MORPHOLOGICAL SIMULATION FOR HUMAN INTRVENTION TOWARDS THE NILE RIVER (CASE STUDY CAIRO REGION)

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ABSTRACT

Channel morphology is to describe the geometrical changes in the River as a result of sedimentation, erosion and bank failure. This science is a major importance to the hydraulic engineer, since many of his greatest problems arise because of such forms.
Rivers have been a focus of human activities throughout ancient and modern times. River channel is sensitive to human intervention. This intervention takes several forms as (bridges, barrages, dredging, and water intakes) which cause side effects in the River. This study focuses on Cairo area (El Pharaoh's floating jetty supported by 14 piles) which is located upstream El Gamaa Bridge by 500.0 m. Model is the one of a series of numerical models for simulating the morphological changes in alluvial rivers. This paper describes the two dimensional mathematical modeling performed to study the effects of human activities. Extensive field reconnaissance was conducted to collect different type of data for model application at years 1982, 2004 and 2014. The comparisons of cross sections at different years were studied. The main objectives of this study are analyzed and evaluated the effect of these piles in the Nile River. Based on different results of this study, it is concluded that, the area of study suffered from erosion nearly to west side and around the piles. It's recommended to perform a bathymetric survey for the area of floating jetty regularly every one or two years to monitoring the morphological changes in the channel.

Keywords: Morphology, **Numerical Models**, cross section, Nile River,

1. INTRODUCTION

The Nile River is a great source for all purposes such as navigation, recreation, irrigation and tourism. Morphology refers to the width, depth, slope, and channel planform. Due to the mentioned above variations, many related problems to sedimentation process into and within the River Nile are encountered. the morphology and fluvial characteristics of the Nile have been studied extensively. Before the High Aswan Dam was constructed the Nile was likely stabilized in balance with its natural flows which included peak discharges (those that influence most of the properties of the channel) of about 11,000 m3/s. Channel changes occurred but the average dimensions (width, depth, etc.) were not changing, (Abdelbary, 1992).
After the dam, peak discharges are reducing to about 2,600 m3/s and the average channel dimensions are changing slowly to fit the new peak flows. The channel was too wide for the new flows and it is becoming narrower with time, meander lengths are also becoming shorter, creating more crossings between meanders where navigation becomes difficult.

The construction of Aswan High Dam has caused significant changes in morphological parameters and these changes resulted in deposition and scour along the river channel. Consequently, scouring of bed materials, bank erosion, and deposing in critical areas can affect water depth fulfillment. The transport, erosion and deposition of sediment are key elements for describing and understanding the behavior of rivers. The morphological changes are the impact of physical responses of the River Nile to interventions. The study focuses on floating jetty supported by 14 piles which are located at west bank at km 1.810 upstream El-Roda gauge and upstream El Gamaa Bridge by 500.0 m. The study area characteristics were defined by analyzing the hydrographic and topographic recent maps as shown

in Fig. 1 (NRI, 2003). It shows that El-Roda Island is in the East side of the river along 3.263 km divided the river into two channels. The Eastern channel is called Seiallat El-Roda and the main channel. Numerical models could be considered as the most widely technique to solve mathematical expressions that describe any physical phenomena. A two dimension numerical model, the Surface Water Modeling System (SMS) is used to simulate the impacts of the human interventions. The SMS software provides valuable tools for mesh generation, data interpolation, and graphical visualization. The model can calculate water surface elevation and flow velocities, and any other functional data is calculated at each node of the designed mesh for shallow water flow problems and support both steady and dynamic model simulation. The model was calibrated and tested by using the available data. The available data of hydrographic survey for years 1982, 2004 and 2012 are used. Comparison of cross sections for different years at study area showed the variations occurred in bed level. The current study investigates the potential morphological impact of the changes on the safety of the existing structure (floating jetty) which located on the west side of the Nile River at Cairo.

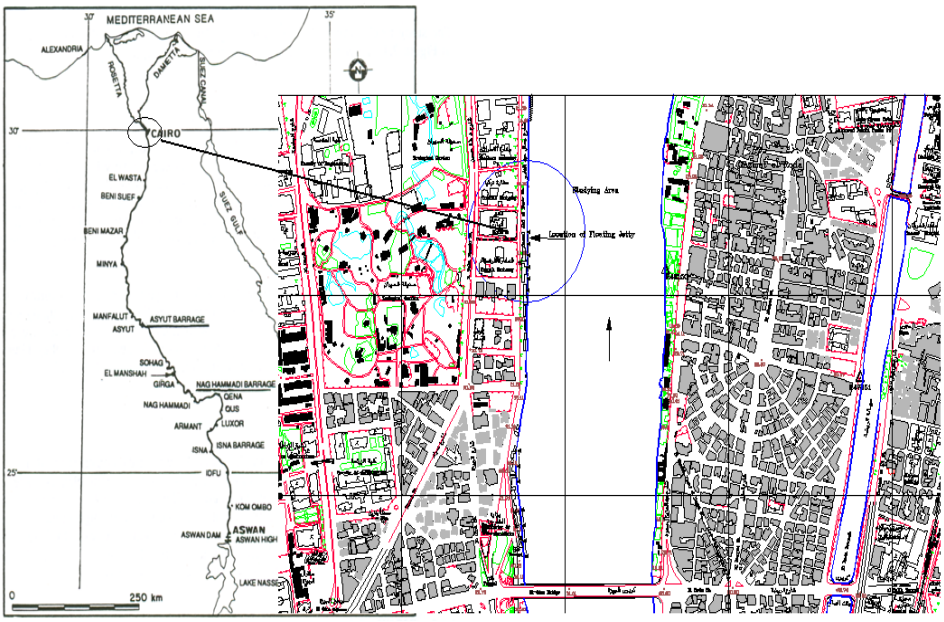

Figure 1. Study area (NRI, 2003)

2. PROBLEM DESCRIPTION

The Ministry of Water Resources and Irrigation has requsted the Nile Research Institute to study the effects of floating jetty on the Nile River. Since year 2004 El Pharaoh's company supported the floating jetty by 14 piles perpendicular to the Nile with spacing illustrated in Fig. 2. The existing structures on the Nile River are expected to affect the morphology of study area.

