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One and Two-Dimensional Hydraulic Simulation of a Reach in Al-Gharraf River

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ABSTRACT

One and two-dimensional hydraulic models simulations are important to specify the hydraulic characteristics of unsteady flow in Al-Gharraf River in order to define the locations that facing problems and suggesting the necessary treatments. The reach in the present study is 58200*m* long and lies between Kut and Hai Cities. Both numerical models were simulated using HEC-RAS software, 5.0.4, with flow rates ranging from 100 to 350 m^3/s. Multi-scenarios of gates openings of Hai Regulator were applied. While the openings of Al-Gharraf Head Regulator were ranged between 60cm to fully opened. The suitable manning roughness for the unsteady state was 0.025. The obtained results show that the average velocities for the one-dimensional model were ranged between 0.36 and 0.5 m/s, and the average water surface elevations range between 15.14 m and 17.84 m. While these values ranged between 0.25 and 0.44 m/s and 14.125 and 18.82 m respectively for the two-dimensional model. The simulation results of the two-dimensional model were more accurate than their corresponding one-dimensional model, due to more agreement of these values with measured values, which achieved minimum values of the root mean square error and the determination coefficient.

Keywords: River Flow Modelling, Hydraulic Simulation, HEC-RAS 5.0.4.

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محاكاة هيدروليكية احادية وثنائية الابعاد لجزء من نهر الغراف

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الخلاصة

تعد عمليات محاكاة النماذج الهيدروليكية أحادية وثنائية الأبعاد مهمة لتحديد الخصائص الهيدروليكية للجريان غير المستقر في نهر الغراف من أجل تحديد المواقع التي تواجه مشاكل النحر أو الترسيب واقتراح المعالجات اللازمة لها. يبلغ طول مقطع الدراسة الحالية 58200 متر ويقع بين مدينتي الكوت والحي. تم محاكاة كلا النموذجين الرقميين باستخدام برنامج HEC-RAS، 5.0.4 ، مع تصاريف تتراوح بين 100 إلى 350 متر مكعب / ثانية. تم تطبيق سيناريوهات متعددة لفتحات بوابات ناظم الحي. في حين أن فتحات ناظم صدر الغراف تراوحت بين 60 سم وحتى الفتح بالكامل. تم ايجاد خشونة التشغيل المناسبة للحالة غير المستقرة وهي 0.025 . أظهرت النتائج التي تم الحصول عليها أن السرعات للنموذج أحادي البعد تراوحت بين 0.36 و 0.5 م / ث ، ويتراوح متوسط ارتفاع سطح الماء بين 15.14 م و 17.84 م. في حين تراوحت هذه القيم بين 0.25 و 0.44 م / ث و 14.125 و 18.82 م على التوالي للنموذج ثنائي الأبعاد. كانت نتائج المحاكاة للنموذج ثنائي الأبعاد أكثر دقة من النموذج أحادي البعد المقابل لها ، نظرًا لزيادة توافق هذه القيم مع القيم المقاسة ، التي حققت الحد الادنى لقيم الجذر التربيعي للخطأ المتوسط ومعامل التحديد.

الكلمات الرئيسية: نمذجة تدفق الانهر,المحاكاة الهيدروليكية,هكراس 5.0.4

1.INTRODUCTION

The priorities of the needed requirement for consuming water resources in different sectors such as for drinking, irrigation purposes, agriculture needs or for the industry sector, furthermore the impact of drought and flood seasons. That's demands water conservation planes in order to save the water to fulfill this requirement for the future and minimize the flood danger and invest it. Al-Gharraf River considered the main subdivision of Tigris River plus it is the primary source of water for cities located in the south of Iraq. It branches from Tigris River near Kut City at Kut Barrage and it connects the Tigris River with Euphrates River at the east of Thi-Qar Governorate. Al -Gharraf River extends from Kut City to Nasyriah City with a 230 km length. In this study, the selected reach is located between Kut-Hai Cities with a length of more than 58 km. And contains important hydraulic structures like Gharraf Head Regulator located at the upstream of the reach and the second structure is Hai Regulator, the reach ends near Hai City, **Fig.1**. There are a few small canals branches from Al- Gharraf River, in this study, only the branches with a discharge greater than 1 m^3/s will be considered, which are Janabiyat Al-Hai, Gamela, and Um Al-Tubaikh.

