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Shoreline changes behind detached breakwater at Baltim beach, Egypt

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الملخص العربي:

شاطيء بلطيم من احد اهم الشواطيء الشعبية الموجودة علي الساحل الشمالي لمصر. يتعرض شاطيء بلطيم لكثير من المشاكل اهمها عمليات النحر والتأكل في خط الشاطيء. قامت الدولة المصرية بأنشاء سلسلة من حواجز الامواج المتقطعة لحماية خط الشاطيء لمصيف بلطيم وذلك خلال الفترة من عام 1994 الي عام 2007 . يتكون حاجز الامواج في منطقة بلطيم من 14 شريحة من حواجز الامواج بأطوال 300 متر تقريبا ومسافات بينية بمتوسط 250 متر وذلك لحماية 8 كيلومتر بطول خط شاطيء منطقة بلطيم. في هذا البحث تم دراسة تأثير أقامة هذه السلسلة من حاجز الأمواج المتقطع علي معدلات النحر والترسيب والتغير في خط شاطيء بلطيم.

تمت الدراسة عن طريق تحليل الصور الملتقطة من القمر الصناعي LAND SAT للفترة بين عامي 2000 الي عام 2016 .باستخدام برنامج DSAS مع برنامج ARCGIS V10.1 وكانت نتائج الدراسة كالتالي:

- في الفترة بين عامي 2000 الي 2007 وقبل انهاء انشاء سلسلة حواجز الامواج فإن معدل الترسيب الحادث كان بمتوسط 14 الي 53 متر/ السنة. بينما كان معدلات نحر خط الشاطيء تساوي 3 الي 15 متر/سنة وخاصة في الجزء الشرقي من الشاطيء.
- خلال الفترة من 2007 الي 2016 اي بعد انشاء الحاجز زادت كمية ترسيب الرمال علي طول خط الشاطيء لتصل الي معدل 60 متر/ سنة.
- أوضحت الدراسة أن التوقع المستقبلي لخط الشاطيء يحدث بيه زيادة في معدل الترسيب بمعدل 5 الي 12 متر/ سنة. كما ان المنطقة الشرقية من خط الشاطيء يحدث بها نحر بمعدل 13 متر/سنة

ABSTRACT

Baltim beach is one of the famous public resorts in Egypt Baltim Beach is located on the northern coast of Egypt. Fourteen segments of detached breakwater were constructed in Baltim beach during year 2007 to minimize the erosion in this coastal zone. The data of Baltim beach were provided by Landsat7 satalite and proccseed by software program ERDAS IMAGINE 2013 which gives high resolution of the studied area. Then the shorelines were digitized by using software ARC GIS 10.1. This study introduce the shoreline response due to the construction of the detached breakwater using the Digital Shoreline Analysis System (DSAS). The analysis shows. Before construction of 14 detached breakwaters at Baltim resort from a year 2000 to 2007, the accretion has filled the zone between the shoreline and the detached breakwaters. This accretion is ranging from 4 to 53 m/year alongshore of the first 7-km in the west of Baltim beach. The maximum erosion is also occurred between detached breakwater No10 and No11 at the average rate of changes ranging from 3 to 15 m/year. After construction of 14 detached breakwaters from a year 2007 to 2016, a high accretion rates in behind the breakwater no 14 with the maximum rate of 60 m /year. The predicted shoreline from a year 2014 to 2060 at the area of fourteen detached breakwaters of Baltim beach is accretes highly by average rates ranging from 4 to 12 m/year.

KEYWORDS: Arc GIS; DSAS, Shoreline; breakwaters; sediment transport; Baltim.

1. INTRODUCTION

The Egyptian northern coast faces serious problems such as erosion and accretion. The interaction between waves and currents causes the main problem of erosion and accretion [Frihy,1991]. Detached breakwater is suggested to control and protect this coastal zone. Baltim beach in Egypt is an example for case study in this research. Change detection is the process of identifying differences in the state of an object as a shoreline by observing it at different periods. Remote sensing has widely been used in environmental change detection studies.ERDAS Imagine software was used to perform image processing of satellite image. In addition image digitizing was applied for delineating the shoreline trend at the study area using the ArcGIS V. 10.1 Software Package. DSAS Software used for anlaysis the shoreline changes of Baltim beach.

2. LITERATURE REVIEW

The Nile Delta coast is located in the middle part of the Mediterranean coast of Egypt between Abu-Quir head land in the west and Port-Said in the east with total length of about 240.0 km. Within the last few years, the Nile Delta has experienced considerable changes in environmental conditions. For instance, there is erosion along the Delta coast, [El Banna and Frihy 2009] and [Frihy et al. 2003]. The changes in environmental conditions increase the vulnerability of the coastal zone regard to sea level rise especially with removing the natural protection and increase the likelihood of land subsidence, [El-Asmar and Hereher 2010].

[Kaiser 2004] used Remote sensing results of land thematic mappers acquired along the Nile Delta coast in the period from 1984-2000 he indicate that the planform area decreased from sediment lost at a rate of $–4.6*10^4$ m^3/yr before the construction of any protection structures to $-2.6*10^3$ m^3/yr after protection structure construction. [El Banna 2009] testified that the anthropogenic factors have influenced the Nile Delta coastal area. These factors are change in the Nile sediment supply, Coastal processes and land subsidence. [Walaa A. Ali et. al. 2017] studied shoreline changes of Baltim beach to determine the effect of detached breakwater systems along Baltim on shoreline. Analysis of satellite images was used from 4 different satellite sensors. Shoreline change was calculated using DSAS Software. The rate of shoreline change was estimated from three statistical models of DSAS: Linear Regression Rate (LRR), End Point Rate (EPR) and Least Median of Square (LMS). Accretion in the form of tombolo between breakwaters number 9 to 14 is about 32.4 m/year. [Mohammed El-Sharabasy et.al, 2013] studies the shoreline changes drastically. The digitizing of shorelines was done by using ArcGis v 10.1. The erosion and acieration for Baltim beach his investgation shows that after the construction of the detached breakwaters, accretion has become the dominat process with the formation of rapid tombolos on the leeward side of these structures. This accretion has filled the down area between the shoreline and the breakwaters [EL-Banna and Hereher 2009] have detected temporal shoreline changes and erosion-accretion rates, using remote sensing, and their associated sediment characteristics along the coast of North Sinai, Egypt. [Frihy and Dewidar 2010] have used the Landsat Multi-spectral Scanner (MSS) and (ETM+) digital data to monitor coastal changes along the north-eastern Nile Delta. [Dewidar 2011] presented shoreline maps illustrating the shoreline erosion accretion pattern in the coastal area between Marsa-Alam and Hamata of Red Sea coastline by using different sources of remote sensing data, Landsat MSS (1972), Landsat TM (1990), Landsat ETM+ (1998, 2000) and Terra Aster (2007) satellite images were used.

