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IMPACT OF DETACHED BREAKWATERS DESIGN PARAMETERS ON BEACH MORPHOLOGY

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الملخص

تعتبر حواجز الامواج المتقطعة واحدة من الحلول التي يمكن استخدامها كتدبير حماية. ومع ذلك، فإن أي تغيير في الشاطئ يحمل تأثير سلبي. مما ينتج عنه عدة عوامل تؤثر على قرار المهندسين لاختيار التكوين المناسب لحواجز لأمواج المتقطعة لمواجهة هذه المشاكل.

ولقد أجريت دراسة مكثفة باستخدام خصائص مختلفة للامواج لدراسة تأثير معاملات التصميم المختلفة لحواجز الامواج المتقطعة على تغيرات و مورفولوجية الشاطئ لتوجيه المهندسين القائمين على التصميم لاختيار المعاملات التصميمة المناسبة.

وقد تم اتمام ذلك باستخدام نموذج هيدروديناميكي لمحاكاة تغيرات خط الشاطئ في منطقة مارينا العالمين والتي تقع في الساحل الشمالي لمصر. وقد تضمن البحث تأثير المعلملات التصميمة المختلفة على تغيرات خط الشاطئ بسبب وجود حواجز امواج متقطعة موازية لخط الشاطئ. وقد تم استخلاص استنتاجات وتوصيات لتوجيه القائمين على التصميم لتصميم فعال لحواجزالامواج المتقطعة.

ABSTRACT

Detached breakwaters is considered one of the solutions that can be used as a protection measure. However, any change in the shoreline has an adverse impact. Several factors affect the decision of coastal engineers to select the suitable configuration of detached breakwaters to counteract these problems.

An intensive parametric study using different wave characteristics has been conducted to study the impact of different parameters of detached breakwaters on shoreline changes and beach morphology to guide designers in selecting the appropriate alternative. This was accomplished by using a hydrodynamic model (MIKE 21 software program) for simulating shoreline changes at the study area. The study area was Marina El Alamein which is located in the northern coast of Egypt. The paper examined the effect of different design parameters on shoreline changes due to the presence of detached breakwaters parallel to the shoreline. Conclusions have been drawn to guide the practitioners how to effectively design the detached breakwater system.

INTRODUCTION

Erosion and sedimentation are natural processes. However, both processes are often in conflict with coastal development. The most noticeable problem created by erosion is the loss of the waterfront property.
Many factors affect the decision of an engineer to select a suitable type and configuration of a coastal protection system. Detached breakwater can be used as a solution for this problem. However, any change in the coastal area may cause a negative impact on the waterfront.

In this paper, the main objective is to investigate the impact of different configurations of detached breakwaters on shoreline changes, beach morphology in Marina Alamein area and determine the guidelines for using different design parameters.

BRIEF REVIEW OF CODES GUIDELINES

Littoral transport is the movement of sedimentary material in the littoral zone, that is, the zone close to the shoreline. Littoral transport is classified to cross-shore transport and alongshore transport. Littoral transport results from the interaction of winds, waves, currents, tides, sediments and other phenomena in the littoral zone. [4]

Sand transport is defined as the movement of particles with sizes in the range of 0.05 to 2 mm as found in the bed of rivers, and coastal waters. There are two main types of sand transport are bed-load transport and suspended load transport. the net total sediment transport in coastal waters is defined as the vectorial sum of net the bed load (q_b) and net suspended load (q_s) transport rates: $q_{tot} = q_b + q_s$.[6]

Detached Breakwater has many variables, which determine the impact on the shoreline. These variable parameters are emerged, submerged or floating type of breakwater, distance from shoreline and location relative to the surf-zone, length, orientation, and single or segmented.[2]. Generally, detached breakwaters are placed in a range of water depths between 1 and 8 m. [3]

According to the Coastal Engineering Manual, there are recommended relations between (gab between detached breakwaters (L_g), wave length (L), breakwater length (L_s) and breakwater offshore distance (Y) as the following [5] :

- A gap between breakwaters (L_g) should range between wave length (L) to breakwater length (L_s).
- A breakwater offshore distance (Y) should equal to (L_s/1.50).

STUDY AREA DESCRIPTION

The study area is located on the northern coast of the Egypt at El-Alamein Marina Resort near the village of El-Alamein in Egypt, figure (1). A satellite image of the study area taken in year 2016 is shown in figure (2).

Figure 7 General Layout Location of Study Area (Marina Al Alamein)

Figure 2 Original Shoreline

The area is located in west of Delta region which is suffering from coastal erosion problems. Construction of detached breakwaters is one of the solutions that might be used to stabilize shoreline and protect it from erosion. This area is valuable as it is considered one of the best of touristic areas in Egypt. The study area extends over 7500 m along the north coast west Delta as shown in figure (3) and a beach profile with max depth of 7.36 m as shown in figure (4).

