Modeling and Analysis of Shoreline Change in the Sidi Abdel Rahman Coast Area, Egypt

Modeliranje i analiza promjene obale u Sidi Abdel Rahman obalnom pojasu, Egipat

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Abstract

Estimating the coastline or shoreline is one of the crucial components in determining coastal accretion and erosion and in analysing coastal morph dynamics. In recent years, the socioeconomic pressure has increased on the Sidi Abdel Rahman coast area with the impact of climate change, which has led to the destabilisation of the coast. Therefore, this study aims to investigate the shoreline changes along the coast in the study area using remote sensing data for the period 2007 to 2021, modeling the shoreline change through the study area, and predicting shoreline change in the period from 2021 to 2024. It also suggests the type of protection required for the area from waves and sea currents.

KEY WORDS
shoreline change
erosion
coastal hazard
remote sensing
numerical model
sidi abdel rahman district

Sažetak

Procjena obrisa obale ili obalnog pojasa jedna je od ključnih sastavnica kad određujemo obalnu akreciju i eroziju te analiziramo obalnu morfodinamiku. Posljednjih godina, uz utjecaj klimatskih promjena, pojačali su se socioekonomski pritisci na Sidi Abdel Rahman obalu, što je dovelo do destablizacije obale. Stoga je cilj ovoga rada istražiti promjene obrisa obale duž odabranog obalnog pojasa upotrebom podataka prikupljenih daljinskim istraživanjem u razdoblju od 2007. do 2021., zatim modeliranje promjene u obrisu obale u području istraživanja te predviđanje promjena u obrisu obale u razdoblju od 2021. do 2024. U radu se također predlaže način zaštite koji je potreban da bi se područje zaštitilo od valova i morskih struja.

KLJUČNE RIJEČI
promjena obrisa obale
erozija
opasnost na obali
daljinsko istraživanje
numerički model
Sidi Abdel Rahman okrug

1. INTRODUCTION / *Uvod*

A coastal zone is a region that is bordered by both land and sea. Although it is continually changing, it represents a large natural and economic resource [1–4]. Furthermore, this microcosm is a very intricate ecosystem in which a variety of climatic, topographical, biological, and human-made factors influence erosion processes and, as a result, the retreat or advancement of the shoreline [5–7]. Monitoring the coastal zone is necessary for a number of reasons, including environmental protection, sustainable development, and cartography [8–10]. The shoreline change estimate is one of the most crucial elements in the investigation of coastal morphodynamics and the detection of coastal erosion and deposition [11]. The border between land and sea is the shoreline, which is subject to erratic change as a result of one or more natural factors, such as morphological, climatic, or geological variables [12]. Due to their dynamic environmental setting and role as a boundary between land and water, shorelines are always undergoing change [13]. The coastline features are influenced by the dynamic interplay of waves, tides, rivers, storms, and tectonic and physical processes [14]. Erosion makes coastal areas more vulnerable, which puts human activities along the coasts in danger. Additionally, the increase in coastal disasters makes the coasts extremely vulnerable and changeable [15]. The geology, geomorphology, wave action along the coast, infrequent storms, sea level rise, sediment transport by longshore currents, and human activity are all factors that can cause this landform type, one of the most dynamic in the world, to change quickly [16-18]. Understanding the dynamics and evolution of coastal areas through the study of shoreline change is essential, and stakeholders could improve their efforts to minimise social, physical, and economic losses as well as the risk of coastal erosion [19]. In coastal zone management, the study of shoreline fluctuation and forecasting is crucial, and its significance is growing in light of climate change and sea level rise [20]. Due to the occurrence mechanism of coastal erosion and its destructive characteristics, coastal erosion is one of the most significant marine geological disasters, and the degree of coastal erosion hazard implies

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that coastal erosion may occur in the future [21-23]. For the mapping and monitoring of coastal changes, conventional field survey techniques and aerial photographs were employed [24]. Recently, shoreline change studies have made extensive use of remote sensing data due to their synoptic and repeated coverage, high resolution, multispectral capabilities, and cost-effectiveness in comparison to older approaches [24-29]. In the recent past, numerous studies at various times at the global and regional scale have already been conducted using remote sensing and Geographic Information System (GIS) techniques to examine shoreline change [30-33].In recent decades, the Egyptian coastal zones, like most other coastal areas across the world, have been altered by natural processes. Due to increased socioeconomic pressure on the coast and global projections regarding the impacts of climate change, which suggest an increase in sea level rises and reinforcement of erosion processes on low-lying coasts, coastal erosion has already destabilized the Egyptian coastline, and it is expected to get worse [34]. The results showed that before the construction of the breakwaters, sedimentation was occurring at a small rate of about 0.34 m/year in the study area south of the southern barrier of the village of L'azurde, from sectors 1 to 15, and erosion was occurring at a rate of 3.23 m/year after the construction of the breakwaters. Before the maritime works, sectors 15 through 22 had erosion at a rate of around 1.62 m/year, while afterward, erosion occurred at a rate of 1.35 m/year. Prior to the construction of marine works, sedimentation occurred from sector 27 to sector 31 at a rate of roughly 8.3 m/year; thereafter, it happened at a pace of roughly 1.47 m/year. Therefore, this study aims to (i) investigate the shoreline changes along the coast in the Sidi Abdel Rahman area using remote sensing data, (ii) modeling the shoreline change through the study area using Deflt-3D, and (iii) predict shoreline change in the period from 2021 to 2024.

1.1. Study area / *Područje istraživanja*

The Sidi Abdel Rahman area in El Alamein is an important tourist area, with important resorts and hotels, as well as some oil companies. The shore line in front of it is special in terms of land and natural formations, and it has many curves. The Northwest Coast region is considered one of the most beautiful regions on the shores of the Mediterranean Sea. The study area is located on the Mediterranean coast, Sidi Abdel Rahman area, Alexandria-Marsa Matrouh governorate, in Egypt, at approximately 120 km west of Alexandria, between 2 latitudes 30˚56′27.63′′ N - 30˚ 56′16.89′′ N and longitudes 28˚49′59.62′′ E - 28˚50′0.89′′ E, as shown in Figure 1. The site is bordered to the east by the Mediterranean coastline, with a shoreline of approximately 300 m, and to the north by the village of Boiland.

2. DATASETS AND METHODS / *Podaci i metode*

This study focused on the following:

1. Determine the nature of the beach area.
2. The impact of the marine installations in the neighboring villages on the study area as well as the impact of the marine protection to be established on the neighboring area using numerical models.

In order to do the design work must first do a survey of the marine area in front of the study area and collect the necessary data for the study ,the work of calculations and the use of

Figure 1 Location of the study area
Slika 1. Lokacija područja istraživanja

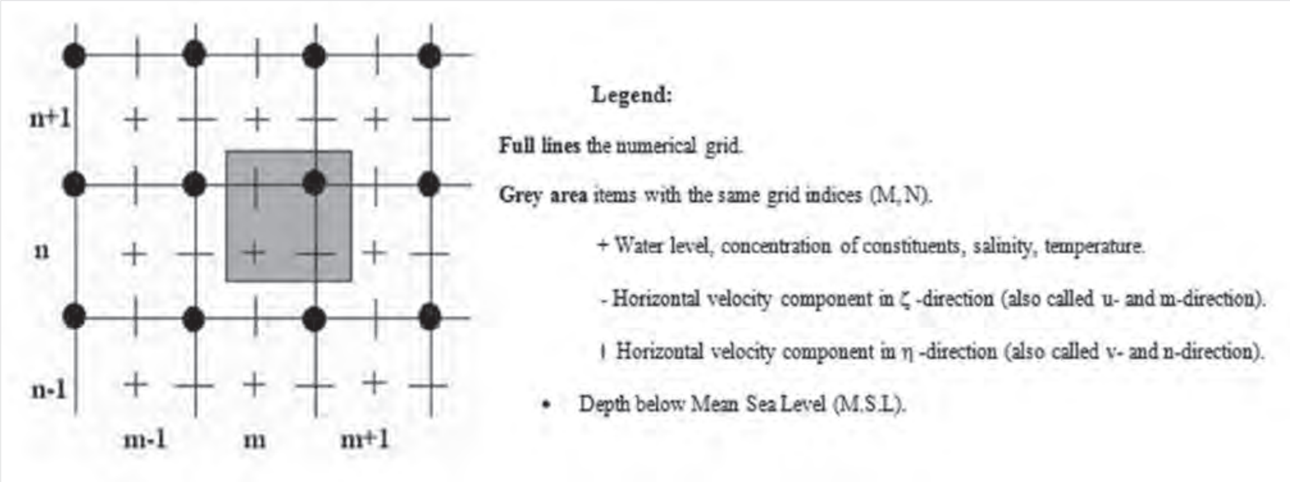


Figure 2 The upwind approach of positioning bed-load sediment transport components at velocity sites uses the Delft-3D staggered grid

Slika 2. Pristup postavljanja sastavnica za prijevoz temeljnog sedimenta na točkama gdje je izmjerena brzina uz vjetar – koristi se Delft-3D mreža

numerical models to calculate the distribution of waves in front of the barriers to be established and the design of these barriers.

