NAVIGATION CHANNEL PROBLEMS DUE TO SEDIMENTATION

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Keywords: Navigation Channel, Sedimentation, Maintenance, Damietta Harbour.

ABSTRACT

Navigation channel is one of the main components of any harbour that it facilitates the access of ships to harbour. Periodic maintenance is required to remove sediment trapped in navigation channel to maintain the required depth of channel. Maintenance costs vary from one harbour to another according to sediment volume and consume a considerable part of harbour income. So, sedimentation problem in navigation channel is considered a crucial issue according to economical and environmental point of view, which depends on geometric of navigation channel, hydrodynamic parameters and protection structures. Improvement of channel by deepening or widening the channel increases the sediment deposition. Also, improper design of protection structures made them insufficient. So many different solutions such as using open cycle pumping system or construct one way sand trap, extension of existing breakwater and changing orientation of channel were suggested to minimize sediment volume. However, Extension of existing breakwaters or using additional structures is considered the most practical solution that it is permanent, applicable alternative and doesn't need periodic cost. Damietta harbour on the northeastern of Nile delta in Egypt is a clear exampleof sedimentation problem, that navigation channel trapping a huge volume of sediment reached 2 million cubic meters per year, and requires high cost periodic maintenance. The conflict between recommended solutions and disadvantages of them prove that Sedimentation problem in Navigation channel of Damietta harbour needs more accurate study to find the proper way to solve the problem. Also, according to navigation channel improvement, these solutions either failed or had not examined. So, comprehensive study is needed to reach the optimum solution for the sedimentation problem ofDamiettanavigation channel problem especially in case of development.

1. INTRODUCTION

Navigation channel is a determined path dredged in sea bed to enable ships to accessharbour or to pass through countries. So, it can be considered one of the major components of ports and deeply effect on international trade and economy. Depth and width of channel depend on ship dimensions, while side slope usually depend on soil type. The length of channel expands from port location to required water depth in sea. Due to waves and currents, when suspended load reacheschannel location with bigger water depth, the velocity reduced and soil particles settle into it, as shown in Figure 1. The depth of channel decreases by sedimentation, so periodic dredging is required to keep the constant depth of channel for safe navigation.Dredging costs vary from one harbour to another according to sediment volume and dredging method. Minimizing sedimentation volume in navigation channel to reduce maintenance costs has become urgent issueespecially for the developing countries. Also, beach system near navigation channel suffers erosion due to the loss of suspended material that was trapped in navigation channel. That mean sedimentation problem has an environmental effect on adjacent beaches. So sedimentation problem in navigation channel is considered a crucial issue according to economical and environmental point of view. Many solutions could be used to reduce sediment volume, but the proper methodologydepends on reasons, volume and sources of sediment which differ from place to another. Sedimentation problem in different navigation channels will be investigated in following part to clarify sedimentation process and the influence of different parameters on it.

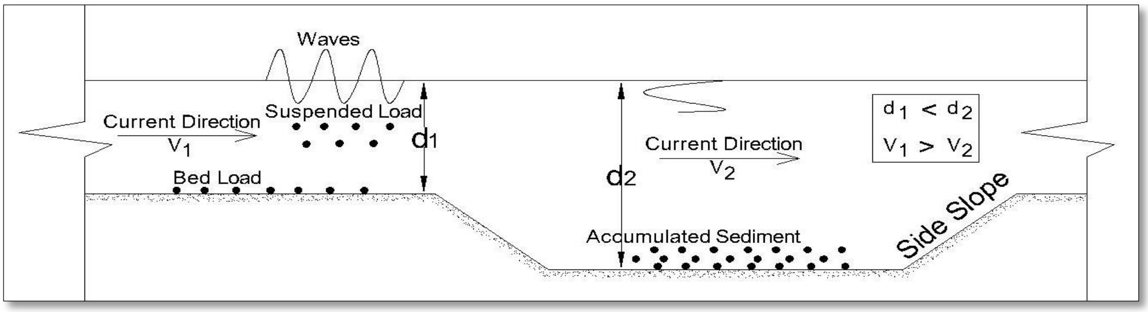

Figure 1: Sedimentation Process in Navigation Channel

SEDIMENTATION PARAMETERS IN NAVIGATION CHANNEL

Sedimentation process is controlled by geometric of channel, hydrodynamics and protection structures. Geometric parameters of channel such as depth, width, orientation and length of navigation channel depend on harbour requirements and dimension of ships that use the channel. Hydrodynamics parameters such as wind, tide, waves and current differ from location and another. Additional structures usually used to protect the channel from sedimentation. The priority of each parameter varies from location to another.

1.1. Geometric parameters

Figure 2 illustrates Geometric parameters of navigation channel such as the depth, width , side slope and orientation of channel.

Orientation of channel should satisfy shortest length and depend on prevailing wind, wave and current. It is preferable to have the prevailing currents aligned with the channel axis, however usually the prevailing wind and wave directions are the dominate design parameters.

