

4.1.5 Beach volume variation during February 2015 and February 2022

This analysis has been carried out to identify and compare the beach volume variation before the commencement of port dredging process with the current scenario. The beach volume changes for February 2015 and February 2022 given in graphs in **Figure 4.24, Figure 4.25**and **Table 4.5**.

On onshore part accretion noticed at Edapadu beach (CSP02), Poovar (CSP15-16) Pulluvila to Adimalathura (CSP28-32), Valliyathura (CSP66), Shangumugham (CSP69,71), and Thumba (CSP80). Erosion noticed at Poovar (CSP17-19,21), Karumkulam (CSP22-26), Adimalathura (CSP33-34), Mullur (CSP36-37), Kovalam (CSP43-44), Pannathura (CSP51-53), Shangumugham (CSP70), Vettucaud to Kochuveli (CSP 72-77) and Thumba (CSP81).

On offshore, accretion taken place at most of the locations except at Edapadu beach to Vallavilay (CSP1-7), Kovalam (CSP45), Punthura (CSP57), Valliyathura (CSP64-66), exhibit erosion.



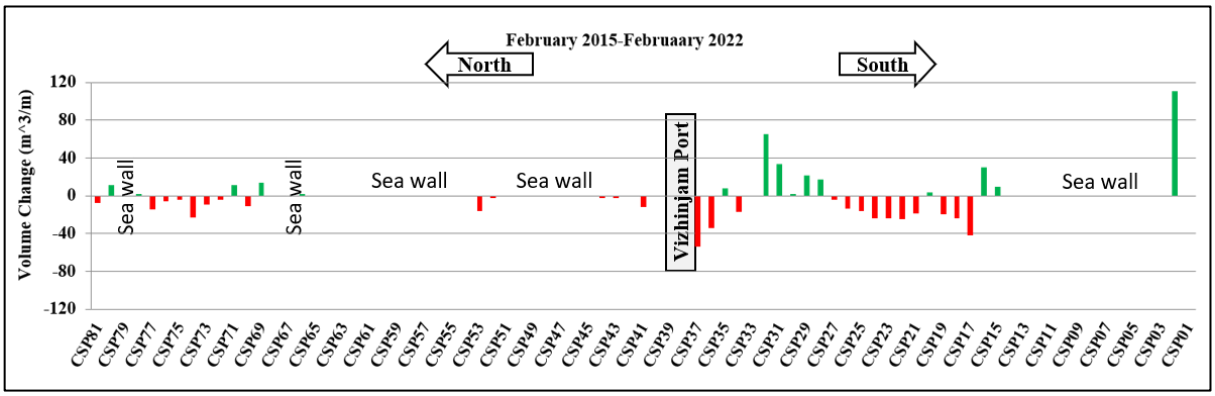
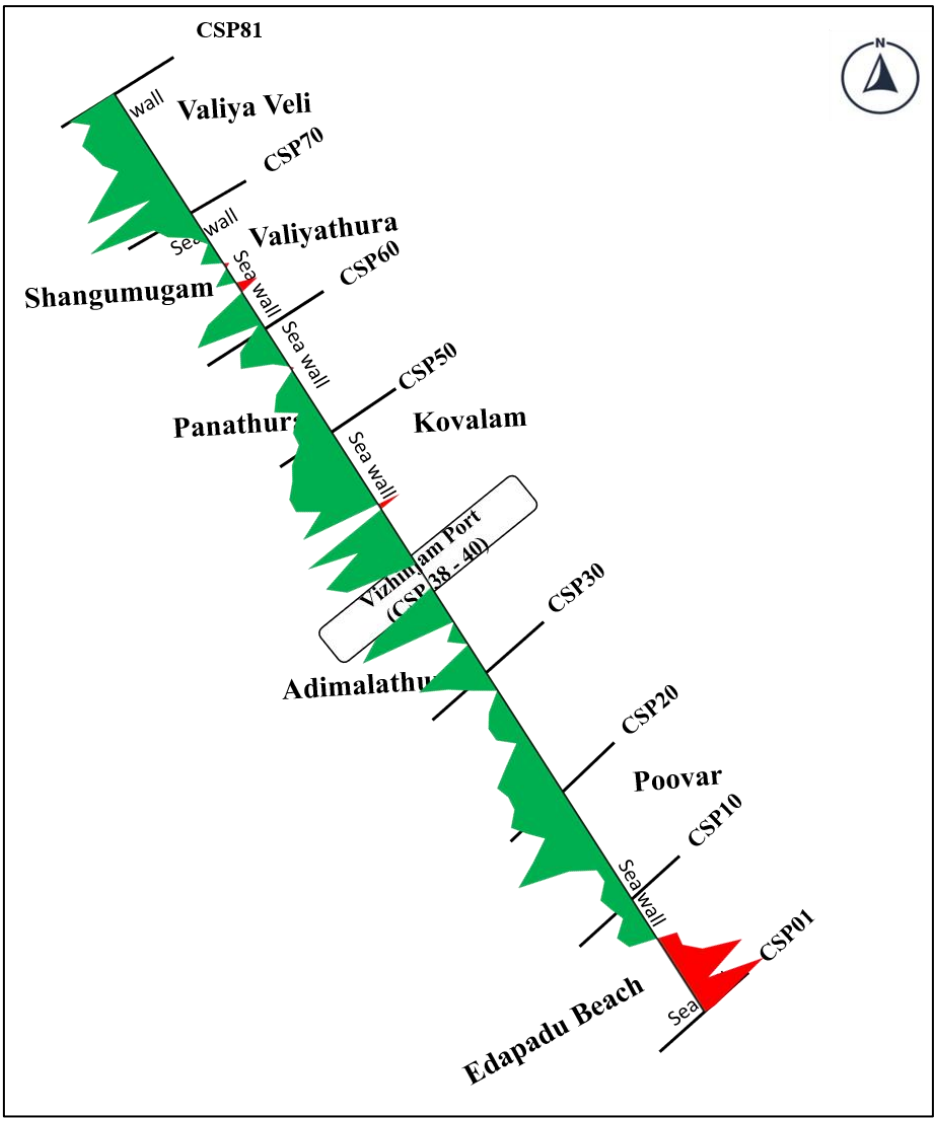


Figure 4.24 Beach Volume Changes - February 2015 and February 2022 in m^3/m (onshore)



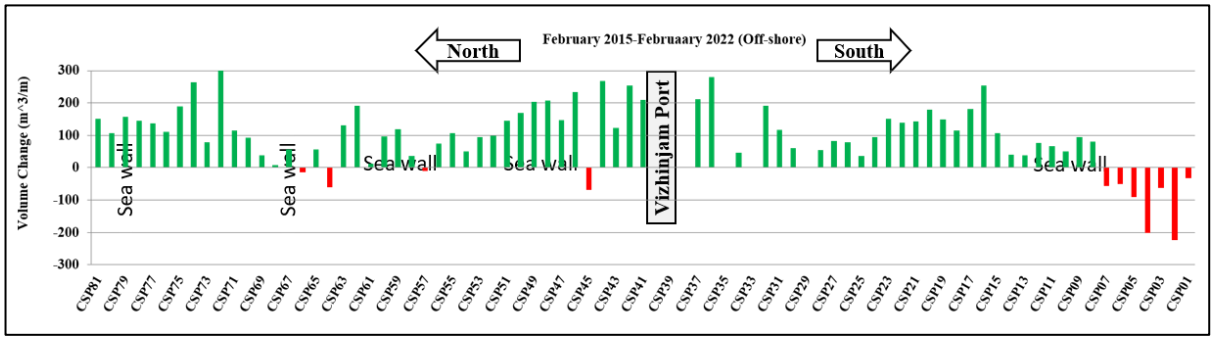


Figure 4.25 Beach Volume Changes - February 2015 and February 2022 in m^3/m (offshore)

Table 4.5Beach Volume Changes comparing the inter-annual months of February 2015 and February 2022 (onshore and offshore) m^3/m

CSP NOs.	AREA	February 2015 and February 2022 (onshore)	February 2015 and February 2022 (offshore)
CSP01	**SOUTH OF PORT**		-33.19
CSP02		110.91	-224.27
CSP03			-61.59
CSP04			-200.62
CSP05			-91.53
CSP06			-50.88
CSP07			-55.86
CSP08			79.96
CSP09			95.32
CSP10			50.46
CSP11			65.55
CSP12			77.17
CSP13			37.52
CSP14			39.41
CSP15		9.45	106.57
CSP16		29.73	253.38
CSP17		-42.13	180.54
CSP18		-23.75	114.67
CSP19		-19.57	148.53
CSP20		3.54	178.82
CSP21		-18.71	142.44
CSP22		-24.5	138.79
CSP23		-24.24	151.09
CSP24		-24.03	94.21
CSP25		-16.46	36.12
CSP26		-13.81	79.21
CSP27		-3.83	81.79
CSP28		17.63	55.28
CSP29		21.18	1.7
CSP30		1.92	60.44
CSP31		33.92	117.34
CSP32		65.33	190.76
CSP33		-0.98	*
CSP34		-17.18	47.04
CSP35		7.88	*
CSP36		-34.08	280.63
CSP37		-54.24	211.64
CSP38	**PORT AREA**		
CSP39			
CSP40			
CSP41	**NORTH OF PORT**	-11.70	209.25
CSP42		*	253.89
CSP43		-2.75	122.87
CSP44		-2.14	267.03
CSP45			-68.37
CSP46			232.76
CSP47			147.9
CSP48			207.64
CSP49			204.12
CSP50			170.04
CSP51		-15.99	145.13
CSP52		-2.17	98.46
CSP53		-0.82	93.73
CSP54			51.35
CSP55			106.47
CSP56			74.97
CSP57			-9.13
CSP58			36.89
CSP59			119.61
CSP60			97.45
CSP61			12.71
CSP62			191.09
CSP63			131.41
CSP64			-59.58
CSP65			-59.95

CSP66		2.07	-14.21
CSP67			56.43
CSP68			7.67
CSP69		14.2	38.32
CSP70		-11.27	92.19
CSP71		10.86	115.29
CSP72		-4.46	304.31
CSP73		-9.56	77.82
CSP74		-22.98	263.14
CSP75		-4.47	190.31
CSP76		-6.09	110.46
CSP77		-14.39	137.92
CSP78		1.7	145.7
CSP79			157.48
CSP80		11.13	105.99
CSP81		-7.22	151.25

4.2 Results for Shoreline Change Analysis from Satellite images

In the previous submitted Annual report for the period October 2020 to September 2021, the results for the monthly, seasonal and annual shoreline change analysis using beach profiles and satellite images were carried out and presented. This report provides the shoreline change over the period from October 2021 to September 2022.

4.2.1 Monthly and overall Shoreline Change from October 2021 to September 2022

The monthly shoreline change analysis from October 2021 to September 2022 has been shown in Figures 4.26 to

The monthly shoreline change analysis carried out using high resolution satellite images of less than 1m spatial resolution for October 2021 has been presented in the **Figure 4.26**. Most of the coast indicates erosion from Thumba to Shangumugam (CSP 68), Valliyathura (CSP 66) and Punthura to Pannathura (CSP 51-53), Adimalathura to Poovar indicates erosion and accretion at Mullur (CSP 36-37) and Paruthiyoor for October 2021.

The monthly shoreline change analysis for November 2021using Sentinel images is shown in **Figure 4.27**. The shoreline change analysis map shows accretion at most of the locations such as Thumba, Kochuveli, Shangumugham, Mullur to Poovar while erosion noted at few sectors of Shangumugam (CSP 68), Valliyathura (CSP 66) and Punthura to Pannathura (CSP 51-53) for November 2021.

The monthly shoreline change analysis using Sentinel images for December 2021 is shown in **Figure 4.28**. The shoreline change analysis map shows that the accretion from Shangumugam to Kovalam (CSP 41-68), Karumkulam and Poovar (CSP15-25) while erosion is noticed at few sectors of Kochuveli, Punthura (CSP 51), Mullur (CSP 36-37), Adimalathura (CSP 31-34), Pulluvila (CSP 27-30) and Poovar (CSP 18-19) for December 2021.

In shoreline change analysis for the month of January 2022 (**Figure 4.29)**, the erosion is noticed at Shangumugham, Valliyathura, Punthura, Poovar and accretion at Kochuveli, Adimalathura, Paruthiyoor and Edapadu beach.

In February 2022, the erosion is noticed at Kochuveli, Shangumugham and Valliyathura while all other locations indicate accretion shown in **Figure 4.30.**

The monthly shoreline change analysis for March 2022 indicates erosion at Thumba, Kochuveli, Valliyathura, Beemapally, Punthura, Mullur, Adimalathura, Pulluvila, Karumkulam and Edapadu beach while accretion at north of Kochuveli and Poovar shown in **Figure 4.31**.

The monthly shoreline change analysis for April 2022 indicates erosion at Kochuveli, Valliyathura, Cheriyathura, Adimalathura and Pulluvila to Poovar shown in **Figure 4.32**.

The monthly shoreline change analysis for May 2022 exhibits erosion at Shangumugham, Pannathura, Adimalathura while accretion at Thumba to Kochuveli, Cheriyathura, Punthura, Mullur, Poovar and Edapadu beach shown in **Figure 4.33**.

For June 2022, the shoreline change analysis shows accretion from Thumba to Shangumugham, Valliyathura, Punthura, Adimalathura to Paruthiyoor while erosion occurs at Cheriyathura and Mullur (**Figure 4.34)**

For July 2022, the shoreline change analysis shows erosion from Thumba to Valliyathura, Adimalathura to Karumkulam and Edapadu beach while accretion at Cheriyathura, Pannathura and Poovar (**Figure 4.35)**

The monthly shoreline change analysis for August 2022 indicates accretion from Thumba to Valliyathura, Adimalathura to Karumkulam while erosion at Punthura to Pannathura, Poovar and Edapadu beach as shown in **Figure 4.36**.

The monthly shoreline change analysis for September 2022 indicates erosion at Thumba, Kochuveli, Shangumugham, Valliyathura, Punthura, Adimalathura to Paruthiyoor while accretion at Mullur and North of Poovar as shown in **Figure 4.37**.