The construction of two vertical breakwaters on the shore line was started in 2013 in the Gulf region. The first barrier was located at a distance from the rocky head, which is 150 m long, and the other was located in the last area of the study area to the south, which is 50 m long. These barriers serve to impound the sediments and sand in the north of the village, causing devastation to the area south of the village.

2.1. Numerical modeling using Delft-3D / *Numeričko modeliranje uporabom Delft-3D*

The overall hydrodynamic modeling approach used in this research is based on the Delft-3D modeling software developed by Delft Hydraulics. Deflt-3D model is used to determine the direction and height of waves direction and speed of currents. Delft-3D is a numerical model based on the finite difference method [35]. A rectangular, curvilinear, or spherical grid is placed over the model region to discretize the 3D shallow water equations in space. It is expected that the grid is well-structured and orthogonal [36]. The Arakawa C-grid is a pattern used to arrange the variables (a staggered grid). The velocity components in this configuration are perpendicular to the faces of the grid cells where they are located, whereas the water level points (pressure points) are established in the center of each (continuity) cell [37], as shown in Figure 2.

2.2. Prediction model / *Model predviđanja*

The coastal engineering's mono-dimensional mathematical models provide a scientific analysis of potential shoreline modifications. These models are based on the assumption that the rate of sediment movement in the research region is constant, and they derive changes in shoreline erosion or accretion from variations in this rate, depending on whether offshore structures are present or not. These models often require wave measurements, which represent the hydrodynamic forces influencing the coastal region, as well as sediment data from the study area's bottom, coastline data, and a study area contour map. Sand dunes on the beach and the location where they will be used again in the future are characteristics of the area. This will be taken into account when determining future shoreline alterations [35]. In order to demonstrate how the breakwater affects the shoreline in the study region, LitPack-Mike21 model was used to forecast shoreline change over the years 2021 to 2024. The LitPack-Mike21 model investigates the shifting of the shoreline and the flow of sediments caused by waves and currents.

2.3. Datasets / *Podaci*

The study of the equilibrium of the shore line is based mainly on the comparison of the location of the shore line to show its behavior over time. To obtain this, the beach line in the study area was drawn based on satellite images for the years 2007, 2009, 2012, 2013, 2016, and 2017, as well as the lift for the year 2021, Figure 3.

Two samples of bottom sediments were collected in the marine area in front of the project site to find out the properties of the bottom components for the coastal area and the seabed, Figure 4. Seventeen survey sectors from P1 to p17 where p : position of the sector were conducted in the study area to determine sea bed levels in the study area. These sectors are perpendicular to the beach line and inside the sea, with distances ranging from 900 to 1600 meters.

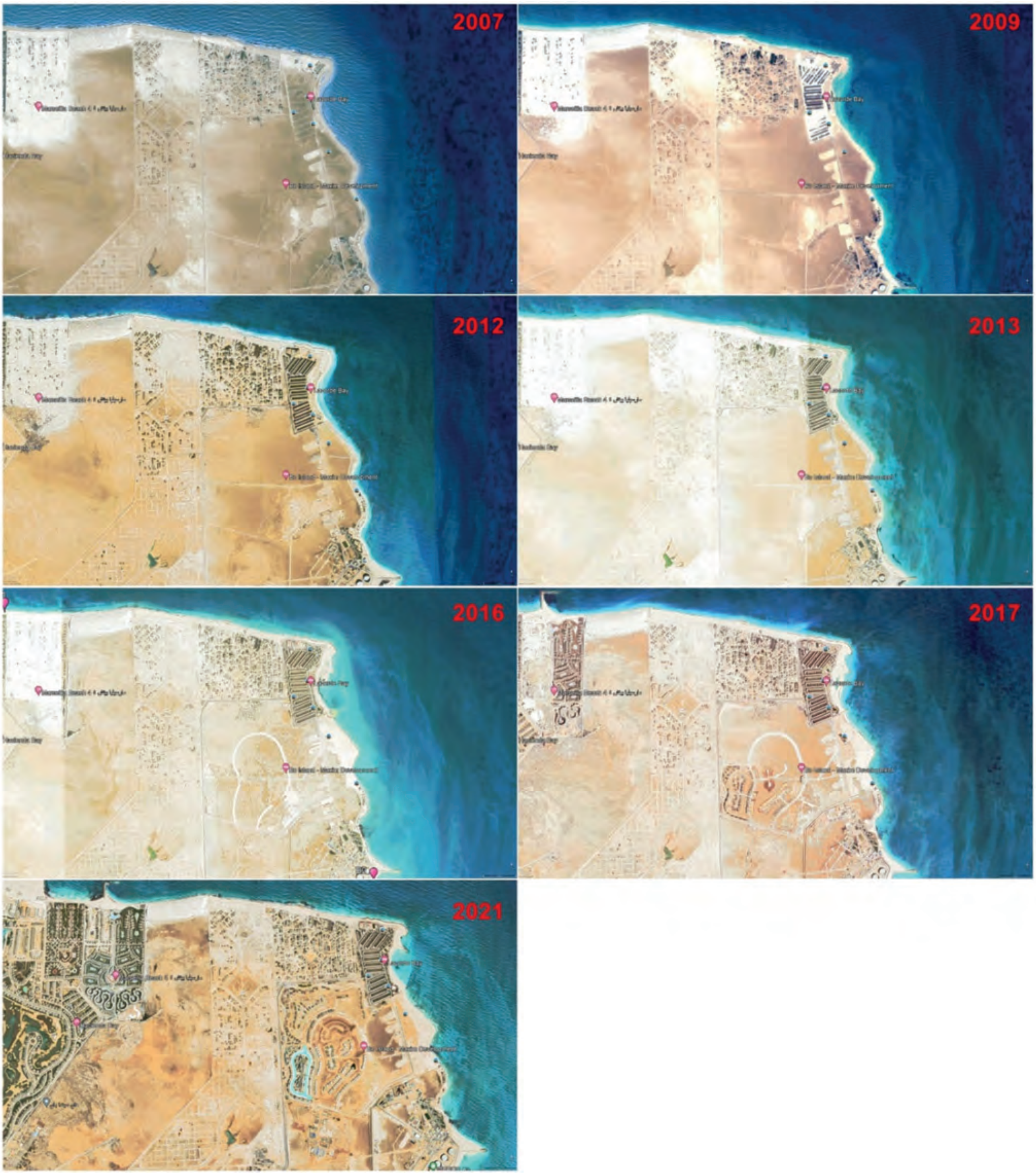


Figure 3 Satellite photos (Google Earth) of shoreline changes in the period of study
Slika 3. Satelitske snimke (Google Earth) promjena na obali u razdoblju istraživanja

3. RESULTS AND ANALYSIS / *Rezultati i analiza*

3.1. Shore line for the study area / *Obalna linija područja istraživanja*

The length of the shore line for the study area was approximately 300 m, and the beach line took a north-south direction. The beach line has been raised to a distance of 1200 m north of the study area and 900 m south of the study area in order to study the balance of the shore line. The beach line, in general, was rocky, with a layer of sand uncovered at times. Figure 5 shows the classification of the shoreline for the study area.

3.2. Marine sectors and the contour map of the bottom / *Morski sektori i karta obrisa dna*

It is clear from the bathymetric and contour maps of the project that the marine area of the project is characterized by four main areas as follows: beach berm, beach face, Zurf Zone, and offshore. Below are the main features of the bottom:

1. Beach berm: The level of the beach in the project area varies to an average of 1.80 m above the average sea level, Figure 3.
2. Beach front: The slope of the beach front ranges from 15:1 to 25:1. The beachfront consists of rocks and is considered a relatively sloping slope, Figure 4.

