Towards a Sustainable Stability of Coastal Zone at Rosetta Promontory/Mouth, Egypt

Abdelazim Negm[1]*, Ali Masria[2], Moheb Iskander[3] and Oliver C Saavedra[4]

[1]*Egypt-Japan University of Science and Technology, E-JUST, Egypt*
[2]*Faculty of Engineering, Mansoura University, Mansoura, Egypt*
[3]*Coastal Research Institute, National Water Research Center, MWRI, Egypt*
[4]*Tokyo Institute of Technology, Tokyo, Japan*

Abstract

Rosetta promontory/mouth where Rosetta branch of the Nile River meets the Mediterranean sea suffers from several severe environmental problems which began to take place since the beginning of the 20th century along Rosetta area, and increased dramatically since the construction of the Aswan High Dam (AHD) in 1964. It suffers from coastline erosion and sedimentation inside the inlet. The shoaling of the inlet leads to hindering the navigation process of fishing boats, negative impacts to estuarine and salt marsh habitat and decreases the efficiency of the cross section to transferring the flood flow to the sea. Many attempts to solve the erosion, and sedimentation problem were performed. Although, hard protection (and dredging) works have been implemented since 1989 including seawalls on the tip of the promontory and several groins along the eastern and western shores of the promontory, the problems still existing. This paper presents the results of testing a huge number of proposed alternative solutions to sustain the stable conditions of the Rosetta promontory/mouth. Hard structures, soft measures, combination of hard structures and soft measures were tested with and without nourishments of predetermined. The utilized Coastal Modeling System in testing the suggested measures was calibrated using collected field data from Ministry of Water Resources and Irrigation authorities and research institutes. The results indicated using only hard structures or soft measures without nourishment is not capable of keeping the Rosetta promontory/outlet stable. Only combination of both hard structures and soft measures with application of nourishment can improve the situation towards sustainable stable conditions but absolutely not the original stable conditions that were there before the construction of AHD.

Introduction

Seven major old deltaic branches of the Nile River are mentioned in various historical documents and in ancient maps. At the point of discharge of the Nile into the Mediterranean, the great Nile delta has formed and furnishes the most fertile area for cultivation in the Egyptian territory [1]. Currently, the Nile delta is embraced by two large branches of the Nile (the Rosetta and Damietta branches and their promontories). Both the Rosetta and Damietta branches discharge some freshwater directly and indirectly into the Mediterranean Sea to form the Nile estuary (also known as the Nile delta coastal area). Fluctuations in both quantity and quality of the Nile water reaching the Mediterranean, especially as a result of the Aswan High Dam (AHD) construction in 1965, have profoundly influenced the ecological characteristics of the river and the surrounding marine environment. These two main branches developed the Rosetta and Damietta promontories which have pro-graded during Holocene times into the Mediterranean Sea [2]. Rosetta Branch flows downstream Delta Barrage to the North-West where it ends with Edfina Barrage which releases excess water to the Mediterranean Sea. The Rosetta Branch water serves for a wide range of functions including tourism, trading and agricultural activities, industrial and domestic water supply, fisheries and recreation [3,4]. Rosetta Promontory is located on the eastern end of Abu-Quir Bay and at a distance of about 60 km to the east of Alexandria city. It was built during the years from 500 to 1000 AD when the water from the Canopic and Sebennitic branches, (Figure 1) was diverted naturally and/or artificially into an existing canal known afterwards as Rosetta Nile Branch [5].

This promontory continued growing up actively till the beginning of the 20th century where it extended seaward by about 14 km [6]. The old maps showed that Rosetta city which was built hundreds years ago at the outlet of this Nile branch now became inland some kilometers south of the sea shore. Figure 2 shows the advance and retreat of the eastern and western sides of Rosetta promontory.

Since 1900 to the present time the water flow and sediments carried out by Rosetta branch to the sea have been reduced due to: the climate changes, the construction of dams and control works along the river Nile itself, the continuous use of water for permanent irrigation requirements and/or man interference with the shoreline. Consequently serious erosion began to affect Rosetta promontory causing the damage to its coastal zone environment. The erosion rate has been accelerated since the completion of the High Aswan Dam in 1964 which trapped all the sediments transported by the River in its upstream side. However erosion is not the only trouble facing this promontory, but sedimentation of its coastal outlet is taking place. This sedimentation is causing serious and intensive shoaling of the exit which hinders fishing operation, coastal navigation of the fishing boats in the area and disturbs the ecosystem of the Rosetta branch [7]. Many protective measures had been executed and/ or under execution to combat the erosion and sedimentation problems of Rosetta area. A
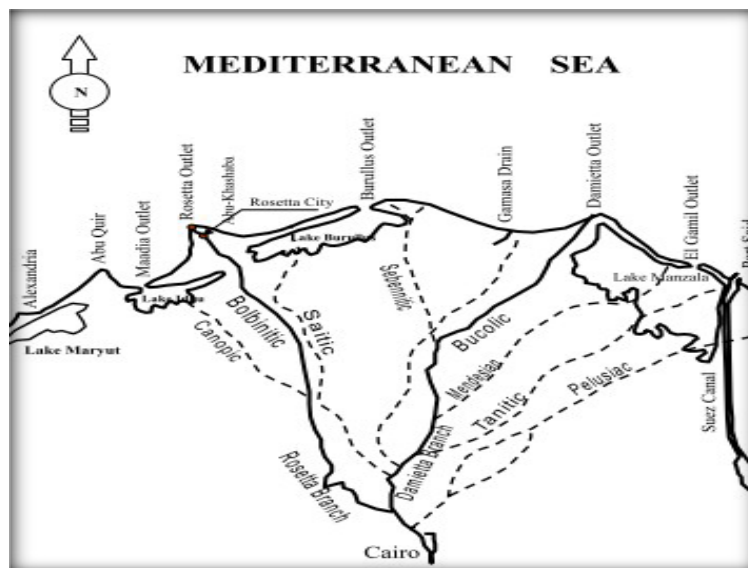
Figure 1: Location map for the Nile Delta and the old Nile branches (El Sayed [5]).
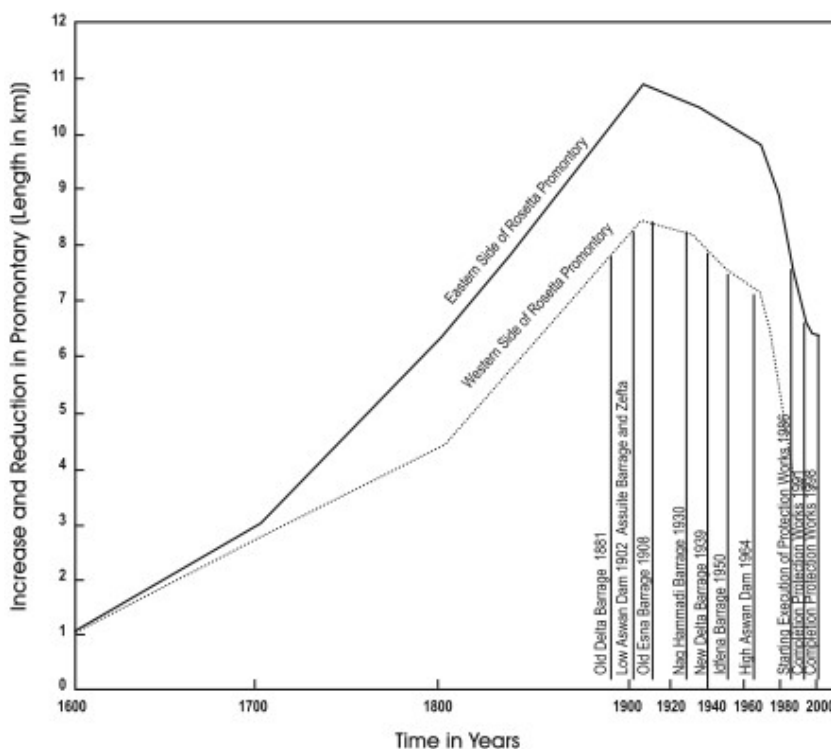

