BEHAVIOUR OF SHORELINE AND COASTAL STRUCTURES AT ELSUKHNA PORT, EGYPT

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ABSTRACT

As a part of the Egyptian Government's future plan to develop the Northwest of the Gulf of Suez by constructing a 232 km² complete commercial and industrial zone, it was necessary to build a new state-of-the-art port in the Elsukhna area with all facilities to serve the zone. The area of land allocated for the port is over 23.3 km², to be used for container handling, general cargo and dry/liquid bulk. This project required numerous studies in order to develop a successful design. Comprehensive layout evaluations and studies were performed prior to the construction of the port, including the use of mathematical models to ensure suitable protection from waves to the berthing and tug basin as well as the wave generation in the Gulf of Suez and wave propagation from a zone offshore from the Elsukhna area to the breakwaters, inner basin and quays. One of the major design studies was the study of the behaviour of the shoreline and the coastal structures to wave action to ensure minimum effects on the environment.

After the port was constructed in 2001, field monitoring was on going for five years to study the impact of the port and the behaviour of the different components.

In this study, the field survey and measurements were analyzed, evaluated and compared with original design data. It was concluded that there were few changes to the coastline as predicted by the detailed design, and it was noticed that there were indeed minimum effects on the coastal structures themselves.

Key words: Coastal Erosion; Elsukhna Port; Breakwaters; Slope Protection; Waves; Shoreline Change

1. INTRODUCTION

Ports, whether natural or artificial, are extremely important to develop any community. The Elsukhna port, which was built in 2001, had initially one berthing basin of 750m length and 350m width, with an approach channel of 3,650m length, 250m width and 18m depth and a turning circle of 650m diameter. The port is protected from the wave attack by two breakwaters of 770m for the north one and 680m length for the south one. The depth of the berthing channel is 17m and the approach channel and the turning circle side slope is 1:3.

The selected area for the port lies about 120 km southeast of Cairo on the Gulf of Suez "Gobet Elbouce" area (North Elain Elsukhna).

This location was selected for the following reasons:

1. Close to international navigation routes.
2. Short approach channel.
3. Minimum waves and currents.
4. No coral reefs.
5. Could be connected to the industrial zone via tunnel.
6. Connected to rail and highway networks.

It was decided to name the new port "Elsukhna," which is the closest known town to the area.

The main objectives of the port were to provide safe navigation to the vessels and suitable protection from waves in the basins, protecting the channel entrance from long shore sediment transport to minimize maintenance dredging, reducing the costs and the construction time and minimizing the impact on the environment.

This study deals with the behaviour of the Coastal Engineering Works and Dredging constructed at Elsukhna Port, Egypt. The behaviour of the shoreline and coastal structures after five years from the initial construction of the port in 2001 is monitored, evaluated and analyzed in this study.

2. PHASES OF THE STUDY

The entire dredging area of the access channel turning circle and basin were subject to detailed hydrographic surveys and reviews after one, two, three, four and five years following the initial construction.

The survey after five years was extended to study, evaluate and analyze the changes to the coastline outside of the dredged areas, including the breakwaters and slope protection works. Figure (1) shows the general layout of the port.

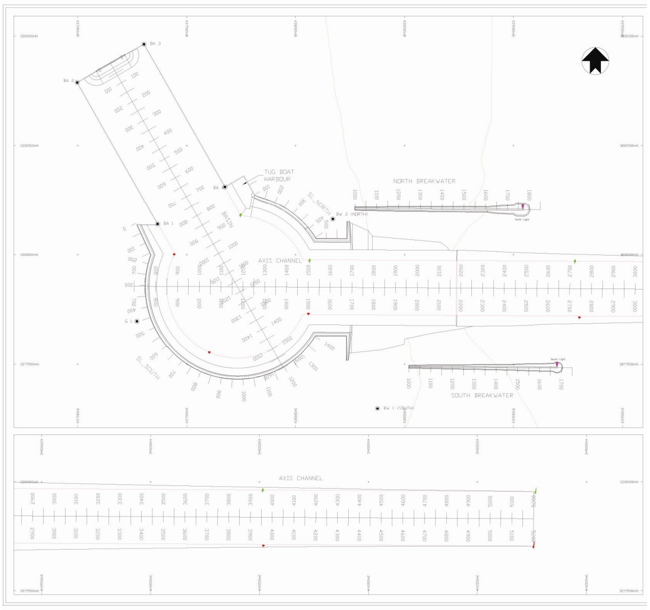

Fig. 1. *General layout of the port*

3. STUDY PROCEDURE

3.1 Dredged areas

The dredged area is defined as the entire area of the access channel turning circle and basin and tug harbour, including all adjacent dredged slopes. The areas were surveyed by means of hydrographic survey methods. The surveys were performed on the following occasions:

- One year after construction
- Two years after construction
- Three years after construction
- In February/ March 2005
- In August/ September 2005

The findings of the hydrologic survey were studied and the need for any dredging work was determined. No dredging works were required to be performed after the one, two and three year surveys, but some minor works were performed following the survey of February/ March 2005.