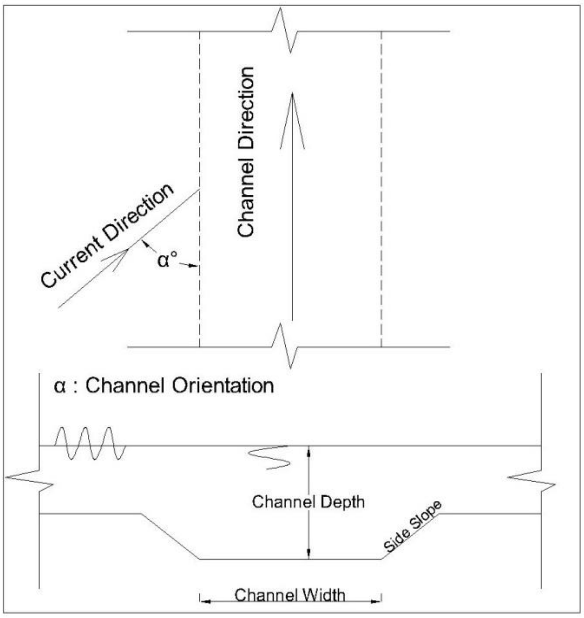

Figure 2: Geometrical Parameters of Navigation Channel

Depth of navigation channel depend on many factors such as ship draft, tidal range, ship squat and wave response, as shown in Figure 3.

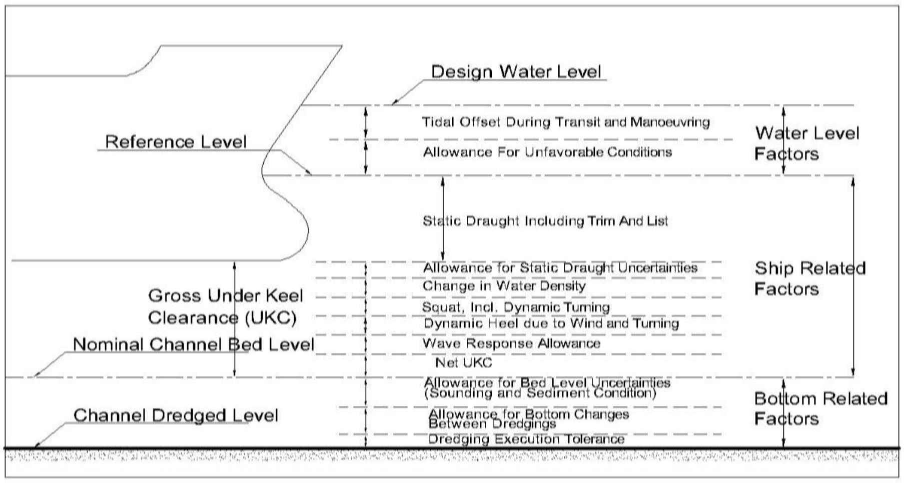

Figure 3:Channel Depth Parameters [26]

Width of navigation channel depend on channel capacity, bank clearance, ship manoeuvrability, bend configuration and environmental forces such as wind, current and waves. [26]

Geometric parameters have a great effect on sedimentation rate of navigation channel. Annual amount of dredged material in Otago harbor on the southeast coast of South Island of New Zealand was ranged from 300000 to 400000 m^3. 2D numerical simulation modelwas performed to study the effect of port development and climate changes on sedimentation. Different scenarios were used such as development of dredging, sea level rise by 0.50 m and using different bathymetric conditions. Results showed that deepening channel increased dredging demand. [31]

In ST. Marys Entrance, FL/GA border, natural channel with depth 5.8 m was deepened to 10.4 m in the interval between 1924 and 1954. Then it was deepened to 12.2 in 1974 and to depth 15.5 m at 1988. Sedimentation rate increased from 169000 m3/yr to 618000 m3/yr with 265% increase ratio when the channel depth increased from 10.4 m to 15.5 m. That's indicates that dredging rate depends more on channel depth than any parameter. **[27]**

Improvement works in harbour basin and entrance channel of Dar el Sallam harbour increased sedimentation rate from 25 cm/ year to 43 cm/ year. These works included deepening, widening and straightening channel and installing navigation aids. It was clear that channelorientation was responsible for increasing of sedimentation rate. The average deposition rate was 168000 m^3/yr. [28]

Mojabi M. et. al. (2010) used finite volume method to study the significant parameters effect on siltation on harbor and navigation channel. Sedimentation rate increased as navigation channel width increased. Also, channel orientation strongly effect on sedimentation, that decreasing the angle between channel and current increasing siltation. [23]

El-Toro navigation channel, Bahia Blanca estuary, Argentina required a periodic dredging to remove 300000 m3 of sediment each year. The channel was acting as a sediment trap because of its orientation. [25]

1.2. Hydrodynamic parameters

Hydrodynamic parameters such as wind, waves, tide and currents deeply effect on sediment transport in navigation channel. In Thailand, approach channel of Bangkok harbour is maintained through continuous dredging of 5million m^3/yr of sediment. The high sedimentation rate was caused by discharged silt from river and due to the effect of waves and tidal current. [9]

In São Francisco do Sul ,navigation channel trapped about 0.35 * 10^6 m^3/ year, and dredged material disposed at Atlantic Ocean. So, beach system suffers erosion due to the loss of suspended material that was trapped in navigation channel. As a result of interaction between tidal currents and waves, the ebb tidal deltas was formed and considered main sedimentation parameter. However, erosion problems could be mitigated if we use eroded sites as a disposal sites. [2]

The estimated rate of sediment deposited in navigation channel of LNG port at Abu-Qir bay on North Western coast of Nile Delta –Egyptwas between 0.048*10^6 m^3/month and 0.388 *$10^6$$m^3$/month, with average annual rate of 1.977 *10^6 m^3/yr, according to mathematical model results. Eroded sediment from Rosetta was the main source of sediment which transported by wind and wave currents acting on S-W direction. In the other hand, prevailing current directions N-W and S-E had insignificant effect that it was flow parallel to the main axis of navigation channel. Also, N-E current had minor effect as navigation channel was protected by 900 m breakwater in western side, as shown in Figure 4.

