A CASE STUDY FOR IMPROVEMENT OF EL BARDAWIL LAGOON OUTLET, EGYPT

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ABSTRACT

El Bardawil lagoon 600 square kilometers of surface area, lies along the northern coast of Sinai. The only source of water feeding this lagoon is the Mediterranean sea through two artificial boughazes and a natural outlet. Serious problems related to shoaling and/or closure of the these boghazes which transfer the lagoon to a salt pan and destroy fish productivity are addressed. This paper reports on the main findings and conclusions drawn from the comprehensive field monitoring program launched by the Coastal Research Institute (CRI) to provide suitable control measures of such problem.

Keywords: Coastal processes, dam effects, Rossetta promontory, sediment transport, shoreline erosion.

INTRODUCTION

El-Bardawil lagoon is situated to the east of Port Said city it is separated from the sea by a long narrow curving sad barrier about 500 m wide, Figure (1), Levy (1974, 1977a, 1977b & 1980). Its surface area is 600 km^2 with maximum water depth of 2m. It differs from the Nile Delta lakes (Idku, Burullus and Manzala) in that it is of tectonic origin, Levy (1980) and not a deltaic one. The only source of water feeding El-Bardawil lake is the tidal prism from the Mediterranean through three outlets (boughazes): two artificial ones and the third is a natural one, Figure (1). These outlets are always subjected to siltations due to sediments transported by waves and currents which tends to transfer the lagoon to a closed salt pan Levy (1980). Such situation places serious hazards to the fisheries industry. Hence appropriate measures must be taken to maintain these outlets opened to ensure good circulation and renewal of water inside the lake by continuous inflow and outflow during flood and ebb tide respectively.

Several dredging operations have been carried out since 1927, and the most recent one took place in 1987. In order to systematically investigate this siltation problem, the Coastal Research Institute in Alexandria (CRI) conducted a comprehensive field monitoring program during the years 1985 and 1986 which was reevaluated and updated in 1990, 1991 and 1992, Khafagy et al (1988, 1990) and Khafagy & Fanos (1990, 1992).

The main objectives of this paper are: (i) to summarize the conclusions drawn from collected field data and results obtained from a developed numerical model and (ii) to highlight the protective works that have been completed and are being recommended, based on the above information.

FIELD MONITORING PROGRAM FOR EL-BARDAWIL BOUGHAZES

The field monitoring program started in 1985 and continued through 1986, included collecting profile data, currents, waves, water levels, discharge measurements through each boughaz, water properties such as salinity and temperature and surface bottom sediment samples. The following sections give brief summary of the most important results drawn from data collected concerning the different environmental parameters involved. Full details are cited in the technical reports published by the Coastal Research Institute, Khafagy et al (1988, 1990).

Figure 1. General location Map.

