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HYDRODYNAMIC MODEL FOR KHOR AL-ZUBAIR AND SHATT AL-BASRAH CANAL, NORTHWEST OF ARABIAN GULF

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Abstract

A hydrodynamic model for Khor Al-Zubair and Shatt Al-Basrah canal was introduced by using the Mike11 routine. The model was run for two months, March and April of 2018 with Δt=40 sec and Δx=300 m. Model calibration and validation were done through a comparison of measurements of water level and flow velocities with simulation results at two sites within the model area. The results of the model have an acceptable agreement with the measurement values, with RMSE of 0.31 m for water level and 0.11 m/sec for flow velocities through the calibration period, while for the validation period the RMSE was 0.36 m and 0.37 m/sec for water level and flow velocity respectively.

Key words: hydrodynamic, Modeling, Mike11, Khor Al-Zubair, Calibration.

1.Introduction

The study of the hydrodynamic characteristics of the coastal waters which deal with the physics of water movement has a high priority to understand their behavior due to its direct impact on the lives and activities of coastal communities. Also, it have direct effects on coastal facilities and navigation, in addition to their impact on the ecosystem of that waterway. Additionally, hydrodynamic processes controls the exchange of water masses along the horizontal and vertical directions through mixing between different water masses, as well as it govern the transfer of sediments to and from waterways, so understanding the behavior of the dynamic processes of coastal waters is particularly important to protect coastal areas from erosion or deposition. Furthermore, hydrodynamic processes also play a prominent role in the transport of pollutants to and from the waterway, they are the main controllers in the physical transport processes of materials and water circulation [1].

There are several methods to study the hydrodynamic characteristics, the most important of it is the direct measurement through collect and record of various hydrodynamic factors like water level fluctuations, current speed and directions, and waves. Secondly, the preparation of physical models to represent the phenomenon under study. Thirdly, the preparation of mathematical models by solving the equations that govern the movement of water to understand the behavior of this waterway, it is also possible by these models to assume different scenarios of future changes that may occur and give a future vision of the response of that waterway to such changes [2-4].

Khor Al-Zubair (KZ) and Shatt Al-Basrah (SB) canal are located southwest of Basrah city and have special importance in southern Iraq. There are four industrial plants located close to KZ and SB; the petrochemical, steel, Umm Qaser cement, and fertilizer plant in addition to the Shatt Al-Basrah electricity station. Additionally, there are two of the most important Iraqi ports situated on the banks of Khor Al-Zubair, Umm Qasar port and Khor Al-Zubair port as well as liquid gas port [5]. The aim of this study is preparing a hydrodynamics modal for Khor Al-Zubair and Shatt Al-Basrah canal by using Mike 11 routine.

2. Materials and Methods

2.1. Theory

The water flow in stream channels is a distributed process since the flow rate, velocity and depth vary spatially throughout the channel. The estimation of flow rate and water level at particular places in the channel system may be acquired using a set of equations that define the conservation of mass and momentum along this channel. This type of model is based on partial differential equations that allow the flow rate and water level to be computed as a function of space and time. However, for most practical purposes, the spatial variations in lateral and transverse directions can be neglected and the flow in a channel system can be approximated as a one-dimensional process along the longitudinal direction (i.e., in the direction of flow). Saint-Venant equations of channel flow that were derived in the early 1870s by Barre de Saint-Venant, based on the assumptions [6] ,

1. The flow is one-dimensional. The water depth and flow velocity vary only in the direction of flow.
2. The flow is assumed to vary gradually along the channel so that the hydrostatic pressure distribution prevails and vertical accelerations can be neglected.
3. The channel bottom slope is small.
4. The channel bed is stable such that there is no change in bed elevations in time.
5. The fluid is incompressible and of constant density throughout the flow.

The general equation of continuity can be given for the particular case of an open channel with an irregular geometry. The conservation of mass then can be written as,

$$\rho(Q + qdx) - \rho\left(Q + \frac{\partial Q}{\partial x}dx\right) = \frac{\partial(\rho A dx)}{\partial t} \quad (1)$$

Applying the assumption of constant density and rearranging produces the conservation form of the continuity equation, which is valid for any irregular cross section [6],

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \quad (2)$$

And the momentum equation can be written as

$$\frac{\partial Q}{\partial t} + \frac{\partial(\frac{aQ^2}{A})}{\partial x} + \frac{gA\partial h}{\partial x} + \frac{gn^2Q|Q|}{AR^{3/4}} = 0 \quad (3)$$

Where Q : total discharge, A: area of cross section, q: accidental discharge, h: change in the water level, n: Manning factor for roughness, R: hydraulic radius, g: gravity, a: kinetic energy coefficient, x: distance along the channel bed, t: time. Mike11 routine is used to simulate the hydrodynamics of Khor Al-Zubair and the Shatt Al-Basrah canal. Mike11 is a one-dimensional modeling system developed by Danish Hydrologic Institute, which is capable of simulating the hydrodynamics properties, water quality, and sediment transport in rivers, estuaries, and channels [6]. It's performed an implicit finite difference computation of unsteady flow by solving the Saint Venant equations.

