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Influence of Coastal Measures on Shoreline Kinematics Along Damietta coast Using Geospatial Tools

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Abstract. The shoreline trajectory of Damietta city, located at the Northern coast of Egypt, is dramatically subjected to significant kinematic changes. Several types of coastal measures have been applied substantially along the coastal stretch of Damietta to protect shoreline (detached breakwaters, Jetties, groins, and seawalls). This study focuses in the assessment of shoreline kinematics response due to the existence of these structures during the period from 1990 to 2015 using satellite images and geo-spatial tools. Three semi-automatic extraction techniques are initially tempted for Landsat ETM 2003 imagery namely; Iso cluster technique, threshold method, and onscreen digitizing. The shoreline variation measurement of is described for three sectors based on the allocation of the coastal measures:(1) the western sector encompassing Damietta port with two jetties; (2) the central sector including detached breakwaters; (3) the eastern portion of Damietta estuary passing through a seawall. The results show that, the shoreline has progressed by +10.0 m/year rate west of Damietta port. Behind the detached breakwaters, the shoreline has advanced by +12.0 m/year from 1999 to 2003 and then has decreased gradually to be near the stable state in 2015. The highly eroded by average rate of -78 m/year appeared at end of eastern seawall.

1. Introduction

The Nile Delta is one of the earliest Delta formed in the world. It extends about 240km from west of port said to east of Alexandria at Egyptian northern coast. Rosetta and Damietta promontories and three lagoons, are the most notable topographic features distinction the Nile Delta,. These range from west Idku, Burullus, and Manzala lagoons, taking a large percentage of delta surface area,[1].

Prior to AHD (Aswan High Dam) construction, 100–115 million m^3/y of sediment were discharged into the Mediterranean,[2] and forms headlands into both Damietta and Rosetta promontories and the intervening embayment beaches. The coastline at Damietta branch progressed offshore by 3.0 km between year 1800 and year 1900,[3].

Shoreline is one of the fast varying coastal landforms,[4]. Researcher largely depending on accurate and up-to-date shoreline change information magnitudes in most of coastal studies such as the aspect of accretion-erosion, design of coastal protection structure, shoreline prediction, hazard zoning, environment defense, safe ship navigation, and sustainable resources management at coastal zones,[5].

Breakwaters are defense structures constructed to protect the coastal areas or to safe an anchorage from both longshore drift and weather effects. Breakwaters decrease the wave action strength in shallow waters and therefore reduce coastal erosion or provide highly safe harborage. Groins, seawalls, and detached breakwaters were uses along Damietta coast to protect it from erosion.

Shoreline changes were detected and mapped by several approaches. The usual field surveys accomplish high-accuracy measurements but are time consuming and labor intensive, in addition of highly cost, [6]. High-resolution aerial photographs contain many details of topography features, and coastline scan be delineated and spotted with high precision, however, periodic over flights and aerial photograph analyses imply a high cost for updating coastlines, [7]. The Satellite images multispectral nature and repetitive coverage is the most suitable method for digitizing and updating the changes of the shorelines at uniform intervals accurately and cost-effectively , [8]. Over recent decades, Satellite images have become increasingly important in detection and mapping of shorelines, especially because digital images from remote sensing satellites are provided in infrared spectral bands where the water-land interface is well defined. Furthermore, remote sensing information can be integrated with Geographical Information Systems (GIS) as a helpful tool for analyzing and extracting more reliable and consistent information by using satellite imagery as a base data, [4].

In many previous research works, the effect of coastal protection structure have been investigated through both numerical simulation and experimental models, [9]. The performance effect and efficiency of each type has been investigated. In this research, the effect of different types of breakwaters shoreline changes was investigated using Remote Sensing, GIS technique and then compare erosion rates with those collected from previous studies. The considered systems are groins, detached breakwaters, seawalls, submerged breakwaters and shore-connected breakwaters.

Damietta is one of the most important areas for observation beach erosion, since it is used for various activities as transportation, agriculture, fishing and commercial activities represented in Damietta port. The siltation inside the inlet is a huge environmental problem, and the continuous erosion that began after the construction of the Aswan High Dam.

2. Study Area

Damietta coast, 25km length, located at estuary of Damietta branch lies on the north-eastern Nile River delta coast is the study area of the present research. The total length in this study extend from 3.0km western of Damietta port, (13.0km from Damietta promontory) to 12.0 km east of promontory. The shoreline located between E31^0 43' 36" to E31^0 58'(Figure 1).