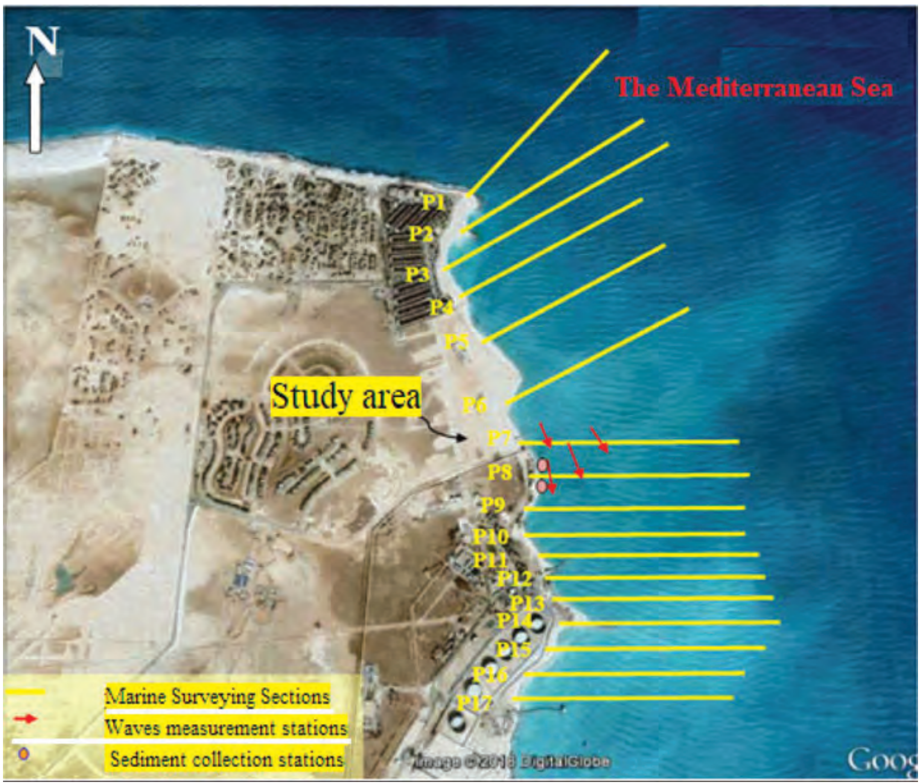


Figure 4 Map of the shore line and the marine area facing the study area
Slika 4. Karta obale i morskog područja pri području istraživanja

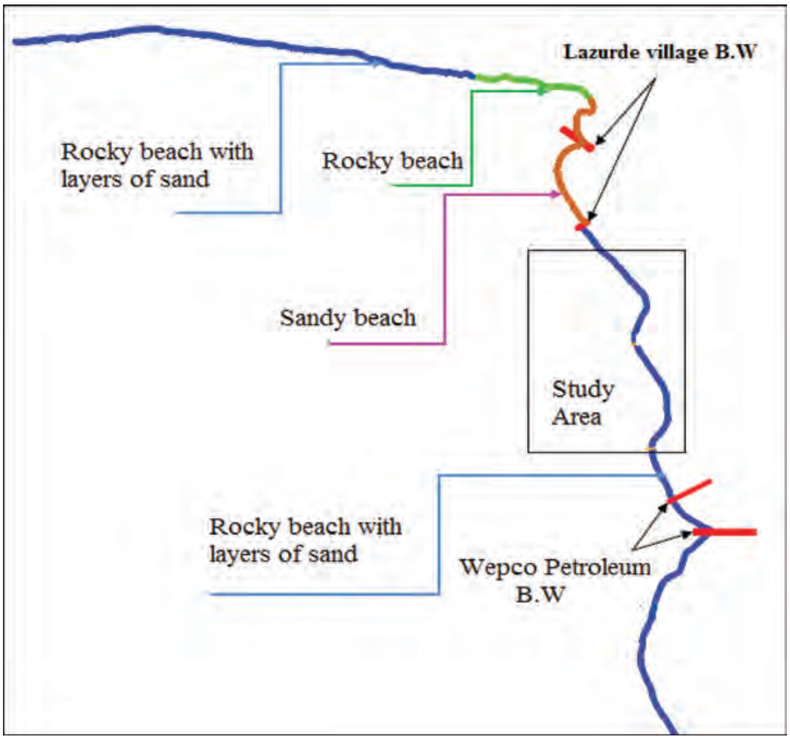


Figure 5 Classification of shoreline for the study area
Slika 5. Klasifikacija obrisa obale u području istraživanja

3. Surf Zone: It is the area where the waves break, reaching an approximate depth of 2 m for the average values of the waves. The width of this area ranges from 40 m to 100 m, and the slope ranges from 20:1 to 45:1, Figure 3. .
4. Offshore area: follows the previous range, where the depth of this area ranges between 2 m to 5 m, and the slope ranges between 1:250 to1:350.

From the above, we find that the bottom of the study area consists of clean white sand on a layer of rocks, and that the beach front tends to slope, and that the width of the fracture area ranges between 40 to 100 m. In general, the slope of the bottom in the area outside the fracture zone has a semi-flat slope with an average of about 1:300.

3.3. Analysis of shoreline changes / *Analiza promjena u obalnoj liniji*

The study of the equilibrium of the shore line is based mainly on the comparison of the location of the shore line to show its behavior over time. To obtain this, the beach line in the study area was drawn based on satellite images for the years 2007, 2009, 2012, 2013, 2016, and 2017, as well as the lift for 2021, as shown in Figure 6.

The shore line changes with time were calculated for 31 sectors covering the study area, with a total length of 1500 m and 50 m intervals in front of the study area. The sectors cover the area between the southern barrier of the village of L'azurde (breakwater No. 2) and the main barrier of the WEPCO Petroleum Company.The precipitation and erosion changes before marine works in the north of the study area in the period from 2007 to 2013 are listed in Table 1 .In the area north of the study area and south of the southern barrier of the village of L'azurde, from sector 1 to sector 15, before the construction of the breakwaters, there was sedimentation at a small rate of about 0.34 m/year. The area in front of the study area, from sector 15 to sector 22, was experiencing erosion at a rate of about 1.62 m/year. The area south of the project, in front of WEPCO's main barrier, from sector 27 to sector 31, had a sedimentation rate of about 8.3 m/year. Sedimentation occurred in sectors 22 to 27, and sedimentation increased near the barrier.

Table 1 Precipitation and erosion changes before marine works in the north of the study area in the period from 2007 to 2013
Tablica 1. Padaline i promjene uslijed erozije prije pomorskih radova na sjevernom dijelu područja istraživanja u razdoblju od 2007. do 2013.

Year	Precipitation (meter/year)		Erosion (meter/year)
	from sector 1 to 15	from sector 27 to 31	from sector 15 to 22
2007	0.33	8.2	-1.63
2008	0.32	8.1	-1.64
2009	0.33	8.2	-1.63
2010	0.34	8.3	-1.62
2011	0.35	8.4	-1.61
2012	0.36	8.5	-1.60
2013	0.35	8.4	-1.61

The erosion was compared in sectors 15 to 22 before and after marine works. It is noted that the erosion values decreased after marine works by about 20%. The preceiptation and erosion changes after marine works in the north of the study area in the period from 2014 to 2021 are listed in Table 2 .The area north of the study area and south of the southern barrier of the village of L'azurde, from sector 1 to sector 15, witnessed erosion at a rate of -3.23 m/year. The area in front of the study area, from sector 15 to sector 22, had erosion at a rate of 1.35 m/year. In the area south of the study area and north of the southern barrier of WEPCO Petroleum Company, from block 27 to block 31, sedimentation occurs at a rate of 1.47 m/year. According to Figure 6, sectors from 22 to 27, it is noticed that after marine works, sedimentation increased significantly due to the presence of the barrier. Figures 7 and 8 show shore line changes from 2007 to 2021.

Table 2 The preceiptation and erosion changes after marine works in the north of the study area in the period from 2014 to 2021
Tablica 2. Padaline i promjene uslijed erozije nakon pomorskih radova na sjevernom dijelu područja istraživanja u razdoblju od 2014. do 2021.

Year	Erosion (meter/year)		Precipitation (meter/year)
	from sector 1 to 15	from sector 15 to 22	from sector 27 to 31
2014	-3.24	-1.36	1.46
2015	-3.25	-1.37	1.45
2016	-3.24	-1.36	1.46
2017	-3.23	-1.35	1.47
2018	-3.22	-1.34	1.48
2019	-3.21	-1.33	1.49
2020	-3.22	-1.34	1.48
2021	-3.21	-1.33	1.49

When comparing the values of sectors from 1 to 10 before and after marine works, sedimentation occurred in the period from 2007 to 2012. As for after the marine works, it is noted that there is a decline in sectors 1 to 15, as is evident from Figure 6 in the period from 2014 to 2021.The reason for the erosion is explained by the reflection of the waves on the barrier, and therefore the reflected waves cause erosion in sectors 1 to 15.

3.4. Changes in sea level / *Promjene razine mora*

The data collected in the region were processed using several specialized programs such as Delft-3D and AutoCAD. Three sectors were chosen from them to represent the shape of the sea bed in the study area, Sector (1), Sector (5), and Sector (17). As shown in Figure (7), where:

a) Sector in the first study area from zero to 1100 m inside the sea.
b) Sector in the middle of the study area from zero to 1600 m inside the sea.
c) Sector at the end of the study area from zero to 1000 m inside the sea, where M.S.L is mean sea level.
   - Marine sectors (horizontal distance with water depth), Figure 7.
   - A contour map with a period of 0.50 m, Figure (8).

Figure 9 shows the characteristics of the tides in the region during 2016 and 2017. The sea level was measured in the Sumid region of the northwest coast. The analysis of the measurements showed that the tide ranged between -0.15 and 0.20 meters. Table 3 shows the tidal variables on the northwest coast. The monthly average sea level on the West Coast is higher in July and August and lower in March, April, and May. The average sea level is 0.00 meters, and the maximum difference in water level is 0.35 meters. Tides create what is known as tidal currents, which is an important factor in determining the entrance to ports and planning navigational passages, in addition to determining the height of some facilities in the port, such as docks and breakwaters, for the study area.