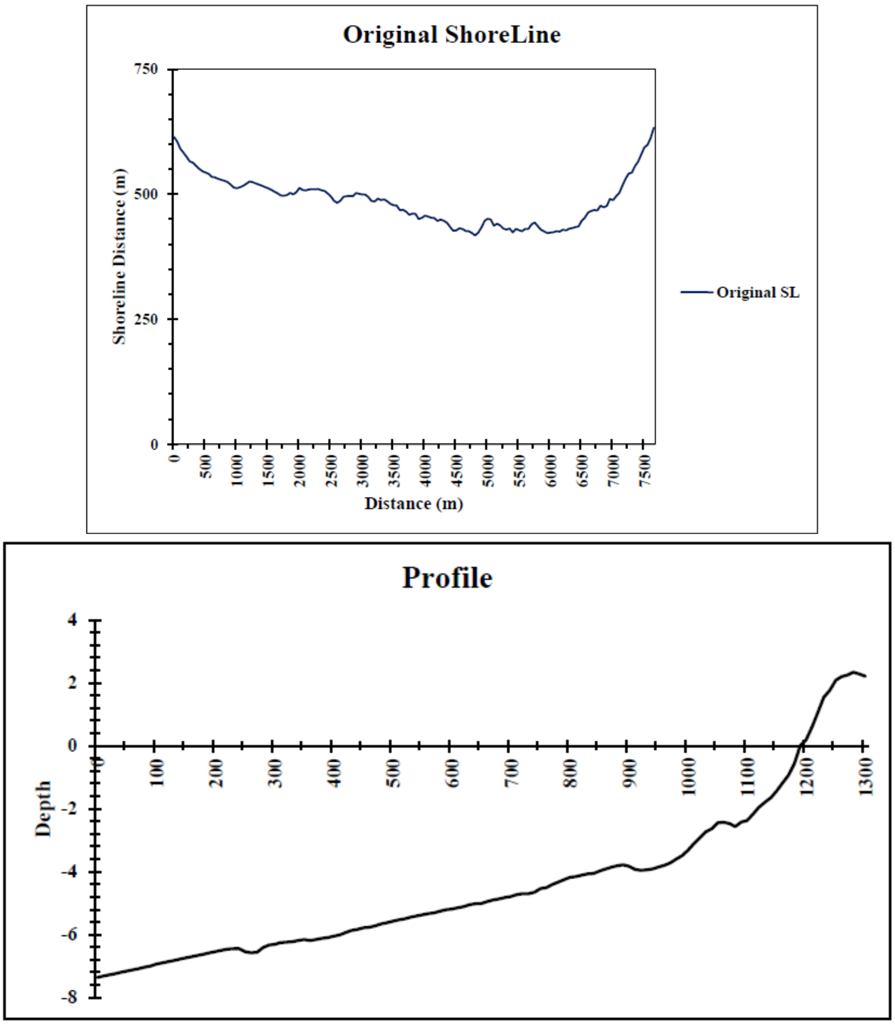

Figure 4 Original Shoreline [1]

MODELING OF CASE STUDY

To investigate the effect of detached breakwaters on the shoreline changes Marina port, three to five offshore breakwaters were modelled using the software program MIKE 21. The breakwaters varied in length between 150 m and 600 m. The gap between breakwaters ranged from 50 m to 600 m and the distance between the breakwaters and the shoreline ranged from 100 m to 600 m. The effect of other parameters on the shoreline changes was also investigated such as wave angle, wave height, wave period, time and number of breakwaters. A wave rose measured at Abo-Quir station was used in modeling with grain size of 0.3mm [1].

DISCUSSION OF RESULTS

Effect of incident wave angle on shoreline changes

Incident wave angles (ϴ) of 0^o, 15^o, 30^o, 45^o, 60^o, 300^o, 315^o, 330^o and 345^o measured clockwise from north were assumed in the simulation. A five years wave event with wave height of 1.00 m and wave period of 7.00 seconds was used in studying. The offshore distance (Y) was 300 m. Each breakwater length (L_S) was 300 m and gaps between the breakwaters (L_g) were 300 m. Figures (5) and (6) show the effect of changing wave angle on shoreline change.

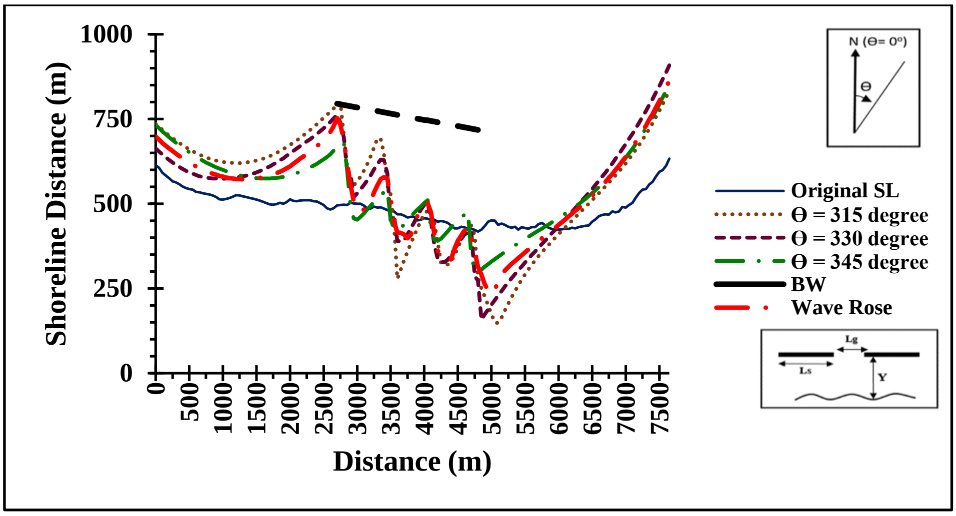

Figure 5 Shoreline change with changing (ϴ= 315^o, 330^o & 345^o)

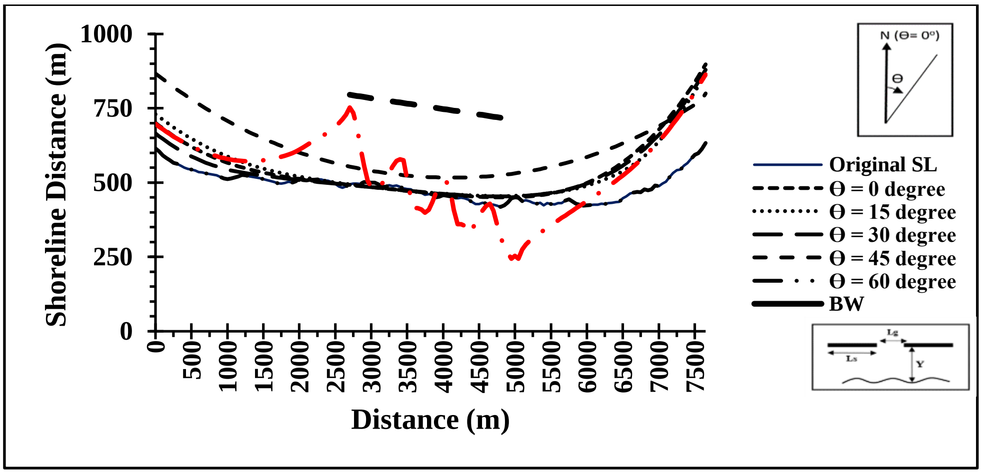

Figure 6 Shoreline change with changing (ϴ= 0^o, 15^o, 30^o, 45^o & 60^o)

It is noted in the case of wave angle 315^o is the only case that resulted in tombolo formation at the first breakwater. And for cases of wave angles 330^o and 345^o, they are the only two cases that had almost the same trend but resulted in different values.

For wave angle 345^o, there were tiny salient formations then a change in shoreline was appearing in accretion formation at distance of 5.50 km to the end of shoreline boundary.

For wave angle of 0^o (coming from north direction), the dominant situation was a bay configuration and these was common situation with wave angles 15^o, 30^o and 45^o, so it is considered that wave angles 0^o, 15^o, 30^o and 45^o had almost the same trend but resulted in different values. And for angle 60^o, there were no change in shoreline.

