

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

**ANNUAL REPORT
(October 2020 to September 2021)**

FOR

ADANI VIZHINJAM PORT PVT LIMITED

PREPARED BY



**Coastal and Environmental Engineering Division
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CHENNAI
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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 2020 to September 2021 using available high resolution satellite images and field measured beach profile data.

In the previous Annual reports for the period October 2017 to September 2018, October 2018 to September 2019 and October 2019 to September 2020, the result from the shoreline change analysis using high resolution satellite images carried out for 2000-2018 and annual variation for the years 2015- 2016, 2016-2017, 2017-2018 has been presented and the spots of erosion listed from the above analysis using high resolution satellite images are Valliyathura (CSP63 to CSP67), Punthura (CSP53 to CSP57), Poovar to Edapadu (CSP01 to CSP09). The zones of erosion and accretion have been derived from the available high resolution satellite images (10m, 5m and 1m) for the months from October 2020 to September 2021 and it indicates erosion (coastal length in m) is noticed at Kochuveli (250m), Shangumugham (100m), Valliyathura (50m), Cheriyaathura (120m), Punthura (150m), Mullur (290m), Pulluvila (500m) and accretion at Thumba, Vettucaud and Shangumugham, Punthura, Adimalathura, Karumkulam, Poovar and Edapadu beach. Shoreline analysis using high resolution satellite images (1m) has been analysed for the years 2011 and 2021. The erosion is noticed at Shangumugham (600m), Valliyathura (200m) and Cheriyaathura (100m) and stable from Thumba o Vettucaud.

AVPPL has provided the monthly beach profile data collected (for the entire stretch of 40Km at 81 sectors) by the surveying agency for the period from October 2020 to September 2021. These have been analyzed, QA and QC have been carried out and final data sets were made. Due to Covid-19 protocol restriction and unfavorable weather conditions onshore profiles for the months of May 2021 and June 2021 and offshore profiles for October 2020, May 2021, June 2021, July 2021 have not been collected. The other data sets for onshore part (after removing the sea wall locations) and for offshore part have been used for analysis of beach changes on monthly, seasonally, yearly and inter-annually basis which has been included in the report. The beach volume change (onshore) for October 2020 to September 2021 shows erosion at Poovar (CSP15-17 and CSP19-21), Karumkulam (CSP24), Pulluvila to Adimalathura (CSP29-31), Adimalathura (CSP34), Mullur (CSP36-37), Kovalam (CSP42-44), Pannathura to Punthura (CSP51-53), Valliyathura (CSP66), Vettucaud to Kochuveli (CSP72-75), Kochuveli (CSP77) and Thumba (CSP81) on onshore. Accretion found at Edapadu beach (CSP02), Poovar (CSP18), Karumkulam (CSP22-23), and Karumkulam to Pulluvila (CSP25-



28), Adimalathura (CSP33), Shangumugham (CSP69-71), Valiyaveli (CSP78) and Thumba (CSP80).

As a part of the scope of work, following reports has been submitted by NIOT:

- I Quarterly report, October 2020 to December 2020 have been submitted in February 2021.
- II Quarterly report, January 2021 to March 2021 has been submitted in May 2021.
- III Quarterly Report April 2021 to June 2021 has been submitted in October 2021.
- IV Quarterly report, June 2021 to September 2021 has been submitted in December 2021.
- In this final report comprising of one year study including available high resolution satellite imageries, beach profile and other related measurement has been analyzed and reported for the period October 2020 to September 2021.

In addition, NIOT has provided a wave rider buoy which is deployed / installed and periodically maintained with the help of AVPPL and the data received by NIOT are evaluated. Monthly and half yearly reports of the periodical data analysis (water quality, oceanographic and bathymetric data) has been received from M/s Shankar and Co., data and modeling report for the period March 2019 to February 2021 by LNTIEL and various measurement reports submitted by AVPPL has been received and vetted by NIOT till September 2021.

1 INTRODUCTION

NIOT had 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 of one year from October 2017 to September 2018. Vizhinjam International Seaport Limited (VISL) has submitted the draft annual report vide letter No. VISL/2016-17/EE&EI-19/1326 dated 11/01/2019 from vetting by NGT appointed expert committee and shoreline monitoring cell. After incorporating the comments received from both the committees during the meeting held on 12/02/2019 and 13/02/2019, NIOT has submitted the final study report on 03/03/2019, the same is forwarded by VISL wide letter No. VISL/2016-17/EE&EI-19/1610 dated 16/03/2019 to Member Secretary NGT appointed committee. Similarly, NIOT has carried out the study on shoreline change analysis using beach profiles and available satellite images for the year October 2018- September 2019 and for the year October 2019- September 2020.

Subsequently, with reference to the mail dated 20/11/2020, NIOT has received the work order to carry out the study on shoreline change analysis using beach profiles and available satellite images for the year October 2020 to September 2021. Accordingly, NIOT procured the latest available satellite data from National Remote Sensing Centre (NRSC) and obtained 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 latest available satellite images and beach profile data for the period from October 2020 to September 2021.

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 October 2020 to September 2021.
- ii) To identify the erosion and accretion hotspots using available moderate and high resolution multispectral images acquired by remote sensing satellites and Field measured beach profile data for the year October 2020 to September 2021.
- iii) Vetting of reports on oceanographic, hydrographic, bathymetric field measured data and numerical model studies provided by AVPPL.

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 2020 to September 2021 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.

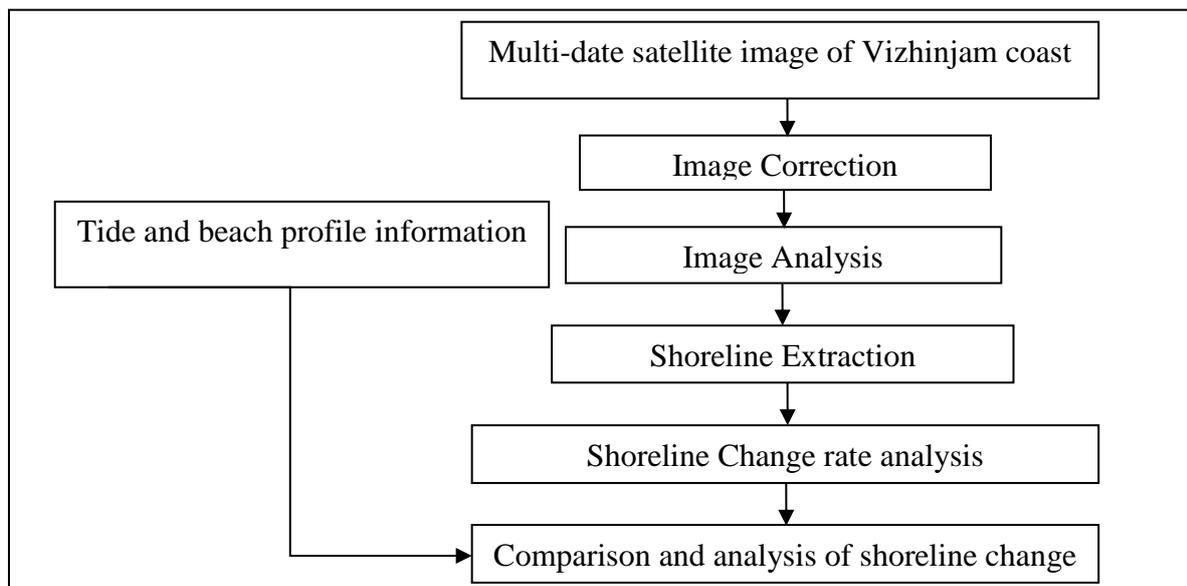


Figure 3.1 Flowchart of the methodology adopted

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 (**Figure 3.2**). 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.

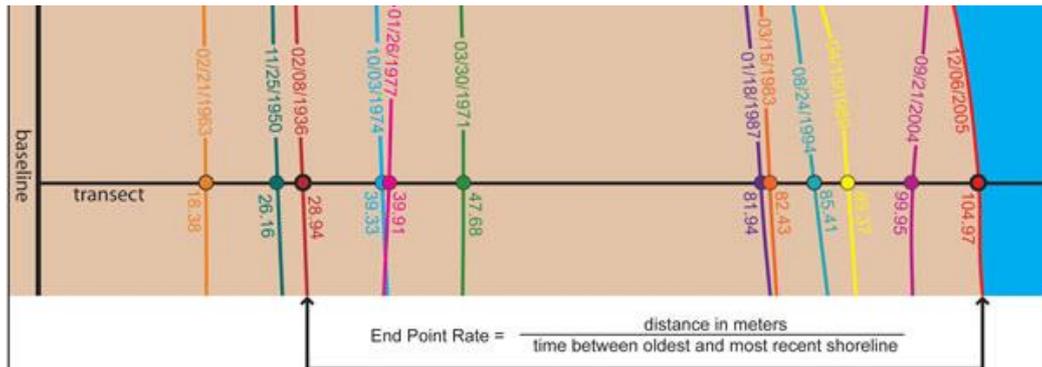


Figure 3.2 Calculation of Short Term Shoreline change analysis
(Sample image source: Thieler et al., 2017)

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.

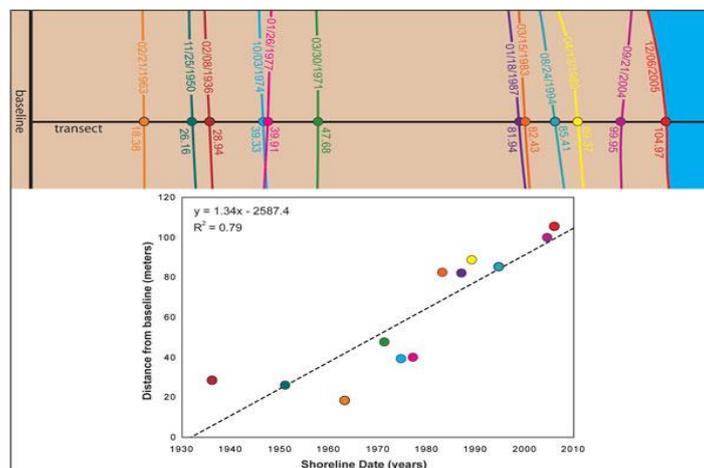


Figure 3.3 Calculation of Long Term (LRR) Shoreline change analysis
(Sample image source: Thieler et al., 2017)

3.1.3 Satellite image used in shoreline change analysis

The input image has been acquired from the European Space Agency for Sentinel 2A MSI images and Indian satellite products from NRSC to study monthly and seasonal change in shoreline for the period from October 2020 to September 2021. The satellite images have been co-rectified, and the available high resolution satellite images for the period from October 2020 to September 2021 are provided in **Table 3.1**. During the study period, satellite images of higher resolution viz. 2.5m resolution have not been procured due to non-availability of the same for the study region. The image has been geo-rectified using the field collected ground control points (GCP) during the field visit carried out during 3rd July 2018 to 5th July 2018. *Note:* For shoreline analysis, the satellite images have been selected without cloud cover along the coast.

Table 3.1 Satellite image data used for shoreline change analysis

Satellite	Date	Sensor	Resolution (m)
SENTINEL	10-09-2020	2B	10
	25-10-2020		
	09-11-2020		
	24-12-2020		
	18-01-2021		
	12-02-2021		
	04-03-2021		
	03-04-2021		
	03-05-2021		
	12-06-2021		
	07-07-2021		
	21-08-2021		
	20-09-2021		
	08-02-2020		
Resourcesat 2A	03-01-2015	LISS4	5
	10-10-2019		
	14-01-2020		
	15-12-2020		
	01-05-2021		
	03-09-2021		
Cartosat 2	12-02-2011	PAN	1
Cartosat 3	30-01-2021	PAN	1

3.2 Beach Profile Analysis

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 Covid-19 restrictions and rough sea condition along the Vizhinjam coast, during May 2021 and June 2021 only few locations (CSP36, 37, 75, 76, 77, 78, 79, 80, 81) were surveyed for onshore part and the offshore part of the cross-shore profiling could not be carried out for the months of October 2020, May 2021, June 2021 and July 2021. Hence these data have not been considered for the overall beach volume change analysis.



Figure 3.4 Beach 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 upto 10m 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	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		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	ADANI RECLAMATION AREA	ADANI PORT OFFICE VIZHINJAM	Seawall
CSP-39			Beach
CSP-40			Beach
CSP-41			Beach
CSP-42	VIZHINJAM LIGHT HOUSE	KOVALAM	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 3.5 Work Flow in SANDS

3.3 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.

3.3.1 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.

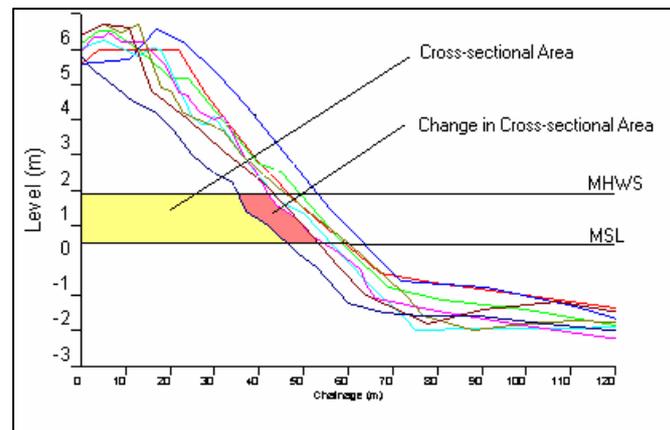


Figure 3.6 Profile Analysis by Level

3.3.2 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**).

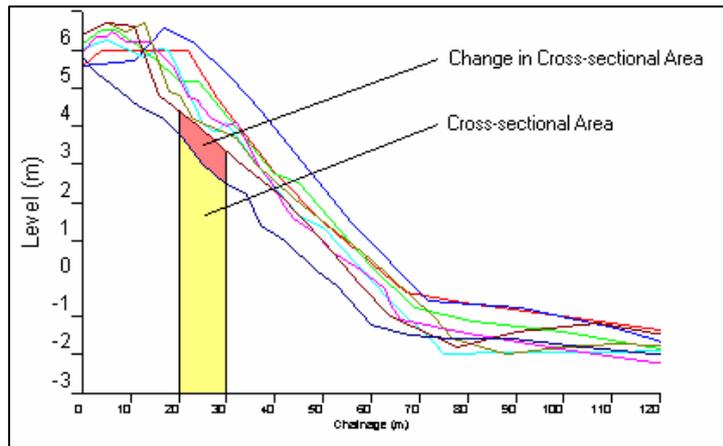


Figure 3.7 Profile Analysis by Chainage

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 of south Kerala coast (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 from October 2020 to September 2021 using 10m, 5m and 1m satellite images is presented in this report.

Hence, with the available satellite images of 10m resolution for the monthly shoreline change analysis, this classification may indicate erosion and accretion based on the scale followed for the same as higher resolution images. Based on the rate of change over the period, shoreline change has been categorized into 5 classes. They are high accretion ($>5\text{m/year}$), moderate accretion ($5\text{m to }1\text{m/year}$), stable coast ($1\text{m to }-1\text{m/year}$), moderate erosion ($-1\text{m to }-5\text{m/year}$), high erosion ($<-5\text{m/year}$).

The observations from the beach profile analysis done using SANDS for the entire 40 km stretch has been presented as monthly, seasonal and half yearly changes in the beach volume for a period from October 2020 to September 2021. The volume changes have been assessed by comparing month to month profiles and the seasonal and the overall beach volume changes. We have removed the locations having sea walls from the analysis. 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 (In the month of May 2021 and June 2021 only few locations were surveyed on onshore part and no survey carried out for offshore part in October 2020, May 2021, June 2021 and July 2021 due to unfavorable weather conditions and covid restrictions). Monthly beach volume changes have been assessed by comparing month to month profiles for onshore and offshore separately. In the previous Annual reports October 2017-September 2018, October 2018-September 2019 and October 2019-September 2020 the beach volume (monthly, seasonal and yearly) changes from February 2015 to September 2020 has been analyzed and reported. In continuation with the previous studies, this report includes the monthly, seasonal and overall changes from October 2020 to September 2021.

4.1.1 Monthly Beach Volume variations – October 2020 to September 2021 for onshore part

In order to study the beach volume change in October 2020, the beach profile data of September 2020 has been considered for the analysis. The changes in every month (October 2020 to September 2021) on onshore part have been represented graphically in **Figures 4.1 to 4.9** and in **Table 4.1**.

At location CSP32 onshore data could not collected from October 2020 to June 2021, no onshore survey carried out at locations CSP41 and CSP67 as these locations were not accessible by foot during July 2021 to September 2021, so these locations are not included in the analysis part for the said period. Onshore survey carried out only for few locations during May 2021 and June 2021 due to Covid restrictions this was not feasible for the analysis hence not included in the report.

- During October 2020 Beach shown erosion in most of the locations. Accretion at Edapadu beach (CSP02), Poovar South (CSP17), Azhimala (CSP36), Pannathura (CSP51-52), Shangumugham (CSP69-71), Thumba (CSP81).
- During the month of November 2020, the sediment accretion has taken place over most of the locations. Erosion noted at Poovar (CSP16-18), Karumkulam (CSP24), Adimalathura (CSP31, CSP33), Mullur (CSP37), Pannathura to Punthura (CSP51-53), Valliyathura (CSP66), Shangumugham (CSP69), Valiyaveli (CSP78), and Thumba (CSP80).

- In December 2020, the profile for the CSP42 found erroneous hence excluded from the analysis. Other than Edapadu beach (CSP02), Poovar (CSP15), Adimalathura (CSP33-34), Mullur (CSP37), Kovalam (CSP41), Pannathura to Punthura (CSP51-53), the beach was found to have accretion in most of the beaches.
- During the month of January 2021, the beach shown accretion trend over most of the locations. Erosion is noted at Poovar (CSP16), Karumkulam (CSP22), Kovalam (CSP41 and 43).
- In February 2021, beach was found to have accretion along most of the locations. Erosion noticed at Edapadu beach (CSP02), Poovar (CSP16), Karumkulam (CSP24), Adimalathura (CSP33), Kovalam (CSP41-42), Pannathura (CSP52), and Valliyathura (CSP66).
- In March 2021, most of the locations shown erosion other than Edapadu beach (CSP02), Adimalathura (CSP33), Azhimala (CSP35), Mullur (CSP37), Kovalam (CSP 41-42), Valliyathura (CSP66), Valiyaveli (CSP78).
- During the month of April 2021 most of the stations are showing accretion and some parts of the beaches at Poovar (CSP15), Karumkulam (CSP22), Adimalathura (CSP33), Azhimala to Mullur (CSP35-CSP37), Kovalam (CSP 41-42), Vettucaud (CSP72), Vettucaud to Kochuveli (CSP74-75) and Thumba (CSP80-81) showing erosion.
- In May 2021 only few locations were surveyed on onshore part. Hence not included in the analysis.
- In June 2021 only, few locations were surveyed on onshore part. Hence not included in the analysis.
- Since no onshore data in June 2021 analysis of July 2021 also could not carried out.
- In July 2021 only very less distance was covered on onshore at CSP72, CSP73 and CSP76 so these locations were excluded from the analysis for August 2021. During August 2021, the beach was showing accretion at Edapadu Beach (CSP02), Poovar South to North (CSP15-21), Pulluvila to Adimalathura (CSP28-31), Adimalathura (CSP33-34), Mullur (CSP37), Pannathura North to Punthura (CSP52-53), Valliyathura (CSP66), Shangumugham South to North (CSP69-71), Vettucaud (CSP74), Valiyaveli (CSP78). Erosion noticed at Karumkulam to Pulluvila (CSP22-27), Adimalathura (CSP32), Azhimala to Mullur (CSP 35-36), Kovalam (CSP42-44), Pannathura North (CSP51), Vettucaud (CSP75), Kochuveli (CSP77), and Thumba (CSP80-81).
- During September 2021 most of the beaches exhibits accretion trend. Erosions noticed at Poovar (CSP15), Kovalam (CSP42), and Shangumugham North (CSP70).

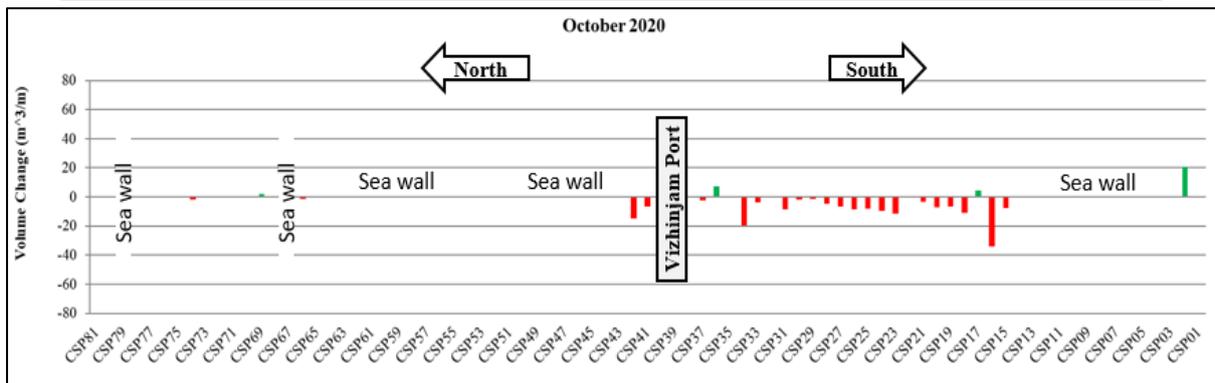
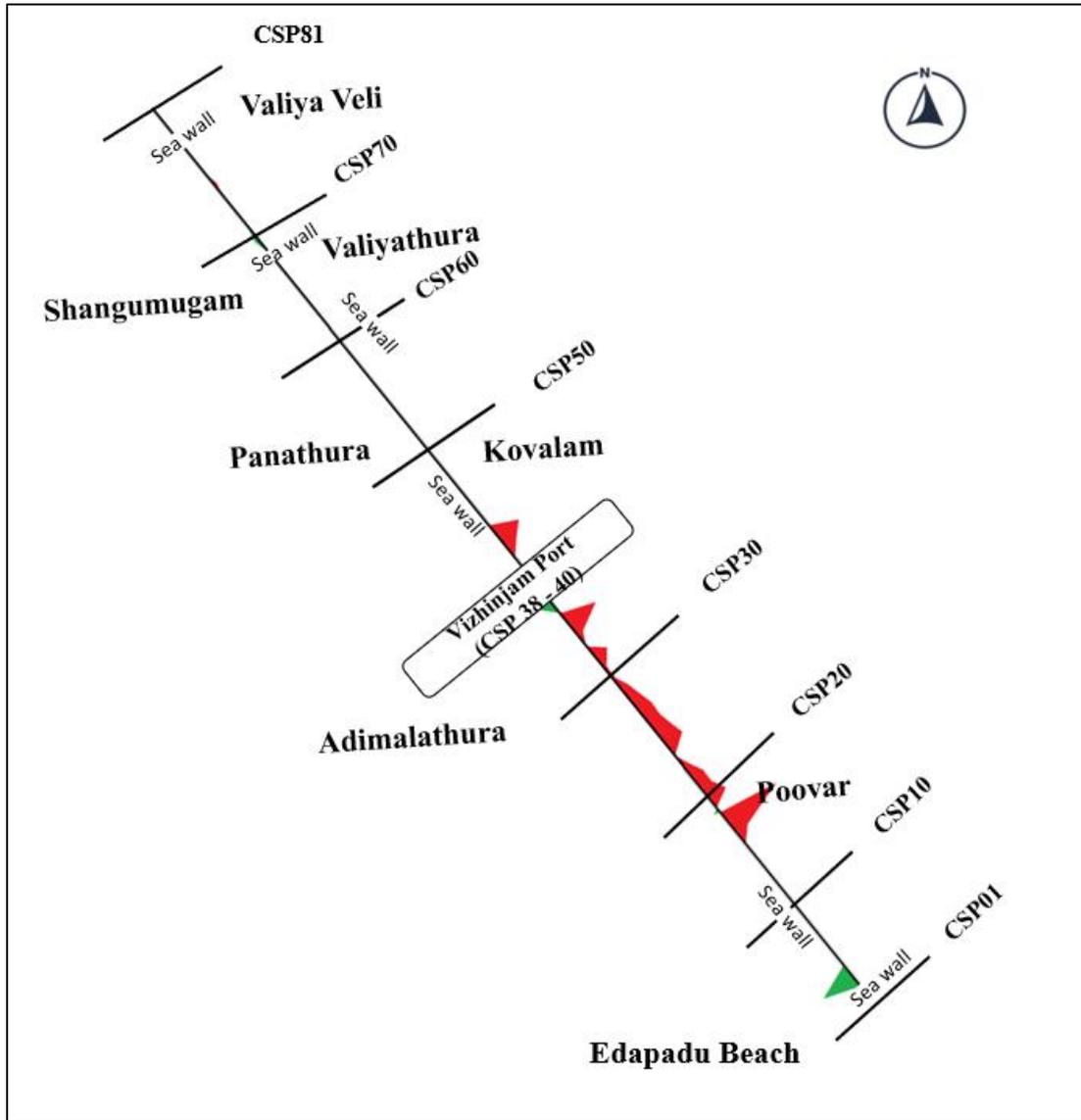


Figure 4.1 Monthly Beach Volume Changes in October 2020 in m³/m (onshore)

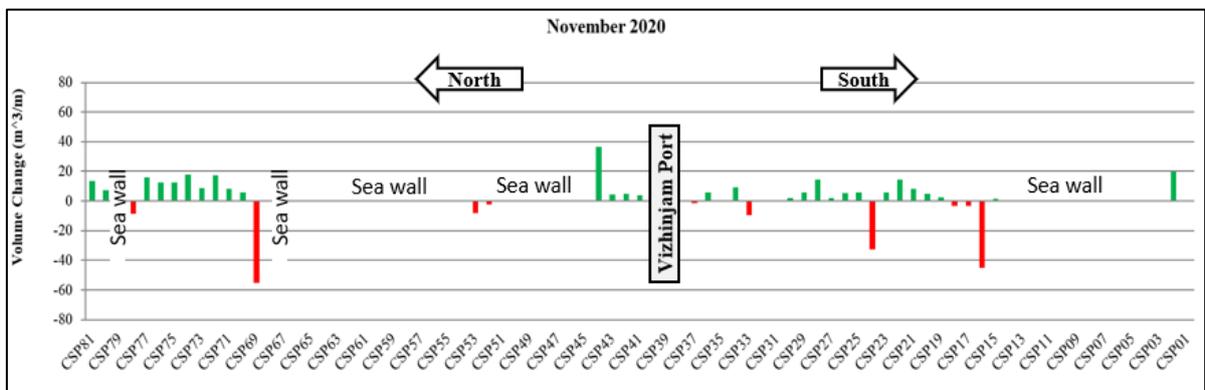
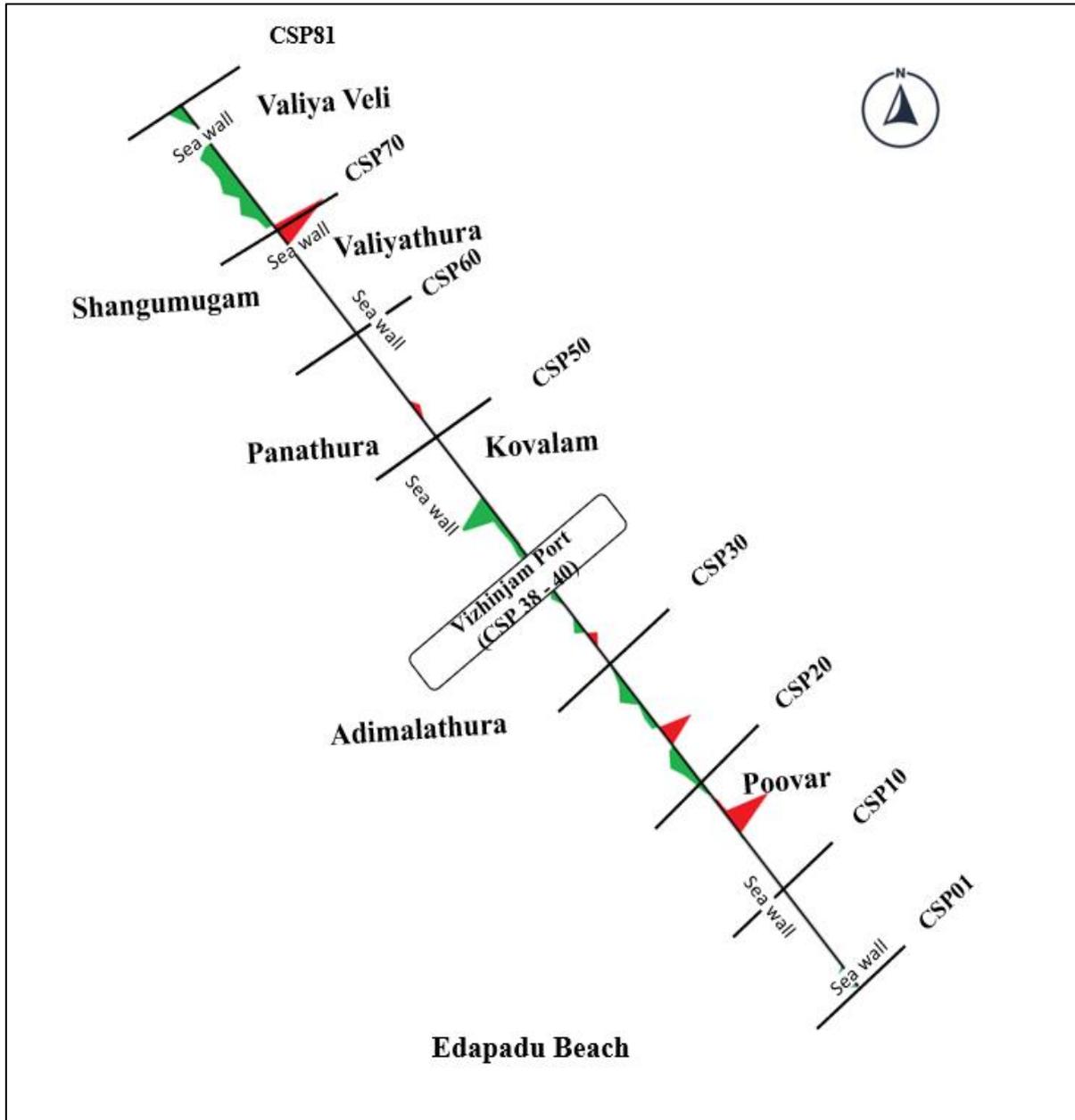


Figure 4.2 Monthly Beach Volume Changes in November 2020 in m^3/m (onshore)

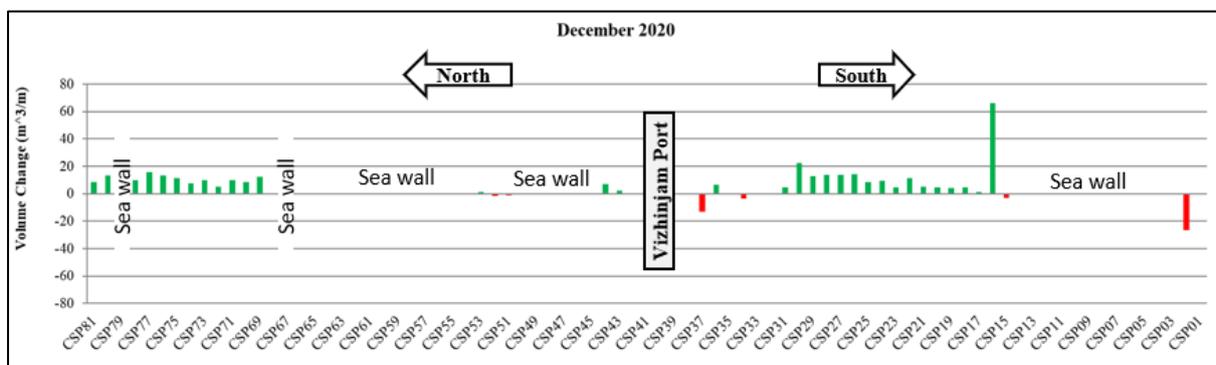
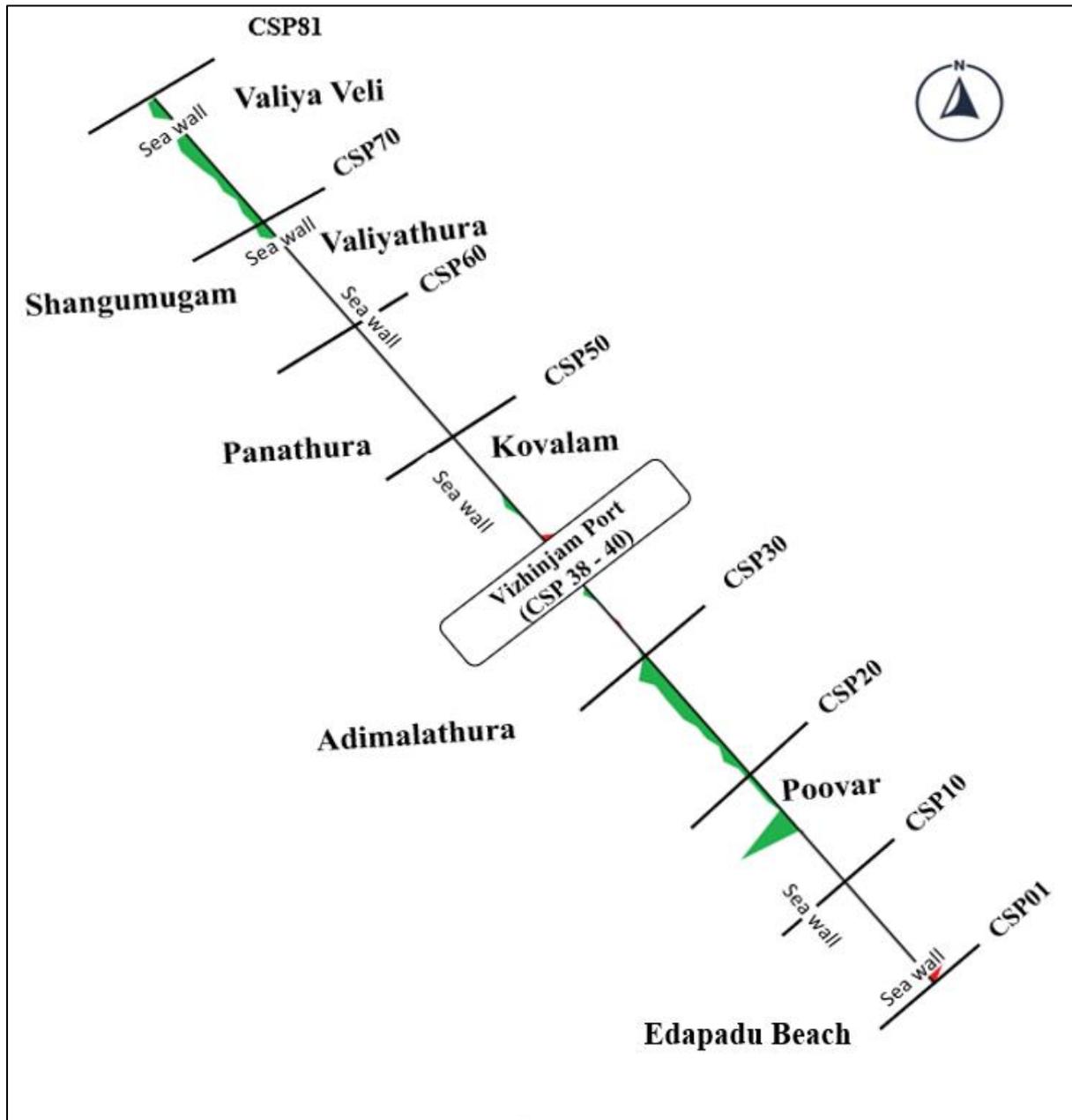


Figure 4.3 Monthly Beach Volume Changes in December 2020 in m³/m (onshore)

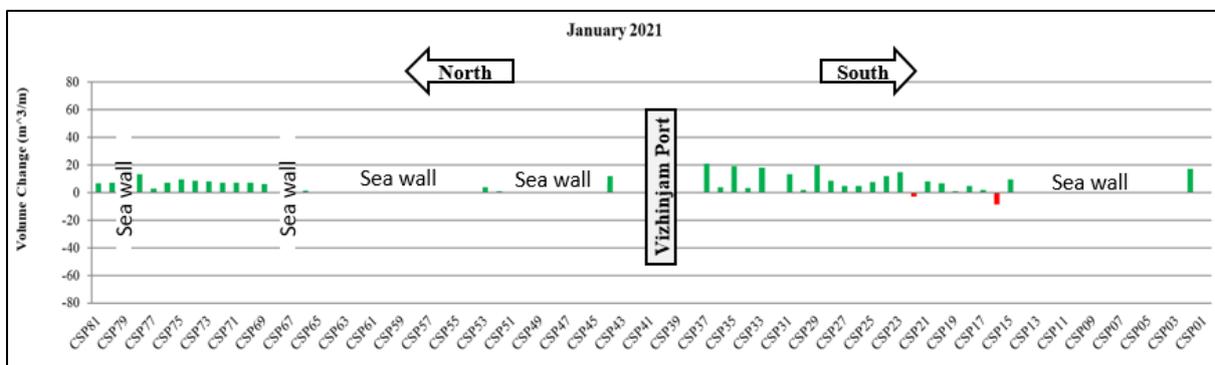
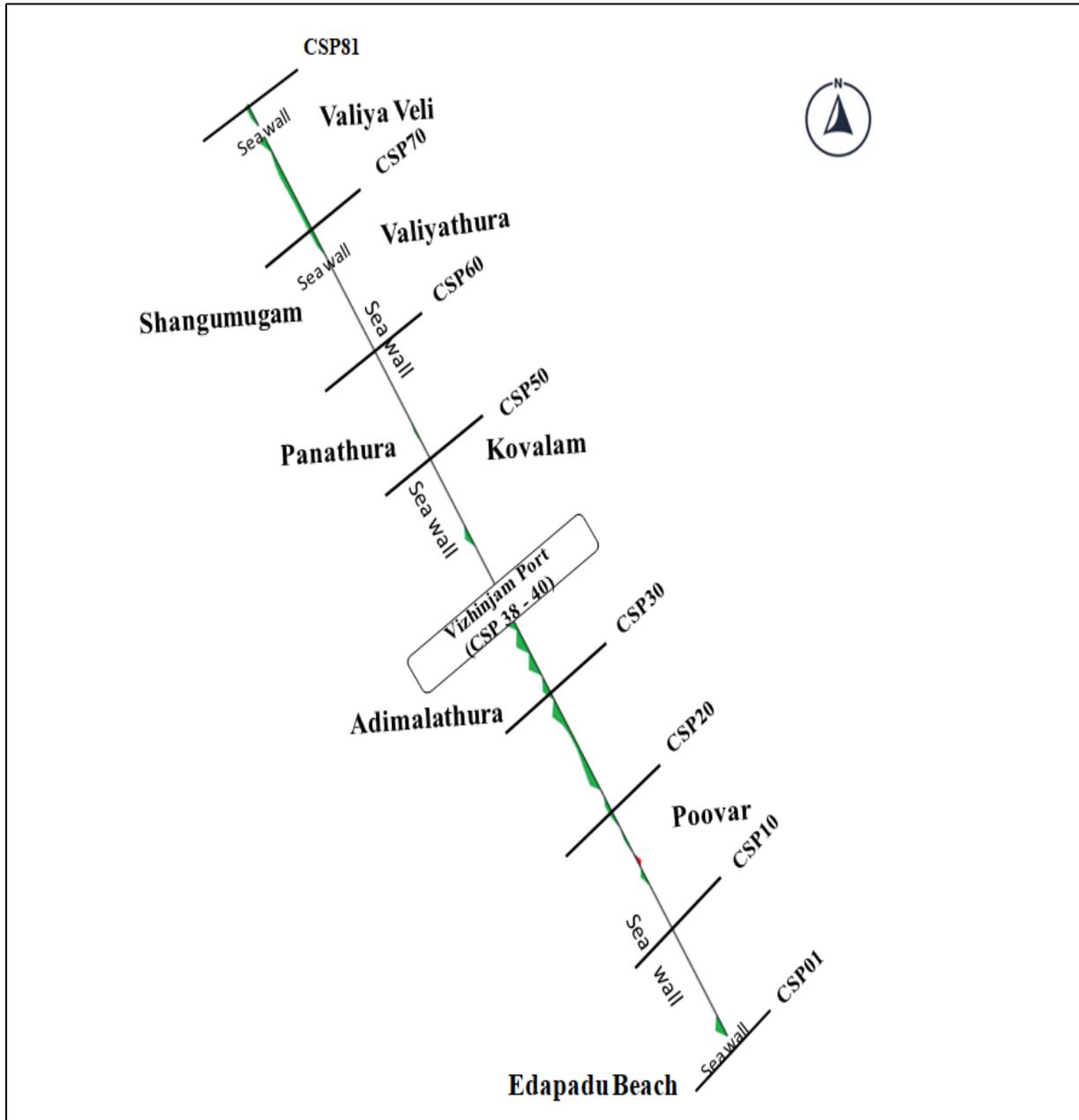