It was found that sedimentation consisted of 78 % bed load and 22 % suspended load and sedimentation rate calculated during winter was greater than that in summer.**[8]**

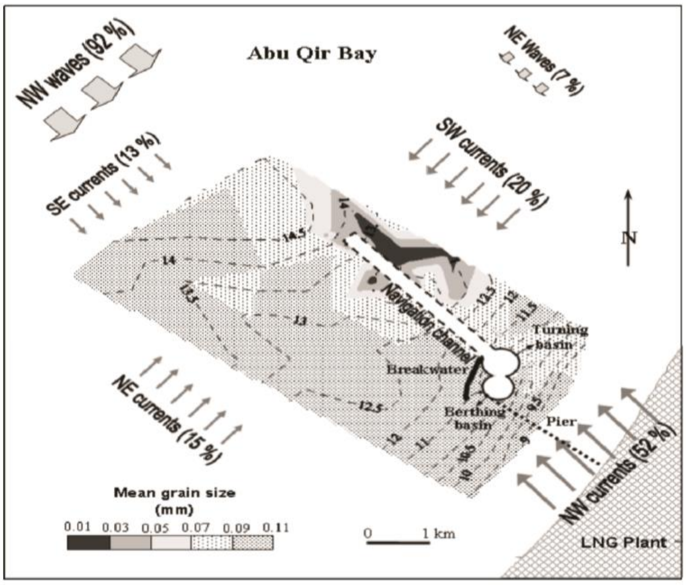

Figure 4:Wave and Current Pattern at Navigation Channel of LNG port at Abu-Qir bay on North Western coast, Egypt [8]

Saint John harbour had average rate of siltation ranged between 0.2 to 1 m/ year. Density currents, tidal exchange and horizontal eddy exchange were the main parameters affected on sedimentation process at port of Saint John.According to numerical simulation of MIKE21 model, the accumulated sedimentation rate was 4.2* 10^6 m^3/year.**[20]**

The entrance channel at Blankenberge harbour, BELGIUM, divided to four zones of siltation with total amount of sediment reached 165000 m^3/yr. It was obvious that, tide, wind and wave significantly effect on siltation. 2D morphological model called X-Beach showed that western groins weren't sufficient to stop sediment. **[32]**

The deep navigation channel of Yangtze River Estaury, China was constructed at 1998 with 92.0 Km length and average depth of 12.0 m, protected by two dikes with length 48.1 Km and 49.20 Km. To increase current speed and decrease siltation, 19 groins with total length of 30.0 Km was constructed with dikes, as shown in Figure 5.Horizontal sediment transport from north to south was trapped with the dikes. Sediment deposition was caused by tidal asymmetry, river discharge, waves and wind. However, the wind had the great effect on siltation in navigation channel. [30]

The Yangtze Estuary is the fourth largest river in the world in terms of sediment discharge, that annual mean is about 60.0–80.0 million m3 . [31]

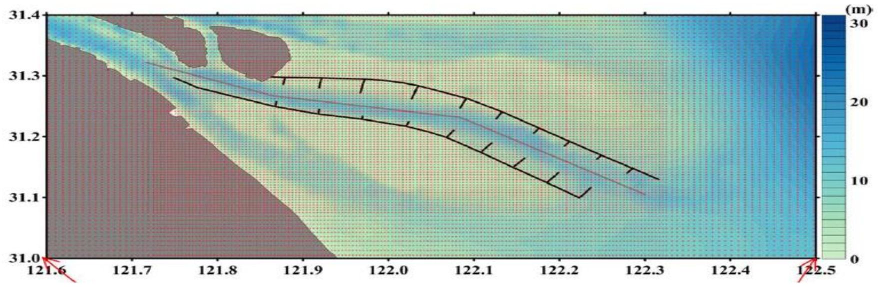

Figure 5:Navigation channel with 92.0 Km length, Protected by Two Dikes with 19 groins. [30]

Due to high siltation volume that reached 1250000 m^3 theinternational navigation channel in Dinh An Estuary, Vietnam, used to be dredged twice a year. The main parameters affected on siltation were tidal current, sediment load, bathymetry and salinity.[24]

At Mongla port in Bangladish, average sedimentation rate was 0.57 m3/day and maximum rate was 4.89 m3/day, which cause navigational problem. It was found that bed materials of fine sand contributed one third of total transport of sediment. Contraction of river width was one of suggested solutions to minimize sediment, but study showed that it couldn't be useful. However, both contraction and dredging can be useful. **[29]**

At Arisaig Harbour , on Nova Scotia, hydrodynamics parameters are the main responsible for sedimentation process thatlongshore sediment transport is dominated by waves. **[20]** A new breakwater and extension of existing rock structures were recently considered to solve sedimentation issue.[3]

Sediment deposition is the main drawback of the Cuddalore port in south India, that there is heavy sediment deposit in the entrance channel. Small boats can access the port easily, however the launchers have to change their route periodically according to tidal range. The estimated amount of sediment was 0.889 Mm3/year due to wave action. Realignment of existing breakwaters may solve this problem. [3]

1.3. Protection structure

According to design criteria, geometric parameters are considered design requirements, and hydrodynamic parameters are considered site constraints. So, protection structures are usually used to protect the navigation channel from sediment and reduce sediment accumulation. For example,navigation channel of LNG port at Abu-Qir bay on North Western coast of Nile Delta –Egypt was protected by 900 m breakwater in western side, as shown in Figure 4. However, in many cases the protection structure was not sufficient due to improper design.