(Arrar, 2018) constructed a one-dimensional model in HEC-RAS software (both steady and unsteady state) to estimate the manning roughness coefficient in Al- Gharraf River between Kut-Hai cities. the obtained values of manning roughness for the steady-state was (0.025-0.027) with 0.026 as the average value. For unsteady state simulation, the manning roughness was (0.024-0.026) with 0.025 as an average value. **(Kayyun and Dagher, 2018)** developed an unsteady state two-dimensional flow model to simulate the Tigris River in the reach within Baghdad, using the HEC-RAS software. The DEM (digital elevation model) was added and the created mesh contained 86951 cells. The result of the two-dimensional model predicted acceptable values for both velocity and water surface elevation, and the evaluated Manning coefficient value was 0.027 for the mainstream and 0.041 for its banks. **(Pinos and Timbe, 2019)** created a two-dimensional model using HEC-RAS software to predict the hydraulic performance of the Santa Barbara River in Ecuador, which considers a mountain river, the model results showed after 20 years, the water will cover 44 % from lands area**. (K .B and S.M, 2019)** create a one-dimensional unsteady flow model using HEC-RAS software to simulate the hydraulic flow of Purna River located in Navsari city in India. The result showed that the Manning roughness coefficient value for the study was 0.03**. (Padalia, et al., 2017)** Developed a one-dimensional unsteady model to simulate Vishwamitri River in India using HEC-RAS software. The result of simulating the model showed that the maximum operating flow capacity of the river was 805 m^3/s.**(Al-thamiry, et al.,2013)**create a one-dimension hydrological model to study the Salinity effect on Euphrates River between Ashshinnafiyah and Assamawa Cities using HEC-RAS software. The result of the one-dimensional model showed that the best discharge value which minimizes the danger was 9 m^3/s.

This research aims to simulate the hydraulic characteristics of unsteady flow in the upper reach of the Gharraf River using both one-dimensional and two-dimensional modeling, to visualize the River sections and the profile. Moreover, comparing the two model results and specify the accuracy of these models.

2. BASIC EQUATIONS GOVERNING 1D AND 2D FlOW MODELING

The software HEC-RAS, version 5.0.4, introduced in the United State,2016, by the Army group of Engineers which adopts several equations that important to perform the hydraulic model and compute the velocity and water surface elevation, the following equations for one-dimensional unsteady simulation**.** At the start the equation of continuity; **(Brunner and Gary W., 2016)**

$$\frac{\partial A}{\partial t} + \frac{\partial q}{\partial X} - Q_l = 0 \quad (1)$$

The Following is known as the equation of momentum; **(Brunner and Gary W., 2016)**

$$\frac{\partial Q}{\partial t} + \frac{\partial QV}{\partial X} + gA\left\{\frac{\partial z}{\partial X} + SF\right\} = 0 \quad (2)$$

Solving the previous equations that represent the equations of "Saint-Venant"; **(Brunner and Gary W., 2016)**

$$\frac{\partial q}{\partial X} + \frac{\partial A}{\partial T} \quad (3)$$

$$\alpha v\frac{\partial V}{\partial X} + \frac{\partial V}{\partial T} + g\,\frac{\partial Y}{\partial X} = g\,(S_0 - S_F) \quad (4)$$

Where: A = area of the cross-sections, q =The cross-section flowrate,Q= Total flowrate, g = gravity acceleration, y=stage,S_o = slope of bed; S_F = slope of energy, v=velocity and α=Velocity Coefficient ,t=time,X=horizontal direction,z=elevation of the bed

While the equations used for Two-Dimensional unsteady simulation is: continuity in two directions, can be written as follows: **(Brunner and Gary W., 2016)**

$$\frac{\partial H}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}+Q=0 \quad (5)$$

And The Momentum Equation in two directions, expressed as follow: **(Brunner and Gary W., 2016)**

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial H}{\partial x}+vt\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-C_F u+fv \quad (6)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial H}{\partial y}+vt\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)-C_F v+fu \quad (7)$$

Where; u and v = velocities component, g = the gravity acceleration, vt = the coefficient of eddy viscosity, C_F = friction coefficient for channel bed, and f = Coriolis parameter.x,y=horizontal and vertical directions, t=time,H=water surface elevation.

