Numerical Investigation of the Impact of Jetties on Accretion Problem at Rosetta Promontory, Egypt

Ali Masria, Abdelazim Negm, Moheb Iskander, and Oliver C. Saavedra

***Abstract*—Estuaries are very sensitive and vulnerable to any interventions in coastal dynamics. Erosion began to take place since the beginning of the 20th century along Rosetta area, and increased dramatically since the construction of the High Dam in 1964. Many protective works have been implemented and/ or under construction since 1989 and up to the present time. Erosion is not the only problem facing the area but also, the accumulation of sediments inside the inlet is also taking place because of the littoral drift and the absence of the outflow of water from Rosetta branch. This paper aims to reach a new condition of stability of Rosetta Promontory by using boundary jetties to reduce coastal dynamics at the outlet .Moreover the effect of the angle of the western jetty was investigated to reach suitable position of it. This target is achieved by using a hydrodynamic model Coastal Modeling System (CMS). About eight scenarios were tested to reach suitable solutions that mitigate the coastal problems at the inlet specially the accretion problem. The results show that 360 m jetty combined with an inclined western jetty of 800 m length enhances the stability of the inlet.**

***Index Terms*—Erosion, Rosetta, sedimentation, jetties.**

I. Introduction

Inlets play an important role in exchanging water and providing a navigational pathway for ships to travel between the open oceans and sheltered waters [1]. It is a unique environment that connect fresh river water and saline coastal water [2]. In addition, it provides a link between the coastal ocean and back-barrier bay, exchanging water, sediment, nutrients, and other materials between them [3]-[5]. They have a high biological productivity, and are generally situated in densely populated areas [6]. Many different hypotheses have been brought forward to explain inlet closure [7]-[10].

Sedimentation problems generally occur at locations where the sediment transporting capacity of the hydraulic system is reduced due to the decrease of the steady (currents) and oscillatory (waves) flow velocities and related turbulent motions, [11].

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Engineering modifications at inlets are usually used to enhance navigation process and typically involve a combination of jetties and maintenance of a dredged channel [12]. Although engineering projects are targeted to solve problems, but it can also contribute in creating problems at other nearby locations as an environmental impacts or side effects. It is better to design in a such way that side effects (sand trapping, sand starvation, downdrift erosion) are minimum, [11]. Therefore, understanding of the intervention-induced effects on inlet dynamics, and quantifying its morpho-dynamics is crucial for successful coastal management. Various solutions were performed. For instance, U.S. Army performed a structural solution involving new jetties at the Mouth of the Colorado River (MCR), Texas as the site has experienced excessive sediment shoaling. It is expected that this new jetty will be a permanent structural solution that would reduce dredging frequency while maintaining a reliable channel [13].

However, interaction between controlling structures and hydrodynamics often results in unexpected morphologic changes [14]. The jetties should be long enough such that the sedimentation at the entrance of the channel due to longshore sediments transport is minimum. Sediment accumulation will generally take place on the updrift side of the jetties and erosion on the downdrift side. Mechanical bypassing of sediment may be required to reduce downdrift erosion [11].

In Egypt, the navigation channels, which connect the Mediterranean Sea and the Nile branches, are economically important for thousands of fishers. Rosetta promontory is located on the eastern side of Abu- Quir Bay at about 60 km to the east of Alexandria city, Egypt as shown in Fig. 1. The promontory suffers from the extensive erosion due to damming the Nile River. Moreover, Rosetta mouth considered as a sink for the eroded sediments transported offshore from Abu Quir Bay and Rosetta [15]. These sediments accumulate inside the inlet and results in a great problems for navigation processes, the living of habitat in this area, and also threaten the nearby areas with inundation in case of flooding conditions as it reduces the capacity of the waterway.

The wide river entrance described probably was responsible for this problem. Fortunately, the problem of sedimentation was solved in 1998. Unexpected high flood waters flushed the lower Nile distributaries including the Rosetta branch [16], but it came back again due the severe reduction in fresh water discharges. In addition, frequent dredging is carried out to overcome the siltation problem inside the estuary, but it failed to solve the siltation problem[15], [17]. This paper focuses on how to stabilize Rosetta promontory by using boundary jetties, and to investigate the best alternative of the western jetty (inclined

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or parallel) in order to reduce the sedimentation at the estuary.