At Bandy Creak Boat Harbour, Esperance, Western Australia, average cost of dredging was estimated in 1991 to be 120000 $ to remove about 25000 m^3 of sediment. It was clear that, western breakwater trapped only 16 % of sediment due to insufficient length. **[5]**

Navigation channel at Damietta port trapped longshore sediment and gained sedimentation with average rate of $1.39*10^6$ m^3 yr^{-1} at 1992. However, sedimentation rate decreased to $0.80*10^6$ m^3 yr^{-1} at 1995 due to stabilization of bed slopes.**[11]**

It was clear that the protection breakwater didn`t reach the closure depth. So, it was recommended to extend the length of eastern breakwater to 1.50 km offshore, while the western breakwater should be extend to1.70 km offshore to reach water depth of 8.0 m. **[13]**

Table 1 summarize the sediment rates in different harbours and major parameters effect on it. Tableproves that sedimentation processes threaten navigation in approach channel and consume large amount of maintenance cost in dredging.

Table1. Sedimentation rates in different harbours

	Nation	Location	Average Sedimentation Rate	Main Parameter
1	United States	ST. Marys Entrance Natural channel inlet	618000 m3/yr	Depth
2	New Zealand	Otago harbor	350000 m^3/yr	Deepening
3	Tanzania	Dar es Sallam Harbour	168000 m3/yr	Channel orientation
4	Argentina	El-Toro navigation channel	300000 m3/yr	Channel orientation
5	Thailand	Approach channel of Bangkok Harbour	5 millions m3/yr	Waves and tidal current
6	Brazil	São Francisco do Sul Navigation channel	$0.35 * 10^6$ m^3/ year	Waves and tidal current
7	Egypt	navigation channel of LNG port at Abu-Qir bay	$1.977 *10^6$ m^3/yr	wind and wave currents
8	Canada	Saint John Harbour	$4.2* 10^6$ m3/year	Current and tidal exchanges
9	Belgium	The entrance channel at Blankenberge Harbour	165000 m^3/yr	Tide, wind and waves
10	China	Yangtze River Estuary	$70 *10^6$ m^3/yr	Wind
11	Vietnam	Navigation channel in Dinh An Estuary	1250000 m^3/yr	tidal current
12	Bangladesh	Mongla port	1790 m^3/yr	Bed material
13	India	Cuddalore Port	$0.889 *10^6$ m3/yr	Wave action
14	Australia	Bandy Creak Boat Harbour	25000 m^3/yr	Insufficient protection structure
15	Egypt	Navigation channel at Damietta port	$1.39*10^6$ m^3 /yr	Insufficient protection structure

From previous, the parameters effect on sedimentation can be conclude in the following

1. Orientation of navigation channel
2. Depth and width of navigation channel
3. Deepening navigation channel
4. Hydrodynamic parameters such as Wind, current, tide and waves
5. Weak protection structure

It was obvious that sediment deposition in harbor and river mouth is considered one of the main issues in different countries, so many researchers studied the effect of different solutions on sedimentation process. It was recommended that, sedimentation problems can be eliminated by dredging, using open cycle pumping system or jetties used to bypass sand from upstream to downstream. **[21]**

PREVIOUS SOLUTIONS

Geometric parameters such as depth and width depend on port requirements, so they cannot be used to reduce sedimentation volume. Also, hydrodynamic parameters depend on natural location and can be considered blocked parameters.

Practical solutions depend on controlling sediment movement by trapping it or redirect it away from channel, that the geometric and hydrodynamic parameters cannot be modified.

So many researchersstudied the effect of different solutions such as using open cycle pumping system, construct one way sand trap, extension of existing breakwater, changing orientation of channel orientation.

1.4. Changing orientation of channel

Different solutionswere investigated to minimize sediment accumulation in El-Toro navigation channel, Bahia Blanca estuary, Argentina. The best solution was changing orientation of channel orientation. The proposed solution decreased sedimentation rate from 300000 m^3/yr to 113250 m^3/yr. [25]

1.5. Extension of existing breakwater

At Bandy Creek Boat Harbour three alternative solutionswere studied to reduce siltation. It was clear that, about 21000 m3 of siltation came from the western side, so that extension of existing western breakwater with different alignment was the first solution. Second one, was breakwater spur and beach groins east to entrance. Last solution was combination of previous solutions. Entrance management programme was performed using a certain solution with two stages. First stage included extend western existing breakwater by 60.0 m and construct one way sand trap east to entrance with total cost of 665000 $. Second stage included extend breakwater with additional 60.0 m. However, monitoring program was used to decide the necessity of second stage. Monitoring program show that 1st stage reduced significantly siltation in the entrance. **[5]**

1.6. *Bypassing techniques and sediment trap*

In the last decades, bypassing and backpassing techniques used to replenishment beaches by restoration dredged sediment from navigation channel. these techniques had a great benefit to environment, neighbouring shore and economy. Also, fluidization system provided a suitable solution to gain and transfer sand that would be useful in beach nourishment and very suitable in sandy soil. However, average cost of that system was very high. [7]

Also, the created noise by the system was one of remarkable operation disadvantages. Fixed planets usually have limited capacity, that the boom had limited area of reach. Also, movable trestle-riding planets had the same shortage. Clogging by gravel, plastics, sea weed or driftwoodis one of the most important drawbacks of the system. High unit cost for small volume of dredged material could be a considerable disadvantage according to economic aspect. Finally, the design of bypassing system requires reliable information to be suitable, effective and economic.**[6]**

At Navigation channel at Damietta port, Sediment trap minimized siltation with about 79 %. However, it was suggested to use combination of sediment trap and extension of western breakwater to decrease siltation by about 84 %. **[18]**

So, there are many different solutions could be suitable. However, choosingthe proper solution depends on reasons, volume and sources of sediment and requires accurate and reliable information, because although in vicinity of these solutions, in many cases the problem is still unsolved.