Effect of wave height on shoreline changes

Wave heights of 0.50, 1.00, 1.50, 2.00, 2.50 and 3.00 m were used in the simulation. A five years wave event with wave angle 300^o measured clockwise from north direction and the wave period 7 seconds was used in the study. Breakwater configuration was as same as used in studying the effect of wave angle.

Figures (7) and (8) show the effect of changing wave height on shoreline change. For case of wave height of 1.50 m that a tombolo formation appeared at one breakwater only while for the cases of wave heights 0.5 and 1.00 m salient formation was the common trend. Also, it is noticed that accretion formation appeared west of the breakwaters and the accretion increased with increasing the wave height.

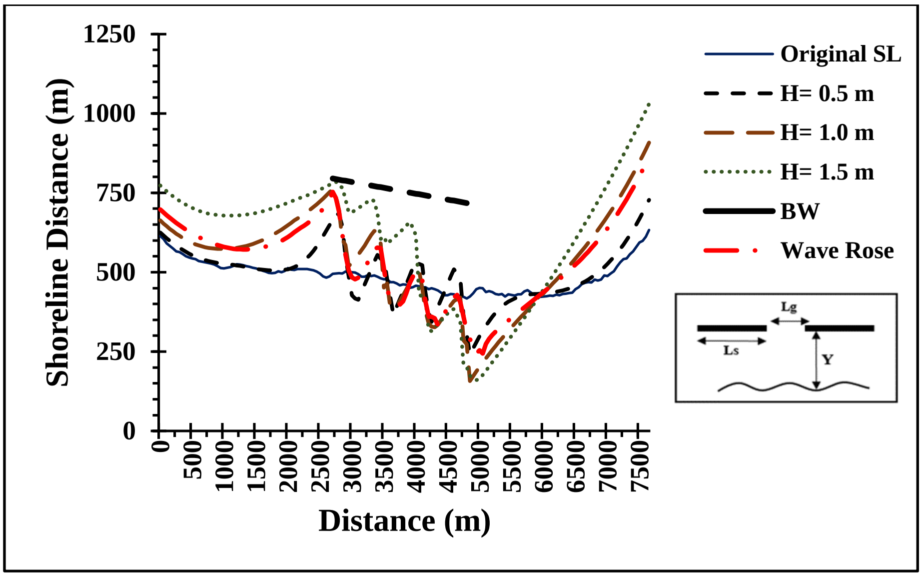

Figure 7 Shoreline change with changing (H= 0.5, 1&1.5m)

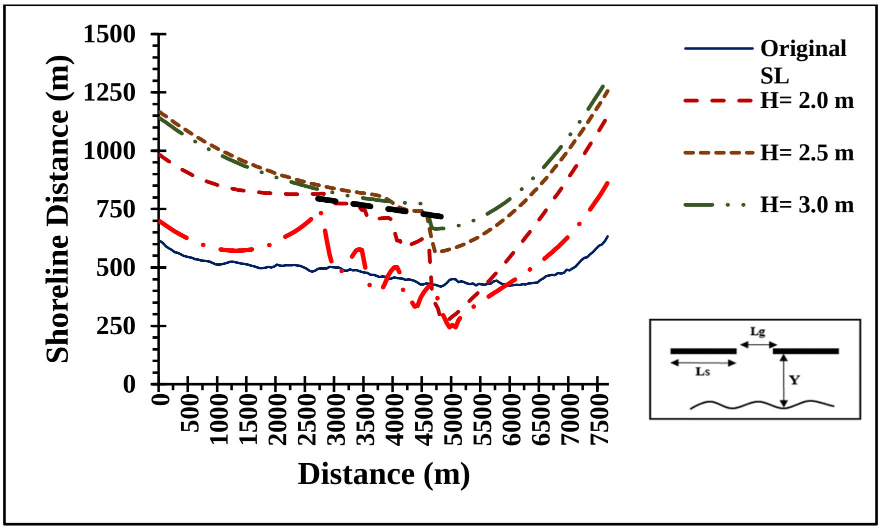

Figure 8 Shoreline change with changing (H= 2, 2.5 &3m)

For all cases of wave heights, erosion started east of the breakwater to the end of the study area. And for the cases of H=2.00, 2.50 and 3.00 m, tombolo formation resulted in which cover first three breakwaters.

Effect of wave period on shoreline changes

Wave periods of 5.00 and 7.00 seconds were used in the simulation. A five years wave event with wave angle of 300^{o} from north and wave height of 1.00 m. Breakwater configuration was as same as used in studying the effect of wave angle.

Figure (9) shows the effect of different wave periods on shoreline change. For all cases, accretion were formed in salient shape. The maximum erosion was formed about 300 m east of the fourth breakwater from the west. Also a five years wave rose was used in the simulation and it resulted in the same trend as of the wave period of 5 and 7 seconds.

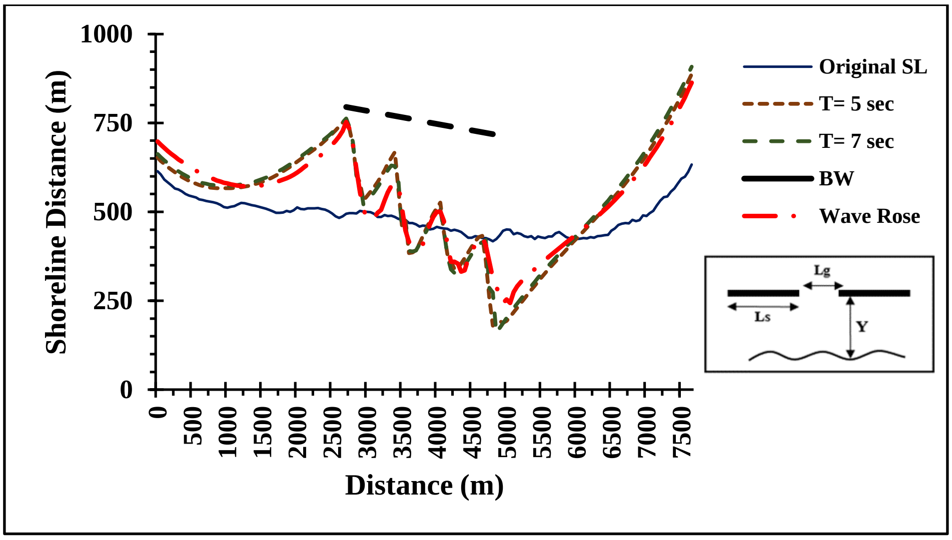

Figure 9 Shoreline change with changing (T= 5 & 7 sec)

Effect of time on shoreline changes

One, three, five, ten and twenty years were used in the simulation. A one year wave rose for Abo-Quir station was used in the study. Figure (10) shows the effect of changing number of years on shoreline change. The LITCONVE module was used to duplicate wave time series for one year to multiple number of years. Breakwater configuration was as same as used in studying the effect of wave angle.