Figure 4.4 Monthly Beach Volume Changes in January 2021 in m^3/m (onshore)

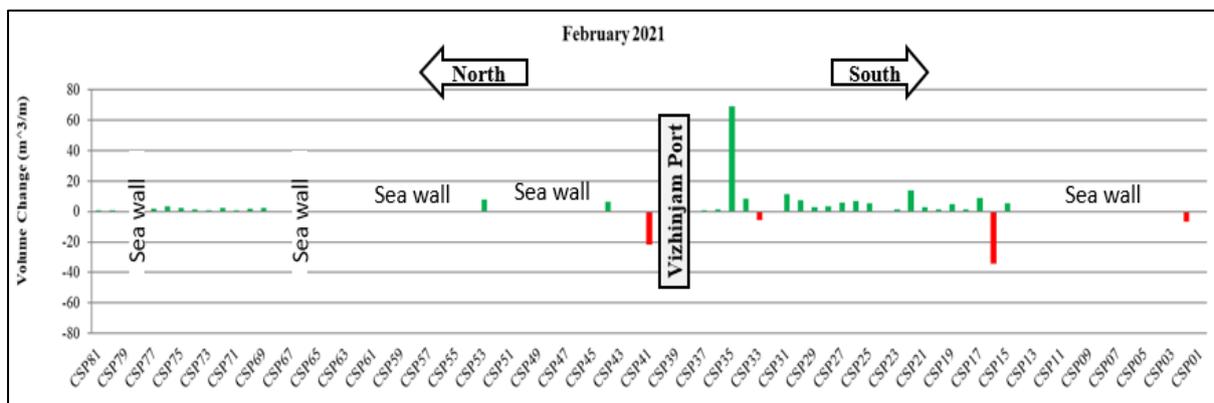
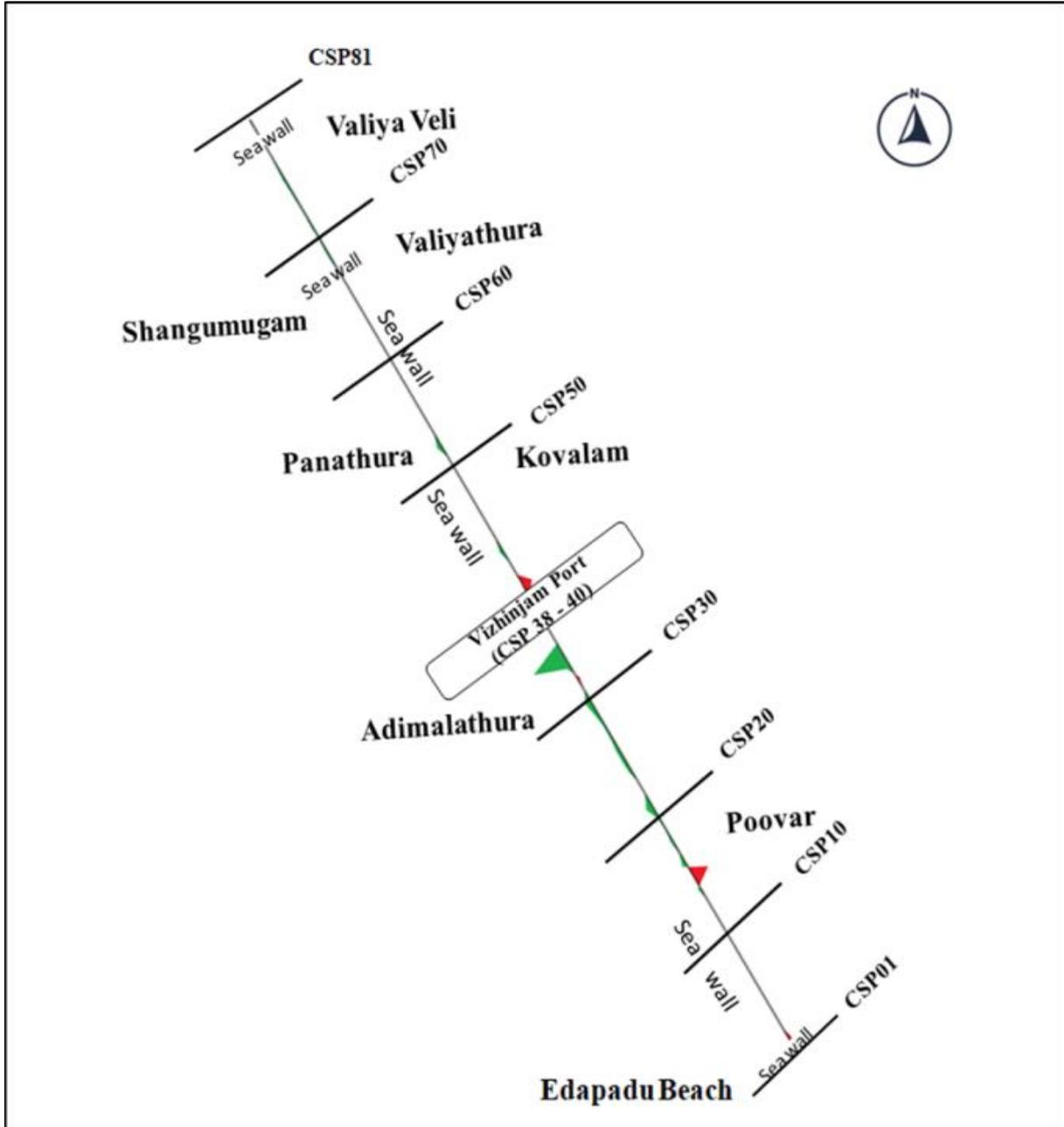


Figure 4.5 Monthly Beach Volume Changes in February 2021 in m^3/m (onshore)

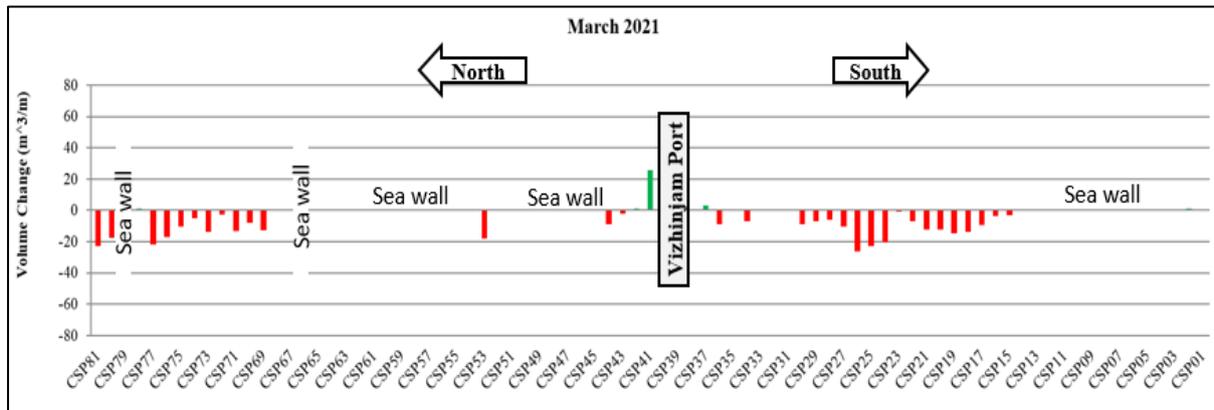
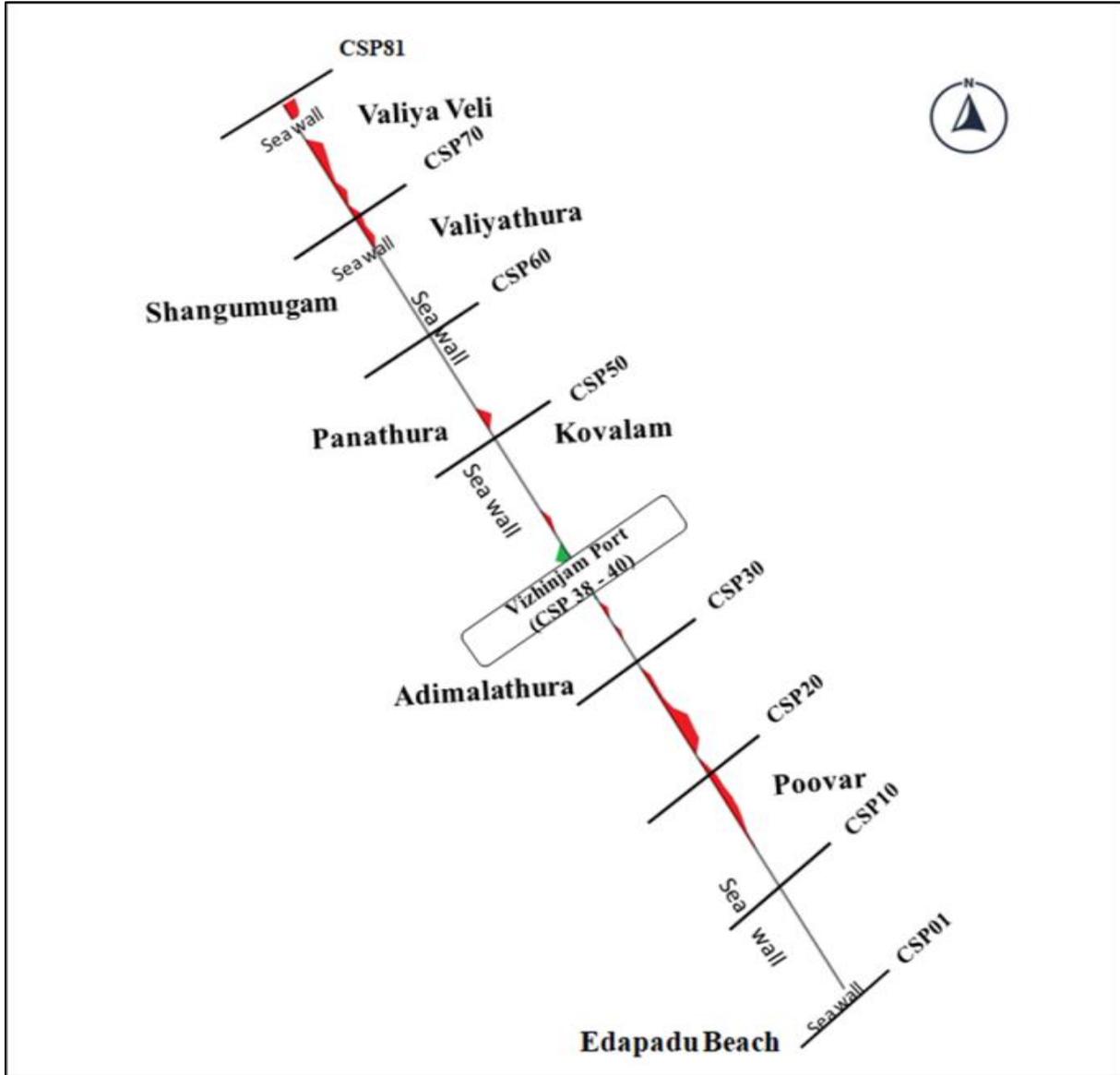


Figure 4.6 Monthly Beach Volume Changes in March 2021 in m³/m (onshore)

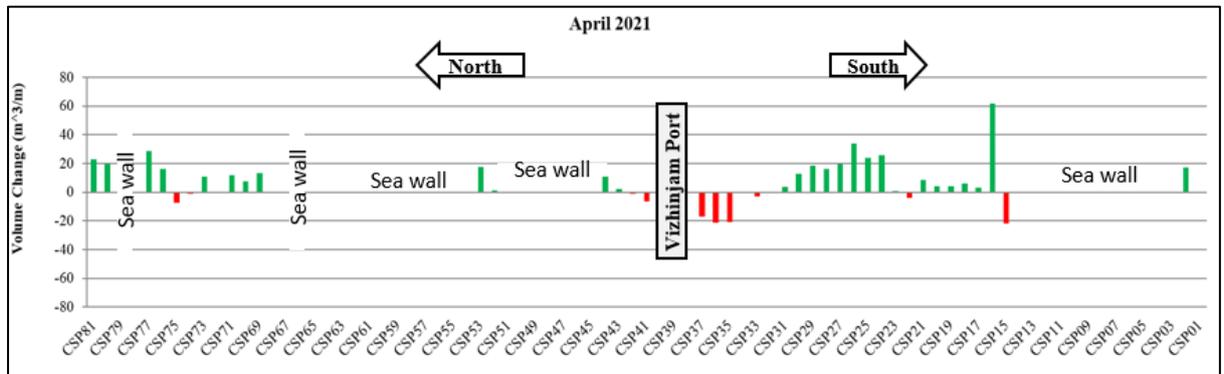
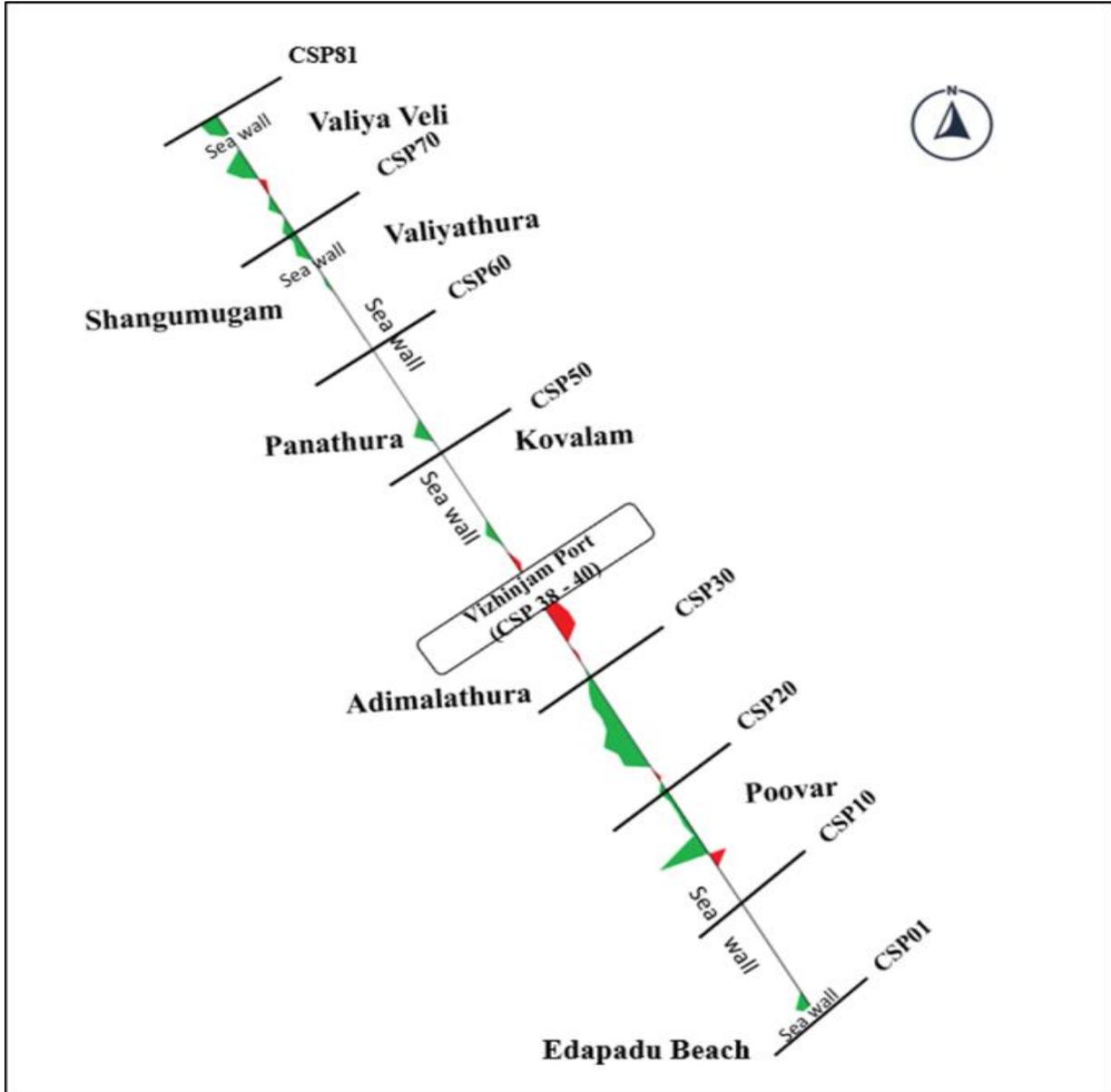


Figure 4.7 Monthly Beach Volume Changes in April 2021 in m^3/m (onshore)

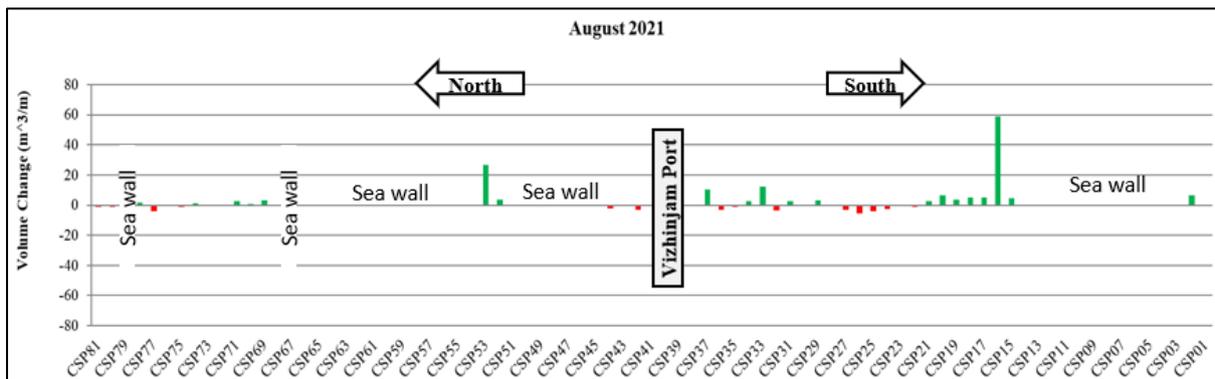
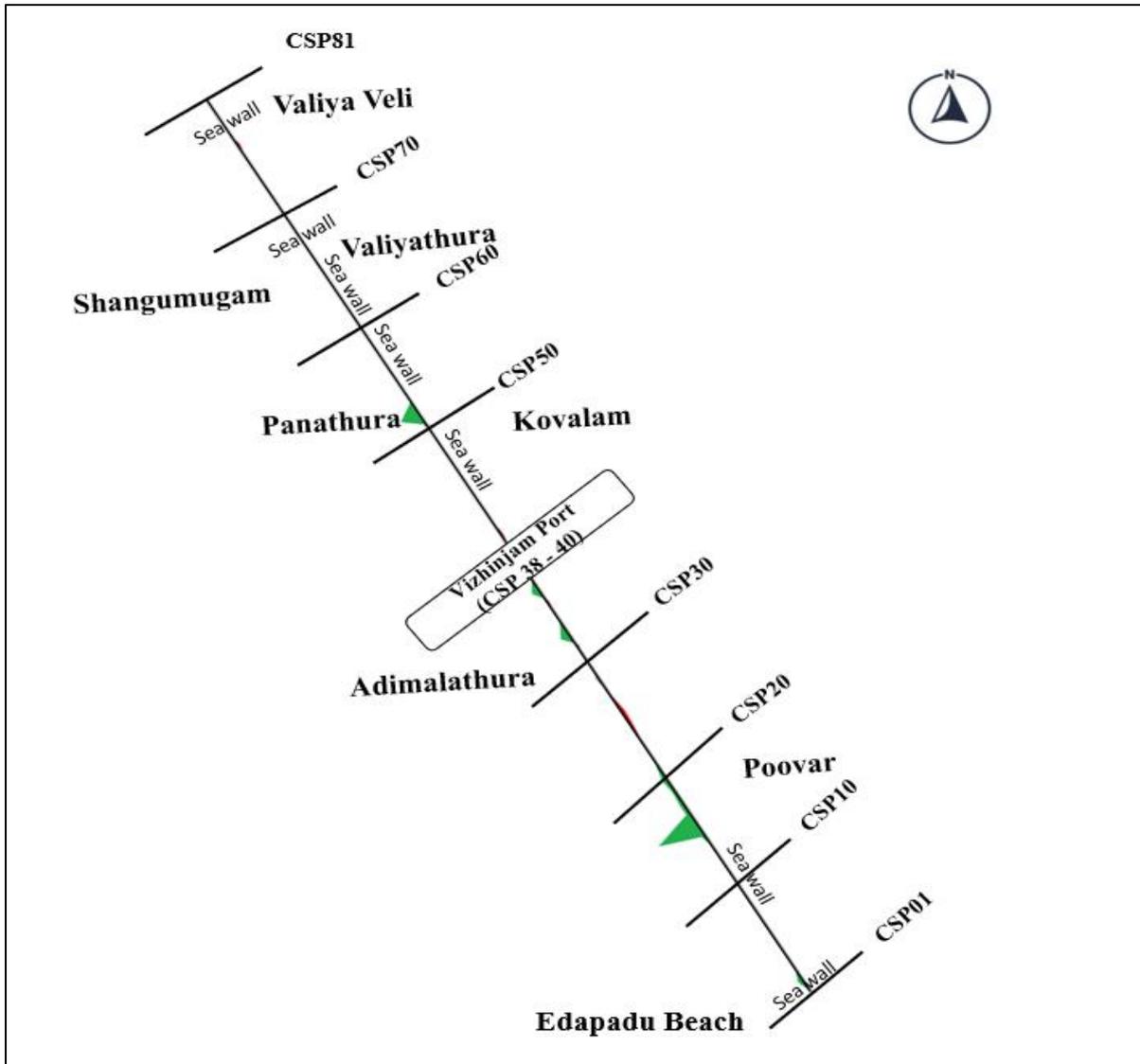


Figure 4.8 Monthly Beach Volume Changes in August 2021 in m^3/m (onshore)

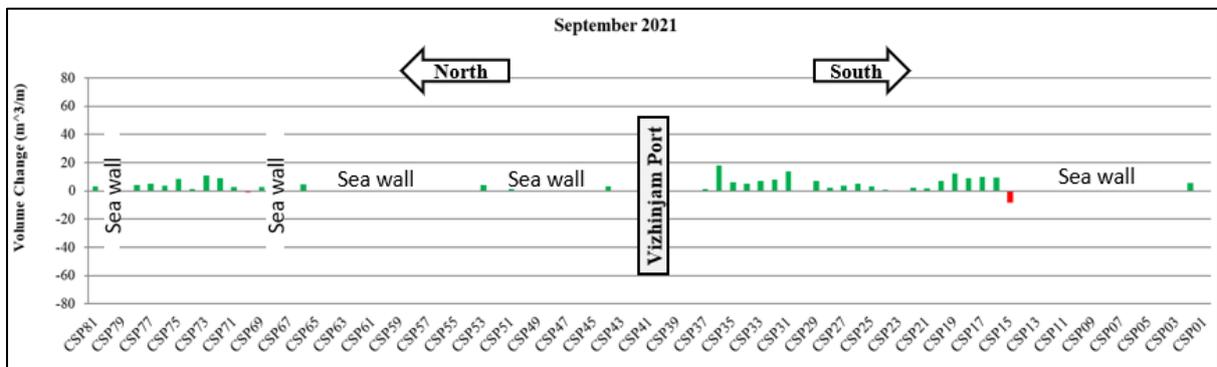


Figure 4.9 Monthly Beach Volume Changes in September 2021 in m^3/m (onshore)

Table 4.1 Monthly Beach Volume Changes during the months from October 2020 to September 2021 in m³/m (onshore)

CSP NOs.	October 2020	November 2020	December 2020	January 2021	February 2021	March 2021	April 2021	August 2021	September 2021									
CSP01	Sea wall																	
CSP02	20.84	19.95	-26.82	16.92	-6.90	1.31	17.16	6.64	5.80									
CSP03	Sea wall																	
CSP04																		
CSP05																		
CSP06																		
CSP07																		
CSP08																		
CSP09																		
CSP10																		
CSP11																		
CSP12																		
CSP13	Sea wall																	
CSP14																		
CSP15										-7.49	1.41	-2.98	9.54	5.54	-3.15	-21.78	4.73	-8.36
CSP16										-34.22	-45.27	66.23	-8.54	-34.22	-3.75	61.73	59.04	9.50
CSP17										4.35	-3.53	1.46	1.64	8.94	-9.27	3.32	4.97	10.06
CSP18										-10.98	-3.21	4.78	4.67	1.23	-13.63	6.14	4.85	8.89
CSP19										-6.77	2.61	4.26	0.80	4.80	-14.85	4.16	3.83	12.33
CSP20										-7.18	5.05	4.84	6.46	1.40	-12.44	4.14	6.44	7.14
CSP21										-3.46	8.38	5.15	7.89	2.82	-12.16	8.59	2.83	1.94
CSP22										-0.27	14.23	11.53	-2.97	13.76	-6.94	-4.00	-0.95	2.10
CSP23	-11.37	5.80	4.77	14.94	1.60	-0.86	0.62	-0.56	0.16									
CSP24	-9.68	-32.84	9.44	11.76	-0.75	-20.43	25.80	-2.72	0.90									
CSP25	-7.90	5.63	8.64	7.45	5.33	-22.64	23.94	-4.11	3.34									
CSP26	-8.47	5.23	14.07	4.87	6.79	-26.16	33.74	-5.60	5.20									
CSP27	-6.63	2.03	13.70	4.90	5.96	-10.58	19.70	-2.90	3.90									
CSP28	-4.70	14.55	13.78	8.54	3.56	-6.19	16.23	0.18	2.13									
CSP29	-1.62	5.69	12.60	19.65	2.80	-7.11	18.34	3.37	7.17									
CSP30	-1.68	1.86	22.35	1.74	7.27	-8.71	12.85	0.24	0.26									
CSP31	-8.60	-0.61	4.56	13.35	11.50	-0.36	3.54	2.71	13.83									
CSP32	*	*	*	*	*	*	*	-3.63	7.78									
CSP33	-3.84	-9.56	-0.14	17.95	-5.72	0.73	-3.18	12.28	6.86									
CSP34	-19.58	8.97	-3.61	3.15	8.60	-7.15	0.48	2.68	5.15									
CSP35	*	*	*	19.26	68.91	0.57	-20.71	-1.14	6.09									
CSP36	7.11	5.84	6.58	3.72	1.23	-8.93	-21.35	-2.94	17.98									
CSP37	-2.51	-1.53	-13.01	20.83	0.63	2.98	-16.97	10.24	1.25									
CSP38	PORT AREA																	
CSP39																		
CSP40																		
CSP41	-6.76	3.79	-1.19	-0.18	-21.77	25.82	-6.46	*	*									
CSP42	-15.05	4.70	*	*	-0.13	1.33	-1.34	-3.26	-0.31									
CSP43	-0.26	4.41	2.21	-0.55	0.12	-2.08	2.30	-0.84	0.05									
CSP44	-0.03	36.36	7.20	11.66	6.24	-8.74	10.77	-2.09	3.36									
CSP45	Sea wall																	
CSP46																		

CSP47									
CSP48									
CSP49									
CSP50									
CSP51	0.01	-0.05	-1.01	0.64	0.01	-0.34	0.33	-0.34	1.08
CSP52	0.03	-2.21	-1.60	0.80	-0.74	-0.49	1.23	3.51	0.08
CSP53	-0.58	-8.01	1.19	3.86	8.12	-18.10	17.70	26.77	4.40
CSP54	Sea wall								
CSP55									
CSP56									
CSP57									
CSP58									
CSP59									
CSP60									
CSP61									
CSP62									
CSP63									
CSP64									
CSP65									
CSP66	-1.27	-0.01	0.52	1.45	-0.80	0.35	4.16	0.08	4.50
CSP67	Sea wall								
CSP68									
CSP69	2.20	-55.29	12.44	6.24	2.41	-12.52	13.34	3.05	2.60
CSP70	0.39	5.83	8.37	7.30	2.10	-8.07	7.59	0.50	-1.09
CSP71	0.48	8.04	9.77	7.29	0.74	-13.30	12.00	2.70	2.73
CSP72	-0.15	17.22	5.21	6.90	2.40	-2.79	-0.72	*	9.12
CSP73	-0.57	8.66	9.68	8.03	1.02	-13.85	10.85	*	10.82
CSP74	-1.95	17.90	7.53	8.63	1.51	-5.08	-1.04	1.01	1.50
CSP75	-0.34	12.67	11.44	9.42	2.44	-10.10	-7.27	-0.95	8.69
CSP76	0.16	12.32	13.47	7.34	3.45	-17.17	16.35	*	3.84
CSP77	-0.07	15.69	15.60	2.70	1.78	-22.11	28.63	-3.92	4.91
CSP78	-0.32	-8.42	9.85	13.36	0.26	1.03	0.13	1.61	4.37
CSP79	Sea wall								
CSP80	-0.18	7.21	13.36	7.12	0.71	-17.48	19.69	-1.30	4.19
CSP81	0.15	13.56	8.26	6.41	0.79	-22.71	22.94	-0.96	3.03

*Data not considered for analysis

4.1.2 Monthly Beach Volume variations – October 2020 to September 2021 for offshore part

The changes in every month (October 2020 to September 2021) on offshore part have been represented graphically in **Figures 4.10 to 4.15** and in **Table 4.2**.

Offshore survey could not be carried out during October 2021, May 2021, June 2021, and July 2021 due to Covid restrictions and unfavorable weather conditions.

- In October 2020 no offshore survey has been carried out hence the analysis for October 2020 and November 2020 could not be carried out.

- In December 2020, at CSP41 there was no offshore data hence this location excluded from the analysis. Most of the locations on offshore found to have erosion. Accretion found at Poovar (CSP21), Kovalam (CSP43-45), Punthura (CSP54), and Punthura to Beemapally (CSP57-59), Cheriyaathura to Valliyathura (CSP61-63), and Valliyathura (CSP66).
- During the month of January 2021, the locations south of the port shown accretion and on the northern side most of the locations shown erosion. On northern side accretion found at Pannathura (CSP49), Valliyathura (CSP64 and 67), Shangumugham (CSP70), Vettucaud (CSP73), Kochuveli to Valiyaveli (CSP77-78).
- In February 2021, the locations, Poovar (CSP17), Karumkulam (CSP22-23), Pulluvila (CSP28-29), Adimalathura (CSP31), Kovalam (CSP45-46), Pannathura (CSP52-53), Beemapally (CSP60), Cheriyaathura (CSP62), Valliyathura (CSP65), Shangumugham to Vettucaud (CSP70-74), Kochuveli to Valiyaveli (CSP77-79) shows erosion.
- In March 2021, other than Pulluvila (CSP29), Shangumugham (CSP70), Valiyaveli (CSP79) most of the locations shown erosion.
- During the month of April 2021 most of the stations are showing accretion other than erosions at Vallavilay (CSP04), Poovar (CSP19), Kovalam (CSP43), Beemapally (CSP59), Valliyathura (CSP 65-66), Shangumugham (CSP69-70), Vettucaud (CSP74), Kochuveli to Thumba (CSP76-81).
- No offshore survey carried out due to unfavorable weather conditions hence analysis for May 2021, June 2021, July 2021 and August 2021 could not be carried out.
- In September 2021 the locations CSP62 to CSP81 were excluded from the analysis as the offshore data could not be collected due to Cyclone Gulab. Locations Pozhiyur to Paruthiyoor (CSP12-14), Poovar South (CSP17), Poovar (CSP20-21), Karumkulam (CSP23-25), Pulluvila to Adimalathura (CSP30-31), Adimalathura (CSP34), Mullur (CSP36), Kovalam (CSP41), Kovalam (CSP45), Pannathura North (CSP50), Punthura (CSP53), Beemapally to Cheriyaathura (CSP60-61) exhibits erosion during September 2021.