Figure 2: Historical advance and retreat of the Rosetta promontory (Hamza 2006).

comprehensive study of the forces affecting the coastal changes in the area began in 1981 including: hydrographic survey, directional wave and current measurements and the movement of the sediment and their characteristics.

This paper continues focusing on the sedimentation problem inside Rosetta estuary which has been studied in details by previous works [8,9]. It aims to improve the Mediterranean coast stability at the Rosetta outlet by developing an integrated sustainable solution

to enhance stability conditions using calibrated/validated Coastal Modeling System.

Methodology

Based on the collected field data, a calibrated/validated depth averaged model has been built to understand the hydrodynamic processes, the sediment transport mechanism and check the validity of a suggested integrated approach based on a combination of hard measures, soft measures and nourishment. The calibrated/verified

Coastal Modeling System (CMS) is used to test the different scenarios in terms of hydrodynamic and morphodynamic effects of these scenarios. A total of 24 scenarios are tested.

The Coastal Modeling System (CMS) interactively calculates wave transformation and wave-induced currents, water level change by tide, wind, waves, interacting waves and currents, sediment transport and morphology change [6] The description of the model was described in details by [10] The setup of the CMS model (flow, and wave), forcing data, sensitivity analysis, and the calibration of the model were described in details by Masria et al. [11,12].The modeling procedure is briefly presented in Figure 3. In order to achieve the objective of this paper, 24 scenarios are tested. The effect of the hard structures at the center of the outlet and at the boundary on the erosion and sedimentation is investigated. The optimal scenario is selected then used with the beach nourishment or near shore nourishment. Six cross sections inside the outlet (Figure 4a) and seven profiles at the boundaries (Figure 4b) are selected to investigate the performance of each scenario or measure.

Model results for each scenario are compared to the case of morphological changes in the case of no action (the recent situation without addition coastal structures).

Testing hard structures (boundary jetties)

This main aim of using the boundary jetties with different lengths is to select the scenario which most control the sediment transport east and west of the promontory via modeling process [7] The eroded sediments from the eastern tip of the promontory move into two directions: one portion towards the west to be deposited on the eastern side of the estuary causing sedimentation of its eastern side, while the second portion is directed towards the east of the promontory. On the other hand, the western jetty is selected to decrease the wave energy
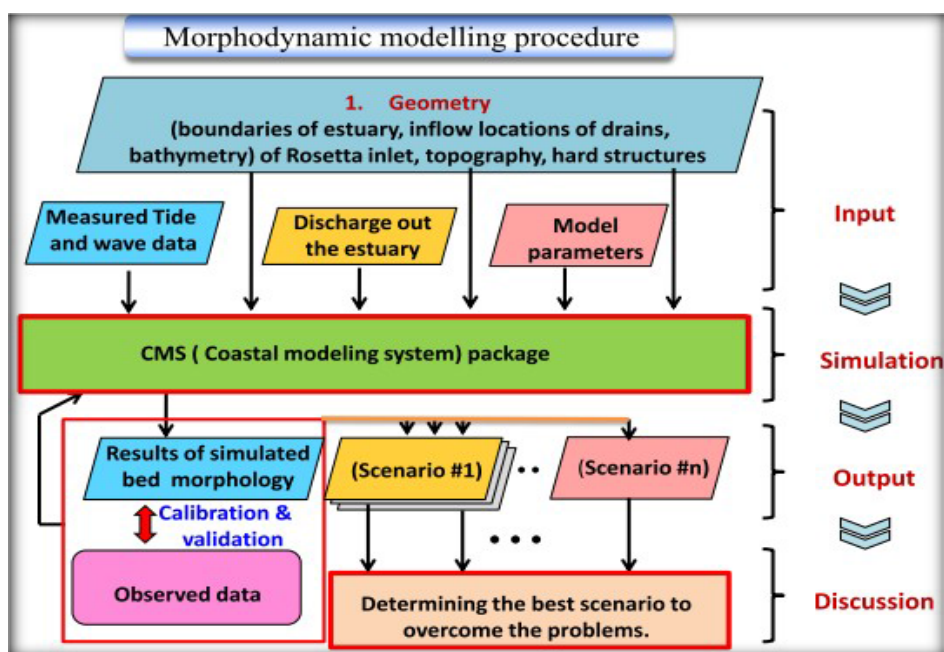

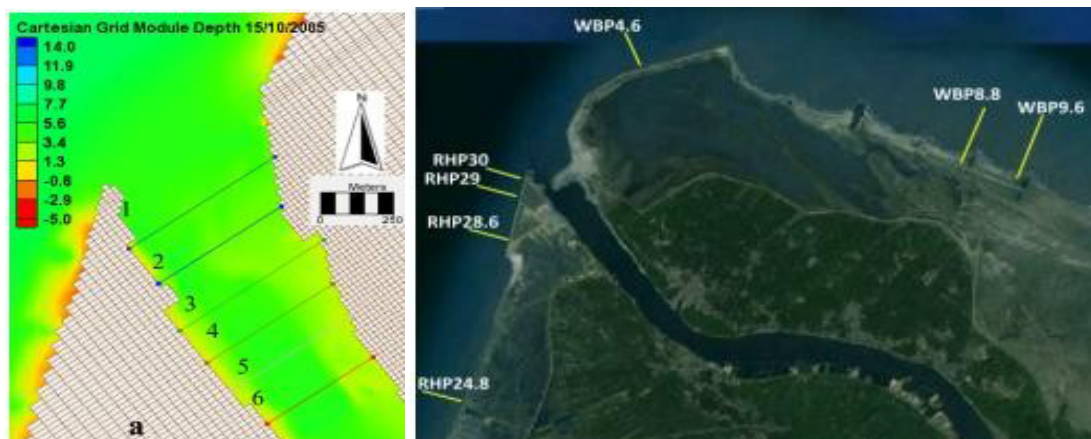**Figure 3:** Hydrodynamic modeling procedure.