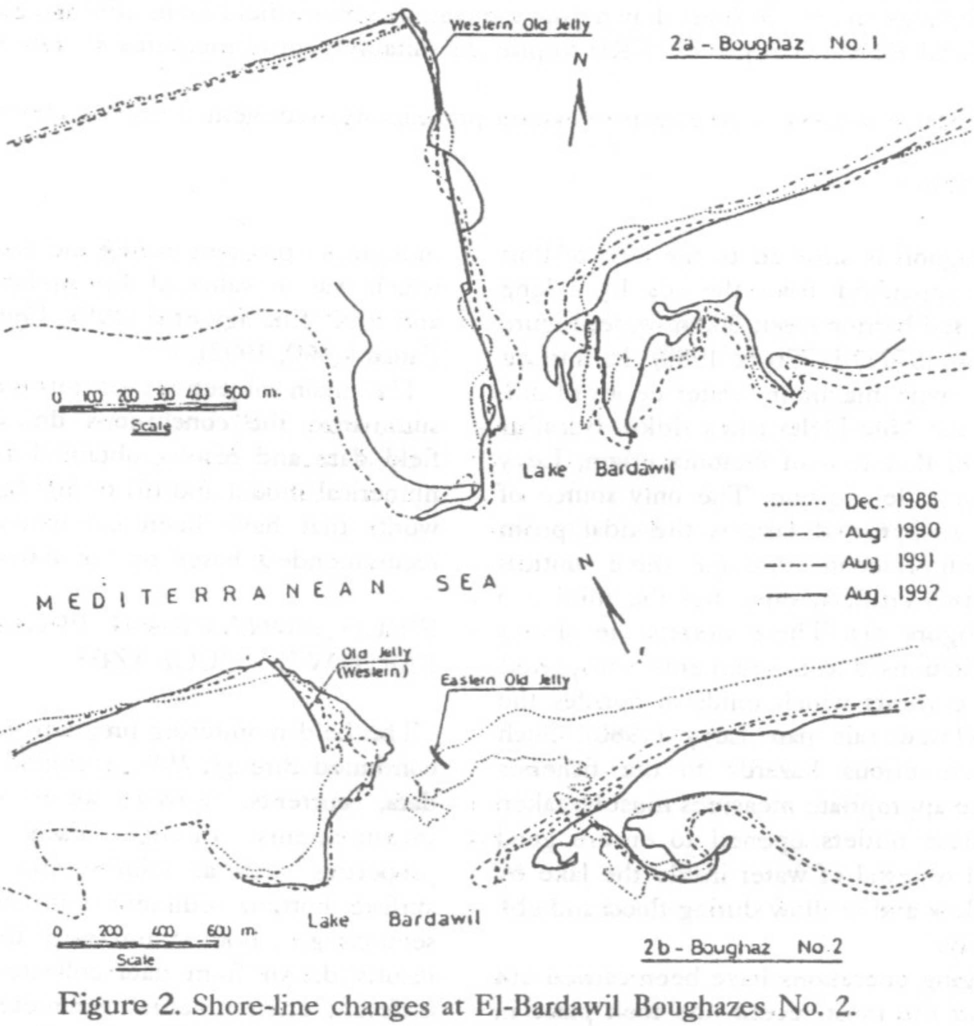

Figure 2. Shore-line changes at El-Bardawil Boughazes No. 2.

WAVE DATA

It was found that the predominant wave direction is NW while the swells are from NE. The maximum wave height observed is 7.5 m in deep water and occurred for 0.2% of the time. The following table summarizes the parameters that are to be taken into consideration for design purposes:

Wave height in deep water Ho (m)	0.75	1.5	2.5	3.5
Wave period (in secs)	5	6	7	8

WATER LEVEL VARIATION

The maximum sea water level recorded in front of the study area during the study period was 60 cm above the mean sea level.

PROFILES SURVEYS AND CONTOUR MAPS

Contour maps have been drawn up from extensive collected profile data. Comparison of four surveys is displayed in Figure (2). It is noticed that there is a difference; of about 900 m & 1000 meters at boughazes no. 1 and 2 respectively; between the western and eastern barriers. This variation is mainly attributed to the erection of two jetties on both sides of the boughaz hence causing accretion to the west of western jetty and erosion on the eastern barrier and destroying the eastern jetty. Also deposition has been taking place near the upper part of the eastern side of the wester jetty causing the shift of contour lines in this area towards the east. At the same time, further to the south of this deposited materials it was observed tat erosion took place and the depths reached about 5.0 meter below mean sea level due to the ebb currents flowing to the sea. On the eastern side the land barrier has been eroded and shifted towards the south by distance of 100 and 400 meters in the period from December 1986 to August 1992. The erosion and south-ward shift of the barrier has created a very wide outlet at boughaz no. 2. The narrowest cross-section became about 800 m width in 1992 as opposed to 300 m in 1986. This can be attributed to the effect of the littoral current which has a predominant direction towards the east. At boughaz no. 1, the cross-section area remained almost the same because the eroded material was transported to the west and deposited in the eastern side of the boughaz.

Part of the eroded material had been transported in the offshore direction thus causing accretion of the depth contours beyond 3.00 m.