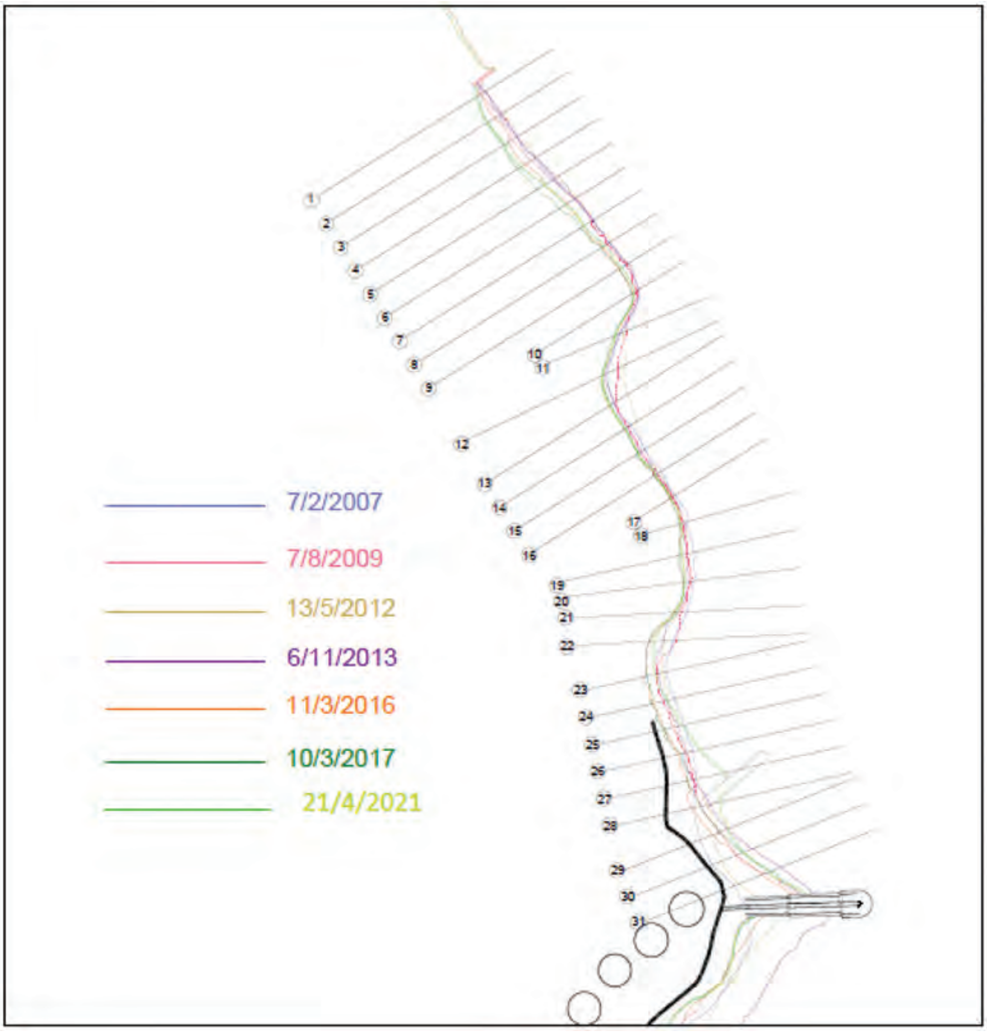
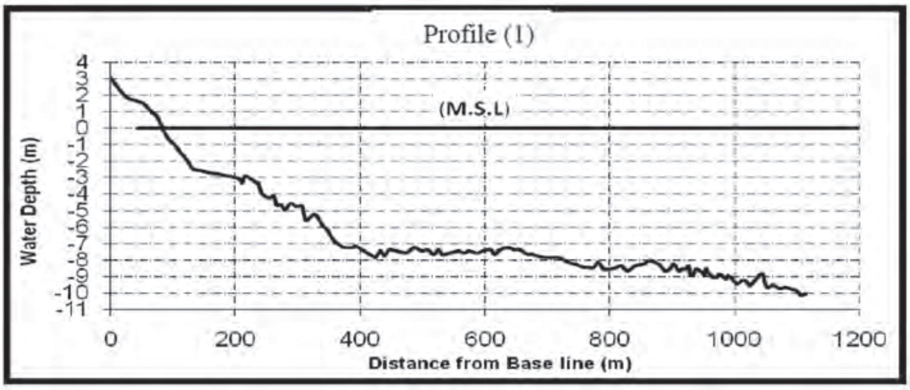
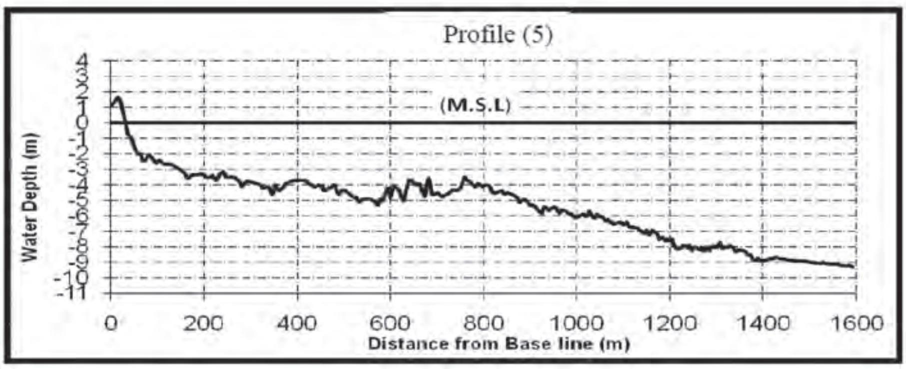


Figure 6 Shore line changes in the period from 2007 to 2021

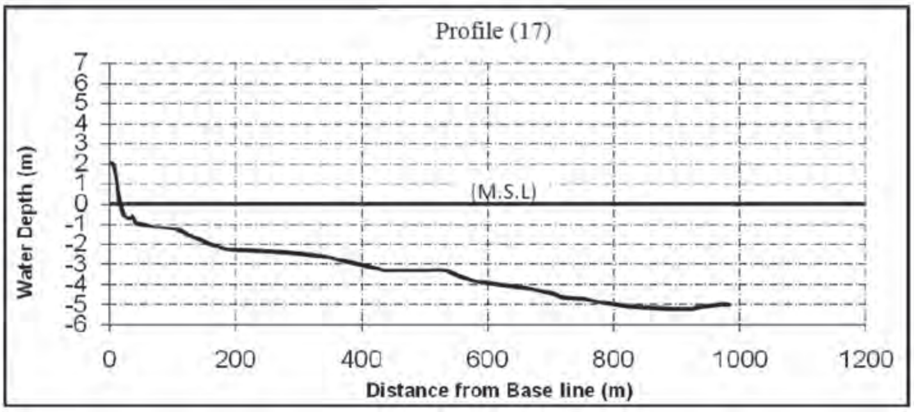
Slika 6. Promjene obrisa obale u razdoblju od 2007. do 2021.



(a)



(b)



(c)

Figure 7 Characteristics and shape of the bottom strip in the study area
Slika 7. Karakteristike i oblik donje trake u području istraživanja

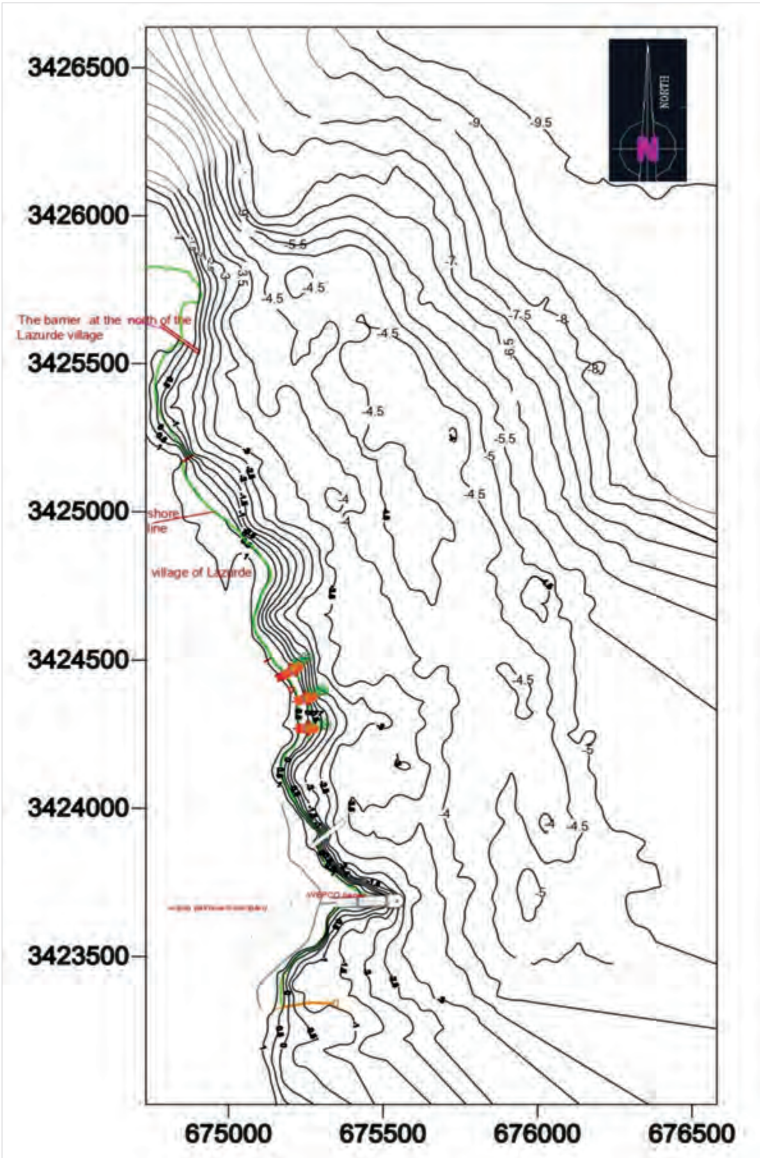


Figure 8 The contour map of the bottom derived from the marine survey sectors
Slika 8. Karta obrisa dna dobivena iz sektora pomorskog istraživanja