Ras El Bar resort town, located 145km to the east of Rosetta promontory and immediately to the west of the Damietta entrance, has suffered erosion and shoreline retreat resulting in the loss of buildings and streets. erosion has also adversely impacted recreational resort beaches. The average retreat of this area was about 30 m/year before the construction of the western jetty in 1941, [10]. Erosion continued west of the jetty, so 400 m long seawall was added in 1965. These structures were also experienced to erosion. For this reason, their bases were protected recently by rip-rap and dolos. As erosion still takes place to the west, three groins were built in 1972, [11], directly at the end of the seawall. In 1980, a 350m long rip-rap seawall protection was installed to stop the continued erosion between the three groins. Erosion hits the coastline along the beaches to the west. The recommendations of Delft hydraulics in year 1987, studied the construction of eight offshore detached breakwaters and add the nourishment process to accelerate the process of accretion composing the salient, [9]. A second small jetty was constructed on the eastern side of the Damietta Estuary entrance in 1976 to reduce siltation in the outlet. Two short breakwaters were constructed in 1980 on both sides of the navigation channel at the new Damietta Port Channel which extends in the sea to 15 m contour.

In 1972 a vertical concrete wall with length 1,500 m was installed to protect the coastal road located in the eastern part of the Damietta Promontory. However, erosion continued and the road was damaged and is no longer passable. The erosion continued and threatened the lighthouse which was then protected by an earthen embankment in 1991. This protection was also ineffective against the extreme erosion pressures, and the lighthouse has now been abandoned and replaced by one farther inland, [10]. Fig. (1) shows the study area.

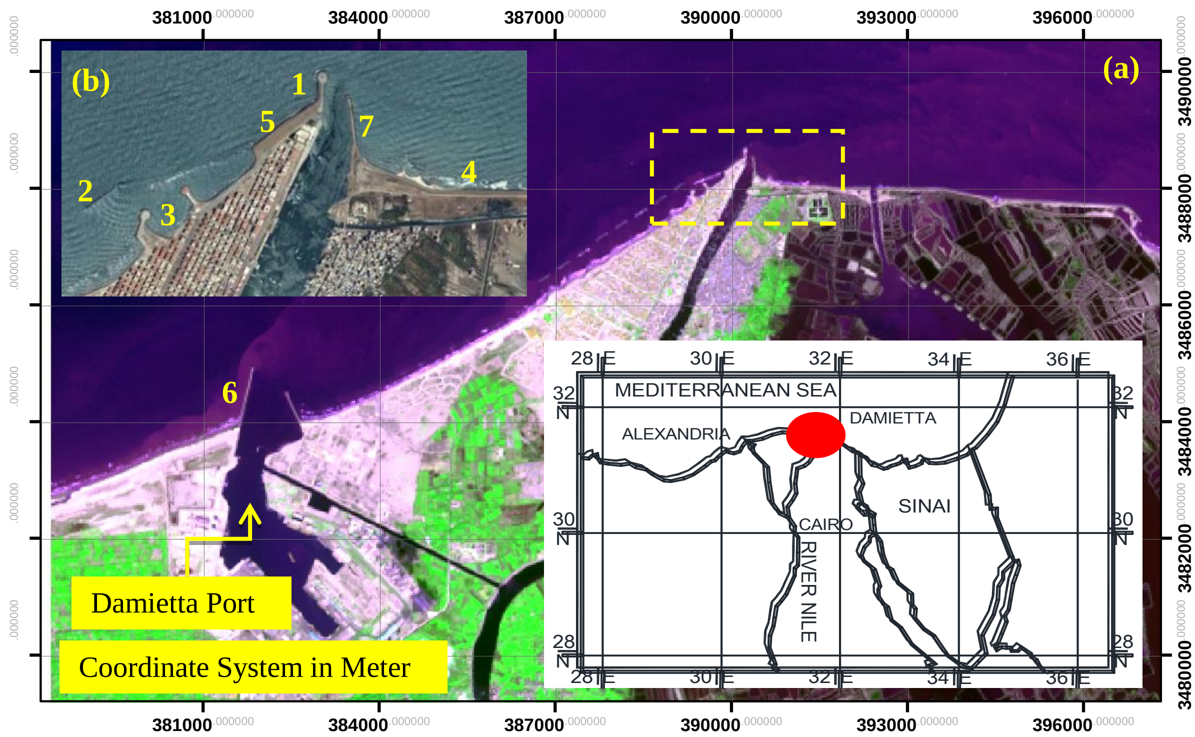

Figure 1. Damietta Promontory Area at the Terminal of Damietta Branch (SPOTimage, 2015);(a)Satellite Image 2015, (b) Google Earth Image, 2017), (1) western jetty of Damietta branch entrance, (2) detached breakwaters, (3) three groins in 1972 and Ras El-Bar now, (4) eastern seawall, (5) rip rap and dolos seawall, (6) Damietta port breakwaters, and (7) eastern jetty of Damietta branch entrance.