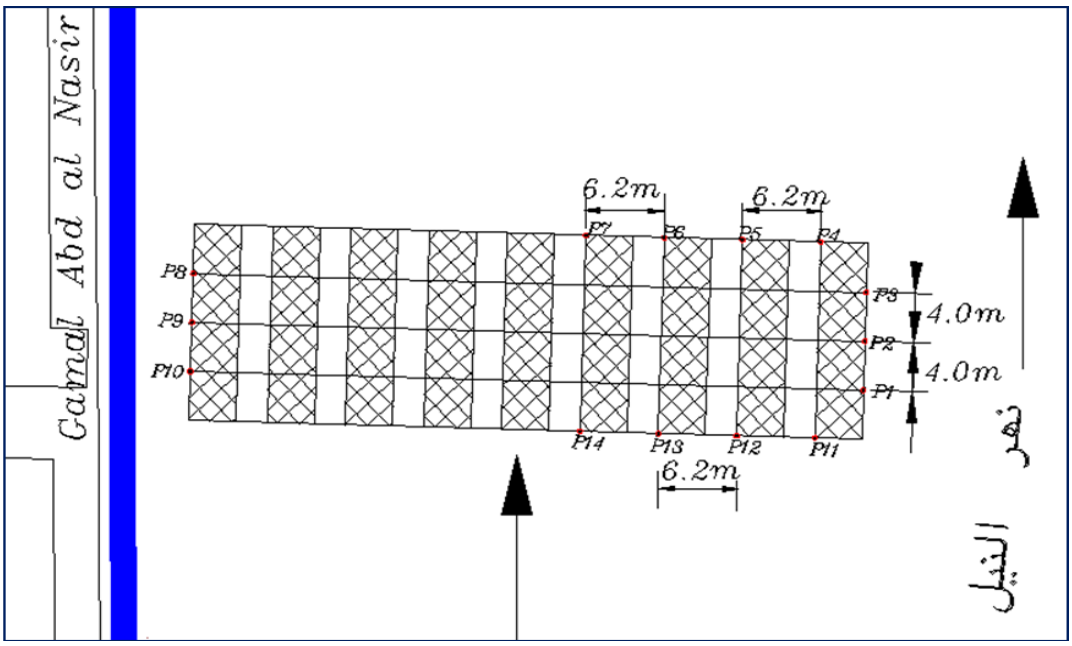

Figure 2. Sketch showing the location of (14) piles in floating jetty

3. OBJECTIVES

- Investigate the floating jetty in Cairo area using historical records to predict, analyze and evaluate the impacts of the existing structure on the river morphology.

4. DATA COLLECTION

Two main sets of data were used to analyze the changes. The first one included River cross-sections results through different years (1982, 2004 and 2012). The contour map produced in 1982 (Kinting), cross sections were deducted for the study area. Also, data were produced in 2004 from hydrographic survey and in May, 2012 the NRI was responsible to studying the effects of floating jetties on the Nile River morphology. Eight cross sections were observed with shorter intervals for the analysis of changes at study area, which extends for about 400.0 meters as shown in Fig. 3.