Table 1 shows that navigation channel of Damietta harbour had one of the highestdeposition rates. So, it could be a suitable example to clarify sedimentation process and how to mitigate it.

CASE STUDY : DAMIETTA HARBOUR

In 1980s, Egyptian authority decided to establish Damietta harbour on the northeastern of Nile delta near the New Damietta city to improve trade and economy potential along the Mediterranean Sea. The selected location 9.7 km west of the Damietta Nile branchwas characterized by minimum wave and current effect. However, the location was described as one of long-term coastal accretion area.[11]

The harbour entrance was protected from siltation by two breakwaters. The western breakwater was constructed parallel to the navigation channel with 1500 m length and extends to a 7.0 m water depth. The eastern breakwater was constructed perpendicular to shore linewith 500 m length and extends to 3.0 m water depth. The navigation channel was completed in 1984, with a total length of 20 km and 15 m average depth and 200 m width of inner part that increased to 300 m in outer part as shown in Fig (6).

Figure 6:Layout of Damietta Harbour

The project consultant estimated that the average volume of annual dredged materials was 1.18 x 10^6 m^3/yr . However, the sedimentation rate exceeded this value to reached 2.0 x 10^6 m^3/yr in 1990. According to the Damietta Port Authority, the unit cost of maintenance dredging in 1988 was 0.23 Euro /m3 and had reached 1.10 Euro/m^3 in 2001. In 2004, the yearly cost of maintenance the access channel of Damietta harbour had reached 7.1 million Euro. [1]

Figure 7 show sediment rates and dredging costs in the interval between 1985 and 2015, with maximum sediment rate of 2 million m^3.

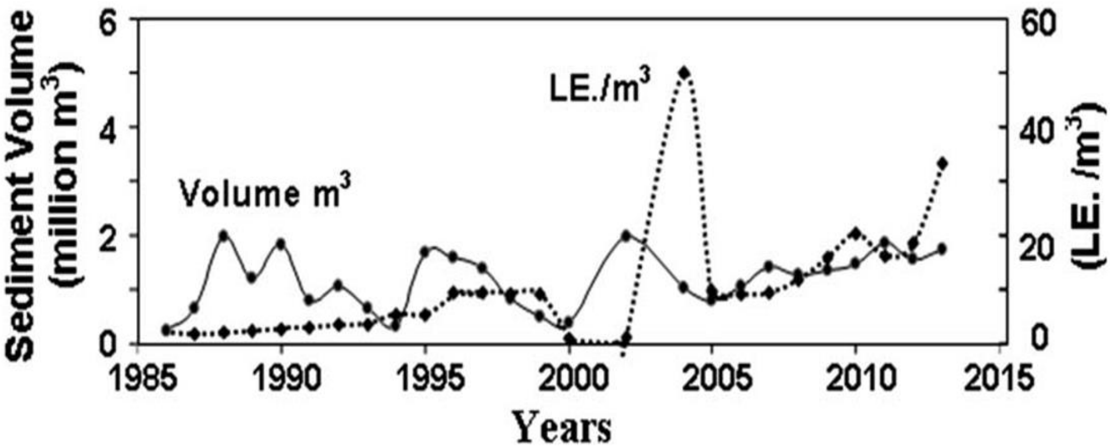

Figure 7:Sediment Volume from Navigation Channel of Damietta Harbour and Annual Dredging Cost since 1985 to 2015 [14]

Damietta harbor and Damietta promontory were considered two main zones of erosion due to construction of Aswan High Dam and cut of sediment discharge, also construction of coastal protection works deeply effected on shoreline. Construction of Damietta harbor had affected long shore current sediment, that western side of harbor had accretion rate of 12.0 m^3/year. On the other hand, the eastern side suffered from erosion with maximum rate -39 m/yr. The shoreline between harbor and Ras El-Bar was subjected to sediment movement westward due to seasonal reversal current that generated by waves from NE direction. **[12]**

It is found that, harbor jetties interrupted eastward moving littoral drift. So, western beach had accretion of fine mean grain size sand with average rate of 25m yr^{-1} during interval from 1983 to 1993, as shown in figure 8.a. In the other hand, eastern shoreline was losing coarse sand that was trapped in navigation channel, as shown in figure 5.b. Navigation channel trapped longshore sediment and gained sedimentation with average rate of $1.39*10^6$ m3 yr^{-1} at 1992. However, sedimentation rate decreased to 0.80 $*10^6 m^3 yr^{-1}$ at 1995 due to stabilization of bed slopes. **[11]**

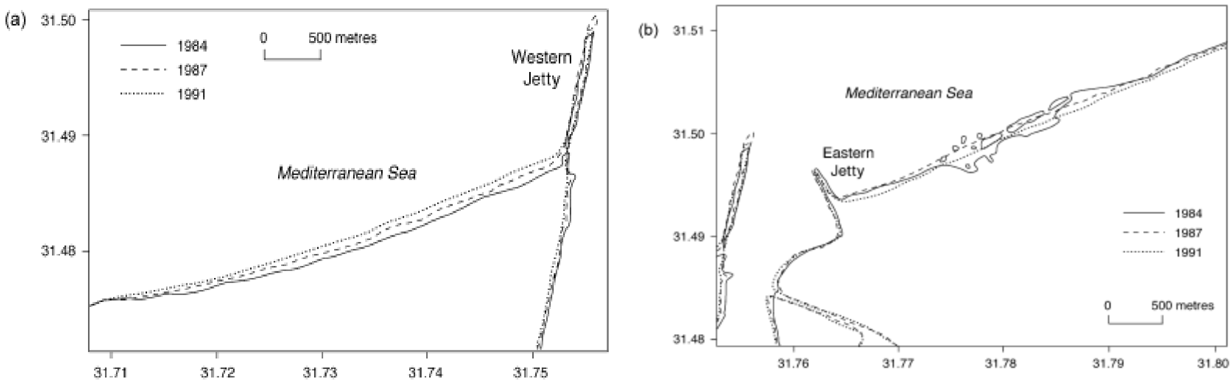

Figure 8:**a)**Accretion in Western Side of Damietta Habour **b)**Erosion in Eastern Side of Damietta Harbor (from 1984 to 1991) [10]

It is obvious that construction of Damietta harbor had a greater effect more than expected that effect extend for about 10.50 Km of shoreline. So, sedimentation in channel has economical effect of maintenance cost and environmental effect on adjacent beach.