Fig. 1. Location of the study area (Rosetta promontory at the terminal of Rosetta branch, Google earth (2007).

II. Methodology

A. Field Data Collection

The field data (bathymetric, wave, tide, Rosetta branch discharges) was obtained from the Coastal Research Institute, Hydraulic Research Institute (National Water Research Center, Egypt), and Coastal Protection Authority (Ministry of Water Resources and irrigation, Egypt). The bathymetric survey (about 50 profiles which are perpendicular to the coastline) utilized in this study was conducted in October 2005. The bathymetric survey of May 2006 was used to calibrate the numerical model. The wave data are the averaged wave climate of five years between 1986 and 1990. The wave directions are from WNW, NNW, N, and W with a small portion of waves arrived from the NNE and NE especially in March and April [17]. Fig. 2 shows the average wave height- direction distribution where NW is dominant. The Nile delta coast is a typical micro tidal semi-diurnal tidal regime with a tidal range of 30 cm [18].

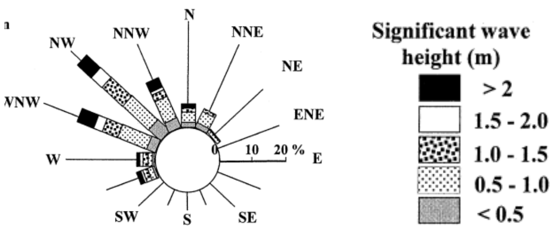


Fig. 2. Average wave direction-height distribution [19].

The available tide data represented in water levels at Rosetta promontory covered the period from October 2005 to October 2006, Fig. 3. The sediment grain sizes(d_{50}) at the nearshore zone of the area of interest are between 0.16 mm and 0.24 mm based on previous study [20]. In order to transform the wave from offshore station at depth 18 m to the model boundary at 11m depth, the maximum entropy code (by CMS developers) was applied for the directional spectrum to be ready as input in the model.

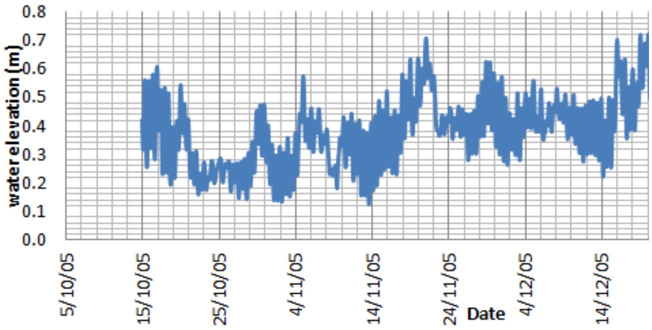


Fig. 3. Sample of measured water levels data by Coastal Research Institute, Egypt (CoRI) 2005.

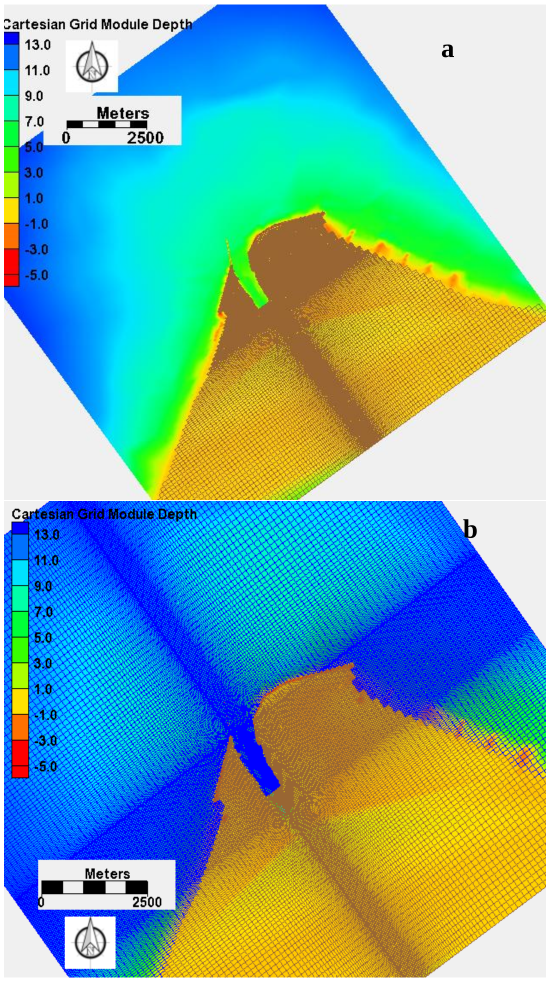


Fig. 4. a) The model domain of Rosetta estuary, depths (positive) are relative to mean sea level, b) The Cartesian grid of the study area.