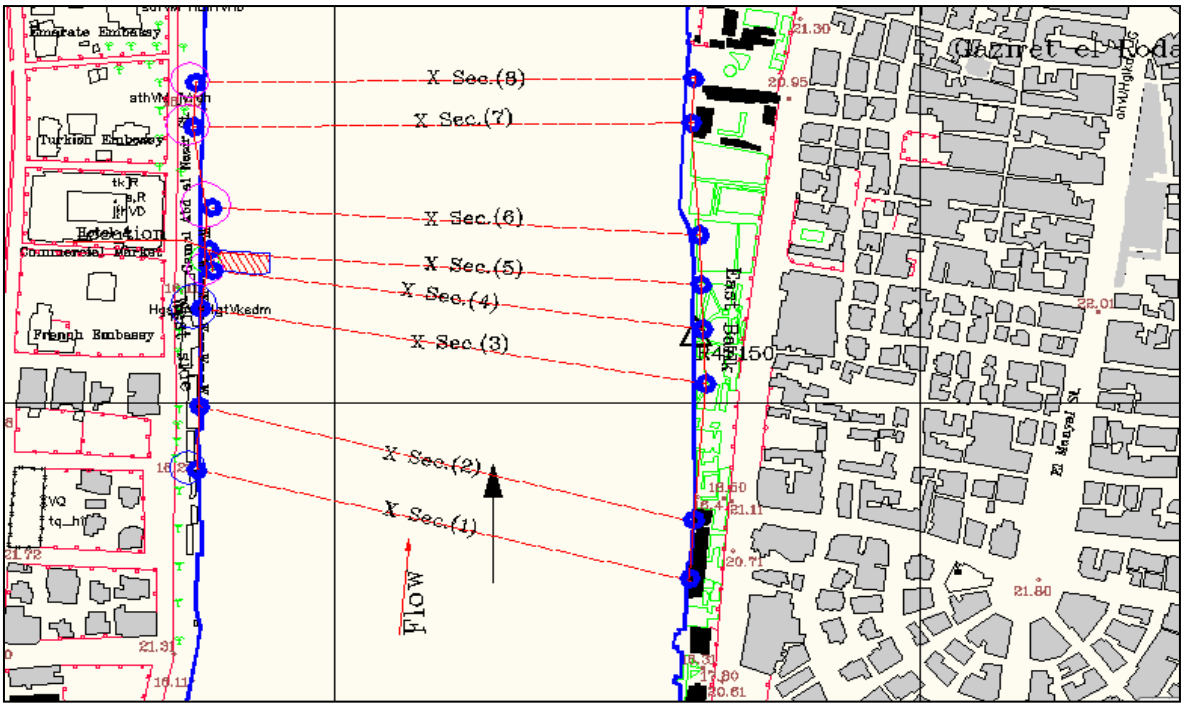

Figure 3. Illustrate cross sections at study area

4-1 Hydrological data

The second group of data was the average discharges passing at Cairo area which measured at El-Ekhsas station, (located south Cairo at Km 39.0 upstream (U. S.) El-Roda gauge) and the mean ten days corresponding water levels of the eight years from 1996 till 2003. These discharges data were used as U.S. Boundary Condition for the model applications. Table 1 illustrated the discharges and water levels data at Cairo region. These water levels values are used to calculate the water level which corresponds to the discharges passing at El- Gamaa Bridge, which is located at kilometer 2.40 D.S El Roda gauge. The calculated water level used as the downstream (D.S.) Boundary Condition for the model application.

Table 1. The inflow discharges and water levels at Cairo region (NRI, 2012)

water level (m)	Discharges passing through study area (mm^3/day)		Total discharges (mm^3/day)
	El-Roda Island		
	Western Channel (main channel)	Eastern channel (Seiallat El-Roda)	
15.04	47.86	5.97	53.78 (minimum)
17.06	161.09	19.91	181 (maximum)
18.56	311.5	48.5	350(future)

5. METHODOLOGY

5. 1 Modeling Approach

The Surface Water Modeling System (SMS) was used for the present study. This system consists of a family of numerical models that provide multidimensional solutions to open channel flow. The SMS model is suitable for use in solving hydraulics behavior, sedimentation, and transport problems of rivers, reservoirs, wetlands, estuaries and lakes. The SMS modeling system is the Corps of Engineers' standard for general purpose modeling of two dimensional depth averaged open channel flow and sediment transport problems. The SMS package consists of Finite Element Surface Water modeling System (FESWMS) model and SED2D model. The FESWMS model is a two-dimensional, depth-averaged hydrodynamic model used to compute water levels and depth averaged velocities. SED2D model is a companion two-dimensional, depth-averaged sedimentation model used to compute the scour, transport, and deposition of bed sediments. During a simulated flood event, FESWMS was used to compute a time history of water depth and depth averaged velocity at each node in the mesh (U.S. Department of Transportation 2002).

Mesh Generation. A preliminary finite element mesh was developed, using the SMS 8.0 software (U.S. Department of Transportation, 2002). A finite element mesh is defined as a network of triangular and quadrilateral elements constructed from nodes. The study area is defined by means of an unstructured grid composed of quadrangular and triangular elements. Water depths are specified at the vertices (nodes) of each element composing the mesh. The water surface elevations and the components of velocities are computed at the nodes. Fig. 4 shows the finite element mesh generation, developed for the study area, the mesh was divided to many parts according to fraction coefficient for the bed level, protected area and swamped area. The study area is protected at two sides and there is some swamped area. The mesh consists of 1151 elements and 3678 nodes were developed from the bathymetric data to

cover the modeled reach. Nodal coordinates were referenced to the WGS84 ellipsoid with Universal Transverse Macerators (UTM) Projection. Typical mesh element size was 1400 m in the longitudinal direction (x-direction) and 400 m in the transverse direction (y-direction). In the areas of interest such as the area in front of floating jetty the mesh element are condensed to give more sensitivity for these areas. The bed levels of the mesh nodes are calculated by the interpolation between the mesh nodes and the bathymetry survey, which is obtained from the field data. Fig. 5 represents the bed elevation to the mesh geometry of the area under study.