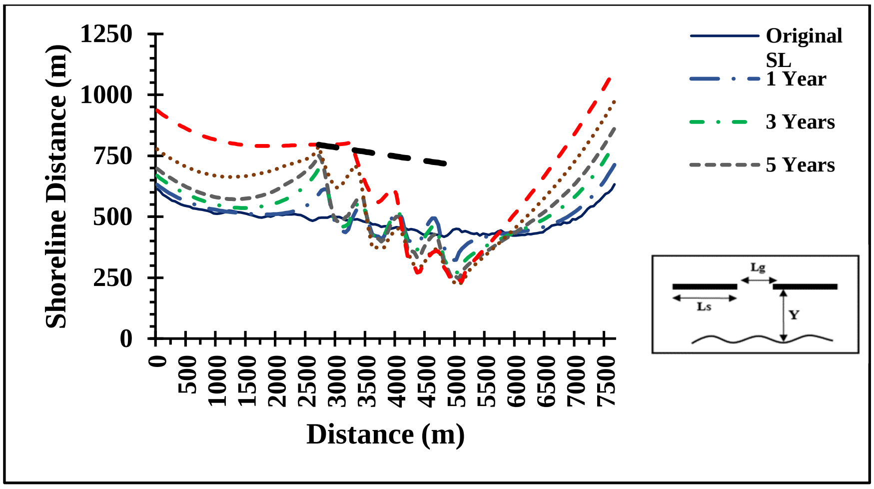

Figure 10 Shoreline change with changing number of years (1, 3, 5, 10, 20) years

Duration of 1, 3, 5, 10 and 20 years were considered. Changing number of years is significant at the first accretion formation for all cases except for ten and twenty years, the accretion was so excessive and it extended to more than 250 m north of the shoreline exceed the first and second breakwater. Also, for all cases that the erosion started 4.00 km west boundary of the study area.

Effect of gap between breakwaters on shoreline changes

A three years wave rose for Abo-Quir station was used in the study. A wave length was calculated to be about 50 m at the position of breakwater and length of detached breakwaters (L_g) used were 300 m.

Figures (11 to 16) present the effect of gap (L_g) between offshore breakwaters on shoreline changes. A gap of 50, 100, 200, 300, 450 and 600 m ($L_g = L_s/6$ to $L_g = L_s/0.50$) between detached breakwaters were used. The offshore distance from shoreline (Y) was 300 m.