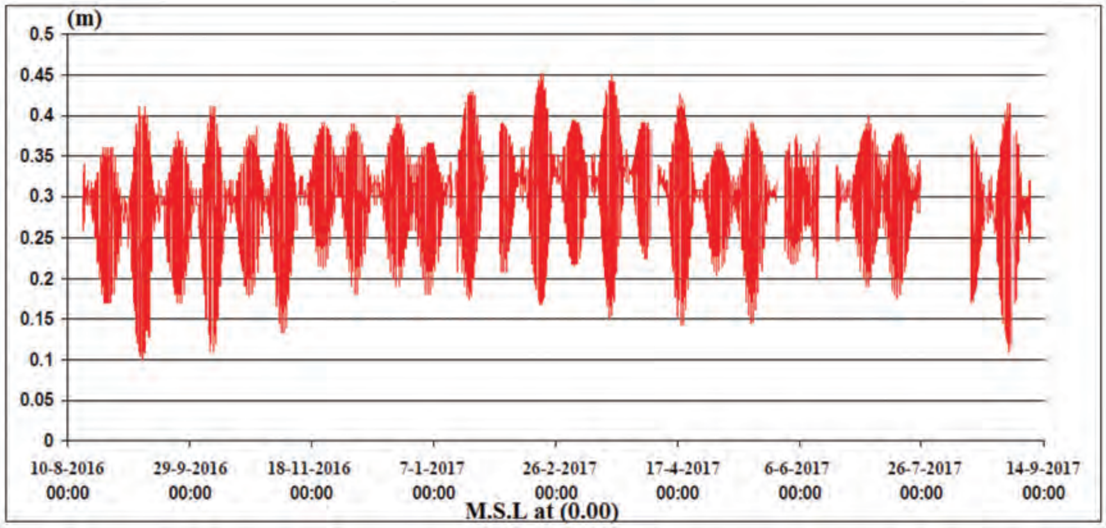


Figure 9 The region tides characteristics during a year (2016/2017)
Slika 9. Karakteristike morskih mijena u području tijekom jedne godine (2016./2017.)

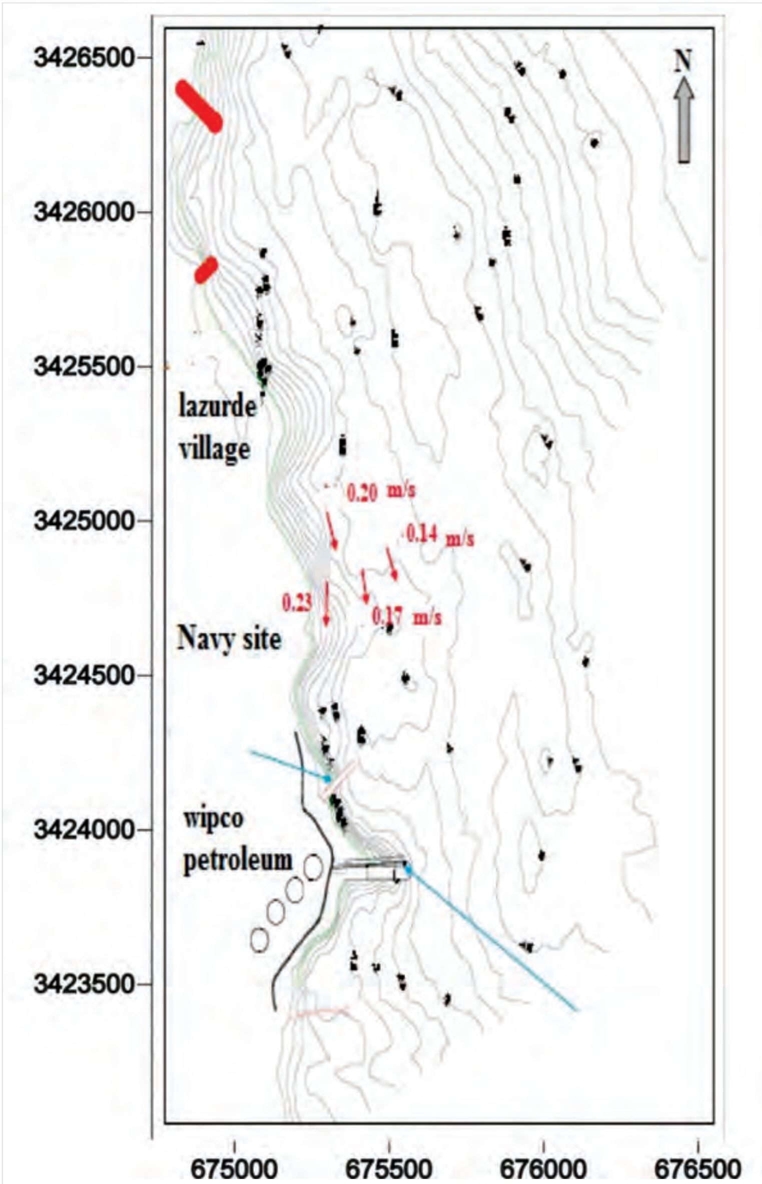


Figure 10 Distribution of coastal currents in front of the study area during field work
Slika 10. Distribucija obalnih struja ispred područja istraživanja tijekom terenskog rada

Table 3 Tidal variables in the northwest coast
Tablica 3. Varijable morskih mijena na sjeverozapadnoj obali

Tidal variables	Water Level (m)
Lowest Astronomical Tide	-0.24
Mean Low water Spring	-0.15
Mean Low Water Neep	-0.09
Mean Sea Level (M.S.L)	0.0
Mean High Water Neep	0.07
Mean High Water Spring	0.20
Highest Astronomical Tide	0.15

3.5. Surface currents / *Površinske struje*

The coastal current generated in the Zurf Zone, which is formed as a result of breaking waves, is the one that influences the movement of water bodies and the transport of sediments. The currents generated outside the fracture zone are generally relatively weak compared to the coastal currents. Therefore, the coastal current in the area was measured to determine its value and prevailing direction. In general, the coastal current heads from west to east as the direction of the waves prevails from the northwest.

The coastal current was measured in medium wave conditions, where the waves were 1.00 m high, with a frequency of 6 seconds, and directed from the northwest. Figure 10 shows the general form of the distribution of areas in the study area. The most important results obtained can be summarized in several points as follows: The coastal current's speed ranges between 0.14 m/s and 0.23 m/s and takes a direction of south-southeast.

3.6. Sediments / *Sedimenti*

Two samples of bottom sediments were collected in the marine area in front of the study area to know the properties of the bottom components for the coastal area and the seabed (Figure 11). The mechanical analysis of the bottom sediments showed that the mean grain diameter ranged between 0.27 and 0.52 mm for the study area. Figure 12 shows sedimentation in front of the northern barrier. Figure 12 illustrates the sedimentation south of the northern barrier head of the village of Lazurde.