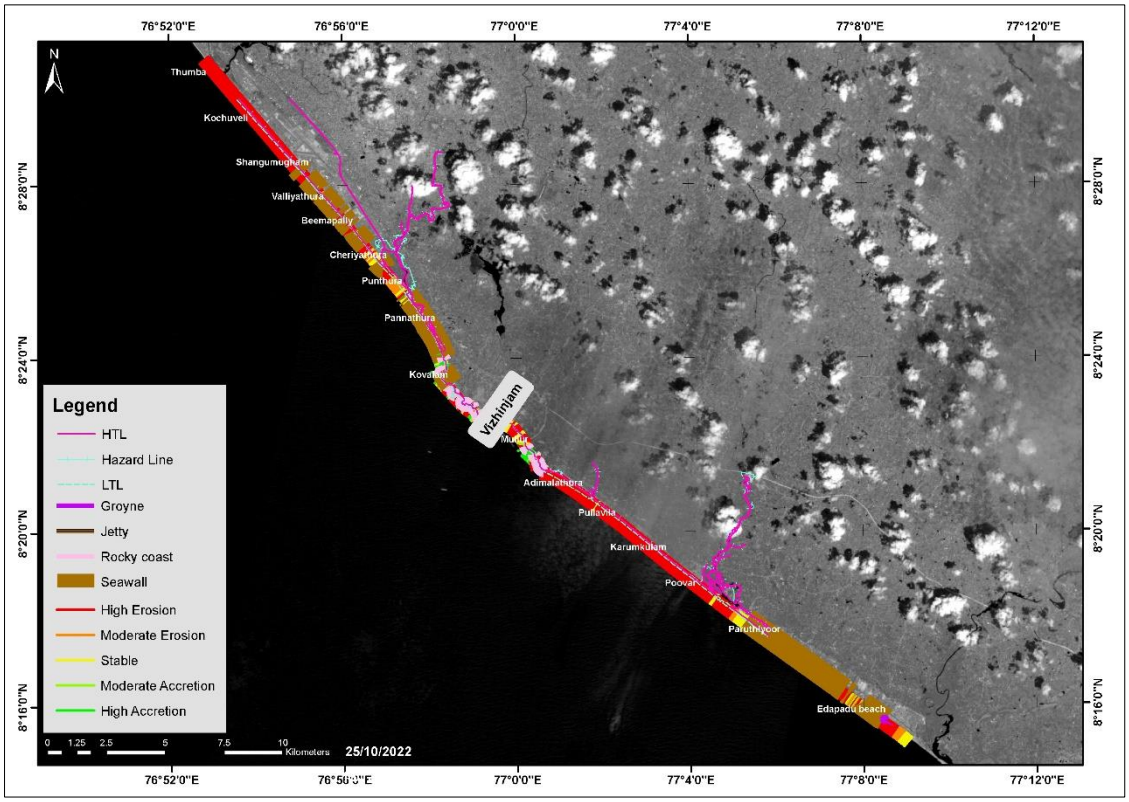


Figure 4.26 Shoreline Change Map -October 2021

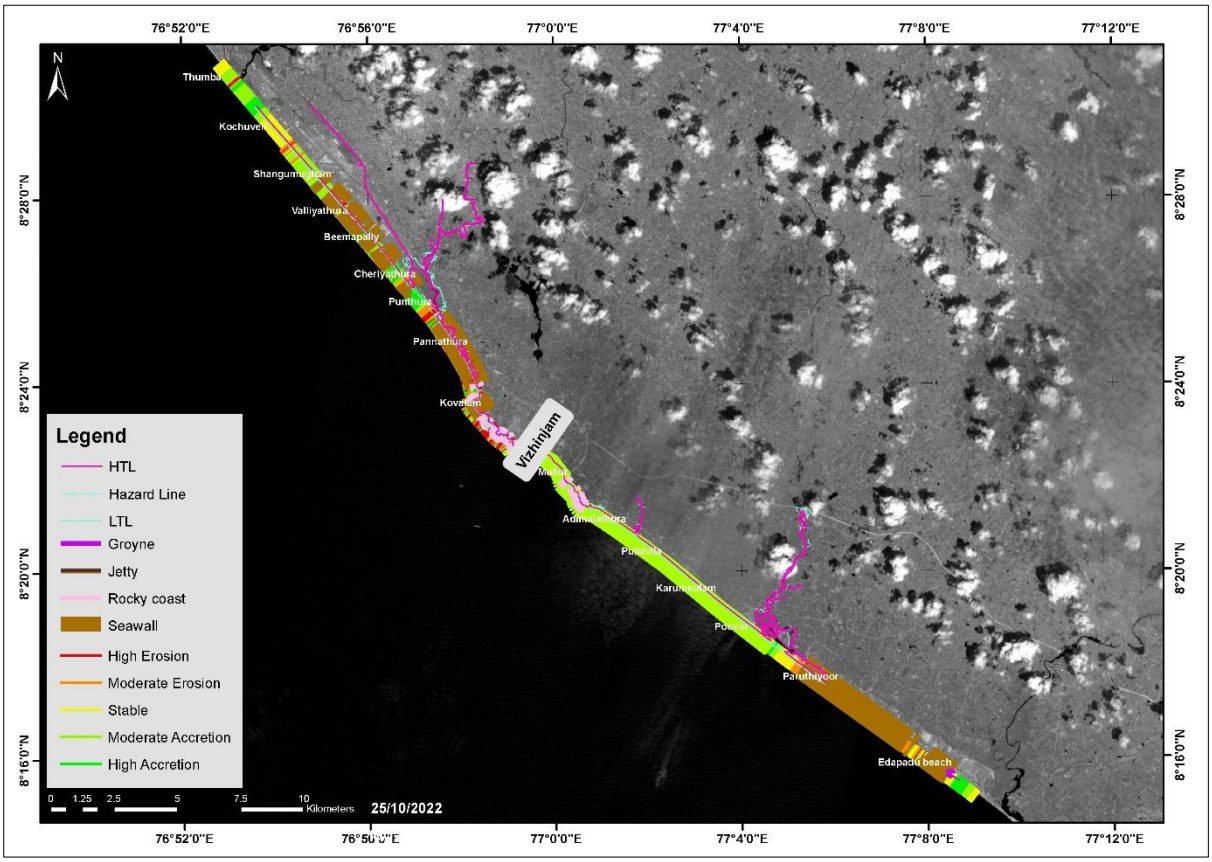


Figure 4.27 Shoreline Change Map - November 2021

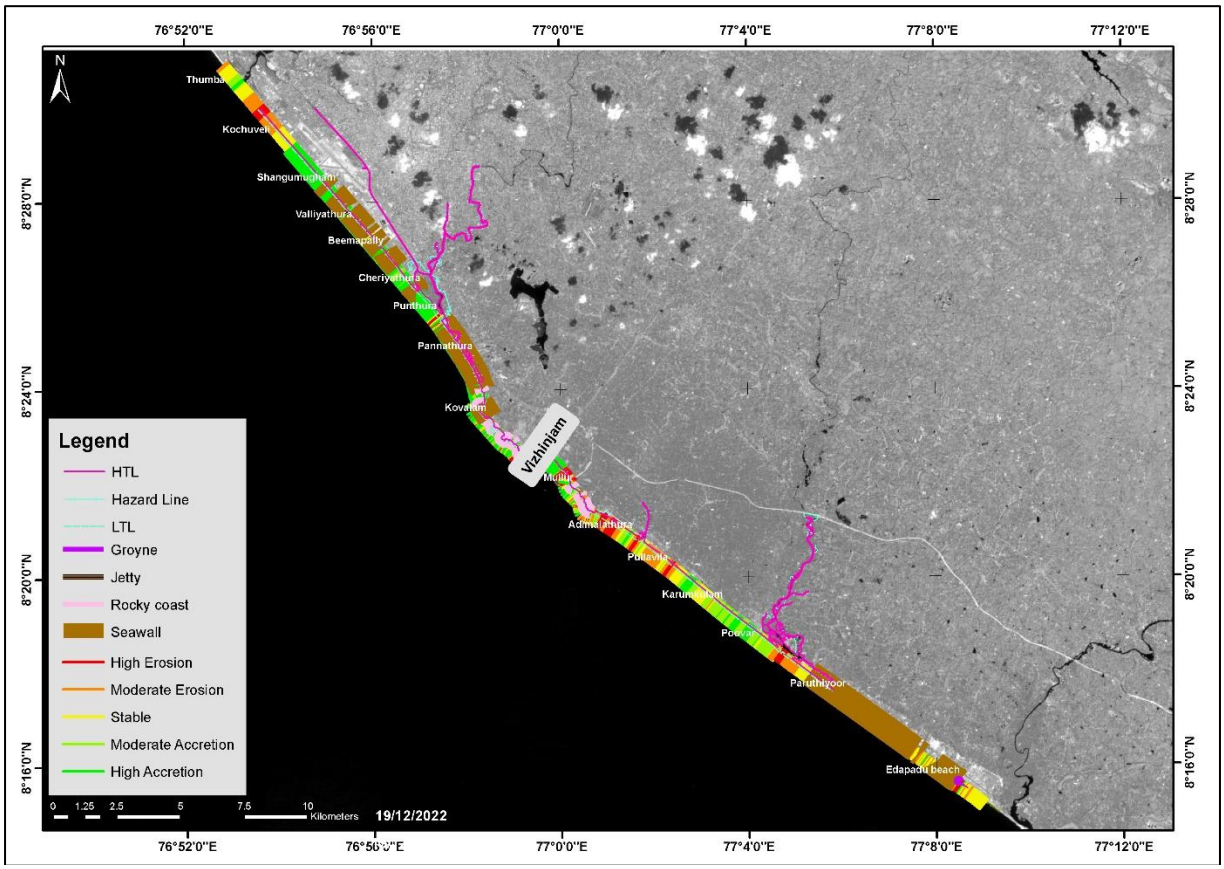


Figure 4.28 Shoreline Change Map - December 2021

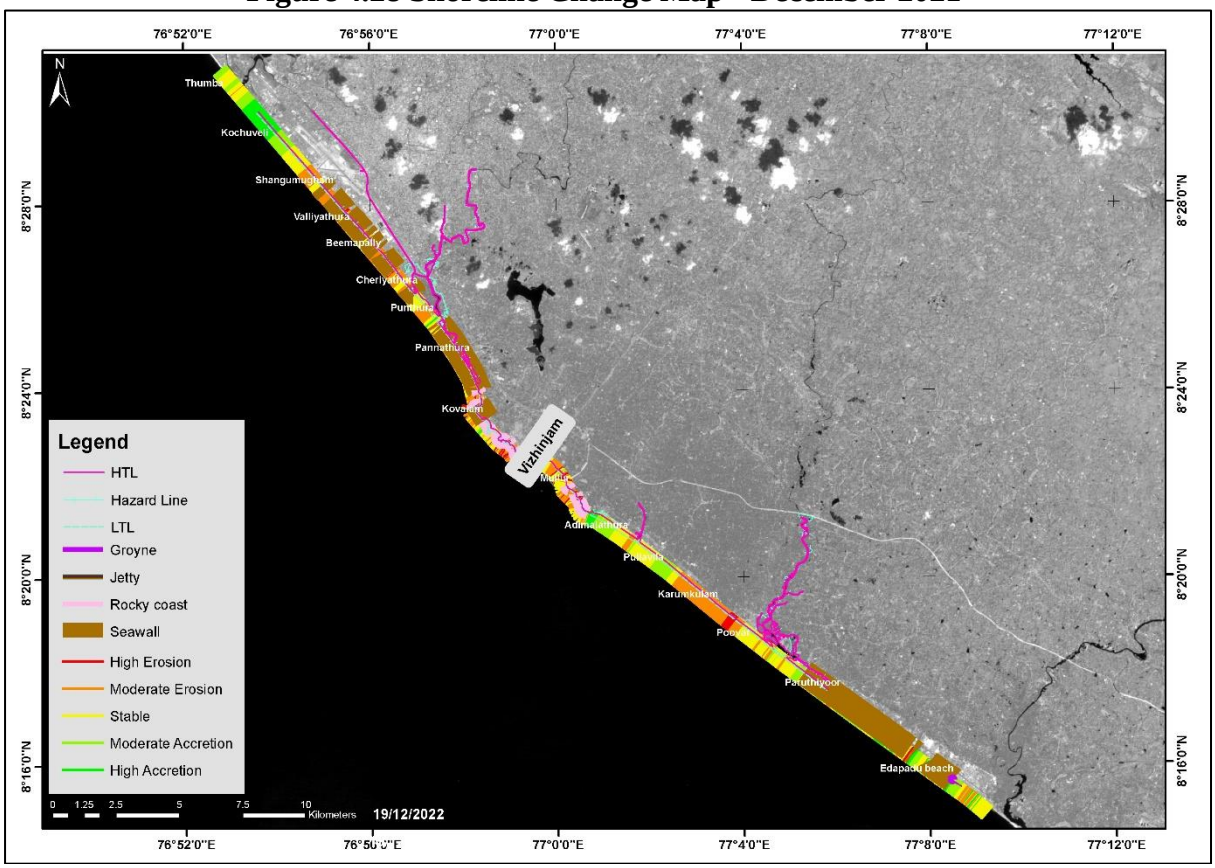


Figure 4.29 Shoreline Change Map - January 2022

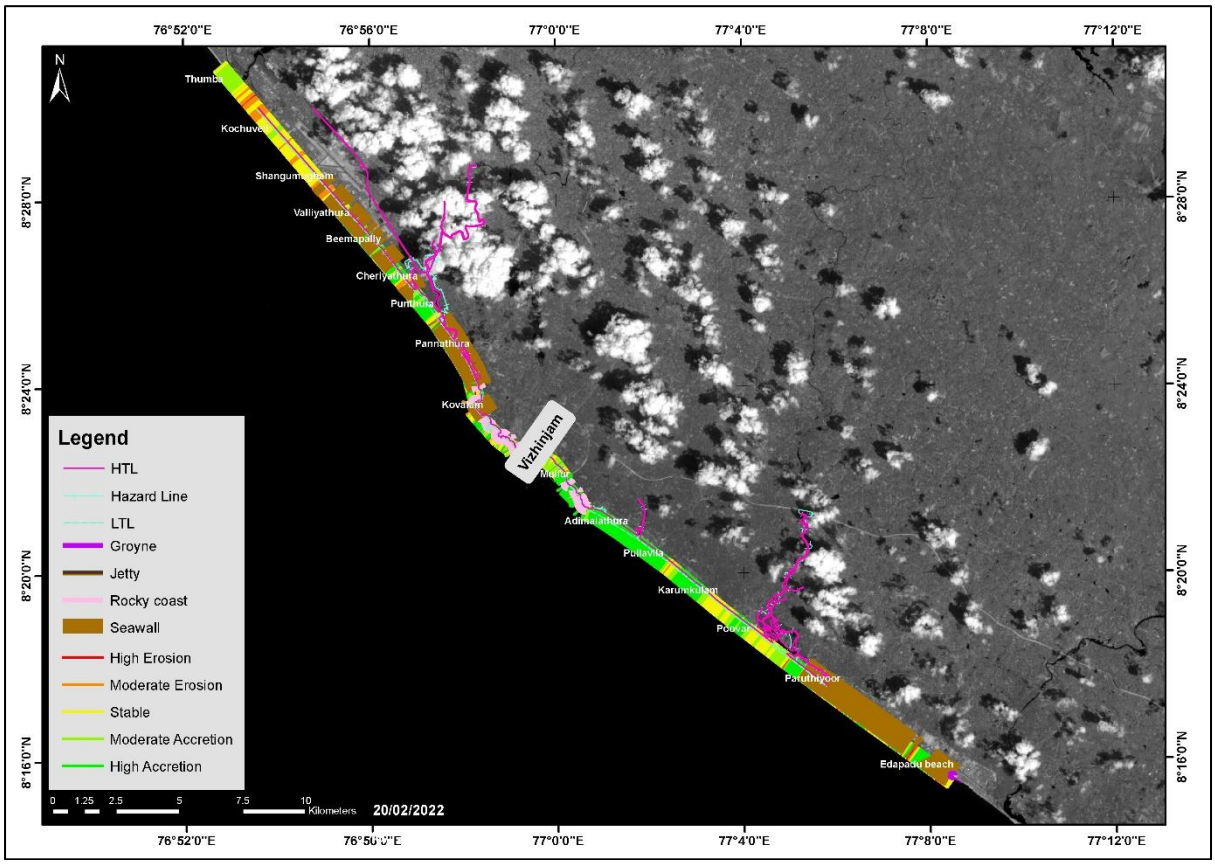


Figure 4.30 Shoreline Change Map - February 2022

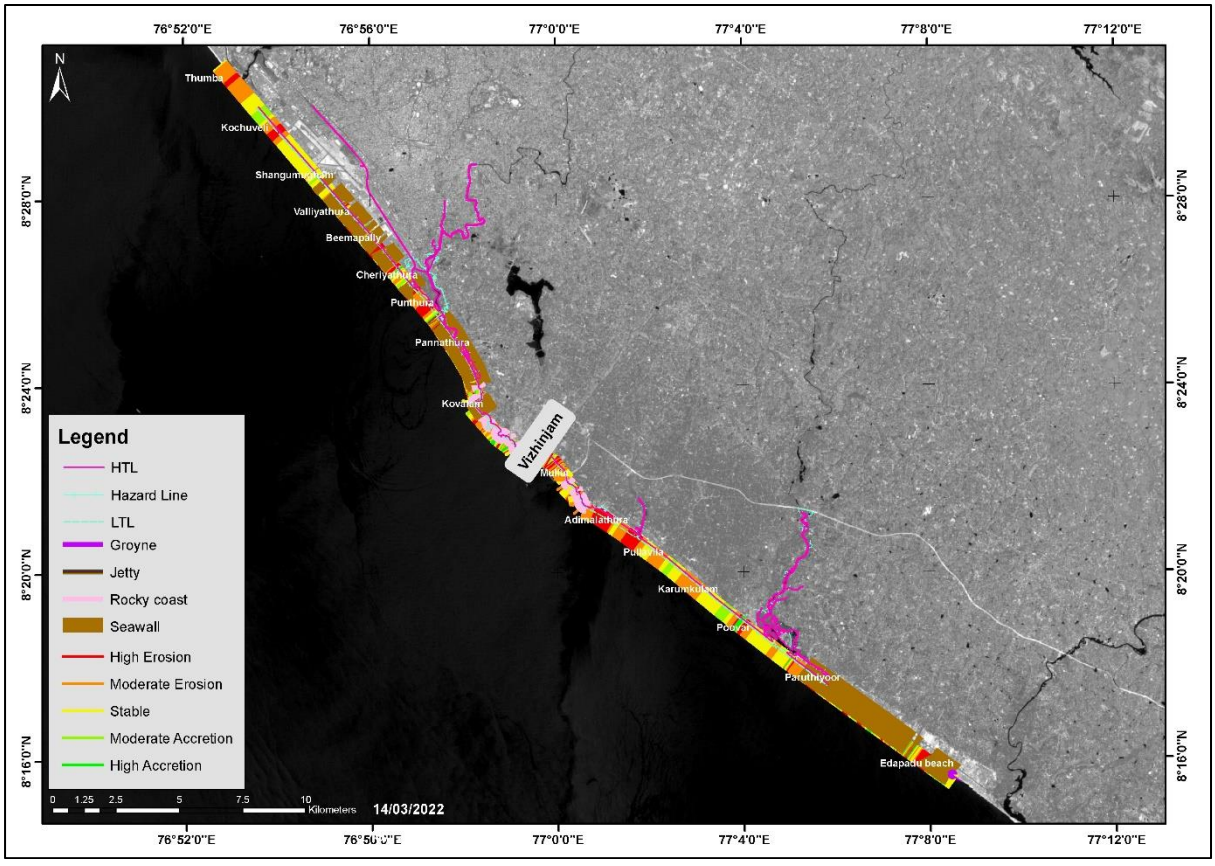


Figure 4.31 Shoreline Change Map - March 2022

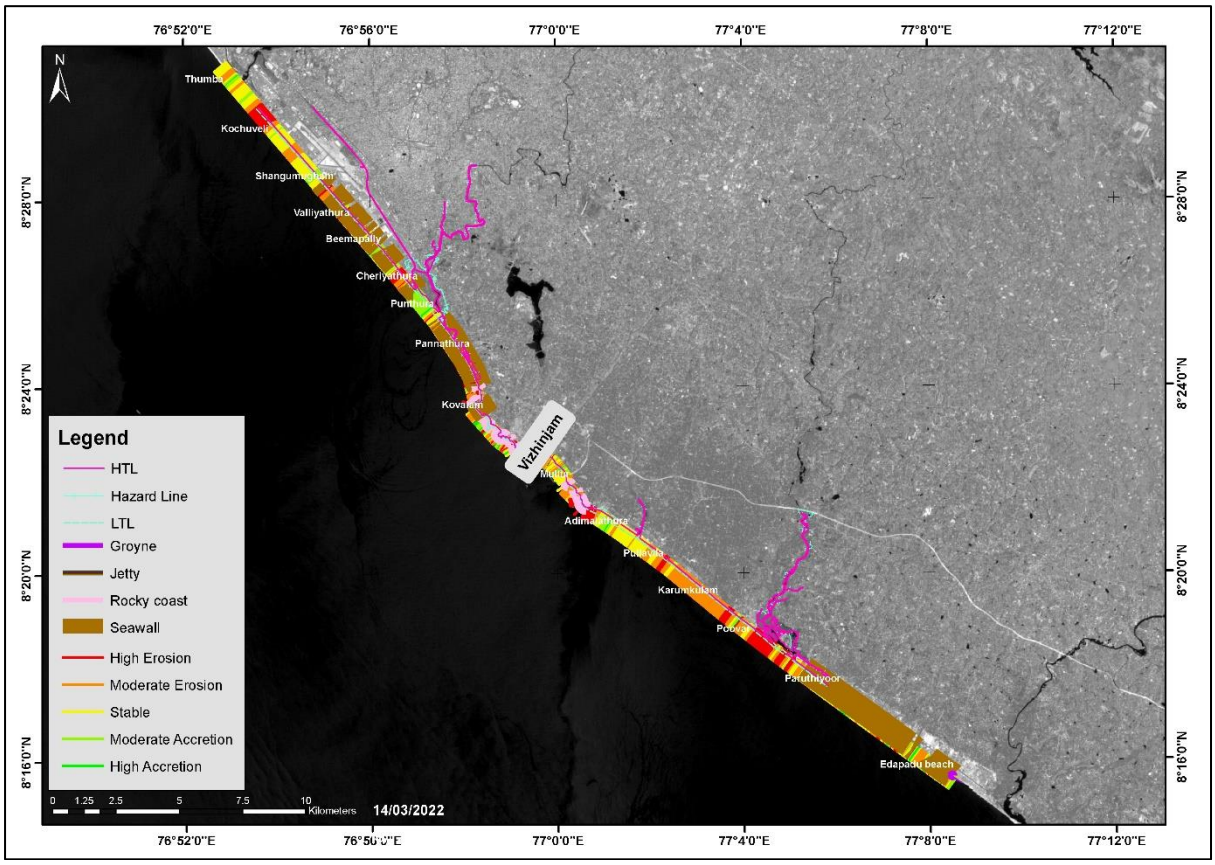


Figure 4.32 Shoreline Change Map - April 2022

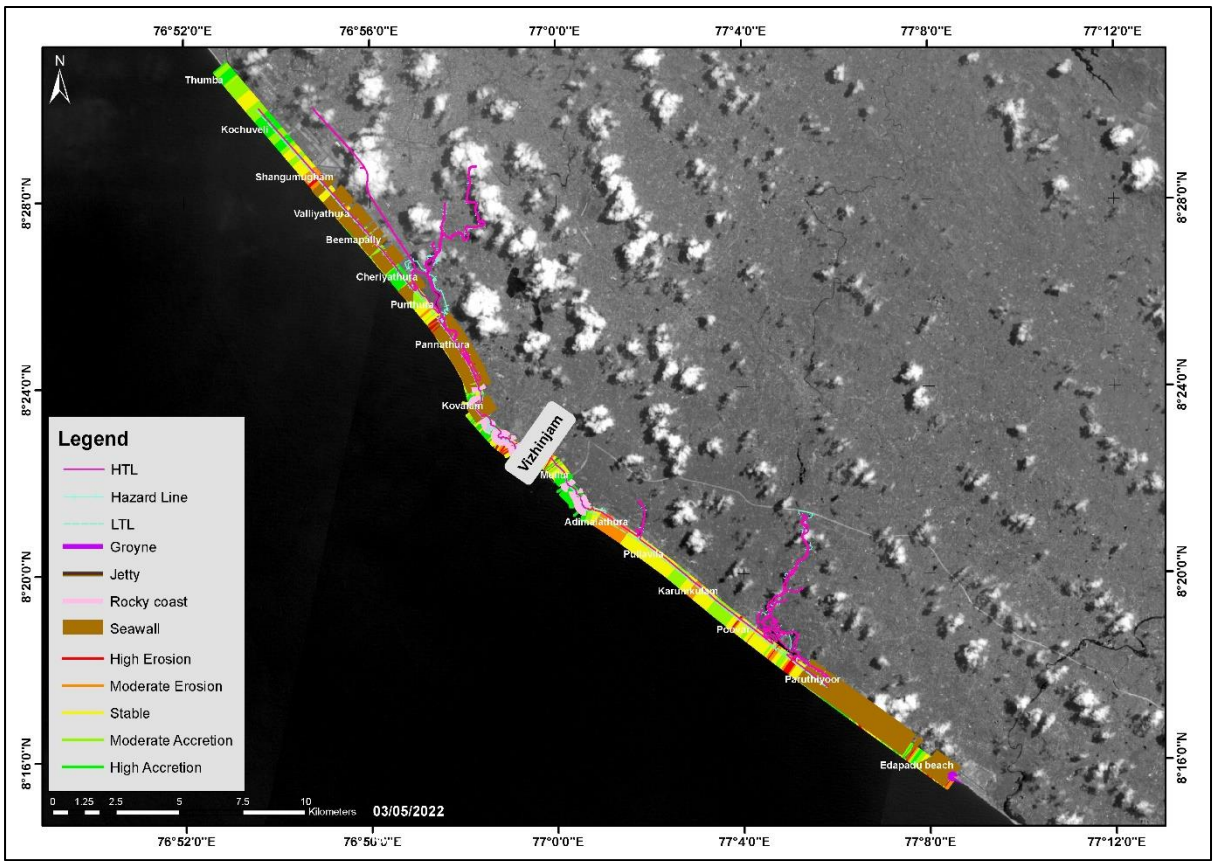


Figure 4.33 Shoreline Change Map - May 2022

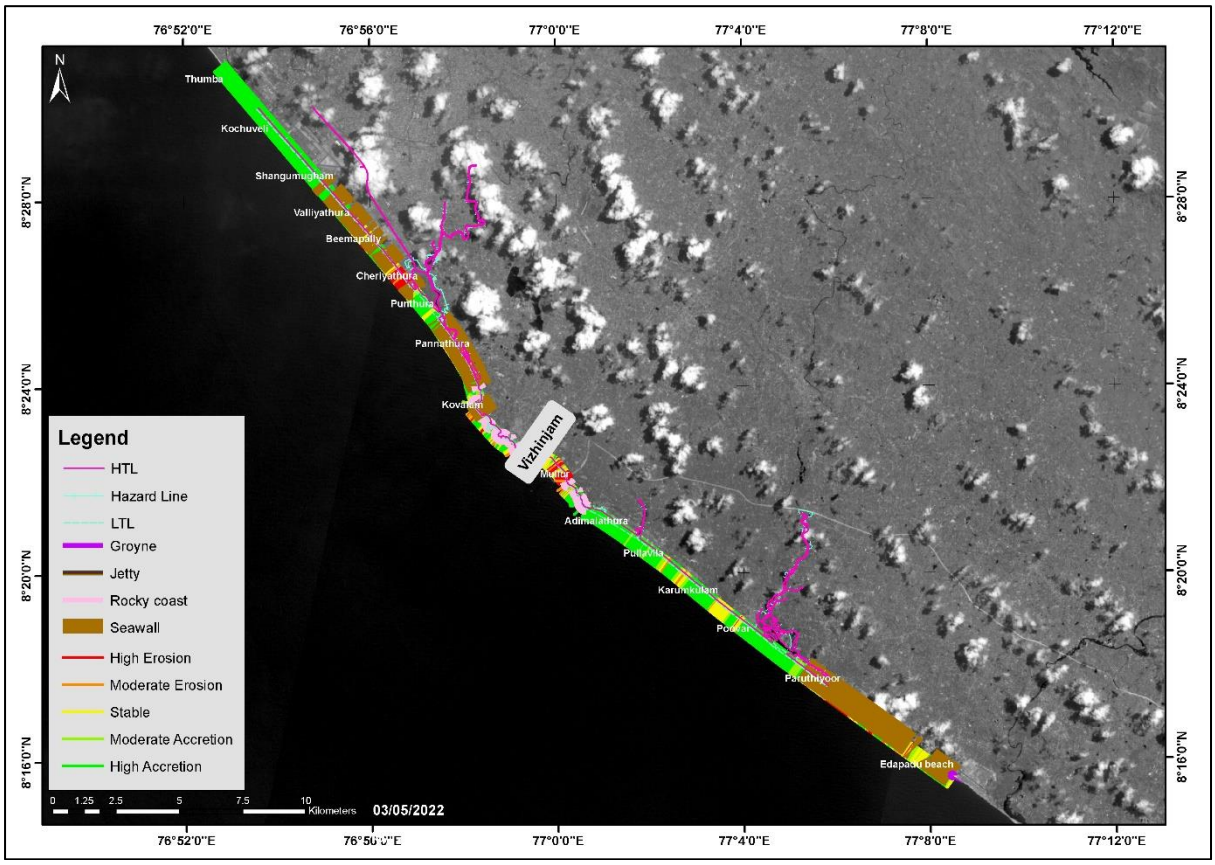


Figure 4.34 Shoreline Change Map - June 2022

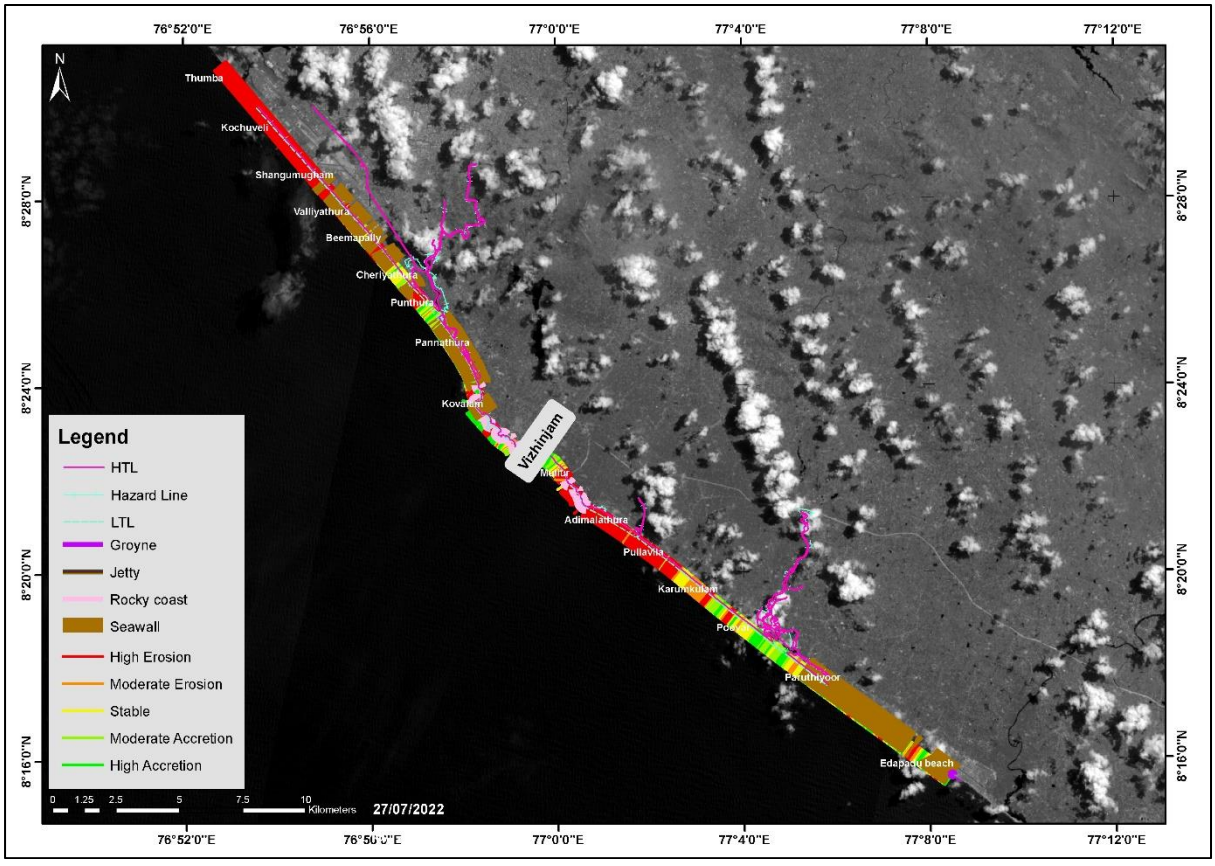


Figure 4.35 Shoreline Change Map - July 2022

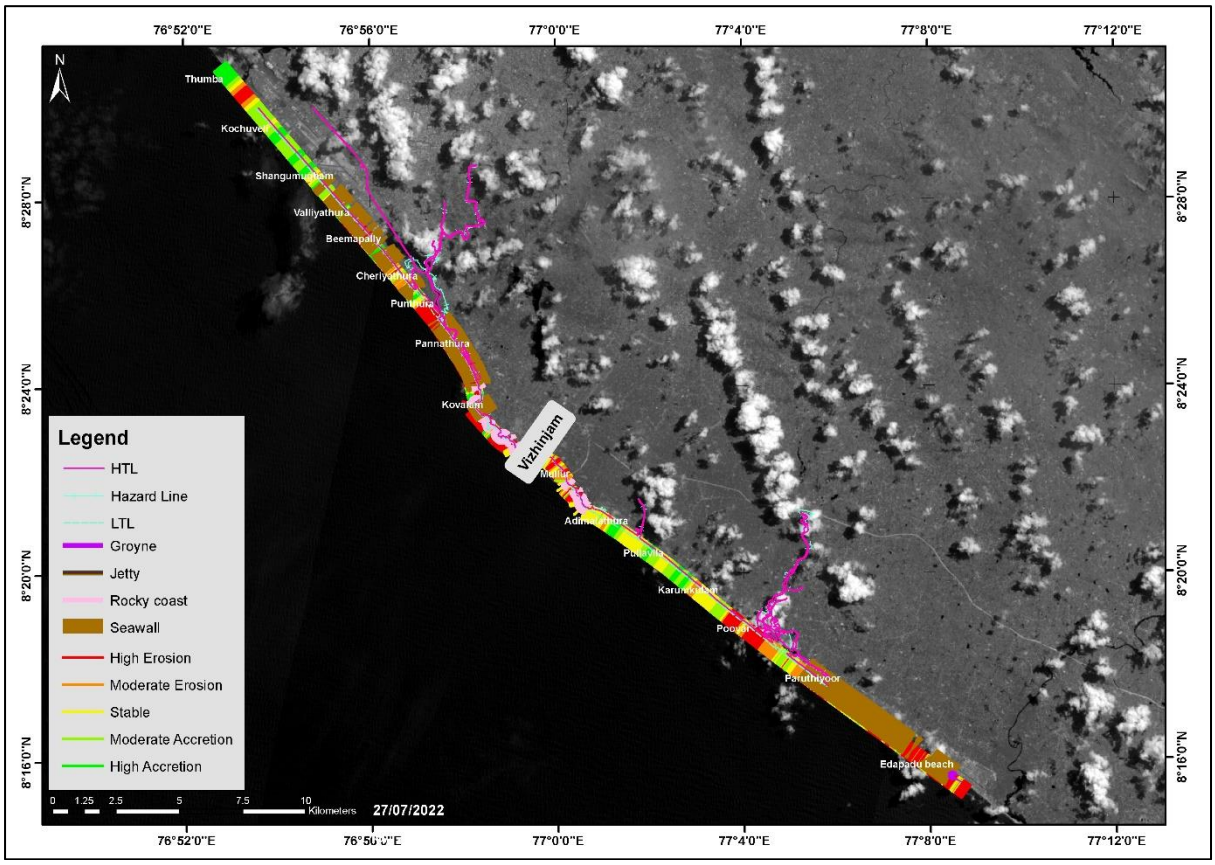