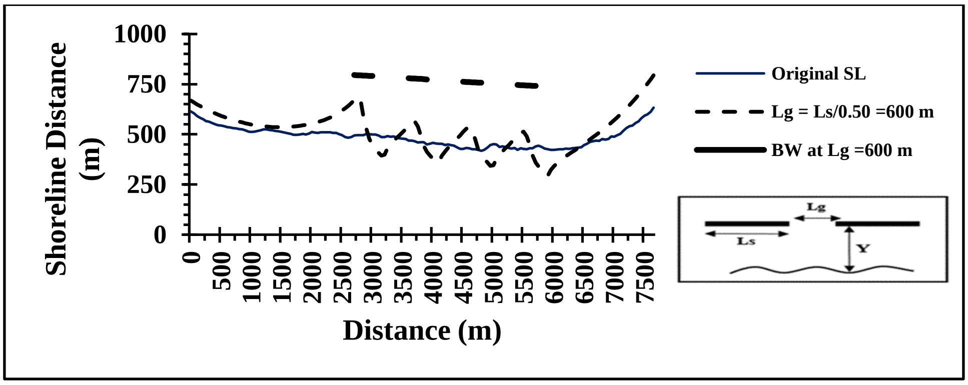

Figure 11 Shoreline change with changing gap between breakwaters Lg=Ls/0.50=600m

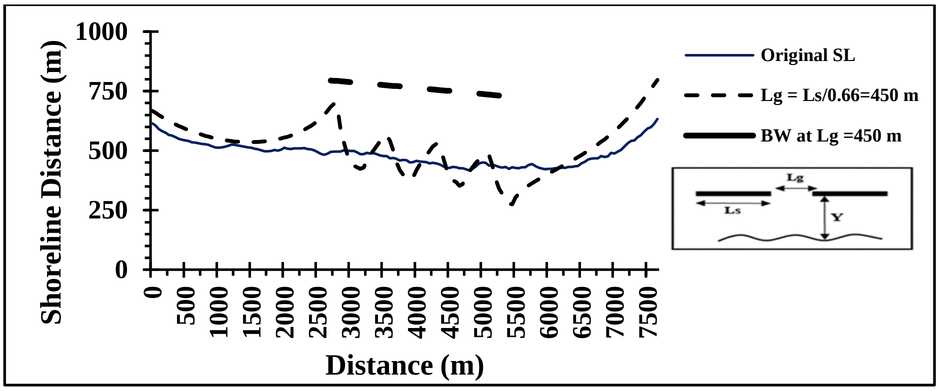

Figure 12 Shoreline change with changing gap between breakwaters Lg=Ls/0.66=450m

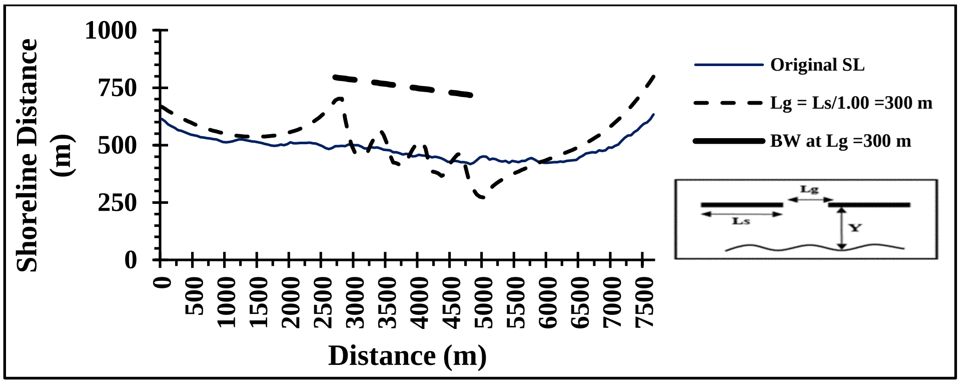

Figure 13 Shoreline change with changing gap between breakwaters Lg=Ls/1.00=300m

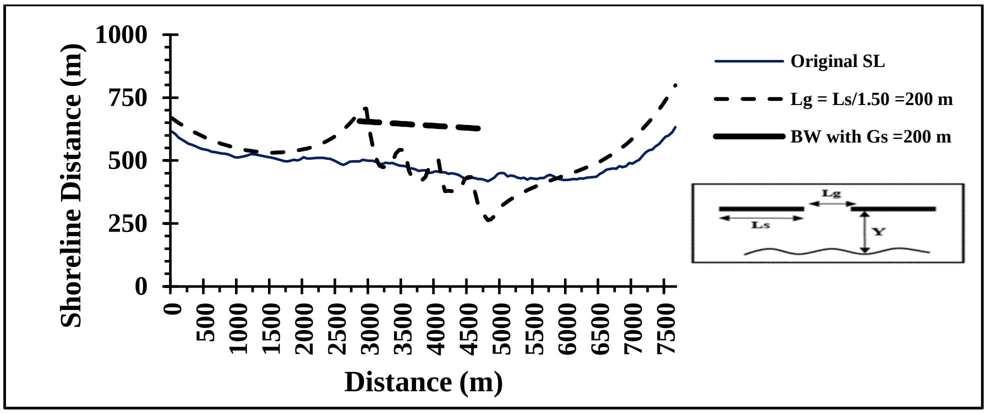

Figure 14 Shoreline change with changing gap between breakwaters Lg=Ls/1.50=200m

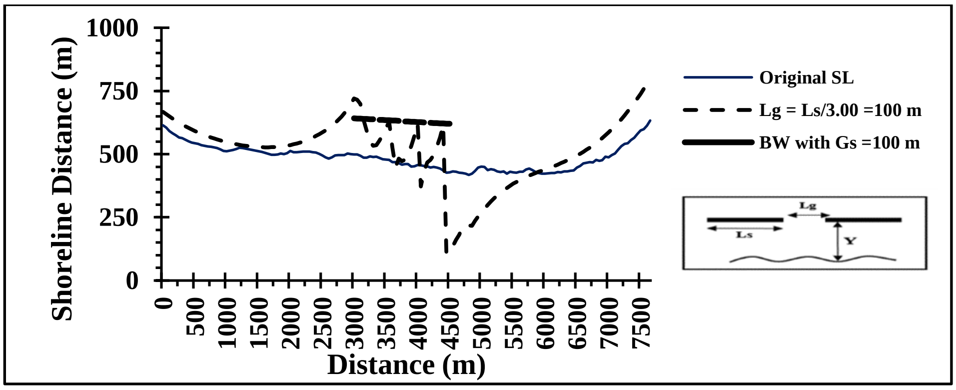

Figure 15 Shoreline change with changing gap between breakwaters Lg=Ls/3.00=100m

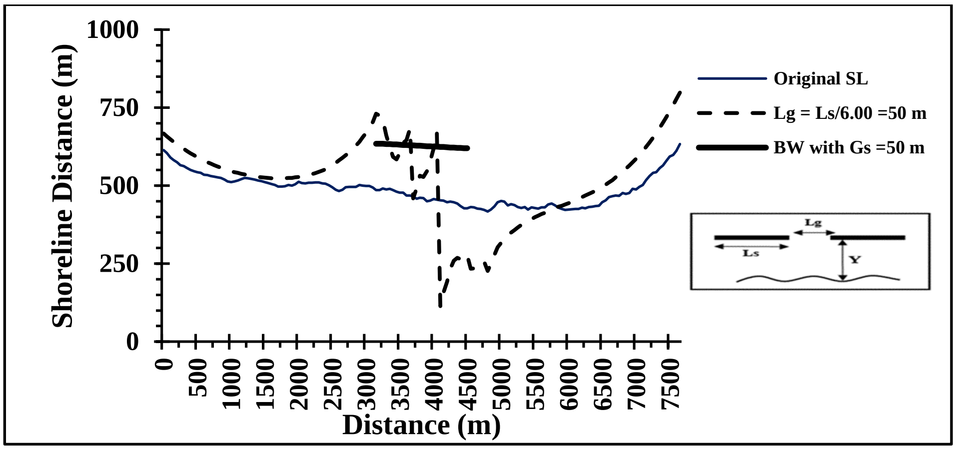

Figure 16 Shoreline change with changing gap between breakwaters Lg=Ls/6.00=50m

In all cases when gap was decreased the salient formation were so close to each other except the case of 50m gap which is not recommended to use.

Effect of the breakwater offshore distance on shoreline changes

A three years wave rose for Abo-Quir station was used in the study. An offshore distance (Y) of 100, 150, 200, 300, 375 and 600 m (Y =L_s/3 to Y =L_s/0.50) were used in the study. Each breakwater length (L_s) was 300 m and gaps between the breakwaters (L_g) were 300 m.

Figures (17 to 22) show the effect of changing offshore distance of breakwater on shoreline change. For the 600m offshore distance (L_s/Y=0.50) there were small salient formations increased gradually by decreasing offshore distance till 200m (L_s/Y=1.50). Then the decreasing offshore distance had no effect on formation size but the salient formation began to disappear and breakwater became as a part of the new beach.