Figure 4: a) Cross sections through the inlet used in the comparative study, and the bed elevations at the beginning of simulation, b) location of the selected profiles along eastern and western sides of Rosetta inlet.

at the outlet, hence decreasing the radiation stress that generates the sediment transport inside the outlet.

Sand nourishment scenarios

The sand nourishment is considered to overcome or at least minimize the erosion in front of the seawalls. Two different nourishment sets were simulated: beach nourishment, and near shore nourishment. The authors Masriaet. al. [13] checked the availability of sediment resources for the nourishment and identify two main sources; offshore source with mean grain size range between 0.1 and 0.18 mm and land source with mean grain size range between 0.24-0.32 mm. Also by using Particle Tracking Model (PTM) they found that the sediment source come from El Khatatba which located 150 km from the site landward with mean grain size 0.32 mm is more efficient within this area.

Testing a combination of using jetties and nourishment

These group of scenarios used a combination of the optimal jetties from 2.1 and the nourishment. From 2.2 to obtain an improved integrated solution for long term stability (sustainable) to Rosetta promontory/eastury.

Results and Discussion

Hard structures effect on the outlet stability

Eastern jetty: In this group, four scenarios were tested. The boundary jetty has been used in this group at the eastern tip of the promontory to cut the vortex within this area which causes the sedimentation problem in the outlet.

The model results are summarized in Figure 5. The results show that the eastern jetty has a remarkable effect on decreasing the siltation problem inside the outlet especially for jetty length exceeds 350 m. The new outlet cross section is more suitable for navigation compared to the case of no action. On the other hand, these jetties partially eliminate the erosion in front of the east revetment as well as the tip of the west revetment. But the accumulation of sediment in the eastern side of the jetty causes sand bypass which regenerate the siltation problem in the outlet.

In general, the eastern jetty with length more than 350 m can help in improving the hydrodynamic condition of the promontory. The main point here is sediment filling in the upstream of the jetty should
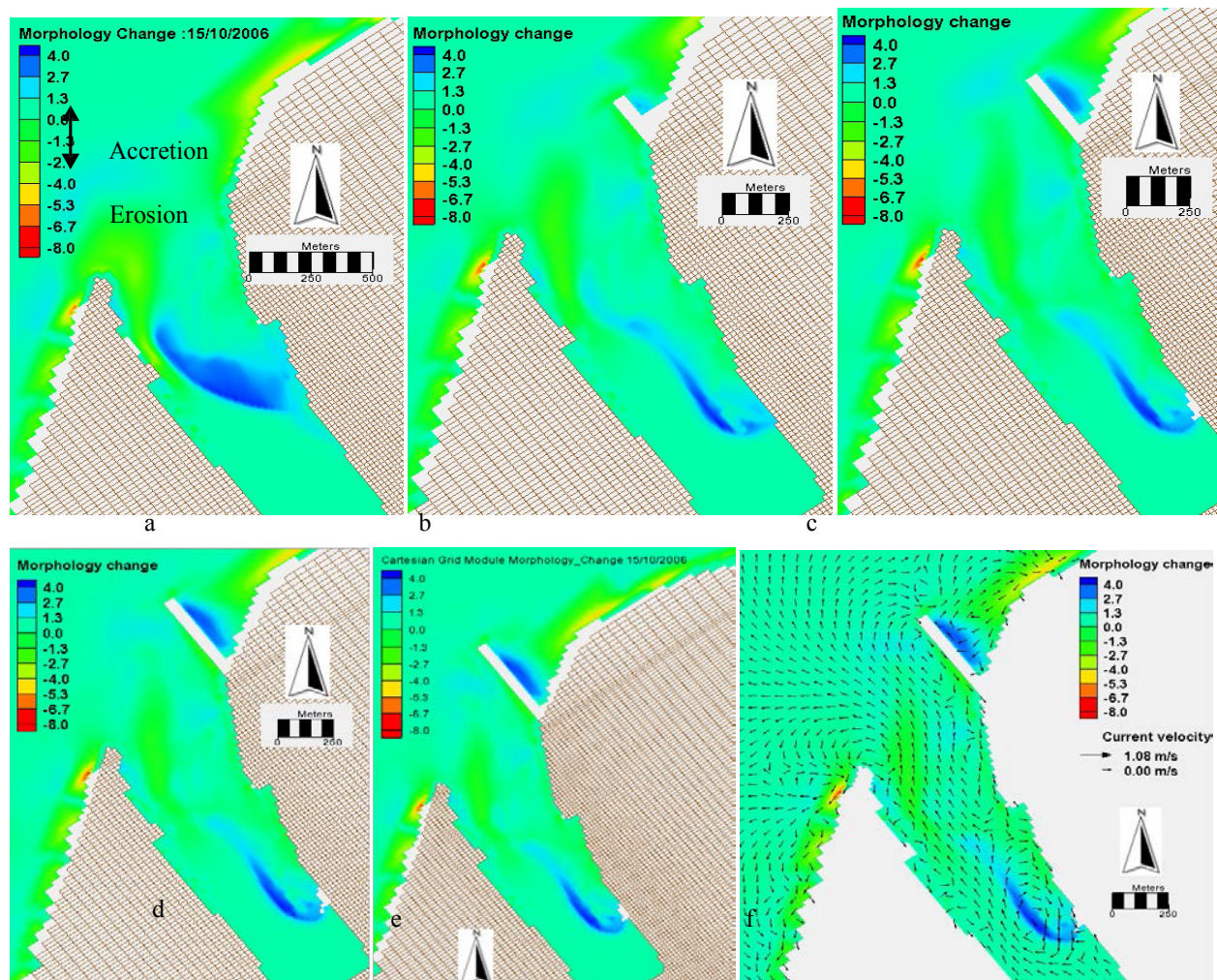