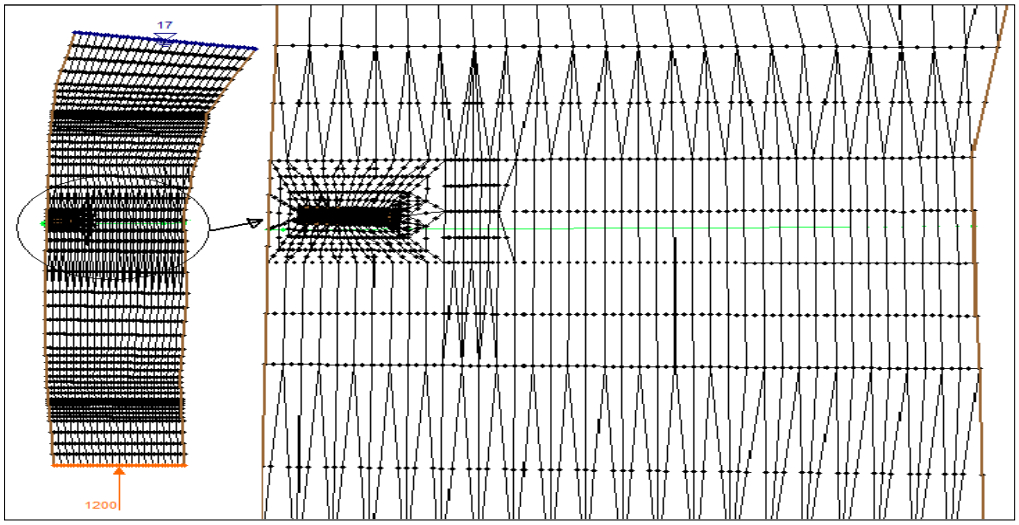

Figure 4. The finite element mesh generation at the study area

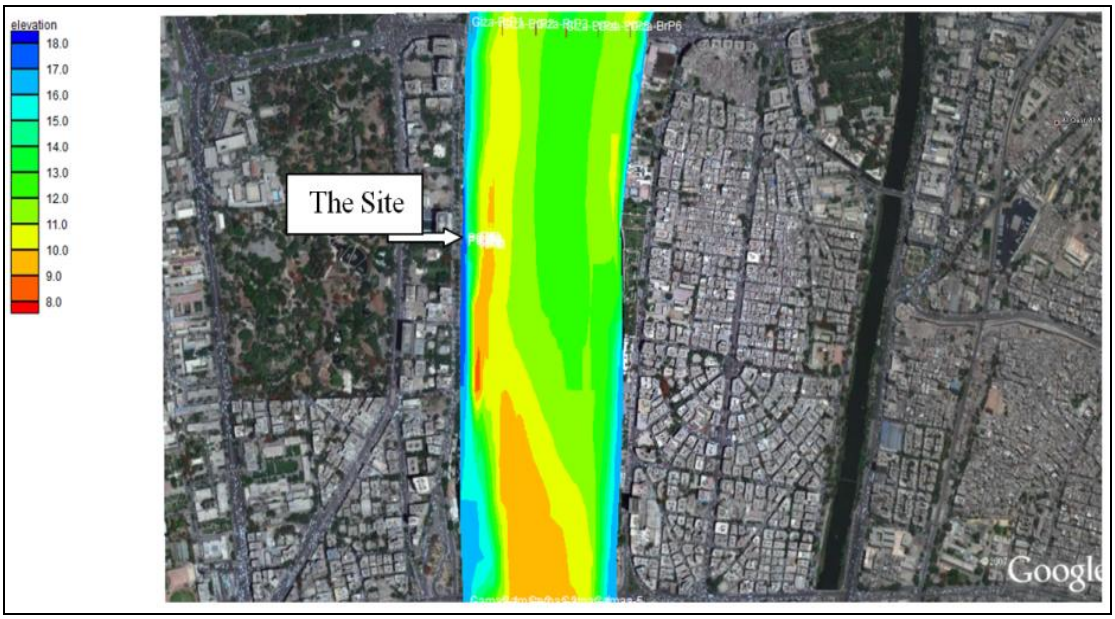

Figure 5. Bed Elevation at study area

Initial and Boundary Conditions. In addition to mesh geometry, the hydrodynamic model requires input data describing initial and boundary conditions. The initial conditions were defined as the initial bed elevations for all net work nodes, which were collected during the field survey in 2012. The boundary conditions consist of three types that are inflow, outflow, and side boundary conditions. The

inflow boundary condition is defined as the inflow discharge to the study area. The outflow boundary condition is defined as the upstream water level at the study area. The initial bed gradation for the modeled reach of study was based on the analysis of the collected samples. The bed materials gradation was determined; the samples were analyzed to determine particles size distributions, where Particle Size Distribution D50 is also known as the median diameter or the medium value of the particle size distribution, it is the value of the particle diameter at 50% in the cumulative distribution. It is one of an important parameter characterizing particle size.

Model Calibration and Validation. Calibration phase is considered the most important stages which are sure to match the model to the situation in nature and its potential to simulate water flow imprisonment subject of the study. During the process of establishing a numerical model to represent a given study area, calibration is performed to ensure adequate prediction for hydrodynamic conditions. The model was calibrated using the available data in years 1982, 2004, and 2012 by using an inflow discharges at Cairo region.

During the calibration of the model using the vertical distribution data for the flow velocity at some of cross sections in the study area in addition to water levels for each cross section, were used in the calibration of the two-dimensional mathematical model.

After the model calibration phase was completed. The manning coefficient values estimated in different locations in each of the bed and two sides of the channel are shown in Table 2.

Table 2. The values of friction coefficient and Manning coefficient

Case of Friction Coefficient	Manning Coefficient
Natural Bed level	0.02
Natural Sides	0.025
Bank Protection	0.035
Swamped area	0.045

The model was verified using the inflow discharges at El-Ekhsas station and water levels at EI-Roda gauge. The verification period was adopted from year 2000 to 2004. The model was run with time step 10 days. The original bed elevations for the study area were used during the calibration period. During model verification, no adjustments of the model parameters or the roughness coefficients have been performed. Comparison of the observed and simulated depth average velocity at the study area at year 2004 is shown in fig 6. The comparison also, showed good agreement especially in the middle of the river at the study area.

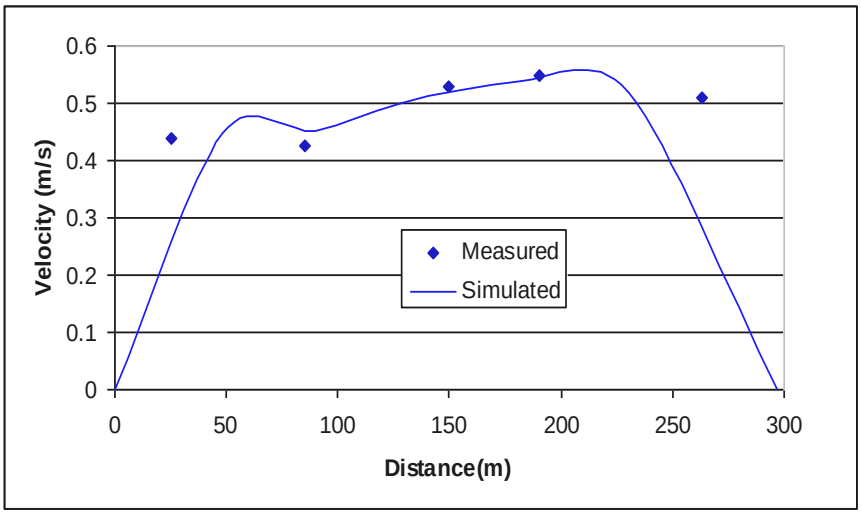

Figure 6. Measured and Simulated Velocity at Sec. (3) year 2004(Verification process)

5-1-1 Mathematical model results

The model calibration phase has been achieved through the actual discharges at field data collection, which is equivalent to 95 Mm^3/day. Then the model calibrated results through this stage has been achieved in order to ensure fully calibrated and matching the results that are obtained from the field data. The model has been calibrated using the maximum discharge recorded at El-Ekhsas Station, which is equal to 181.00 Mm^3/day. This part of the study shows the results of the SMS model to analysis the hydro morphology changes of the Nile River.