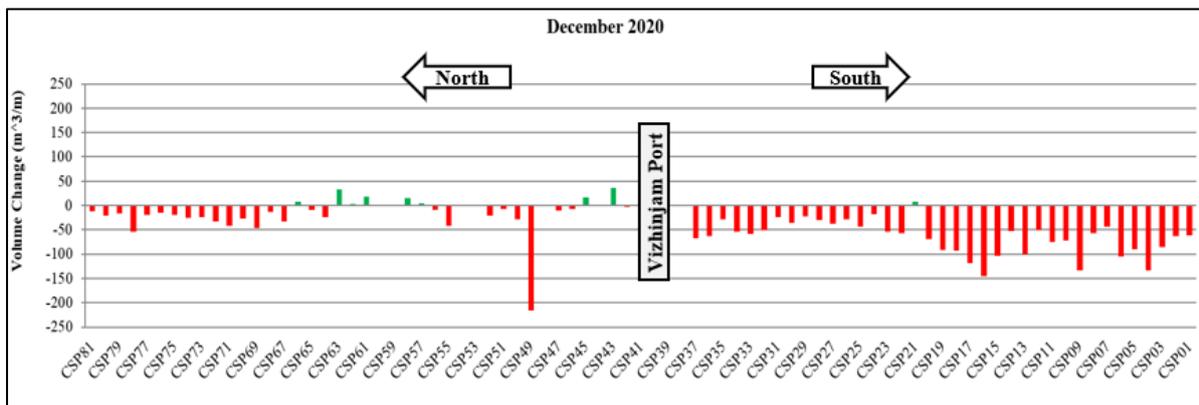
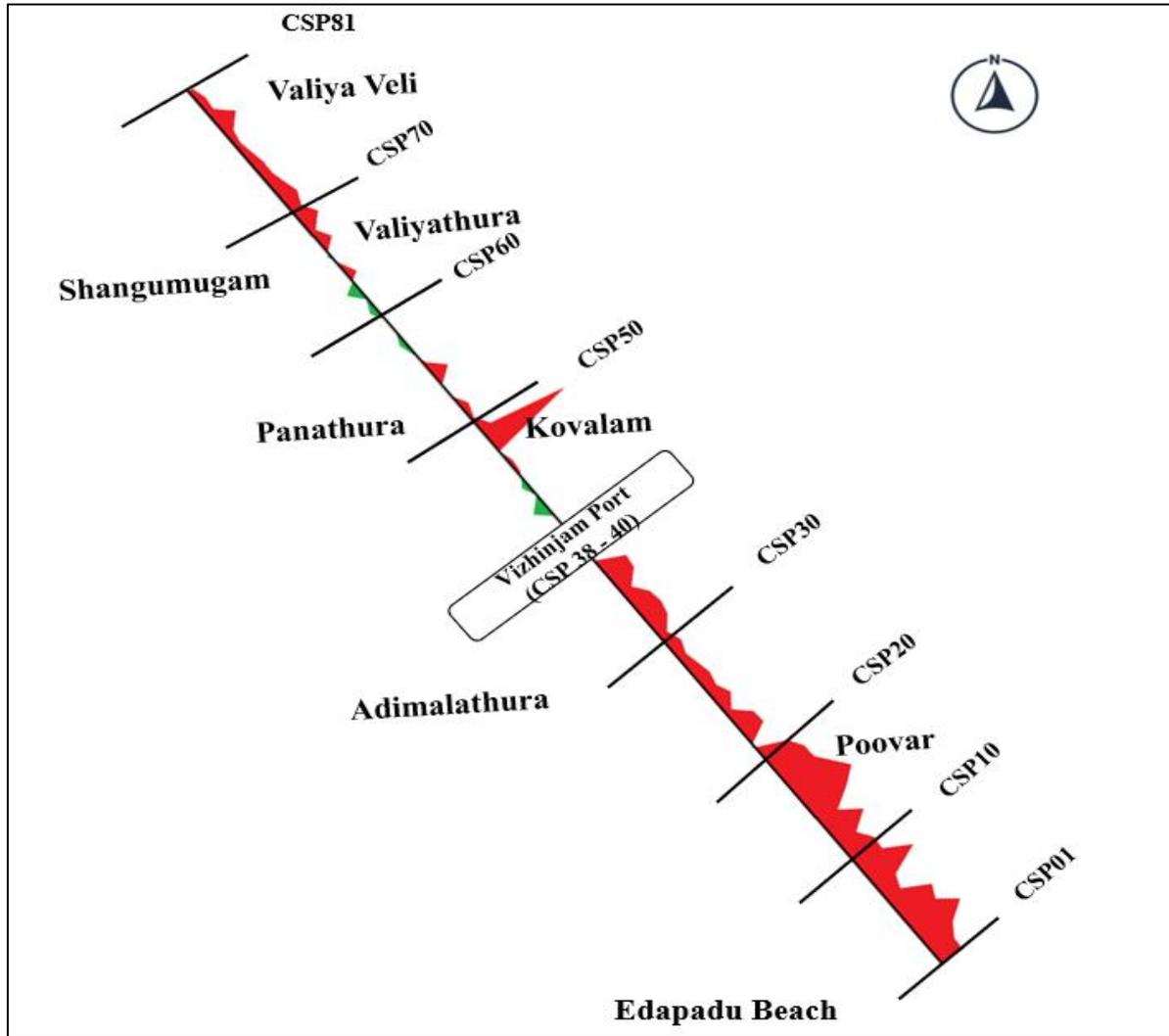


Figure 4.10 Monthly Beach Volume Changes in December 2021 in m³/m (offshore)

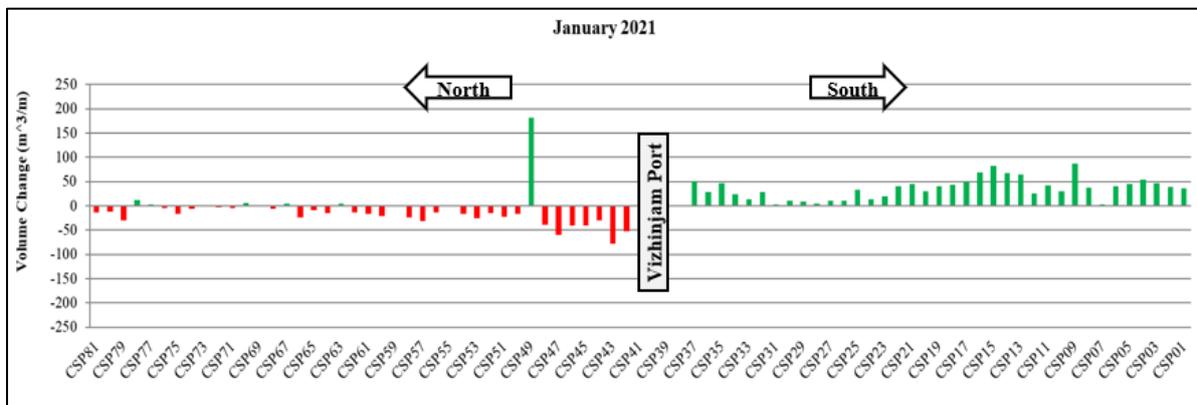
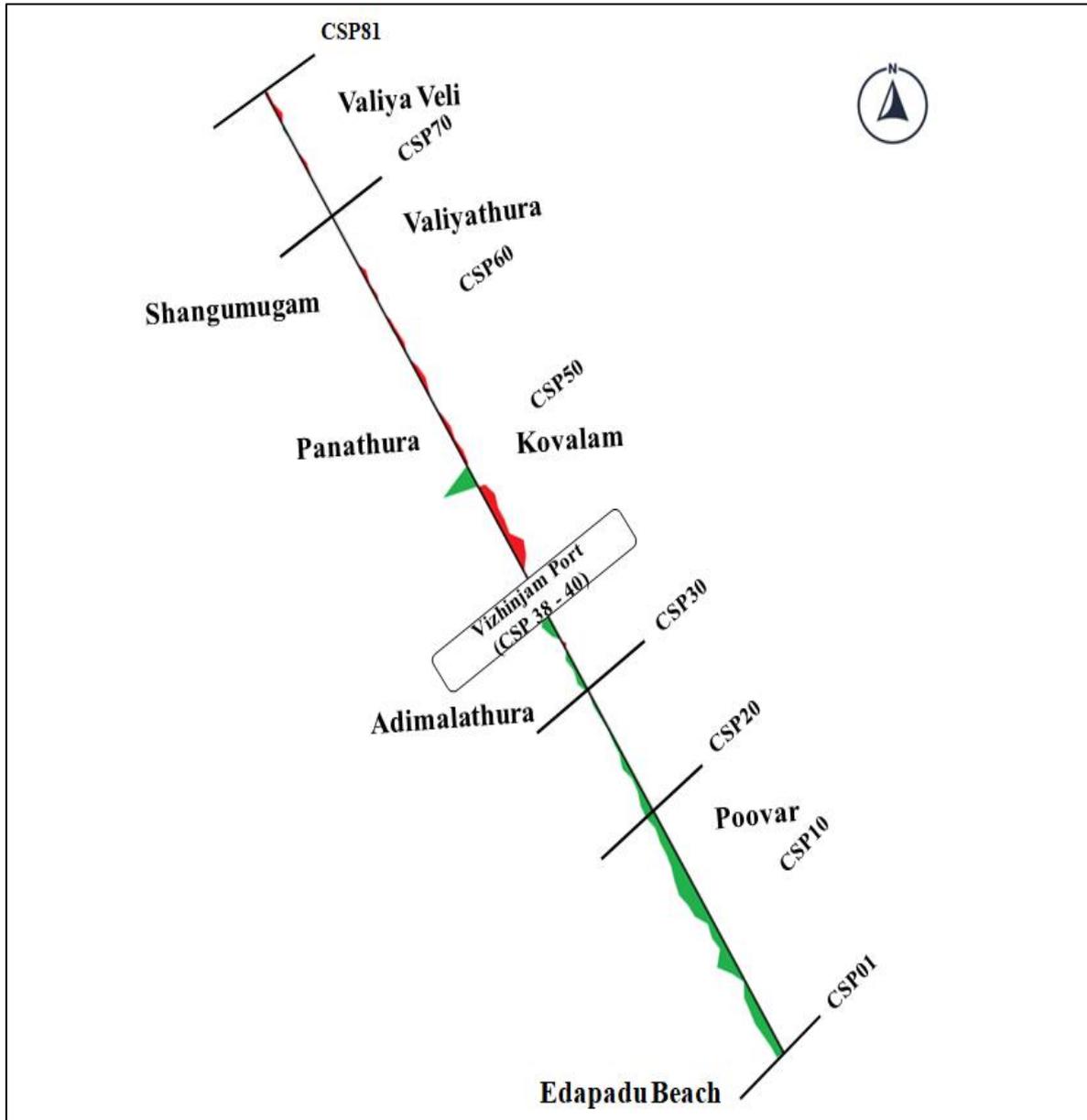


Figure 4.11 Monthly Beach Volume Changes in January 2021 in m^3/m (offshore)

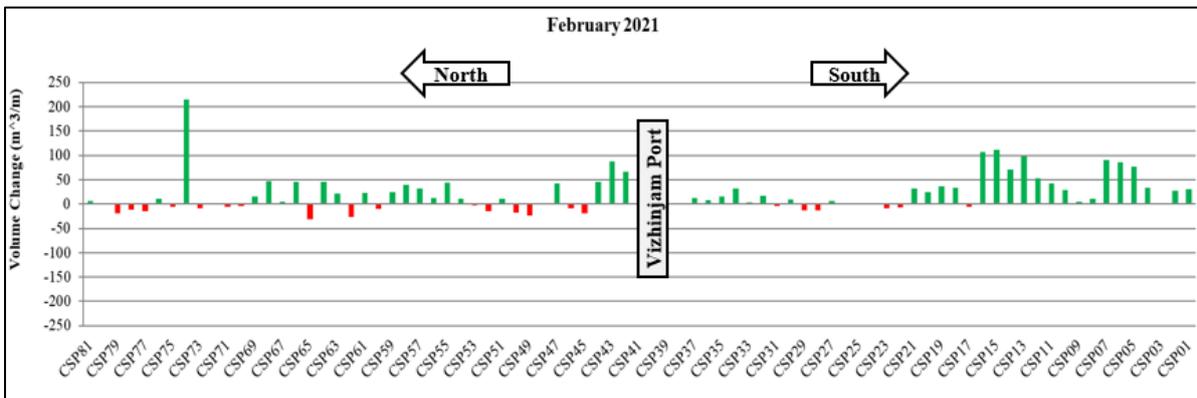
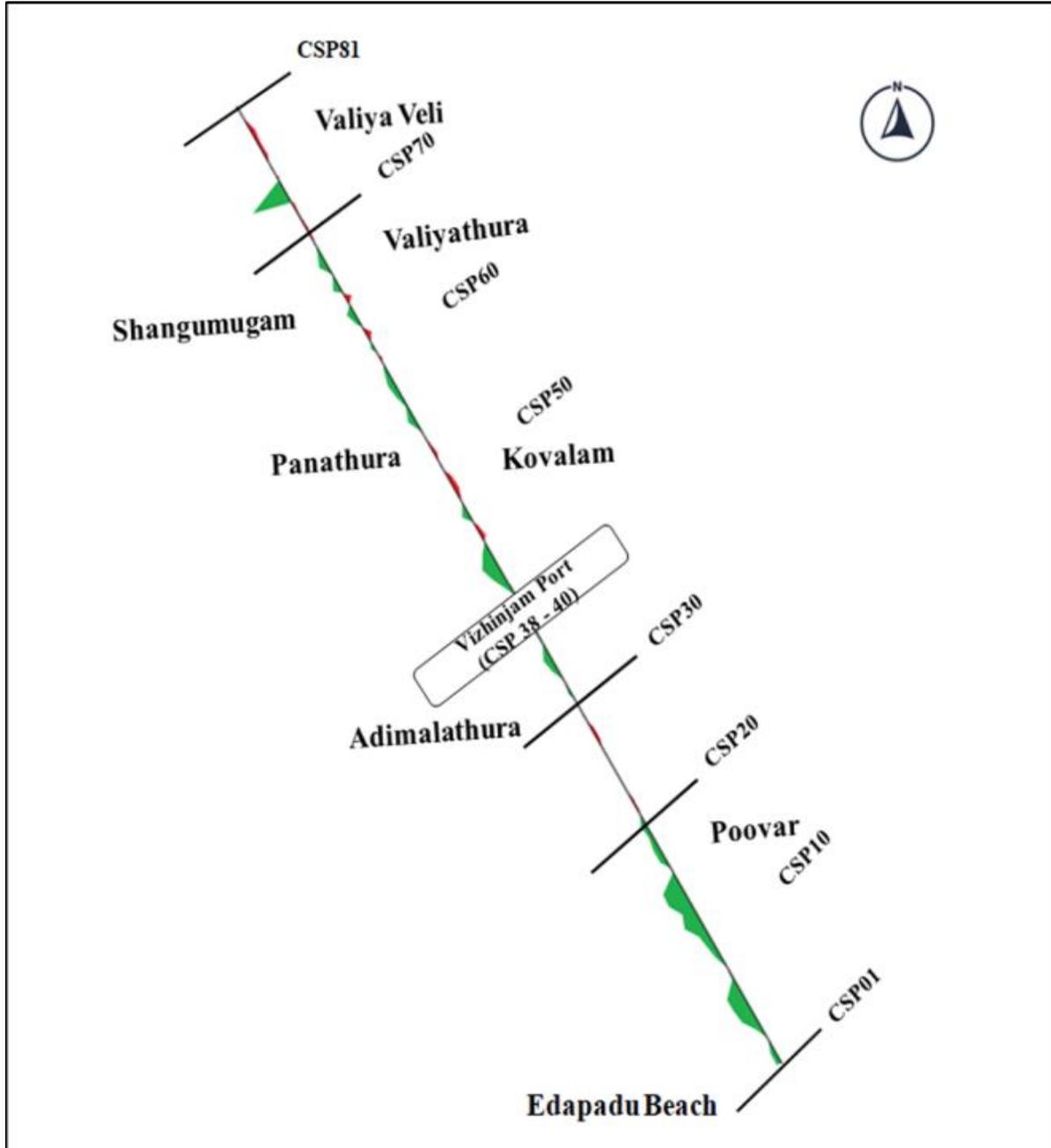


Figure 4.12 Monthly Beach Volume Changes in February 2021 in m³/m (offshore)

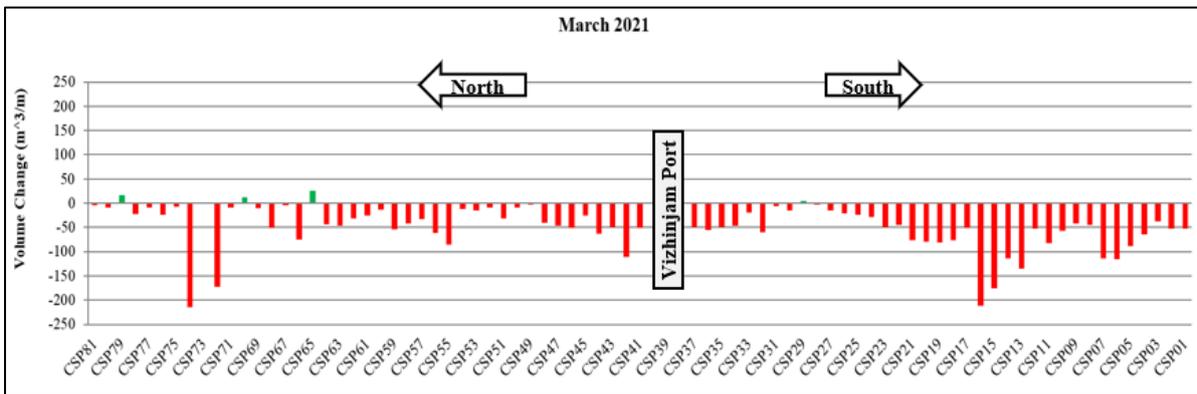
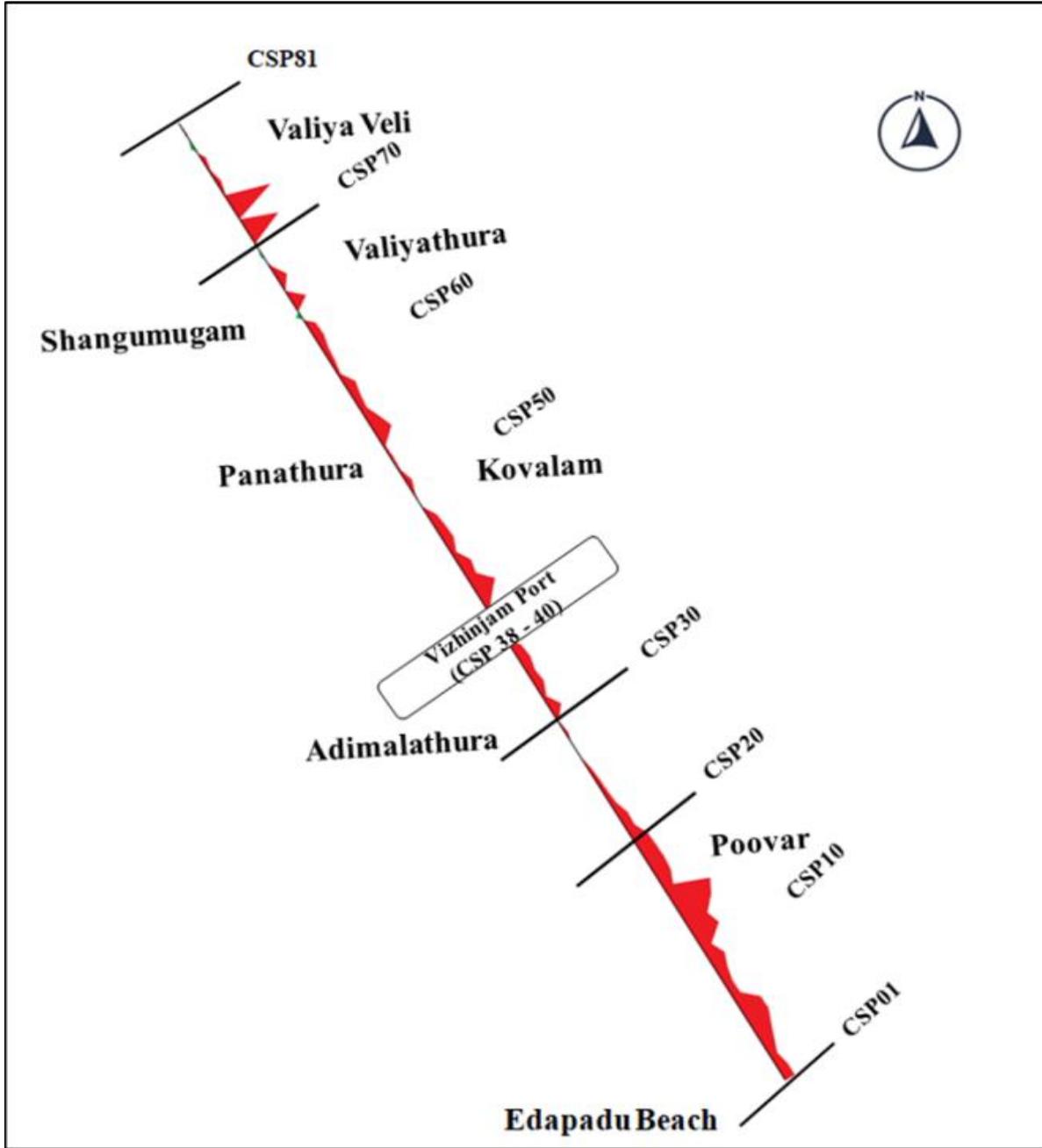


Figure 4.13 Monthly Beach Volume Changes in March 2021 in m³/m (offshore)

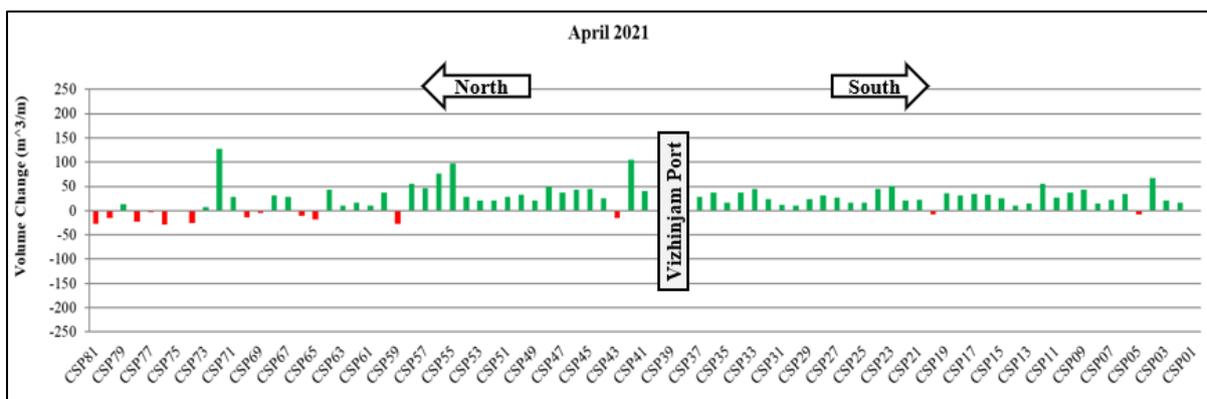
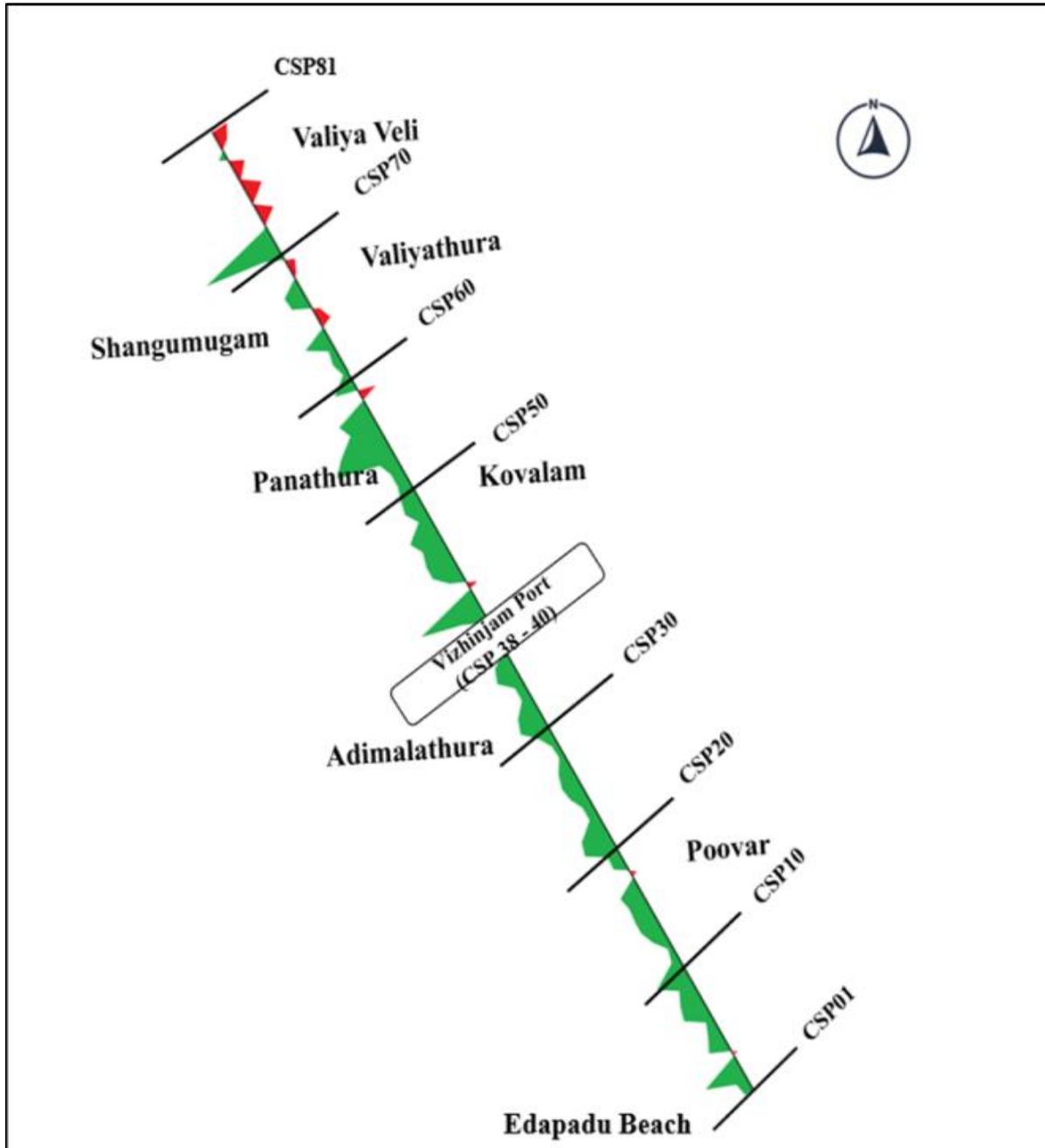


Figure 4.14 Monthly Beach Volume Changes in April 2021 in m³/m (offshore)

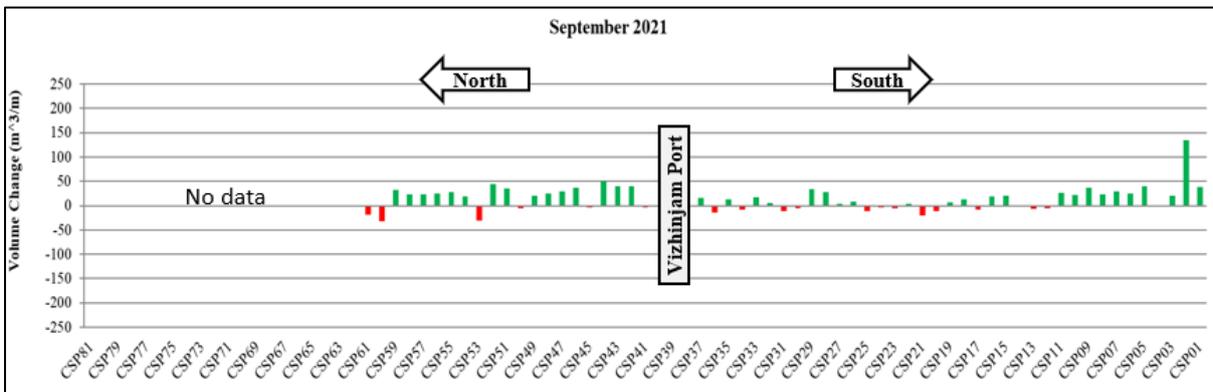
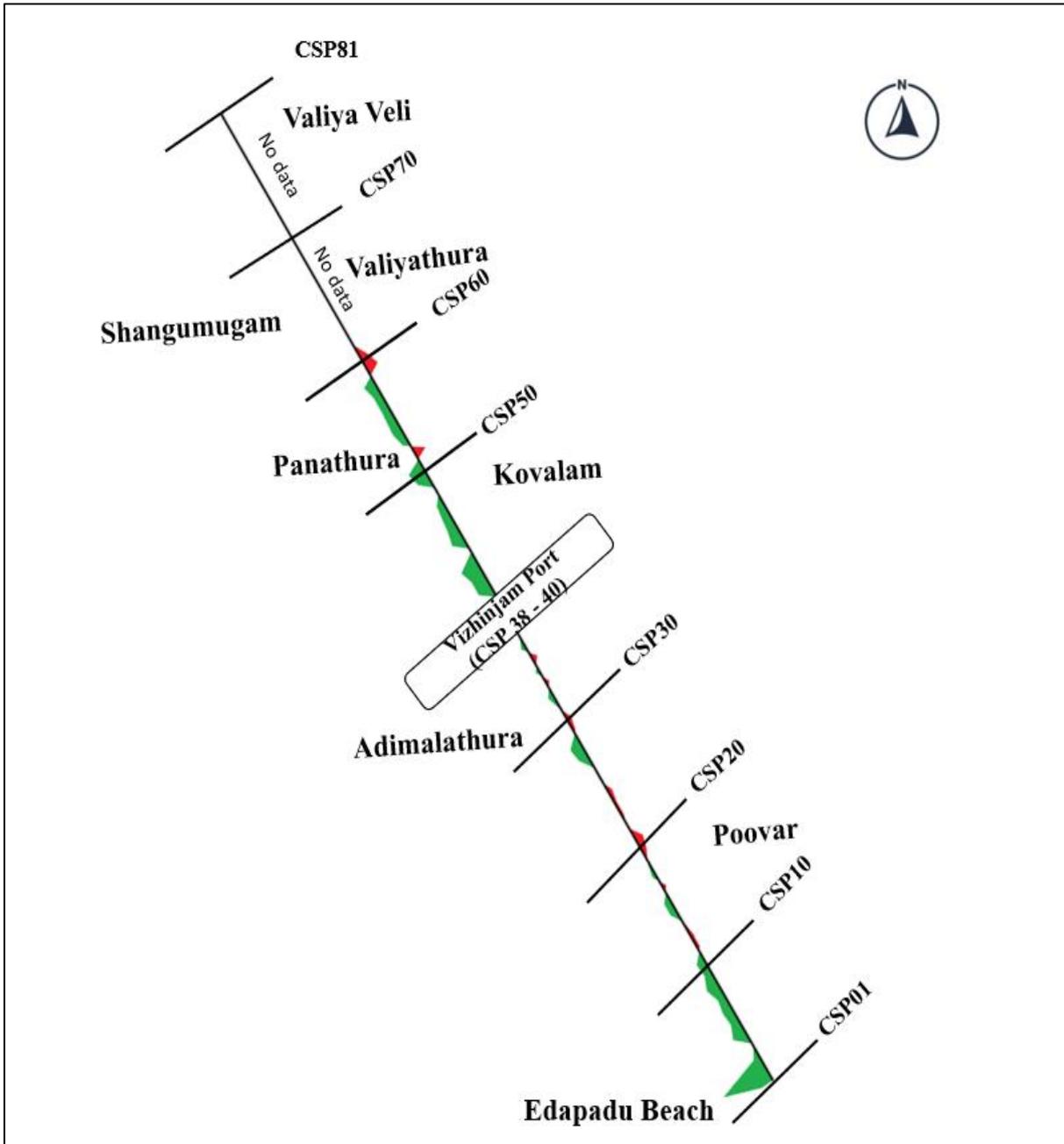


Figure 4.15 Monthly Beach Volume Changes in September 2021 in m³/m (offshore)

Table 4.2 Monthly Beach Volume Changes during October 2020 to September 2021 in m³/m (offshore)

CSP NOS.	December 2020	January 2021	February 2021	March 2021	April 2021	September 2021
CSP01	-60.67	36.09	30.13	-52.54	16.65	38.48
CSP02	-62.65	38.66	27.08	-52.03	20.89	135.02
CSP03	-84.81	45.94	0.63	-37.89	66.63	20.01
CSP04	-132.95	54.71	32.92	-63.71	-8.07	0.36
CSP05	-89.49	45.56	77.59	-87.89	34.11	39.49
CSP06	-105.46	40.75	85.51	-115.61	22.55	25.43
CSP07	-43.70	3.30	89.85	-114.10	14.47	28.99
CSP08	-57.57	37.25	10.95	-44.42	43.28	23.26
CSP09	-133.36	87.22	4.42	-41.64	36.73	36.31
CSP10	-72.25	30.20	28.82	-57.44	26.65	21.47
CSP11	-75.23	41.48	41.69	-82.66	55.25	25.81
CSP12	-51.31	24.88	53.15	-52.05	15.50	-5.74
CSP13	-100.52	63.78	97.44	-134.95	9.91	-6.72
CSP14	-52.34	67.40	70.75	-113.24	24.72	-1.07
CSP15	-103.70	83.18	111.81	-175.20	33.47	19.90
CSP16	-145.11	69.50	106.61	-211.54	33.64	19.17
CSP17	-118.60	49.67	-6.34	-50.40	31.04	-8.86
CSP18	-92.41	43.23	33.67	-77.10	35.48	12.20
CSP19	-91.06	40.88	36.35	-81.59	-8.17	6.10
CSP20	-69.09	29.30	23.75	-79.94	22.38	-11.80
CSP21	7.59	45.06	32.12	-76.52	20.82	-20.92
CSP22	-56.80	40.37	-7.58	-45.43	50.61	3.33
CSP23	-53.68	18.75	-8.45	-49.70	44.28	-5.15
CSP24	-17.73	12.78	2.54	-27.84	16.51	-4.14
CSP25	-43.10	33.53	1.56	-23.38	16.29	-10.89
CSP26	-28.63	11.17	1.86	-20.63	27.15	8.36
CSP27	-36.73	10.16	6.49	-15.38	30.81	4.11
CSP28	-30.25	4.54	-12.84	-3.25	24.39	27.48
CSP29	-22.98	8.43	-13.34	4.58	10.56	33.29
CSP30	-35.36	11.21	9.83	-15.22	11.86	-5.00
CSP31	-23.45	2.77	-4.80	-5.48	23.31	-11.51
CSP32	-50.63	28.16	16.75	-59.77	44.17	5.82
CSP33	-59.03	13.33	2.88	-19.88	37.05	17.78
CSP34	-53.70	24.45	32.32	-47.04	17.39	-8.93
CSP35	-28.20	46.62	15.59	-48.65	16.50	12.92
CSP36	-62.28	28.06	7.36	-54.89	37.59	-14.26
CSP37	-66.98	51.67	12.39	-48.90	28.89	15.38
CSP38	PORT AREA					
CSP39						
CSP40						



CSP41	*	*	32.91	-51.41	39.81	-2.95
CSP42	-3.57	-52.58	66.17	-110.42	104.84	40.37
CSP43	35.85	-78.01	87.85	-49.90	-15.18	39.41
CSP44	1.01	-30.65	46.08	-62.72	24.62	50.49
CSP45	16.39	-40.53	-19.77	-25.81	44.63	-3.13
CSP46	-7.88	-40.70	-8.60	-51.37	43.60	37.34
CSP47	-10.83	-60.39	43.11	-47.11	37.39	28.95
CSP48	-1.09	-39.21	2.08	-40.00	48.62	25.01
CSP49	-215.39	181.22	-23.09	-2.19	20.26	20.74
CSP50	-28.85	-16.10	-17.76	-8.41	32.27	-5.92
CSP51	-7.97	-22.75	11.00	-30.71	27.73	34.74
CSP52	-20.38	-14.39	-13.93	-9.24	20.51	44.30
CSP53	-1.92	-25.21	-3.12	-14.12	20.69	-30.63
CSP54	1.96	-15.99	11.13	-12.04	28.81	19.02
CSP55	-42.22	-0.70	43.40	-85.54	97.44	27.43
CSP56	-8.42	-13.13	12.53	-61.33	75.83	25.25
CSP57	4.95	-31.22	31.33	-32.26	46.27	23.72
CSP58	14.68	-23.68	39.86	-41.16	54.57	22.72
CSP59	0.13	-0.81	23.85	-53.89	-27.70	32.18
CSP60	-1.41	-21.75	-9.98	-13.45	37.69	-31.66
CSP61	18.70	-16.20	23.40	-25.69	9.74	-18.37
CSP62	3.37	-12.94	-26.29	-31.45	15.75	*
CSP63	32.61	5.10	21.86	-46.08	11.00	*
CSP64	-24.39	-15.61	44.87	-42.71	42.63	*
CSP65	-8.22	-8.42	-30.83	26.12	-18.23	*
CSP66	7.68	-24.13	45.97	-75.36	-10.70	*
CSP67	-32.94	4.96	5.08	-3.84	28.11	*
CSP68	-13.35	-5.37	47.19	-51.15	30.71	*
CSP69	-46.57	-0.17	14.81	-10.80	-5.01	*
CSP70	-26.78	6.15	-4.45	12.15	-14.45	*
CSP71	-41.25	-3.80	-6.25	-8.87	28.93	*
CSP72	-32.28	-3.37	-1.69	-172.91	126.93	*
CSP73	-24.19	1.22	-8.92	-2.10	6.92	*
CSP74	-24.79	-6.11	214.52	-214.17	-25.51	*
CSP75	-19.05	-16.76	-6.26	-7.18	*	*
CSP76	-14.17	-4.91	11.12	-24.01	-29.12	*
CSP77	-20.11	2.51	-14.34	-9.38	-2.90	*
CSP78	-54.43	11.79	-11.79	-22.21	-22.45	*
CSP79	-16.73	-29.59	-19.62	17.31	13.81	*
CSP80	-20.14	-11.88	0.46	-8.20	-14.74	*
CSP81	-11.82	-13.93	5.85	-4.17	-26.79	*

*Data not considered for analysis

4.1.3 Seasonal Beach Volume variations from October 2020 to September 2021

Seasonal variation has been analyzed as post monsoon (October 2020 to November 2020), fair weather period (December 2020 to March 2021) and pre-monsoon period (April 2021 to May 2021), Monsoon (June 2021 to September 2021) for the period October 2020 to September 2021. 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. The changes in every season on onshore and offshore part have been represented graphically in **Figures 4.16 to 4.18** and in **Table 4.3**.

4.1.3.1 Results for Beach Volume Change in Post Monsoon 2020 (October 2020-November 2020)

During the post monsoon (October 2020 to November 2020) the sediment accretion has taken place over most of the locations on onshore part. The location CSP32 and CSP35 are not included in the analysis as there is no data. Erosion noted at Poovar (CSP16-18), Karumkulam (CSP24), Adimalathura (CSP31, CSP33), Mullur (CSP37), Pannathura to Punthura (CSP51-53), Valliyathura (CSP66), Shangumugham (CSP69), Valiyaveli (CSP78), and Thumba (CSP80) as shown in **Figure 4.16**. The offshore change during this period could not be carried out as there was no offshore data in October 2020.

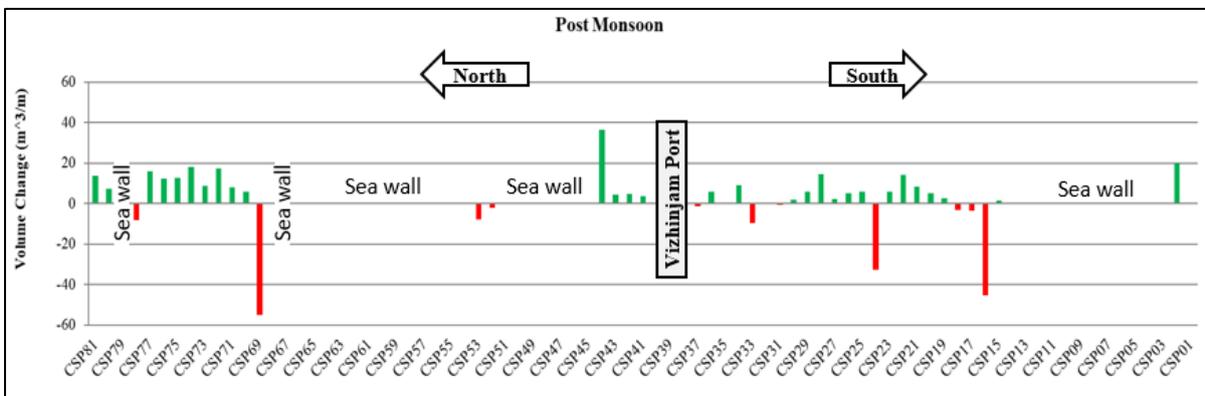
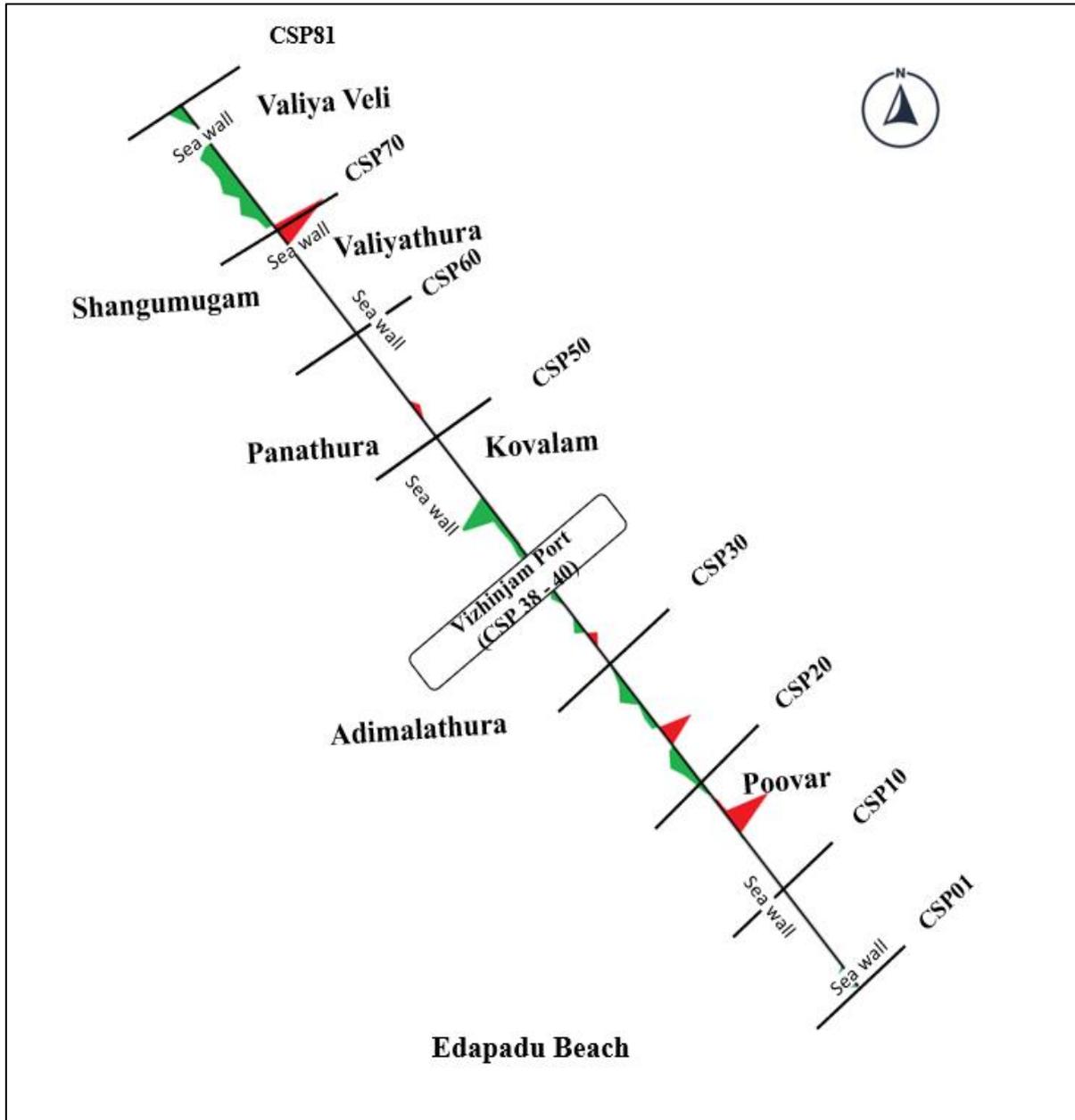


Figure 4.16 Seasonal Beach Volume Changes during Post Monsoon in m^3/m (onshore)

4.1.3.2 Results for Beach Volume Change in Fair Weather Period 2021 (December 2020-March 2021)

During the fair weather period on onshore (**Figure 4.17**) the beach exhibits accretion for most of the locations. The locations CSP32, CSP35 and CSP41 are excluded from the analysis. Erosions are noticed at Edapadu beach (CSP02), Poovar (CSP18-19), Karumkulam (CSP25-26), Kovalam (CSP43), Pannathura to Punthura (CSP51-53), Kochuveli (CSP77), Thumba (CSP81).