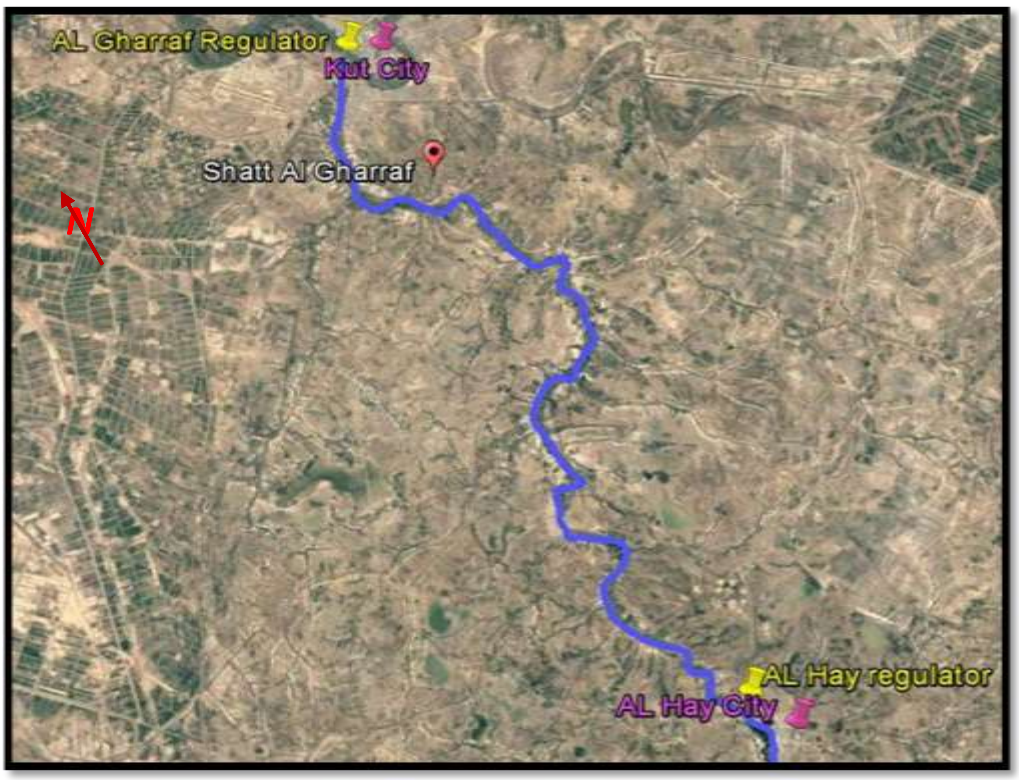

Figure 1. Satellite image of the upper reach of Al-Gharraf river, Google earth.

3. INPUTS AND BOUNDARY CONDITIONS

HEC-RAS is a software used to analyze rivers systems. For the present study, the software is used to create hydraulic models for the flow in one-dimension and two-dimension to simulate the unsteady state for the River.

3.1. One-Dimensional Unsteady Flow Modeling

There are necessary input data required to develop the one-dimensional unsteady flow model like a schematic of the one-dimensional river which extends from station 58200m upstream of the Gharraf Regulator and it ends near Hai city at station 100m downstream of the Hai Regulator, with total number of 24 cross-sections using interval space of 100 to 1000m between each station, **Fig .2**. These cross-sections data were measured by**(Ministry of Water Resources, MOWR,2012)**. While the hydraulic information data For the main river, subdivisions and Regulators were obtained from **(Ministry of Water Resources, MOWR,2017-2019).** The discharges are necessary to simulate the hydraulic model, different flowrate scenarios are used and ranged between 100-350 m^3/s using the discharge interval of 100 m^3/s. In each case, a gate height scenarios of the tail, Hai, Regulator was adopted that varied from quarter gate opening to fully gate opening while the Head Regulator remains at the normal operative case. The flow hydrograph is the selected boundary conditions for upstream, downstream and subdivisions. The taken values of discharges for tributaries ranged between 1-6 m^3/s that values represent the branch's normal operative discharge. The simulation period was one day.