3.1.1 Survey

The following equipment was used during the survey:

- Positioning Trimble R8 RTK (base station and rover)
- Echo sounder Atias Deso 22

This equipment was mobilized in a launch, along with a laptop that used Van Oord software for navigating and processing the lagged information.

The following parameters/checks were used during the surveys:

- Chart Datum: The benchmark (BA1) was used to define the lowest astronomical tide (LAT) chart datum. This is related to the Suez datum.
- Geodetic Datum: The following projection system was used to define the position in the harbour as shown in table (1):
- The RTK base station was set-up on BA1 for the duration of the survey, using the following coordinates as shown in table (2):
- Calibration: Position Checks were done at the start of the survey. The following is the summary of the results that confirm compliance with the bathymetric survey specifications as shown in table (3):
- A check on any time delays in the positioning system with relationship to the computer and on the inclination of the transducer bracket was executed by performing latency test. Lines in opposite direction over a well-distinguished surface (e.g. slope of the channel) were sailed.
- Each survey was started with a bar check.
- The surveys were performed at 25m centres along the entire length of the access channel, turning circle and basin.

Table 1. Projection System

Projection	Zone 36	
	Origin lat.	0º 00' 00"
	Origin long	33º 00' 00"
	False Easting	500 000.00
	False Northing	0.00
	Scale factor	0.9996

Table 2. Base Station Coordinates

Point	Easting (m)	Northing (m)
BA 1	437 366.22	3 280 140.19

Table 3. Bathymetric Survey Results

Date	6 June 2005			
Point	Easting (m)	Northing (m)	Δ m E	Δ m N
BA 3	437303.64	3280962.65	-0.02	+0.16
BA 4	437674.91	3280311.24	+0.18	-0.03

3.1.2 Corrections needed

- Removal of high spots close to the Western quay wall between stations 0 to 220 to the design level of -17.0 CD.
- Dredging on the south berm turning circle of 30m width from St 1100 to St 1700 to the design level of -1.5 CD.
- Dredging on the berm for south slope protection from St 1500 to St 1700 to the design approved levels of -1.5 CD.
- Dredging on the berm for north slope protection from St 1500 to St 1700 to the design approved levels of -1.5 CD.
- Re-grading the north and south beach area from St 1700 to St 2100.
- Dredging areas up drift North and South Breakwater.

The total volume of material to be dredged from the above locations is 40.970m³.

3.1.3 After corrections

The final survey is a compilation of the survey performed in February/March 2005 and the survey performed in August/September 2005 in the locations where corrections are performed.

The combined results of the surveys are presented in Figures 2-3 show sample cross sections for the turning circle including the adjacent slope protection and Figures 4-5 show sample cross profiles for the shore access channel showing the adjacent breakwater.

Small differences are discernible between the different surveys when plotted on the cross profiles even though no correction works have been performed at the location. This may be explained by the processing of the echo-sounding data into cross profiles that requires interpolation to be performed between adjacent measured points in locations of rapid change of elevation, such as a dredged slope. This can lead to differences developing on the survey plot despite there being no change in the seabed profile.

The extent of the work performed within the navigable areas of the port was minimal, and the jobs performed never posed any danger to navigation within the port.