3. Study Material and Methods

3.1. Satellite Images

There are four images were acquired for different periods 1990, 1999, 2003 and 2015 for total period of 28 years. All images were selected to be in high quality and the cloud is less than 10% effective and of 30m spatial resolution. They are downloaded in GeoTIFF format at no cost from the US Geological Survey (USGS) Earth Explorer Website (http://www.earthexplorer.usgs.gov). These Landsat data constitute the largest useable database of medium- resolution images that was available, [4]. There are two images 1999, and 1999 from Landsat-1 Multispectral Scanner (MSS), Landsat-5 Thematic Mapper (TM) and other two images 2003, and 2015 were acquired from Enhanced Thematic Mapper Plus (ETM+). The software ENVI v4.8 and ARC GIS v10.1 were used in processing using all mentioned images for extracting shoreline. Table 1 illustrates all images information.

Table 1. Details of the satellite images used.

Acquired Date	SpaceraftID/Sensor	Path/Row	Pixel Size (m)	Coordinate System/Datum	Zone
Aug04, 1990	Landsat_5/TM	176/38	30	UTM/WG84	36
Sep 06, 1999	Landsat_7/TM	176/38	30	UTM/WG84	36
Feb 05, 2003	Landsat_7/ETM	176/38	30	UTM/WG84	36
Nov 29, 2015	Landsat_8/ETM	176/38	30	UTM/WG84	36

3.2. Image Processing

Figure 2 illustrates the pre-processing and post processing operations in this study. Images pre-processing is an operation to prepare images to be more convenient purpose of the study. All images must be checked and corrected before extracting shoreline. Firstly, all images were selected without any stripping defects and were stacked and clipped to the study area, then geometric and radiometric corrections were conducted. Radiometric correction is very important to reduce the atmospheric effects. Landsat satellite sensor type, Sun elevation and data acquisition (Day, month and year for every image) were used in radiance type technique to conduct the radiometric correction.

All images were subjected to Geo-reference process to the World Geodetic System (WGS84) datum and the Universal Transverse Mercator (UTM) projection system. Geometric correction interpretation based on the digital Satellite map as a base map to Landsat image in 2015[12].

For images post-processing, Remote Sensing and GIS technologies have been used for mapping shoreline and for monitoring the coastal processes. In the present study, the accretion and erosion rates and eroded/accreted regions are noticeable in the multi-temporal satellite data (i.e. coastline). GIS thematic layer was built where erosion and accretion rates were calculated. Simply, a transformation of GIS polyline into polygon was carried out to isolate areas of accretion and erosion [13].