3.2. Two-Dimensional Unsteady Flow Modeling

The army group of engineering of HEC-RAS software developed its ability in performing the Two-Dimensional model in (version 5.0.4) by adding new capabilities in Ras mapper window. The terrain layer is associated with a Digital Elevation Model, DEM, for this study. The DEM loaded from the following site **(JAXA,2019)**. The digital elevation model must be changed its type into a Terrain Layer using Arc GIS program, the DEM was converted and improved its resolution by Arc map version 10.2. Then the Terrain layer was added from Ras mapper window after the projection of the project was set. After that, the Terrain layer has been modified using bathymetry in Hec-Ras. To generate a 2D flow area, a polygon line must be drawn in the geometry window**.** After that, the grid is created by entering the spacing value between each grid 20×20m and the computational mesh contains 117×10^3 cells, with an average cell area of 9×10^2 m^2, the area of maximum cell was 2×10^3 m^2. While the area of minimum cell was 6×10^2 m^2. To select the boundary condition type it must draw the boundary condition line and connect it to the 2D flow area. For this research, the boundary condition adopted in the upstream was the flow hydrograph and the simulation time was 24 hours **Fig .3**. The two-dimensional modeling was used to simulate different scenarios that will occur when the Gharraf head regulator releases flowrates ranged between 100 to 350m^3/s to simulate water surface elevation and velocity regions.

4. RESULTS AND ANALYSIS

4.1. Calibration and Verification of the Unsteady Flow Model

The calibration of the unsteady state model was conducted to specify the adequate value of manning roughness coefficient that achieves the minimum difference between the predicted and simulation results of water surface elevations and velocities and that was conducted by computing the coefficient of determination R^2. As well as comparing these results and selecting the Manning n that introduces the lowest value of root Average square error RMSE, using hydraulic data measured by**(MOWR,2017 - 2019),**which represent the discharge of Gharraf Head Regulator and the stage of upstream of Gharraf Head Regulator, the observed discharges For the year 2017, was ranged between 200 to 240 m^3/s using the discharge interval of 10 m^3/s and the maximum and minimum elevation was 16 and 17.2 m respectively, as shown in **Table1**. Several manning roughness values were tested to obtain the optimal value for both mainstream and banks, the values are 0.024, 0.025, 0.026, 0.027, and 0.028. the minimum error was found with Manning, n of 0.025 with RMSE value equal to 0.0967, and the R^2 value equal to 0.998, **Fig .4** and **Fig.5** illustrates the verification of the simulation model using the measurement data for the period 2018, using the optimum value of Manning n, 0.025, that achieves high agreement between the measured and the simulated results with R^2 value equal to 0.99

Table 1. The observed data of Gharraf Head Regulator in **(MOWR,2017).**

Month	**Discharge m^3/s**	**Measured stage m**
June	200	16
July	210	16.3
August	220	16.5
Septemper	230	17
October	240	17.2

4.2. The Result of One- Dimensional Unsteady State

After conducting the optimal manning roughness value and apply it to the model and simulate different flow cases, The obtained results of the unsteady flow modeling in one dimension, represented by profile of the water surface elevation and velocity, **Fig.6** the entered discharges were 90-100,190-200,290-300,340-350 m^3/s with four cases of gate opening fully, three quarter, half. When Q equals 100 m^3/s The model introduced result only in the case of quarter opening because the model was an unstable and present error since the discharge 90 to 100 m^3/s didn't fill the branches needs, the water surface elevation was ranged between 14.1-15.2m and for the velocity, the values were ranged between 0.08 to 0.4m/s. For the discharge value equals 190 to 200 m^3/s, the water surface elevation ranged between13.72- 16.87m and the velocity is ranged from 0.13 to 0.8m/s. When the discharge value equals 290 to 300 m^3/s, the water surface elevation was ranged from 14 to 18m and the velocity value was ranged from 0.14-1m/s.At the case when discharge 340-350 m^3/s both water surface elevation and velocity were ranged between 14.56-19.1m and 0.2-1.01m/s respectively.