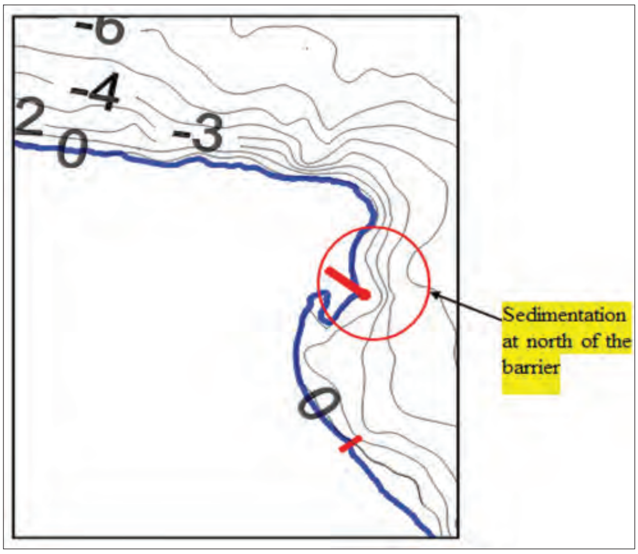


Figure 11 Sedimentation in front of the northern barrier
Slika 11. Sedimentacija ispred sjeverne barijere

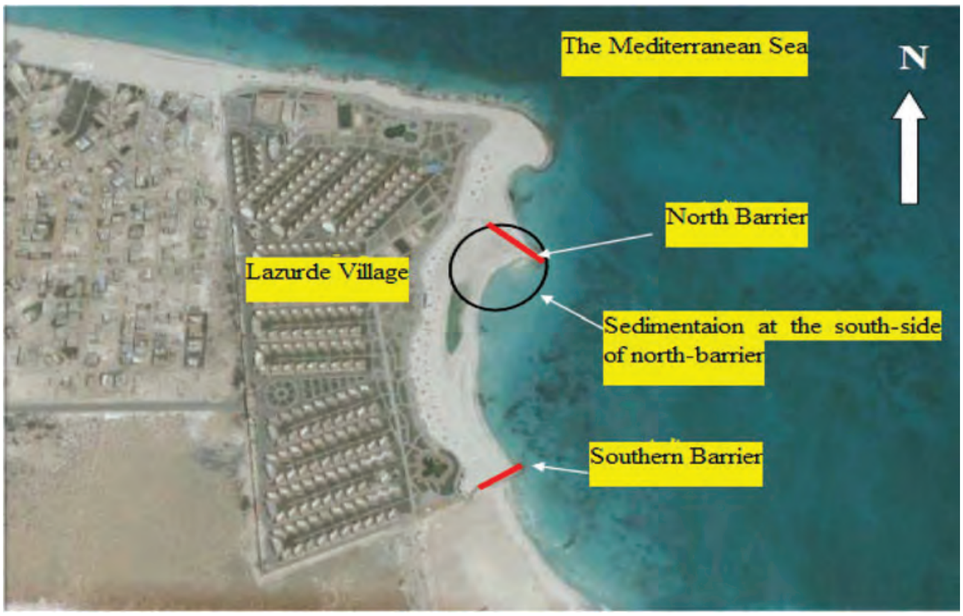


Figure 12 The sedimentation south of the northern barrier head of the village of Lazurde
Slika 12. Sedimentacija južno od sjeverne barijere ispred mjesta Lazurde

3.7. Wind energy change / *Promjene snage vjetra*

The prevailing natural system of winds along the Mediterranean coast of Egypt is controlled by different weather conditions that occur mainly on a monthly basis. The main characteristics of wind, such as speed and direction, can be obtained from scientific publications and specialized meteorological sites worldwide. The wind speed data was analyzed to calculate the incidence of each wind speed and direction of movement and from the analysis of the data of the different wind directions, the wind rose was drawn in the region during the different months as shown in Figure 13.

During the winter season, which is the period from December to March, a semi-permanent low-pressure area known as the Cyprus Depression is formed, usually located in the eastern Mediterranean. This is a region of low pressure arising in part due to topographic features and due to stagnation in the eastern Mediterranean and winter low-pressure areas that move eastward across the Mediterranean as shown in Figure 13 Winds blow in the winter from the southwest and northwest. The average wind speed ranges from 11 to 16 knots, and during the storm, it ranges from 20 to 30 knots. The maximum wind speed is 54 knots during the winter months.

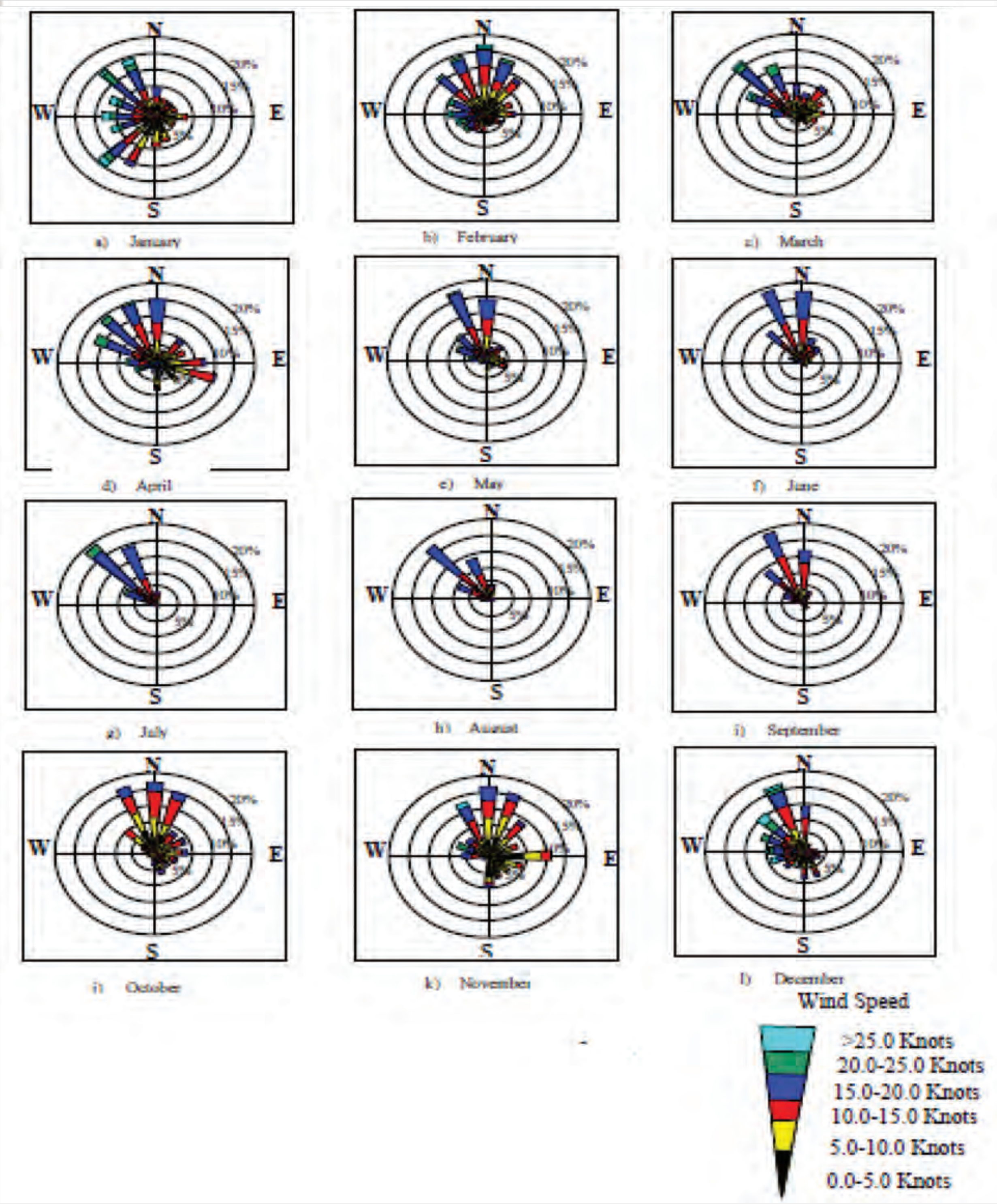


Figure 13 Monthly wind rose in the northwest coast

Slika 13. Mjesečna ruža vjetrova na sjeverozapadnoj obali

3.8. The waves / *Valovi*

Waves are responsible for generating currents in areas of the North Sea area of traffic. Well, knowing the characteristics of the waves in the area in which the inshore zone appears. Waves are generated from communication waves. The wave climate is in the Mediterranean and is widely associated with pressure regimes beyond the Mediterranean limits. The waves were measured using a wave meter, which was installed in front of the northwest coast at a depth of approximately 10.5 m. During the winter period, during the period of gradation, during the period of gradation, during the period of about 3 to 4 days. Figure 14 shows the shape of the wave that rose on the western coast during the winter season.

Waves of more than 2 m have an area of 9.7% on the west coast and waves that come from a northwest direction have an area of 70% m. The average wavelength is 34.5 m and the maximum wavelength is 104.9 m.

During the summer from May to October, the surface winds blow over the eastern part of the Mediterranean, generating long waves that come mainly from the northwest and north directions. figure 15 shows the wave rose on the west coast during the summer, where in the summer the percentage of waves on the west coast that are more than 2 metres (1.8%). The average wavelength is 33.1 m, and the maximum wavelength is 58.1 m.

The spring and autumn are limited wave periods. May and October are the quietest in the year, but during the spring and autumn the weather is less severe, while in the spring, the percentage of waves with a height of more than 2 metres is 6.2% per hour in the west, and the waves that come from the average length The wavelength is 31.6 m, and the average wavelength is 56 m. In the autumn, the percentage of waves on the west coast with a height of more than 2 metres is 5.3%, and waves that come from the northwest are 69%. In autumn, the average periodic time of the wave is 4.4 seconds and the maximum time is 6.4 seconds. The average wavelength is 30.2 m and the maximum wavelength is 63.9%.