In case of a future Release of maximum Discharges 350 Mm^3/ day and water level at the study area is (18.50) m. Velocity values in the study area ranges from 0.80 m / s to 1.0 m / s as shown in Fig. 7,water depths ranging study area from 8.30 meters to 9.10 meters as shown in Fig. 8 and water surface at site is about 18.54 meters as shown in Fig. 9.

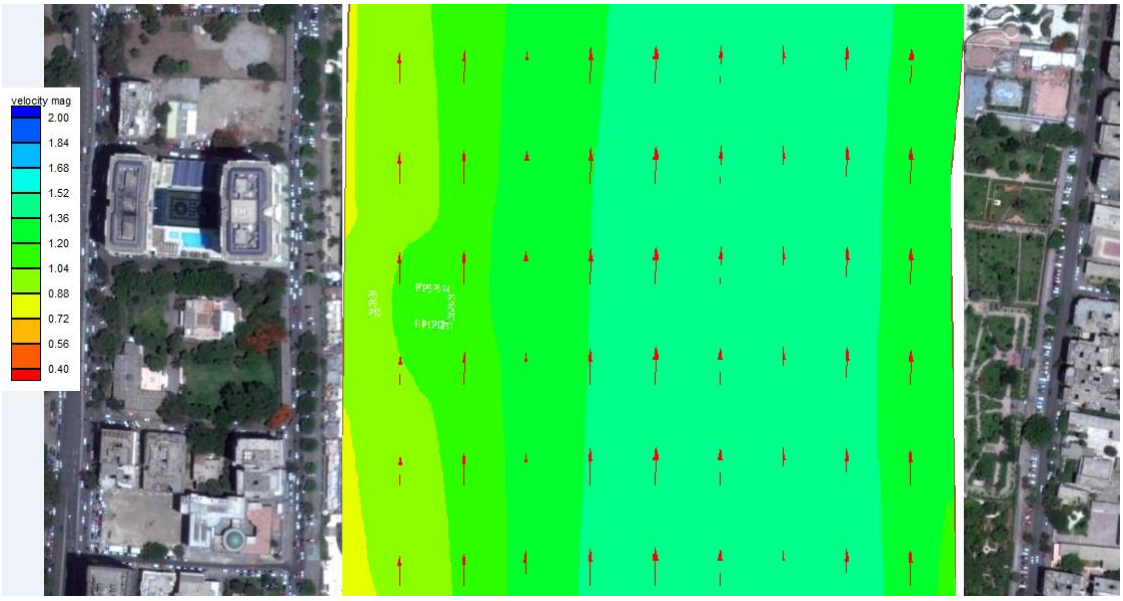

Figure 7. Velocity Magnitude and Directions at study area

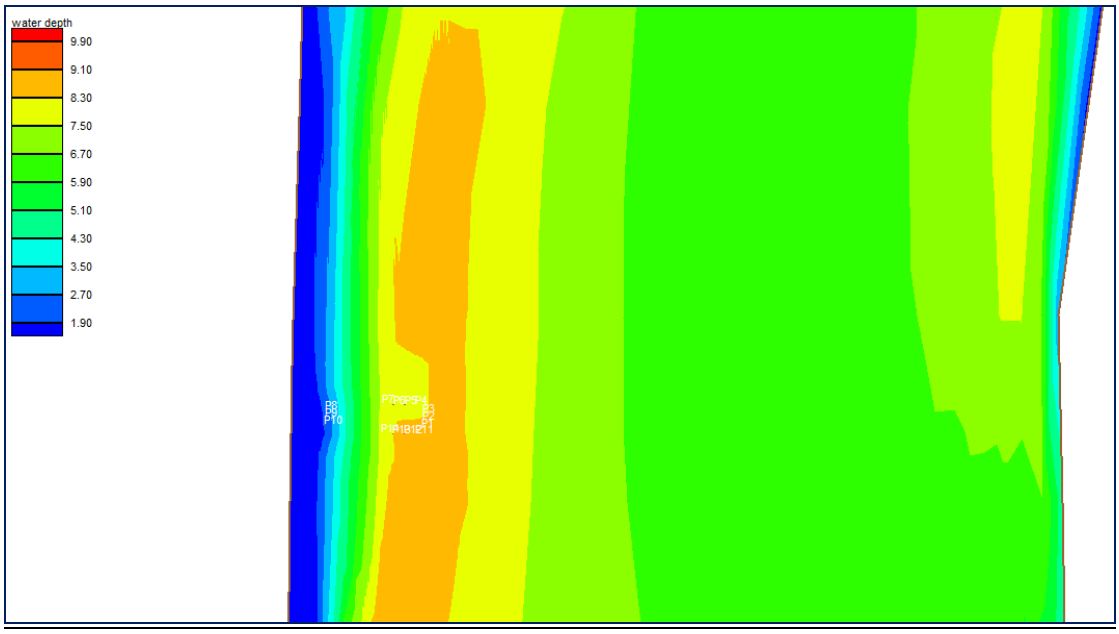

Figure 8. Water Depth (m) in the study area

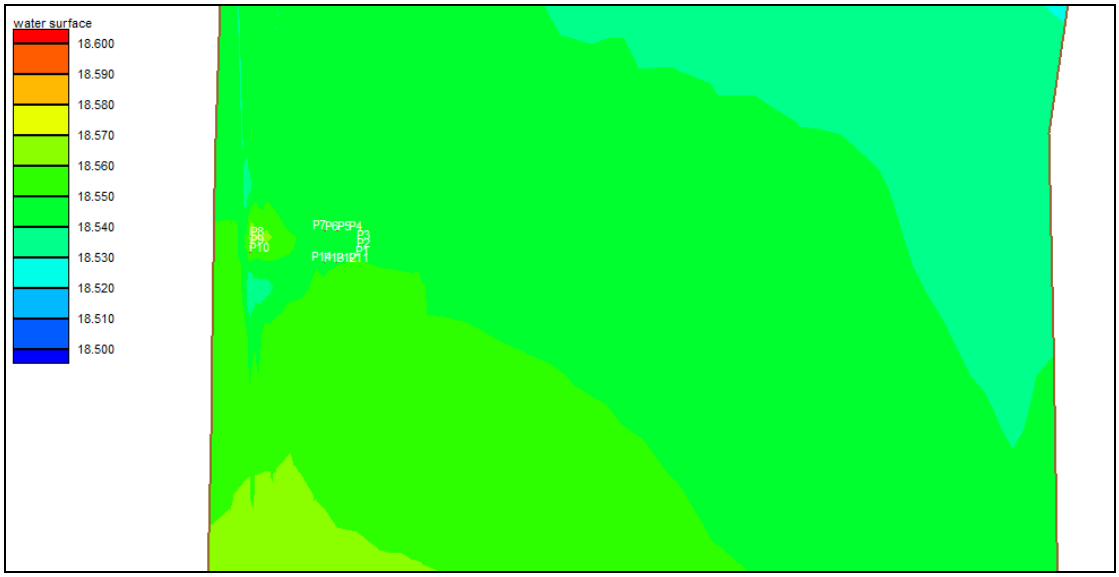

Figure 9. Water surface (m) in the study area

5-1-2 The morphological changes at the study area

From the contour maps produced in 1982, available in NRI which used the bed levels in the mathematical model, where the model results showed that the bed level of the study area before the establishment of Floating jetty which ranged from 8.0 m to 14.0 m as shown in Fig. 10.

From the previous studies which carried out by NRI for the region in 2004 and 2012 were input to the model, the data model results showed that the bed level in 2004 ranged from 9.0 m to 14.0 m as shown in Fig. 11 which shows deposition occurring before floating jetty area, which led to reduced depths and in 2012 the bed level ranged from 8.0 m to 14.0 m as shown in Fig. 12 where there is erosion at the front of floating jetty.