Figure 4.36 Shoreline Change Map - August 2022

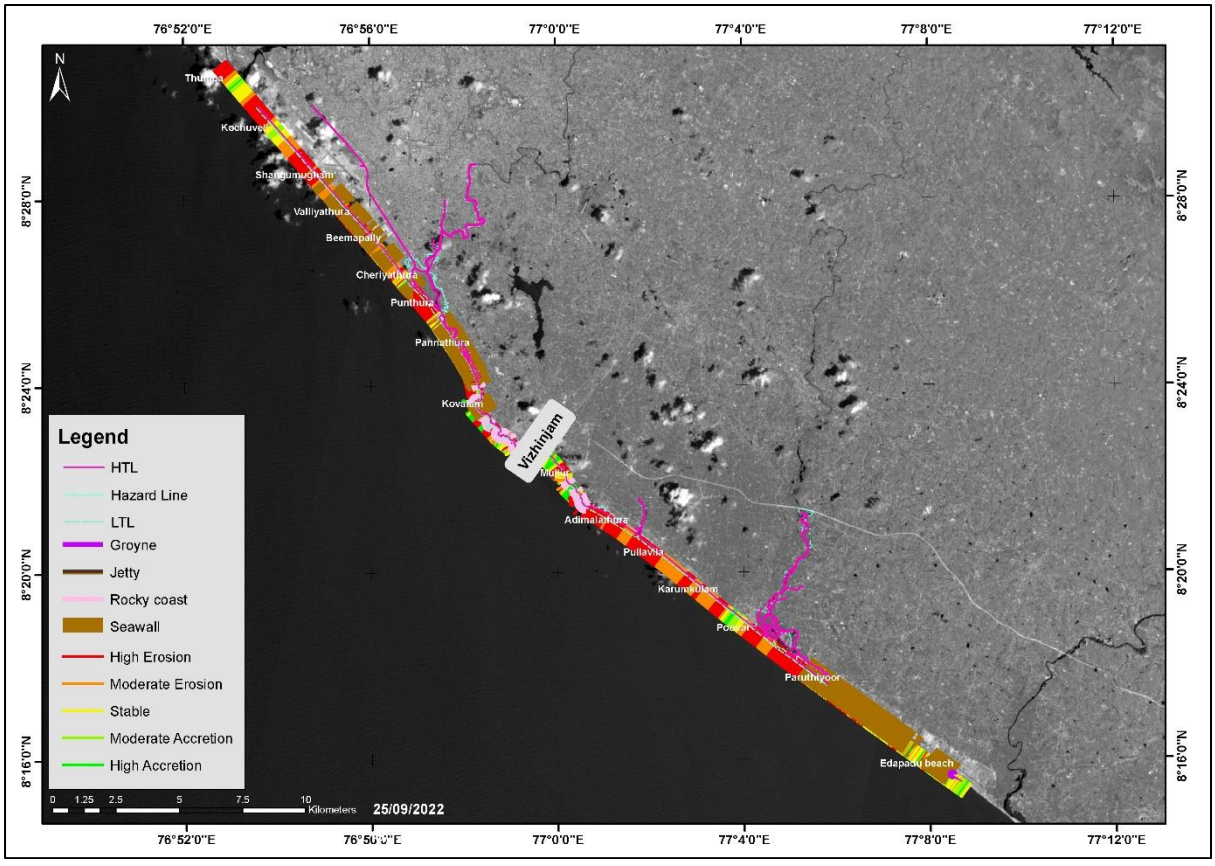


Figure 4.37 Shoreline Change Map –September 2022

4.2.2 Seasonal and Overall Shoreline change analysis from October 2021 to September 2022

The seasonal shoreline change analysis for the post monsoon period 2021 is shown in **Figure 4.38.** The shoreline change analysis map shows accretion at most of the locations while erosion noted at few sectors of Shangumugam (CSP68), and Punthura (CSP53) for the post monsoon period (October 2021 to November 2021).

The seasonal shoreline change analysis for the fair weather period is shown in **Figure 4.39.** The shoreline change analysis map shows accretion at Kochuveli, Adimalathura to Edapadu beach while erosion noted at few sectors of Shangumugam (CSP 68), Valliyathura (CSP 66), Mullur and Punthura (CSP 51-53) for the fair weather period (December 2021 to March 2022).

The seasonal shoreline change analysis for the pre monsoon period is shown in **Figure 4.40.** Pre monsoon period (April 2022 to May 2022) exhibits erosion at Shangumugham, Pannathura, Adimalathura while accretion at Thumba to Kochuveli, Cheriyathura, Punthura, Mullur, Poovar and Edapadu beach

The seasonal shoreline change analysis for the monsoon period is shown in **Figure 4.41.** Monsoon period for 2022 indicates erosion along the coast while stable coast is noticed at Cheriyathura, Mullur, Poovar and Paruthiyoor.

The overall shoreline change map for the period October 2021 to September 2022 shown in **Figure 4.42**. Erosion is noticed at Thumba to Kochuveli, Valliyathura (CSP 64,66), Punthura (CSP51-53), Mullur (CSP 37), few sectors north of Adimalathura (CSP 35), Poovar (CSP16) and Edapadu beach (CSP2) while accretion is noticed at Shangumugam (CSP 69-71), Adimalathura to Poovar (CSP 22-34) for the period October 2021 to September 2022.