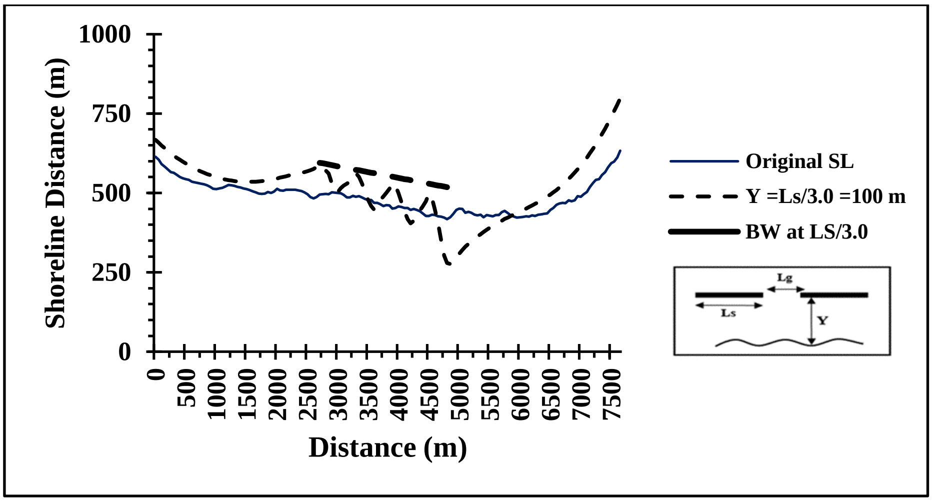

Figure 17 Shoreline change with changing offshore distance Y=Ls/3.00 =100m

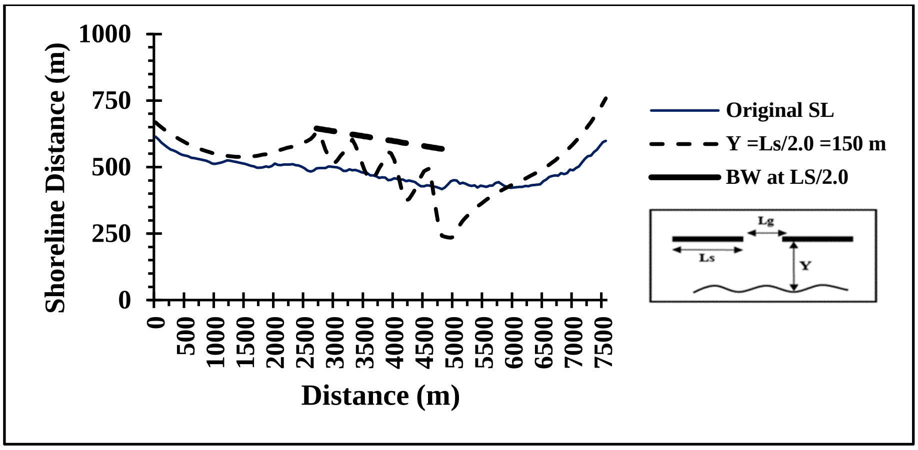

Figure 18 Shoreline change with changing offshore distance Y=Ls/2.00 =150m

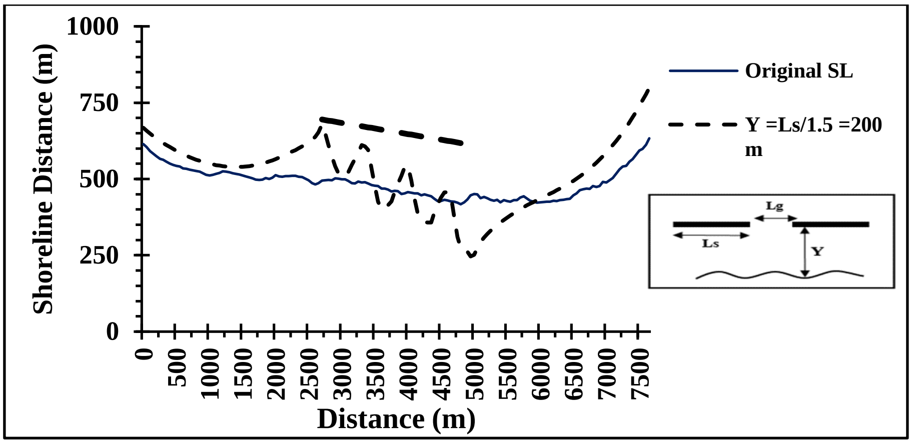

Figure 19 Shoreline change with changing offshore distance Y=Ls/1.50 =200m

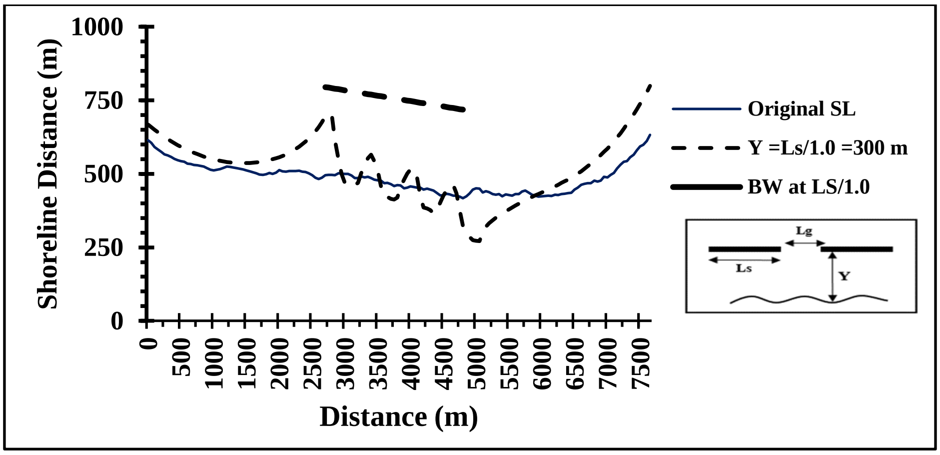

Figure 20 Shoreline change with changing offshore distance Y=Ls/1.00 =300m

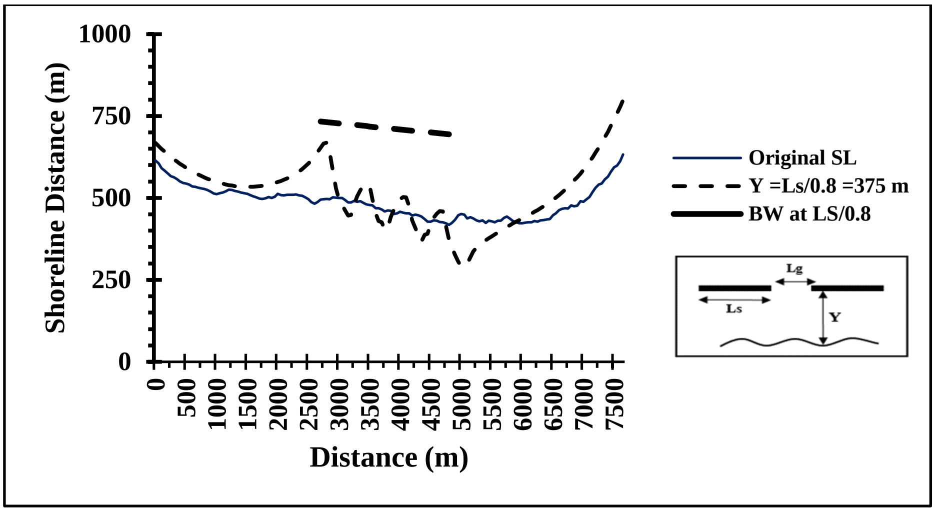

Figure 21 Shoreline change with changing offshore distance Y=Ls/0.80 =375m

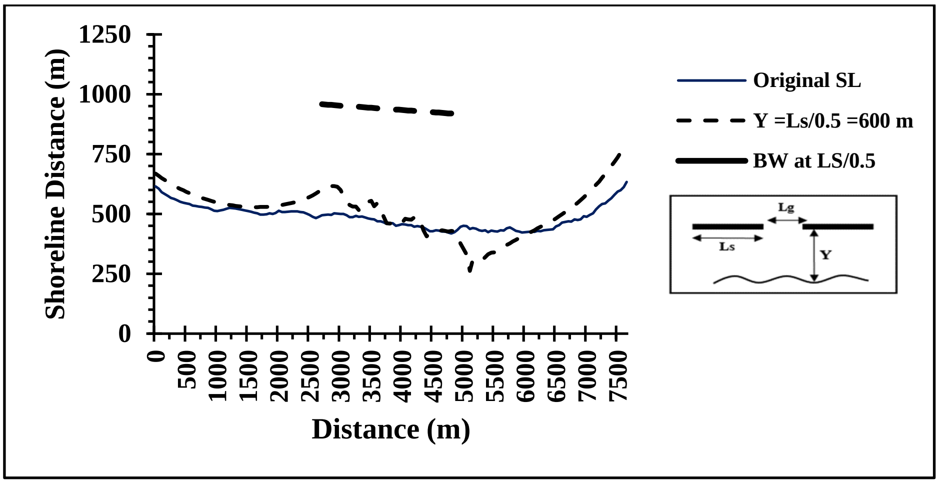

Figure 22 Shoreline change with changing offshore distance Y=Ls/0.50 =600m

Effect of breakwater length

A three year wave rose for Abo-Quir station was used in the study. 150, 300 and 600 m length detached breakwaters were used in the study. An offshore distance (Y) was 300 m and gaps between the breakwaters (L_g) were 300 m.