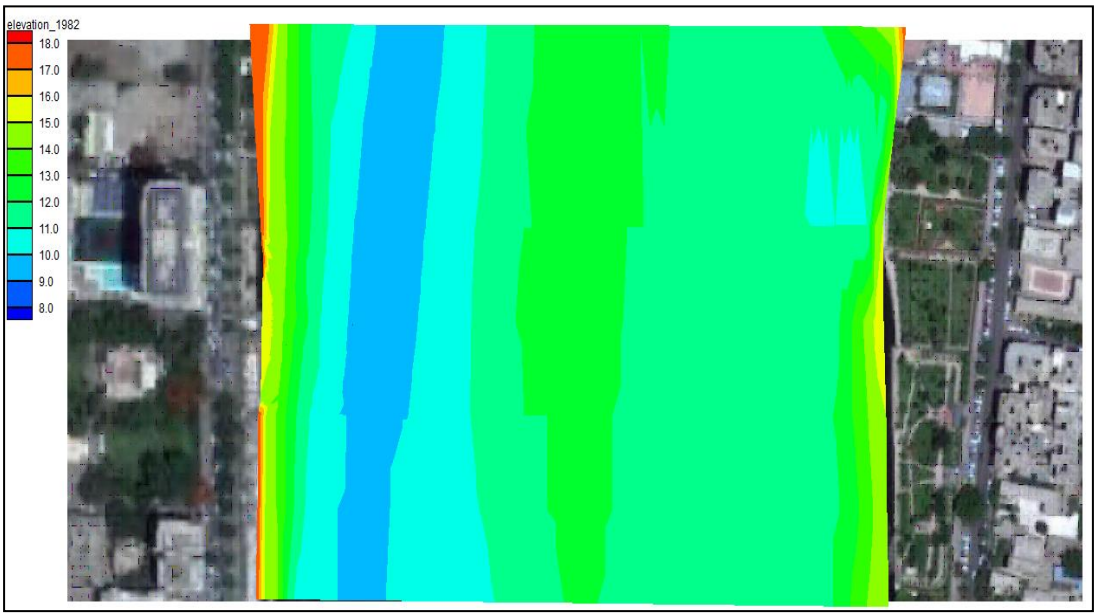

Figure 10. The bed level at study area year 1982

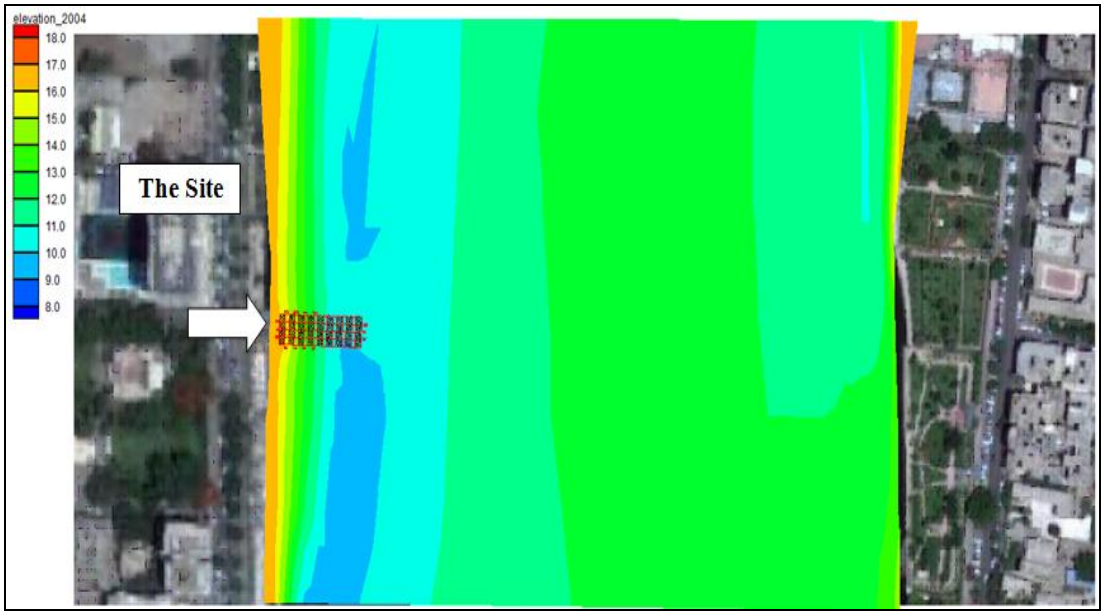

Figure 11. The bed level at study area year 2004

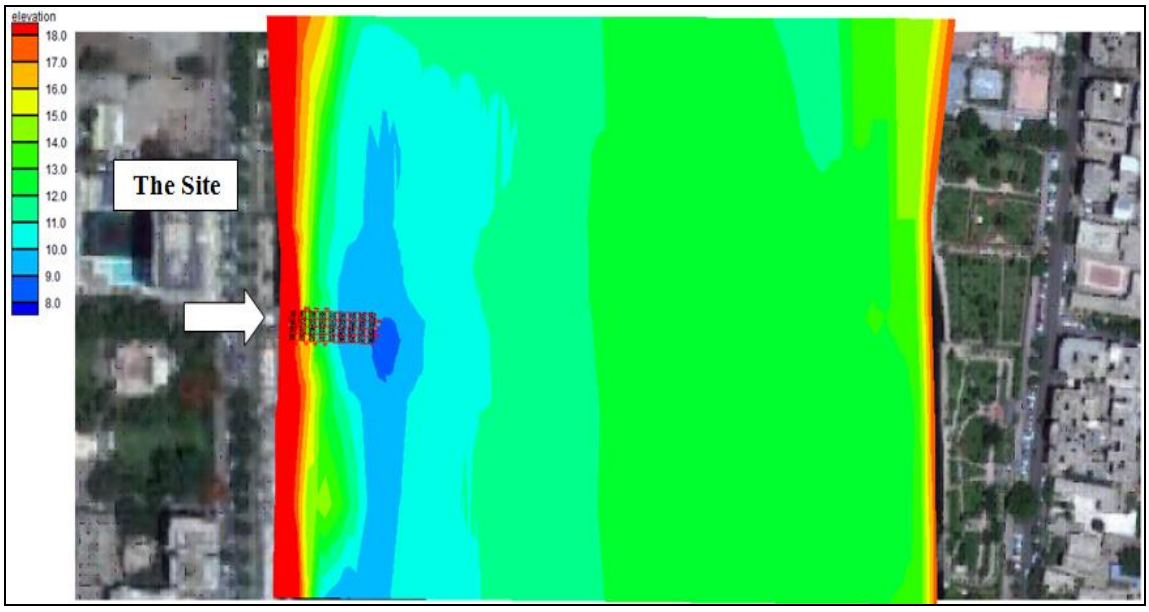

Figure 12. The bed level at study area year 2012

From results of the previous studies for the years 1982, 2004 and 2012 where the comparisons between the bed level at piles area according to the available data shown in Table 3. The table illustrated that the difference in bed level between 2004 and 2012 ranged from zero (No difference in elevation) to 1.3 m (erosion) around the piles. Furthermore, the difference in bed level between 1982 and 2012 ranged from zero (does not have a difference in elevation) to 2.3 m (erosion around the piles).

Table 3. The values of bed elevations around piles for different years

Year	Bed Elevations (m)		
	1982	2004	2012
P1	9.85	10.01	9.90
P2	9.86	10.10	9.40
P3	9.86	10.30	10.30
P4	10.01	10.43	9.50
P5	10.36	10.61	9.30
P6	10.69	10.65	9.40
P7	9.75	10.79	9.50
P8	15.00	14.00	12.88
P9	15.00	14.00	12.70
P10	15.00	14.00	12.88
P11	9.97	10.11	9.50
P12	10.38	9.98	9.10
P13	10.72	10.31	9.20
P14	11.10	10.95	9.40

5-2 Comparisons of the cross-sections

A bed level analysis based on a comparison of cross-sections with space varied between 20 m to 90 m where, cross section no. (4) at the front of floating jetty and cross section no. (5) behind the floating jetty at different years (1982, 2004 and 2012) were observed to indicate the changes in the study area as shown in Fig. 13 and 14. The figures shows that the difference between the bed level of the year 2004 and 2012 up to 1.60 m (erosion) and between year 1982 and 2012 the erosion up to 2.30 m. Fig 15. Shows the longitudinal section nearest to west bank resulted from the used model where the zero distance is the location of floating jetties, the elevation values is varied from 9.8 m to 10.6 m.