During the same period on the offshore (**Figure 4.18**) all the locations except at Cheriyaathura (CSP61), Valliyathura (CSP63) and Poovar (CSP21) exhibit erosion. Edappadu beach (CSP02), Poovar (CSP18-19), Karumkulam (CSP25-26), Kovalam (CSP43), Pannathura to Punthura (CSP51-53), Kochuveli (CSP77) and Thumba (CSP81) shows erosion.

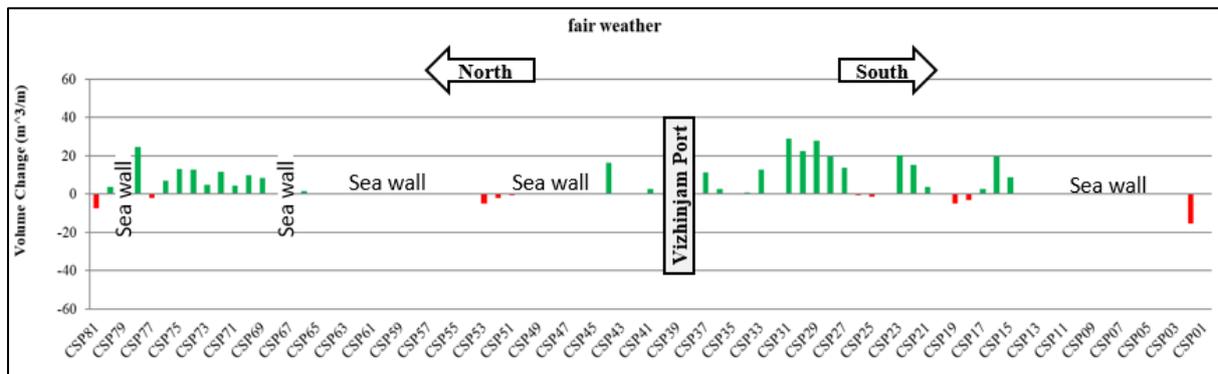
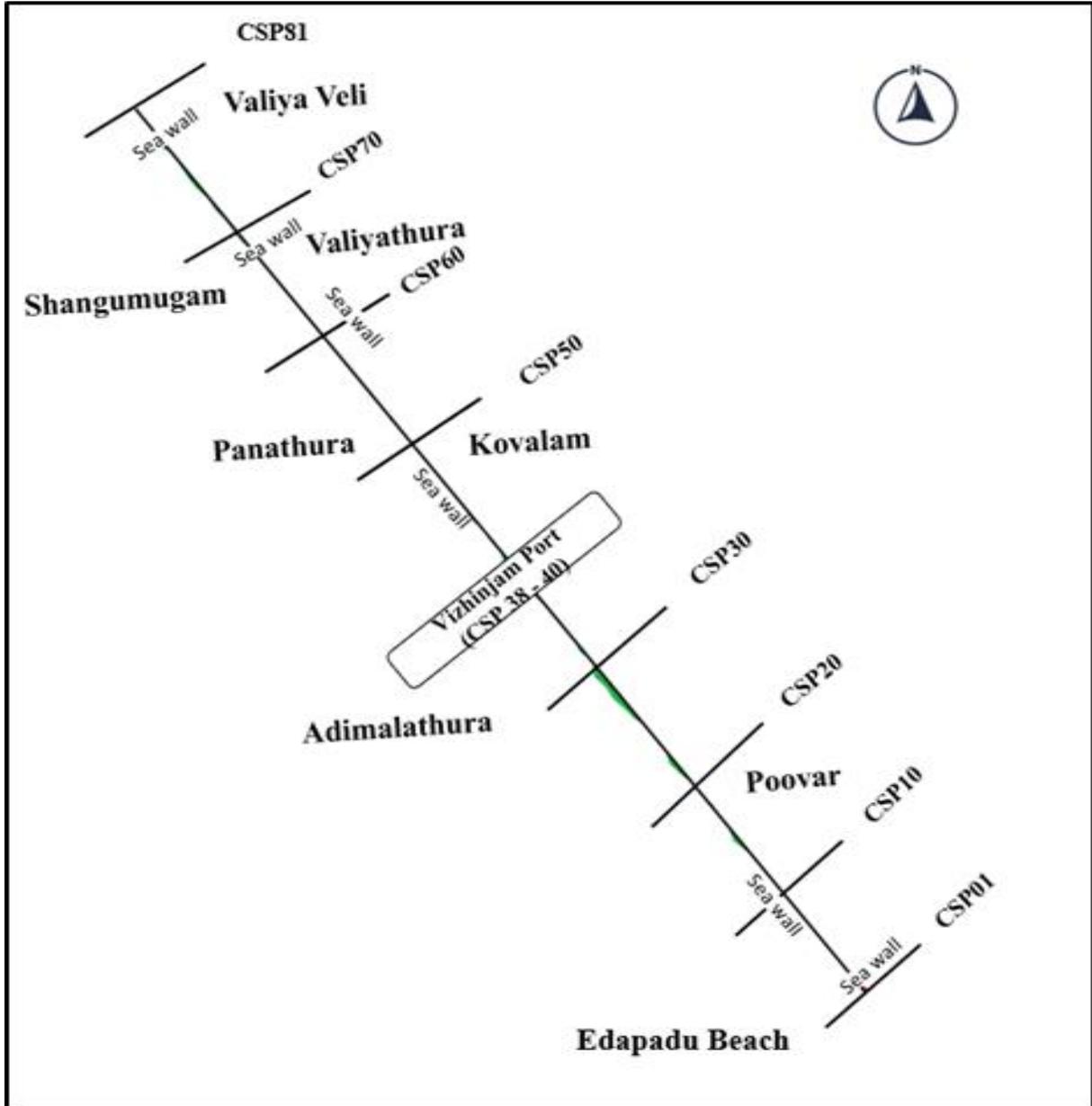


Figure 4.17 Seasonal Beach Volume Changes during Fair weather period in m³/m (onshore)

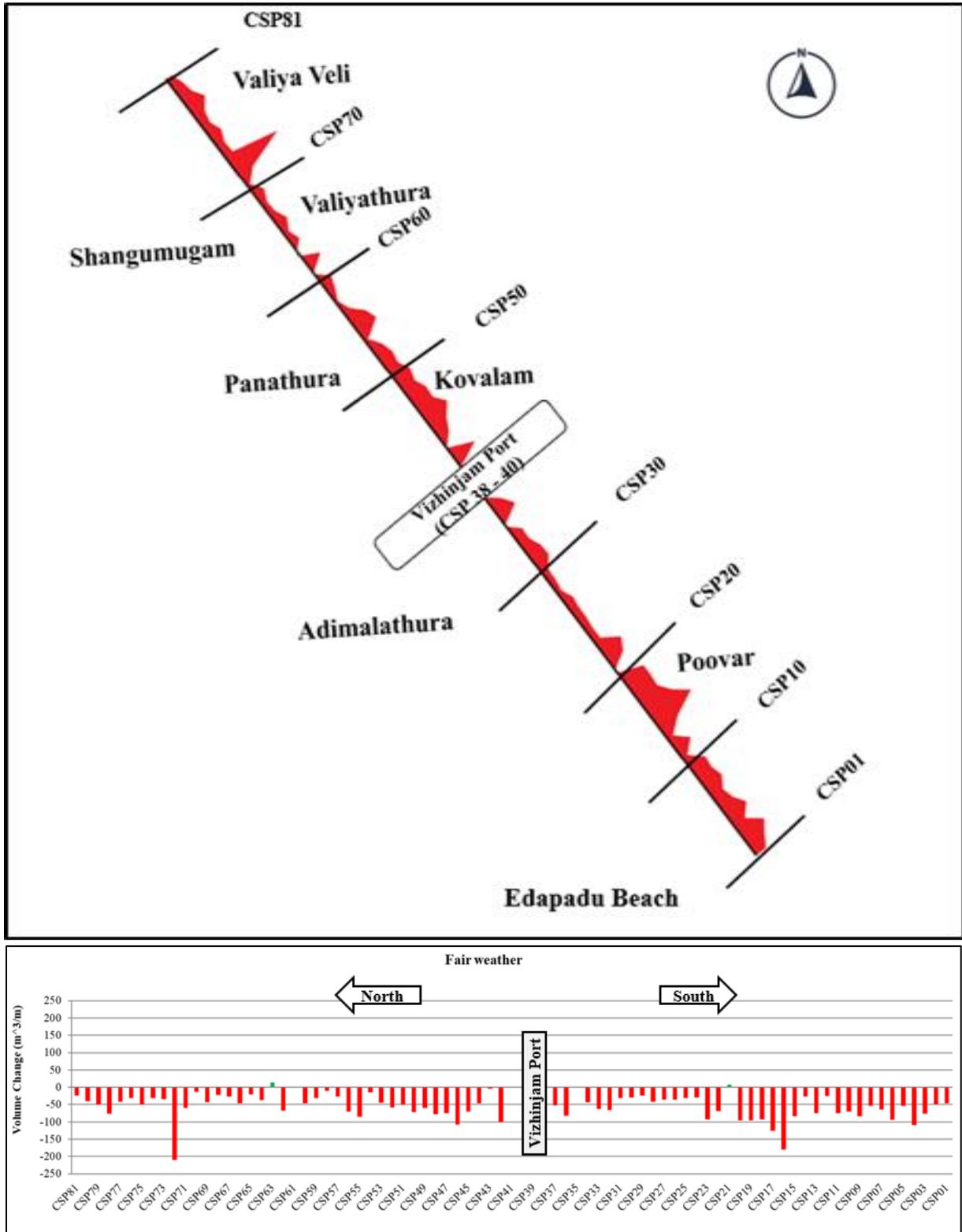


Figure 4.18 Seasonal Beach Volume Changes during Fair weather period in m^3/m (offshore)

4.1.3.3 Results for Beach Volume Change in Pre-Monsoon Period 2021 (April 2021-May 2021)

The analysis for this period could not be carried out as there was no feasible data on onshore and no offshore data during May 2021.

4.1.3.4 Results for Beach Volume Change in Monsoon Period 2021 (June 2021-September 2021)

The analysis for the onshore part during monsoon period could not be carried out as there is no onshore data in June 2021. And the analysis for the offshore part could not be done as there is offshore data in June 2021, July 2021.

4.1.4 Overall beach volume variation during October 2020 to September 2021

The beach volume change for October 2020 to September 2021 could be carried out only for the onshore part as there was no offshore data during October 2020. This analysis is done by comparing the profiles of September 2021 with October 2020. CSP32, CSP35 and CSP41 were excluded from the analysis as there is no data. During this period, the beach shown erosion at Poovar (CSP15-17 and CSP19-21), Karumkulam (CSP24), Pulluvila to Adimalathura (CSP29-31), Adimalathura (CSP34), Mullur (CSP36-37), Kovalam (CSP42-22), Pannathura to Punthura (CSP51-53), Valliyathura (CSP66), Vettucaud to Kochuveli (CSP72-75), Kochuveli (CSP77) and Thumba (CSP81). Accretion found at Edapadu beach (CSP02), Poovar (CSP18), Karumkulam (CSP22-23), Karumkulam to Pulluvila (CSP25-28), Adimalathura (CSP33), Shangumugham (CSP69-71), Valiyaveli (CSP78) and Thumba (CSP80). The results are shown in **Figure 4.19** and in **Table 4.3**.

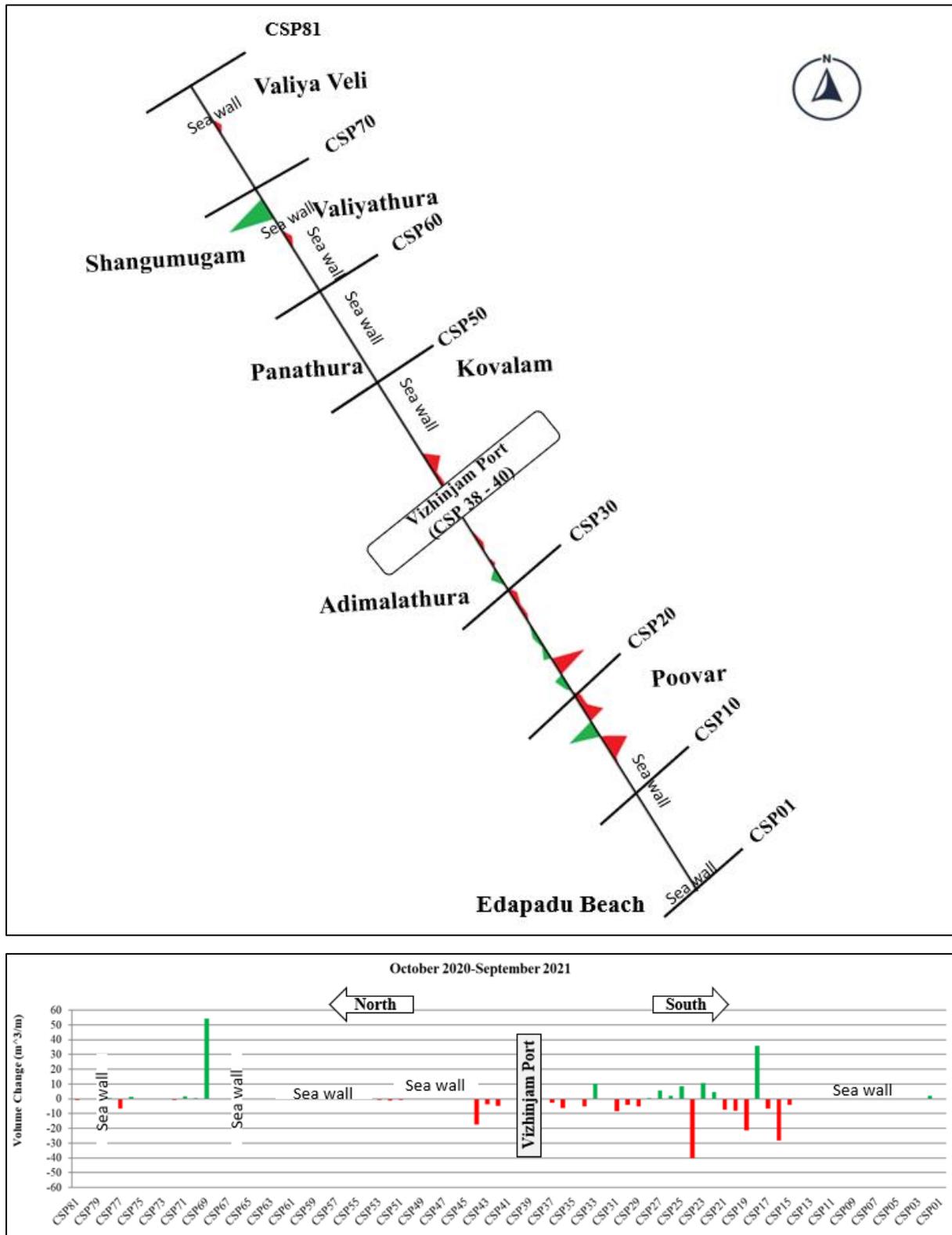


Figure 4.19 Overall Beach Volume Changes - October 2020 to September 2021 in m³/m

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

CSP NOs.	Post monsoon (onshore)	Fair weather (onshore)	Fair weather (offshore)	Overall (October 2020-September 2021)
CSP01	Sea wall		-46.99	Sea wall
CSP02	19.95	-15.49	-48.95	1.92
CSP03	Sea wall		-76.13	Sea wall
CSP04			-109.03	
CSP05			-54.21	
CSP06			-94.82	
CSP07			-64.65	
CSP08			-53.79	
CSP09			-83.36	
CSP10			-70.67	
CSP11			-74.71	
CSP12			-25.33	
CSP13			-74.25	
CSP14			-27.43	
CSP15	1.41	8.94	-83.91	-3.93
CSP16	-45.27	19.71	-180.53	-28.19
CSP17	-3.53	2.77	-125.67	-6.57
CSP18	-3.21	-2.96	-92.61	35.90
CSP19	2.61	-4.99	-95.42	-21.46
CSP20	5.05	0.27	-95.98	-7.98
CSP21	8.38	3.70	8.26	-7.33
CSP22	14.23	15.39	-69.44	4.73
CSP23	5.80	20.44	-93.08	10.54
CSP24	-32.84	0.02	-30.25	-40.22
CSP25	5.63	-1.21	-31.39	8.50
CSP26	5.23	-0.43	-36.23	1.91
CSP27	2.03	13.99	-35.47	5.47
CSP28	14.55	19.70	-41.80	0.73
CSP29	5.69	27.93	-23.31	-5.04
CSP30	1.86	22.65	-29.54	-4.24
CSP31	-0.61	29.05	-30.96	-8.32
CSP32	*	*	-65.49	*
CSP33	-9.56	12.83	-62.70	10.49
CSP34	8.97	1.00	-43.98	-5.27
CSP35	*	*	*	*
CSP36	5.84	2.60	-81.75	-6.13
CSP37	-1.53	11.44	-51.83	-2.63
CSP38	PORT AREA			
CSP39				
CSP40				
CSP41	3.79	2.67	*	*



CSP42	4.70	*	-100.40	-4.63
CSP43	4.41	-0.29	-4.20	-3.87
CSP44	36.36	16.35	-46.28	-17.31
CSP45	Sea wall		-69.72	Sea wall
CSP46			-108.54	
CSP47			-75.22	
CSP48			-78.22	
CSP49			-59.44	
CSP50			-71.12	
CSP51	-0.05	-0.69	-50.43	
CSP52	-2.21	-2.03	-57.94	-1.28
CSP53	-8.01	-4.94	-44.37	-0.99
CSP54	Sea wall		-14.93	Sea wall
CSP55			-85.06	
CSP56			-70.35	
CSP57			-27.21	
CSP58			-10.30	
CSP59			-30.72	
CSP60			-46.60	
CSP61			0.22	
CSP62			-67.33	
CSP63			13.49	
CSP64			-37.84	
CSP65			-21.34	
CSP66	-0.01	1.53	-45.85	
CSP67	Sea wall		-26.75	Sea wall
CSP68			-22.68	
CSP69	-55.29	8.57	-42.72	54.11
CSP70	5.83	9.70	-12.93	0.71
CSP71	8.04	4.50	-60.17	1.73
CSP72	17.22	11.73	-210.26	-0.77
CSP73	8.66	4.88	-33.98	-0.57
CSP74	17.90	12.59	-30.54	-0.57
CSP75	12.67	13.20	-49.26	-0.32
CSP76	12.32	7.09	-31.96	1.28
CSP77	15.69	-2.04	-41.32	-6.74
CSP78	-8.42	24.51	-76.63	0.73
CSP79	Sea wall		-48.63	Sea wall
CSP80	7.21	3.71	-39.76	0.34
CSP81	13.56	-7.25	-24.07	-0.87

*Data not considered for analysis

4.1.5 Seasonal beach volume change comparison between 2019-2020 and 2020-2021

October 2019 and October 2020 (Post Monsoon period)

The comparison between October 2019 and October 2020 shows erosions at Edapadu beach (CSP02), Poovar (CSP15-16 and CSP18-19), Karumkulam to Adimalathura (CSP23-31), Adimalathura (CSP33), Kovalam (CSP42 and 44), Pannathura (CSP51-52), Valliyathura (CSP66) and Vettucaud to Kochuveli (CSP72-75) on the onshore. At locations Poovar (CSP16), Poovar to Karumkulam (CSP20-22), Adimalathura (CSP34), Mullur (CSP36-37), Kovalam (CSP41), Kovalam (CSP43), Punthura (CSP53), Shangumugham (CSP69 and CSP71), Kochuveli to Valiyaveli (CSP76-78) and Thumba (CSP 80-81) accretion taken place on onshore side in October 2020 compared to October 2019. There was no offshore data for the month October 2021 to compare with October 2019. The results have been presented in **Figure 4.20** and in **Table 4.4**.

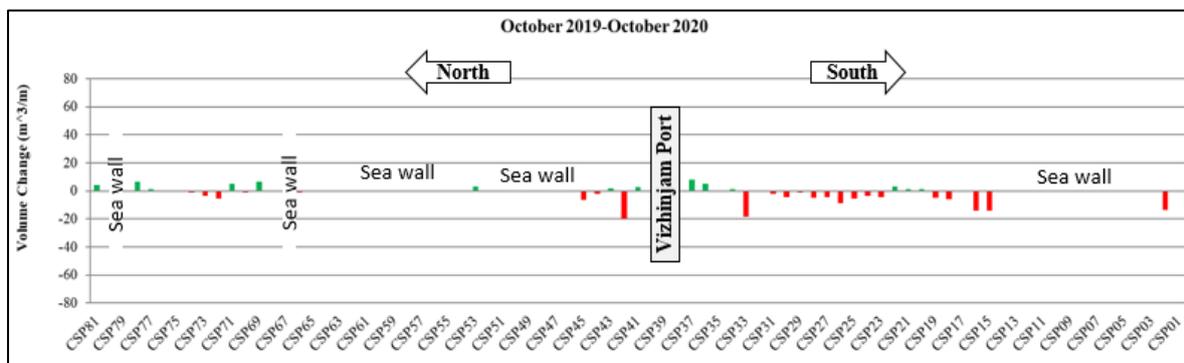
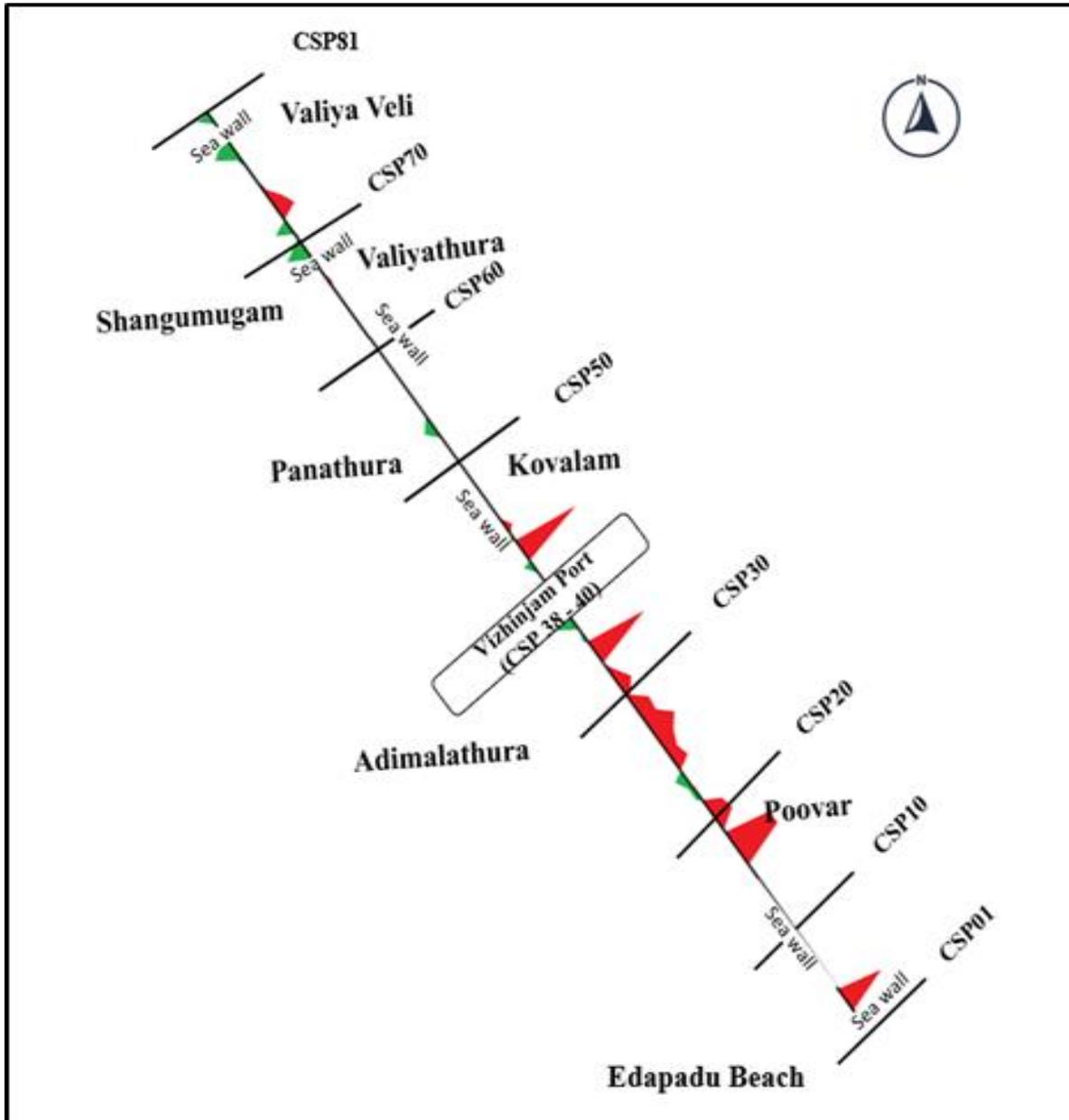


Figure 4.20 Beach Volume Changes during October 2019 and October 2020 in m^3/m (onshore)

February 2020 and February 2021 (Fair weather period)

The comparison between the profiles for the February 2020 and February 2021 are presented graphically in **Figure 4.21**, **Figure 4.22** and in **Table 4.4**.

On the onshore part erosion noticed at Edapadu beach (CSP02), Poovar (CSP16), Poovar to Pulluvila (CSP18-28), Mullur (CSP37), Kovalam (CSP41), Pannathura to Punthura (CSP51-53), Shangumugham (CSP69), Vettucaud to Valiyaveli (CSP72-78) and Thumba (CSP80-81). Accretion found at Poovar (CSP15 and CSP17), Pulluvila to Adimalathura (CSP29-31), Adimalathura (CSP33-34), Mullur (CSP36) Kovalam (CSP42-44), Valliyathura (CSP66), and Shangumugham (CSP70-71).

On the offshore erosion taken place at Edapadu beach (CSP02), Neerody to Pozhiyur (CSP08-10), Pozhiyur (CSP12), Poovar (CSP17), Karumkulam (CSP22-25), Pulluvila to Adimalathura (CSP27-33), Mullur (CSP37), Kovalam (CSP 41), Pannathura to Punthura (CSP47-53), Beemapally to Valliyathura (CSP60-63), Valliyathura (CSP65 and CSP67), Shangumugham to Vettucaud (CSP70-73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78), Thumba (CSP81). Accretion found at Edapadu Beach (CSP01), Edapadu to Neerody (CSP03-07), Pozhiyur (CSP11), Paruthiyoor to Poovar (CSP13-16), Poovar (CSP18-21), Karumkulam (CSP26), Adimalathura (CSP34), Mullur (CSP36), Kovalam (CSP42-46), Punthura to Beemapally (CSP54- 59), Valliyathura (CSP64 and 66), Shangumugham (CSP68-69), Vettucaud (CSP74), Kochuveli (CSP76), Thumba (CSP80).

The locations Edapadu beach (CSP02), Karumkulam (CSP22-25), Pulluvila (CSP27-28), Mullur (CSP37), Kovalam (CSP 41), Pannathura to Punthura (CSP51-53), Vettucaud (CSP73), Kochuveli (CSP73), Kochuveli (CSP75), Kochuveli to Valiyaveli (CSP77-78), Thumba (CSP81) eroded on onshore and offshore.

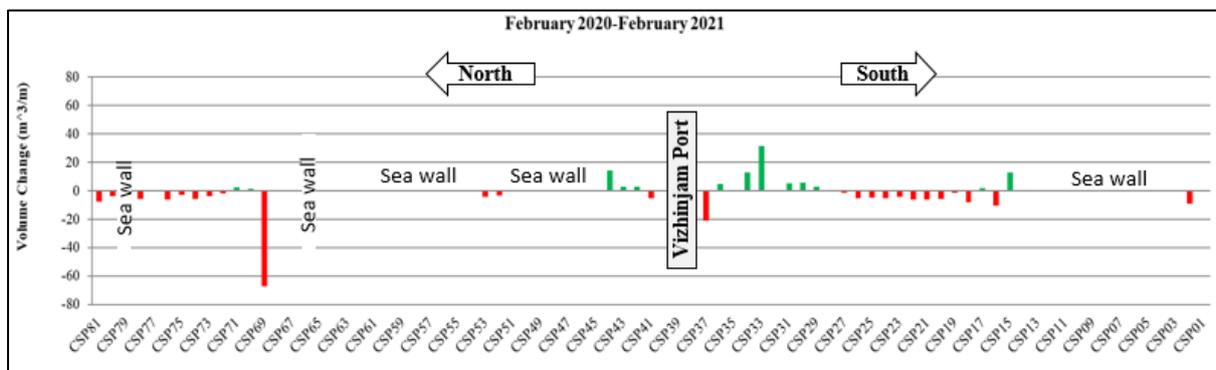
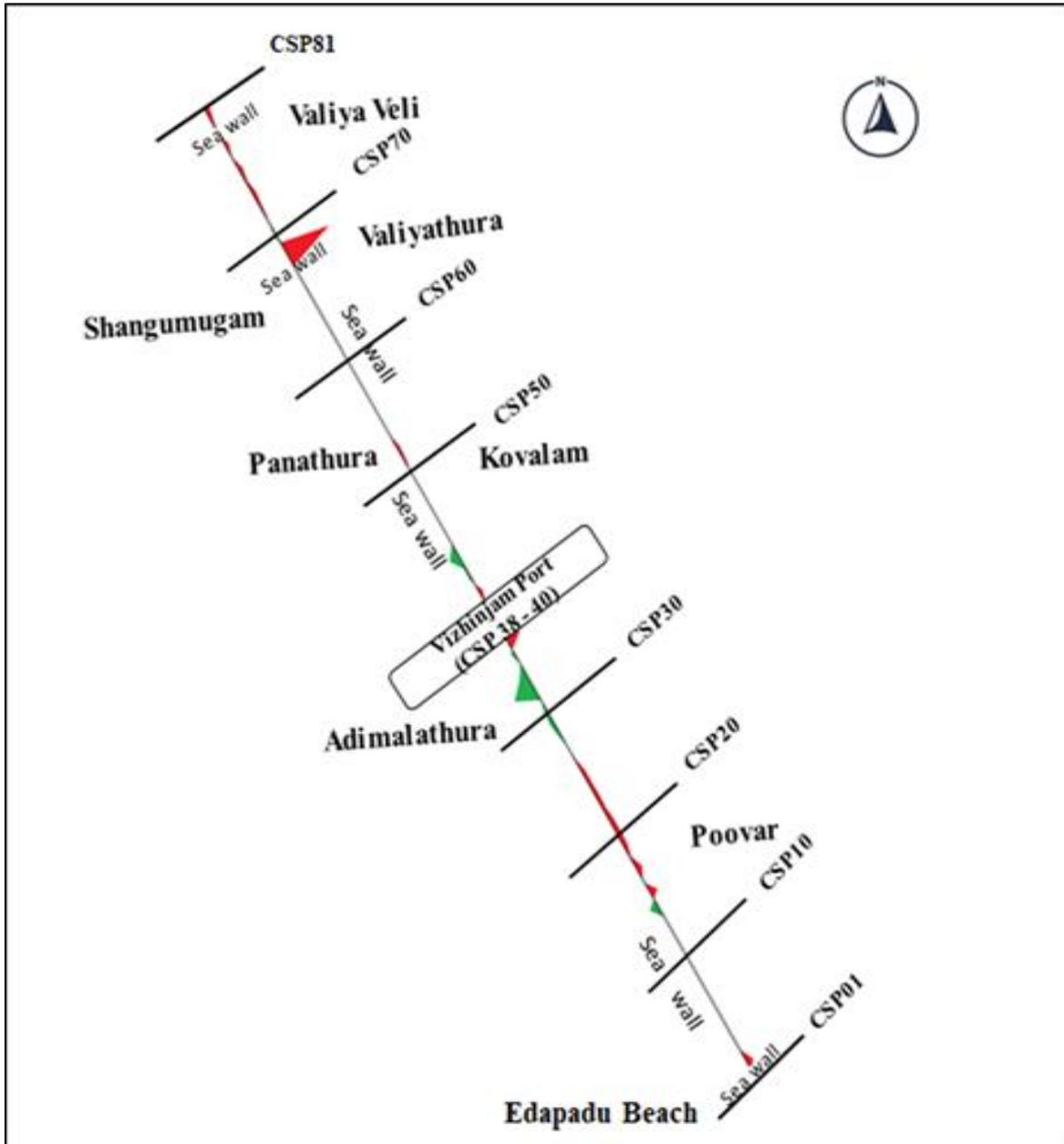


Figure 4.21 Beach Volume Changes during February 2020 and February 2021 in m³/m (onshore)

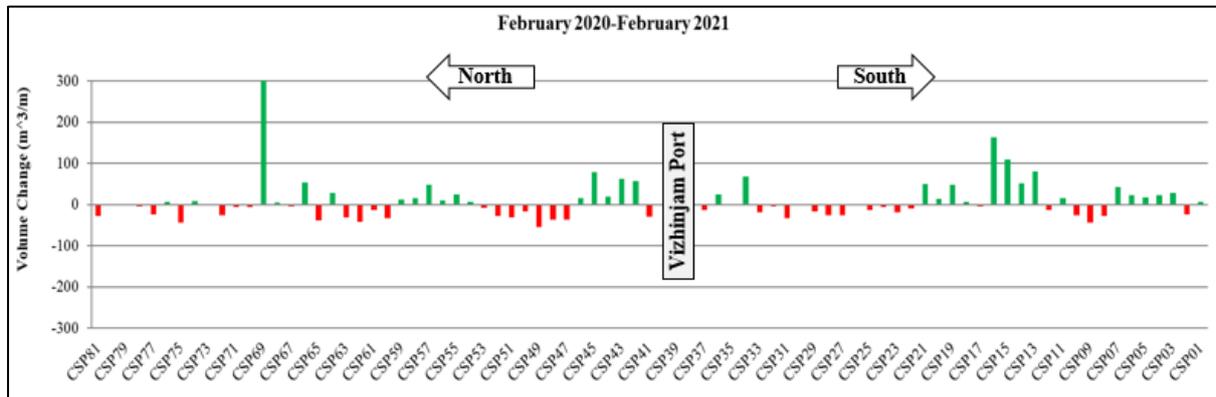
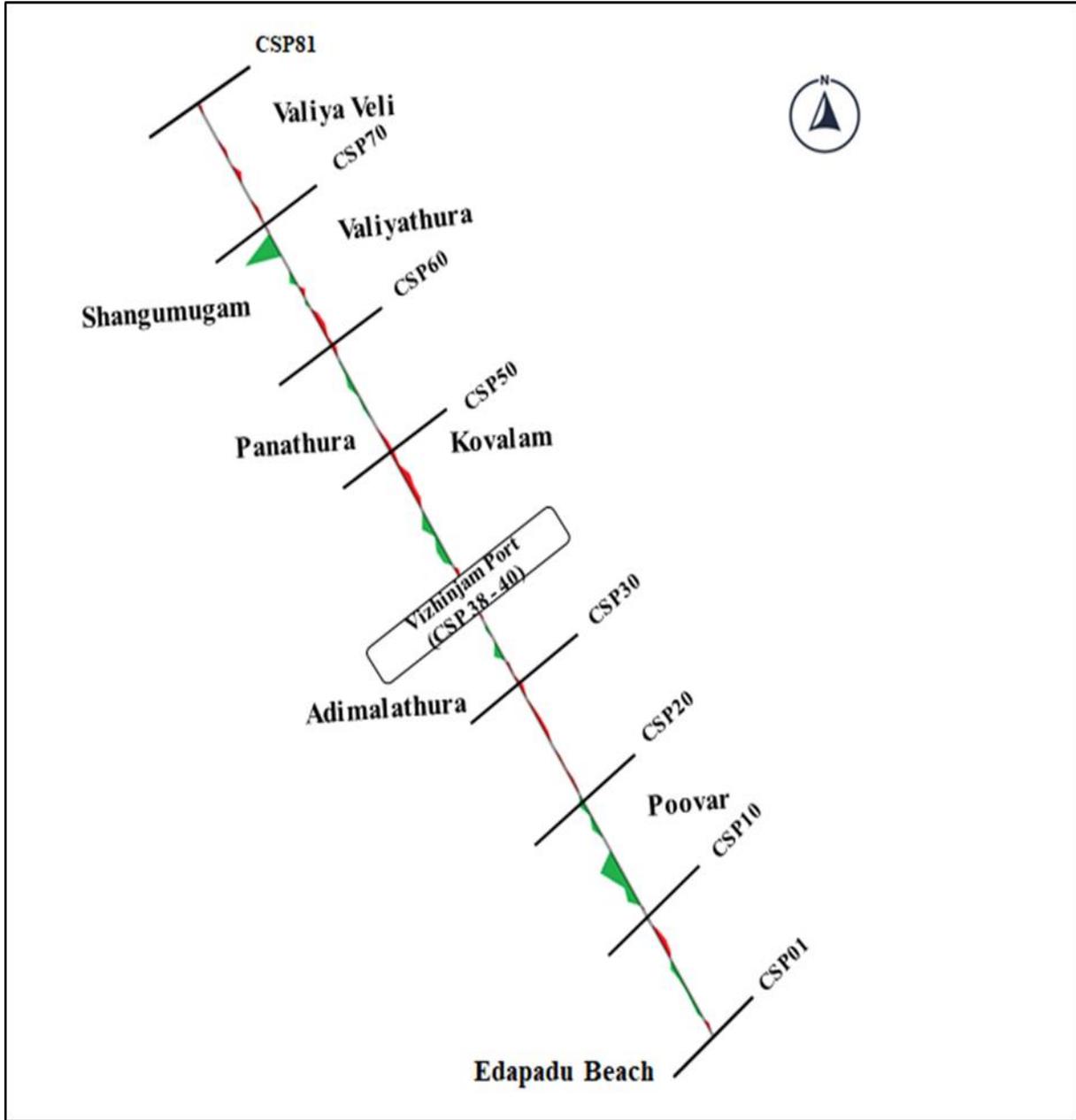


Figure 4.22 Beach Volume Changes during February 2020 and February 2021 in m³/m (offshore)

April 2020 and April 2021 (Pre-Monsoon period)

The results for the comparison of profiles between April 2020 and April 2020 has been presented graphically in the figures given below (**Figure 4.23, Figure 2.4 and in Table .4.4**).