N-E orientation on approach channel trapped sediment moving from east or west, and navigation channel acted as a sediment sink from different direction. Figure 9 shows the current pattern around navigation channel that longshore currents were generated by predominated wave directions which were found to be N.N.W , N.W. and W.N.W and transported sediment from eroded beach of Burullus . Also, waves from N-E sector generate a reversed longshore current southwest and bring sediment from Ras El-Bar beach and damping site navigation channel. In addition, offshore and onshore current was responsible for siltation. Sediment accumulated at first four kilometres of navigation channel at harbour entrance was about 65% of total sediment, and navigation channel reach balance at distance of 9.0 km offshore. It was concluded that the length of existing breakwaters were less than required length to reach closure depth. So, it was recommended to extend the length of eastern breakwater 1.50 km offshore to reach water depth of 8.0 m. in the other hand the western breakwater should be extend to1.70 km offshore to each the same depth. **[13]**

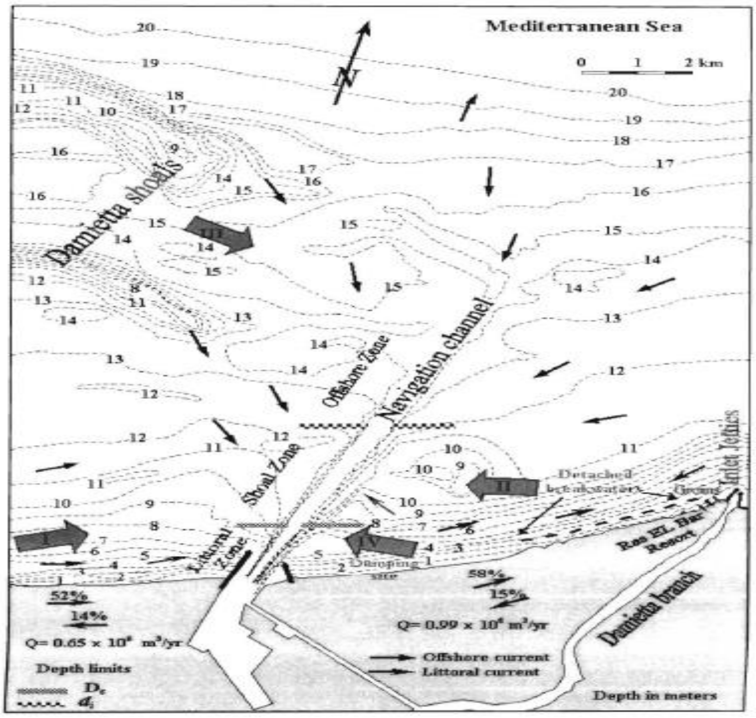

Figure 9:Sedimentation Processes at the Navigation Channel of Damietta harbour. [13]

At Damietta promontory current reversals and littoral drift to west could be neglected because of orientation of shore line at Damietta promontory. So, eroded beach from Damietta promontory was transported to east and curvilinear sand spit was formed and did not effect on navigation channel, as shown in Figure 10.**[19]**

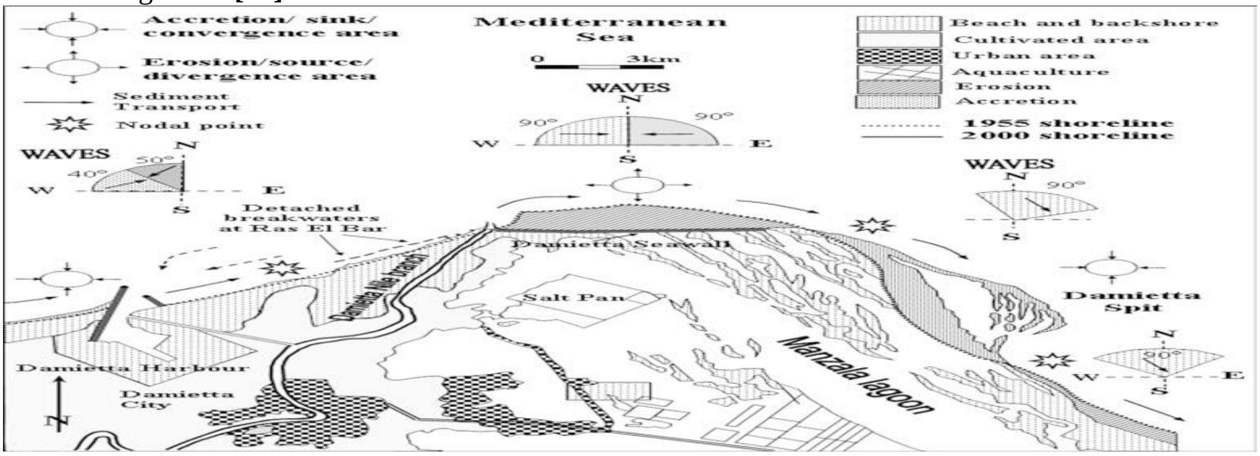

Figure 10:Curvilinear Sand Spit in Eastern Side of Damietta Promontories[18]