Figure 5: Model results of the morphological changes on Rosetta Promontory due to using eastern jetties after one year. a) without structure, b) jetty length 230 m, c) jetty length 360 m, d) jetty length 460 m, e) jetty length 580 m, f) morphology change with current velocity.
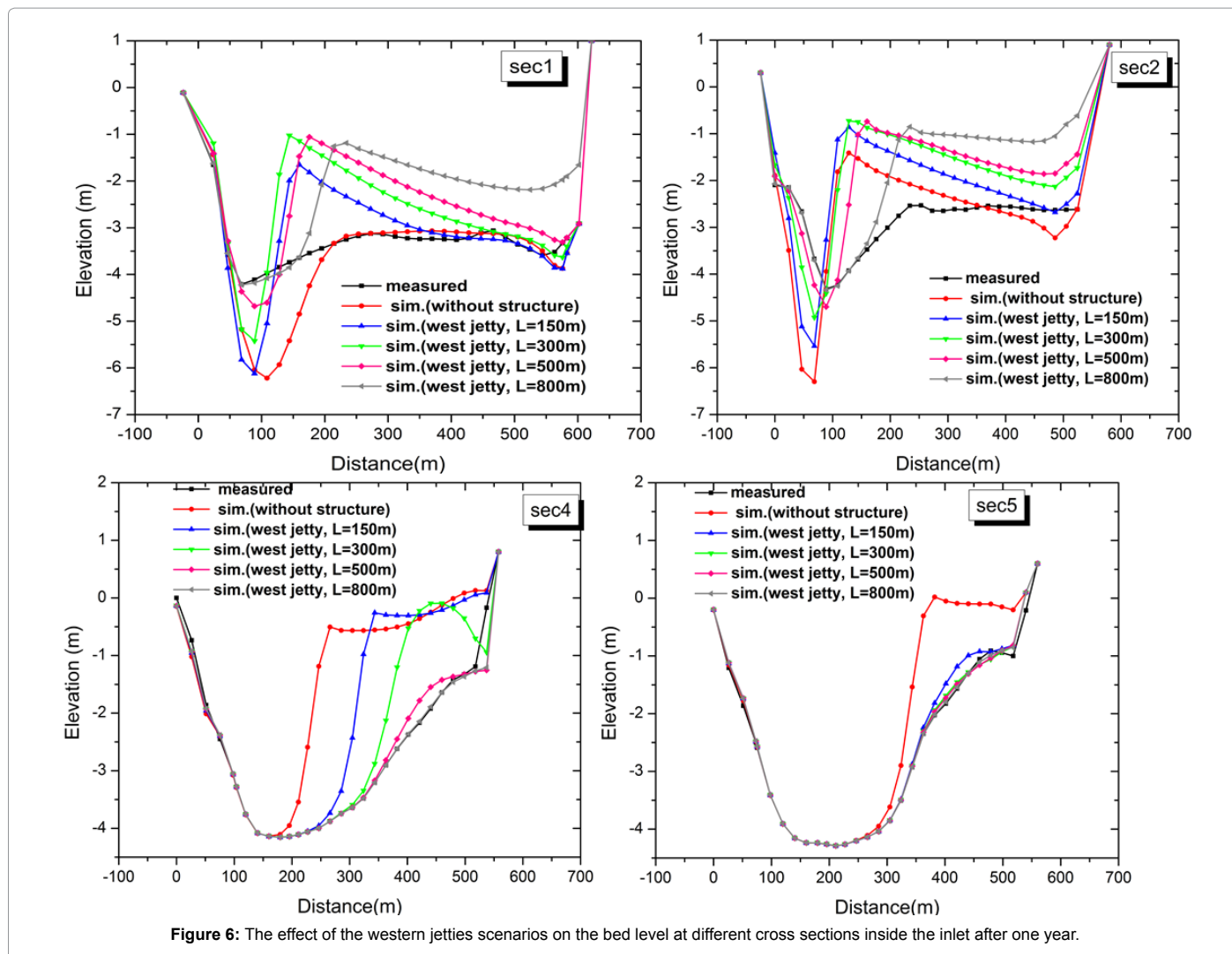
Figure 6: The effect of the western jetties scenarios on the bed level at different cross sections inside the inlet after one year.

not be allowed to avoid sediment bypass which will accumulate inside the estuary (Figure 5f).

Western jetty: In the western jetties group, four scenarios were tested including the boundary jetty at western tip of the promontory to eliminate the hydrodynamic force west of the estuary. Figure 6 shows the effect of the different lengths of the western jetty on the bed morphology as well as on the hydrodynamic parameters at Rosetta promontory after one year. It is clear that the western jetty decreases the wave energy that reaches the outlet which accelerates the sediment accumulation within the estuary. Increase the jetty length will move the sedimentation area seaward. Generally, the western jetty is not sufficient alone to solve the promontory problems but can be useful if combined with other system of protection measures.

In spite of the eastern jetty which has some advantage in developing the hydrodynamic characteristics of the Rosetta promontory, all the above alternatives failed to solve the promontory problems. Accordingly, the next group of alternatives is proposed to reach the desired stability condition of the promontory. These alternatives are combination of the best scenarios concluded from the centered, eastern, and western control measures.

Combination between the best of eastern and western: In this

group, additional three scenarios were tested. The first two successive scenarios represent a combination between the eastern jetty of 360 m length and the western one with two different lengths (500 m, 800 m) , and the last one is to add centered front jetty (the best in the centered jetties group) with the eastern jetty (360 m) and the western one (800 m).

Figure 7 shows the effect of these scenarios on the bed level at different outlet's cross sections after one year. Generally, it is concluded that both eastern jetty alone and the combination between the eastern (360 m) and the western one (800m), enhance the hydrodynamic condition of the estuary and can be used to stabilize the Rosetta outlet. The only restriction in these two solutions is the request for continuous dredging for the accreted area behind the eastern jetty and bypassing the sediment to the hotspot areas in front of the revetments which suffer from severe erosion as shown in Figure 8.