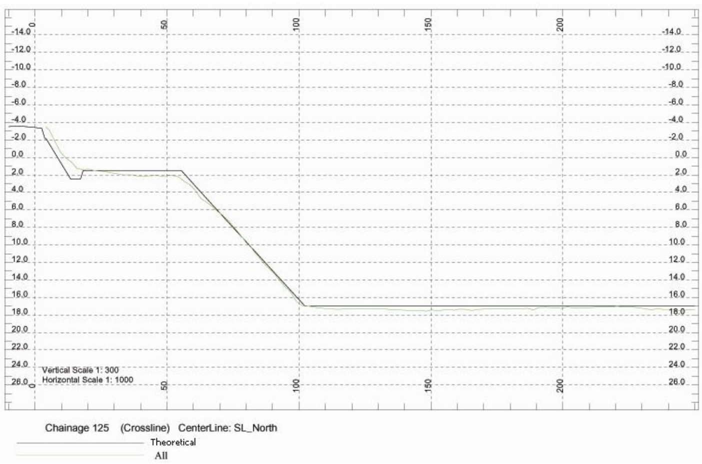

***Fig. 2.** Cross section of the turning circle for the North side*

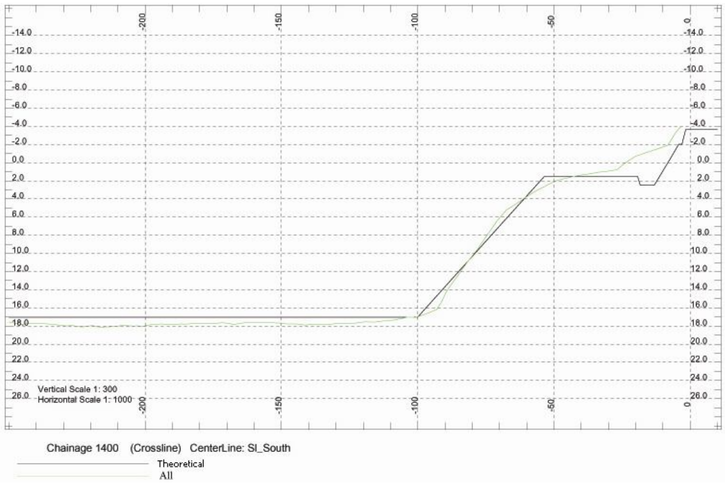

Fig. 3. *Cross section of the turning circle for the South side*

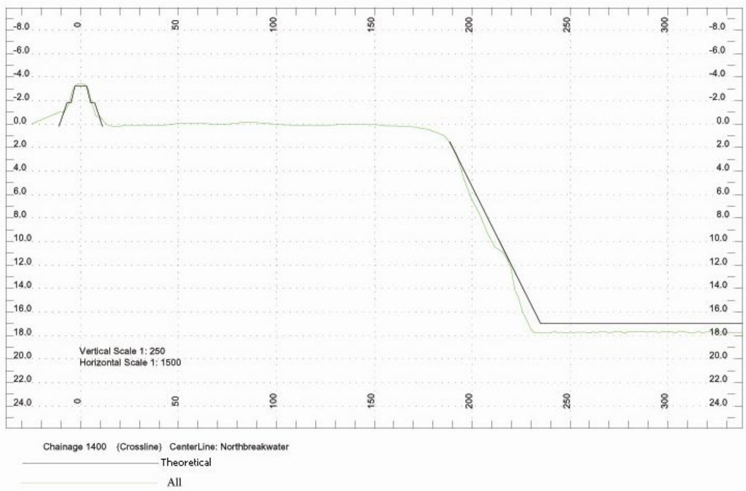

Fig. 4. *Cross profile for the inshore access channel and the north breakwater*

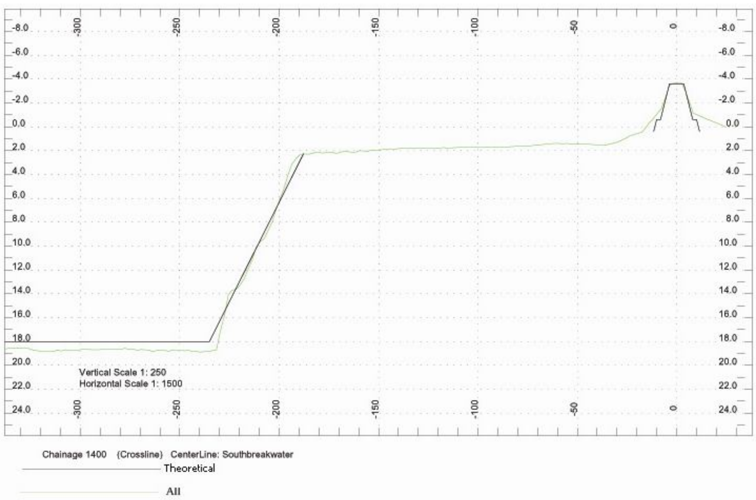

Fig. 5. *Cross profile for the inshore access channel and the South Breakwater*

3.2 Outside of dredged areas

During the bathymetric survey in February/March 2005, the survey was performed outside of the dredged areas in order to determine the changes, if any, to the coastline profile caused by the construction of the breakwaters and channel. The following areas were inspected:

- The un-dredged area between the access channel and the inside of the breakwaters;
- The portion of coastline to the south of the south breakwater and extending to the location of the artificial drainage channel (approx. 1500m); and
- The portion of the coastline extending 150m to the north of the north breakwater.