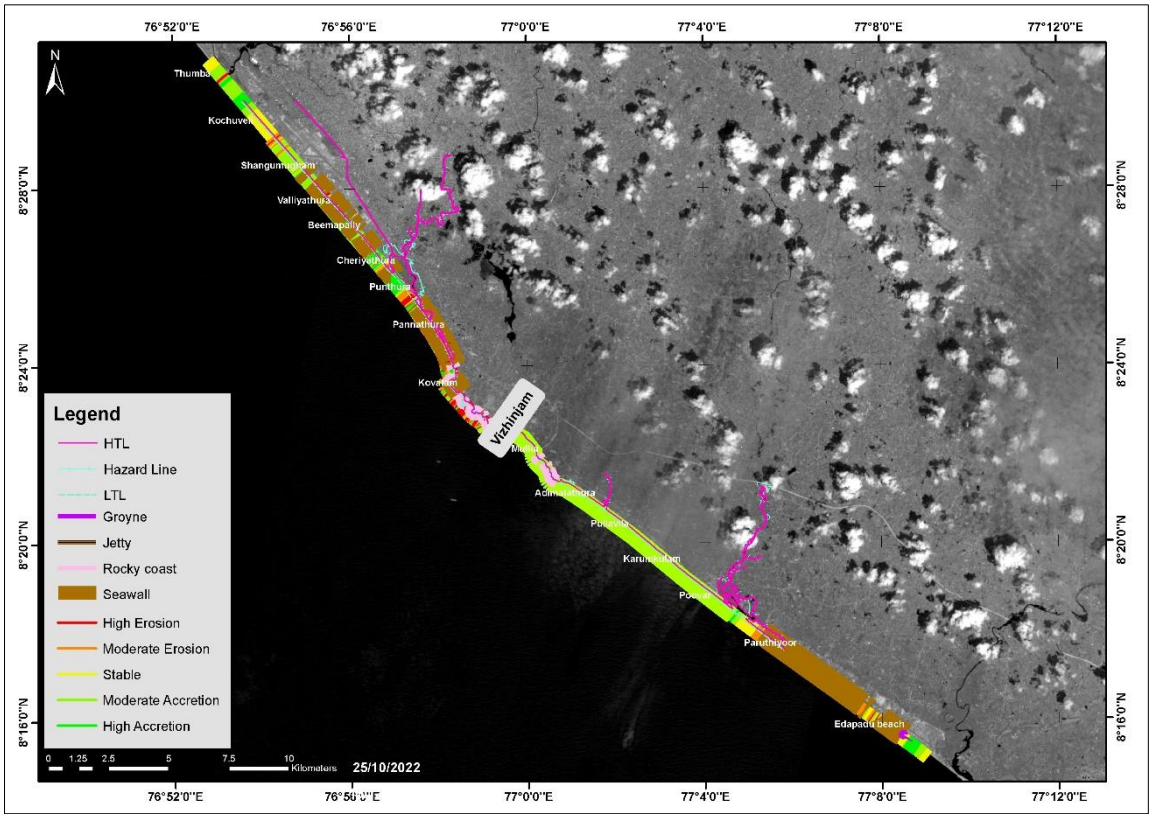


Figure 4.38Shoreline Change Analysis - Post Monsoon Period (October 2021 – November 2021)

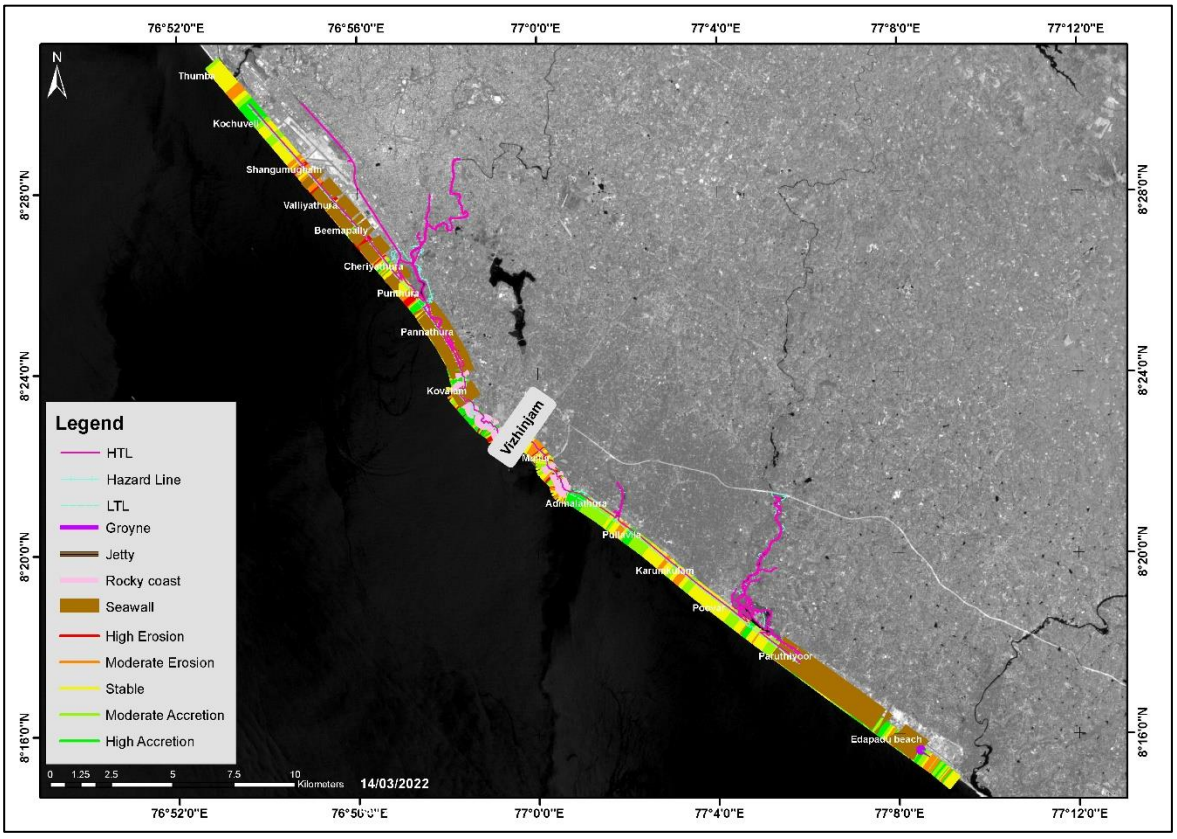


Figure 4.39Shoreline Change Analysis - Fair weather Period (December 2021 - March 2022)

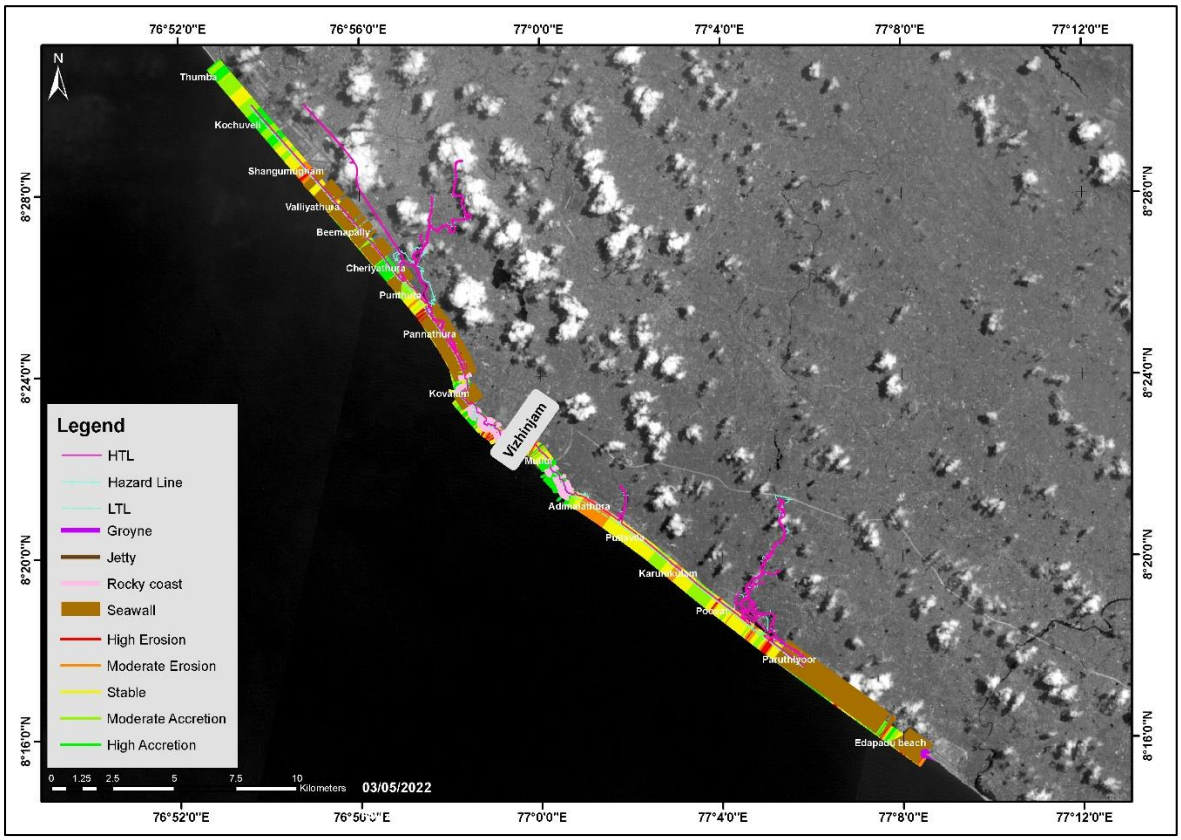


Figure 4.40Shoreline Change Analysis – Pre-Monsoon Period (April 2022-May 2022)

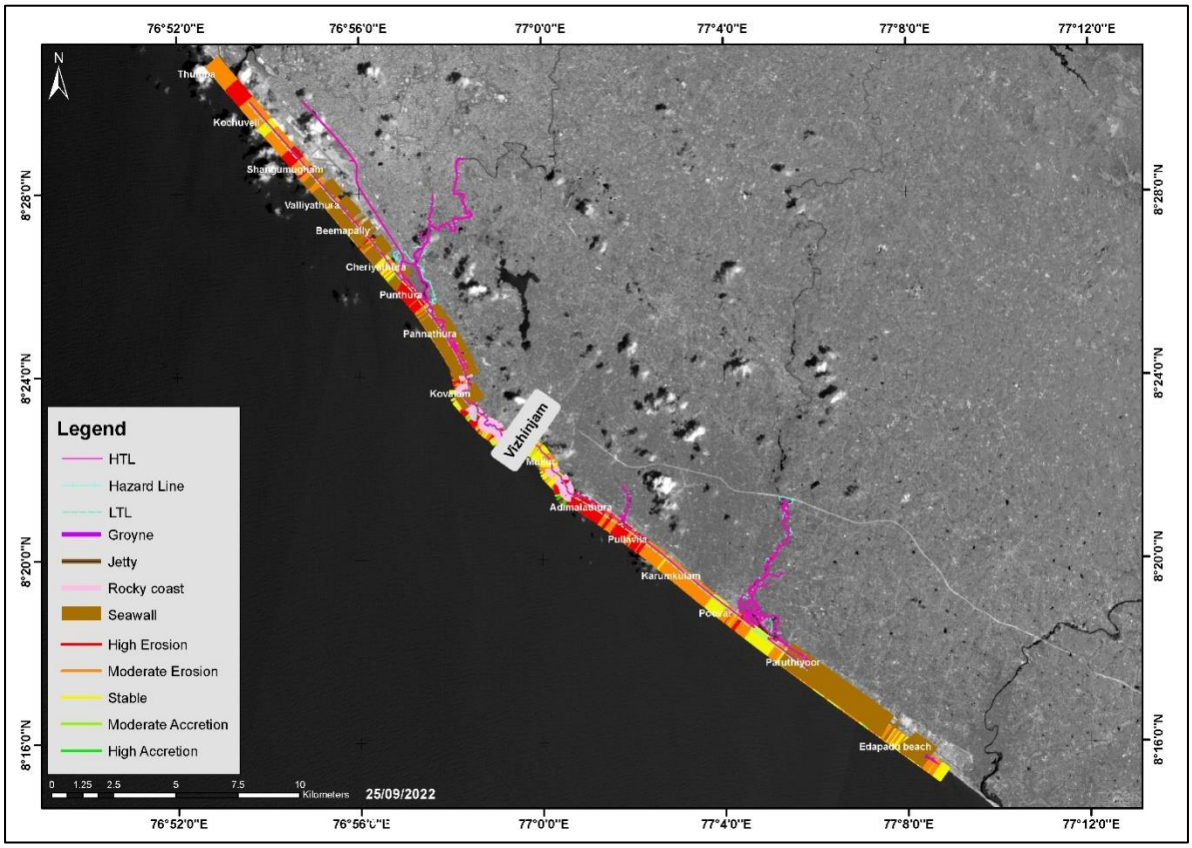


Figure 4.41Shoreline Change Analysis - Monsoon Period (June 2022 – September 2022)

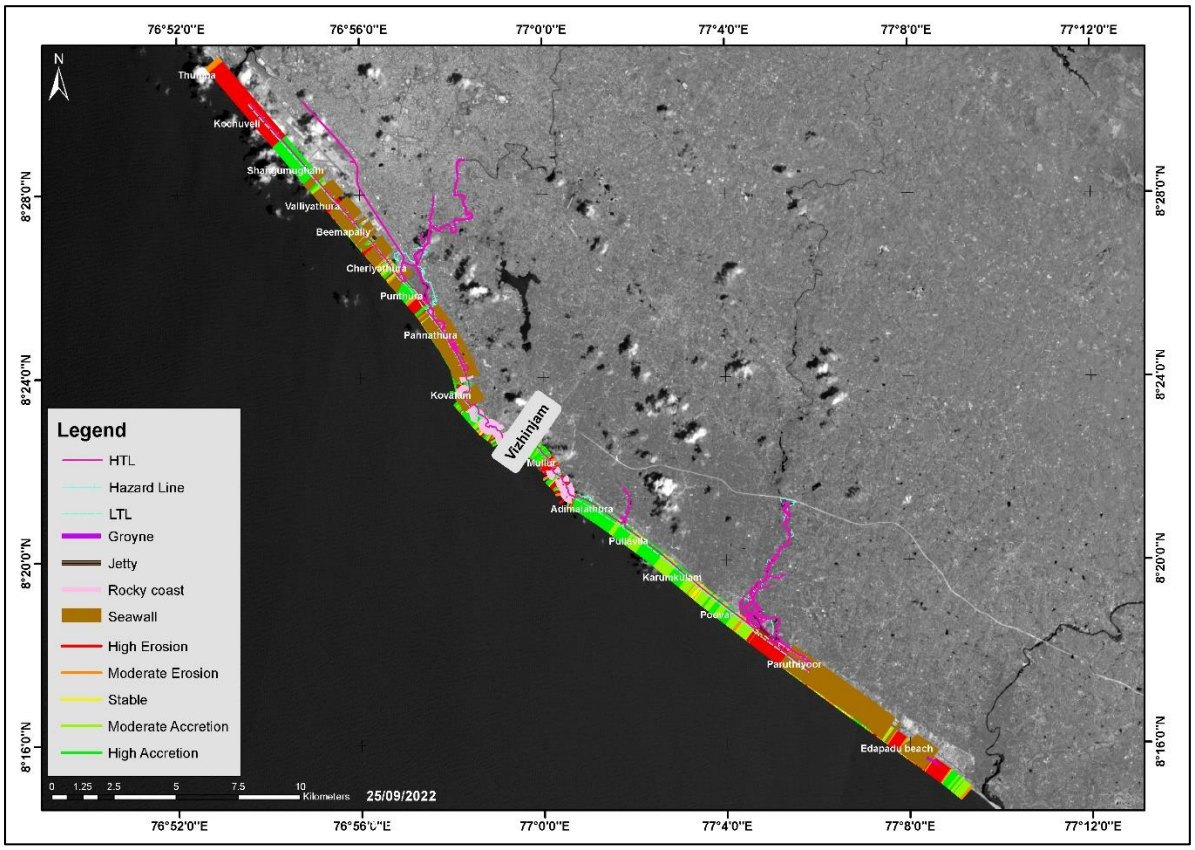


Figure 4.42 Overall Shoreline Change Map for October 2021- September 2022

4.2.3 Shoreline comparison for the period October 2020-September 2021 and October 2021- September 2022

Shoreline comparison between October 2020 and October 2021

The shoreline change has been compared between the October 2020 and October 2021shown in **Figure 4.43**Accretion is noticed at Cheriyathura (CSP 57), Kovalam to Poovar (CSP 17-44) while erosion is noticed at Shangumugam (CSP 68) and Valliyathura (CSP 66).