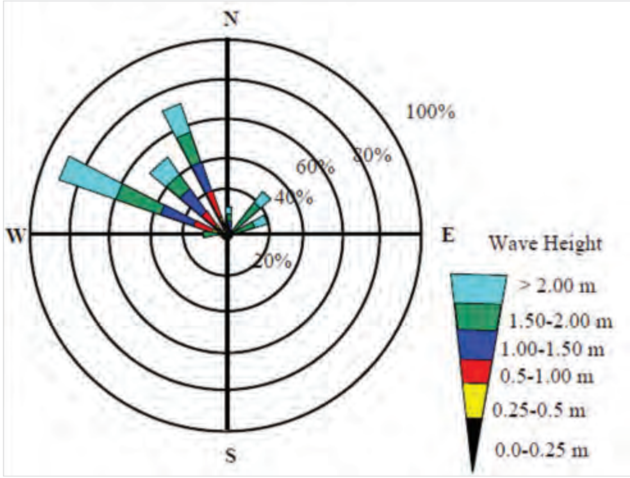


Figure 14 Distribution of the waves rose in the northwest coast during the winter period

Slika 14. Distribucija ruže valova na sjeverozapadnoj obali tijekom zimskog perioda

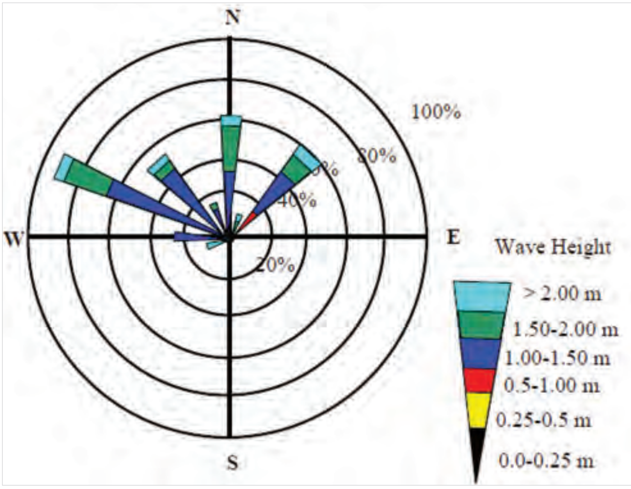


Figure 15 Distribution of the waves rose in the northwest coast during the summer period

Slika 15. Distribucija ruže valova na sjeverozapadnoj obali tijekom ljetnog perioda

3.9. Numerical model Analysis / *Analiza numeričkog modela*

The LitPack-Mike21 model was used, which is a one-dimensional model and is widely used in coastal engineering [38-39]. The main inputs of the model are the shore line, marine sectors, wave characteristics, wind characteristics, tides and tides in the study area. The model outputs are changes in the future shore line and the rate of sediment movement in the study area. Distances are measured by entering the shore line and marine sectors of the model, and by choosing distances every 200 m, the axes are drawn.The distribution of the ocean currents was deduced under the influence of the waves that were during the measurement of the ocean currents in the study area, as shown in Figures 16 and 17 shows that the deduced currents approximate the measured currents. The shore line for 2017 was also derived using the shore line for 2016 and the actual was compared with the conclusion. Figure (18) shows the difference between the shoreline deduced from the mathematical model and the actual occurrence in nature. We find that the shore line has the same behavior of erosion and sedimentation with time, and that the difference is small between the inferred and the actual. And that the standard deviation of the 2017 beach line is 2.3 m, with an error rate of 16%, which is a very good result for one-dimensional mathematical models. These values are considered good and acceptable values and give us confidence in the accuracy of the inferred shore line in the future. The waves come from the north-northwest direction, with a height of 1.00 meters, diagonally at the shore line, so the waves break and are reflected inside the sea towards the northeast, sweeping along with the sand dunes of the shore line, and erosion occurs.The tides affect the rate of sediment movement after the construction of barriers, and it ranges from 20,000 to 60,000 cubic meters per year. It is also close to the amounts of sand that are dredged north of the barrier of WEPCO Petroleum Company, where the sediments move in the study area to the south. This direction of the movement of the sediments is compatible with the movement of the measured currents. The wind is a major cause of the waves, and as the waves head from the north and northwest to the south in the study area and the height of the waves was about 1.00 meters, the waves over time drag the sand towards the south towards the breakwater, so erosion occurs in the study area and sedimentation in front of the breakwater.These results prove that it gives confidence in the results of the used modeling and show that numerical modeling can study similar cases to that study. The shore line change in the study area was predicted in the period from 2021 to 2024 as shown in Figure 19. From predication model it was found that by the year 2024, the shore line will reach to the end of the breakwater within the sea, with a rate of about 90%. The groins are sea capes that represent a breakwater, and in the model they represent the present and the future its lengths were calculated from the results of the study of mathematical models. In Figure 18, a comparison between two actual and fixed beach lines for the implemented barriers (in yellow, offshore heads) as a calibration method for the program. In Figure 19, the numerical model was used to deduce the changes of the shore line after adding marine facilities (in red, marine heads) in the future. The area was divided into a horizontal axis that represents the shore line and a vertical axis on it that represents the depth of the barrier inside the sea (groins in yellow), and the beginning of the horizontal axis is the direction of the north. The groins (in red) were proposed in the future to maintain the balance of the beach line and the proposed depth based on the future change of the beach line. The currents and movement of sediments in the study area are from north to south, and since there are vertical marine protection installations on the shore line (groins) before and after the study area, the most likely solution is to establish a sea head in the study area at the end of the protruding part into the sea where this barrier will stop the movement of sediments in front of the study area until it is filled, and thus it will advance the progress of the beach line. While the groins behind it at WEPCO port, they will work to protect the area behind it from slaughter.

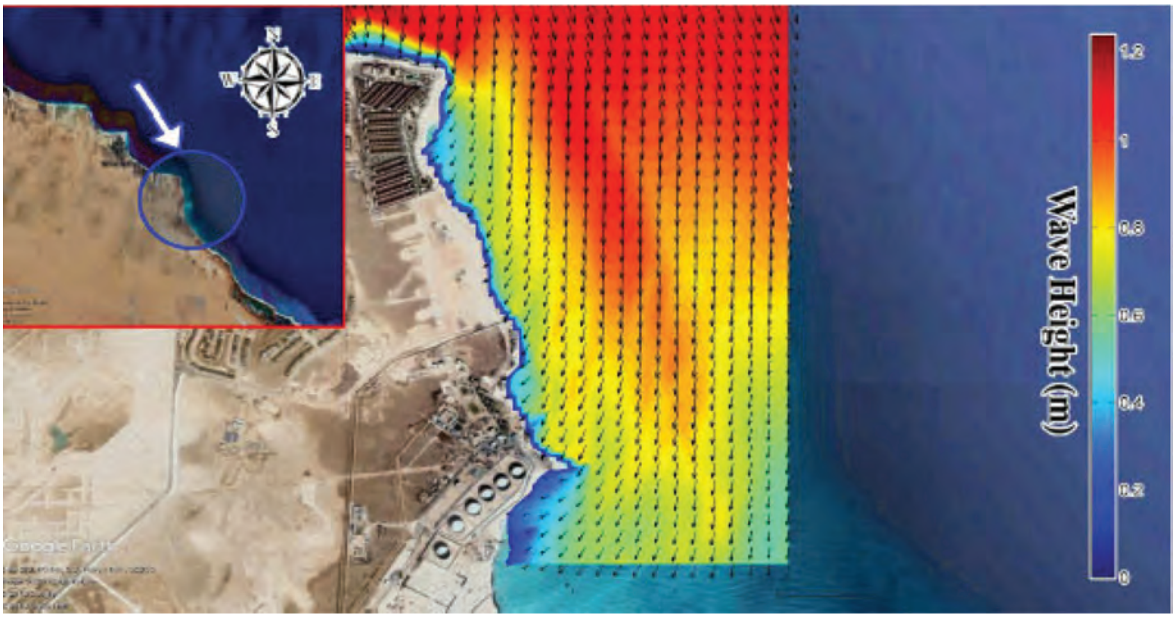


Figure 16 The calibration state is a wave with wave height =1 m and wave period= 6 seconds
Slika 16. Kalibracija prema valu s visinom vala = 1 m i periodu vala = 6 sekundi