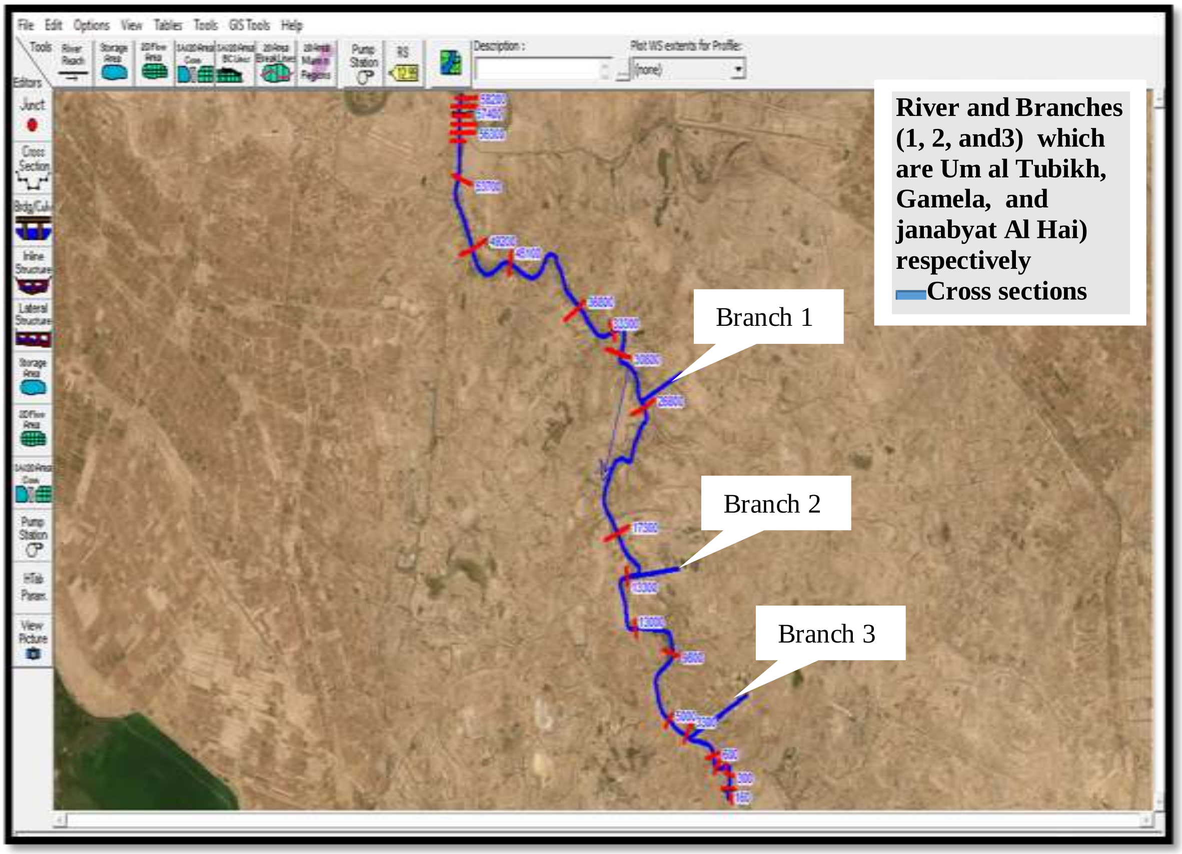

Figure 2. The selected cross-sections along the reach of Al- Gharraf River.