Although that eastern jetty of length 360 m or a combination between the eastern jetty and the western jetty of length 800 m show good results compared to the other alternatives in term of decreasing the accretion inside the outlet, but still not have a significant effect on mitigating erosion in front of the revetments. So, the second approach as mentioned earlier will focus on obtaining an integrated solution to maintain the stability at the promontory.
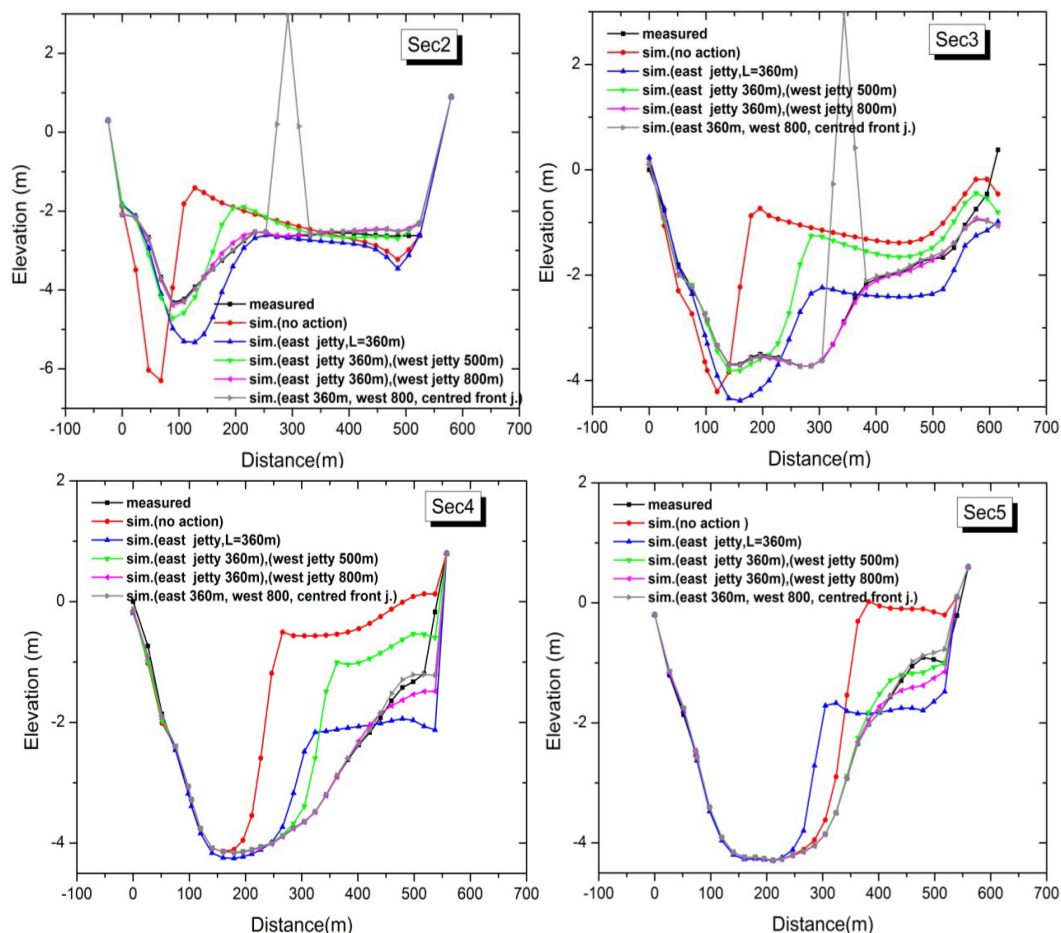
Figure 7: The effect of the second advanced group on the bed level at different cross sections inside the outlet after one year.

Sand nourishment effect on rosetta outlet stability

This approach is conducted by supplying sediments (sand nourishment) in front of revetments. The sediments are supplied through the following nourishment techniques: beach nourishment and near shore nourishment.

The proposed placement sites of the nourishment material were selected in a previous work by Masria et al. [10] according to the hot spots of the erosion at both the (nodal point) at the eastern side of the promontory where long shore sediment transport is diverted to east and west and also at the western side of the promontory with different volumes and geometries for both techniques.

The morphological change after one year, for different scenarios of applying 100,000 m³, 200,000 m³, and 300,000 m³ were simulated using the CMS software. Figure 9 shows a sample of the results for the near shore nourishment volume of 300,000 m³. From the results, it is clear that all scenarios almost have the same trend at the accreted areas. To accurately study the second scenarios with different volumes, the hotspot area was divided into three subareas; the eastern, middle and western as shown in Figure 10. The bed profiles are plotted compared to the initial profile before adding the nourishment material. It is clear that all scenarios showed a negligible effect compared to no action scenario except scenario two which showed slight improvement at the eastern profile WBP 3.8 as shown in Figure 11.

Although the second set of scenarios with sand volume (300,000 m³) is slightly better than other scenarios in comparison with no action scenario, it is clear that there is no significant effect of the near shore nourishment technique in decreasing the severe erosion in front of the seawalls. It may be due to the interaction between the revetment and the hydrodynamic force which guide the sediment outside the desirable area. On the other hand, it increases the siltation problem inside the outlet.

So, it is recommended in the next section to test boundary jetties which control the flow and sediment from the outlet with beach nourishment east and west of the promontory to solve the erosion problem.

Combination between hard and soft measures

From above mentioned alternatives, it was found that both beach nourishment and near shore nourishment are not sufficient to mitigate the promontory problems. So, the best solution from each of the previous methods will be combined with the hard structures in order to trap the long shore sediment that present the key for erosion problem.