Natural beachesare influenced by many factors such as incoming waves, alongshoreand cross-shore currents in the surf zone, wind-drivencurrent outside the surf zone, and constantly changingtides.[21]

At Ras El Bar area, shoreline showed accretion area beyond detached breakwater with average rate 9 m/yr, and erosion area in the region between detached breakwater and eastern jetty of Damietta harbour with average rate -13m/yr. According to field measurements, predominate longshore current directed southwest with average velocity 30 cm/s, as shown in Fig (11) . Grain sorting studies showed that waves and longshore current were responsible for eroded sand from beach face and transport sand alongshore and deposit in accretion area.[16]

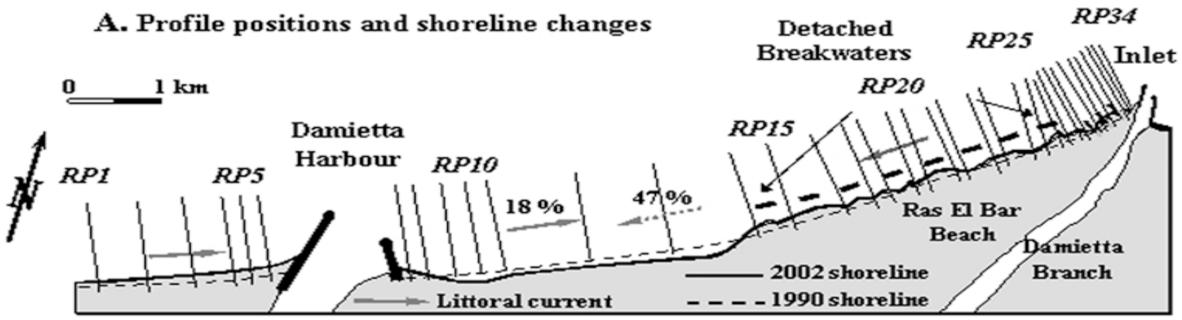

Figure 11:Predominate Longshore Current Directed Southwest (47 %) with Average Velocity 30 cm/s. [16]

ABO BAKER. I. ABO ZED (2007) studied dynamic factors that effect on sedimentation processes in navigation channel of Damietta port. Studied area consisted of Gamasa drain, Damietta harbor and Damietta shore line and Damietta promontory. Author showed that, N-NW waves were responsible for predominate long shore current westward. However, small portion of wave act on S-E direction that generates a reversely current during winter and spring. It was found that, during winter season maximum current speed was generated toward SSW that led the redistribution of eroded sediment.So, navigation channel interrupt sediment movement from various direction such as back part of dredged sediment from damping location, eroded beach of El Brullus and Ras el bar , submerged Damietta shoals and Damietta promontory. Author concluded that existing breakwaters were not sufficient to trap sand bypassing from various directions. [1]

From previous we can conclude that:

1. N-E orientation on approach channel trapped sediment moving from east or west.
2. Navigation channel interrupt sediment movement from various direction such as back part of dredged sediment from damping location, eroded beach of El Brullus and Ras el bar.
3. The existing breakwaters were not sufficient to trap sand bypassing from various directions.

M. A. Gad et al. (2013)used multicomponent numerical model to minimize the volume of dredged materials in Damietta navigation channel. Authors used data of bathymetry, wind and current in interval from 1989 to 1997. They suggested four solutions with 13 configurations by modifying existing breakwaters, as shown in figure 12. Results show that sediment transport from western side reduced by about 62-74 % and from eastern side reduced by about 60-70%. However, study focused on first 5.0 Km of navigation channel and neglect sedimentation in the rest of it as it is in deep water and sedimentation is insignificant. It was obvious that maximum sedimentation occurred in the area between the tips of two breakwaters and sedimentation depth reached 3.0 m. Among various modifications, results showed that modification to western breakwater is the worst solution. In the other hand modification to eastern breakwater showed better results.[17]

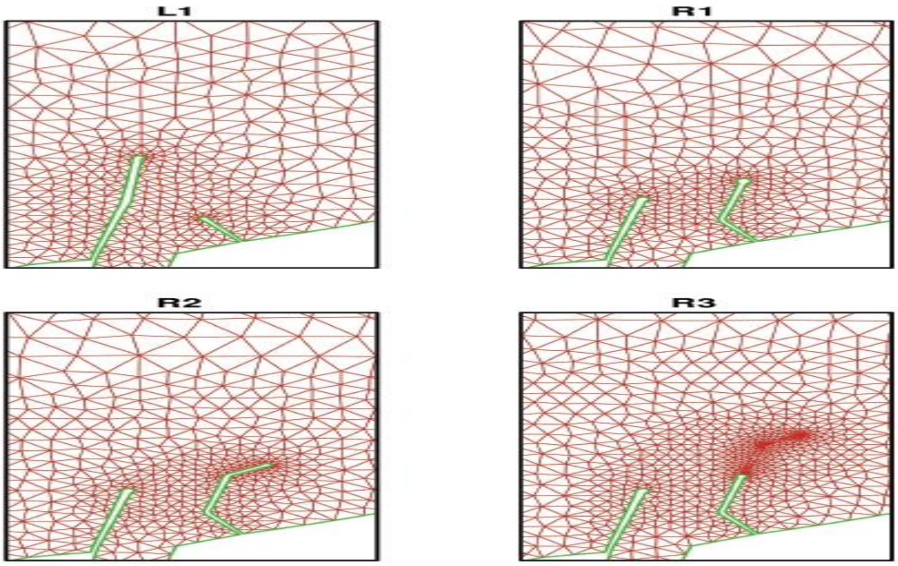

Figure 12:Four Modification to Existing Breakwater to Reduce Sedimentation in Navigation Channel of Damietta Harbor.[17]

The results weren'tcompatible with previous researches that proved that main sediment source came from western side.