3.2.1 Survey

Removal of material between -2 and -6 CD was requested. The areas to be dredged were marked using small buoys.

Bathy charts and cross profiles of 0m to 125m from both the breakwaters were produced. See Figures 6-7.

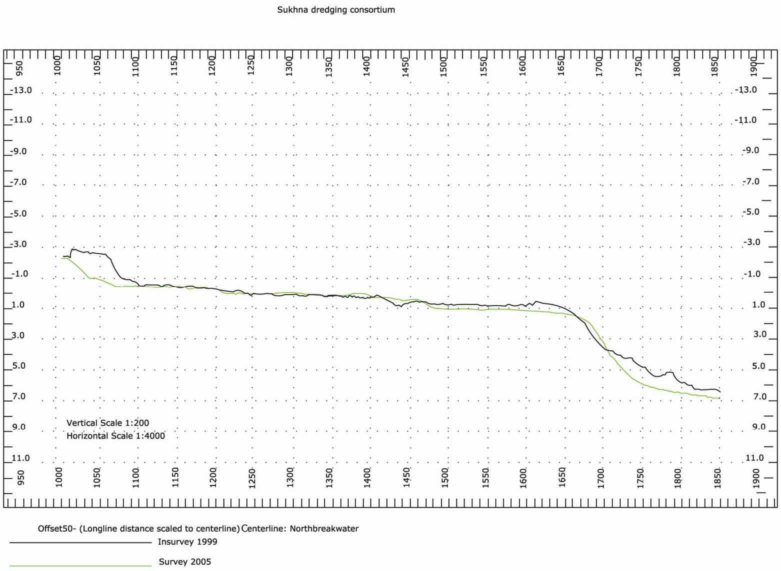

Fig. 6. *Cross profile for the beach outside the North Breakwater*

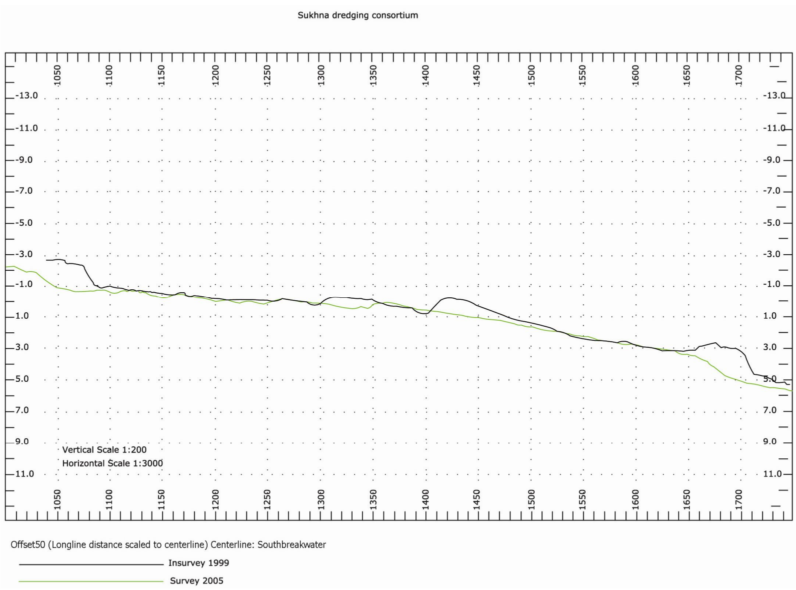

Fig. 7. *Cross profile for the beach outside the South Breakwater*

3.2.2 Corrections needed

Difference of seabed levels between the original survey in 1999, before the port was initially built, and the survey of February/March 2005 (between -2 and -6 CD) were removed up drift the north and south breakwaters. The dredged volume of the areas mentioned above is 2.99m³.

3.2.3 After corrections

Sample results of the surveys are presented in Figures 6-7, showing the comparison between the initial and final surveys.

3.3 Breakwaters and slope protection

Studies of the breakwaters and slope protection behaviour were performed. It was generally found the works to be in good order, but some minor irregularities were deleted in the slope protections around the turning circle. Corrections were needed, using material retained in stockpiles.

In February and March 2005, the rocks were generally found to be in a good condition, but some minor defects were detected in the toe and armour layers of both breakwaters.

3.3.1 Survey

Both the breakwaters were surveyed with the L and RTK survey systems. The results were shown by means of cross profiles at 25m centres along the entire length of the breakwaters. The requested areas to be repaired were identified.

3.3.2 Corrections needed

Additional rocks were placed at all locations of both the breakwaters where defects were detected.

3.3.3 After corrections

The results of these rockworks and various surveys are represented in Figures 8-9.