LONGSHORE CURRENTS

Longshore current characteristics are measured at three points at each boughaz. It was found that:

- The predominant longshore current direction is towards the east causing siltation on the western side of boughaz no. 1 and 2.
- Maximum velocity recorded at boughaz no. 1 is 56 cm/sec. towards the east and 67 cm/sec. towards the west. The average velocity is about 34 cm/sec. in both directions.
- Maximum velocity recorded at boughaz no. 2 is 40 cm/sec. towards the east and the average velocity is 22 cm/sec/ in the same direction while there is no current towards the west during the study period.

DISCHARGE THROUGH THE OUTLETS

The current distribution was measured across the narrowest cross-section of the two boughazes and discharges through each one are computed. It is concluded that

At Boughaz No. 1:

- The maximum inflow is about 660 m^3/sec with average velocity of 0.91 m/sec, and maximum one is 1.15 m/sec.
- The maximum outflow is about 390 m^3/sec with average velocity of 0.54 m/sec. and maximum one is 0.80 m/sec.

At Boughaz No. 2:

- The maximum inflow is about 1115 m^3/sec with average velocity of 0.82 m/sec, and maximum one is 1.25 m/sec.

- The maximum outflow is about 1235 m^3/sec with average velocity of 0.96 m/sec. and maximum one is 1.20 m/sec.

SURFACE BOTTOM SEDIMENT SAMPLES

Several samples were collected, washed, dried and mechanically analyzed to get their distributions. It was found that coarser sediments of D50, ranging between 0.3 and 0.5 mm are found along the beach while the adjacent deeper parts are characterized by finer sediments between 0.05 and 0.3 mm.

MAIN RESULTS OF DEVELOPED NUMERICAL MODEL

A numerical model was developed and tested for estimating velocities, discharge and lagoon water level as function of the geometry of the system and water level fluctuation in the sea. The continuity and motion equations governing the system are as follows:

i. The continuity equation which relates rate of lagoon water level change dh_l/dt to inlet velocity v, by assuming that the surface water level is uniform through out the lagoon at any time.

$$Va_c = A_l \frac{dh_l}{dt} \qquad (1)$$

Where A_l is the lagoon surface area and a_c is the inlet cross-sectional area.

ii. The motion equation is given by:

$$\frac{dv}{dt} + V\frac{dv}{dx} = -g\frac{dH}{dx} - \frac{gv[v]}{c^2R} \qquad (2)$$

where x is the distance along the channel axis from some reference point, H is the water surface elevation, R is the channel hydraulic radius, C is Chezy factor.

Equation (2) relates the horizontal driving force due to water surface slope to the channel frictional resistance, the convective acceleration caused by velocity variation along the channel axis and the temporal acceleration (or inertia) caused by velocity variation with time. By the use of the relation between Chezy factor C and the Channel friction factor of Darcy-Weisback f given by

$$f = \frac{2g}{c^2} \qquad (3)$$

Equation (2) could be rewritten as follows:

$$\frac{dv}{dt} + v\frac{dv}{dx} = -g\frac{dH}{dx} - \frac{fv[v]}{2R} \qquad (4)$$

In this numerical model the inlet is divided into a series of channels and cross sections to produce a flow net grid.

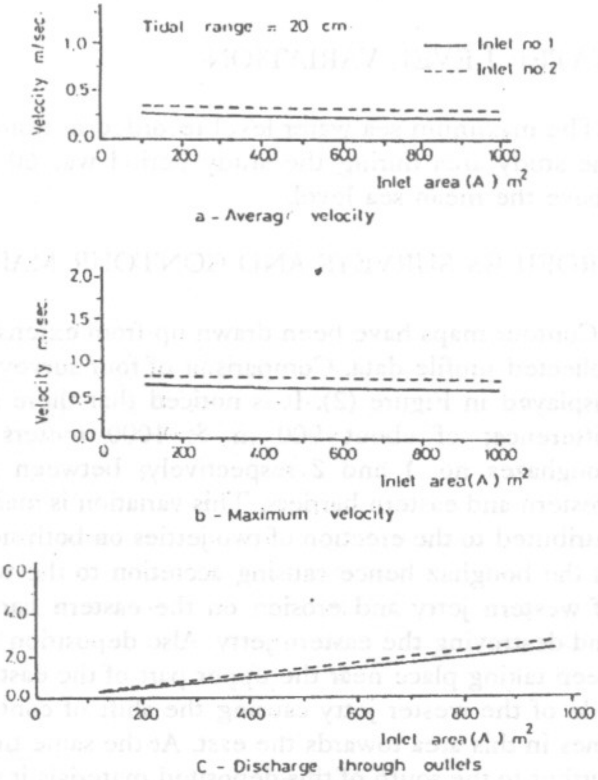

Figure 3. Average and maximum velocity and discharge versus inlet area.