In this section two scenarios are tested. The first scenario include the best from the near-shore nourishment (placement site is at eastern side centered on the nodal point for sand volume 300,000 m³) with an inclined groins at the western revetment (to prevent the erosion occurs at the western tip of the revetment), and eastern jetty of 360 m length
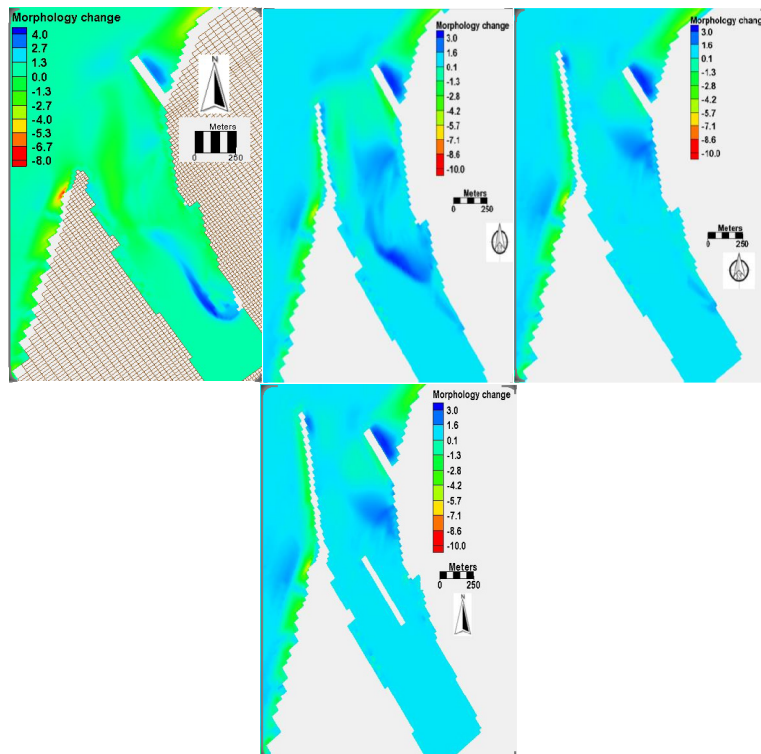
Figure 8: Model results of the morphological changes on Rosetta outlet due to different scenarios after one year. (a) jetty length 360 m, (b) eastern jetty360 m with the western 500m, (c) eastern jetty360 m with the western 800 m, (d) eastern jetty360 m with the western 800m and front jetty.
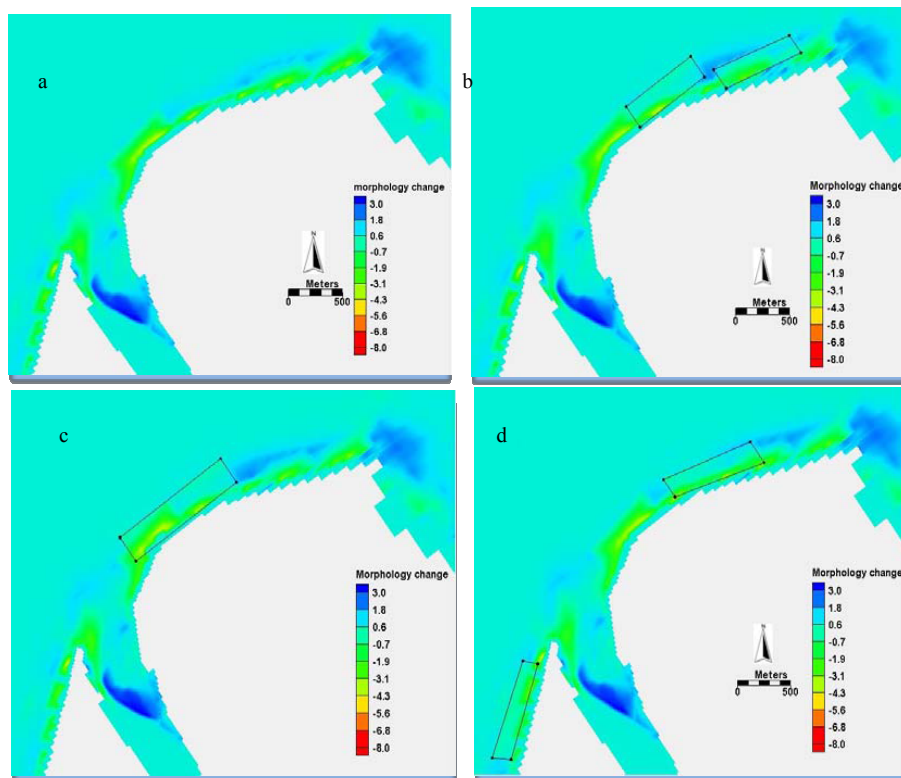

Figure 9: Model results of the morphological changes of different near shore nourishment scenarios for (3000000 m³ of sediments a) no action, b) at right side of nodal point, c) at centered of the nodal point, d) at both eastern and western side.
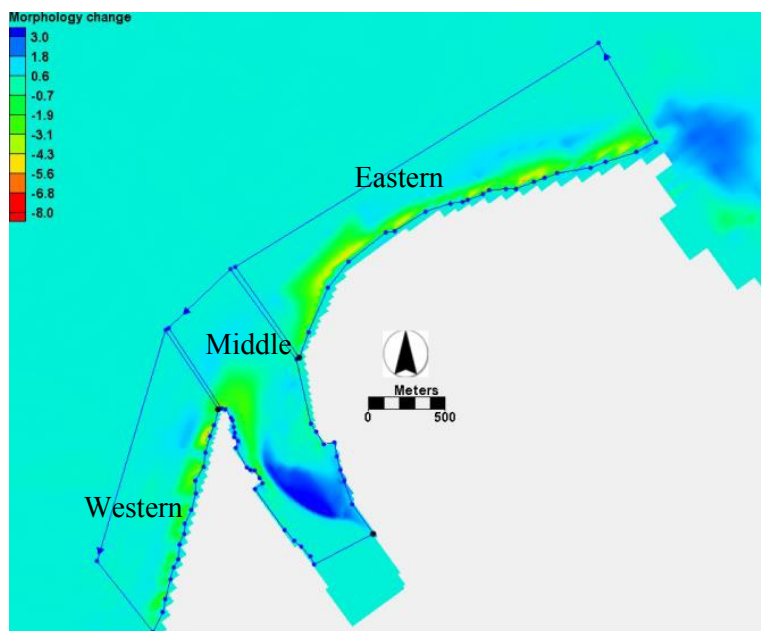
Figure 10: Three subareas used to estimate sediment volume (accretion erosion and net volume).
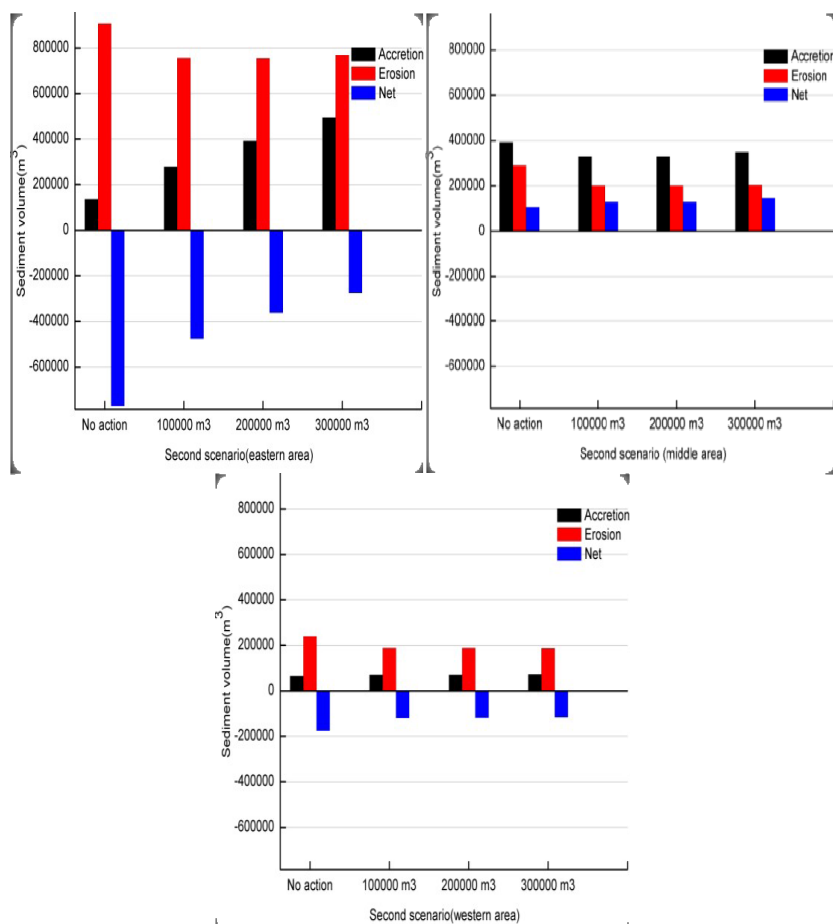