CSP32 (no onshore data), CSP35 (no onshore data), CSP16 (April 2020 profile found erroneous), CSP02 (no data in April 2020) has not been included for the analysis. In April 2021 erosion found at Poovar to Karumkulam (CSP18-23), Karumkulam to Pulluvila (CSP25-27), Mullur (CSP36-37), Pannathura (CSP51-53), Shangumugham (CSP69), Shangumugham to Vettucaud (CSP71-72), Vettucaud (CSP74), Valiyaveli (CSP78) and Thumba (CSP81) compared to April 2020. Accretion found to have at Poovar (CSP15 and 17), Karumkulam (CSP24), Pulluvila to Adimalathura (CSP29-31), Adimalathura (CSP33-34), Kovalam (CSP41-44), Valliyathura (CSP66), Shangumugham (CSP70), Vettucaud (CSP73), Kochuveli (CSP75-77) and Thumba (CSP80).

On the offshore part erosion taken place at Edapadu beach (CSP01), Vallavilay (CSP05), Neerody to Pozhiyur (CSP09-10), Poovar (CSP19-20), Karumkulam to Adimalathura (CSP24-31), Mullur (CSP37), Kovalam (CSP41 and 44), Kovalam to Pannathura (CSP 47-49), Pannathura (CSP51-52), Cheriyaathura (CSP62), Valliyathura (CSP66), Vettucaud (CSP72) and Vettucaud to Thumba (CSP74-81). The locations Edapadu beach (CSP01), Edapadu to Vallavilay (CSP03-04), Vallavilay to Neerody (CSP06-08), Pozhiyur to Poovar (CSP11-18), Poovar to Karumkulam (CSP21-23), Adimalathura (CSP32-34), Mullur (CSP36), Kovalam (CSP 42-43 and 45-46), Pannathura (CSP50), Punthura to Cheriyaathura (CSP53-61), Valliyathura (CSP63-65), Valliyathura to Shangumugham (CSP67-71), Vettucaud (CSP73) shows accretion.

At Poovar (CSP19-20), Karumkulam to Pulluvila (CSP25-27), Mullur (CSP37), Pannathura (CSP51-52), Vettucaud (CSP72 and 74), Valiyaveli (CSP78) and Thumba (CSP81) erosion occurred on both sides of the cross shore line in April 2021 compared to April 2020.

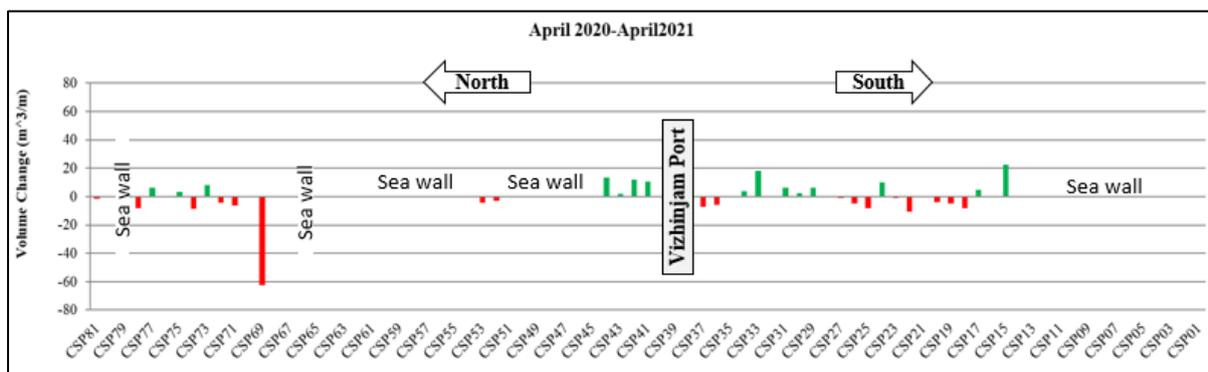
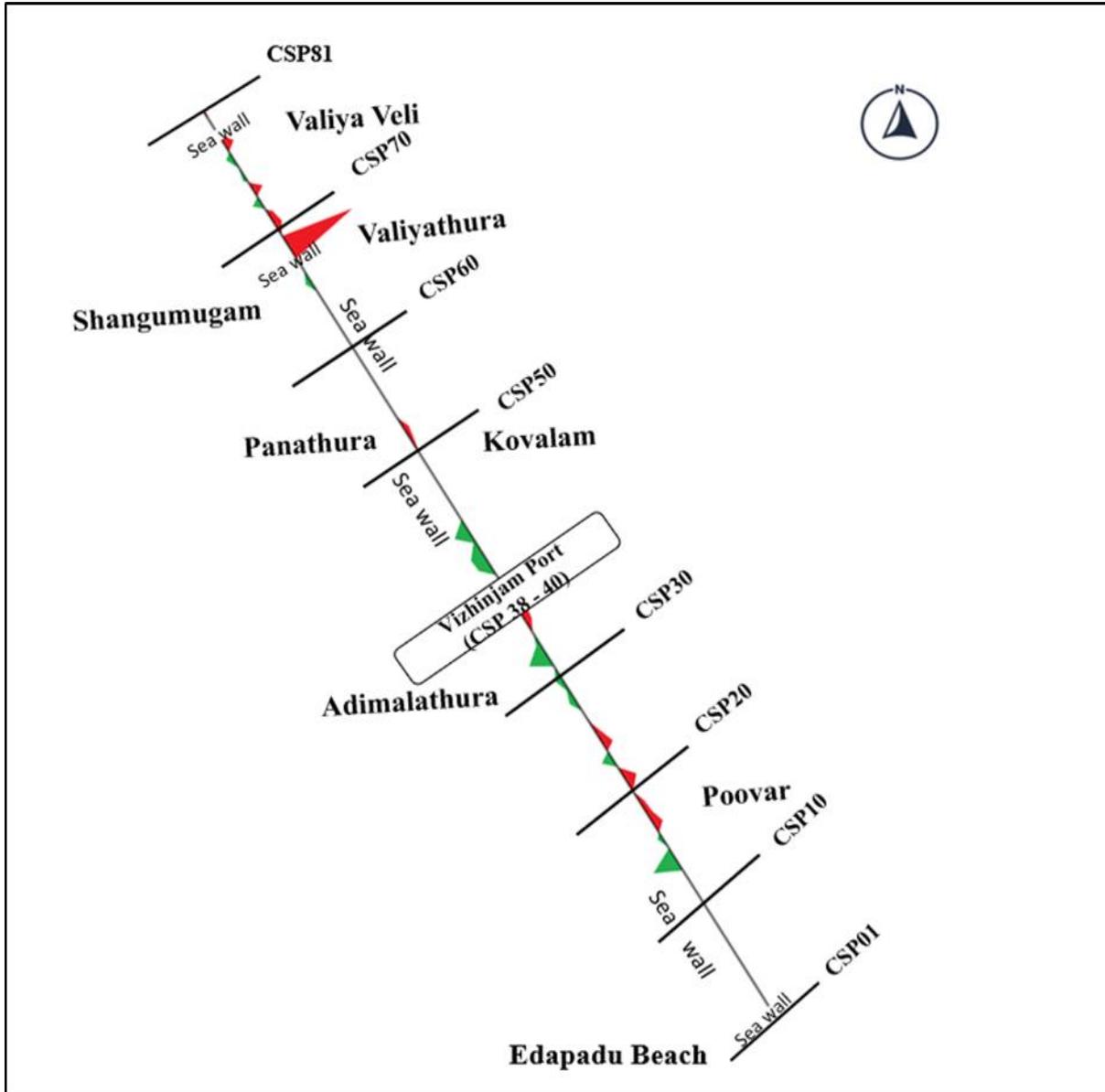


Figure 4.23 Beach Volume Changes during April 2020 and April 2021 in m^3/m (onshore)

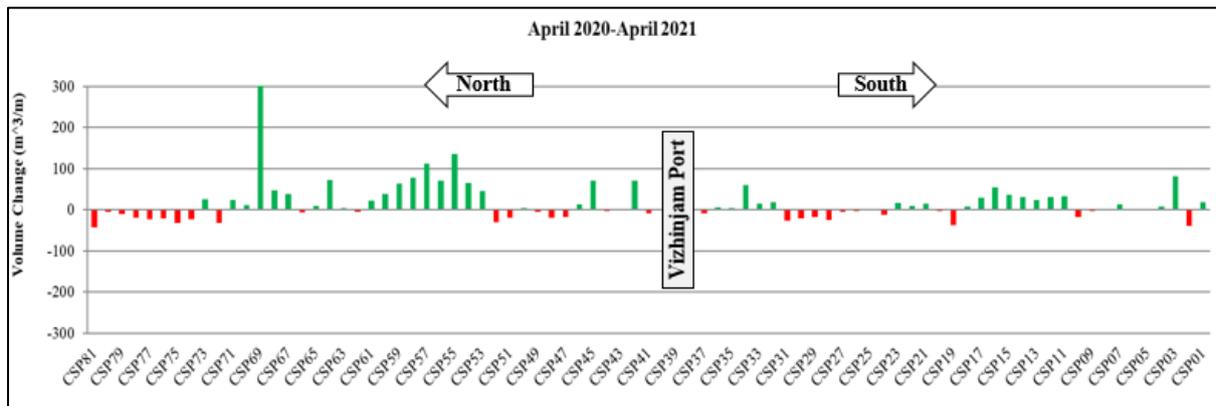
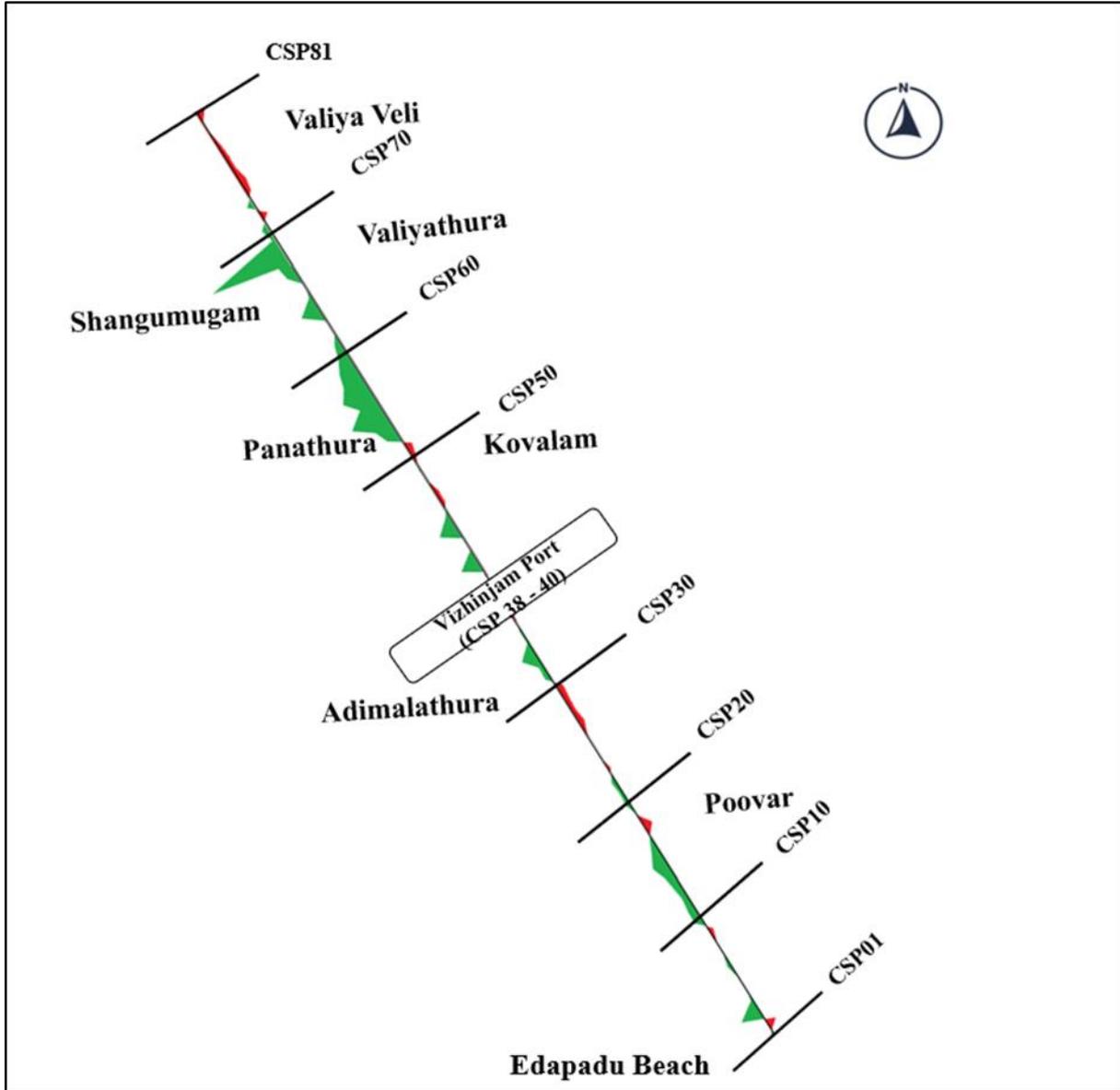


Figure 4.24 Beach Volume Changes during April 2020 and April 2021 in m³/m (offshore)

September 2020 and September 2021 (Monsoon period)

The comparison of September 2020 beach profiles with September 2021 for onshore part has been presented in the **Figure 4.25** and in the **Table 4.4**.

No onshore survey carried out at locations CSP41 and CSP67 as these locations were not accessible by foot during September 2021. The locations CSP01-CSP10, CSP32 and CSP35 were not surveyed on onshore part during September 2020. These locations have not been included for the analysis. The beach was shown accretion at Poovar (CSP15-17), Pulluvila to Adimalathura (CSP29-31), Adimalathura (CSP34), Mullur (CSP37), Kovalam (CSP42-44), Pannathura to Punthura (CSP51-53), Valliyathura (CSP66), Vettucaud to Kochuveli (CSP72-75), Kochuveli to Valiyaveli (CSP77-78), Thumba (CSP80-81) in September 2021 compared to September 2020. Poovar to Pulluvila (CSP18-28), Adimalathura (CSP34), Mullur (CSP36), Shangumugham South to North (CSP69-71), and Kochuveli (CSP76) eroded during September 2021 compared to September 2020.

The comparison of September 2020 beach profiles with September 2021 for offshore part has been presented in the **Figure 4.26** and in the **Table 4.4**.

In September 2021 offshore data could not be collected from CSP62 to CSP81 due to Cyclone Gulab. On offshore part accretion was found at locations Edapadu to Vallavilay (CSP02-04), Neerody (CSP07), Pozhiyur to Paruthiyoor (CSP11-13), Poovar (CSP15-16), Adimalathura to Mullur (CSP32-37), Kovalam (CSP41-43), and Pannathura to Beemapally (CSP48-60). Erosion found at locations Edapadu (CSP01), Vallavilay (CSP05-06), Neerody to Pozhiyur (CSP08-10), Paruthiyoor (CSP14), Poovar to Adimalathura (CSP17-31), Kovalam to Kovalam North (CSP44-47) in September 2021 compared to September 2020.

From Poovar to Pulluvila (CSP18-28) the beach shows erosion on both sides of the cross shore line.

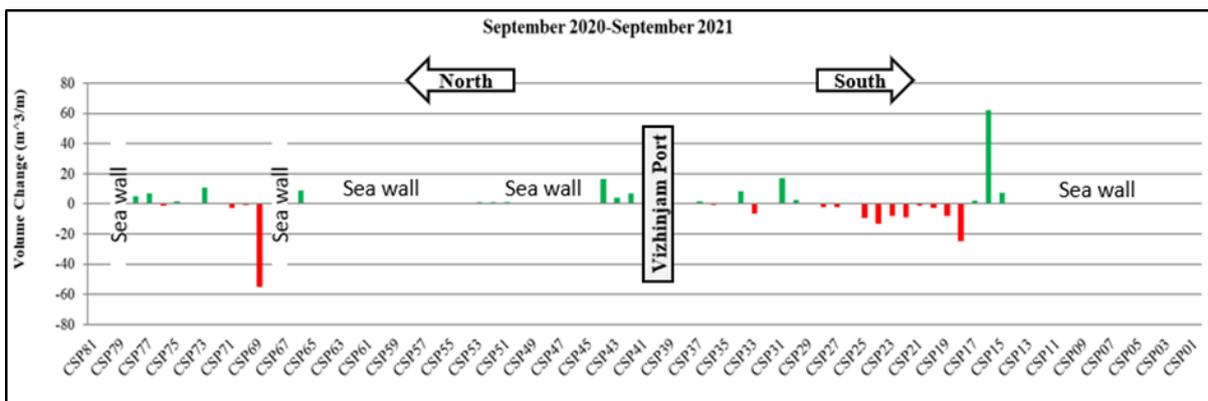
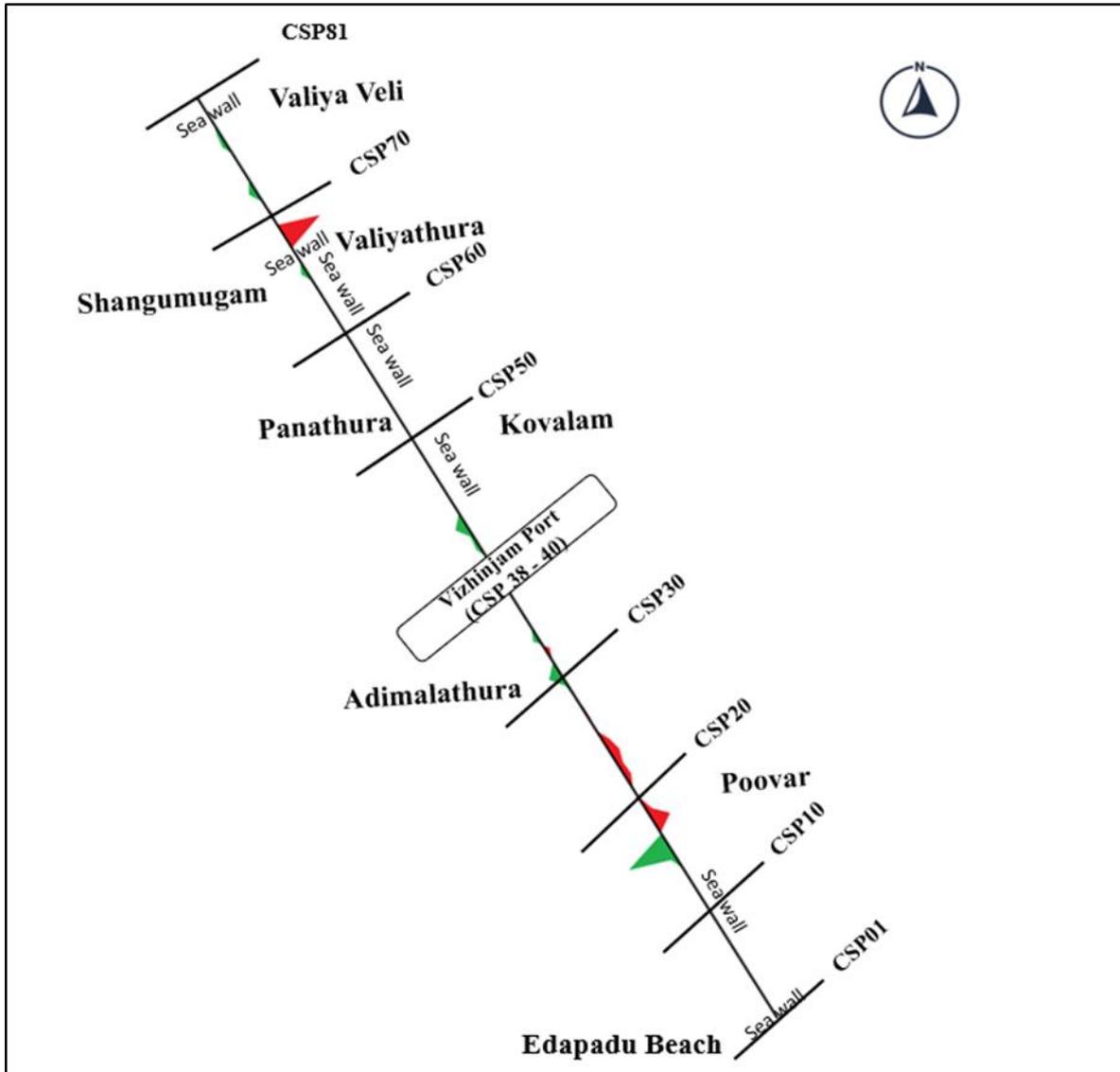


Figure 4.25 Beach Volume Changes during September 2020 and September 2021 in m^3/m (onshore)

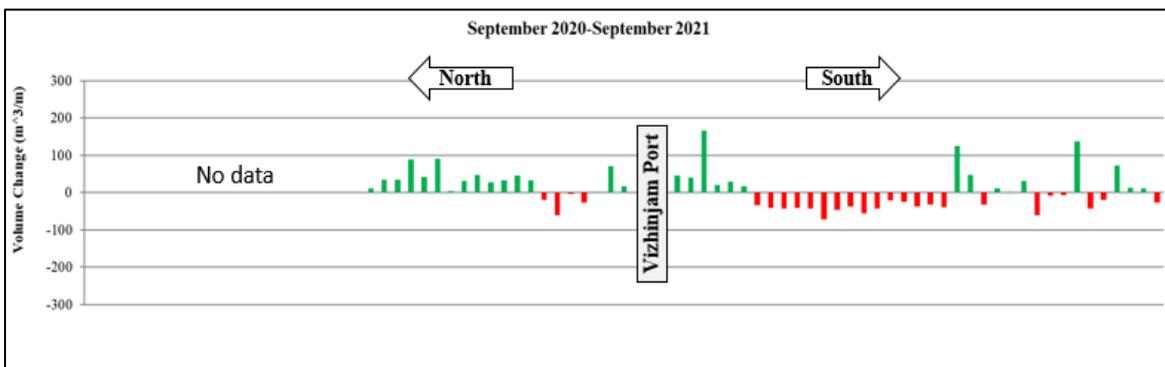
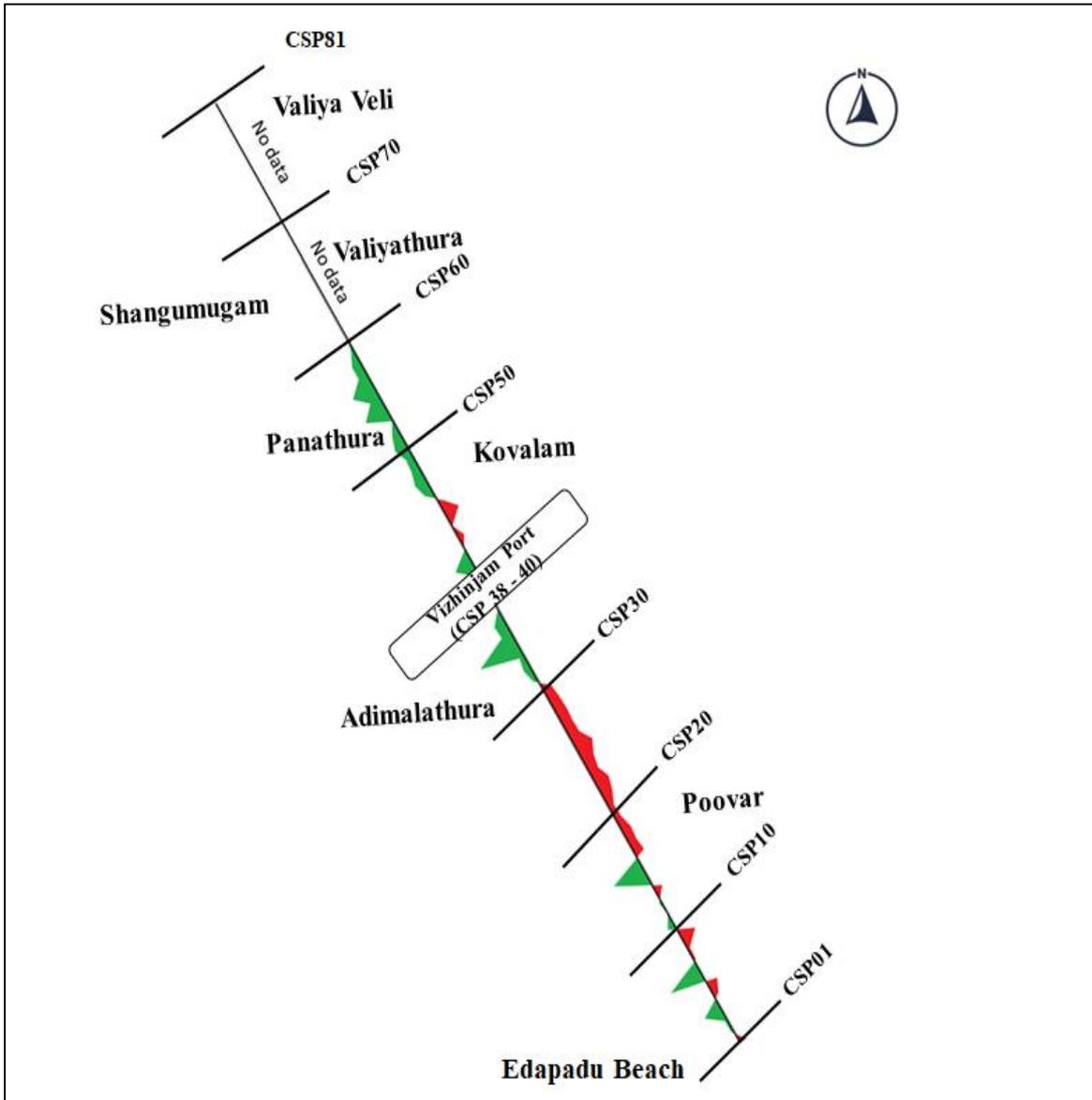


Figure 4.26 Beach Volume Changes during September 2020 and September 2021 in m³/m (offshore)

Table 4.4 Seasonal beach volume change comparison between 2019-2020 and 2020-2021

CSP NOs.	October 2019- October 2020- Post Monsoon (onshore)	February 2020- February 2021- Fair weather (onshore)	February 2020- February 2021- Fair weather (offshore)	April 2020- April 2021-Pre Monsoon (onshore)	April 2020-April 2021-Pre- Monsoon (offshore)	September 2020- September 2021- Monsoon (Onshore)	September 2020- September 2021- Monsoon (Offshore)				
CSP01	Sea wall		6.99	Sea wall	17.87	Sea wall	-27.06				
CSP02	-13.68	-9.11	-23.18	*	-38.49	*	11.39				
CSP03	Sea wall		27.76	Sea wall	81.07	Sea wall	13.05				
CSP04			22.47		7.01		72.77				
CSP05			17.53		-0.80		-18.60				
CSP06			23.12		1.64		-41.84				
CSP07			42.49		13.86		137.23				
CSP08			-28.17		2.52		-6.20				
CSP09			-43.31		-2.83		-8.50				
CSP10			-25.59		-17.43		-61.12				
CSP11			16.43		32.24		31.43				
CSP12			-12.48		30.36		3.47				
CSP13			80.68		23.52		11.98				
CSP14			51.73		30.85		-31.76				
CSP15			-13.96		12.94		108.56	22.44	36.41	7.64	48.29
CSP16			-14.07		-10.52		164.04	*	55.36	62.40	126.03
CSP17	0.47	1.86	-4.82	4.55	29.43	2.27	-37.91				
CSP18	-6.12	-8.12	5.81	-8.16	8.06	-24.92	-32.04				
CSP19	-5.22	-1.31	48.87	-4.73	-37.52	-7.89	-36.20				
CSP20	1.08	-5.85	13.76	-3.95	-2.52	-2.63	-24.02				
CSP21	1.07	-6.31	50.05	-0.20	14.59	-0.99	-20.66				
CSP22	3.09	-6.31	-9.87	-10.46	10.24	-8.92	-42.70				
CSP23	-4.63	-4.32	-18.76	-1.03	16.44	-8.02	-55.73				
CSP24	-3.56	-5.38	-5.69	10.02	-12.68	-13.33	-37.32				
CSP25	-5.30	-4.68	-13.42	-8.43	-1.53	-9.27	-46.72				
CSP26	-8.61	-5.09	0.45	-4.85	-2.36	-0.36	-70.78				
CSP27	-4.73	-1.50	-26.04	-0.95	-5.46	-2.37	-41.99				
CSP28	-5.19	-0.64	-26.48	0.00	-24.66	-2.33	-39.92				
CSP29	-1.16	2.97	-17.49	5.96	-17.64	0.67	-42.90				
CSP30	-4.56	5.50	-3.30	2.23	-21.14	2.77	-39.80				
CSP31	-2.07	5.15	-32.30	6.19	-26.57	16.98	-34.16				
CSP32		*	-4.16	*	19.34	*	17.39				
CSP33	-18.47	31.20	-18.04	18.15	15.44	-6.65	29.79				
CSP34	1.08	12.78	67.97	3.73	60.11	8.25	20.93				
CSP35		*	*	*	*	*	165.81				
CSP36	5.30	4.75	24.08	-5.81	5.29	-0.79	41.06				
CSP37	8.02	-21.10	-13.72	-7.40	-9.27	1.52	45.02				
CSP38											



CSP39	PORT AREA						
CSP40							
CSP41	2.55	-5.42	-29.42	10.51	-8.03	*	17.77
CSP42	-20.08	2.73	56.29	12.02	70.67	6.97	71.58
CSP43	1.58	2.71	63.14	2.08	0.89	4.06	2.98
CSP44	-2.24	14.28	18.93	13.65	-2.85	16.59	-25.90
CSP45	Sea wall		79.43	Sea wall	70.76	Sea wall	-3.36
CSP46			14.97		12.76		-59.94
CSP47			-36.91		-17.83		-18.60
CSP48			-36.84		-19.81		32.57
CSP49			-55.17		-5.31		45.94
CSP50			-16.98		3.34		32.63
CSP51	-0.26	-0.29	-31.42	-0.30	-18.78	1.00	28.44
CSP52	-0.18	-3.19	-27.57	-2.80	-29.90	1.26	47.58
CSP53	3.26	-4.32	-7.66	-4.48	45.52	1.17	31.82
CSP54	Sea wall		6.85	Sea wall	66.12	Sea wall	4.39
CSP55			24.41		136.55		91.23
CSP56			9.85		71.48		41.76
CSP57			47.62		112.16		89.92
CSP58			16.04		78.67		34.97
CSP59			11.72		63.80		34.98
CSP60			-32.72		38.54		11.01
CSP61			-12.94		22.91		-1.82
CSP62			-42.55		-5.35		*
CSP63			-31.35		4.62		*
CSP64			27.71		72.43		*
CSP65	-38.85	8.91	*				
CSP66	-0.94	1.12	53.06	5.22	-6.28	8.64	*
CSP67	Sea wall		-4.84	Sea wall	39.18	Sea wall	*
CSP68			4.20		46.78		*
CSP69	6.42	-67.24	304.45	-62.43	308.80	-55.08	*
CSP70	-1.05	1.31	-5.96	0.47	11.18	-0.67	*
CSP71	4.91	2.10	-6.39	-6.45	24.02	-2.67	*
CSP72	-5.41	-2.06	-25.37	-4.20	-32.69	0.46	*
CSP73	-3.57	-3.72	-0.47	7.94	25.42	10.84	*
CSP74	-0.93	-5.67	8.51	-8.92	-23.04	0.33	*
CSP75	-0.26	-2.86	-43.89	3.27	-31.96	1.50	*
CSP76	0.06	-6.18	7.16	0.60	-20.57	-1.21	*
CSP77	1.23	-0.78	-24.71	6.12	-22.49	7.15	*
CSP78	6.35	-6.02	-4.29	-8.31	-18.43	5.07	*
CSP79	Sea wall		*	Sea wall	-9.54	Sea wall	*
CSP80	0.15	-4.02	0.04	0.04	-4.82	0.80	*
CSP81	4.08	-7.71	-27.81	-1.48	-42.65	0.67	*

*Data not considered for analysis

4.1.6 Overall Beach volume variation during February 2015 and February 2021

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 2021 given in graphs in **Figure 4.27, Figure 4.28** and **Table 4.5**.

On onshore part accretion noticed at Edapadu beach (CSP02), Poovar to Pulluvila (CSP17-27), Pulluvila to Adimalathura (CSP33-34), Mullur (CSP36-37), Kovalam (CSP41-44), Punthura (CSP53), Pannathura (CSP51), Shangumugham (CSP70), Vettucaud (CSP 72-78) and Thumba (CSP81). Erosion noticed at Poovar (CSP15-16), Pulluvila (CSP28-29), Pannathura (CSP52), Valliyathura (CSP66), Shangumugham (CSP69 and 71) and Thumba (CSP80).

On offshore, accretion taken place at locations Edapadu to Poovar (CSP01-16), Poovar (CSP21), Adimalathura to Azhimala (CSP34-35), Kovalam (CSP43, CSP 45 and 47), Pannathura (CSP50-52), Punthura to Beemapally (CSP54-58), Beemapally to Cheriyaathura (CSP60-61), Valliyathura to Shangumugham (CSP63-71), Vettucaud (CSP73), Kochuveli (CSP76), Valiyaveli (CSP78). The locations Poovar (CSP17-20), Karumkulam to Adimalathura (CSP22-33), Mullur (CSP36-37), Kovalam (CSP41-42, CSP44, CSP46), Pannathura (CSP48-49), Punthura (CSP53), Beemapally (CSP59), Cheriyaathura (CSP62), Vettucaud (CSP72), Vettucaud to Kochuveli (CSP74-75), Kochuveli (CSP77), and Valiyaveli to Thumba (CSP79-81) exhibit erosion.

At Pulluvila (CSP28-29) and Thumba (CSP80) erosion taken place on onshore and offshore.