3. STUDY AREA

Baltim beach locates between 31°30′00″N to 31°40′00″N latitudes (3492000 to 3600000) and 31°00′00″E to 31°15′00″E longitudes (318000 to 328000). Baltim beach is one of the most important public beaches fronting the central sector of the Nile Delta and is located about 11.5 km east of the Burullus lagoon inlet. Baltim resort is located on a very active convex shoreline which covering 8 km along Nile Delta Coast. Baltim beach has remained unprotected until 1992, at which time construction of protective breakwaters has commenced. Off this coastline, a total of 14 shore-parallel detached breakwaters have been constructed in four phases between 1993 and 2007 as shown in figure (1).

Baltim beach remained unprotected until 1992, at which time construction of protective breakwaters commenced. Outside this coastline, a total of 14 shore-parallel detached breakwaters have been constructed in four phases between 1993 and 2007. Nine breakwaters (4-7 ton dolos, 250-350 m length, 220m far from the coast, 300-400 m gap between each other, 3-4 m water depth, and 2.5 m crest level) were constructed between the years 1993-2002. Additional five breakwaters were constructed after 2003 with the same characteristics. Figures (2) show the details of the fourteen detached breakwaters

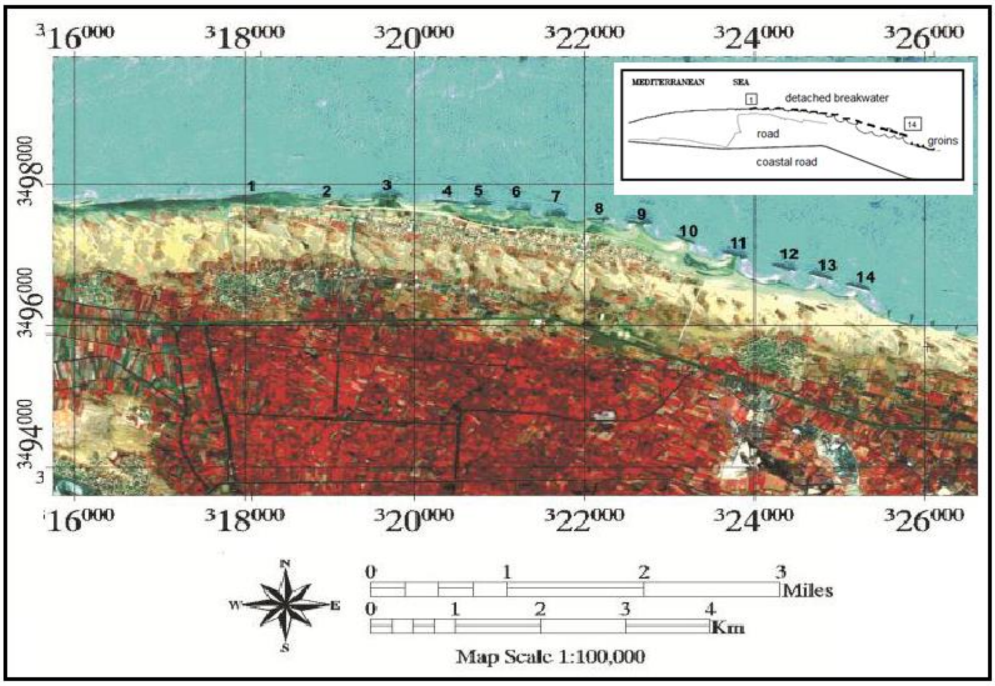

Figure (1): Location of Baltim beach and its detached breakwaters.

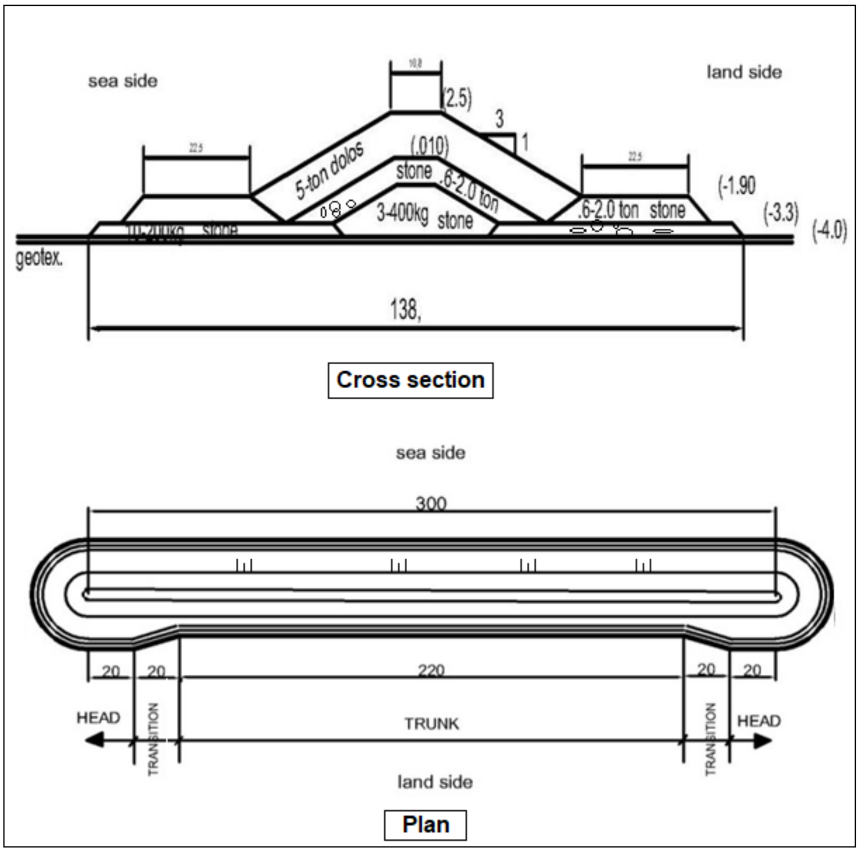

Figure (2): Details of Baltim detached breakwaters.

4. MATERIAL AND METHODS

4.1. Tides Data

Tides cause a significant change in sea level so this effect has to be evaluating during the image acquisitions to locate the free-surface level. The changes in sea level were measured using an automatic gauge called “horizontal seba water level recorder". It records the water levels continually on a graph. The recorders are related to the datum of zero level of the Egyptian Survey Authority (the mean sea level). Tides along the delta coast have a little impact on Nile coastal processes. The tide is semi-diurnal with a range 25 to 30 cm. The maximum difference in water level at the study area is 84 cm above the survey authority datum and it has happened in February 2010 as described in figure (3).