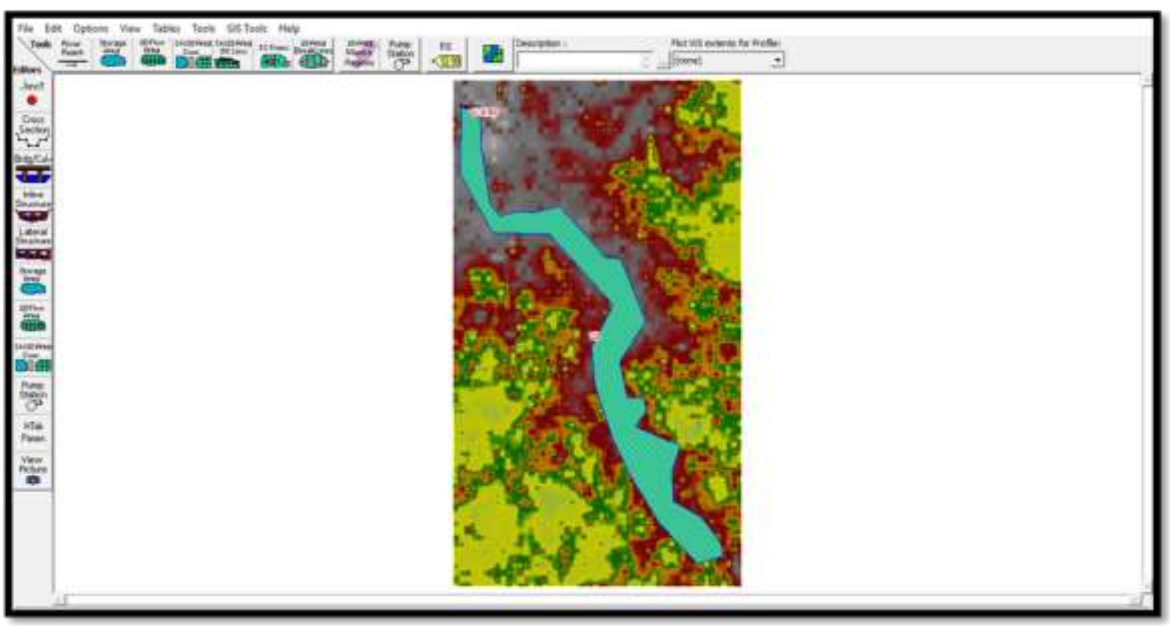

Figure 3. Two-dimensional flow area with computational mesh, B.C.lines, and terrain layer.

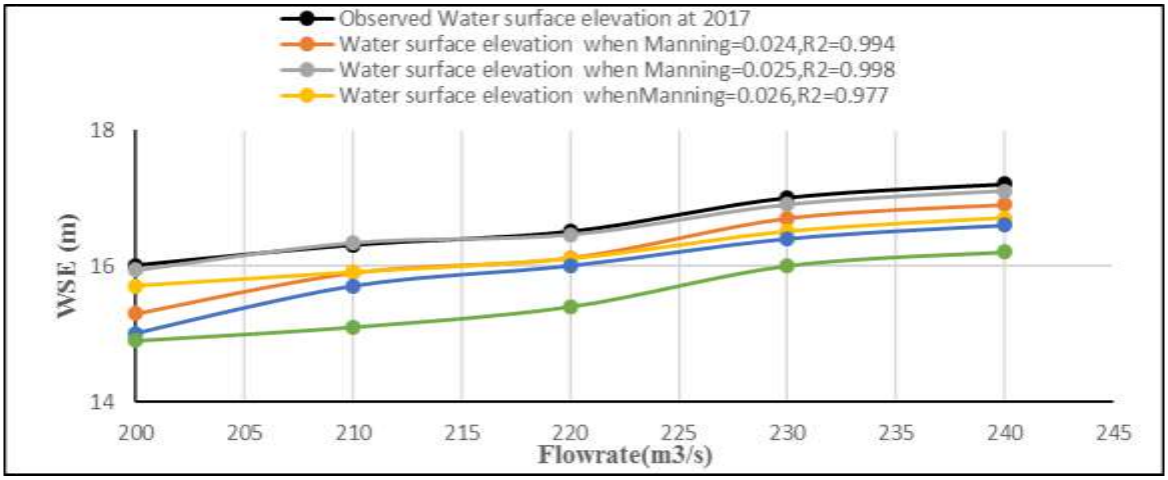

Figure 4. Calibration of unsteady-state flow model in the reach of study in 2017.