2.2. Study Area

Khor Al-Zubair is an extension of the Arabian Gulf waters. The lower boundary of Khor Al-Zubair is close to Warba Island about 8 km south east of Umm Qasar town (Fig. 1). The total length of KZ channel is about 40 km. The depth of the navigational channel ranges between 10 and 20 m. At high spring tide, the area that covered by water is approximately 60 km^2 [7]. The tidal regime of Khor Al-Zubair is a mixture of the semi-diurnal and diurnal types, but the semi-diurnal type is dominant, hence two high waters and two low waters occur daily with inequalities in heights and time of occurrence [7].

However, Shatt A-Basrah canal is an artificial canal was opened In 1983, in order to connect the Euphrates river (in Qarmat Ali), after it emerges from Al-Hammar marsh, with Khor Al-Zubair. The long of Shatt ABasrah canal is about 36 km that extends from Qarmat Ali river at northwest Basrah city to downstream at the head of KhorAl- Zubair channel as shown in Figure(1) [8,9]. In 1993, Shatt Al-Basrah canal connection with Qarmat Ali river was closed, and new connection made with MOD (Main Outfall Drain) at about 10 km from a head of the canal [10]. The MOD canal which contains the water of the drained regions of the Euphrates basin is agricultural water drainage through Shatt Al-Basrah canal then discharged towards the Arabian Gulf through Khor Al-Zubair [8]. To prevent the sea water from Khor Al-Zubair to Shatt Al-Basrah canal during the flood tide, the flow in the canal was controlled by a barrage (Al-Basrah Barrage) located at about 22 km from canal upstream. However, through the Gulf war, this barrage was demolished and hence the environment of KZ and SB turn to a hypersaline environment with salinity reaches 44 PSU through summer months. In the last years, the inflow of MOD was converted towards the Iraqi marshlands and in the present time, a very little amount of water (do not exceed 10 m^3/sec) discharged in the Shatt Al-Basrah canal. The climate of the region is characterized by an arid desert climate with two distinct seasons, the summer which is a hot and long and winter that represent a cold and rainy season. There are two types of prevailing winds in the area, northwest winds, which causes dust storms in the summer, and locally known as Al-Shammal which is a characteristic of the region and southeast winds mostly during autumn and winter that is relatively warm and moist and occasionally brings rainy clouds [11].