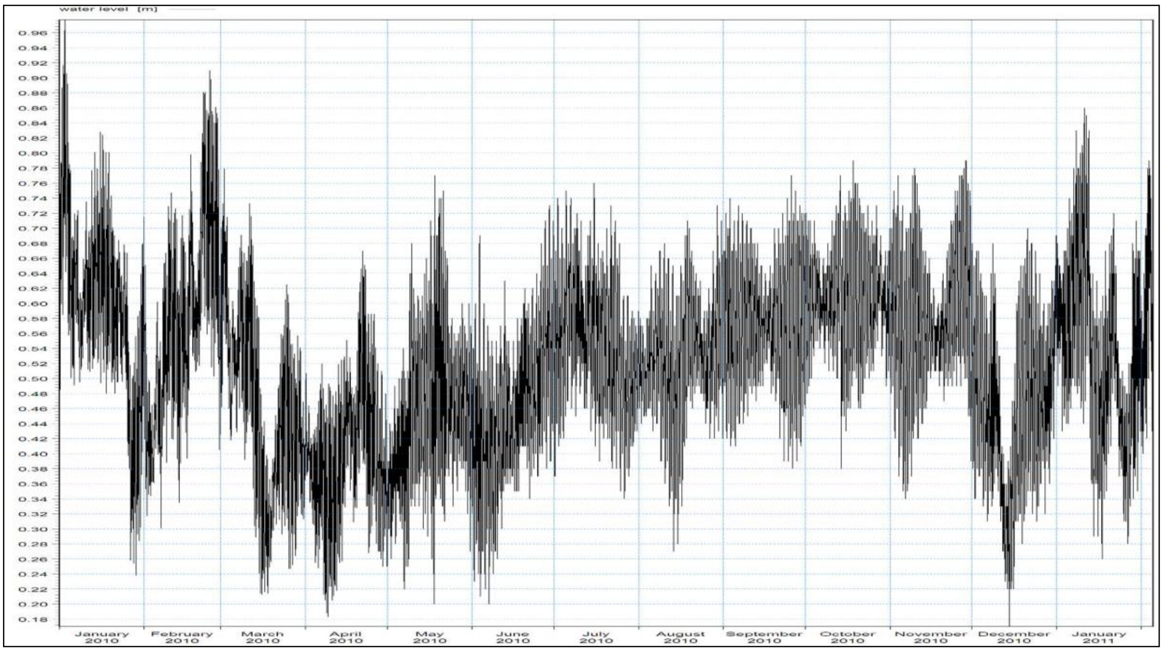

Figure (3): Values of Tide heights variations of the year 2010 at Baltim area.

4.2. Bathymetry and Shoreline changes

The Egyptian government has implemented many measures to protect the eroded areas by constructing groins and detached breakwaters. All these types of structures were built to protect the eroded zone along the coast of the study area at Baltim beach. The coastal Research Institute (CORI), National Water Research Center (NWRC), and Ministry of Water Resources and Irrigation (MWRI), have conducted hydrographic surveys for the shoreline in the form of 30 profiles along 6-km, as shown in Figure (4). Profile No.1 locates at 2 Km at the west of Kitchener drain. The spacing between the profiles varies from 200 m and 1200 m depending upon the nature of the shoreline. The direction of the profile lines is more or less perpendicular to the coastline. Shoreline changes were surveyed between 2000 and 2014 along the 13 km long Baltim beach, covering a time span of 9 years. The land survey is conducted using a Nikon total station power set 3010, as shown in Figure (5). Bathymetric data and contour lines are very important to study the wave characteristics, as shown in Figure (6).

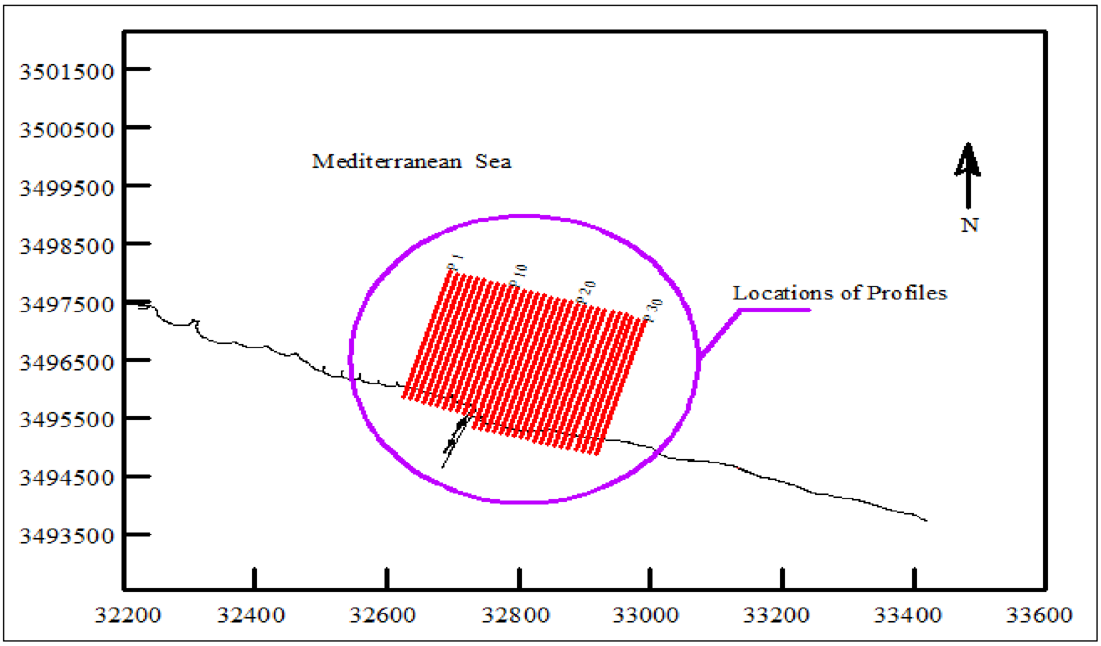

Figure (4): The location of profiles at Baltim area.

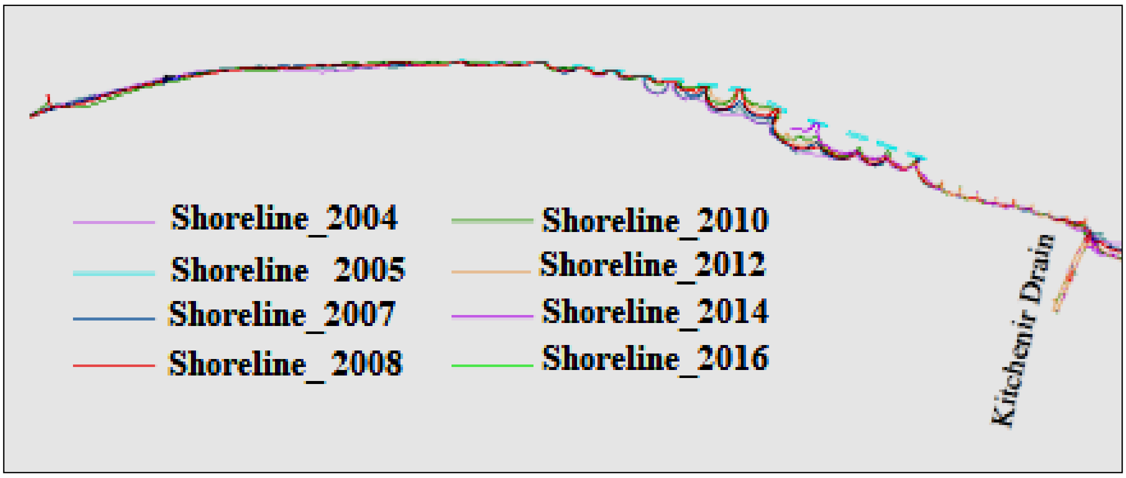

Figure (5): Surveyed shoreline changes from a year 2004 to 2016 at Baltim beach.