B. Model Establishment and Calibration

The near-shore, offshore, the inlet, Rosetta branch, and adjacent beaches were surveyed between 2005 and 2006 by Coastal Research Institute. The CMS grid was constructed based on the above mentioned bathymetric data. A variable sized rectangular-cell grid system, with a spatial resolution ranging from 20×20 m in the vicinity of the inlet, and the near-shore zone, navigation channel to 70×120 m near the ocean boundary was generated. Having the fine grid spacing at and around the estuary enabled capturing the sediment transport and morphologic change processes where they mainly occurred. Larger the offshore grid spacing, the speeder the computational process is. A CMS-Wave was also generated that had the same dimensions of the flow grid. To simulate the flow field, CMS-Flow was driven by the measured tide along the open boundaries from October 2005 to May 2006. After examining 5 years (1986-1990) records, wave during 1986 was judged to be representative and used in the modeling effort. The half-plane model of CMS-Wave was selected for this study. Fig. 4a, 4b shows the model domain, the CMS grid bathymetry based on the available bathymetric data in October 2005.

The model was calibrated with main focus on the parameter: hydrodynamic time step, Manning coefficient, different transport formulas, scaling factor for bed load and suspended load, total adaptation length, and also the effect of smoothing the bathymetric contour. The correlation coefficient according to bed change and bed depth was calculated at all profiles. The results show that a good agreement with the measurements can be picked up with 0.025 of Manning coefficient, 0.20 mm of d_{50}, 450 sec time step, scaling factor of 2.0 and adaptation length of 10 m. Interested reader can consult [21] for more details on the calibration processes.

III. Results and Discussion

This work is an attempt to reach a new stability condition for the Rosetta promontory. This target can be achieved by controlling the flow and the sediment transport from the eastern and/or western side of the promontory.

This main idea is translated into two groups of coastal structures checked its efficiency by using CMS model. The first group focuses on controlling the sediment transport west of the promontory by using western jetties with different lengths, Table I. This group is proposed as the prevailing wave direction in study area come from WNW, NNW, NW to eliminate the hydrodynamic force west of the estuary.

TABLE I: The Different Scenarios of Group 1

Scenario	Description
1	An inclined western jetty, (150m long)
2	An inclined western jetty, (300m long)
3	An inclined western jetty, (500m long)
4	An inclined western jetty, (800m long)

The second group includes the combination from the most effective scenarios among the first group and eastern jetty, and compare between these scenarios if the western jetty becomes straight not inclined.

Six cross sections inside the Rosetta Inlet were utilized to compare the morphology of bed profiles for the different scenarios as shown in Fig. 5.

In the first group, four scenarios were tested, Table I. Fig. 6 shows the effect of the different lengths of the western jetty on the bed morphology as well as the hydrodynamic parameters at Rosetta promontory after one year. It is clear that accumulated sediments move seaward compared to case of no action. This is due to the existence of the western jetty that shifted the breaking of the waves outside the inlet creating calm conditions behind the jetty as shown in Fig 7a. These conditions reduced the wave induced current inside the inlet which constitute a weak eddy vortex. But, the wave induced-current coming from nodal point at the eastern revetment, still affects the accelerated accumulation of sediments inside the inlet as shown in Fig. 7b. In general, the western jetty is not sufficient alone to solve the promontory problems but can be useful if combined with eastern one.

In the second group, a combination of western jetty of length 500, and 800 m (inclined and parallel) with an eastern jetty of length 360 m are checked. The eastern jetty has been used in this group at the eastern tip of the promontory to cut the vortex within this area which has an effect for the sedimentation problem inside the inlet.

The computed bed morphology at the Rosetta inlet after one year from the different scenarios was extracted from model results as shown in Fig. 8.