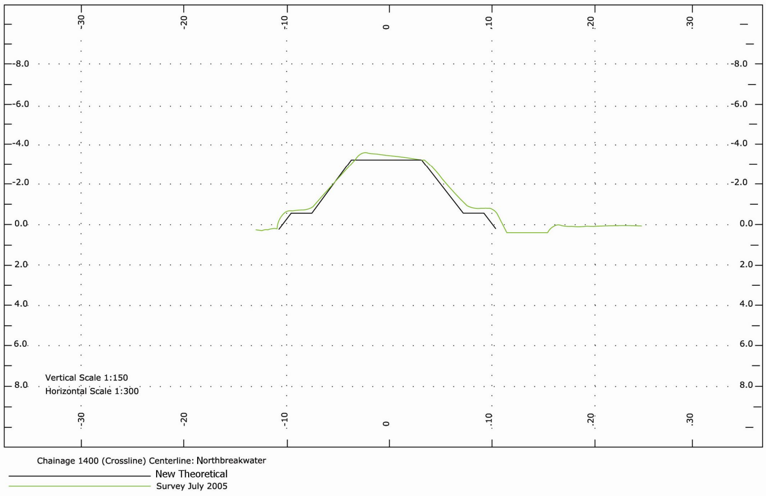

Fig. 8. *Cross profile for the North Breakwater*

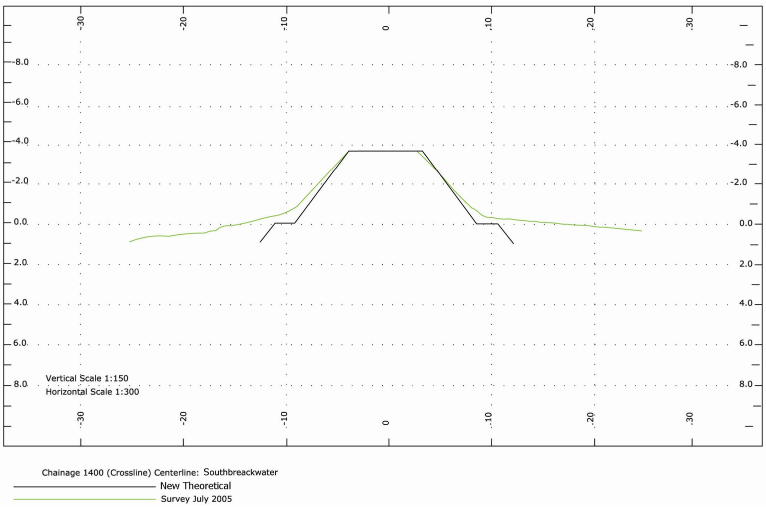

Fig. 9. *Cross profile for the South Breakwater*

4. RESULTS AND ANALYSIS

Regular inspections have been performed during the five year period of field monitoring, with inspections being performed after one, two, three and five years. More comprehensive and thorough inspections have been performed between February and September 2005 that have recorded the condition of all the works and the surrounding areas.

The design and construction of the port has resulted in the requirement for very little maintenance dredging. The location of the isolated high spots close to the quay wall indicates that they may have resulted from accidental spillage within the harbour and not due to any form of sedimentation. All high spots have been removed and the full navigational depth is available to users of the port.

The breakwaters have protected the access channel from the deposition of the material known to migrate along the coastline at Elsukhna. The structure of the two breakwaters has been thoroughly inspected both above and below the water line. No significant changes to the condition of these structures have been recorded over the five year period. Where minor imperfections were observed in the rockwork, these were corrected by the rearrangement of stones and/or the placement of additional stones.

Dredging has been performed upstream of the breakwaters so as to increase the capacity of this upstream area to accommodate additional sediments that may be expected to accumulate in the future.

5. CONCLUSIONS

After regular periodic inspections were performed during the five year of field monitoring and conditions were recorded, the following was concluded:

1. With little maintenance dredging needed due to the port construction, the only locations found to be above the specified bed level were found to be marginal or very small, with none representing any hazard to navigation.
2. The underwater dredged slopes were all found to be stable and have not changed over the five years since the end of the construction in 2001.
3. The stone slope protections within the port have performed well over the period of monitoring and have only required minor repairs following adverse weather.
4. The coastline has undergone some changes due to the construction of the port as predicted by the detailed design studies performed before the construction.
5. Deposition has occurred upstream of the two breakwaters where the flow of coastal sediment has been interrupted by the breakwaters.
6. The coastline is adapting to the new arrangement including the port, and no significant changes are expected in the near future.

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