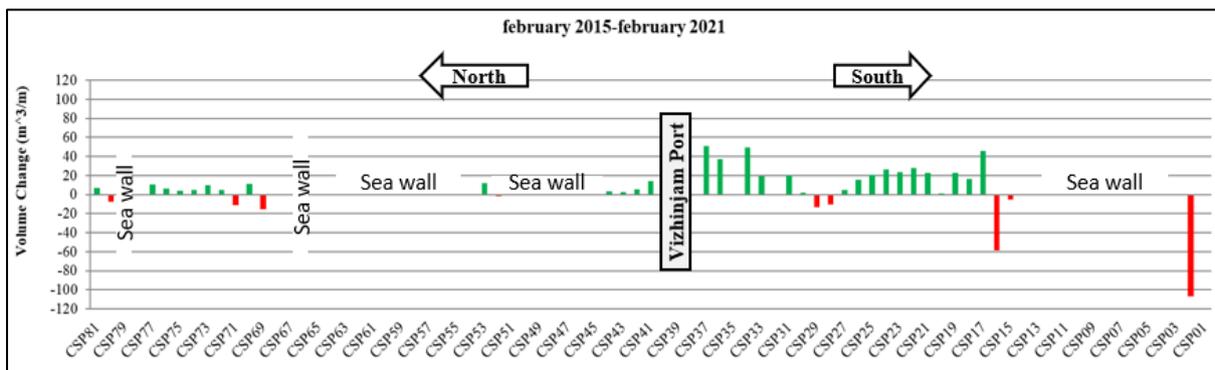


Figure 4.27 Beach Volume Changes - February 2015 and February 2021 in m^3/m (onshore)

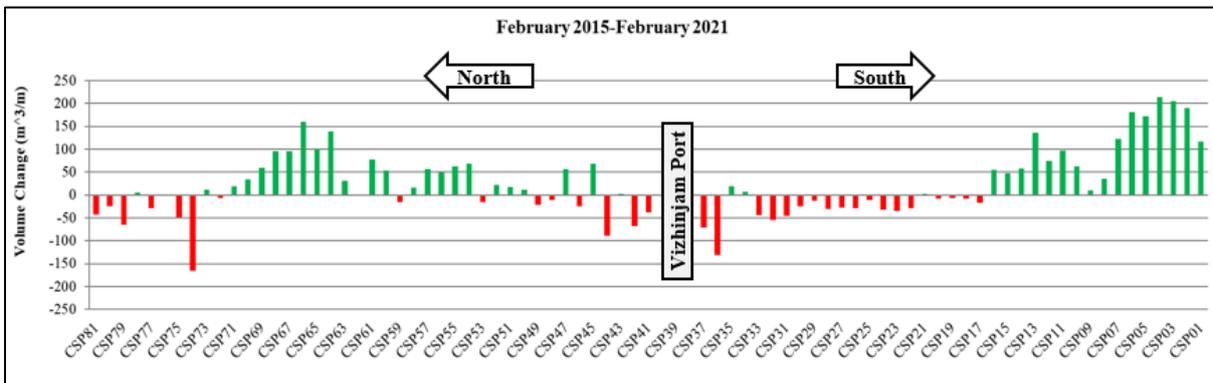
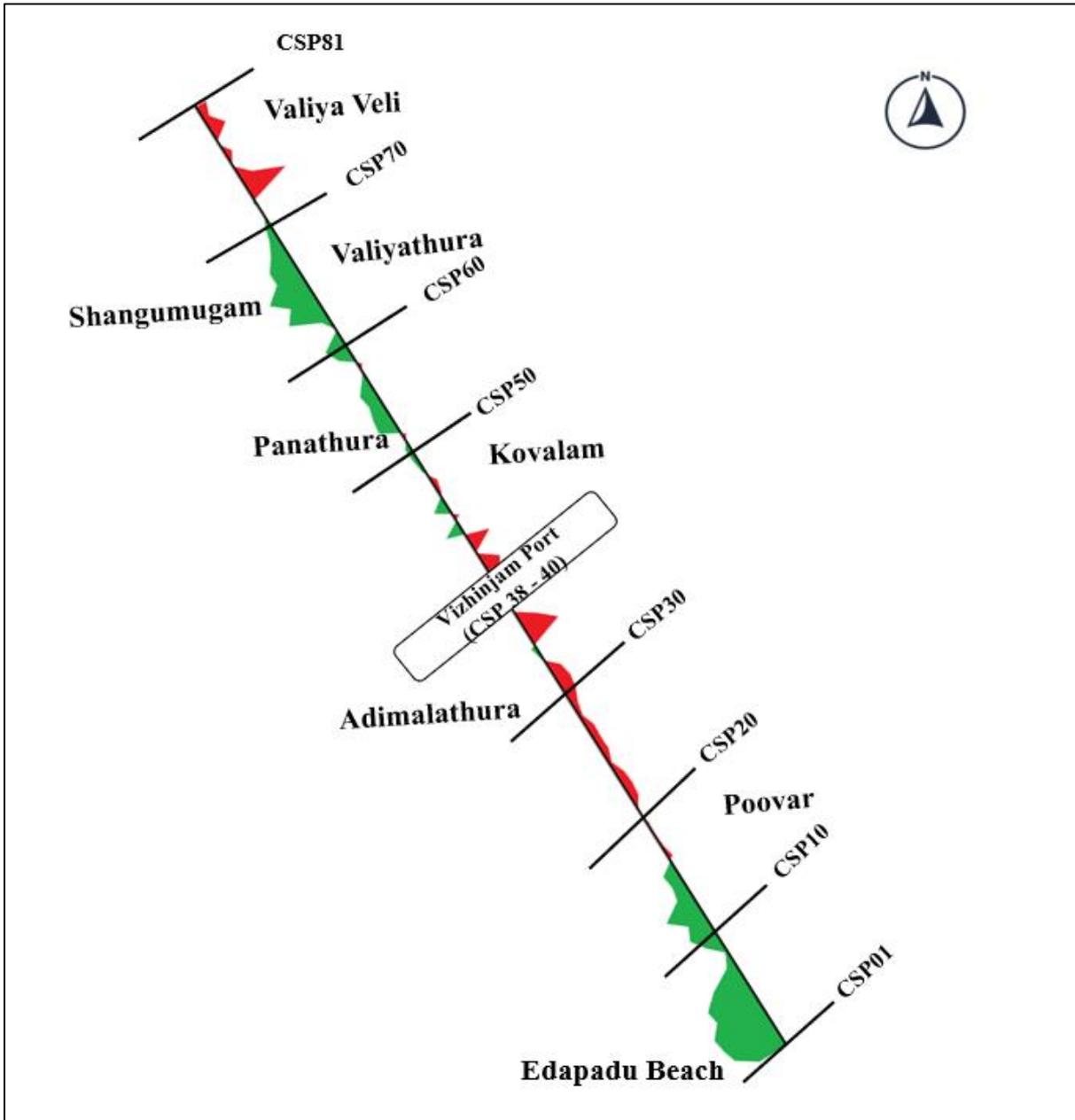


Figure 4.28 Beach Volume Changes - February 2015 and February 2021 in m³/m (offshore)

Table 4.5 Overall Beach Volume Changes during February 2015 and February 2021 in m³/m

CSP No.	February 2015-February 2021 (onshore)	February 2015-February 2021 (offshore)
CSP01	Sea wall	115.85
CSP02	-106.71	190.34
CSP03	Sea wall	205.69
CSP04		214.67
CSP05		172.29
CSP06		180.48
CSP07		123.29
CSP08		35.57
CSP09		9.33
CSP10		62.09
CSP11		97.47
CSP12		73.92
CSP13		135.71
CSP14		58.16
CSP15	-5.32	46.89
CSP16	-58.35	55.20
CSP17	45.57	-17.35
CSP18	16.03	-7.29
CSP19	22.80	-6.20
CSP20	1.49	-8.49
CSP21	22.49	2.53
CSP22	27.78	-29.60
CSP23	23.77	-35.03
CSP24	26.09	-31.33
CSP25	20.48	-11.53
CSP26	15.62	-28.73
CSP27	5.01	-27.45
CSP28	-10.04	-30.96
CSP29	-13.04	-13.16
CSP30	2.04	-23.79
CSP31	20.24	-44.96
CSP32	*	-54.64
CSP33	19.22	-43.63
CSP34	49.61	7.63
CSP35	*	19.69
CSP36	37.40	-130.91
CSP37	50.79	-70.83
CSP38	Port Area	
CSP39		
CSP40		



CSP41	13.96	-38.72
CSP42	5.74	-67.50
CSP43	2.71	2.38
CSP44	3.35	-89.41
CSP45	Sea wall	68.37
CSP46		-24.09
CSP47		56.11
CSP48		-10.34
CSP49		-21.40
CSP50		11.99
CSP51	0.54	17.97
CSP52	-1.77	21.43
CSP53	12.14	-16.08
CSP54	Sea wall	69.04
CSP55		62.95
CSP56		48.42
CSP57		57.21
CSP58		16.24
CSP59		-15.77
CSP60		53.04
CSP61		78.27
CSP62		-1.74
CSP63		31.38
CSP64		138.99
CSP65		100.60
CSP66	-1.52	159.40
CSP67	Sea wall	95.23
CSP68		95.84
CSP69	-15.04	59.47
CSP70	11.60	33.85
CSP71	-11.01	19.62
CSP72	5.02	-5.83
CSP73	9.72	11.84
CSP74	4.92	-164.98
CSP75	4.26	-48.81
CSP76	6.53	0.53
CSP77	10.69	-28.30
CSP78	0.60	5.27
CSP79	Sea wall	-65.47
CSP80	-7.75	-24.33
CSP81	6.97	-43.20

*Data not considered for analysis

4.2 Results for Shoreline Change Analysis from Satellite images

In the previous submitted Annual reports for the period October 2017 to September 2018, the result from the shoreline change analysis using high resolution satellite images carried out for 2000-2018 and annual variation for the year 2015-2016, 2016-2017, 2017-2018 has been presented. As a part of NGT direction, the shoreline change analysis has been carried out for the years 2000-2010, 2010-2018, 2000-2018 using high resolution LISS 4 (5m) and PAN (2.5m) images to study the changes before and after 2010. Further, the shoreline change analysis has been carried out for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018 to study the immediate changes prior and after port commencement activity (December 2015). Similarly, in Annual report for the period October 2018-September 2019, October 2019-September 2020, monthly, seasonal, annual and inter annual shoreline changes has been assessed and reported.

The spots of erosion listed from the above analysis using high resolution satellite images are Valliyathura (CSP63 to CSP67), Punthura (CSP53 to CSP57), Poovar to Edapadu (CSP01 to CSP09). Hence, in continuation with the earlier Annual reports October 2017- September 2018, October 2018 to September 2019 and October 2019 to September 2020, this annual report compiles the monthly, seasonal and overall shoreline change over the period from October 2020 to September 2021 using available high resolution satellite images.

4.2.1 Monthly Shoreline Change Analysis from October 2020 to September 2021

The monthly shoreline change analysis from October 2019 to September 2020 carried out using available high resolution satellite images has been presented in the Figure 4.29 to 4.40 respectively.

- Most of the sectors indicate accretion while Cheriyaathura (150m), Mullur (250m) indicates erosion (coastal length in m) for October 2020.
- The shoreline change analysis map shows accretion at most of the locations while erosion noted few sectors of Vettucaud (200m), Mullur (150m), Karumkulam (300m), Poovar (500m) and Edapadu beach (120m) for November 2020.
- The shoreline change analysis map shows that the accretion from Thumba to Vettucaud, Cheriyaathura, and Mullur to Vallavilay while erosion is noticed at Thumba (150m), Punthura (300m), few sectors of Mullur (200m), Poovar (300m) and Edapadu beach (600m) for December 2020.

- Most of the sectors indicate accretion and stable except Kochuveli (300m) and Cheriyaathura (90m) indicates erosion for January 2021.
- The shoreline change analysis map shows erosion noted at few sectors of Thumba (250m), Cheriyaathura (150m), Punthura (250m), Pulluvila (200m), Karumkulam(450m) and Edapadu beach (300m) while accretion at Mullur and Adimalathura for February 2021.
- The shoreline change analysis map shows that the accretion at most of the location while erosion is noticed at Cheriyaathura (250m), Punthura (900m) and few sectors of Edapadu beach (300m) for March 2021.
- Most of the sectors indicates erosion at Vettucaud (900m), Shangumugham (400m), Valliyathura (170m), Punthura (300m) and Poovar(3km) while accretion noticed at Thumba, Kovalam, Adimalathura, Pulluvila, Karumkulam and stable coast at Kochuveli and Edapadu beach for the April 2021.
- The shoreline change analysis map shows accretion at Karumkulam (360m) and Poovar (900m) while erosion noted at Thumba (1.5km), Vettucaud (250m), Shangumugham (700m), Punthura (1.25km), Mullur (670m), Adimalathura (700m), Poovar (1.5km) and Edapadu beach (500m) for May 2021.
- The shoreline change analysis map shows accretion at Mullur and few sectors of Poovar and Edapadu beach while erosion is noted from Thumba to Shangumugham (6km), Punthura (900m) and Adimalathura to northern sectors of Poovar (8.5km) for June 2021.
- The erosion is noted at the stretches of Mullur (250m), Adimalathura (250m), Pulluvila (1km), Karumkulam (1km) and Poovar (500m) for the month of July 2021.
- For August 2021, the shoreline change analysis map shows that the erosion is noted at Thumba (1km), Kochuveli (500m), Vettucaud (1km), Shangumugham (1.5km), Cheriyaathura (270m), Punthura (400m), Karumkulam (2.5 km) and Poovar (900m).
- For September 2021, the shoreline change analysis map shows that the erosion is noted along Thumba (200m), Kochuveli (400m), Vettucaud (600m), Punthura (600m), Cheriyaathura (200m), Adimalathura (600m), Karumkulam (400m), Poovar (1.2km) and Edapadu beach (100m).