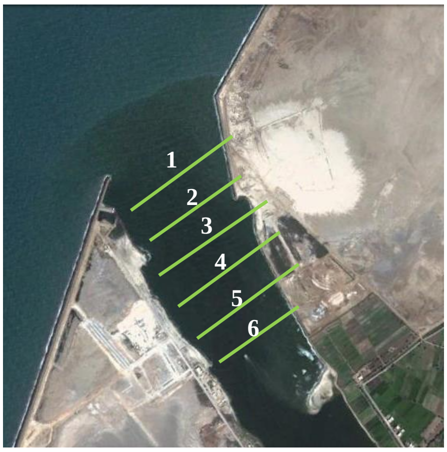


Fig. 5. Cross section through the inlet used in the comparative study of different scenarios.

The results show that, the behavior of the eastern jetty of length 360 m with inclined western one of length 500 m, and 800 m is better than the same scenarios with parallel ones. This is due to that, inclined western jetty shifts the wave breaking outside the inlet which creates calm conditions inside the inlet as the wave heights get smaller than those resulted from parallel jetties as shown in Fig. 9a and Fig. 9b. These conditions reduce the wave induced current inside the inlet which constitute a weak eddy vortex.

In addition, the inclined jetties increase the width of the navigation channel as shown in Fig. 9a and Fig. 10. This is due to increasing the current velocity inside the inlet which slows the closure of the inlet rather than parallel ones.

The accumulation of sediments inside the inlet in the case of parallel jetty resulted from a strong eddy vortex formation at the inner part of the inlet as shown in Fig. 11b. In general, results identify that combined eastern jetty of length 360 m with inclined western one of 800 m will contribute in enhancing the stabilizing Rosetta promontory but the inlet will require to be dredged annually. It is also recommended that dredged materials could be placed in the critical spot that experience erosion as shown in Fig. 11a to protect seawall from failure if the foundation are exposed.

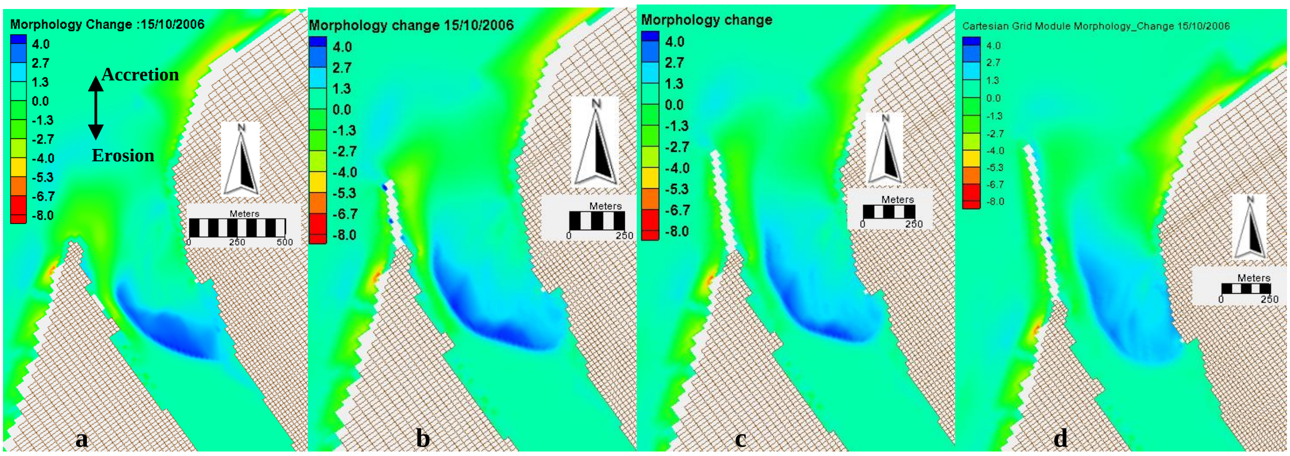


Fig. 6. Model results of the morphological changes on Rosetta Promontory due to using western jetties after one year. a) no action case, b) jetty length 300 m, c) jetty length 500 m, d) jetty length 800 m.