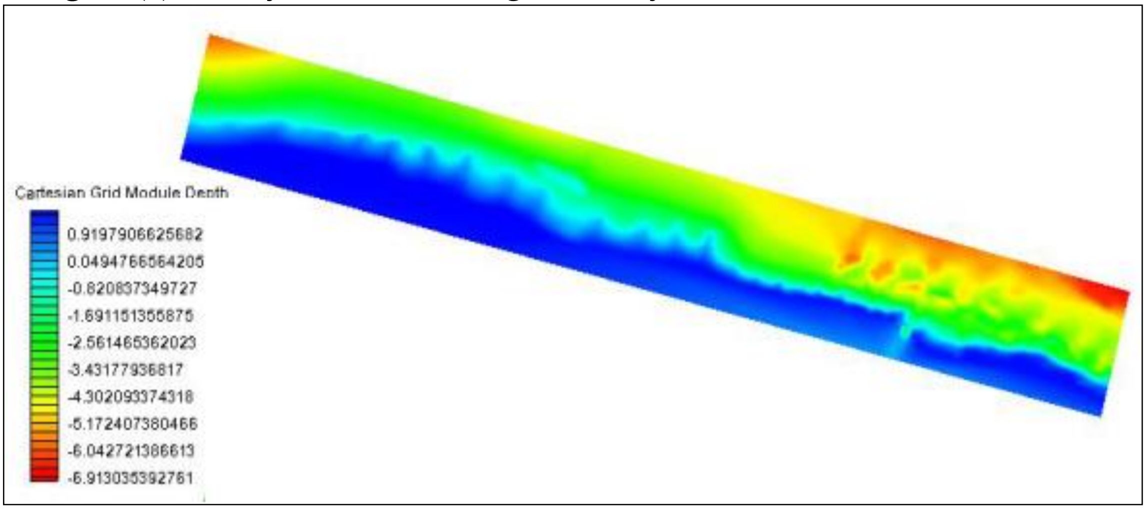

Figure (6): Bathymetric data and contour lines at Baltim area.

4.3. Landsat Dataset

Satellite images used for the present study are downloaded from the United States Geological Survey (USGS) Earth Explorer which online resources without any costs. Ten Landsat images (Mss, TM, ETM+ and OLi's) at unequal intervals along 26 -year period between 2000 and 2016 are acquired to calculate erosion and accretion pattern along the coastline of Baltim beache as described in Table (1). The construction of protection structures at Baltim beache are taken into consideration when Landsat image acquisition time is chosen. Baltim beach is located within the dataset of World Reference System path 189, 190 and Row38for MSS and within path 176, 177 and row 38 for TM, ETM+ and OLi's. All images are with a correction level 1-T. The correction level 1-T provides geometrically corrected according to the Universal Transverse Mercator (UTM) map of projection system; zone 36 north, using 25 ground control points (GCPs) that are selected at well-known features using a Geographic Information System (GIS).

Table (1): Landsat sensors data used in this study.

Satellite	Sensor	Scene Path/row	Date	Spatial resolution (m)
Landsat 5	TM	176/38	2000	30
Landsat 5	ETM	176/38	2001	30
Landsat 5	TM	176/38	2002	30
Landsat 7	ETM	176/38	2008	30
Landsat 7	ETM	176/38	2008	30
Landsat 7	ETM+	176/38	2009	30
Landsat 7	ETM	176/38	2010	30
Landsat 7	ETM+	176/38	2012	30
Landsat 8	Oli/TiRs	177/38	2014	15
Landsat 8	Oli/TiRs	177/38	2016	15

5. SHORELINE ANALYSIS

5.1. Shoreline Digitizing

Ten Images of shorelines of Baltim for years from 2000 to 2016 were taken by Landsat7 satalite and proccseed by software program ERDAS IMAGINE 2013 which gives high resolution of the studied area. Then the shorelines were digitized by using software ARC GIS 10.1 as presented in figure (7). the shoreline was illustrated and established as a shape files as shown in figures. Thos Images. Change in shoreline position were determined by establishing 161 transects along 8 km of coastline. Transects are oriented perpendicular to the baseline at 50 m spacing alongshore by using DSAS model as described in figure (8).

5.2 Analysis of Shoreline Changes

Digital Shoreline Analysis System (DSAS) softwar used to calulate the rate of changes in shoreline using 3 models as shown in figure (9):

a- Linear Regression Rate (LRR):

A linear regression rate-of-change statistic can be determined by fitting a least-squares regression line to all shoreline points for a particular transect.

b- End Point Rate (EPR):
The end point rate is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline.