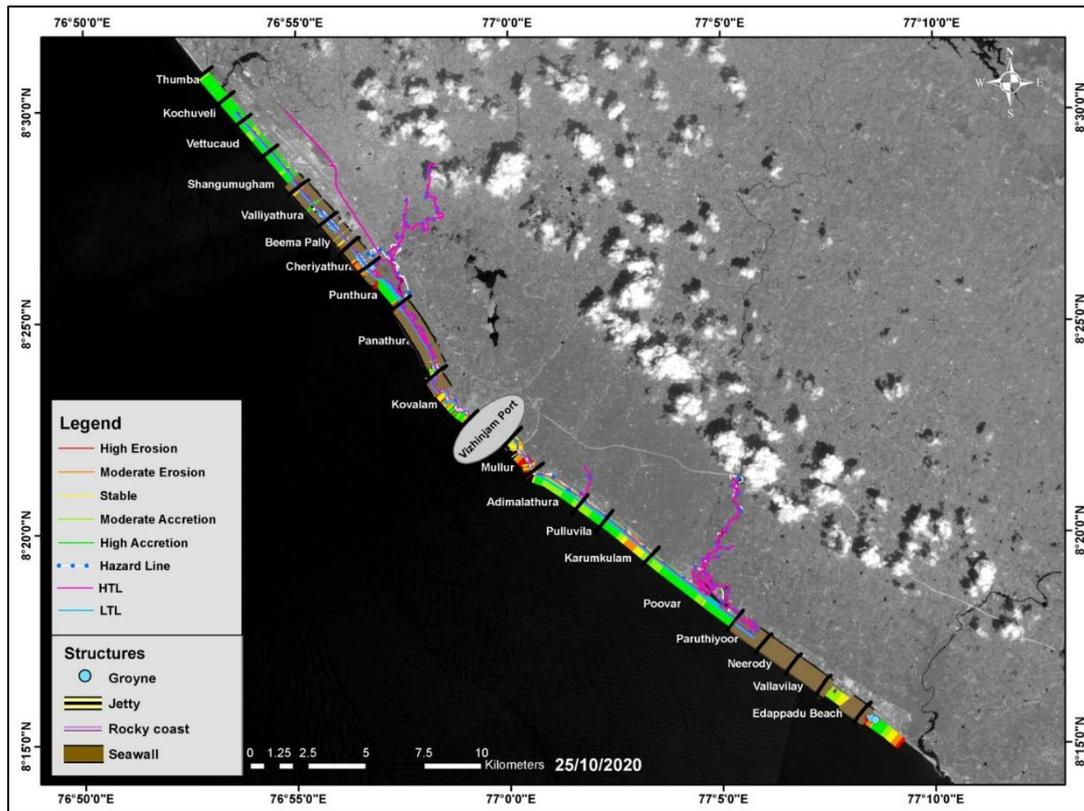


Figure 4.29 Shoreline Change Map -October 2020

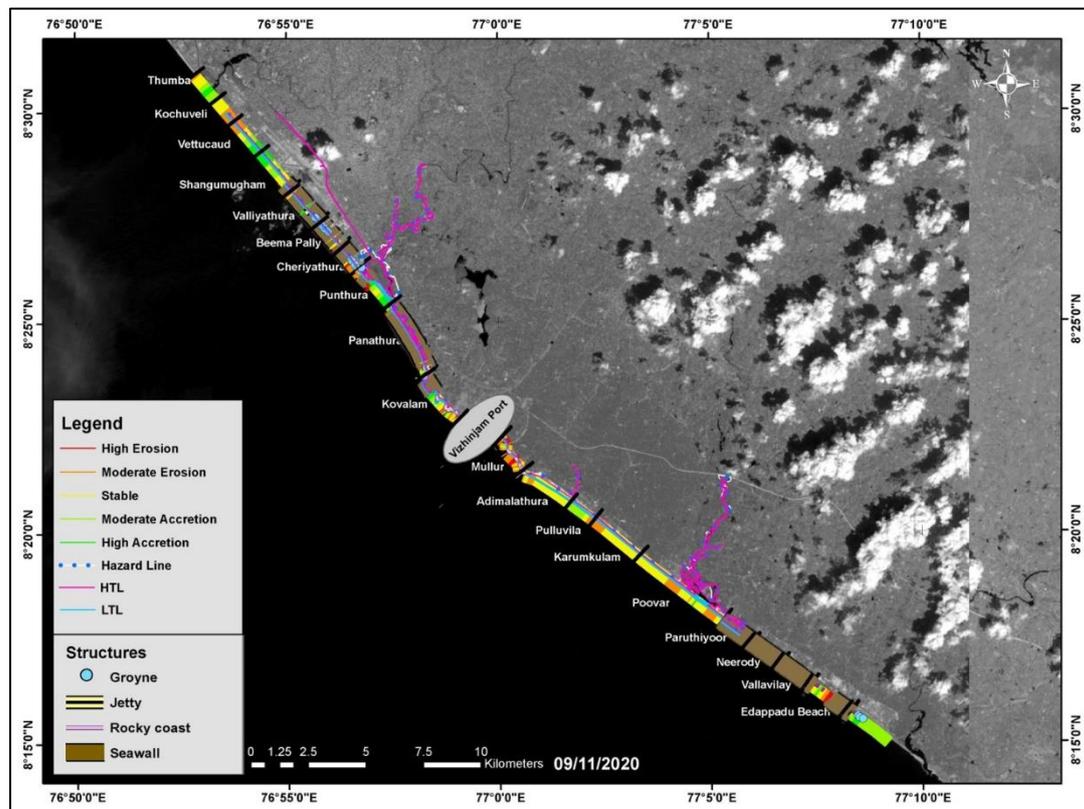


Figure 4.30 Shoreline Change Map - November 2020

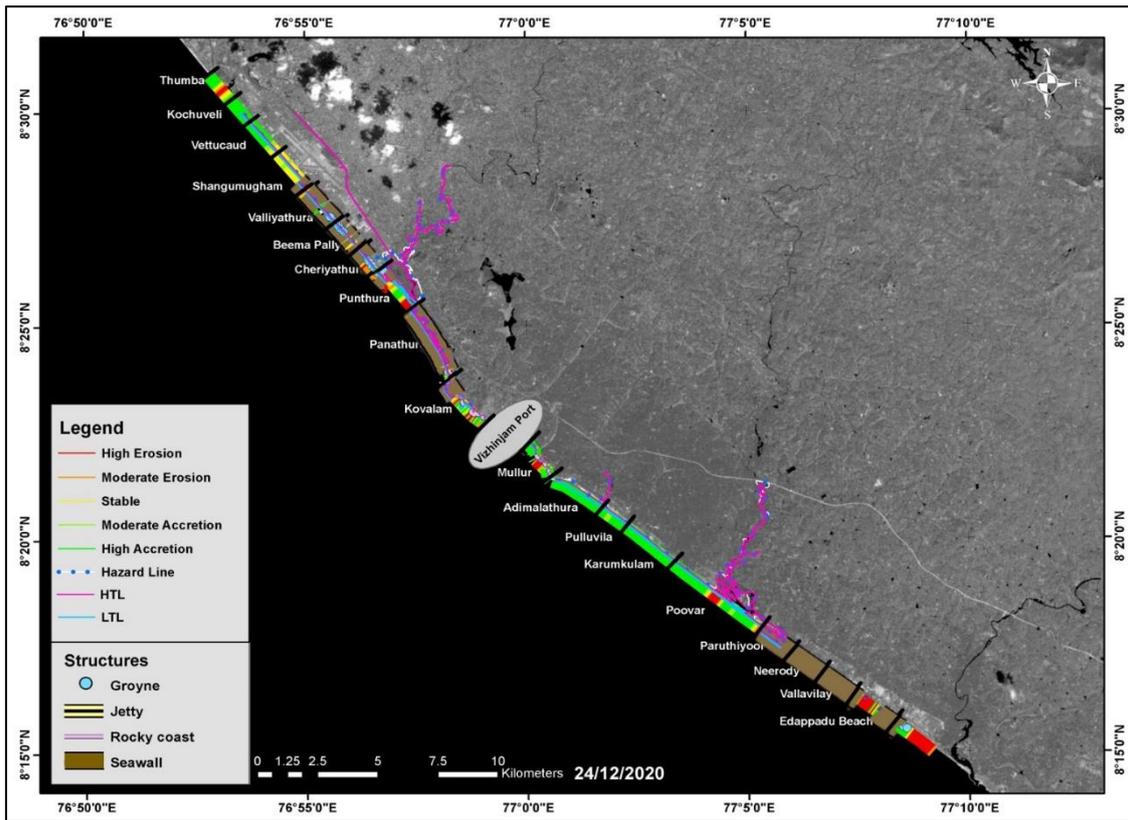


Figure 4.31 Shoreline Change Map - December 2020

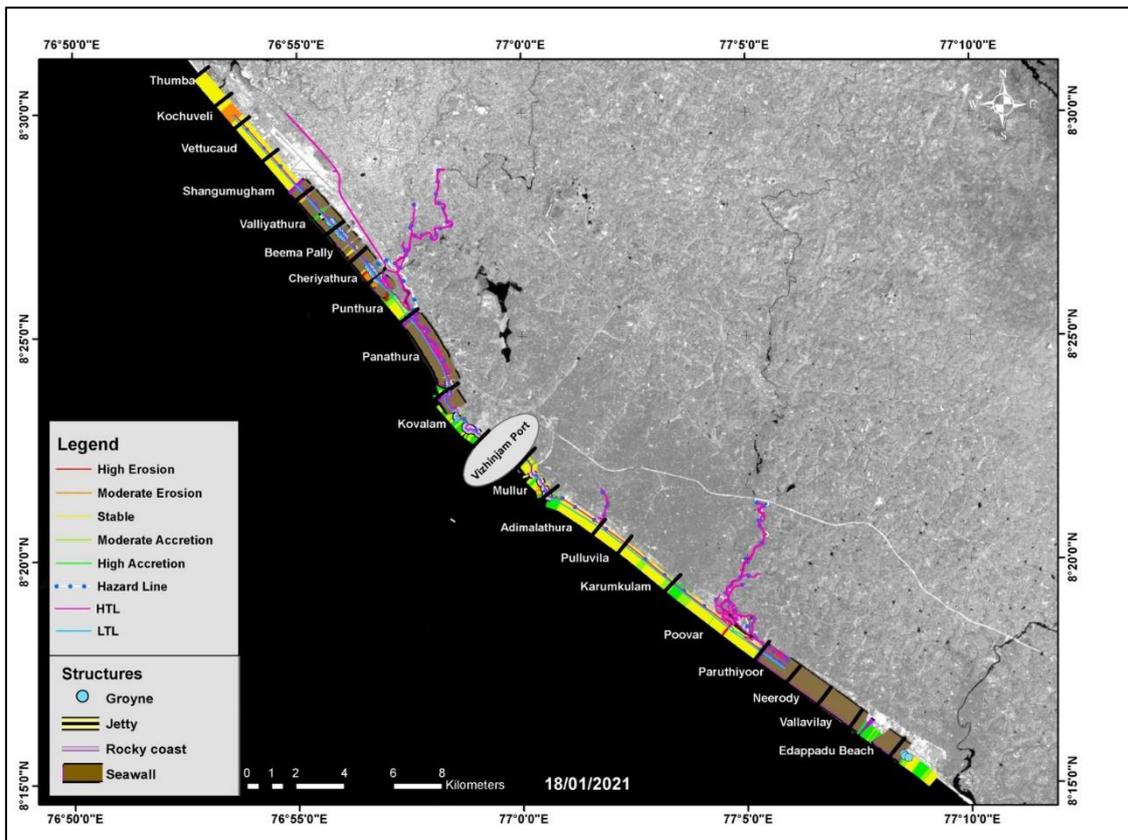


Figure 4.32 Shoreline Change Map -January 2021

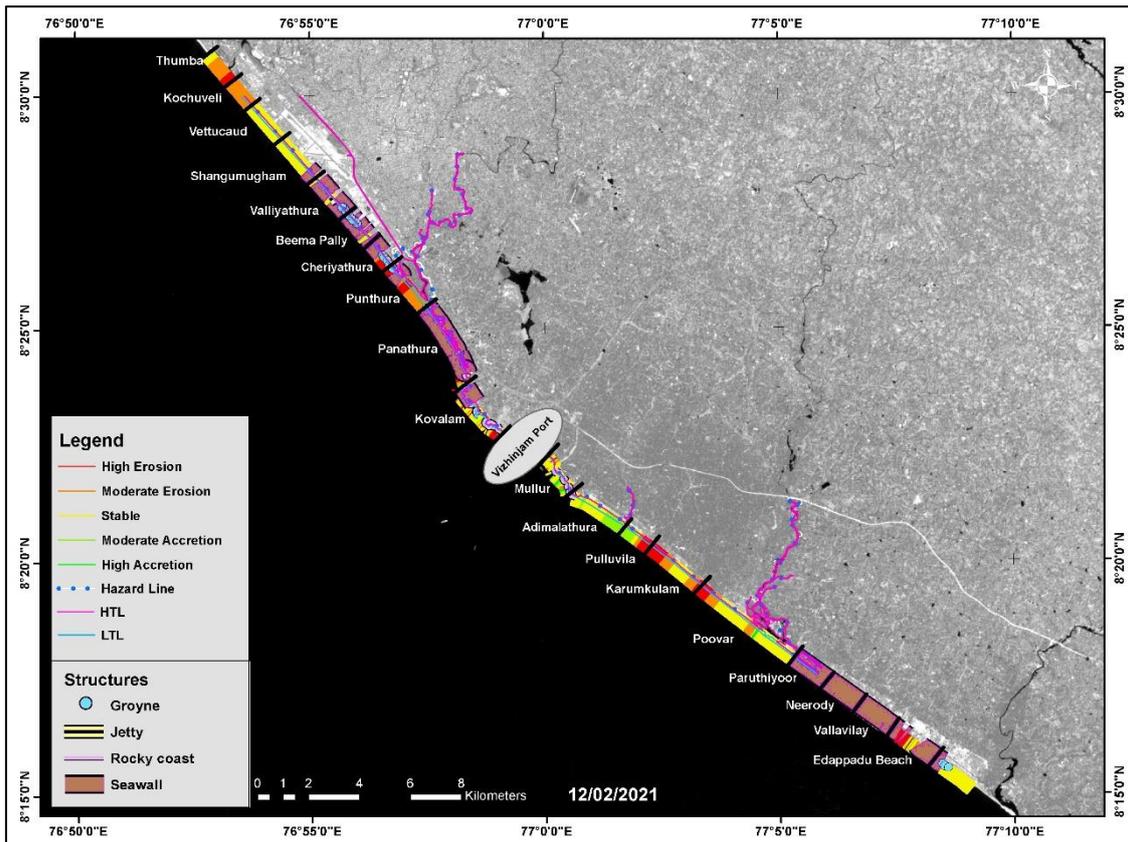


Figure 4.33 Shoreline Change Map - February 2021

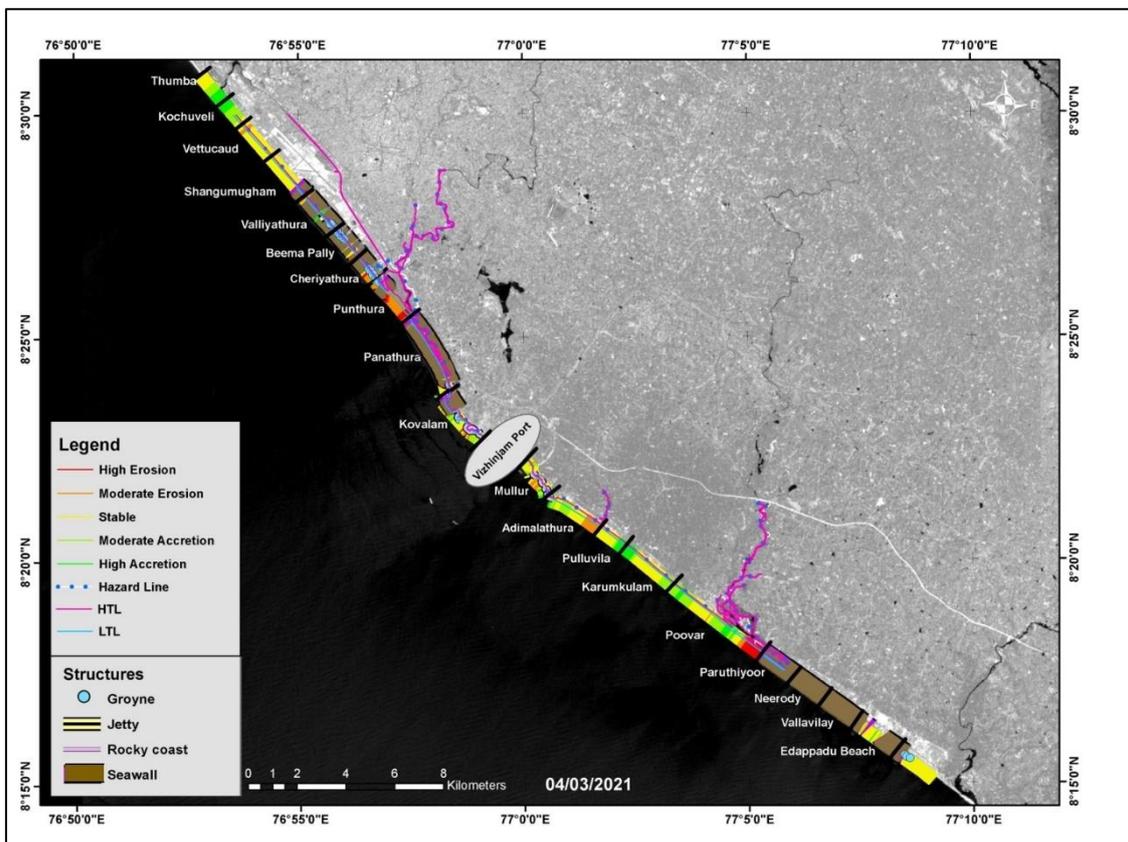


Figure 4.34 Shoreline Change Map -March 2021

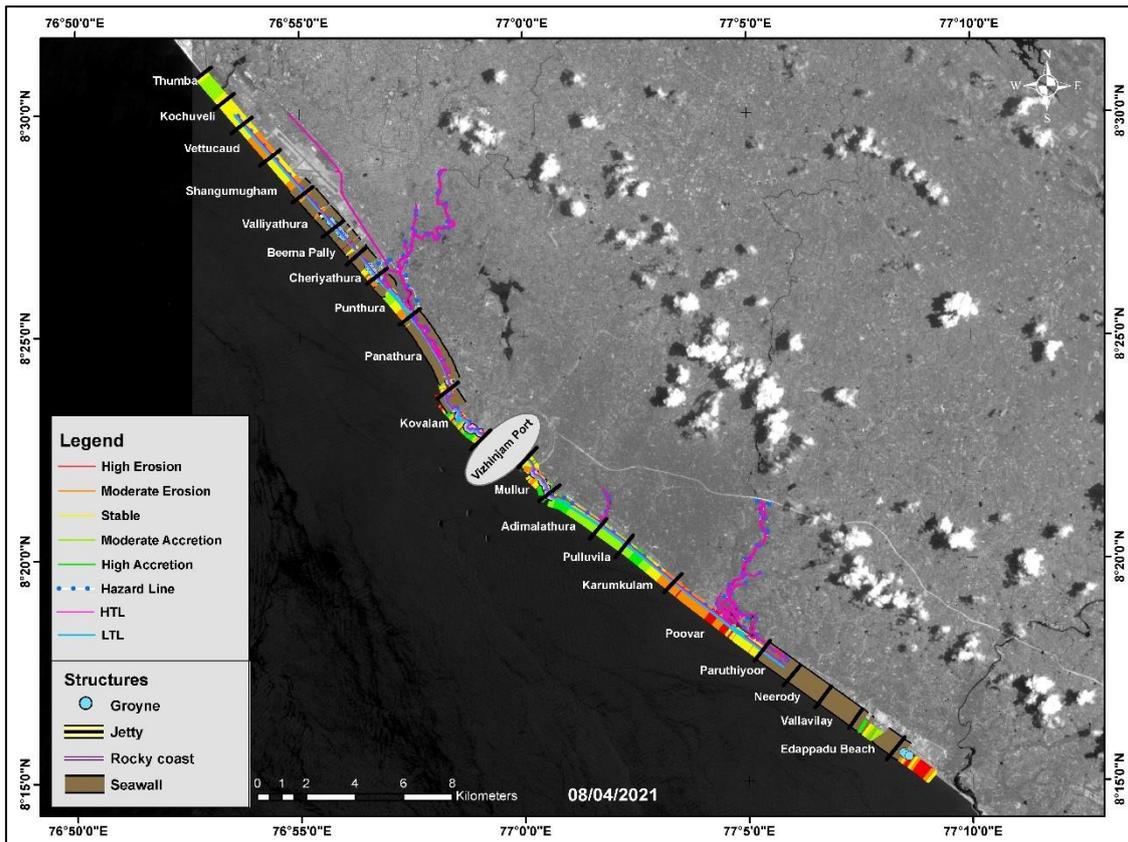


Figure 4.35 Shoreline Change Map - April 2021

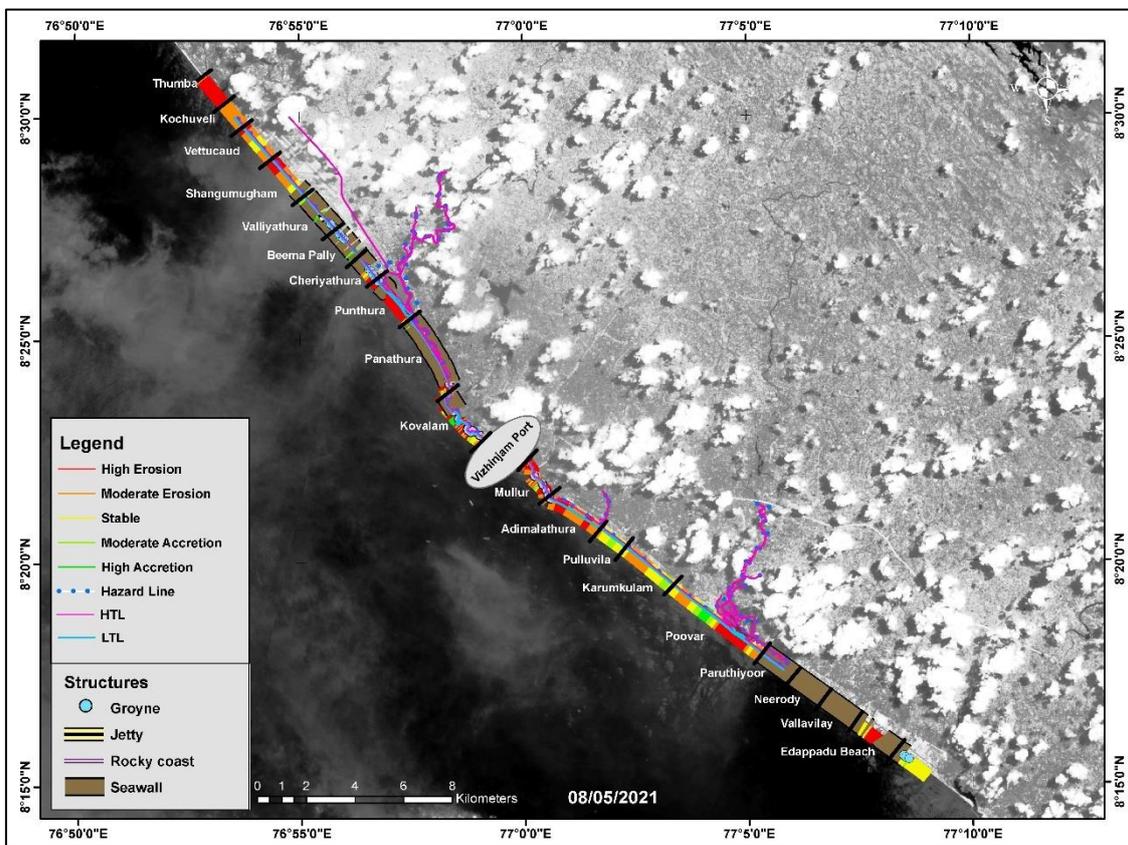


Figure 4.36 Shoreline Change Map - May 2021

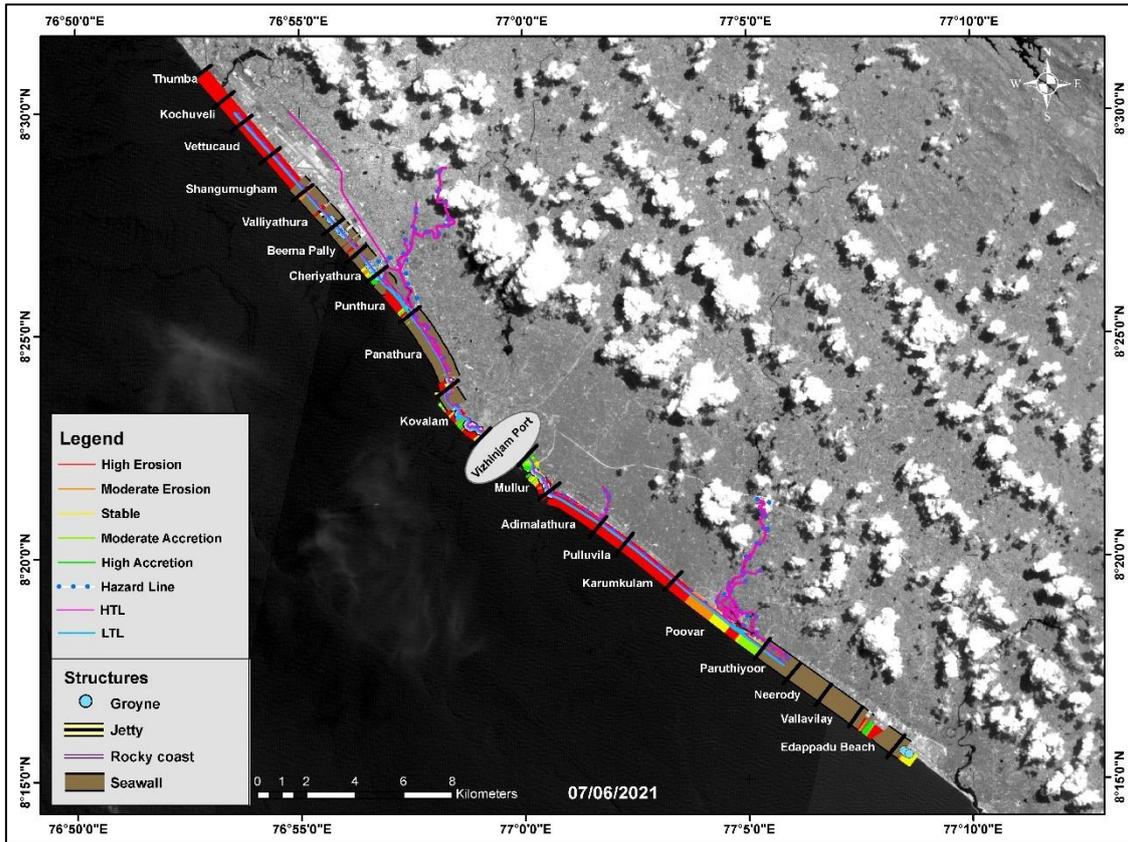


Figure 4.37 Shoreline Change Map - June 2021

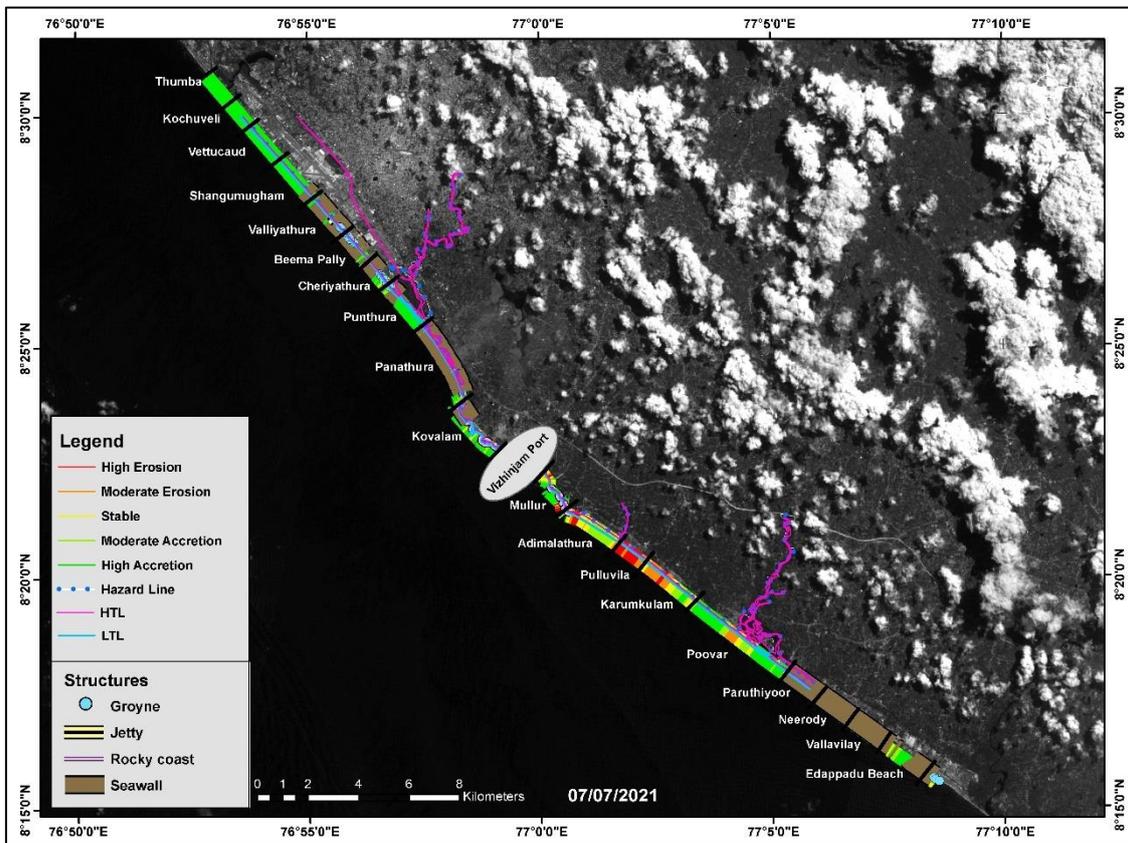


Figure 4.38 Shoreline Change Map - July 2021

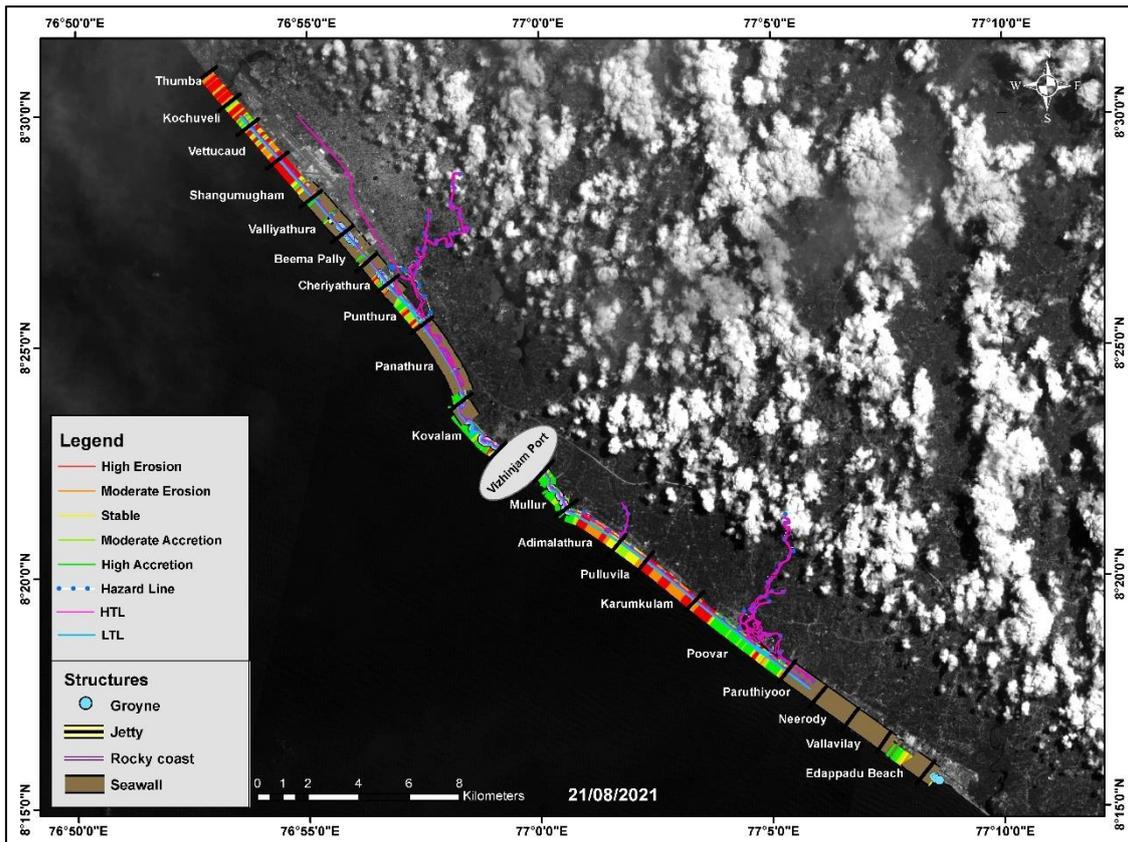


Figure 4.39 Shoreline Change Map - August 2021

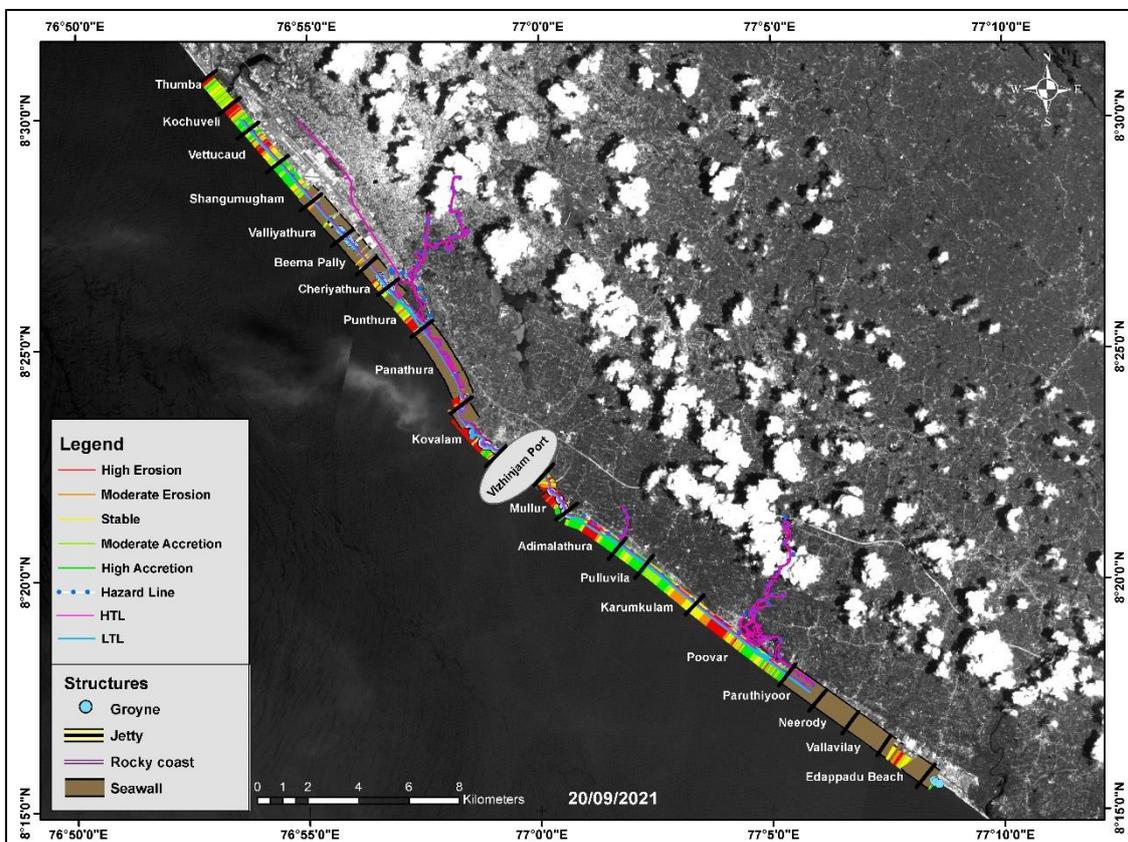


Figure 4.40 Shoreline Change Map - September 2021

4.2.2 Seasonal Shoreline Change from October 2020 to September 2021

As suggested by the shoreline and expert committee meeting held during 12th and 13th February 2019, the seasonal pattern has been followed in this report as Post monsoon (October-November 2020) Fair weather period (December 2020-March 2021), Pre-monsoon (April-May 2021) and Monsoon (June – September 2021).

4.2.2.1 Results for Shoreline Change in Post Monsoon 2020 (October-November 2020)

The seasonal shoreline change analysis for the post monsoon period 2019 is shown in Figure 4.41. The shoreline change analysis map shows accretion at most of the locations while erosion noted at few sectors of Vettucaud (200m), Mullur (150m), Karumkulam (300m), Poovar (500m) and Edapadu beach (120m) for the post monsoon period (October 2020 to November 2020).

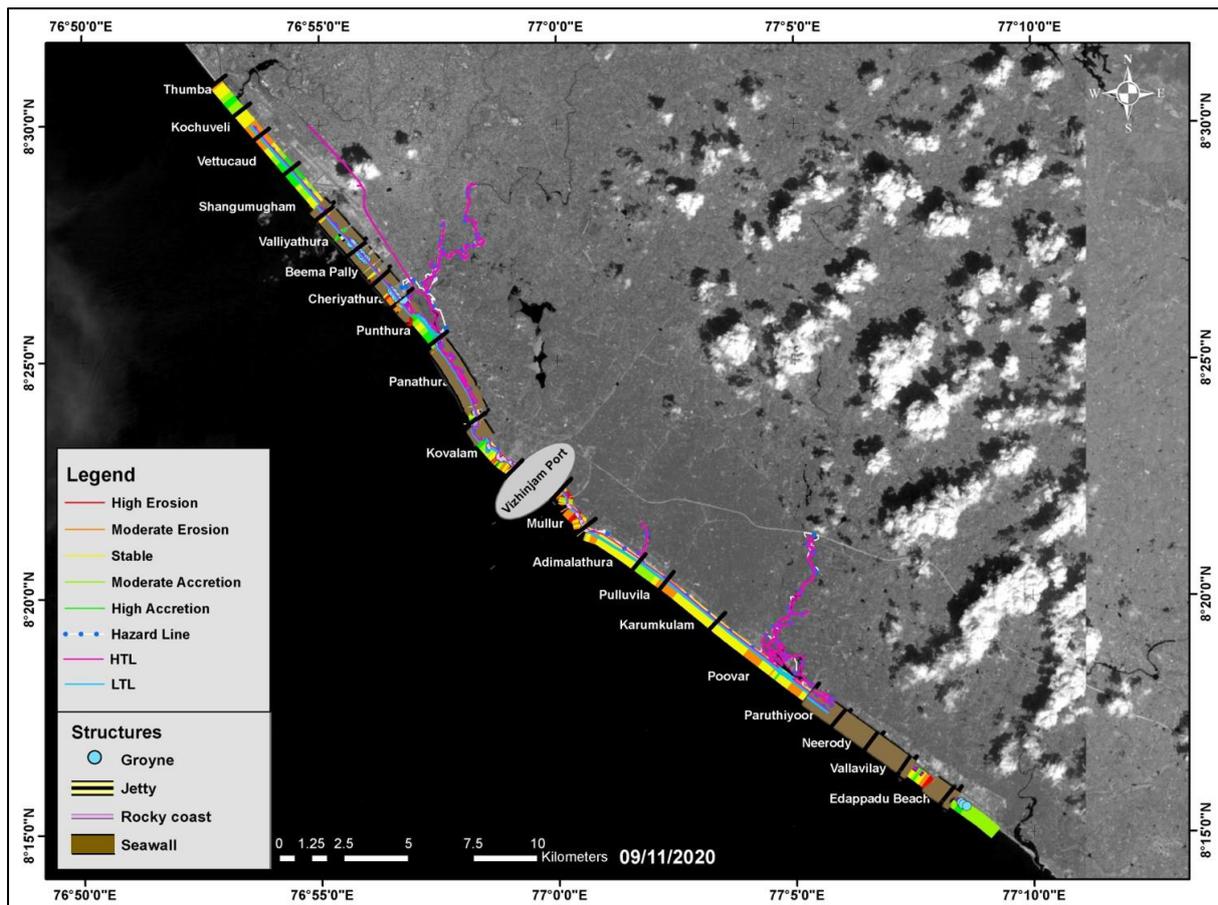


Figure 4.41 Shoreline Change Map –Post Monsoon 2020

4.2.2.2 Results for Shoreline Change in Fair Weather Period 2020 (December 2020-March 2021)

The seasonal shoreline change analysis for the fair weather period 2021 is shown in Figure 4.42. The fair weather period (December 2020 to March 2021) indicates stable at most of the locations while erosion is noticed at Punthura (600m) and Poovar (630m) and accretion at Kovalam (860m), Mullur (150m), Adimalathura (950m), Pulluvila(600m) and Poovar (1.4km).

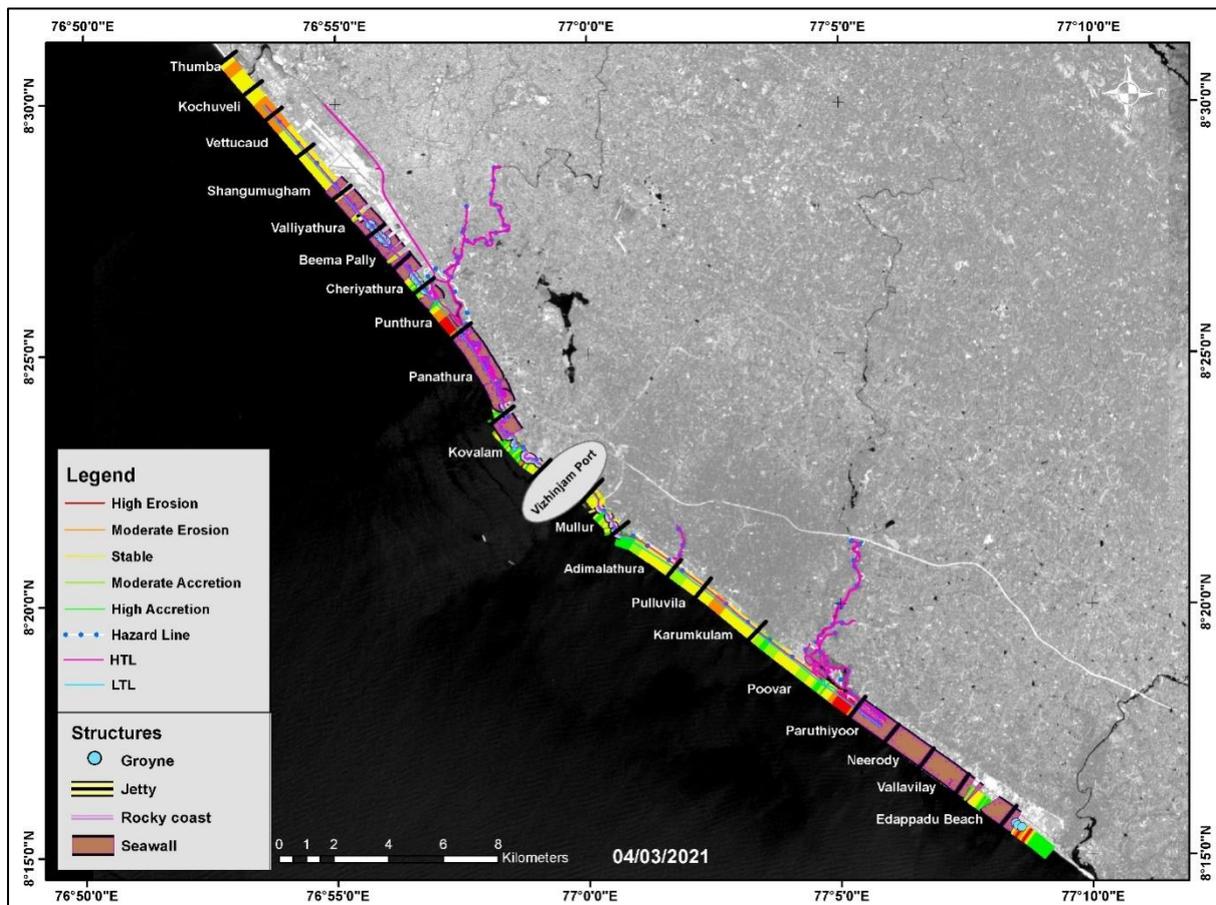


Figure 4.42 Shoreline Change Map –Fair Weather Period 2021

4.2.2.3 Results for Shoreline Change in Pre-Monsoon Period 2021 (April 2021-May 2021)

The seasonal shoreline change analysis for the pre-monsoon period 2021 is shown in Figure 4.43. The pre-monsoon period (April 2021 to May 2021) indicates accretion at Karumkulam (360m) and Poovar (900m) while erosion noted at Thumba (1.5km), Vettucaud (250m), Shangumugham (700m), Punthura (1.25km), Mullur (670m), Adimalathura (700m), Poovar (1.5km) and Edapadu beach (500m).

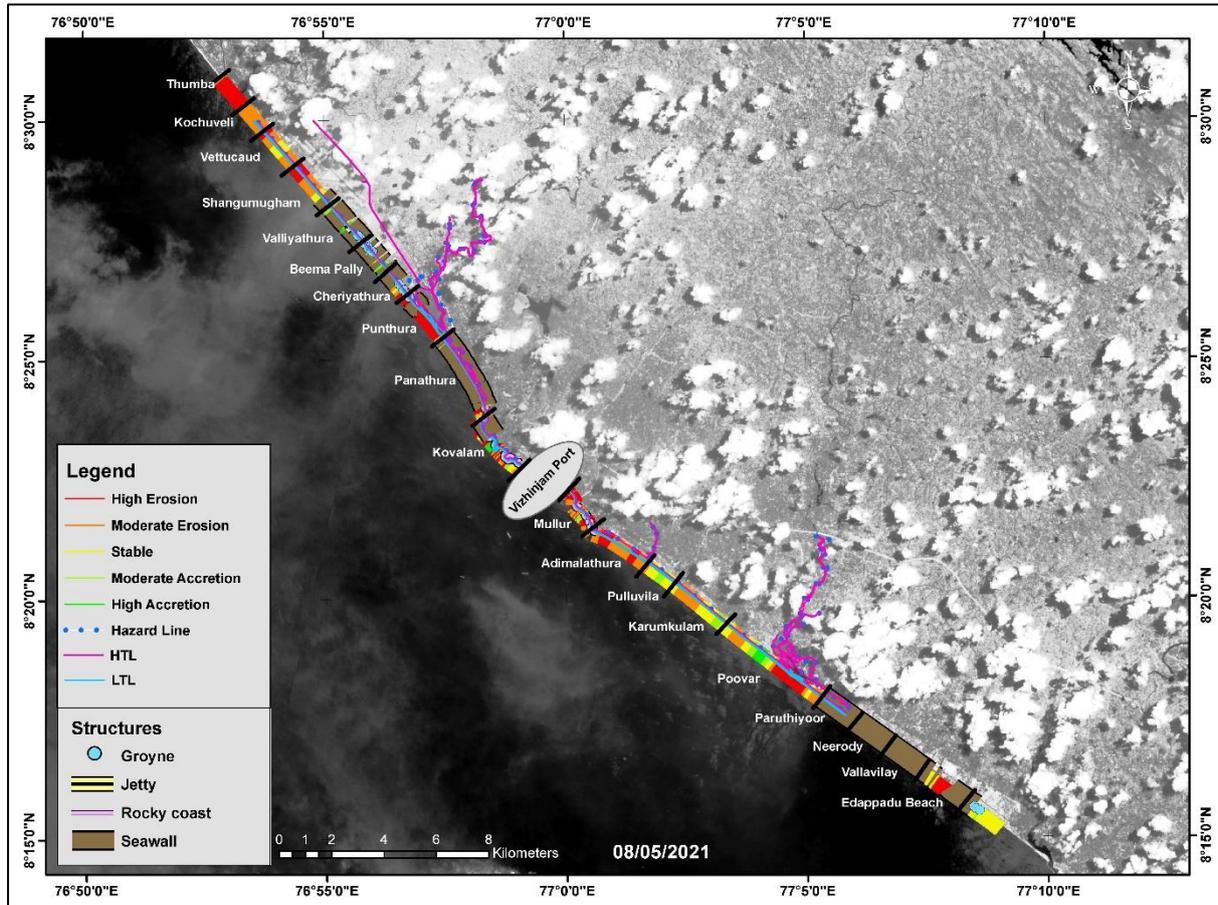


Figure 4.43 Shoreline Change Map –Pre-Monsoon Period 2021

4.2.2.4 Results for Shoreline Change in Monsoon Period 2021 (June 2021-September 2021)

The seasonal shoreline change analysis for the monsoon period 2021 is shown in Figure 4.44. During monsoon period (June 2021 to September 2021) erosion is noticed along Adimalathura (900m), Pulluvila (720m), Karumkulam (2.5km) and Poovar (700m) and accretion from Thumba to Mullur, Poovar and Edappadu beach.

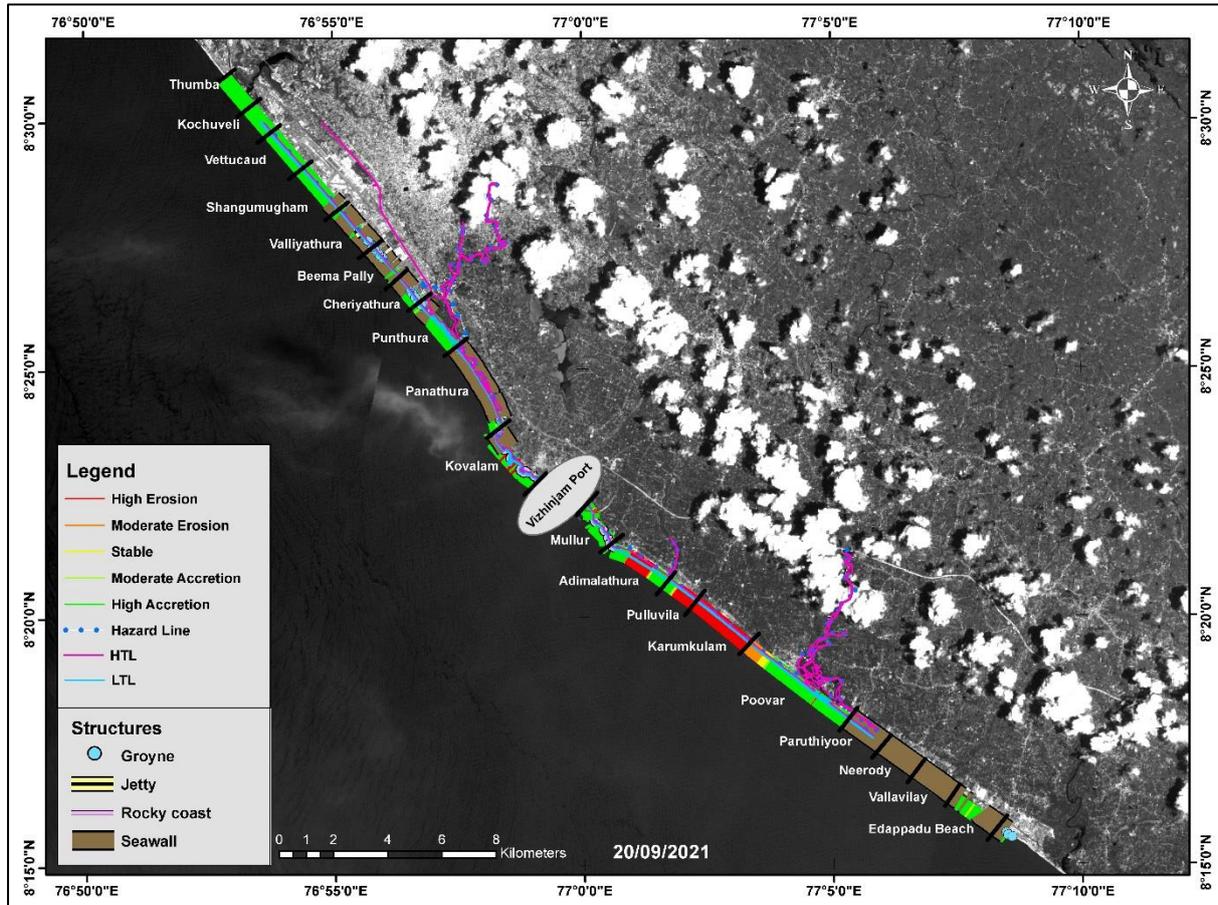


Figure 4.44 Shoreline Change Map – Monsoon Period 2021

4.2.3 Overall Shoreline Change from October 2020 to September 2021

Using high resolution satellite images (1m, 5m and 10m spatial resolution), the result has been processed for the period October 2020 to September 2021. Figure 4.45 shows the shoreline change map from October 2020 to September 2021. Erosion is noticed at Kochuveli (250m), Shangumugham (100m), Valliyathura (50m), Cheriyaathura (120m), Punthura (150m), Mullur (290m), Pulluvila (500m) and accretion at Thumba, Vettucaud and Shangumugham, Punthura, Adimalathura, Karumkulam, Poovar and Edappadu beach.

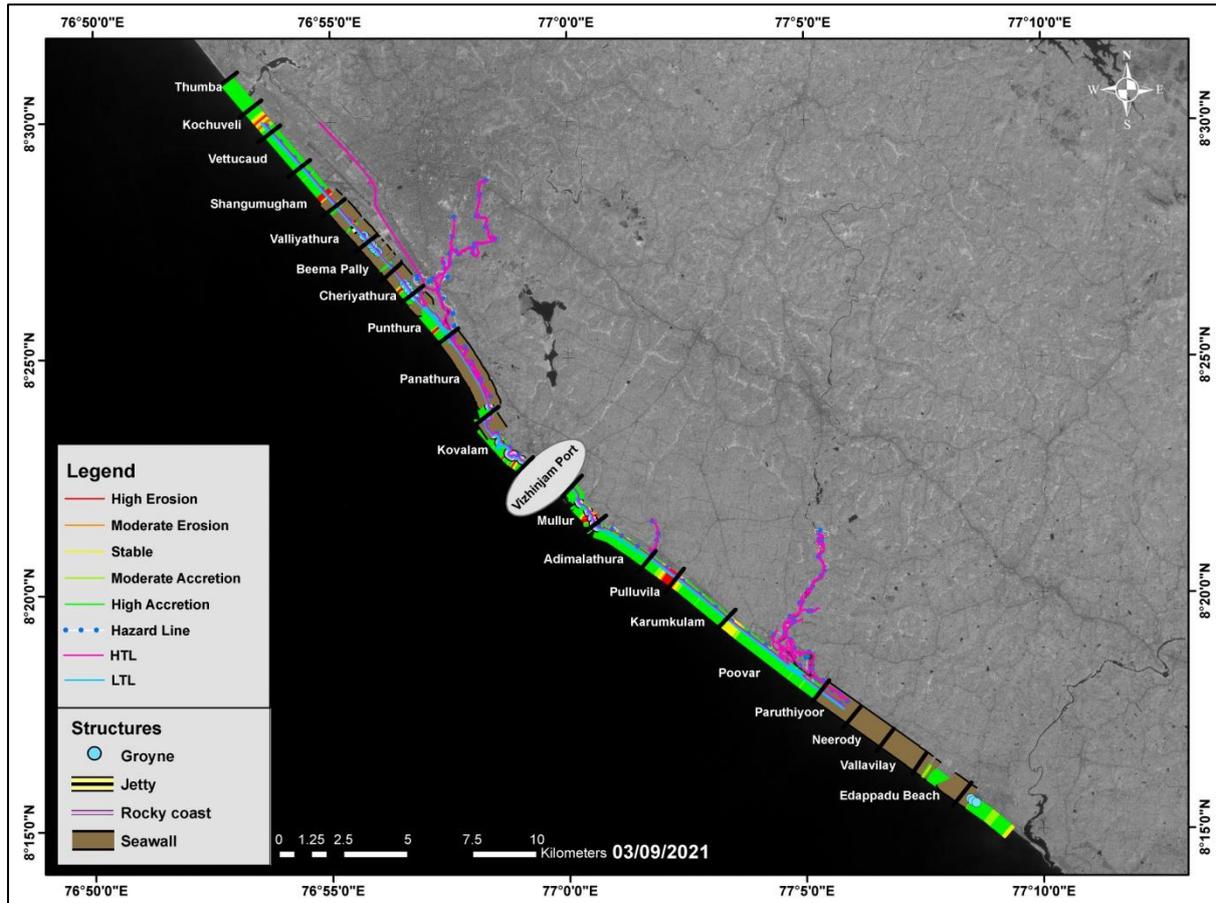


Figure 4.45 Overall Shoreline Change Map October 2020 to September 2021

4.2.4 Seasonal Shoreline Change comparison between 2019-2020 and 2020-2021

October 2019 and October 2020 (Post Monsoon period)

Using Resourcesat 2A-LISS4 and Sentinel 2A/2B-MSI satellite images (5m and 10m spatial resolution), the shoreline change has been compared between the October 2019 and October 2020 shorelines. Figure 4.46 shows the shoreline change map for October 2019 and October 2020. Accretion is noticed at Thumba, Kochuveli, Beemapally, Poovar, and Neerody and at few sectors of Beemapally, Kovalam, and Mullur while erosion is noticed at Vettucaud, Shangumugham beach, Valliyathura, Cheriyaathura, Punthura, Pannathura, Adimalathura to Karumkulam, Paruthiyoor, Vallavilay and Edappadu beach for the shoreline change comparison between October 2019 and October 2020.

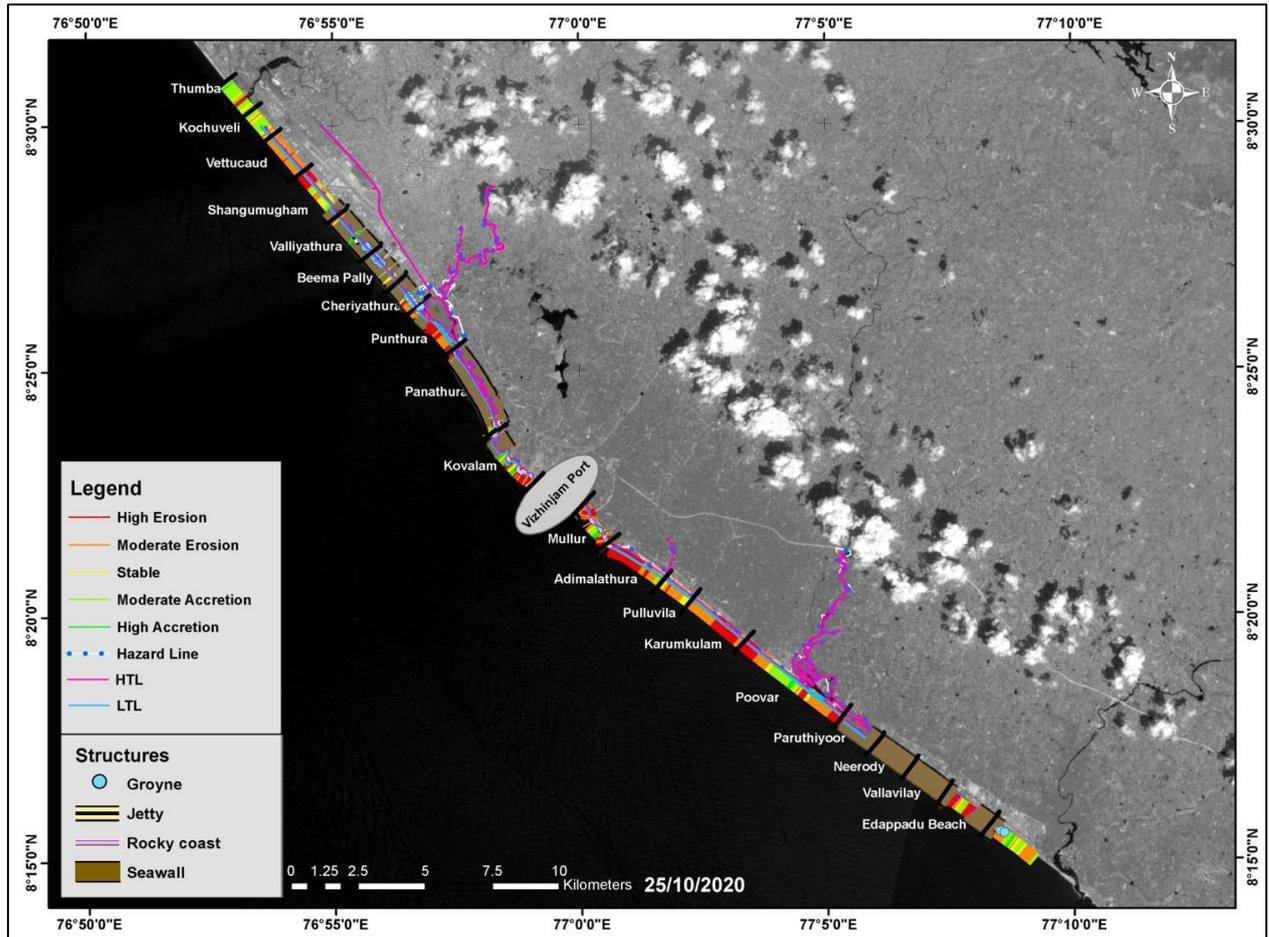


Figure 4.46 Shoreline Change Map October 2019 and October 2020

February 2020 and February 2021 (Fair weather period)

Using Resourcesat 2A-LISS4 and Sentinel 2A/2B-MSI satellite images (5m and 10m spatial resolution), the shoreline change has been compared between the February 2020 and February 2021 shorelines. Figure 4.47 shows the shoreline change map for February 2020 and February 2021. Accretion is noticed at Thumba, Kochuveli, Beemapally, Poovar, Neerody and at few sectors of Beemapally, Kovalam, and Mullur while erosion is noticed at Vettucaud, Shangumugham beach, Valliyathura, Cheriyaathura, Punthura, Panathura, Adimalathura to Karumkulam, Poovar, Paruthiyoor, Vallavilay and Edapadu beach for the shoreline change comparison between February 2020 and February 2021.

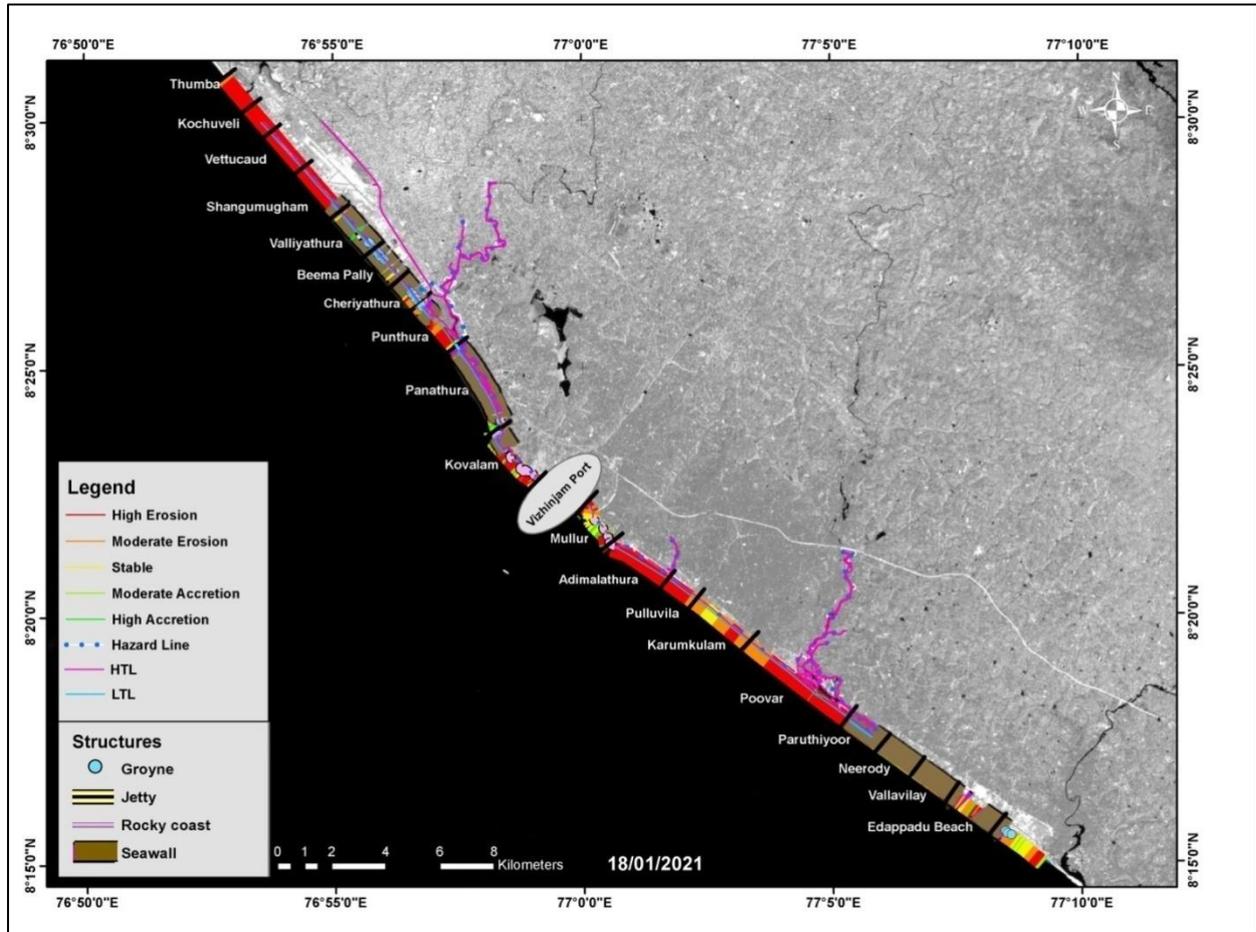


Figure 4.47 Shoreline Change Map February 2020 and February 2021

April 2020 and April 2021 (Pre-Monsoon period)

The shoreline change has been compared between the April 2020 and April 2021 shorelines using Sentinel 2A/2B-MSI satellite images (10m spatial resolution). Figure 4.48 shows the shoreline change map for April 2020 and April 2021. Accretion is noticed at Shangumugham beach, few sectors of Mullur, Adimalathura, northern sectors of Karumkulam while erosion is noticed at Kochuveli, Valliyathura, Punthura, southern sectors of Karumkulam, Poovar and Edapadu beach for the comparison of shorelines between April 2020 and April 2021.