Figures (23 to 25) show the effect of changing length of breakwaters on shoreline change. All cases have almost the same trend in salient formation. Also, in the case of 150 m breakwater length, the average accretion distance was 70 m. For the 300 m and 600 m breakwater length (L_s), accretion inside the sea extended to a distance of about 180 m to 250 m from the shoreline, respectively. A salient formation was widespread along the shoreline in the case of 600 m more than the other two cases.

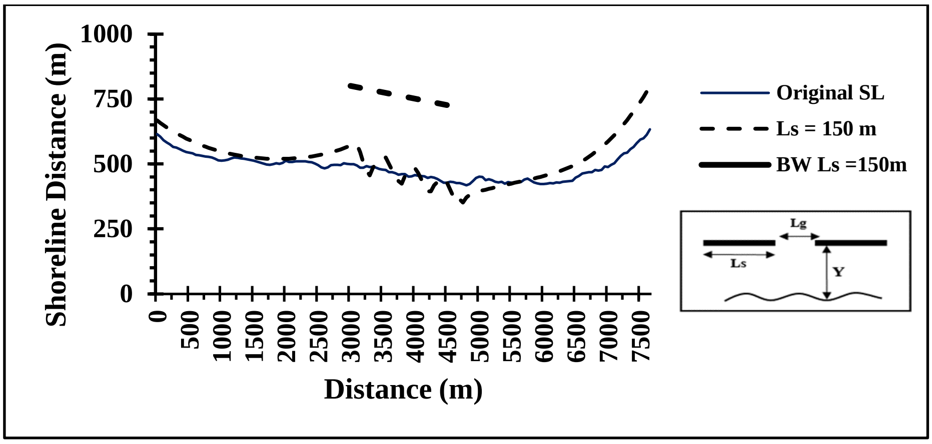

Figure 23 Shoreline change with changing breakwater length Ls=150m

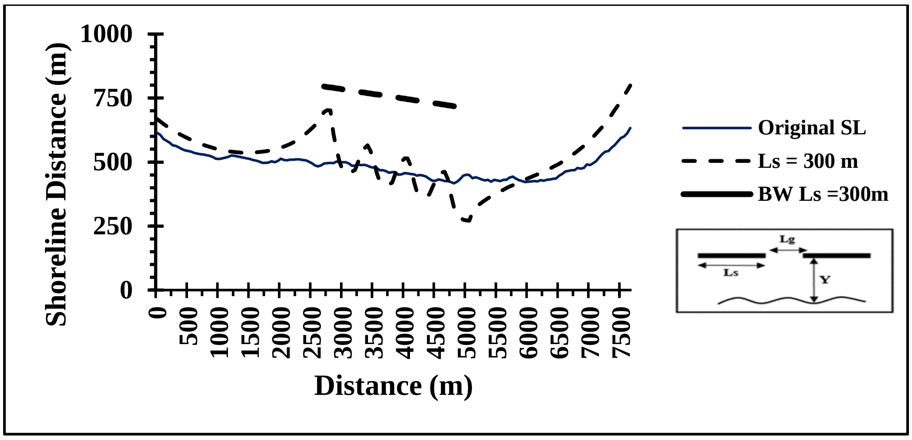

Figure 24 Shoreline change with changing breakwater length Ls=300m

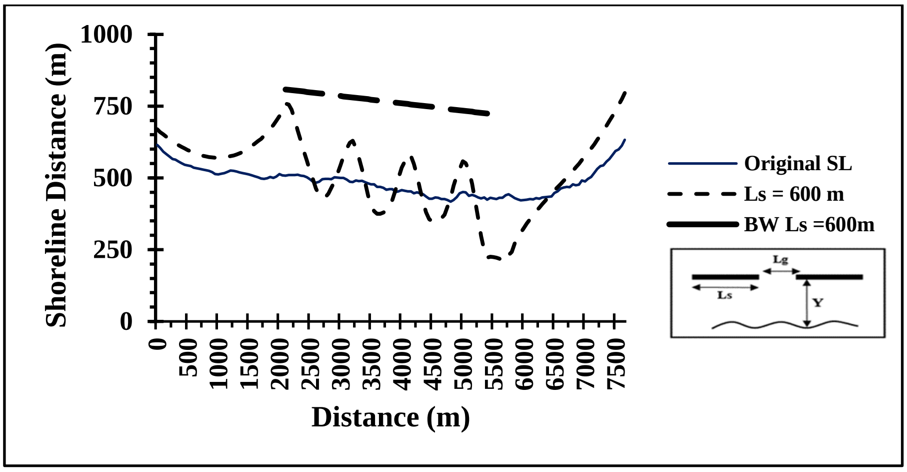

Figure 25 Shoreline change with changing breakwater length Ls=600m

Effect of changing the number of breakwaters

A three years wave rose for Abo-Quir station was used in the study. The offshore distance from shoreline (Y) was 300 m. Each breakwater length (L_s) was 300 m and gaps between the breakwaters (L_g) were 300 m.