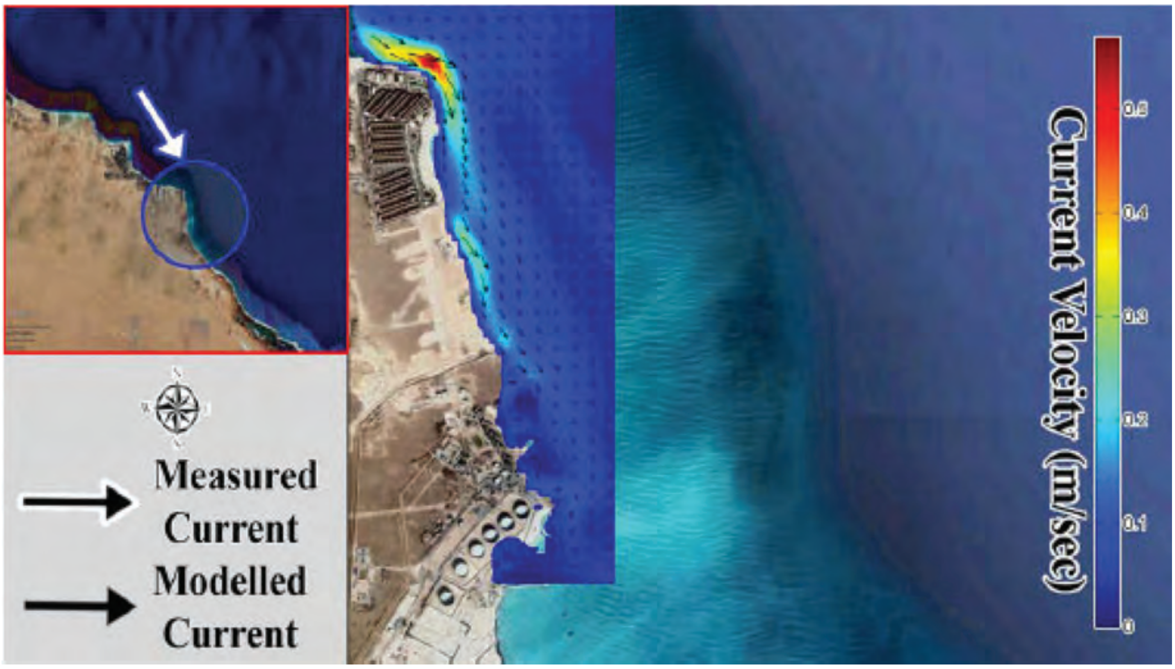


Figure 17 Calibration status for measuring currents in the study area
Slika 17. Kalibracija za mjerenje struja u području istraživanja

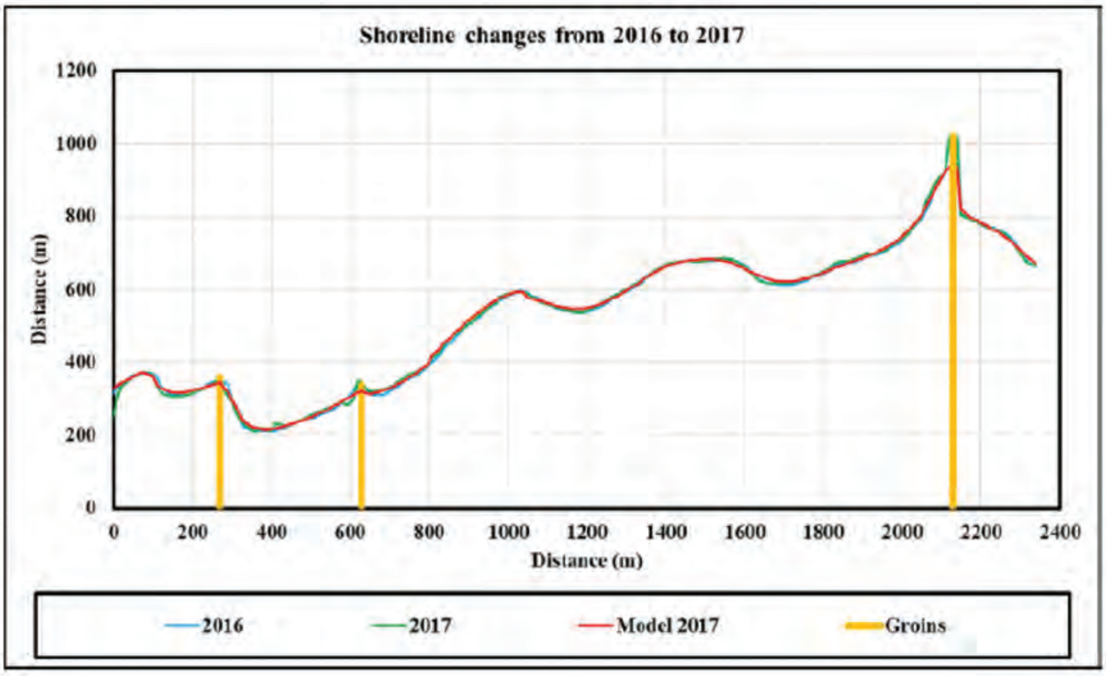


Figure 18 The results of model calibration between 2016 and 2017
Slika 18. Rezultati kalibracije modela između 2016. i 2017.

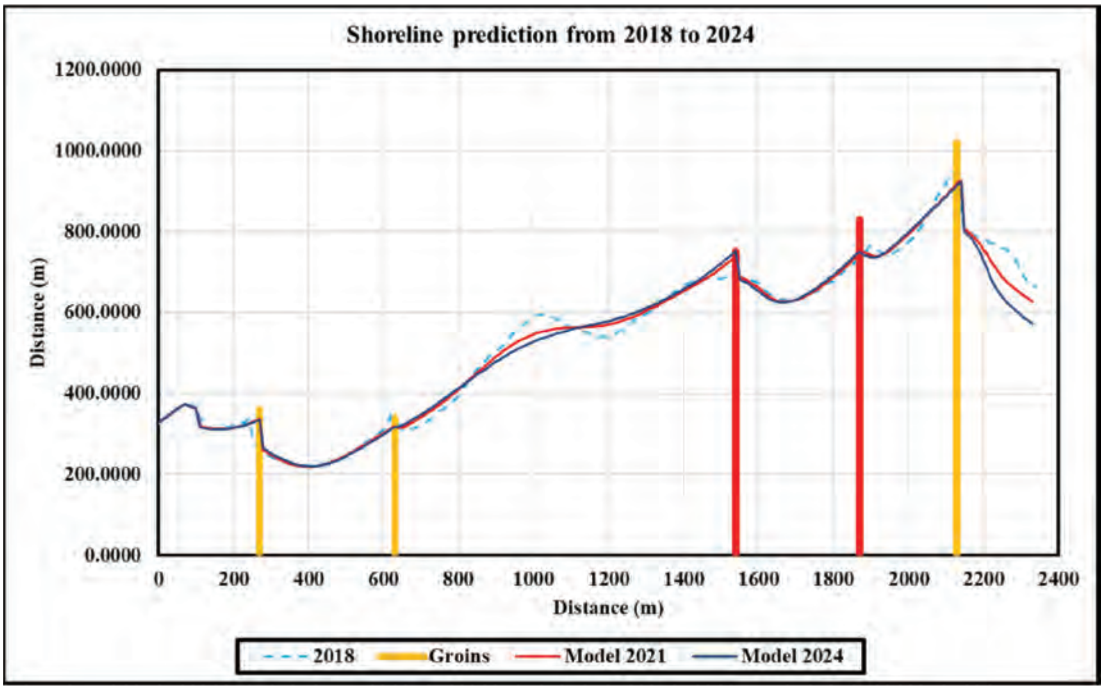


Figure 19 Prediction of shoreline change in the period from 2021 to 2024
Slika 19. Predviđanje promjena obrisa obale u razdoblju od 2021. do 2024.

4. CONCLUSIONS / *Zaključci*

This study investigated the shoreline change in Sidi Abdel Rahman Coast Area, Egypt using multi-temporal satellite images (Google Earth) and ground measurement data (wave, wind, and precipitation). Also in this study, the shoreline change was modelled using LitPack-Mike21 model. Moreover, the shoreline change was predicted in the period from 2021 to 2024.

Summary of the impact of marine works in the north of the study area:

The first vertical barrier of the village of L'azurde in the north of the Gulf had sediments impounded to the north between it and the rocky head, and the shore line advanced to a large extent, the northern area was filled with sand (up drift), and the beach line reached a distance of 35 m from the head of the barrier, so the (surf zone) area crossed the first barrier. Therefore, sand bypassing occurs moving north to south of the barrier, since the area is in the form of a bay and the prevailing waves coming from the northwest and northwest come at an external angle from the direction of the barrier. The energy of the waves is greatly reduced behind it, so deposition occurs at the south of the barrier head. The formation of a sedimentation zone adjacent to it to the south begins as a result of the waves being dispersed and weak to a large extent behind it. Then, these sediments move through the bay to the south; part of them helps to balance the shore line in the bay, and the other part moves south.

The removal of sand hills (Sand Dunes) at the beach of Badland village caused erosion in the study area (the Naval Forces area), where these hills were used to hunt sand, and then the winds transported it and fed the navy beach.

The coastal area south of the second barrier, erosion occurred when the construction of the sea barriers began, but as a result of the beach line reaching the end of the second barrier, most of the sediments moved to the south of the barrier, which caused the current rates of erosion to be low.

Aside from its effects on the local level, the current study has the potential to advance knowledge about studies of shoreline change at the local, national, and worldwide levels. This study can be used for managing beach erosion and coastal dynamics in the study area and similar areas.

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