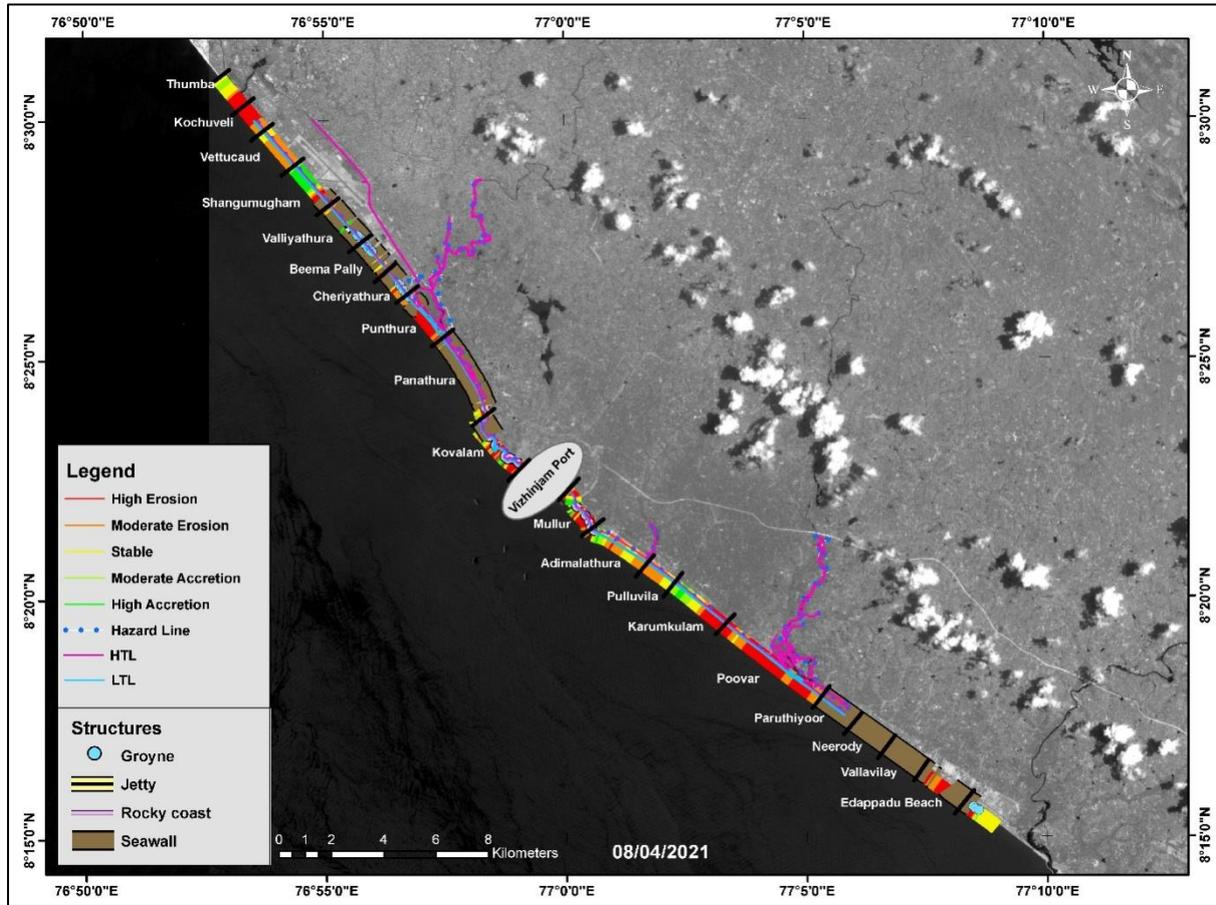


Figure 4.48 Shoreline Change Map April 2020 and April 2021

September 2020 and September 2021 (Monsoon period)

The comparison of shorelines of September 2020 with September 2021 is shown in Figure 4.49 and erosion is noted at Cheriyaathura (150m), Adimalathura (600m), Karumkulam (2km) and Poovar (380m).

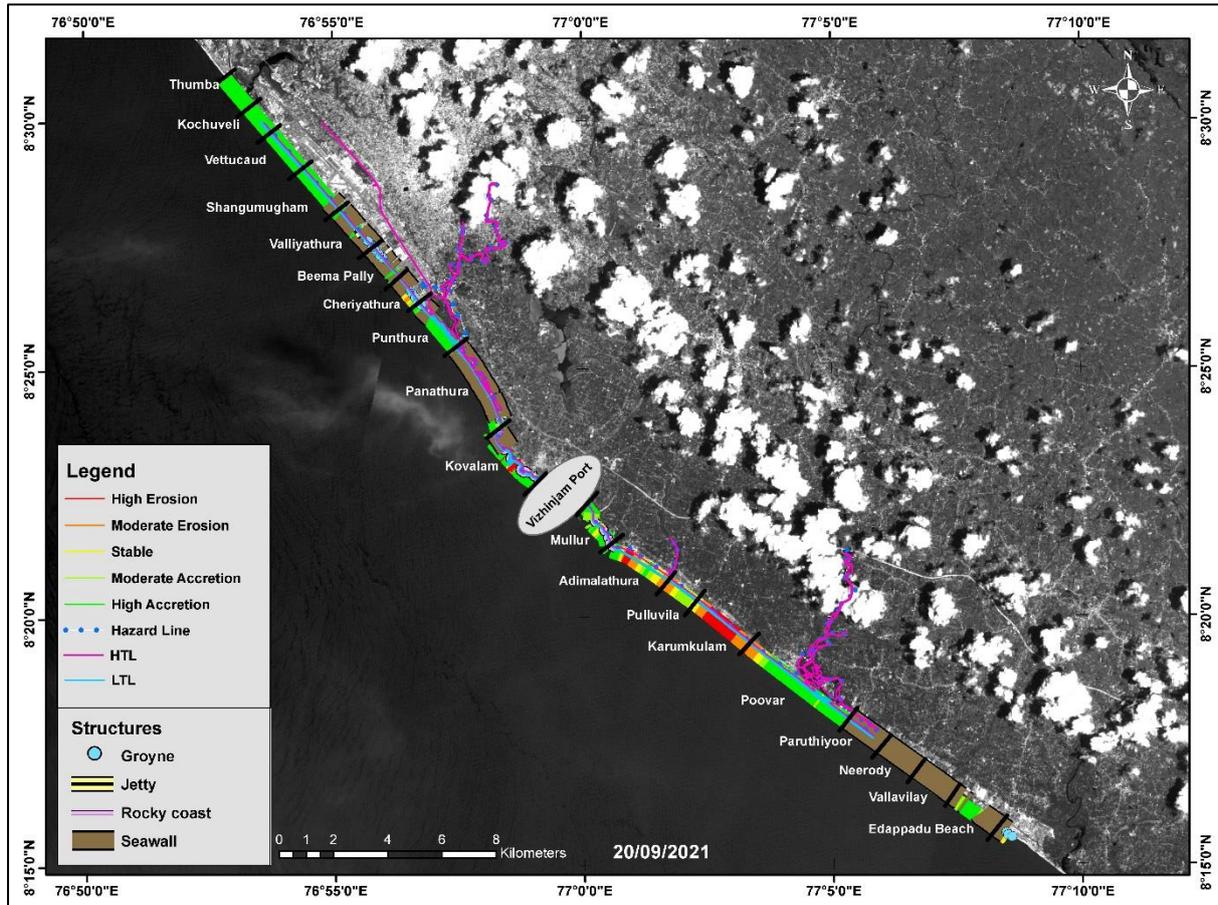


Figure 4.49 Shoreline Change Map September 2019 and September 2020

4.2.5 Shoreline Change comparison between January 2015 and January 2021

The comparison of January 2015 shoreline with January 2021 using high resolution satellite images has been presented in the Figure 4.50. The comparison shows erosion at Thumba to Shangumugham beach, Punthura while Mullur and Edapadu beach shows accretion and stable at Poovar.

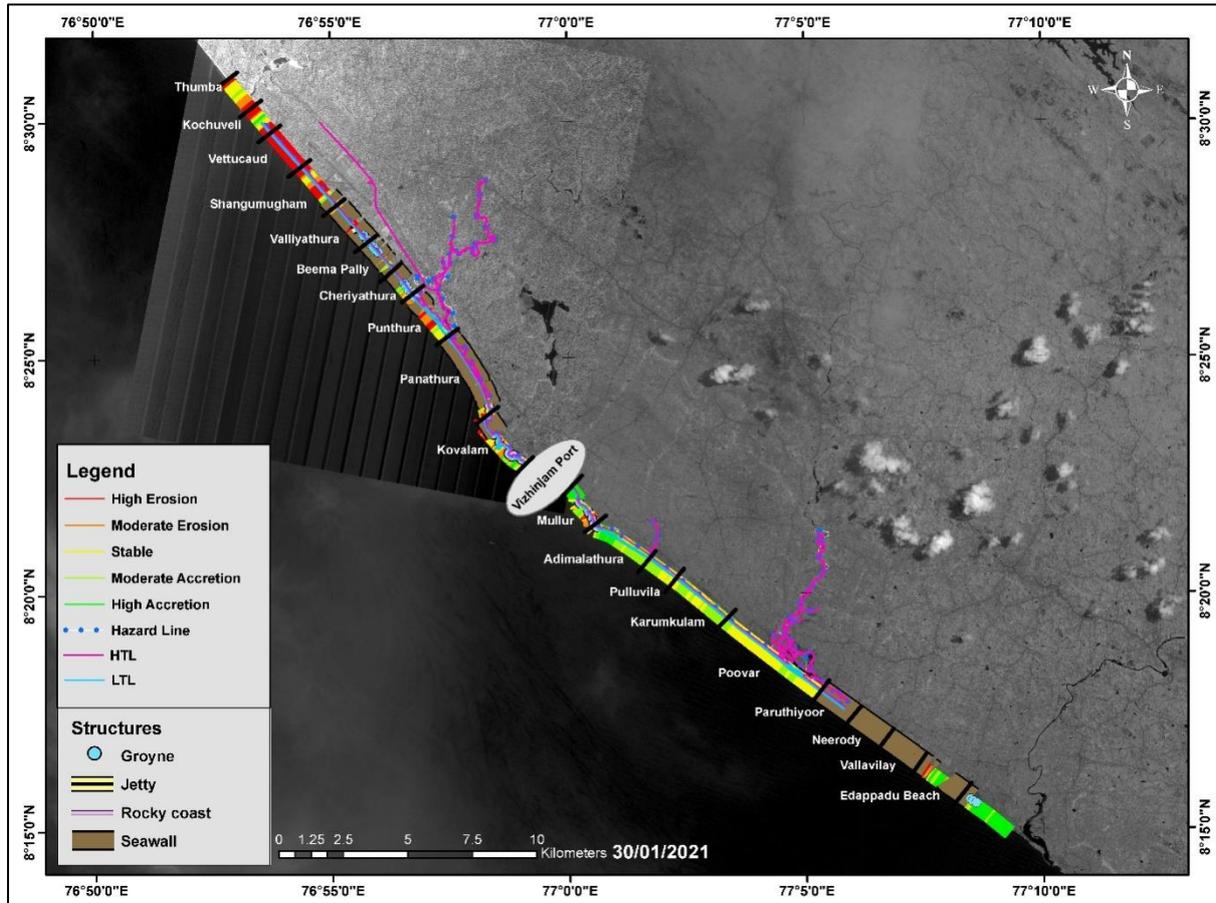


Figure 4.50 Shoreline Change Map- January 2015 to January 2021

4.2.6 Shoreline Change Comparison using High resolution satellite images - February 2011 vs January 2021

The shoreline change comparison of February 2011 with January 2021 has been carried out using high resolution images of 1m spatial resolution covering north of Vizhinjam Port (as available and procured from NRSC). The result from the analysis indicates erosion at Shangumugham (600m), Valliyathura (200m) and Cheriyaathura (100m) and Stable from Thumba o Vettucaud.

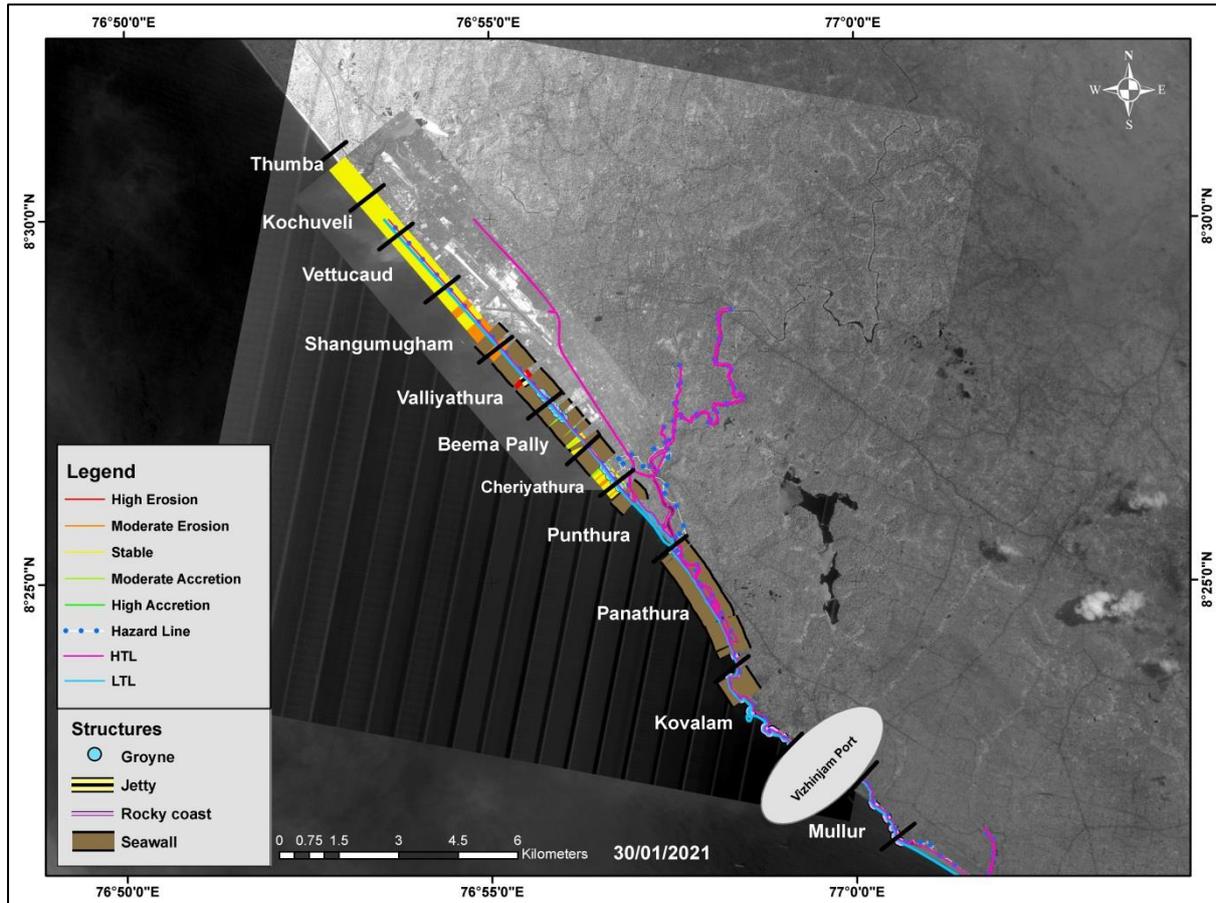


Figure 4.51 Shoreline Change Comparison- February 2011vsJanuary 2021

4.3 Validation and Comparison of results

For the validation of the results from the shoreline derived from the satellite images of different spatial resolution (PAN (2.5m), LISS 4 (5m) and MSI (10m)) has been compared as shown in Figure 4.51. The transect numbers indicate the 30m interval along the 40km stretch from Thumba to Edapadu beach (1350 number of sectors). The comparison shows that the error in extraction of shoreline from 10m Sentinel images is 4.65m while the error from 5m satellite image is 2.75m when compared with the shoreline derived from 2.5m satellite images. The error in extracting the shoreline from satellite images reduces with respect to the spatial resolution of the satellite images.

It can be noted that the result from the two analysis (high resolution satellite image and beach profile data) shows concurrence. The difference in the shoreline distance along the sectors south of Vizhinjam port is due to the fact that the beach profile data has been collected at different time and date whereas the satellite image captures the entire coast at a single time and date.

The field shoreline data collected by NIOT during September 2018 using DGPS has been compared with shoreline derived from Beach profile (collected by Surveying agency) and satellite imagery is shown in Figure 4.51. With the higher resolution satellite images, the field shoreline exactly matches with the shoreline derived from the satellite images whereas shoreline derived from the beach profile matches at every 500m.

As suggested in the shoreline committee dated 5th September 2019, the LTL, HTL and Hazard line has been demarcated on the shoreline maps provided in this report. Also, the graph shown in Figure 4.52 compares the shoreline derived from 5m and 10m satellite images, beach profile data, LTL, Hazard line with the field collected shoreline data specific to the stretch from Shangumugham to Punthura.

A comparison of shorelines extracted from the satellite images of different spatial resolution has been shown in Figure 4.53. The difference error has been estimated for 10m and 5m satellite image compared with 1m satellite image. The average difference error for 10m satellite image when compared to 1m satellite image is 3.3m and the average difference error for 10m satellite image when compared to 5m satellite image is 2.9m while the average difference error for 5m satellite image when compared to 1m satellite image is 0.4m. However, due to non availability of higher resolution images (5m and 1m) for the monthly analysis, only 10m satellite images have been used and the available 5m and 1m satellite image has been incorporated in the analysis.

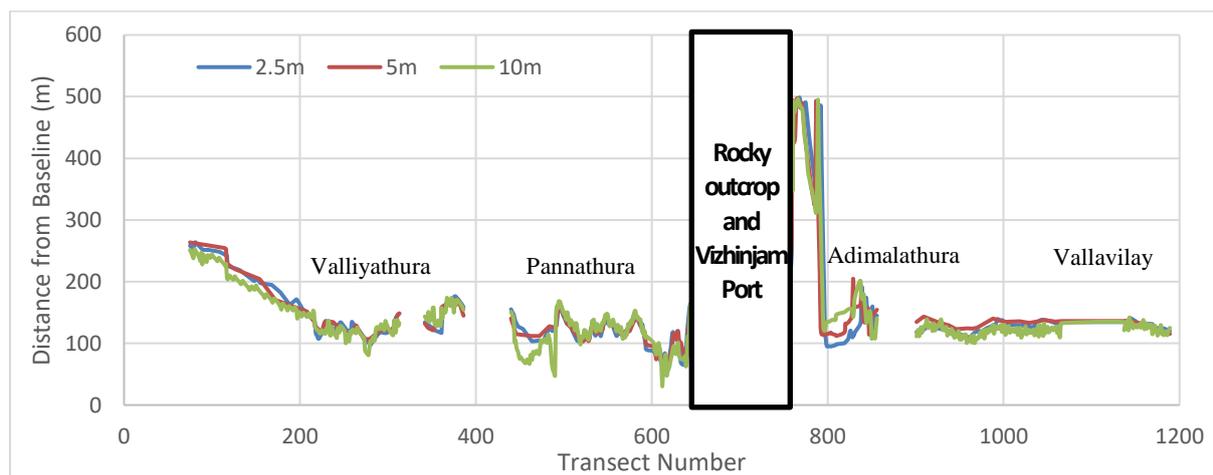


Figure 4.52 Comparison of Shoreline data from satellite images of different spatial resolution and beach profile data with field shoreline

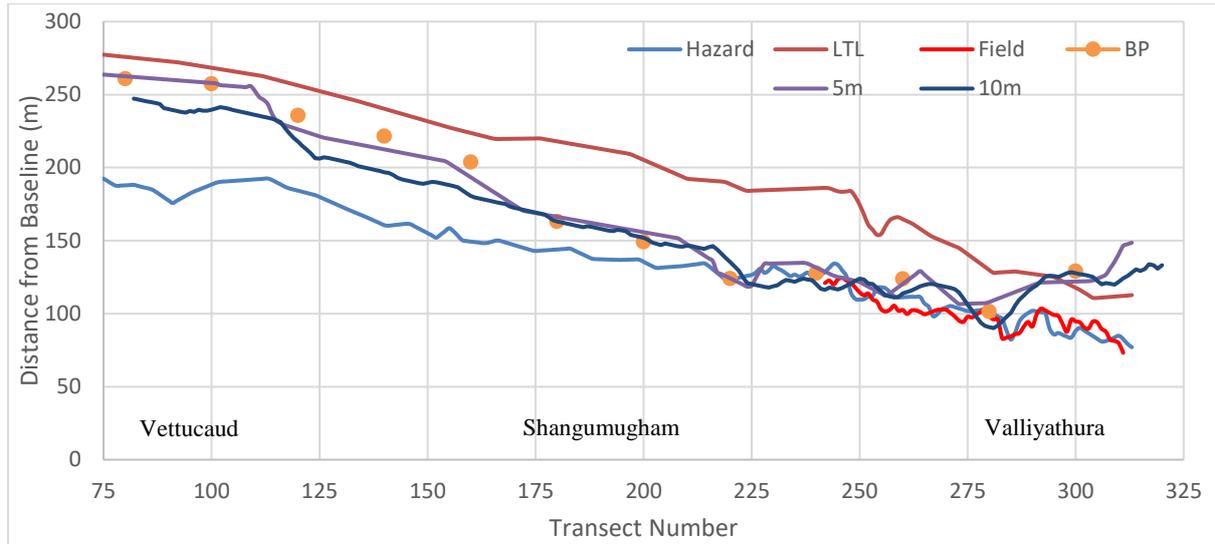


Figure 4.53 Comparison of Shoreline data from satellite images of different spatial resolution, beach profile data, LTL, Hazard line with field shoreline from Vettucaud to Valliyathura

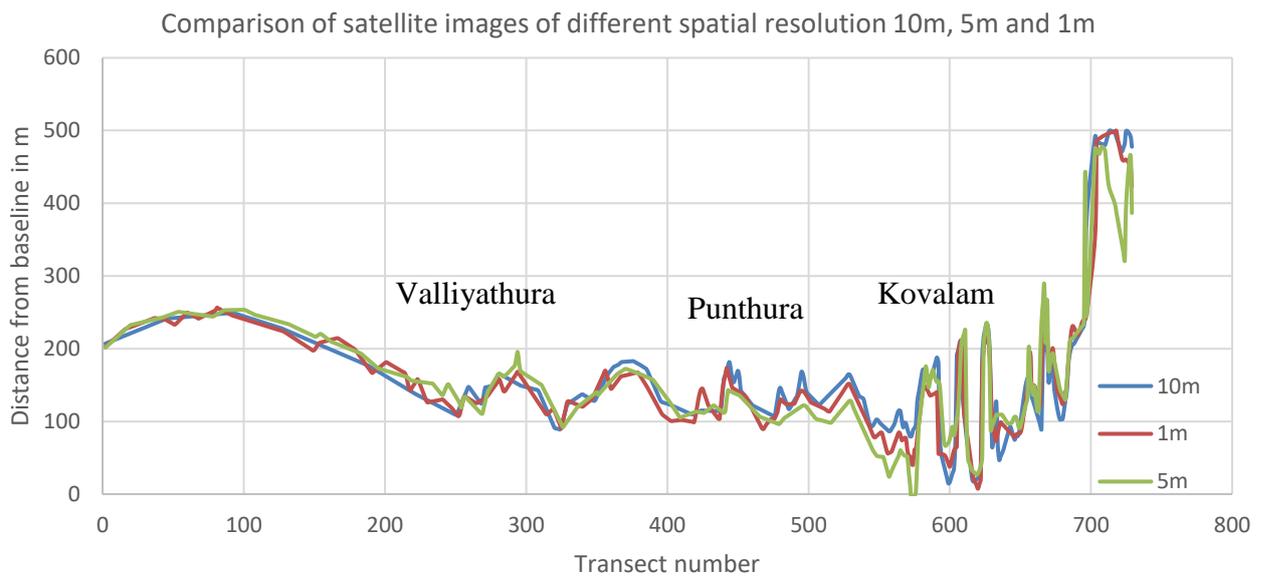


Figure 4.54 Comparison of shorelines from satellite images of different resolution viz. 1m, 5m and 10m

The comparison of the erosion spots from the previous annual report October 2017-September 2018 for the shoreline change analysis for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018, 2018-2019 and 2019-2020 has been compared with the results of 2020-2021 shown in Table 4.6 and the erosion spots from satellite image and beach profile analysis for the period October 2020 to September 2021 has been listed in Table 4.7.

Table 4.6 Comparison of Erosion spots since 2000 using high resolution satellite images

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

Table 4.7 Comparison of Erosion spots from satellite image analysis and beach profile analysis for October 2020 to September 2021

Erosion spots from satellite image analysis	Erosion spots from beach profile analysis (onshore)
Pulluvila (500m), Mullur (290m), Punthura (150m), Valliyathura (50m), Shangumugham (100m), Cheriyaathura (120m), Kochuveli (250m),	Poovar (CSP15-17 and CSP19-21), Karumkulam (CSP24), Pulluvila to Adimalathura (CSP29-31), Adimalathura (CSP34), Mullur (CSP36-37), Kovalam (CSP42-44), Pannathura to Punthura (CSP51-53), Valliyathura (CSP66), Vettucaud to Kochuveli (CSP72-75), Kochuveli (CSP77), Thumba (CSP81).

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 2019 to February 2021) by LnTIEL during November 2021, water quality, oceanographic and bathymetric data collection (by Shankar & Co from June 2019) for assessment of Shoreline changes has been completed till September 2021.

Table 5.1 Data Status October 2020 to September 2021

Sl no.	Parameters	Post monsoon (October 2020 - January 2021)				Pre monsoon (Feb 2021-May 2021)				Monsoon (Jun 2021-Sep 2021)			
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	Wave (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Tide (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Met (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	ADCP (4 locations) at 20 m water depth	x				✓				✓			
5	Bathymetry	✓								✓			
6	Beach Profile (81 locations at 500 m distance)	Onshore profiles	✓	✓	✓	✓	✓	✓	Onshore (few locations)	Onshore (few locations)	✓	✓	✓
7	Turbidity	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
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 into 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.

6 CONCLUSION

NIOT has carried out shoreline analysis using available high resolution satellite images and analysis of beach profile data for October 2020 to September 2021. Apart from that NIOT has also vetted / reviewed project proposals, field measured data and reports on various oceanographic data related to port development and modeling report by LNTIEL.

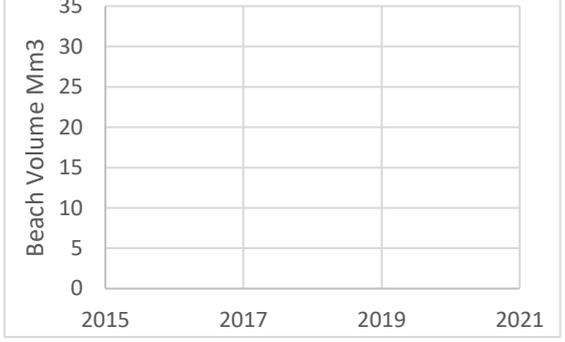
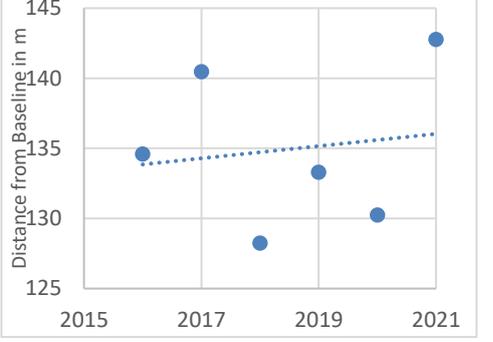
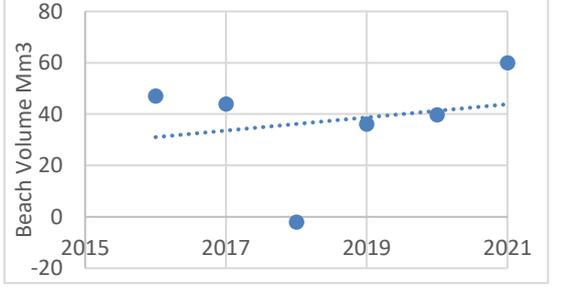
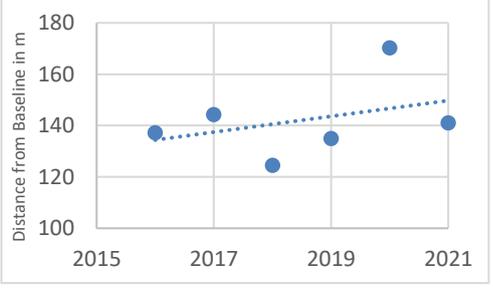
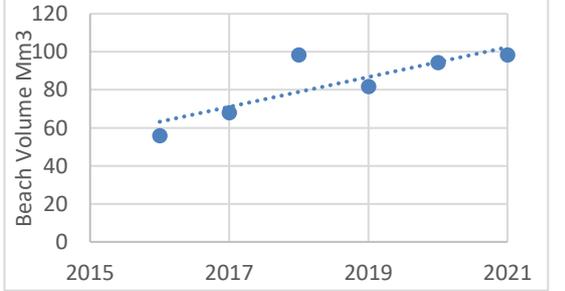
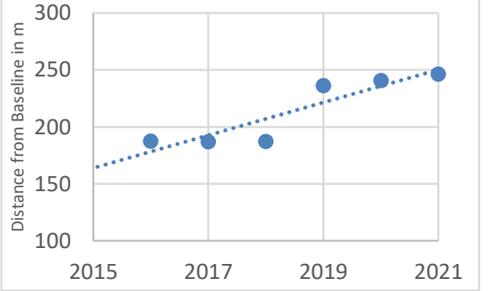
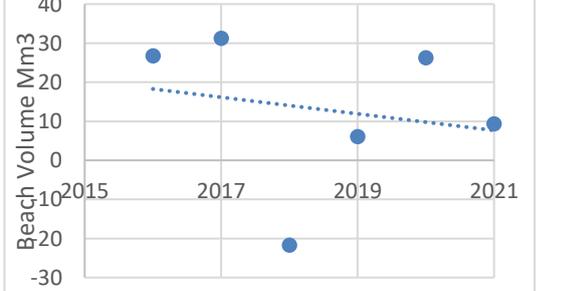
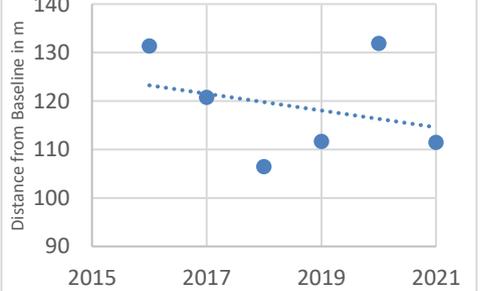
The zones of erosion and accretion have been derived from the available high resolution satellite images for the study period. Erosion is noticed at Kochuveli (250m), Shangumugham (100m), Valliyathura (50m), Cheriyaathura (120m), Punthura (150m), Mullur (290m), Pulluvila (500m) and accretion at Thumba, Vettucaud and Shangumugham, Punthura, Adimalathura, Karumkulam, Poovar and Edapadu beach.

Beach profile analysis for the entire 40km stretch has been carried out to estimate the monthly, seasonal and annual changes in the beach volume. During October 2020 to September 2021 the beach shown erosion at Poovar (CSP15-17 and CSP19-21), Karumkulam (CSP24), Pulluvila to Adimalathura (CSP29-31), Adimalathura (CSP34), Mullur (CSP36-37), Kovalam (CSP42-44), Pannathura to Punthura (CSP51-53), Valliyathura (CSP66), Vettucaud to Kochuveli (CSP72-75), Kochuveli (CSP77) and Thumba (CSP81). Accretion found at Edapadu beach (CSP02), Poovar (CSP18), Karumkulam (CSP22-23), Karumkulam to Pulluvila (CSP25-28), Adimalathura (CSP33), Shangumugham (CSP69-71), Valiyaveli (CSP78) and Thumba (CSP80). The shorelines derived from the satellite images of different spatial resolution and beach profile has been compared with the shoreline collected from field.

The comparison of the erosion spots from the shoreline change analysis (Annual Report 2017-2018) for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018, 2018-19, 2019-20 has been compared with the results of 2020-2021 and 2015-2021. It can be noted that the spots of erosion such as Valliyathura, Shangumugham and Punthura remains same before and after the commencement of the port (December 2015). However, the spots such as Kochuveli, Cheriyaathura to the north of Valliyathura show erosion during the period October 2020-September 2021.

As per the suggestion provided by honorable NGT committee experts to bring out the ongoing port construction have any impact on either side of the coast up to 10km, a review study has been made based on the available satellite image analysis and onshore beach profile data from 2015 to 2021 (Table 6.1). Minor port activities like dredging, filling and construction of Breakwater etc. started since December 2015 (Table 6.2) and high wave activities during same period have also been reported. It is noticed that in recent years frequent cyclone and cyclonic events have occurred and the coastline has undergone various changes. The Cyclone Ockhi had a large impact on the shoreline either side of the port, while the coast is recovering back to its previous form gradually. Recently, 10 cyclones (Sagar, Mekuru, Luban, Vayu, Hikka, Kyarr, Maha, Pavan, Nisarga, Gati) formed in Arabian sea and hit along the east coast of India in three years (2018-2020). Similarly, in the west coast of India, more cyclones and frequent depressions were also experienced since the year 2018 after cyclone Ockhi. It can be noticed from the study that due to no major work happened during this period by the port authorities and considering the natural events that occurred are more than earlier day, the impact of the port activity on either side of the coast have less significance till date. Further, continuous monitoring of the port activity and its impact on coast has to be carried out.

Table 6.1 Trend analysis comparison of beach volume change (onshore) and shoreline change using satellite images

Place	Beach Volume Change (Onshore) (in Mm ³)	Shoreline Change (Satellite image) (in m)
Poovar		
	Stable to accreting trend	
Adimalathura		
	Accreting trend	
Vizhinjam		
	Accretion due to Port reclamation activity	
Punthura		
	Eroding trend	



<p>Valliyathura</p>	<table border="1"> <caption>Beach Volume Mm3 - Valliyathura</caption> <thead> <tr> <th>Year</th> <th>Beach Volume Mm3</th> </tr> </thead> <tbody> <tr><td>2015</td><td>-50</td></tr> <tr><td>2016</td><td>-55</td></tr> <tr><td>2017</td><td>-55</td></tr> <tr><td>2018</td><td>-25</td></tr> <tr><td>2019</td><td>-55</td></tr> <tr><td>2020</td><td>-5</td></tr> <tr><td>2021</td><td>-5</td></tr> </tbody> </table>	Year	Beach Volume Mm3	2015	-50	2016	-55	2017	-55	2018	-25	2019	-55	2020	-5	2021	-5	<table border="1"> <caption>Distance from Baseline in m - Valliyathura</caption> <thead> <tr> <th>Year</th> <th>Distance from Baseline in m</th> </tr> </thead> <tbody> <tr><td>2015</td><td>132</td></tr> <tr><td>2016</td><td>130</td></tr> <tr><td>2017</td><td>130</td></tr> <tr><td>2018</td><td>117</td></tr> <tr><td>2019</td><td>145</td></tr> <tr><td>2020</td><td>138</td></tr> <tr><td>2021</td><td>114</td></tr> </tbody> </table>	Year	Distance from Baseline in m	2015	132	2016	130	2017	130	2018	117	2019	145	2020	138	2021	114
Year	Beach Volume Mm3																																	
2015	-50																																	
2016	-55																																	
2017	-55																																	
2018	-25																																	
2019	-55																																	
2020	-5																																	
2021	-5																																	
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2020	138																																	
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<p>Eroding trend</p>																																		
<p>Shangumugham</p>	<table border="1"> <caption>Beach Volume Mm3 - Shangumugham</caption> <thead> <tr> <th>Year</th> <th>Beach Volume Mm3</th> </tr> </thead> <tbody> <tr><td>2015</td><td>1</td></tr> <tr><td>2016</td><td>3</td></tr> <tr><td>2017</td><td>-2</td></tr> <tr><td>2018</td><td>-25</td></tr> <tr><td>2019</td><td>-15</td></tr> <tr><td>2020</td><td>-15</td></tr> <tr><td>2021</td><td>-17</td></tr> </tbody> </table>	Year	Beach Volume Mm3	2015	1	2016	3	2017	-2	2018	-25	2019	-15	2020	-15	2021	-17	<table border="1"> <caption>Distance from Baseline in m - Shangumugham</caption> <thead> <tr> <th>Year</th> <th>Distance from Baseline in m</th> </tr> </thead> <tbody> <tr><td>2015</td><td>180</td></tr> <tr><td>2016</td><td>180</td></tr> <tr><td>2017</td><td>180</td></tr> <tr><td>2018</td><td>180</td></tr> <tr><td>2019</td><td>150</td></tr> <tr><td>2020</td><td>180</td></tr> <tr><td>2021</td><td>140</td></tr> </tbody> </table>	Year	Distance from Baseline in m	2015	180	2016	180	2017	180	2018	180	2019	150	2020	180	2021	140
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<p>It can be inferred from the beach profile analysis and shoreline analysis using satellite images, high erosion has been noted during 2018.</p>																																		

Table 6.2. Timeline of climatic and Port events along Vizhinjam coast and corresponding wave measurements

Date	Month	Climatic events	Wave observations captured in WRB during the month	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	Cyclone 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	May-21	Cyclone Tauktae	maximum Hs-4.12m, maximum Hmax-9.44m, maximum Tp-18.2s	



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