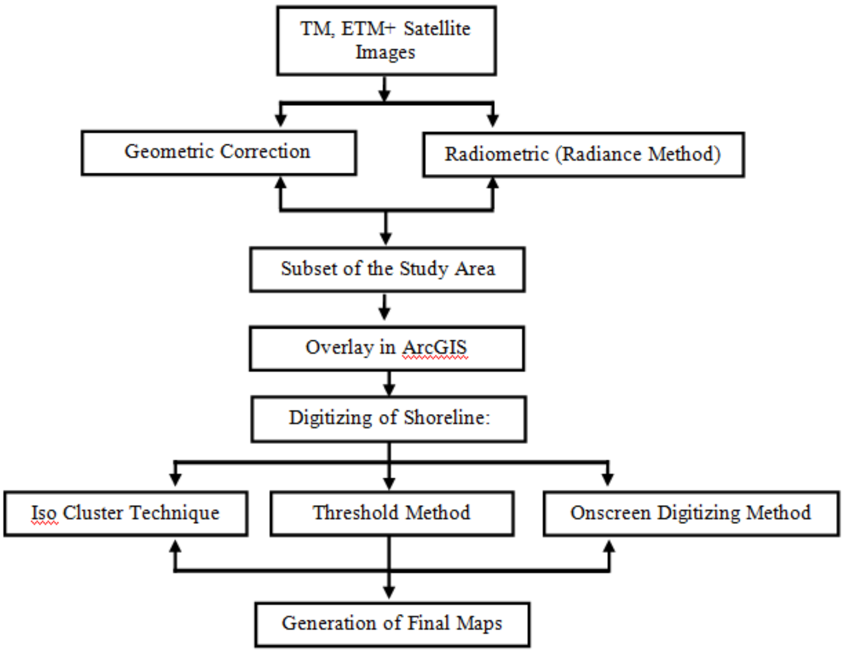

Figure 2. Flow-chart diagram showing the image processing steps applied in the study

3.3. Shoreline Extraction

Three methods were used to extract the studied zone shoreline, Iso cluster technique, threshold method, and onscreen digitizing method. The first and second one are automated shoreline extraction methods that have been developed using ArcGIS 10.1 software from geometrically rectified single band satellite images.

Near-infrared (NIR) wavelengths, water unclouded dark in the image because of its powerful absorbance and exposed soil areas or mainly vegetation that appear brighter because of their strong reflectance, [14]. According to this concept, shoreline can be delineated from a single band image, since the reflectance of water is approximately equal to zero in the reflective infrared bands. This can be completed through measuring histogram threshold for one of the infrared TM or ETM+ bands. According to the histogram threshold technique, water areas can be separated from other land covers and coastline is consequently extracted from Band 5 (mid-infrared) in TM and ETM+ images, [15].

Iso cluster technique is one of unsupervised classification methods which employed a modified iterative optimization clustering processes, also known as the departing means technique. The algorithm disconnect all cells into the specified number of featured unimodal groups in the multidimensional space of the input bands. Two main steps are used to execute this method, firstly is generate clusters, secondly is classify to clusters, [16].

Onscreen digitizing method is considered as one of the most common tools that used specifically for shoreline demarcation, [17], as it provides a highly precision resolution approaches up to 5.0 m. Therewith, this technique depends mainly on the manual tracing of the land-water boundary line in the saturated zone via selecting a path from the Google Earth tool bar. Where, the high-visibility vision of the saturated zone limitation enables the path to be easily traced over the sinuosity of the coastline with the least possible errors.

4. Results and Discussion

4.1. Shoreline Extraction Verification

The shoreline was digitized by the above mentioned three different methods. The results obtained are validated by comparing the data on shoreline change available in situ measurements in year 2003, which indicated a good correlation, (Figure 3).

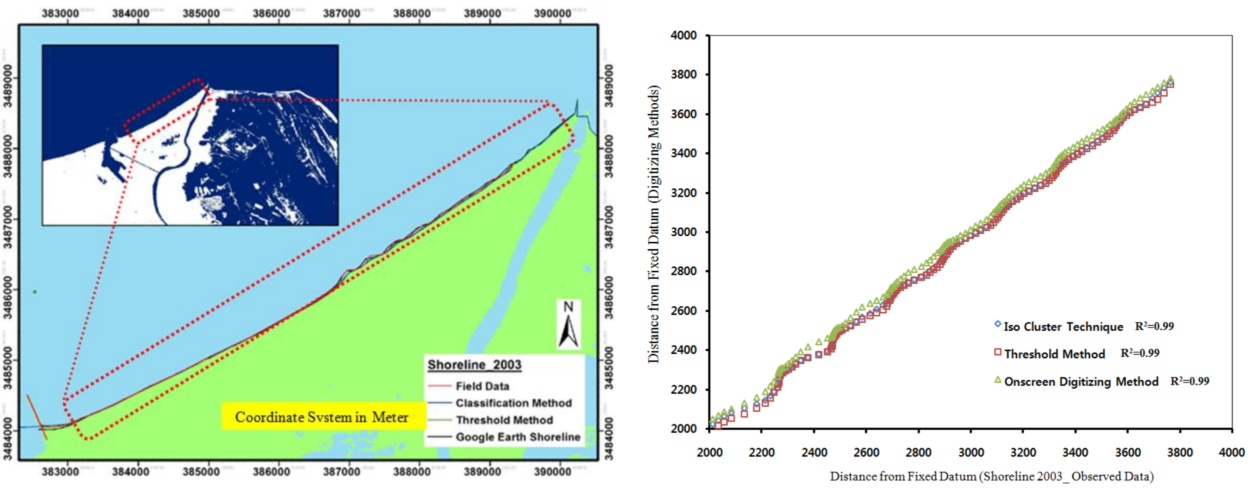

Figure 3. Shoreline in 2003; Field data, Iso Cluster, threshold and Onscreen Digitizing method.