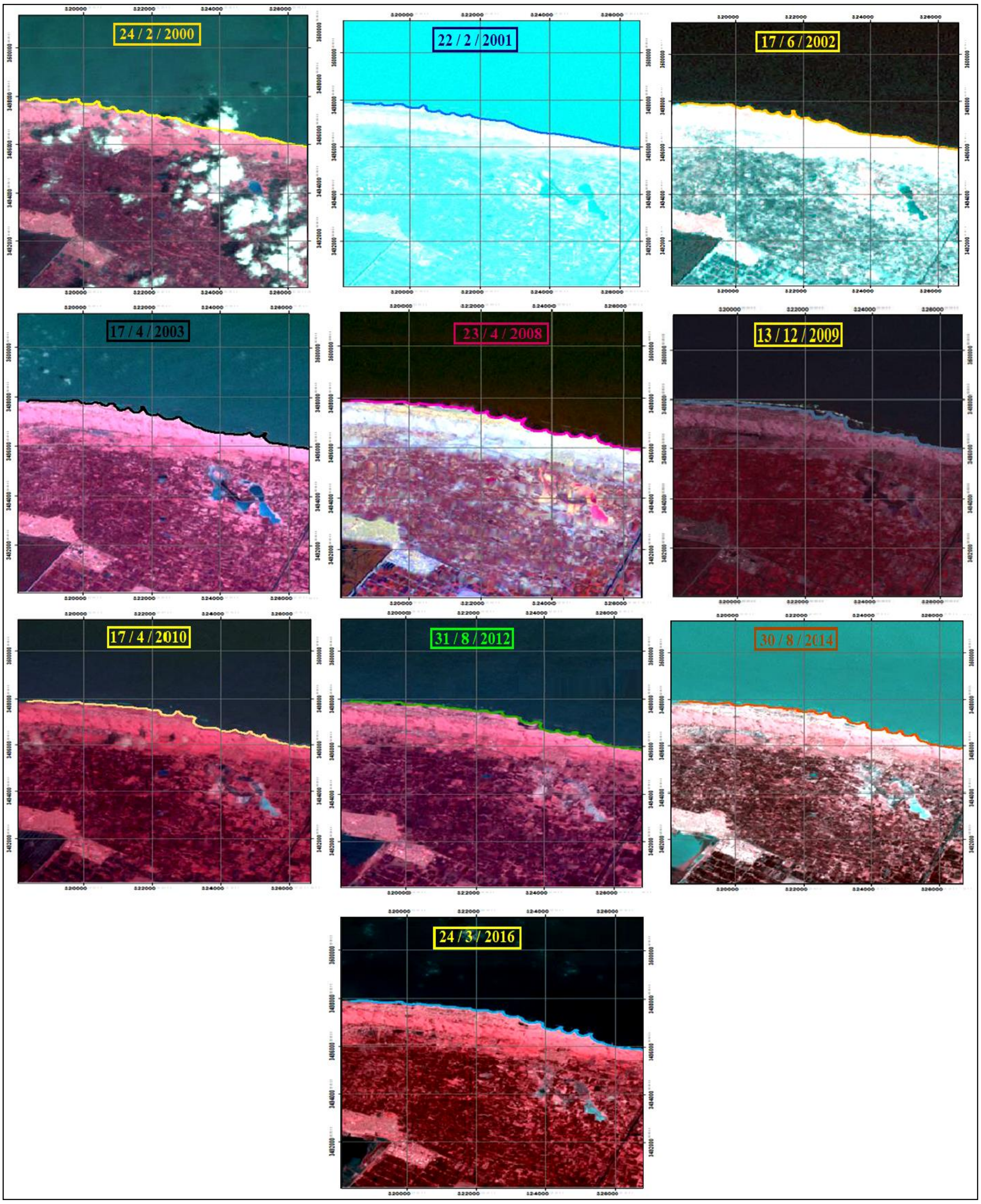

Figure (7): Processing and digitizing shorelines during years 2000 to 2016 at Baltim beach.

c- Least Median of Squares (LMS):
In ordinary and weighted least-squares regression, the best-fit line is placed through the points in such a way as to minimize the sum of the squared residuals. In the least

median of squares method the median value of the squared residuals is used instead of the mean to determine the best-fit equation for the line; Rousseeuw and Leroy (1987).

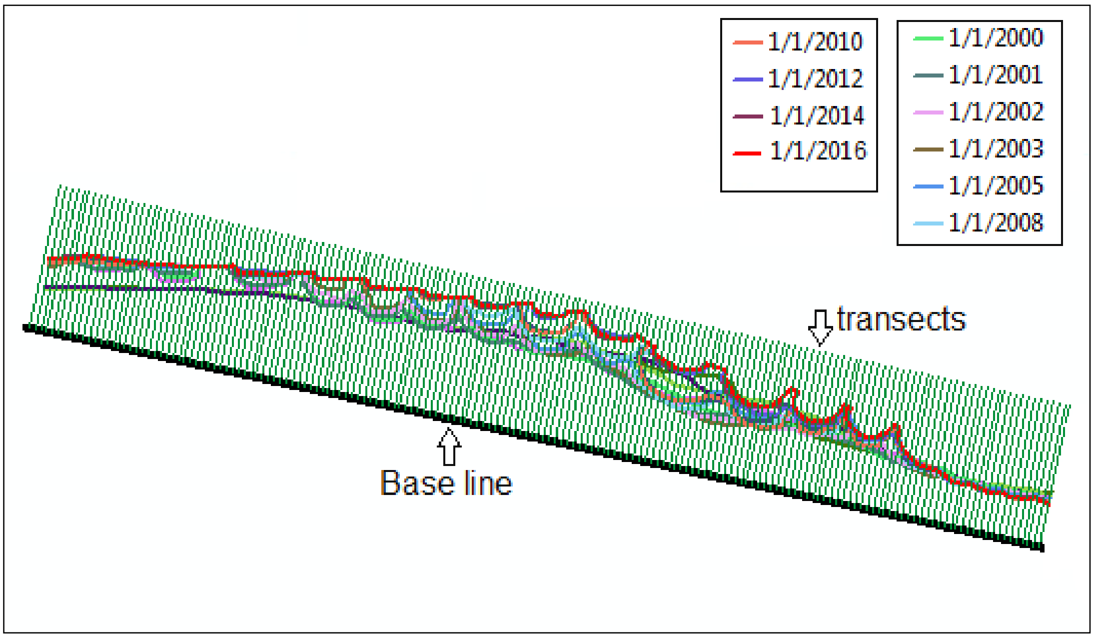

Figure (8): The digitized shoreline for years from 2000 to 2016.

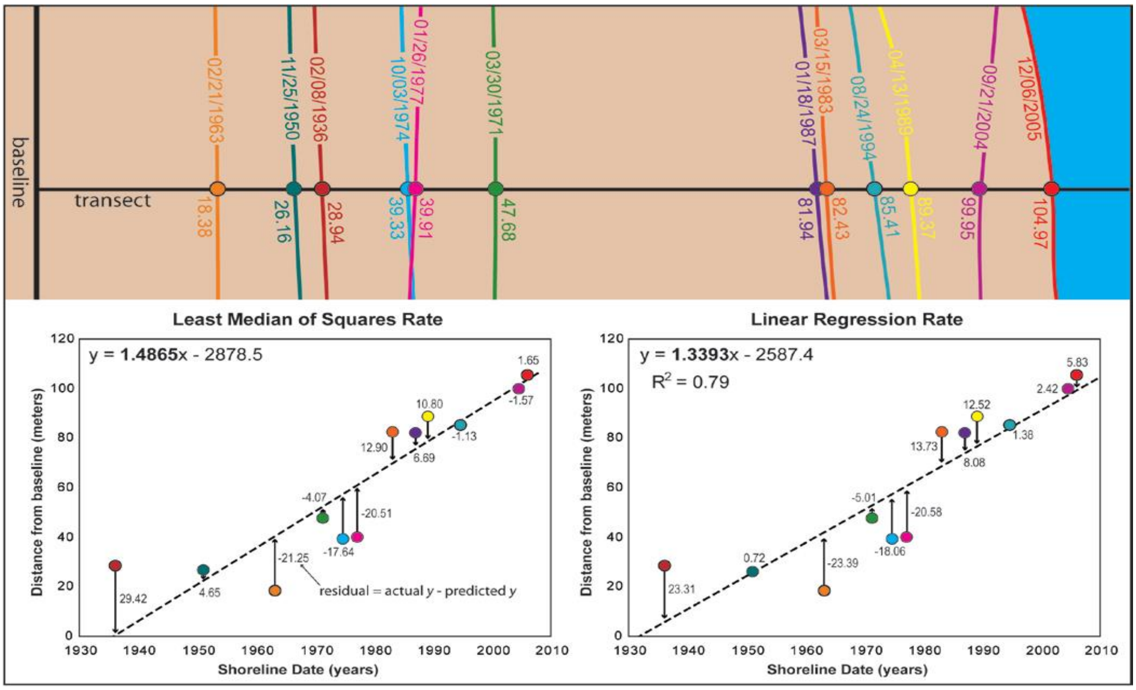

Figure (9): comparison between the least median of squares rate and the linear regression rate.

6. Results and Discussion

6.1. Shoreline change along Baltim beach

Figures (10) present rates of shoreline changes before end of construction of fourteen detached breakwaters at Baltim resort from a year 2000 to 2007. The annual rates of erosion and accretion are calculated from landsat image data using three different statistical techniques: LRR, EPR and LMS models. The figure shows that the accretion has filled the zone between the shoreline and the detached breakwaters. This accretion is ranging from 4 to 53 m/year alongshore of the first 7-km in the west of Baltim beach. The maximum erosion is also occurred between detached breakwater No10 and No11 at the average rate of changes ranging from 3 to 15 m/year using LRR model and EPR model but varying from 3 to 35 using LMS model. The plan form of the formed tombolo indicates that these accretionary features have been developed from the prevailing alongshore current to the east.