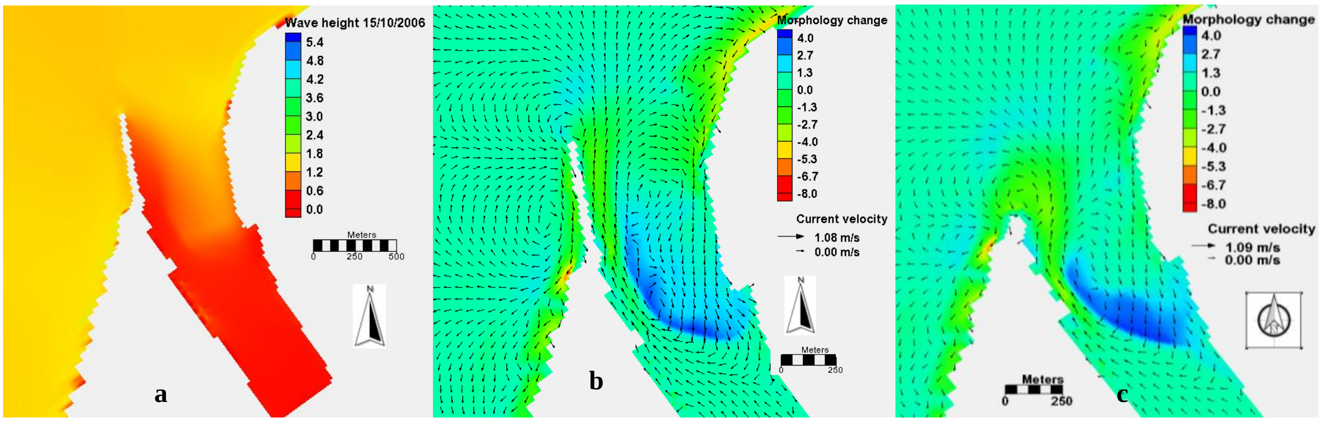
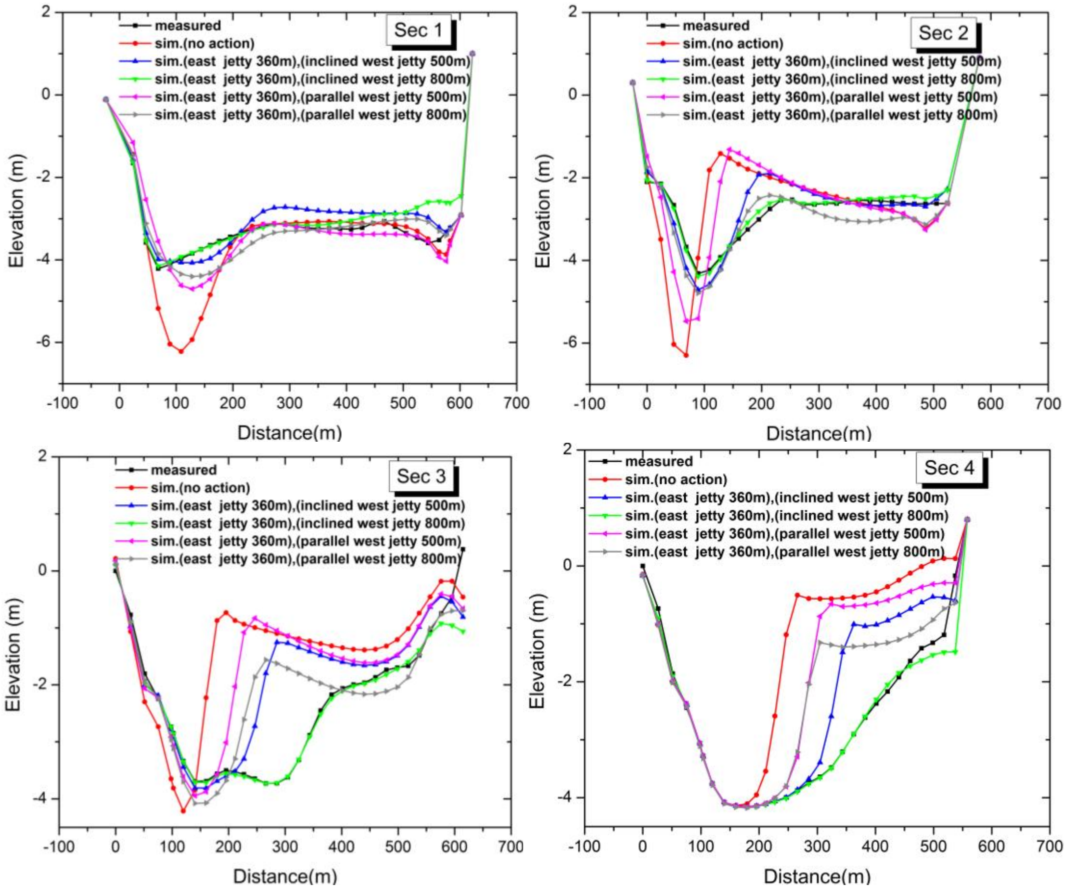