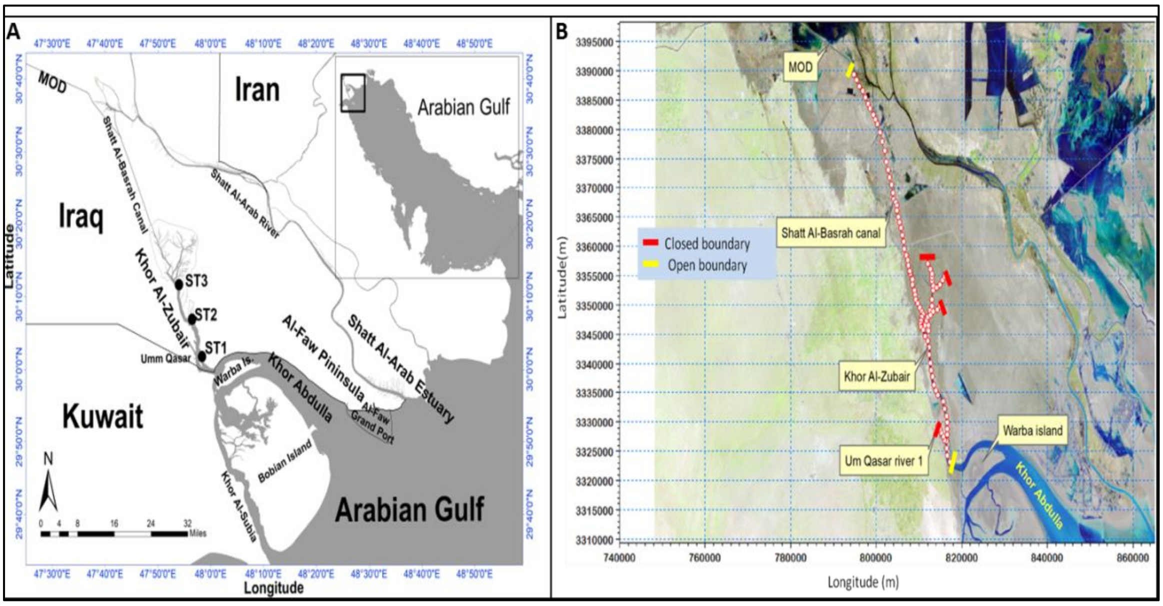

Fig. 1: Geographical location (A) and network of the study area (B).

2.3. Data Collection

To fulfill the study objectives, many kinds of data are used, which includes water level measurements, bathymetry, flow velocity, and wind speed and direction. The water level measurements at two sites are carried out, the first situated at Umm Qasar town (ST1 in Fig.1), the water levels data are collected by installing a Valeport TideMaster Portable Tide Gauge with pressure sensor, while the second site located at Khor Al-Zubair port (ST3), the water level data are acquired by Khor Al-Zubair Port

Authority. All these data are hourly records and references to the local chart datum (Lowest Low Water) in this region. It is worthy to mention that there are interruptions in recordings of water level for twenty days through April/ 2018 in Khor Al-Zubair port station. Bathymetric data were acquired from many sources, marine science center/ Basrah university surveys conducted in 2006, survey along Shatt Al-Basrah conducted by Al-Aesawi [12] and the surveyed along Khor Al-Zubair and Shatt Al-Basrah canal that carried out by Tatweer Office to South Oil company/ Iraq [13]. Furthermore, the flow velocity measurements were carried out by using an Acoustic Doppler Current Profile (ADCP) at ST2 in Fig.1, with an hourly record on a full tidal cycle on the 16th to 17th of March and on the 22nd to 24th April 2018. Metrological data including the wind speed and direction were obtained from the weather station installed by Daewoo Engineering and constructing company near Khor Al-Zubair (Fig. 2).

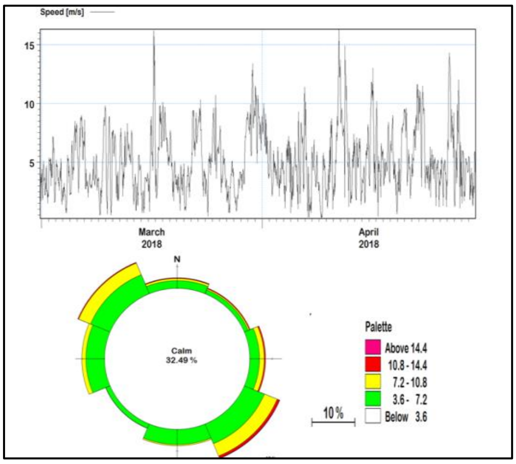

Fig. 2: Wind speeds and wind rose at study area.

3. Results And Discussion

The geometry of the study area has created in one dimension in a network file. The networking process began from the head of the Shatt Al-Basrah canal and finished at Warba island about 8 km southeast of Umm Qasar town Fig. (1 B). The bathymetry module was set up using the surveying data along the Khor Al-Zubair and Shatt Al-Basrah canal and conducted by bathymetry editor file in Mike11 with spatial discretization (Δx) of 300 m. The boundary condition of the upstream and downstream is an open type. At upstream, the discharge was used as a constant and equal to 10 m^3/sec. A time-series file for downstream water level was created using data measured at ST1 Fig. (3).

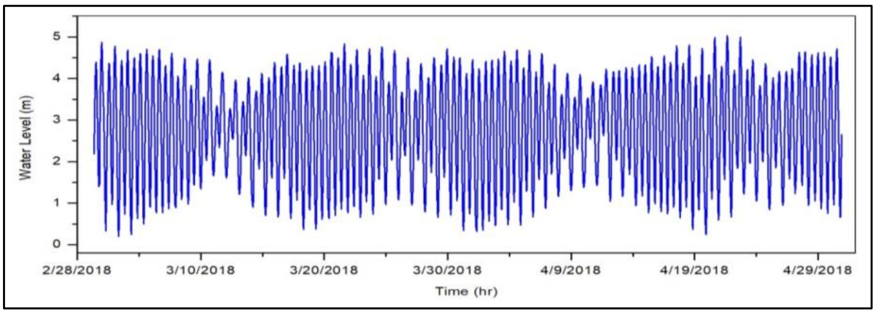

Fig. 3: Water level measurments at ST1.