Equations (1) and (4) are then solved by a variable marching time step Runge-Kutta Gill procedure. The model was calibrated using the previous field data and was applied for the two artificial outlets of El Bardawil lagoon. The tidal prism, the maximum and mean velocities at the outlets are calculated for different cross sectional areas and different tidal ranges. Figure (3) gives a sample of results for tidal range 20 cm.

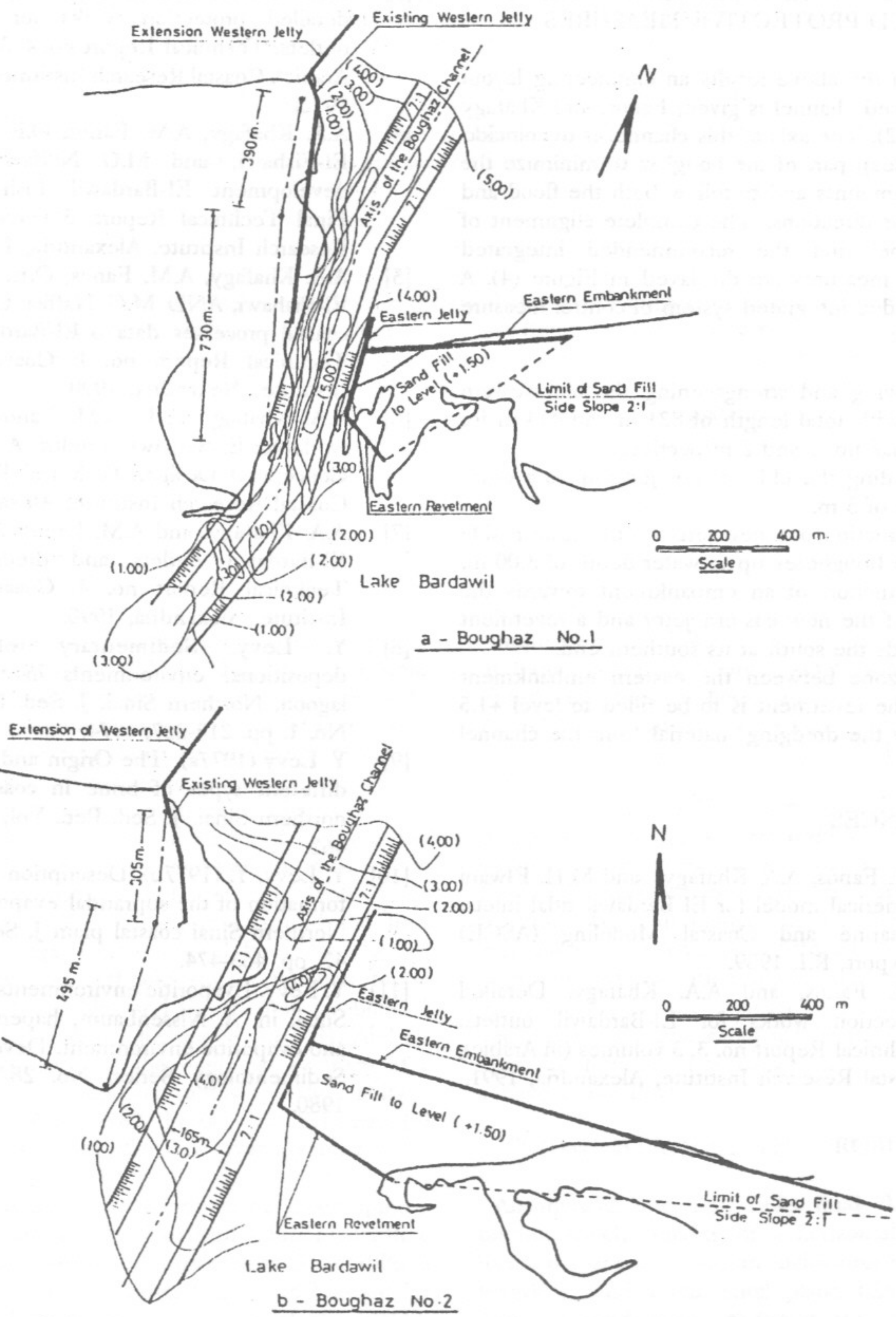

Figure 4. Recommended protection works for Boughaz No. 1&2 of El-Bardawil Lagon.

CONCLUSIONS AND RECOMMENDED PROPOSED PROTECTIVE MEASURES

Based on the above results an engineering layout of a proposed channel is given, Fanos, and Khafagy (1991, 1992). The axis of this channel is to coincide with the deep part of the boughaz to minimize the dredging amounts and to follow both the flood and ebb current directions. The complete alignment of the channel and the recommended integrated protective measures are displayed in Figure (4). A recommended integrated system of control measure consists of:

- i- Renewing and strengthening the old western jetty with total length of 821 m and 414 m for boughaz no. 1 and 2 respectively.
- ii- Extending the old western jetty up to a water depth of 5 m.
- iii- Construction of a new jetty on the eastern side of the Boughazes up to water depth of 3.00 m.
- iv- Construction of an embankment towards the east of the new eastern jetty and a revetment towards the south at its southern end.
- v- The zone between the eastern embankment and the revetment is to be filled to level +1.5 m, by the dredging material from the channel itself.

REFERENCES

[1] A.M. Fanos, A.A. Khafagy, and M.H. Elwani Numerical model for El Bardawil tidal inlets. Estuarine and Coastal Modeling (ASCE) Newport, R.I, 1989.