4.2. Comparative Study

For the three suggested classification techniques, it was found that the extracted shorelines have the same trend. From statistical point of view, It is confirmed by the meaning of Coefficient of determination (R^2) which have almost the same value of 0.99 for each technique. Consequently, (RMSE) is precisely selected to assign the optimal one. The obtained (RMSE) values are calculated and presented in Table 2. Accordingly, Iso cluster technique has statistically the superiority of shoreline delineation and attempt to evaluate the transient effect of protection works on the morphology of the shoreline in the study areas.

Table 2. RMSE Values for Every Method.

Digitizing method	Iso Cluster Technique	Threshold Method	Onscreen Digitizing Method
RMSE	22.20	29.50	26.42

Extraction of Damietta shoreline depends on some parameters as; waves, current, grain size, beach slope and beach layout. The shoreline changes are the main indicator for the efficiency of protection works, so digitizing of shoreline at Damietta coast was carried out using spatial tools at four different years 1990, 1999, 2003, and 2015 covered 28 years. Four types of protection works were constructed at Damietta coast; Port breakwaters, seawalls, detached breakwaters and two groins manufactured Ras El Bar bayas shown in Fig. 1, and the results are explained as following:

4.3. Damietta Port Breakwaters

In 1980, two breakwaters were constructed to protect navigation channel for Damietta port. The west one is 1500m length and east one is 800m length as shown in Figure 4. The effect of the two breakwaters are strongly apparent in accretion at west side of port and erosion at other side in all years. The period from 1990to 1999, the effect of Damietta port breakwaters appears in shorelines behavior, accretion occurs western the port by 14.0 m/year, and erosion process occurs at the eastern part of the port by a rate of 10.0 m/year (Figure 4). The accretion still advanced by the same rates to year 2015 but the erosion rate was decreased to be 5.0 m/year. The shoreline changes in west and east of the port represents the dangerous to both port navigation channel and the land east the port.

4.4. Detached Breakwaters front of Ras El Bar Resort

Eight detached breakwaters 200m in length with 200m spaces between each of them were constructed through the period from 1986 to 2000, (Figure 5). The main function of these breakwaters is to protect Ras El-Bar sea resort.The period from 1990 to 1999, the erosion extended from the port east to the area behind the detached breakwater which has been constructed before this period, this part of shoreline had advanced by rate 12.0 m/year.

Thereafter, the pattern of shoreline from year 1999 to year 2003 almost continued in accretion but with lower rates of 6.0 m/year. The changes in shoreline behind detached breakwaters reached to stable state within the period 2003-2015.

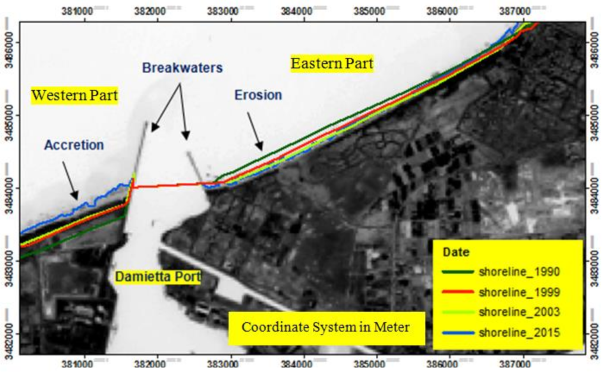

Figure 4. Satallite Image (Landsat_8/ETM); Shoreline at Damietta Port; 1990,1999,2003, and 2015.

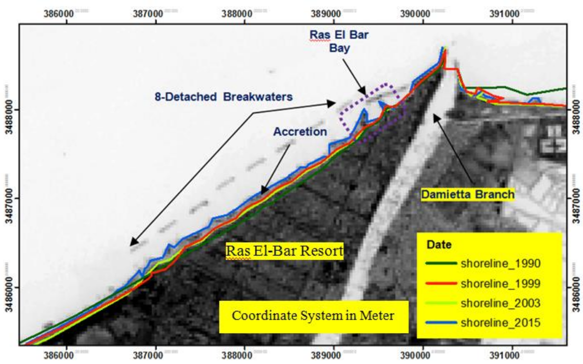

Figure 5. Satellite Image (Landsat_8/ETM); Shoreline at Ras El Bar Resort; 1990,1999,2003, and 2015.