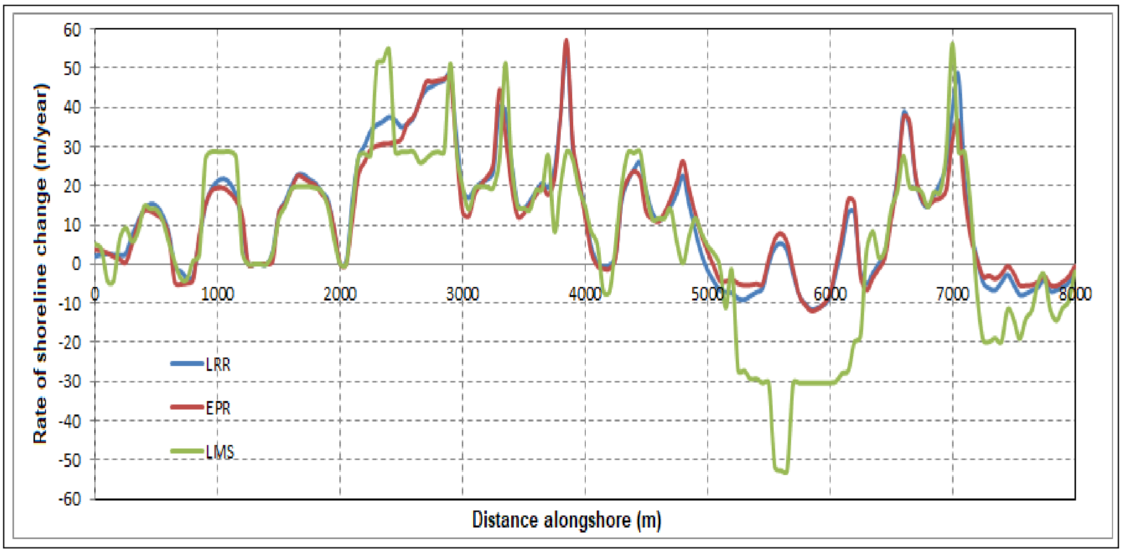

Figure (10): Rate of shoreline changes along Baltim beach from 2000 to 2007.

The rates of shoreline changes after construction of fourteen detached breakwaters along 8-km at Baltim beach from a year 2007 to 2016 are presented in figure (11). The rates of shoreline changes are calculated depending on the goedatabase for digitizing shorelines using three different statistical techniques of LRR model, EPR model and LMS model .It is clear from these figures that the construction of these detached breakwaters with the different characteristics of length, width, spacing between them, angle of detached breakwaters and spacing between the coastline lead to stable pocket beaches, good protection, poor water quality, poor aesthetic appearance, unsafe for swimmers and lee side erosion. In other words, the bulge formation of the tombolo has eventually transformed the breakwater system to act as a shore-parallel seawall. ALso, identify the high accretion rate in behind the breakwater no 14 with the maximum rate of 60 m /year for LRR model, EPR model and LMS model. The sediment transport occurred by using 14-detached breakwaters and their associated tombolo formations, thus increasing sand starvation of down coast beaches of this area.

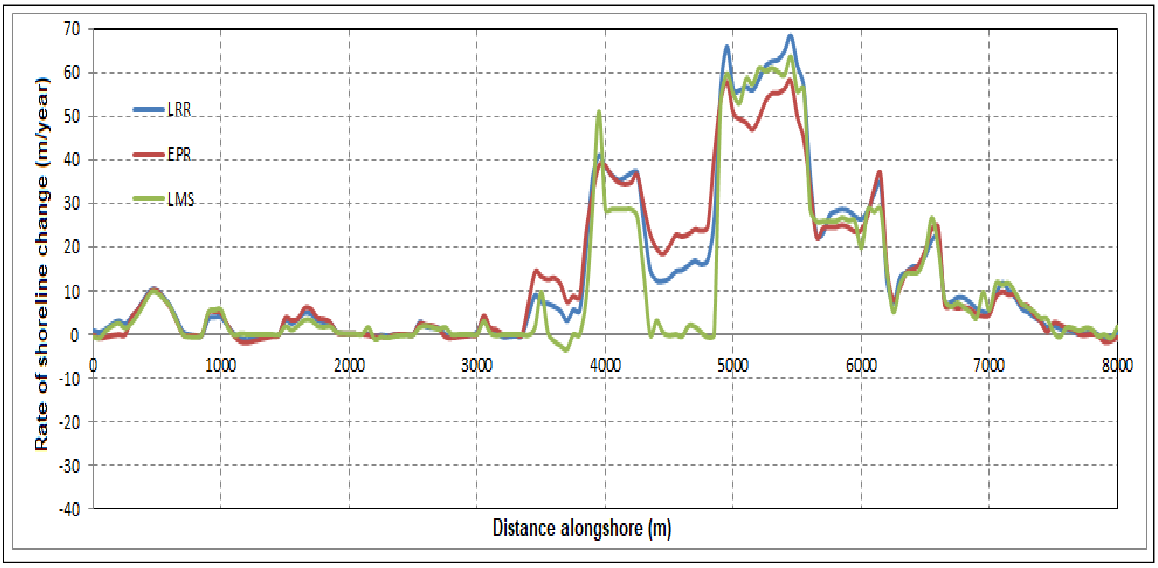

Figure (11): Rate of shoreline changes along Baltim beach from 2007 to 2016.

6.2. DSAS Model Validation

To validate results obtained from the analysis of imagery processing were compared by the rates of shoreline change calculated from ground survey in a period between years 2004 to 2014. A total of 161 profiles, that cover the study area have been chosen for validation of beach changes estimated after construction the detached breakwaters from 2004 to 2014. Some of annual rates of shoreline changes determined from ground survey and those estimated from analysis of imagery data are presented in figure (14). Positive and negative values indicate accretion and erosion respectively. Locations of the examined profiles for field data and landsat image are shown in Figures (12) and (13).