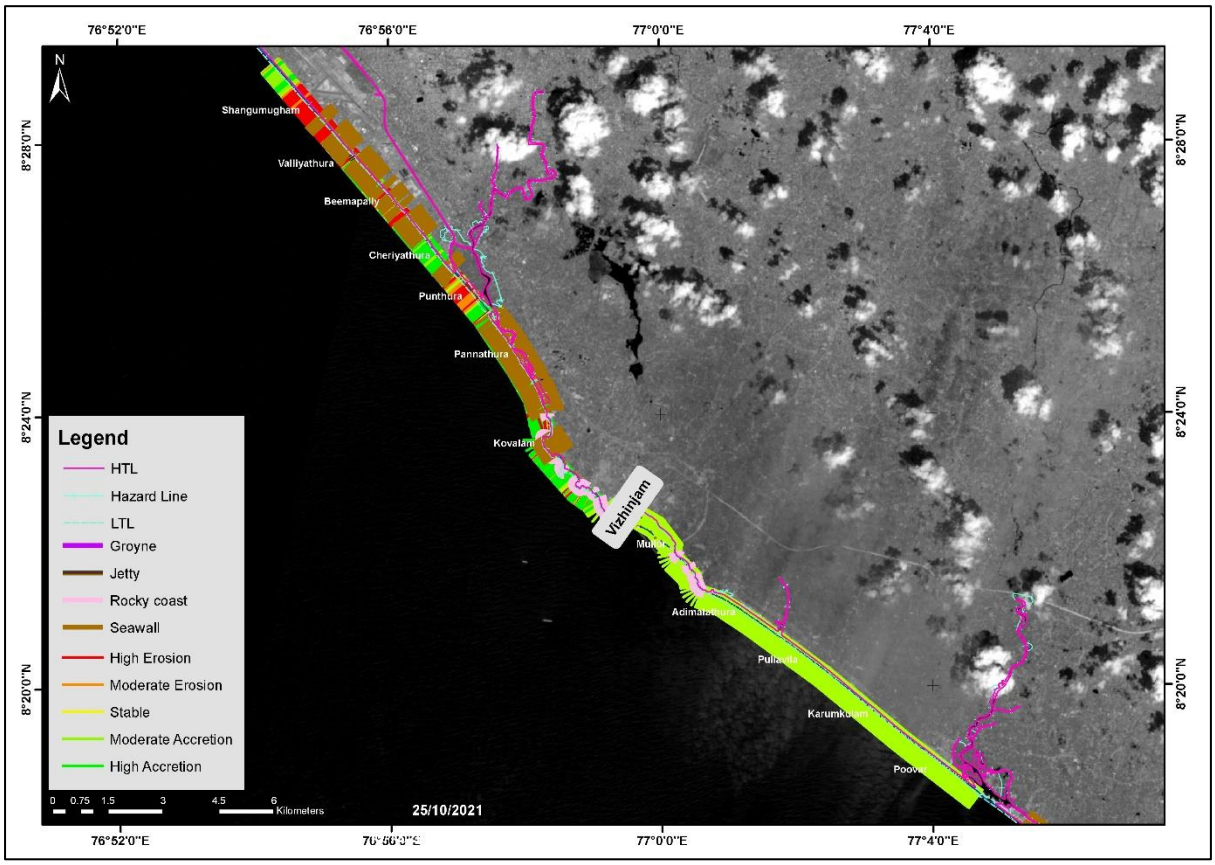


Figure 4.43 Shoreline Change Map –October 2020 and October 2021

Shoreline comparison between January 2021 and January 2022

The shoreline change has been compared between the January 2021 and January 2022 shown in **Figure 4.44**. Accretion is noticed at Valliyathura (CSP 66), Cheriyathura (CSP 61) and Mullur (CSP37) while erosion is noticed at Shangumugam (CSP 68) and Punthura (CSP 53) for the shoreline change comparison between January 2021 and January 2022. The shoreline coverage (without cloud) is from Shangumugam up to Mullur only due to very high resolution (0.5m and 1m) images.

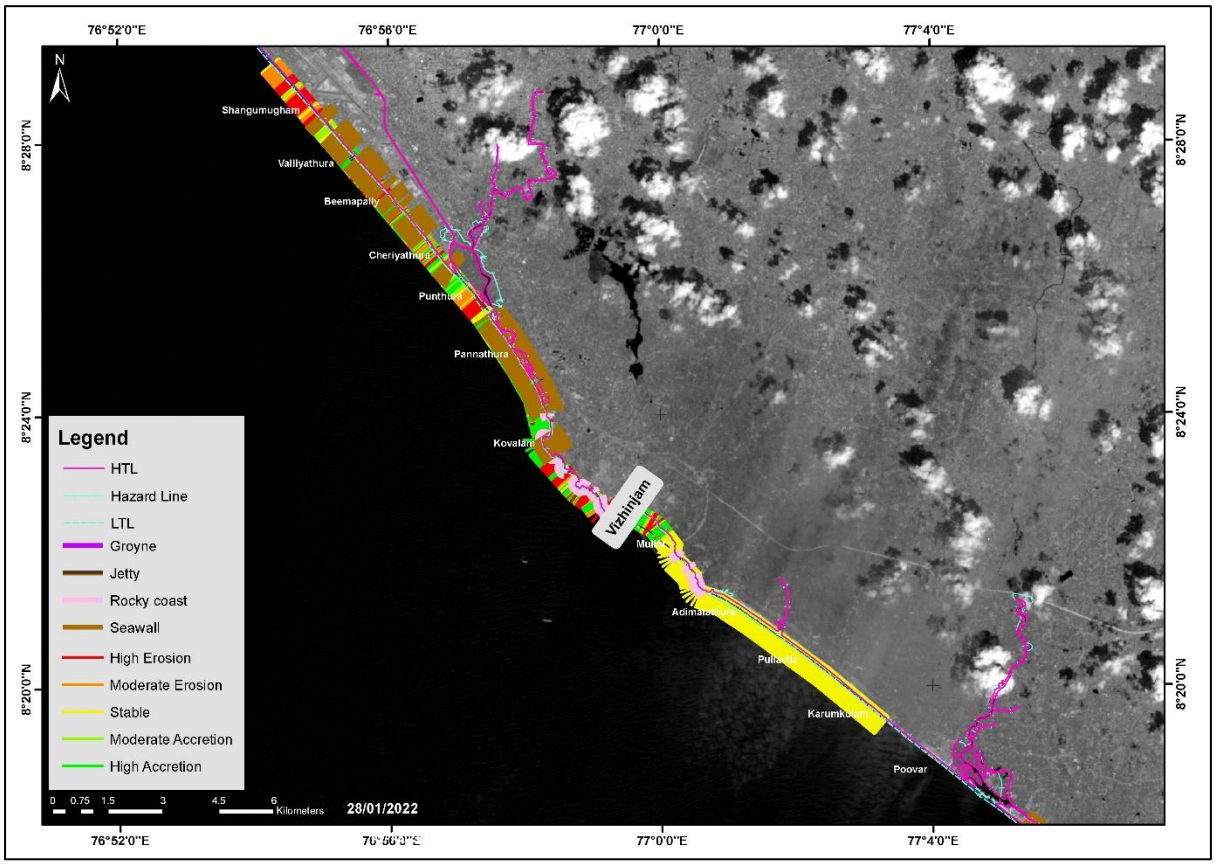


Figure 4.44 Shoreline Change Map –January 2021 and January 2022

Shoreline comparison between April 2021 and April 2022

The shoreline change has been compared between the April 2021 and April2022 shown in **Figure 4.45**. Accretion is noticed at Shangumugam (CSP 68) and Punthura (CSP 53), Valliyathura (CSP 66), while erosion is noticed at Adimalathura to Karumkulam, south of Poovar.

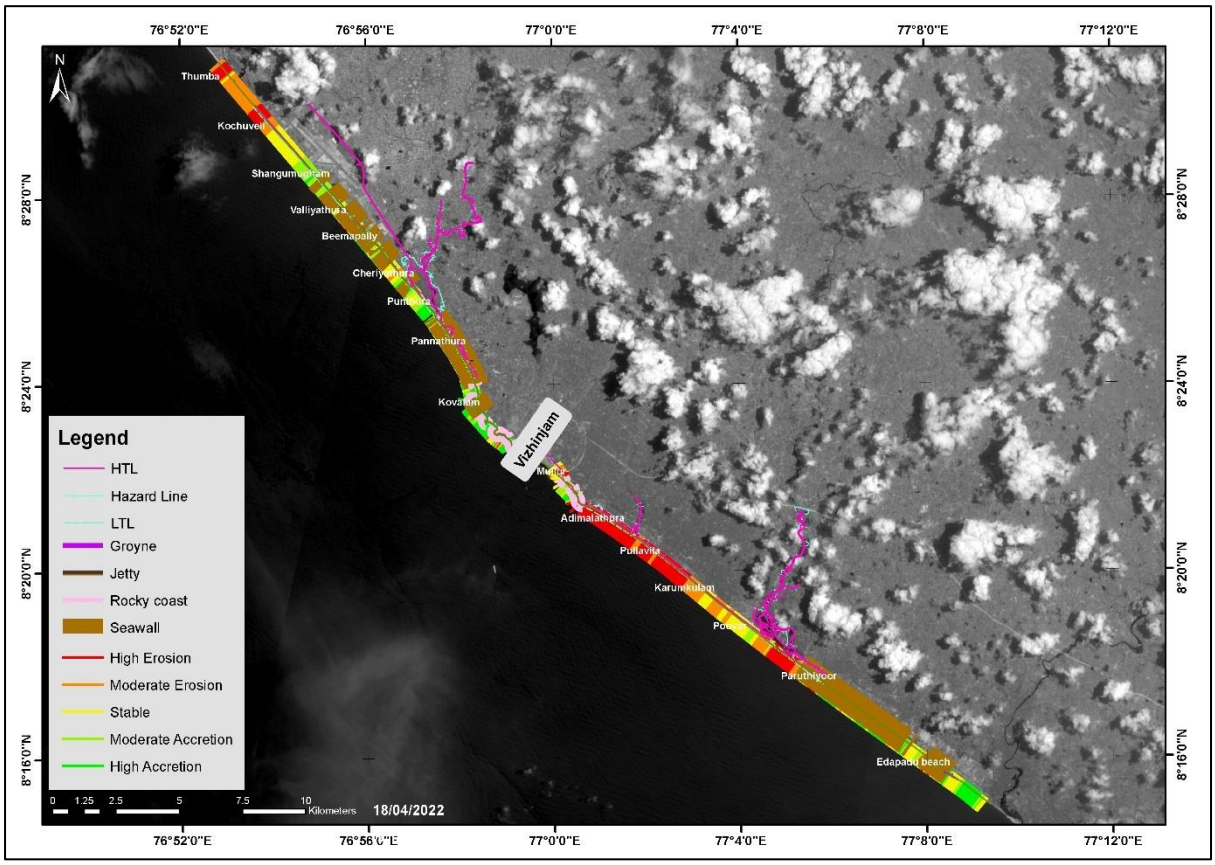


Figure 4.45 Shoreline Change Map –April 2021 and April 2022

Shoreline comparison between September 2021 and September 2022

The shoreline change has been compared between the September 2021 and September2022 shown in **Figure 4.46**. Accretion is noticed at Kovalam and Mullur while all other locations exhibit erosion at Thumba, Shangumugam (CSP 68), Valliyathura (CSP 66), Punthura (CSP 53), Adimalathura to Poovar.

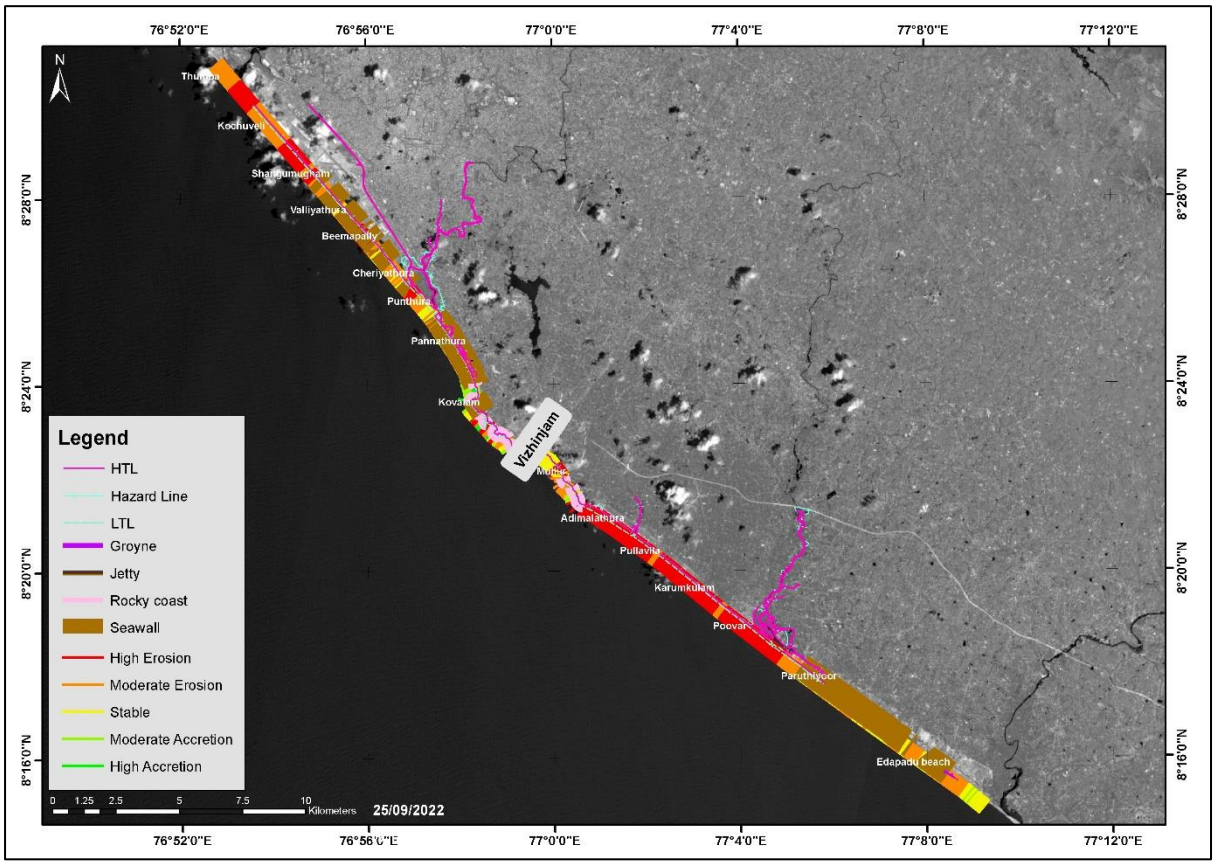


Figure 4.46 Shoreline Change Map –September 2021 and September 2022

4.2.4 Shoreline Change comparison before and after 2015 using high resolution satellite data

The shoreline change comparison of February 2011 with January 2015 has been carried out (Figure 4.47) using high resolution images of 1m spatial resolution (Worldview-multispectral sensor). The result from the analysis indicates erosion at Punthura, Karumkulam and Paruthiyoor.