Khalifa, A. M. (2017) used number of scenarios such as using extension the western jetty , using submerged breakwater , current deflector wall (CDW) and sediment trap to minimize sedimentation volume in navigation channel of Damietta harbour using 3D numerical model. Using submerged breakwater was the worst solution, as sediment passed above breakwater crest and settle in navigation channel. Current deflector wall significantly decreased sedimentation volume, however current speed in approach channel threatened navigation. Extension of western jetty wasn't sufficient solution, that dredged material decreased by about 37 %. Sediment trap minimized siltation with about 79 % to be the best solution among previous alternatives. However, author suggested using combination of sediment trap and extension of western breakwater to decrease siltation by about 84 %. Fixed pump system was recommended to install to exchange siltation gained in sediment trap. [18]

Using pumping system could have disadvantages of maintenance, operation and initial costs which neglected in study. Also, results disagreed with **M. A. Gad et al.** suggestions**.**

In 2017 Damietta harbour authority decided to improve the navigation channel to accommodate the improvement in berths and development in ship industry. The sedimentation problem could be aggravated due to channel improvement, and even suggested solution could be useless.

In 2018, M. Bahgat made numerical simulation for different scenarios to mitigate sediment volume in navigation channel of Damietta harbour using Delft 3D software package. Results showed that, construction of sand trap either offshore or onshore at the western side of the harbour will not have significant impact on minimizing the sediment deposition inside the approach channel.Also, increasing the length of western jetty has no significant effect of sedimentation in navigation channel. The proposed solution is to increase the length of eastern jetty with 450 m to reach the depth of 5.5 m. it will decrease the sediment volume by about 40 %. However, according to the study the proposed solution is not sufficient in case of development of approach channel. [4]

Table2. Illustrates the previous studies and proposed solutions to mitigate sediment deposition in navigation channel.

Table 2. Summarise of Previous Studies

Authors	**Used Model**	**Main Conclusions**			**Proposed Solution**	**Sediment reduction**
		Western Jetty	Eastern Jetty	Construction of Sand Trap		
M. A. Gad et al. (2013)	Multi component numerical model	Modification was the worst solution	Should be increased.	-	Increasing eastern jetty by 700 m.	68 %
Khalifa, A. M. (2017)	Delft 3D	Decrease sediment volume	No need for modification	Decrease sediment volume	Construction of sand trap and extension of western jetty by 100m.	84 %
M. Bahgat (2018)	Delft 3D	Had no impact	Should be increased.	No significant effect	Increasing eastern jetty by 700 m.	40 %

The conflict between recommended solutions proves that sedimentation problem in Navigation channel of Damietta harbour needs more accurate study to find the proper way to solve the problem. Also, suggested solutions either failed or had not examined in case of development of approach channel.So, comprehensive study is needed to reach the optimum solution for the sedimentation problem of Damietta navigation channel problem especially in case of development.

According to previous research,practical solutions depend on controlling sediment movement by trapping it or redirect it away from channel by many ways such as:

1. Using open cycle pumping system.
2. Construct one way sand trap.
3. Extension of existing breakwaters.
4. Changing orientation of channel.

However,the main target of study is to minimize the periodic maintenance cost. So, using open cycle pumping system isn't the best solution because of average cost of that system is very high and required periodic cost for operation and maintenance.

Constructing sand trap is considered a temporary solution that accumulated sediment in sand trap will be dredged with the same cost. So, this solution has the advantage of moving dredging site away of navigation channel to avoid obstruction of ships movement in the period of dredging.

Changing orientation of channel could be unsuitable choice in case of existing harbour, that consumes huge cost and may causeawkwardness in ships movement.

Extension of existing breakwaters or using additional structuresis considered the most practical solution that it is permanent, applicable alternative and doesn’t need periodic cost. So, this solution can be considered the most suitable solution to minimize the sediment in navigation channel of Damietta harbour.

CONCLUSION

Sedimentation processes threaten navigation in approach channel and consume large amount of maintenance cost in dredging and has environmental effect on adjacent beach.

The parameters effect on sedimentation can be conclude in the following:

1. Orientation of navigation channel
2. Depth and width of navigation channel
3. Deepening navigation channel
4. Hydrodynamic parameters such as Wind, current, tide and waves
5. Weak protection structures

However geometric parameters and hydrodynamic parameters can be considered blocked parameters. So, practical solutions depend on controlling sediment movement by trapping it or redirect it away from channel by many ways such as:

1. Using open cycle pumping system.
2. Construct one way sand trap.
3. Extension of existing breakwater.
4. Changing orientation of channel orientation.

However, Extension of existing breakwaters or using additional structures is considered the most practical solution that it is permanent, applicable alternative and doesn’t need periodic cost. So, this solution can be considered the most suitable solution to minimize the sediment in navigation channel.

Damietta harbour on the northeastern of Nile delta in Egypt is a clear example of sedimentation problem, that navigation channel trapping a huge volume of sediment reached 2 million cubic meters per year, and requires high cost periodic maintenance.The clear conflict between recommended solutions proves that Sedimentation problem in Navigation channel of Damietta harbour needs more accurate study to find the proper way to solve the problem. So, comprehensive study is needed to reach the optimum solution for the sedimentation problem of Damiettanavigation channel problem especially in case of development.

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