Fig. 7. a) Wave distribution around the jetty of 500 m length, b) Current distribution around the jetty of 500 m length, c) Current distribution in case of no action.



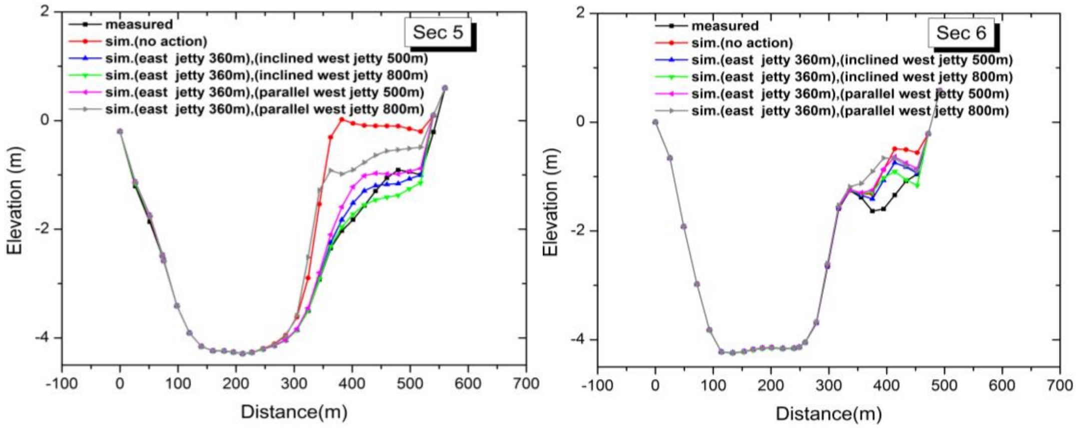


Fig. 8. The effect of the different scenarios on the bed level at different cross sections inside the inlet after one year.

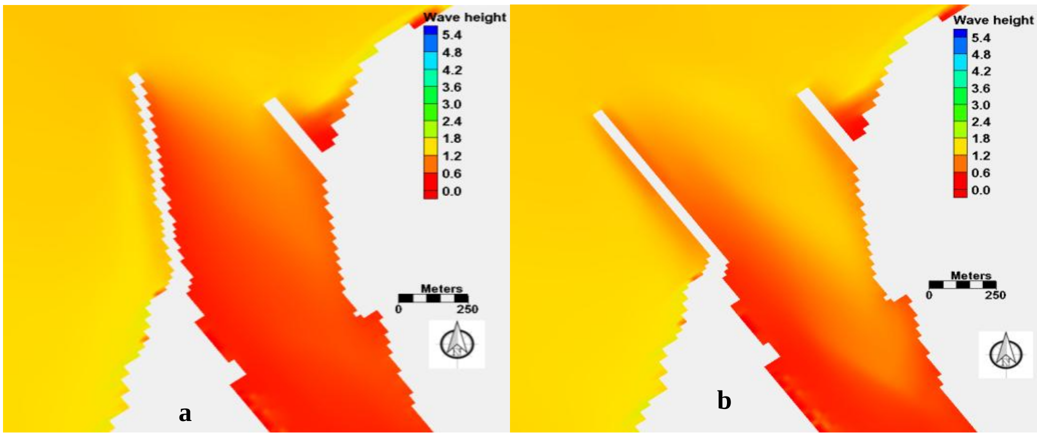


Fig. 9. a) Wave distribution around the eastern jetty of 360 m length with inclined western one of length 800 m , b) Wave distribution around the eastern jetty of 360 m length with parallel western one of length 800 m.