The comparison of January 2015 shoreline with January 2022 using high resolution satellite images has been presented in the Figure 4.48. The comparison shows erosion at Thumba, Valliyathura, Adimalathura while Kochuveli, Mullur, Paruthiyoor and Edapadu beach shows accretion and stable at Cheriyathura, Punthura and Pulluvila to Poovar.

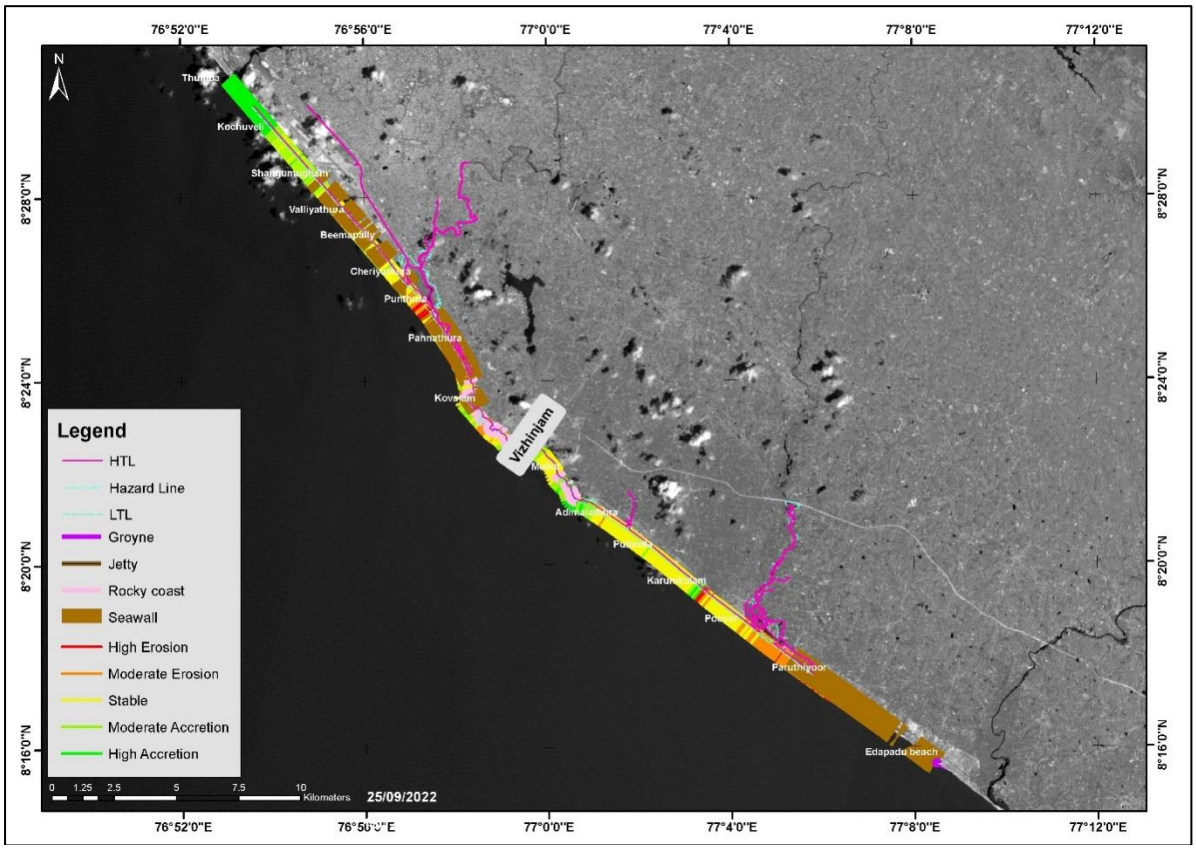


Figure 4.47 Shoreline Change Comparison- 2011 to 2015

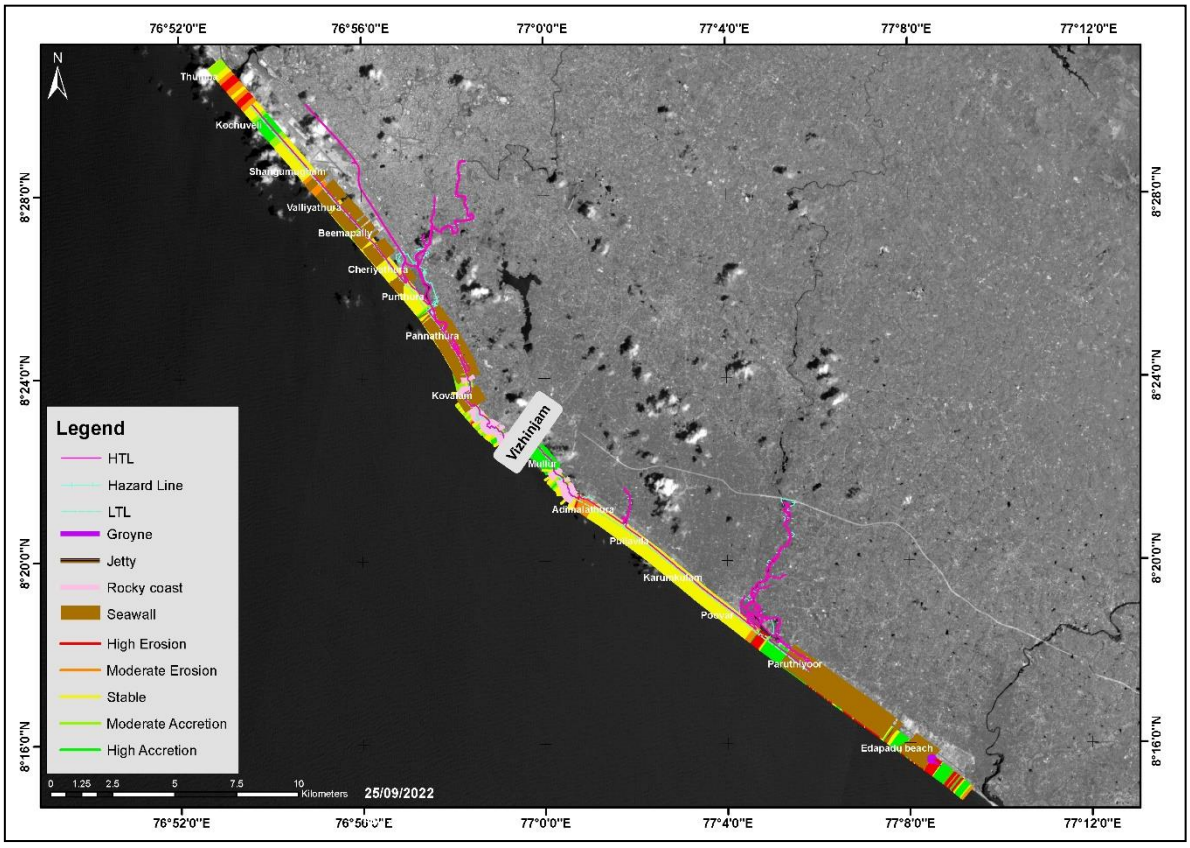


Figure 4.48 Shoreline Change Map- 2015 to 2022

5 VETTING OF REPORTS/ DATA

Periodical (monthly, seasonal and half yearly) reports on field data quality check and data on water quality, sediments, shoreline monitoring, etc. are scrutinized by NIOT. The Oceanographic and bathymetric data received from AVPPL for the year 2020-2021 are listed in tables 5.1. Sediment samples were collected at the cross-shore profile locations seasonally. Water quality (turbidity, TSS and salinity being carried out at 4 locations, two each north and south of Vizhinjam port). Vetting of Reports on data analysis and model studies for Vizhinjam Port using data collected by AVPPL (March 2021 to September 2022) by LnTIEL during November 2022, water quality, oceanographic and bathymetric data collection (by Shankar & Co from June 2019) for assessment of Shoreline changes has been completed till September 2022.

Table 5.1 Data Status October 2021 to September 2022

Sl no.	Parameters	Post monmsoon (October 2021 - January 2022)				Pre monsoon (Feb 2022-May 2022)				SW Monsoon (June 2022- September 2022)			
		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	×				✓				✓			
5	Bathymetry	✓				✓				×			
6	Beach Profile (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓ (onshore	✓ (onshore	✓ (onshore)	✓ (onshore)	✓ (onshore)	✓ (onshore)
7	Turbidity	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8	Water sample (TSS, Salinity and temp)	✓				✓				✓			
9	Grain size(81 locations at 500 m distance)	✓				✓				×			
10	LEO (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

5.1 Methodology adopted for verifying various monitored data

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

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

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

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 arising due to some reasons are carefully examined and removed before the analysis. Further to normalize the gaps in a single profile bilinear interpolation has been carried out to fill the data gaps and uniform 1 meter interval profile data has been generated. Shoreline and Near shore 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 ends up with error. All profiles are manually checked before entering the data in to SANDS.

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

TSS data provided was analyzed was verified using the protocol prescribed by the American Public Health Association (APHA) 21st Edition 2540 D and also validated using

available data. Turbidity was measured using turbidity meter as per APHA protocol. The instrument was calibrated using formazin / factory calibrated standard.

The ADCP current data analyzed using standard oceanographic methods and analysis techniques by the software being used by the surveying agency. These includes standard visualization techniques, pre and post calibration at lab, time-series and 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 was tabulated against time. Data gaps, Spikes or improbable data was verified and removed. As the present used directional wave rider buoy is working based on the GPS principle, hence 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, duplicate set of few samples are collected and analysed at NIOT Geotechnical laboratory for cross verification of results submitted.

5.2 Wave Analysis

The significant wave height (H_s) ranges from 0.45 m to a maximum of 3.62 m. The dominant direction of wave approach during monsoon season is between 180^o to 260^o. The maximum of peak wave period (T_p) are ranges from 16.67 s to 22.0 s during different seasons while the average T_p is consistent around 12 s for all seasons from June 2021 to May 2022. The average wave height during the monsoon season (June 2022 to September 2022) is 1.60 m and average peak wave period is 11.89s The Tp ranges between 5.88 s and 22.22s. The maximum significant wave height of 3.57m is observed at 21:05 hrs on 5th September 2022. The predominant direction of wave approach is 180^o to 260^o and majority of waves are confined in 1.0 to 2.0 m wave height and 8s to 16s peak wave period. The minimum Hs observed during the season is 0.99m.

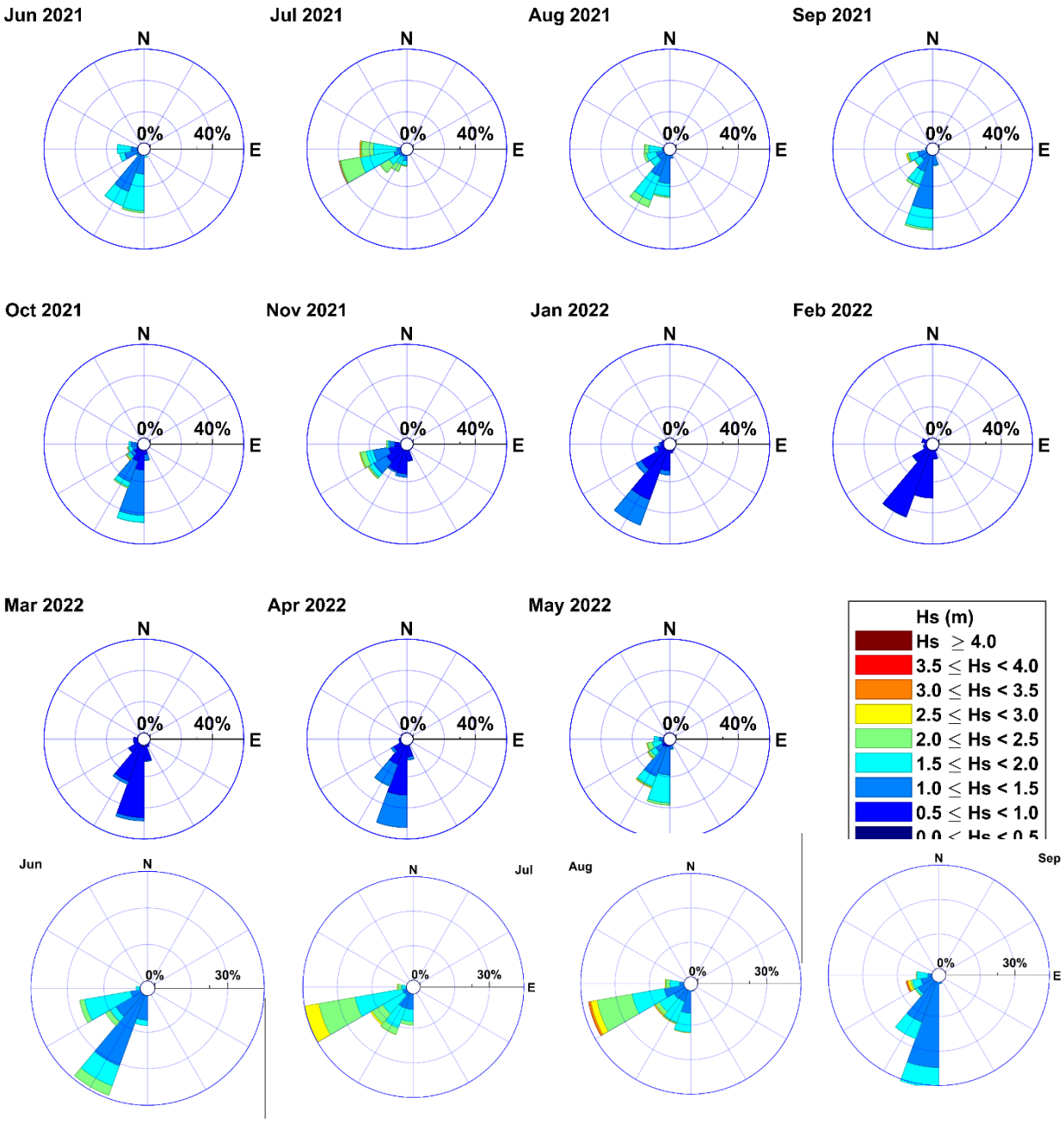


Figure 5.1Monthly wave rose plot (H_s v/s Dir) during the observation period June 2021 to May 2022.