Figures (26 to 28) show the effect of changing the number of breakwaters on shoreline change. Number of accretion formation is directly proportional to the number of detached breakwaters. Also the case of four breakwaters was the only case which caused a tombolo formation at the first breakwater.

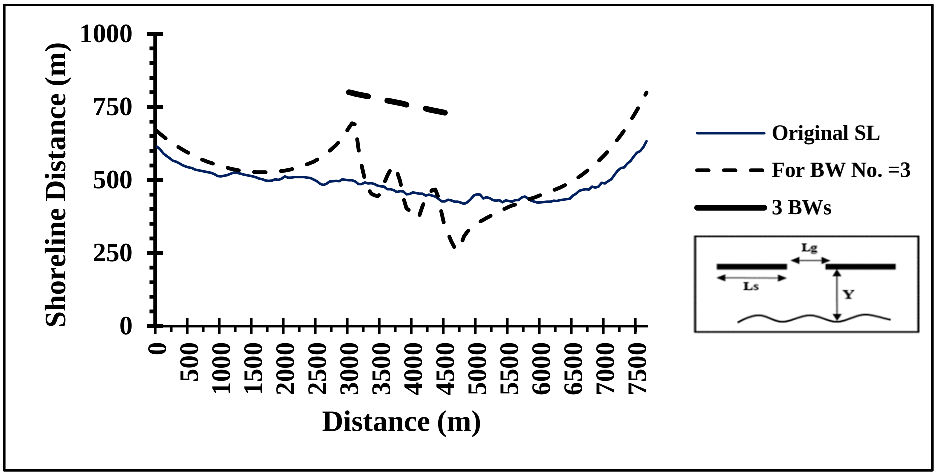

Figure 26 Shows shoreline change with changing breakwater number BW No.= 3

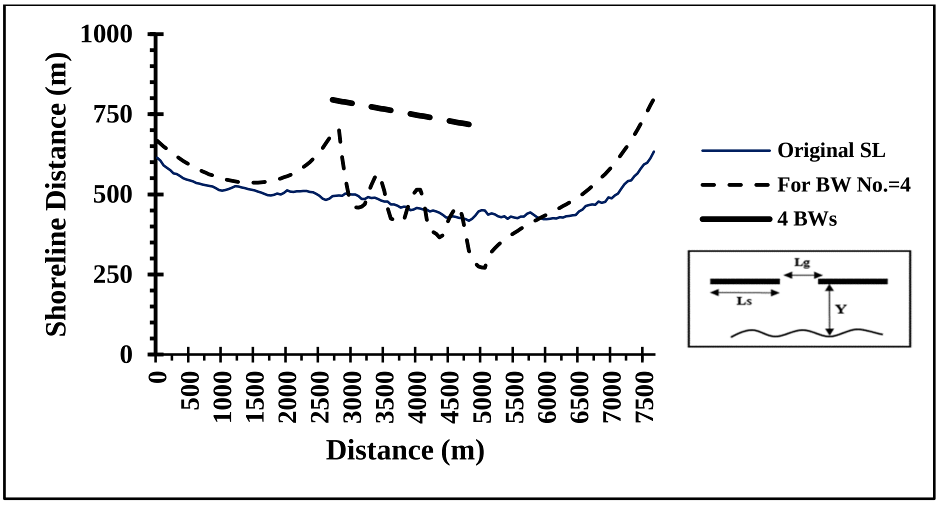

Figure 27 Shows shoreline change with changing breakwater number BW No.= 4

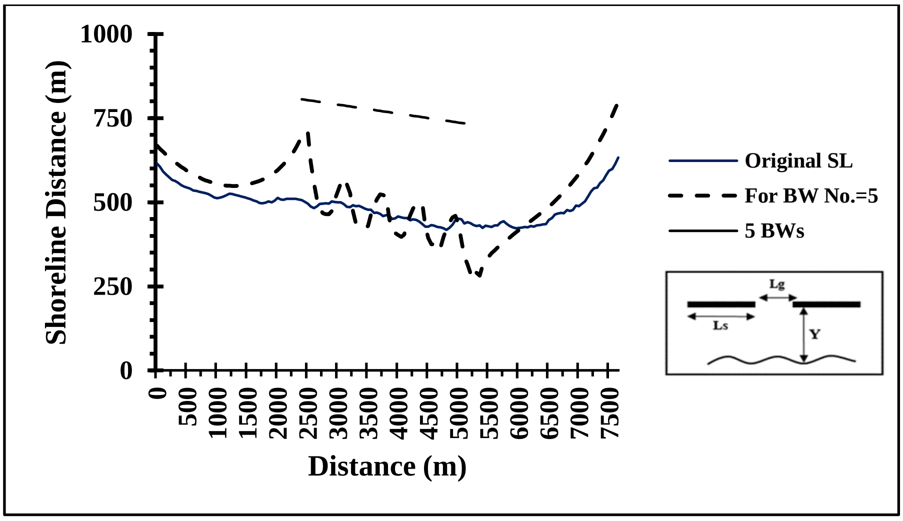

Figure 28 Shows shoreline change with changing breakwater number BW No.= 5

CONCLUSIONS

1. Changing wave angle has significant effect on shoreline change. As for changing wave angle, a big change in trend in shoreline change was noticed, which is ranged from no change in wave angle 60^o to salient accretion formations in 330^o and 345^o and with tombolo formation in 315^o.
2. Changing wave height has minor effect on shoreline change as all cases have the same trend.
3. A five years wave rose was used in the simulation and it resulted in the same trend as of the wave period of 5 and 7 seconds. This is because wave period was taken 6 seconds in the wave rose.
4. Changing the number of years has a significant effect on shoreline change especially for long time periods.
5. It is noticed that when gap was decreased the salient formations were so close to each other except the case of 50m gap which is not recommended to use. It was noted that gap distances more than recommended in the CEM have no significant effect on shoreline change.
6. Changing offshore distance has limited effect until a certain distance the formation became flatter. And it is recommended to use the ratio as stated in the CEM to get the efficient usage of detached breakwater.
7. A directly proportional relationship is between breakwater length, offshore distance and widespread. As when the length of breakwater is increased the offshore accretion distance and widespread will increase.
8. A strong relationship between the number of breakwaters and number of formations resulted from the presence of breakwaters. Increasing number of breakwaters only shifts the erosion area out the area which protected by breakwater.

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