Figure 11: Annual sediment volume of the second scenario for different nourishment volumes (1000000, 200000, and 300000 m³); a) eastern area, b) middle area and c) western area.
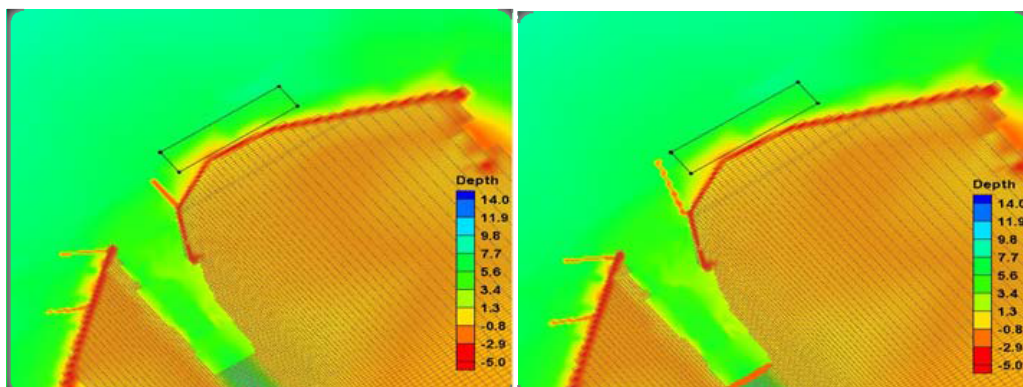
Figure 12: The two tested scenario (combination between the best scenarios in near shore nourishment group with hard structures).
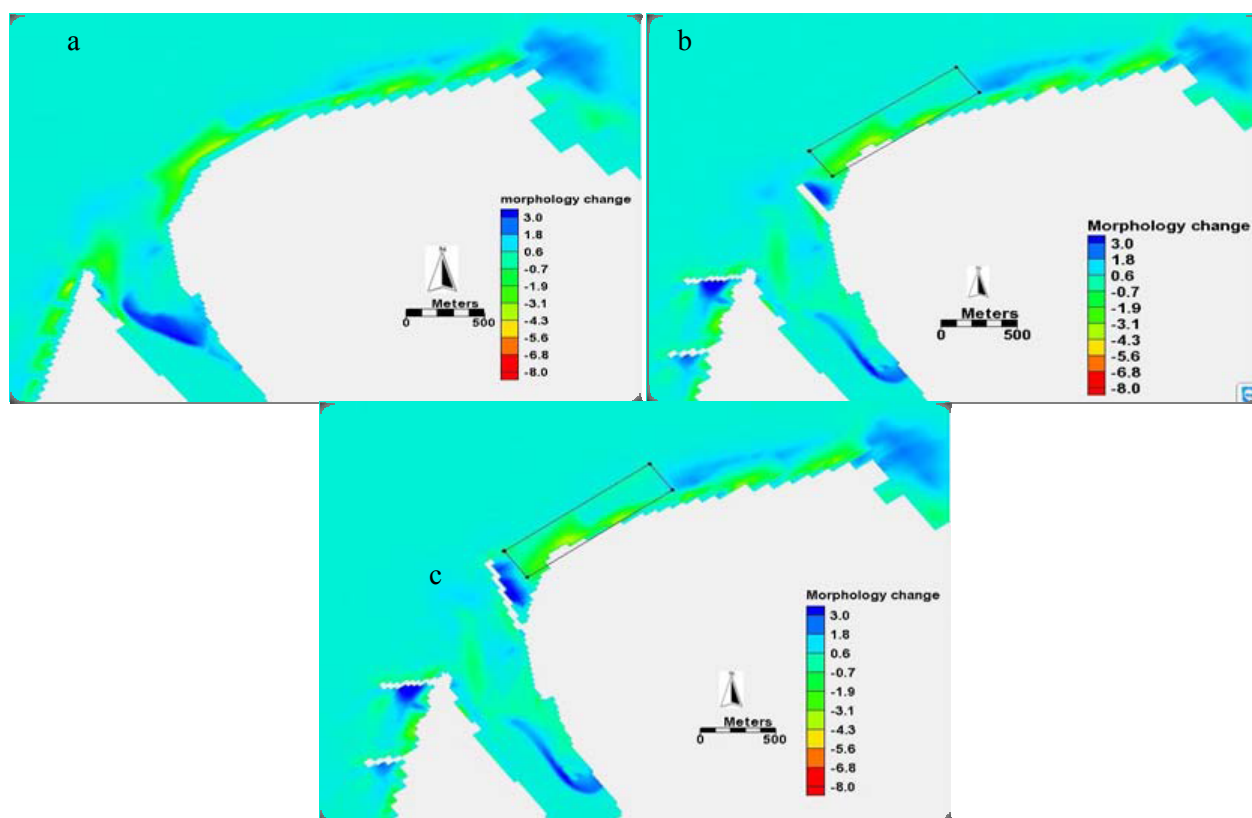

Figure 13: Model results of the morphological changes of different nourishment scenarios (a) no action, (b) first scenario and (c) second scenario.

(to prevent the accumulation of the sediments through nodal point inside the inlet). The second scenario is the same as the first one; the only difference is that the eastern jetty is inclined. Figure 12 shows the two proposed scenarios in this section.

Figures 13 and 14 show the morphology change and annual sediment volumes after one year, for the two scenarios. It is illustrated from this figure that the both scenarios enhance the inlet stability compared to the no action case in terms of reducing the sediment accumulation inside the inlet. In addition, it decreases the erosion rate at the hotspot areas in front of the eastern and western revetments (especially the western one).