The model was run for two months covered the period of 1st March to 30th April 2018 with time step (Δt) equal to 40 sec. Calibration and validation are the processes by which adjusted the parameters selected from the model to make the output result match real measurements. In the hydrodynamic model, Manning number (n) is a so-called calibration parameter. The accuracy of the model can be assessed by the Root Mean Square Error (RMSE) between the simulated and measured values of water level and flow velocities.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Mi-Ci)2}{N}} \quad (4)$$

Where, M_i is a sum of measured values and Ci is the sum of simulated values and N is a number of values. One of the most important parameters in developing hydrodynamic models is the bed roughness coefficient. Although such a coefficient is linked to the physical properties of the modeled channel reach, their values have to be determined through a calibration process. By adjusting the Manning number n, the simulated water level and flow velocities become fit with the observed values. The Manning number value set to be 0.02 $m^{1/3}$/sec to obtain the best matching between measured and simulated values. The data of March/2018 was used in the calibration of the model. The comparisons between the simulated and observed water levels at ST3 is shown in Fig. (4 A) with RMSE of 0.31 m, and between simulated and measured flow velocities at ST2 is shown in Fig. (4 B) with RMSE of 0.11 m/sec.

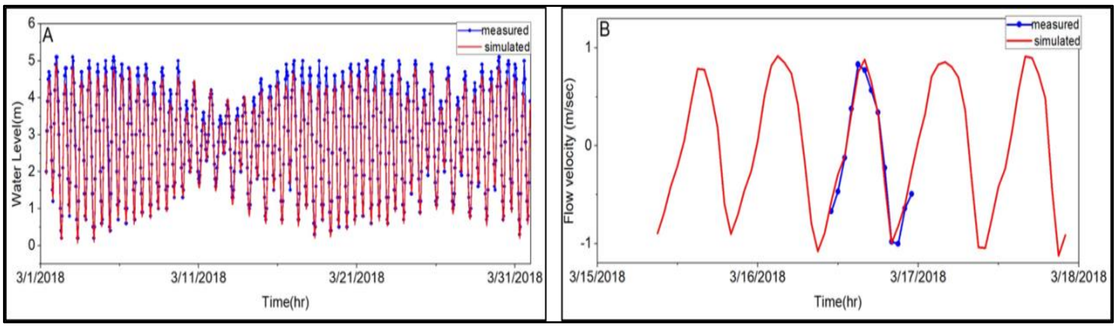

Fig. 4: Comparsion between measured and simulated water level (A) at station ST1, (B) flow velocity at ST2.

Furthermore, the validation of the model was achieved by utilizing the measurements of April/2018. Fig. (5 A) shows the comparison between measured and simulated water levels at ST3 with RMSE of 0.36 m, while Fig. (5 B) illustrates the comparison between simulated and measured flow velocities with RMSE of 0.37 m/sec.

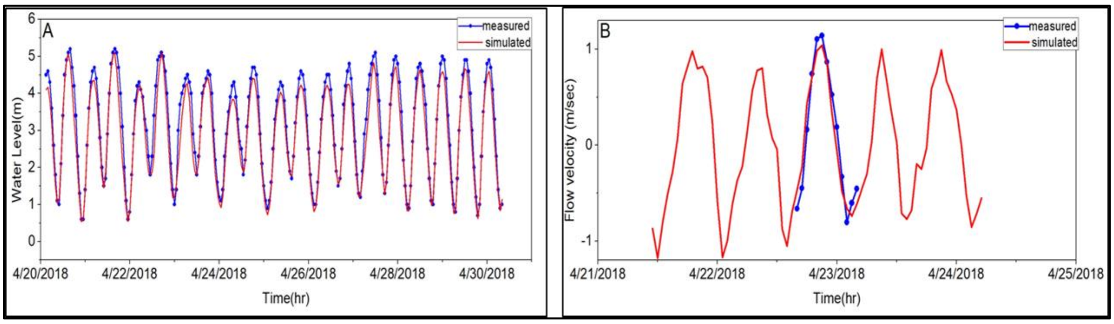

Fig. 5: Comparsion between measured and simulated water level (A) at station ST1, (B) flow velocity at ST2.

4. Conclusion

The study introduced a hydrodynamics model for Khor Al-Zubair and Shatt Al-Basrah canal by using the Mike11 routine. The result of the model has an acceptable agreement with measurements of water level and flow velocities. The results are a major step to establish a model that simulates the water quality, sediment transport processes as well as predict of the future variations that can occur as a response to anthropogenic or natural effects.

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