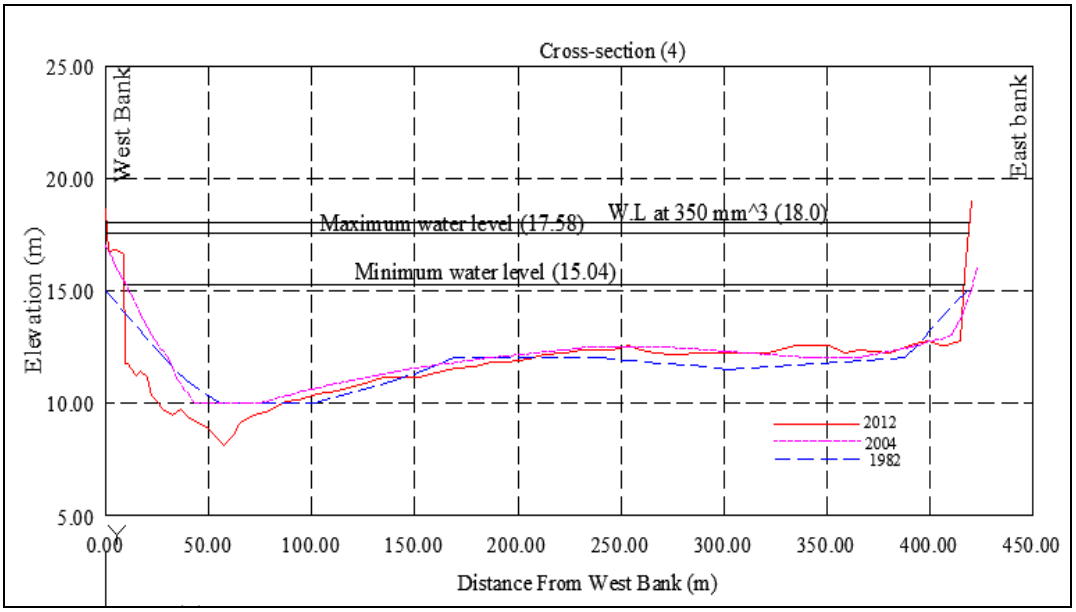

Figure 13. Comparison between year 1982, 2004 and 2012 for X. sec No. (4)

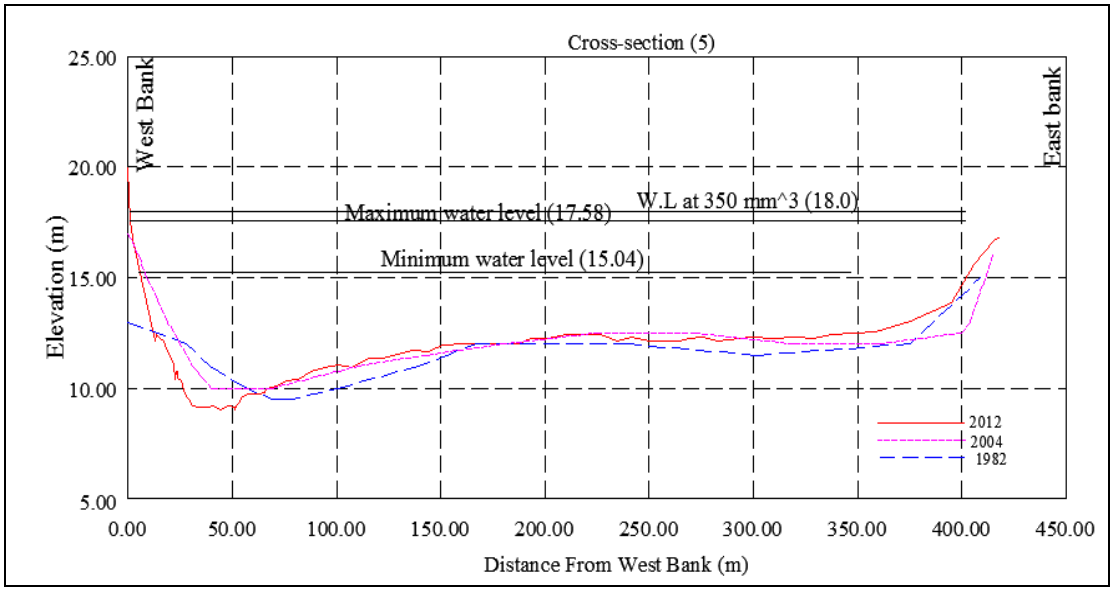

Figure 14. Comparison between year 1982, 2004 and 2012 for X. sec No.(5)

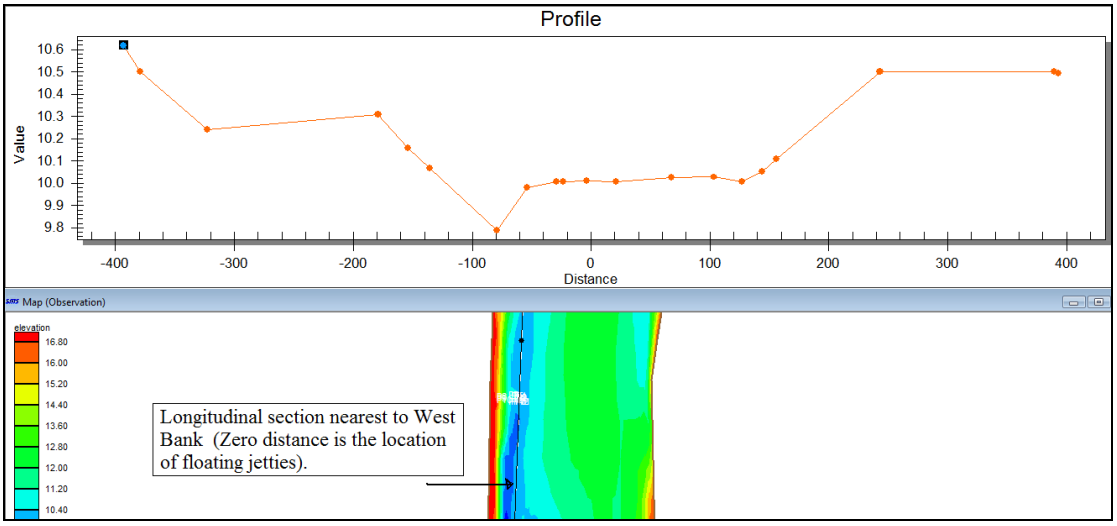

Figure 15. Longitudinal cross section nearest to west bank

6. CONCLUSIONS

The present research used a set of tools to analyze and evaluate the effect of human interventions of the existing structures. A case study, for floating jetty supported by (14 piles) was considered for this study. From successful applications of the model to simulate and evaluate the water surface elevations, velocities distributions and bed changes and cross sections comparisons by using compilation of field data of bathymetric charts and hydrographic surveying for 1982, 2004 and 2012, It was concluded that the indicated changes in river morphology suffered from successive erosion at west side and around the piles but very limited effect on the hydraulic and morphological characteristics.

7. RECOMMENDATIONS

According to this research, it is recommended to perform a bathymetric survey for the area in front of floating jetty regularly every one or two years to follow up the amount of morphological changes in the channel.

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