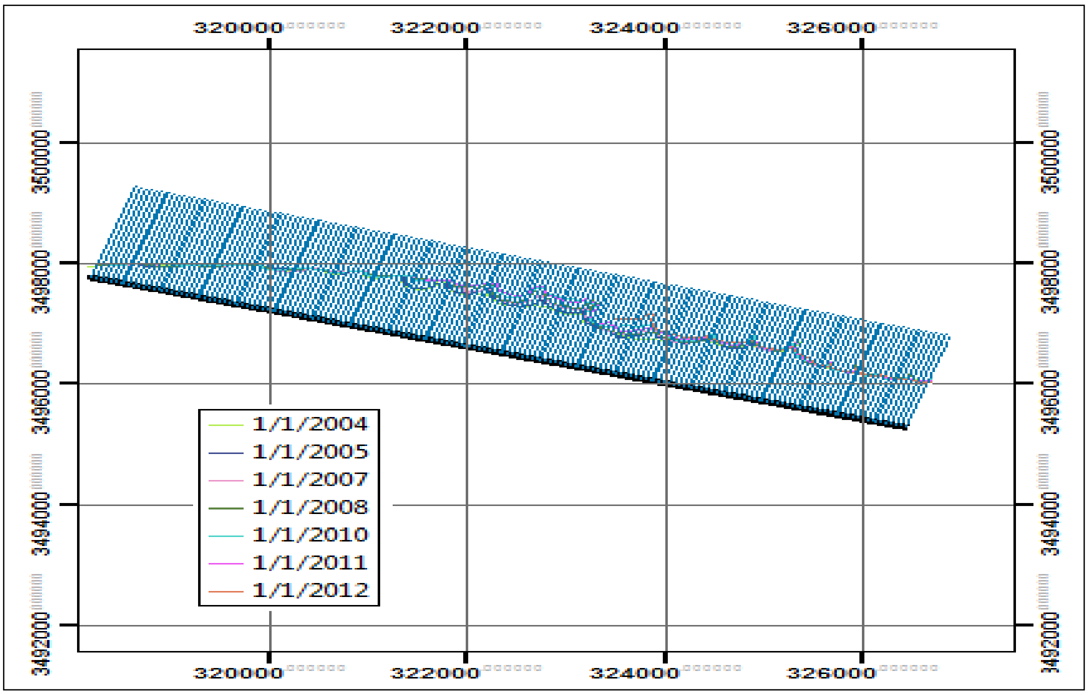

Figure (12): Digitizing shorelines for field surveying data and location of profiles from 2004 to 2012.

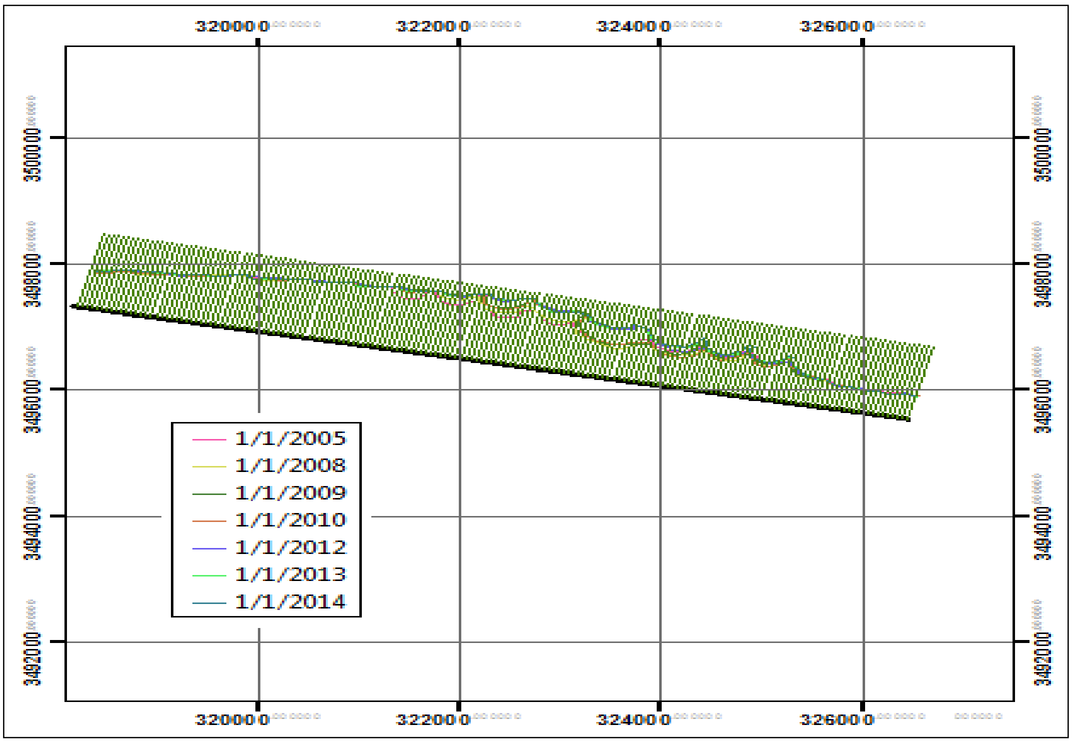

Figure (13): Digitizing shorelines from landsat image analysis data and location of profiles from 2004 to 2014.

Figure (14) shows the best fit regression line between rates of shoreline changes calculated from ground survey measurements and those derived from satellite images (DSAS) by using LRR model. It was found that the correlation coefficient for field data is 0.85 and satellite image data is 0.75 by difference error between them equals 10%. Figure (6.17) shows the difference between field data and Landsat data using EPR model along baltim beach from 2004 to 2014. It was found that the correlation coefficient for field data is 0.83 and satellite image data is 0.77 by difference error between them equals 6%. Figure (6.18) shows the difference between field data and Landsat data using LMS model along baltim beach from 2004 to 2014. It was found that the correlation coefficient for field data is 0.81 and satellite image data is 0.68 by difference error between them equals 13%.

6.3. Prediction Model for Baltim Beach

The prediction accuracy of shoreline position depends on the pervious data (assumed to be captured by Landsat imagery data). In coastline analysis research, extrapolation of a constant rate of change is the most commonly used method to predict the shoreline. Several methods have been used for prediction of shoreline position as a function of time, rate of erosion and deposition. The most simple and useful ones are the EPR and LRR models. In the present study, the LRR model has been adopted to predict the future shoreline. The model is based on the assumption that the observed periodical rate of change of shoreline position is the best estimate for prediction of the future shoreline. The position of the future shoreline for a given data is estimated using the rate of shoreline movement (slope), time interval between observed and predicted shoreline. In that method the regression equation is used to get a relation between the time and distance from the baseline. The regression equation is given by the formula ($y = mx + b$) where (y) is the distance from the baseline in meters, (x) is the shoreline date, (m) is the rate of change given from DSAS for each transect, (b) is y-intercept (the value of y when x=0) is calculated by the equation [y-intercept (b) = (mean of y) - (mean of x) * m].