5.3 Tide

The tides were observed near the coastal Guard jetty. The tide observation carried out with reference to Chart datum provided by VISL. The temporary bench mark (TBM) is marked on the wharf and is 2.711m above CD. The Vizhinjam tide gauge data has been connected to bench mark near jetty and the data were observed with respect to chart datum. NIOT has checked the consistency of water level by installing radar level sensor near to the existing tide gauge. The periodically check by manual measurement logs are also verified and the difference matched well between the acceptable limit. The observed tide data are checked thoroughly and removed the flag suspicious data like spikes. The tide observation from October 2021 to September 2022 is presented in below.

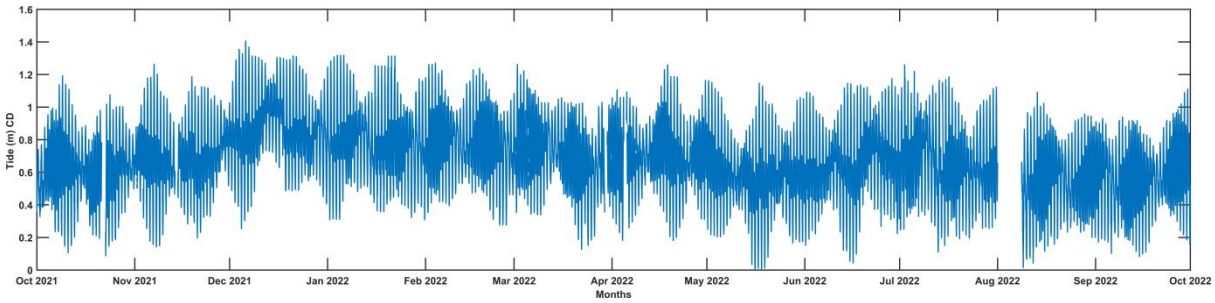


Figure 5.2 Tide observation from October-2021 to September-2022.

6 CONCLUSION

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. The shoreline changes using satellite images for 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).

Table 6.1 Erosion and Accretion spots identified from Beach profile and satellite image analysis for the period October 2021 to September 2022.

	From Satellite image analysis	From Beach profile analysis-Onshore
Erosion spots	Thumba to Kochuveli (CSP 75-81), Valliyathura (CSP 64,66), Punthura (CSP51-53), Mullur (CSP 37), few sectors north of Adimalathura (CSP 33), Poovar south (CSP15) and Edapadu beach (CSP2)	Vettucaud (CSP73), Valliyathura (CSP66), Pannathura to Punthura (CSP51-53), Kovalam (CSP42-43), Adimalathura (CSP31,33), Pulluvila (CSP27,30), Poovar south (CSP15) and Edapadu beach (CSP 2)
Accretion spots	Shangumugam (CSP 69-71), Adimalathura to Poovar (CSP 22-34)	Thumba to Shangumugam (CSP 69-81), Pulluvila to Poovar (CSP 17-29),

Table 6.2 Erosion and Accretion spots identified from Beach profile and satellite image analysis for the period 2015 to 2022.

	From Satellite image analysis	From Beach profile analysis-Onshore	From Beach profile analysis-Offshore
Erosion spots	Thumba (CSP81), Valliyathura (CSP65), Adimalathura (CSP33-34)	Thumba (CSP81), Vettucaud to Kochuveli (CSP 72-77), Shangumugham (CSP70), Pannathura (CSP51-53), Kovalam (CSP43-44), Mullur (CSP36-37), Adimalathura (CSP33-34), Karumkulam (CSP22-26) and Poovar (CSP17-19,21).	Valliyathura (CSP64-66), Punthura (CSP57), Kovalam (CSP45), and Edapadu beach to Vallavilay (CSP1-7),
Accretion spots	Kochuveli (CSP75), Mullur (CSP35-37) Pulluvila to Poovar (CSP15-17) and Edapadu beach (CSP2)	Thumba (CSP80). Shangumugham (CSP69,71), Valliyathura (CSP66), Pulluvila to Adimalathura (CSP28-32), Poovar (CSP15-16) and Edapadu beach (CSP02).	Thumba to Shangumugham (CSP67-81), Punthura to Pannathura (CSP47-56), Mullur to Paruthiyoor (CSP8-37)

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, accretion spots have been listed in Table 6.3 & 6.4.

Table 6.3 Summary and significant findings of Annual reports submitted

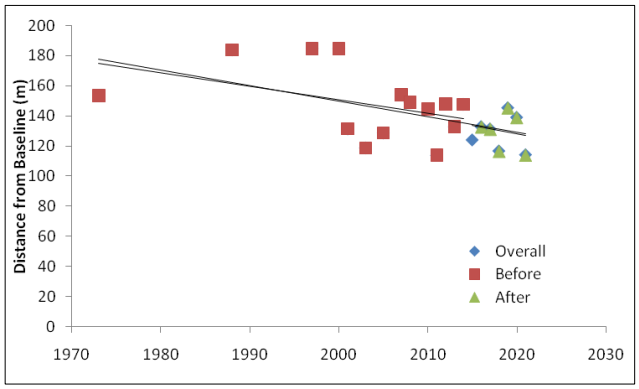
Reports	Period	Significant finding
Annual Report 2018	October 2017 to September 2018	• The shoreline change analysis using available high resolution satellite images was carried out for 2000-2018 and annual variation for the years 2015-2016, 2016-2017, 2017-18. • Erosion spots are Valliyathura, Punthura, Neerody to Edapadu 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) show that these sites have undergone erosion since a long time along the Vizhinjam coast.
Annual Report 2019	October 2018 to September 2019	• The overall shoreline analysis for the period October 2018 to September 2019 shows accretion at few transects of Cheriyathura and Mullur, it is stable at Pannathura and Adimalathura whereas erosion is noticed at Kochuveli, Shangumugam, Valliyathura, Punthura, Pulluvila to 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 remain same before and after the commencement of the port 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 remain same before and after the commencement of the port (December 2015). However, additionally, the 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. • During October 2020 to September 2021 the beach shown erosion at Thumba, Vettucaud to Kochuveli, Valliyathura, Pannathura to Punthura, Kovalam, Mullur, Pulluvila to Adimalathura, Karumkulam and Poovar. • Accretion 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 remains same before and after the commencement of the port 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 is noticed that high erosion occurred during Ockhi cyclone along the Vizhinjam and has not recovered the original profile.

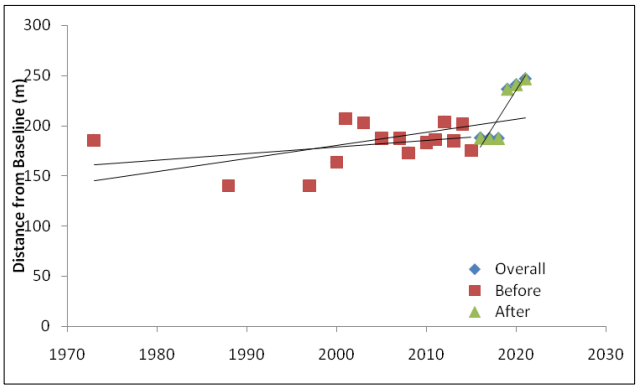
Table 6.4. Comparison of Erosion spots since 2000 using high resolution satellite images

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

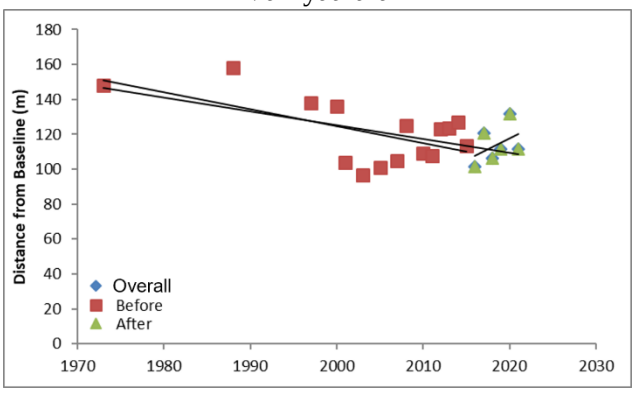
The trend of the shoreline analysis using satellite images shows the trend before and after 2015 shown in Figure 6.1 and listed in Table 6.4. It shows that the erosion spots like Valliyathura, Shangumugham and Punthura have been eroding before and after the commencement of the port (December 2015). The timeline of climatic events and port activities along Vizhinjam coast is listed in Table 6.5.



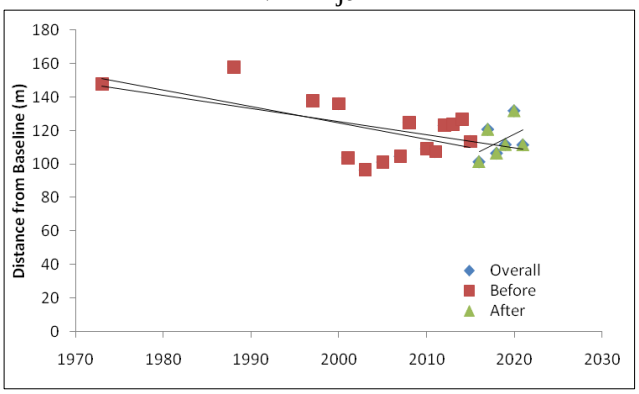
Valliyathura



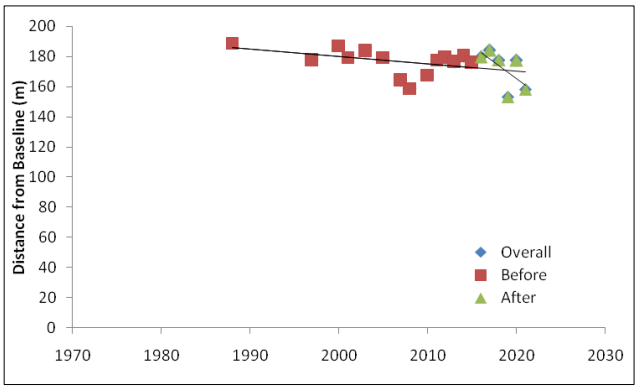
Vizhinjam



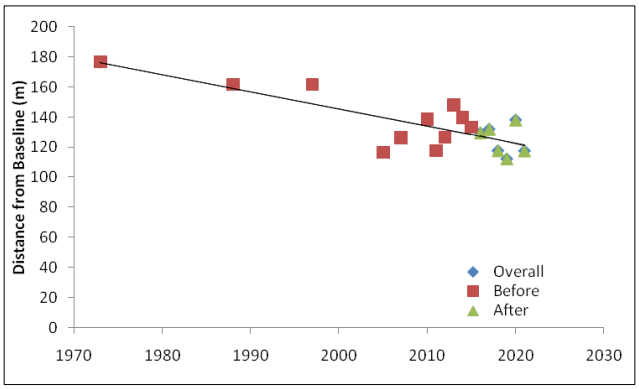
Punthura



Adimalathura



Shangumugam



Poovar

Figure 6.1 Trend analysis of shoreline change distance from baseline for the period from 1973 to 2021 and trends before and after 2015.

Table 6.5. 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			D&R (0.2Mm3)
	Apr-16			Breakwater construction of initial 676m
	Nov-16			Dredging (0.25Mm3)
December 17-December 18	Dec-16	Depression ARB02	maximum Hs-1.53m, maximum Hmax-2.56m, maximum Tp-18.18s	Dredging (0.25Mm3)
	Jan-17			Dredging (0.2Mm3) Reclamation (0.3Mm3)
	Feb-17			Dredging (0.2Mm3) Reclamation (0.3Mm3)
	Mar-17			Jetty construction Dredging (0.2Mm3) Reclamation (0.3Mm3)
	Apr-17			Dredging (0.2Mm3) Reclamation (0.4Mm3)
November 29- December 6	Dec-17	Cyclone Ockhi	maximum Hs-4.05m, maximum Hmax-7.29m, maximum Tp-20s	
	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	
October 6 to October 15	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)	
December 2 to December 5	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	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 6th December 2021	Dec-21	Cyclonic storm Jawad	No Data	
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	
4th August 2022	Aug-22	Monsoon	Maximum Hs- 2.89m Maximum Hmax– 5.08m Maximum Tp- 15.38s	
5th September 2022	Sep-22	No associated extreme events	Maximum Hs- 3.57m Maximum Hmax– 6.87m Maximum Tp- 10.0s	

The information regarding the list of erosion spots before and after 2015 are provided in the annual reports (Table 6.4) along with the timeline of events on port construction and the intensity of the climatic events that have happened along the Vizhinjam coast (Table 6.5), these indicate that there is no significant impact due to construction of port along the Vizhinjam coast.

References:

1. Annual Report on shoreline change analysis using high resolution satellite images October 2017 to September2018, National Institute of Ocean Technology 09-April 2019.
2. Annual Report on shoreline change analysis using beach profiles and satellite images. October 2018 to September2019, 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.
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