[2] A.M. Fanos, and A.A. Khafagy. Detailed protection works for El-Bardawil outlets. Technical Report no. 3, 3 volumes (in Arabic), Coastal Research Institute, Alexandria, 1991.

[3] A.M. Fanos, and A.A. Khafagy. Modified detailed protection works for El-Bardawil outlets. Technical Report no. 4, 3 volumes (in Arabic), Coastal Research Institute, Alexandria, 1992.

[4] A.A. Khafagy, A.M. Fanos, O.E Frihy, N.M. El-Fishawi, and M.G Naffaa. Project of development El-Bardawil Fish Resources. Final Technical Report, 3 volumes, Coastal Research Institute, Alexandria, 1988.

[5] A.A. Khafagy, A.M. Fanos, O.E. Frihy, N.M. El-Fishawi, AND M.G. Naffaa. Up-dating the coastal processes data o El-Bardawil outlets. Technical Report, no. 1, Coastal Research Institute, Alexandria, 1990.

[6] A.A. Khafagy, and A.M. Fanos. Protective works for El-Bardawil outelts: Alignment and Conceptual Design. Technical Report no. 2, Coastal Research Institute, Alexandria, 1990.

[7] A.A. Khafagy, and A.M. Fanos. Alignment of El-Bardawil outlets and dredging works. Technical Report no. 4, Coastal Research Institute, Alexandria, 1990.

[8] Y. Levy. Sedimentary reflection of depositional environments in the Bardawil lagoon, Northern Sinai. J. Sed. Pet., Vol. 44, No. 1. pp. 219-227, 1974.

[9] Y. Levy (1977a). The Origin and evolution of different types of brine in coastal sabkhas, northern Sinai. J. Sed. Pet., Vol, 47, pp. 451-462.

[10] Y. Levy, Y. (1977b). Description and mode of formation of the supratidal evaporite facies in Northern Sinai coastal plain J. Sed. Pet., Vol, 47, pp. 463-474.

[11] Y. Levy. Evaporitic environments in Northern Sinai, in: A. Nissenbaum, hapersaline brines and evaporitic environment. Developments in Sedimentology Series, No. 28, p. 131-143, 1980.