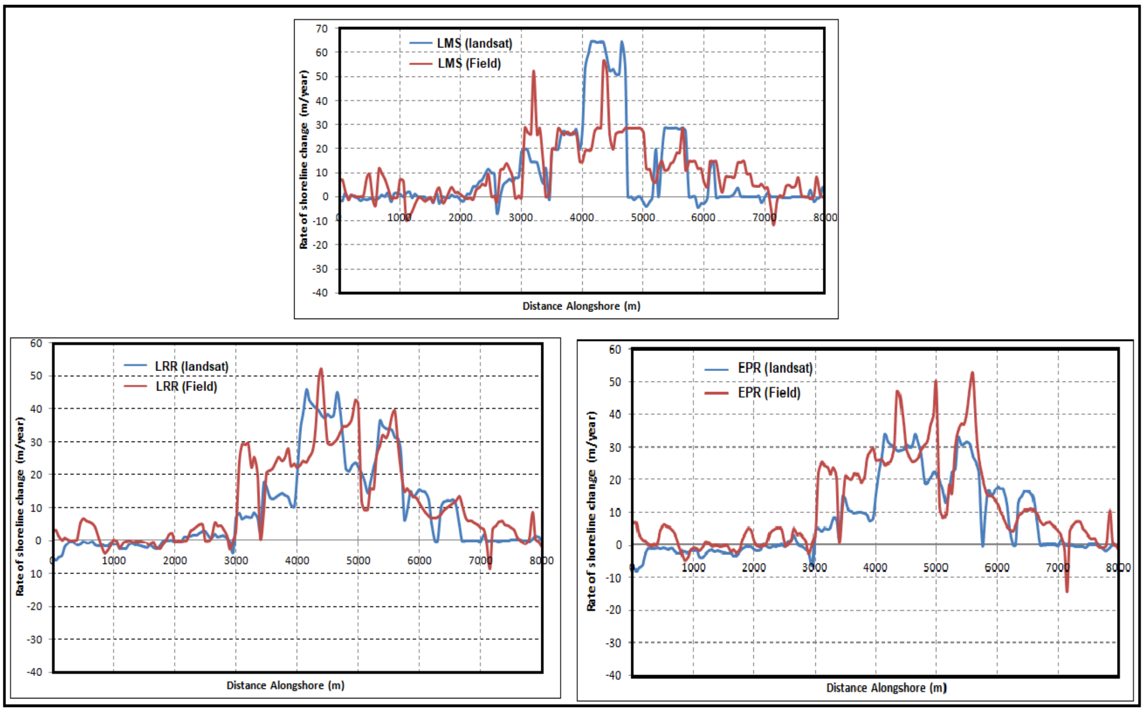

Figure (14): Difference between Landsat data and field data along Baltim beach from 2004 to 2014 by using LRR, EPR and LMS models.

Figure (15) shows the DSAS model for digitizing shorelines from a year 2014 to 2060 to study the effect of shoreline changes at Baltim beach for a long term of alongshore sediment transport movement. This figure presents the location of Baseline which is far from a shoreline 2014 about 5 to 200 m. Also, the distance of transect lines is outline to intersect perpendicular at the digitizing shorelines (2014-2020-2030-2040-2050-2060) to calculate the location of erosion and accretion using LRR model, EPR model and LMS model as shown in Figures (16) through (18) . It is clear from these figures that the shoreline at the area of fourteen detached breakwaters is accretes highly by average rates ranging from 4 to 12 m/year for three models. Examples of the estimate of the future scenarios that are obtained using the prediction model for all transects lines with continuous accretion and erosion are shown in Table (2).

7. CONCLUSIONS

Baltim beach is one of the most important public resorts along the Mediterranean coast, Egypt. Baltim beach faces many erosion and accretion problems. 14 segments detached breakwater was installed to protect the shoreline of Baltim beach during years 1993 to 2007. Digitizing of landsat Images for shoreline from year 2000 to year 2016 were processed by the layer stacking function using ERDAS Imagine, 2013 and Geographic Information System (GIS) model. Change in shoreline position were determined by establishing 161 transects along coastline that are oriented perpendicular to the baseline at 50 m spacing alongshore by using DSAS model. The rates of erosion and accretion along the study area are calculated from three statistical approaches of DSAS (End point rate, Linear regression rate, Least median of square).

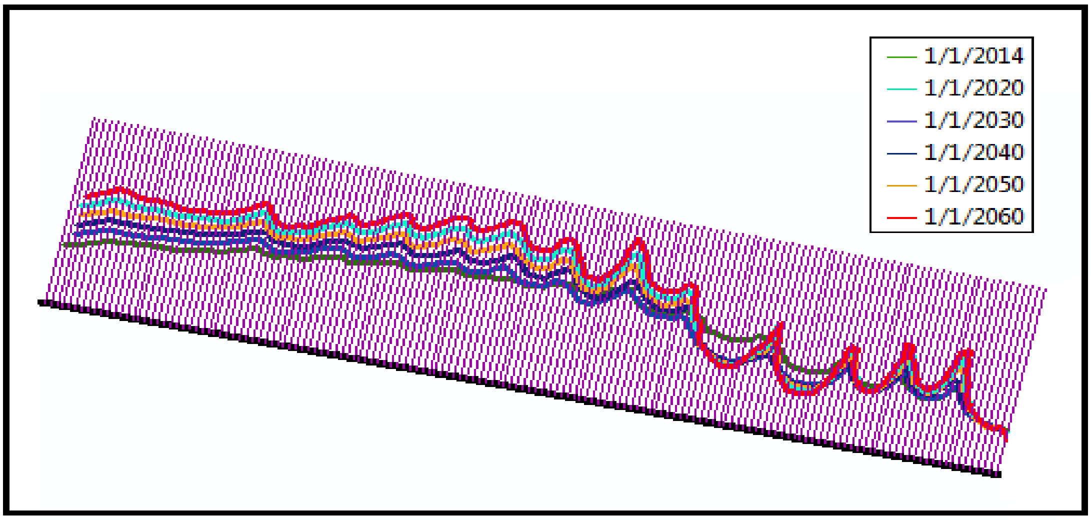

Figure (15): Digitizing of predicted shorelines form year 2014to 2060.

Table (2): Examples on the future estimates for shoreline retreat at Baltim beach

Distance (m)	Transect No	Distance from shoreline 2014 to 2020	Distance from shoreline 2014 to 2030	Distance from shoreline 2014 to 2040	Distance from shoreline 2014 to 2050	Distance from shoreline 2014 to 2060
0	1	-22.02	-121.72	-221.42	-321.12	-420.82
1000	21	71.68	147.88	224.08	300.28	376.48
2000	41	85.51	155.51	225.51	295.51	365.51
3000	61	67.52	177.42	287.32	397.22	507.12
4000	81	-92.24	-33.34	25.56	84.46	143.36
4050	82	-99.25	-44.75	9.75	64.25	118.75
4950	100	-171.62	-139.02	-106.42	-73.82	-41.22

Results showed that; before construction of 14 detached breakwaters at Baltim resort from a year 2000 to 2007, the accretion has filled the zone between the shoreline and the detached breakwaters. This accretion is ranging from 4 to 53 m/year alongshore of the first 7-km in the west of Baltim beach. The maximum erosion is also occurred between detached breakwater No10 and No11 at the average rate of changes ranging from 3 to 15 m/year using LRR model and EPR model but varying from 3 to 35 using LMS model. After construction of 14 detached breakwaters from a year 2007 to 2016, a high accretion rates in behind the breakwater no 14 with the maximum rate of 60 m /year. The predicted shoreline from a year 2014 to 2060 at the area of fourteen detached breakwaters of Baltim beach is accretes highly by average rates ranging from 4 to 12 m/year.

ABBREVIATIONS

GIS: Geographic Information System.
DSAS: Digital Shoreline Analysis System.
LRR: Linear regression rate.

EPR :End point rate.
LMS :Least median of square.
ETM+ : Enhanced Thematic Mapper Plus.
oli,s : Operational Land Imager.
UTM : Universal Transverse Mercator grid.
MSS : Multi Spectral Scanner.

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