4.5. Seawall Front of Ezbet El Borg

The erosion at east side of Damietta Promontory started after constructed of Aswan High Dam and continued until constructed of 6.50km seawall directly eastern of the Damietta estuary at year 2000, (Figure 6). The erosion rates reached to 60 m/year in period between 1990 to 1999, and then the seawall was successful in stopping this erosion however only in its location. The erosion was shifted to lee side of seawall and shoreline still moved onshore but at higher rates reached to 78m/year. The erosion reached to the old coastal road as shown in Figure 7, that shows the importance of protection works at this area.

4.6. Verification with Previous Studies

In comparison with different remote sensing techniques, the established trend of the one-dimensional shoreline change rate (m/year) along the portions (1), (2), (3) and (4) of Damietta coast that extracted using Iso cluster technique is found to be rather consistent with other earlier studies. This is clear by comparing the present results with the results of El-asmar, [1] and El-zeiny, [13] as consigned in Table (3). However, a quiet disparity between the results is found due to the deference in both the selected elapsed times for each study, and the precision of the utilized coastline demarcation technique.

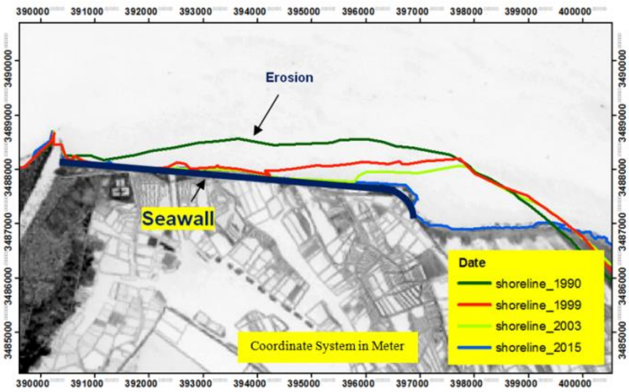

Figure 6. Satellite Image (Landsat_8/ETM); Shoreline at Ezbet El Borg; 1990,1999,2003, and 2015.

Figure 7. Satellite Image 2003, 2010, and 2015 (Google Earth); Shoreline at Ezbet El Borg; 2003,2010, and 2015.

Table 3. Comparing shoreline changes with another studies

Shoreline Part	Date	Rate(m/year)	Previous Rates	
			Date	Rate(m/year)
Part(1) Damietta Port (west)	1990_1999 1999_2003 2003_2015	+14 +14 +14		
Part(1) Damietta Port (East)	1987_1990 1990_1999 1999_2003 2003_2015	-78 -10 -10 -03	[1]1987_1991 [1]1991_2003 [13]1984_2014	-13.5 -10.3 -29.50 to -16.40
Part(2) Detached Breakwaters	1990_1999 1999_2003 2003_2015	+12 +06	[1]1987_1991 [1]2003_2006	-9.9 +6.7
Part(3) Eastern Seawalls	1990_1999 1999_2003	-60 -78	[1]1987_1991 [1]1991_2003 [13]1984_2014	-27.5 to -67.5 -18.3 to -30 -48

5. Conclusions

Damietta coast suffers from shape changed all time due to effects of waves and currents, so several types of coastal protection structure have been used along this coast (i.e Jetties ,groins, detached breakwaters and seawalls). Four Landsat images, 1990, 1999, 2003 and 2015 were used to investigate the coastal measures effects on temporal shoreline change. Effects of three main protection types were investigates. First one is the port breakwaters, whereas, the predominant character is that the shoreline has progressed west of port by an average beach growth rate of +10.0 m/year. Contrariwise, the shoreline on the east side of port (down drift) has negatively retreated and the corresponding beach is regressed at rates of -5.0 m/year. Second type is the eight detached breakwaters in front of Ras El-Bar resort. The shoreline formation is manifest in the parts directly behind of structure, where the shoreline has advanced by +12.0 m/year from year 1999 to year 2004 and then has decreased gradually to be in the stable state in 2015.The last type is the eastern seawall of Damietta promontory, which succeeded to overcome the shoreline erosion by reflecting the wave energy back into the sea, thus the wave energy available to cause erosion are reduced. However, it accelerate erosion of adjoining, unprotected coastal areas in down drift side, as results a highly eroded area by average rate of-78m/year just eastern of seawall.

6. References

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