Generally, it is concluded that both scenarios improve the stability of the promontory, therefore, the scenario with lower construction cost will be preferred. In Egypt, the cost of the breakwater ranges between 6000 to 8000$ per meter) depends on the depth. For the sand nourishment, the cost ranged from 8 to 10$/m³ depending on the location. For Rosetta, the construction cost of the hard structure can be roughly calculated as 7000$ per meter and the nourishment as 9$/m3, "Egyptian *Coastal Research Institute*". The construction cost consists of the cost of constructing the hard measures and the cost of sand nourishment, as follows:

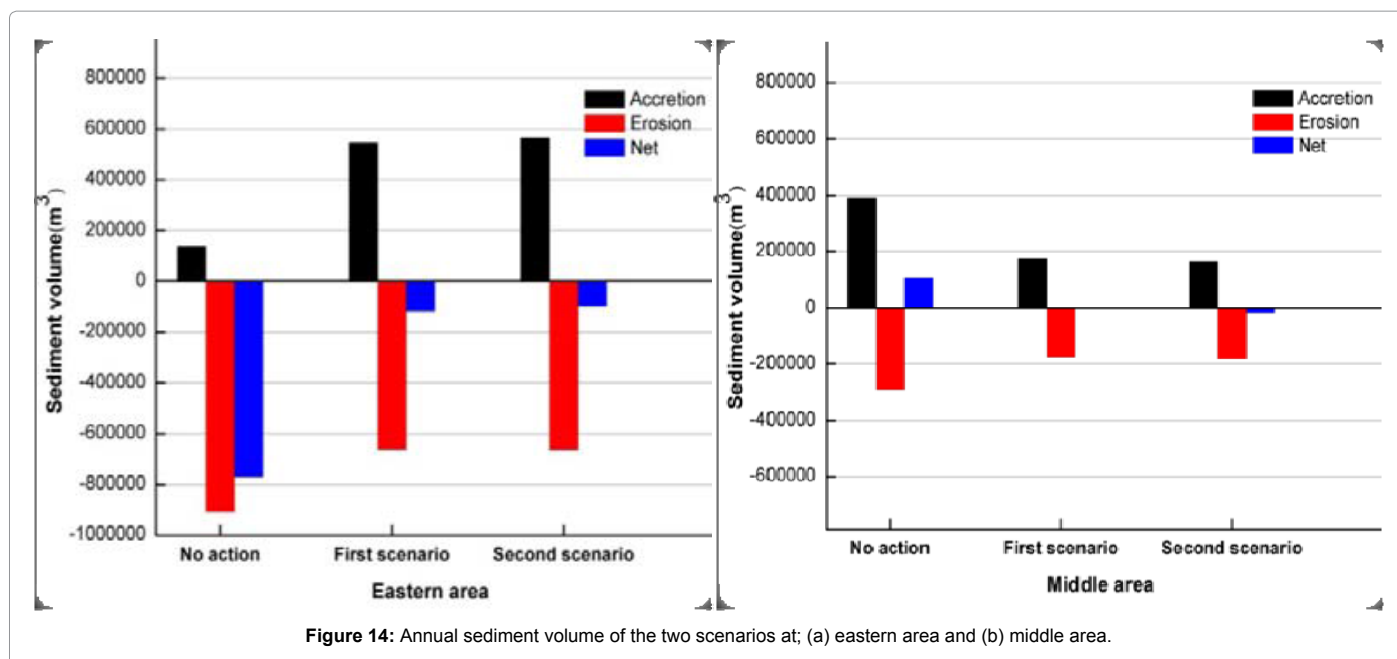Cost for first scenario=(400+400+360)* 7000+(300000*9)=8,120,000 $

Figure 14: Annual sediment volume of the two scenarios at; (a) eastern area and (b) middle area.

Cost for second scenario=(400+400+580)*7000+(300000*9)=9,660,000 $

So, according to construction cost, the best scenario from this group is the first one.

Conclusion

The hydrodynamic modeling was applied through two approaches to solve the coastal problems (erosion and accretion) at Rosetta promontory in terms of obtaining an integrated long-term (sustainable) solution to enhance stability conditions of Rosetta estuary. Different measures including hard (jetties), soft (sand nourishment) and combination between both are presented to investigate the effect of each one on the Rosetta promontory stability, hence reach to an integrated solution.

CMS was used to check the tested alternatives. The hard measures shows a significant effect in mitigating the accretion problem, but the promontory still suffers from erosion in front of the seawalls. On the other hand, it is clear that there is no strong effect of the near shore nourishment technique in overcoming the severe erosion in front of the seawalls. The combination between the hard structures and soft one proved to be an efficient method to mitigate the coastal problems as it decreases the siltation problems inside the inlet, in addition to decrease the erosion in front of the seawalls.

Acknowledgments

References

1. Hamza W (2006) The Nile Estuary. The Handbook of Environmental Chemistry 5: 149-173.

2. El Askary MA, Frihy OE (1986) Depositional phases of Rosetta and Damietta promontories on the Nile delta coast. Journal of African Earth Sciences (1983) 5: 627-633.

3. El-Raey M (2005) Sustainable Management of Scarce Resources In the Coastal Zone.

4. Donia N (2005) Rosetta branch waste load allocation model. In Ninth International Water Technology Conference, IWTC9 2005, Sharm El-Sheikh, Egypt, 277-288.

5. El-Sayed W R , Ali M A , Iskander M M, Fanos A M (2007) Evolution of Rosetta Promontory on Nile Delta Coast during the Period from 1500 to 2005, Egypt.8th International Conference on the Mediterranean Coastal Environment, MEDCOAST 07, E. Ozhan (Editor), 13-17 November 2007, Alexandria, Egypt, 2: 1003-1015.

6. CRI/UNESCO/UNDP (1978) Coastal protection studies. Final Technical Report, Paris, 1, Demirbilek, Z. et al., 2008. Particle Tracking Model (PTM) in the SMS 10: IV. Link to Coastal Modeling System.

7. Fanos AM, Khafagy AA, Dean RG (1995) Protective works on the Nile Delta coast. Journal of Coastal Research. 11: 516-528.

8. Masria A, Abdelazim Negm, Moheb Iskander, Oliver C. Saavedra (2014) Numerical Investigation of the Impact of Jetties on Accretion Problem at Rosetta Promontory, Egypt. International Journal of Environmental Science and Development 5: 510-516

9. Masria A, Iskander M, Abdelazim Negm, Oliver C. Saavedra (2014) Numerical modeling of Rosetta river mouth, Egypt. International Water Technology Journal 4: 190-207.

10. Masria A, Iskander M, Abdelazim Negm, Oliver C. Saavedra (2014) The effect of potential discharges on the stability of the Rosetta promontory, Egypt. In River Flow 2014. CRC Press 1345-1353.

11. Masria A, Abdelazim Negm, Moheb Iskander, Oliver C. Saavedra (2014). Hydrodynamic modeling of outlet stability case study Rosetta promontoryin Nile delta.Water Science 27: 39-47.

12. Masria A, Abdelazim Negm, Moheb Iskander, Oliver C. Saavedra (2013) Numerical Simulation of Constructing Jetties to Stabilize Rosetta inlet, Egypt. Seventeenth International Water Technology Conference, IWTC17, Istanbul, 5-7 November.

13. Masria A , Nadaoka K , Kuriyama Y, Negm A , Iskander M et al. (2015) Near shore and Beach Nourishment effects on the Stability of Rosetta Promontory, Egypt. 18th International Water Technology Conference IWTC18, Sharm Elsheikh, Egypt, 12nd to 14th March 2015, 93: 11.