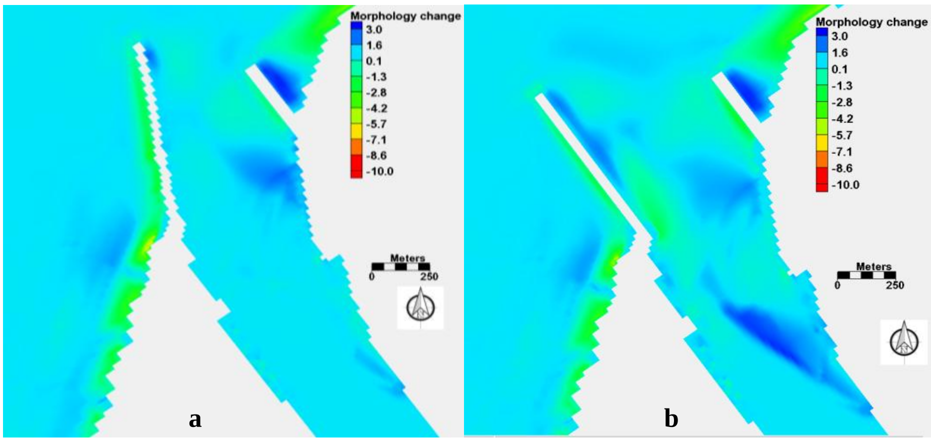


Fig. 10. Model results of morphological changes of Rosetta Promontory after one year, a) eastern jetty of length 360 m with inclined western one of 800m length, b) eastern jetty of length 360 m with parallel western one of 800m length.

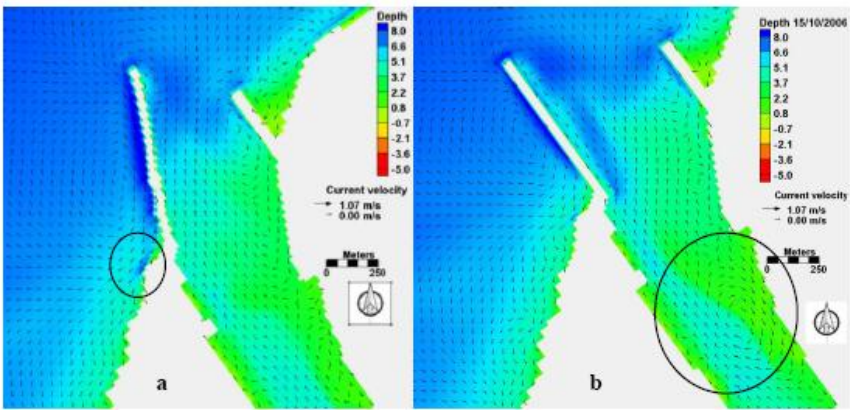


Fig. 11. Model results of grid depths of Rosetta Promontory after one year with current velocity vectors, a) eastern jetty of length 360 m with inclined western one of 800m length, b) eastern jetty of length 360 m with parallel western one of 800m length.

IV. Conclusion

Rosetta promontory suffers from many coastal problems as erosion problem along the coastline and accretion problem inside the inlet. Two groups of scenarios are proposed as an attempt to overcome the problem. The main idea is to reach a new condition of stability for the Rosetta Promontory by using coastal measures. These coastal structures are used to control the coastal hydrodynamics and sediment movement within the estuary.

The first group was used to test western jetty with different lengths resulting in reduction of the wave heights inside the inlet that affect generated currents. The second group consists of the best solution in the first group combined with an eastern jetty resulting in a reduction in the current induced sediments as the nodal point at the eastern revetment divert the current into the estuary.

CMS two dimension numerical model is used to check the effectiveness of these scenarios. All scenarios were simulated for one year.

It was found that the western jetties of lengths 500, 800 m for the first group have a better effect on the stability of the inlet than others. From the comparison between the (eastern jetty combined with the inclined western one), and (eastern jetty combined with the parallel western one), it was found that the inclined jetty has better results than other as it decreases the sediment accumulation inside the inlet due to the shifting of wave breaking outside the inlet. Particularly, combined eastern jetty of length 360 m with inclined western one of 800 m helped in stabilizing the Rosetta promontory. Also it is recommended to dredge the inlet annually, and pumping the sediments in the critical areas that suffer from erosion in front of seawalls till a sustainable solution is reached.

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