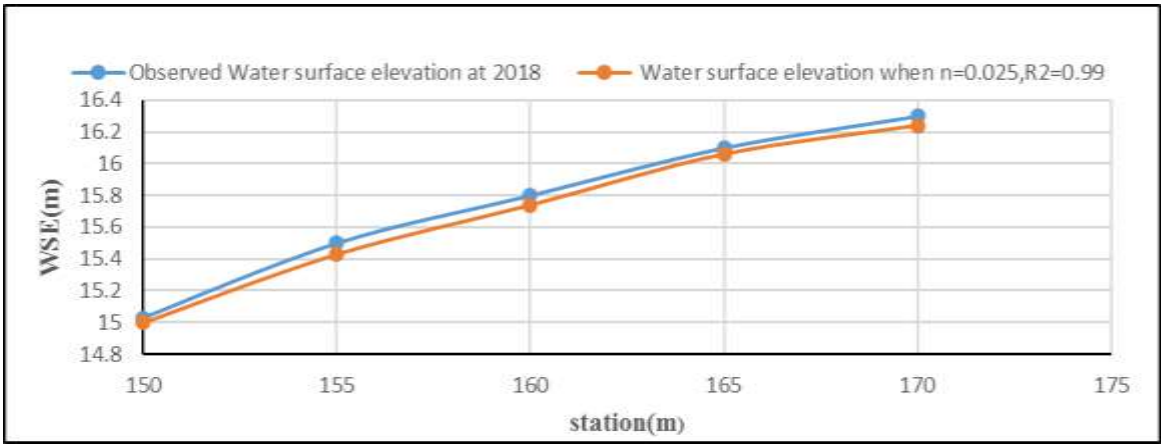

Figure 5. Verification of unsteady-state flow model in the reach of study in 2018.

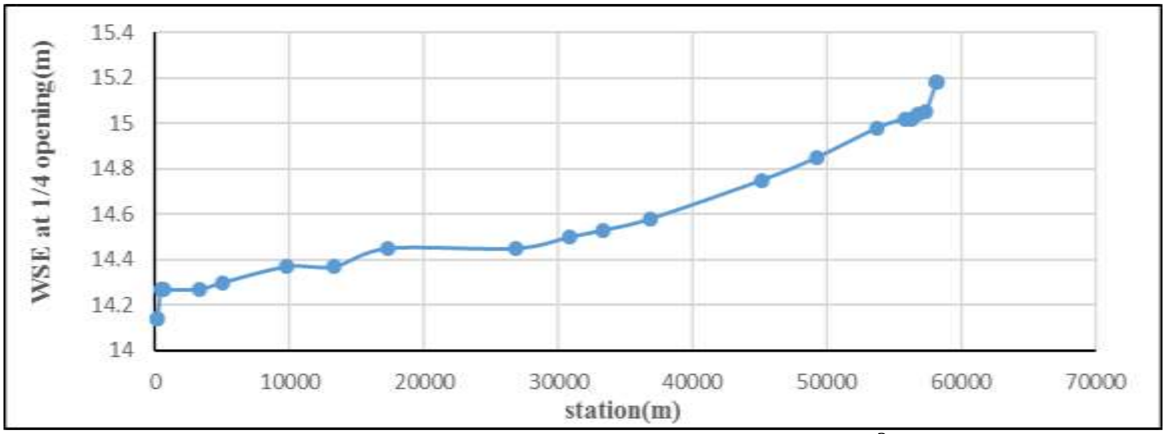

Figure 6. a.WSE in m, when flowrate =90-100 m^3/s.

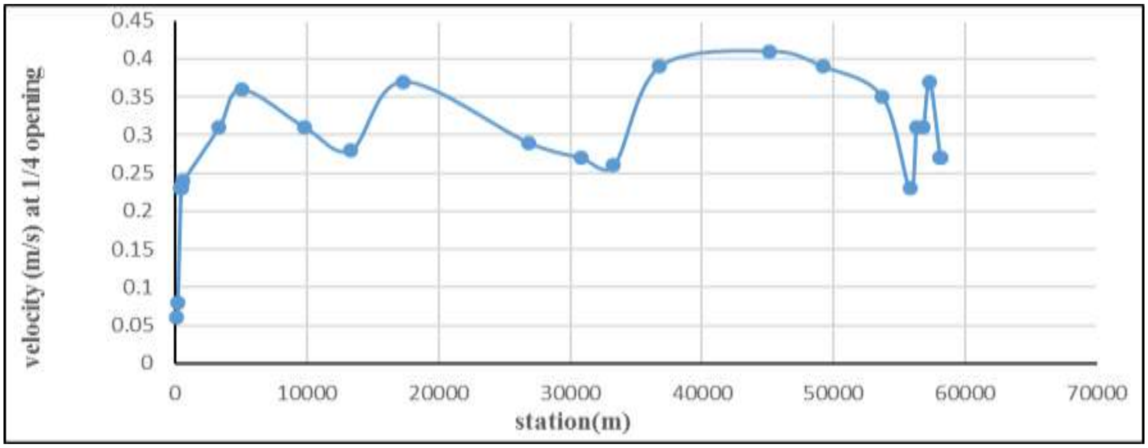

Figure 6. b. Velocity in m/s, when flowrate =90-100 m^3/s.

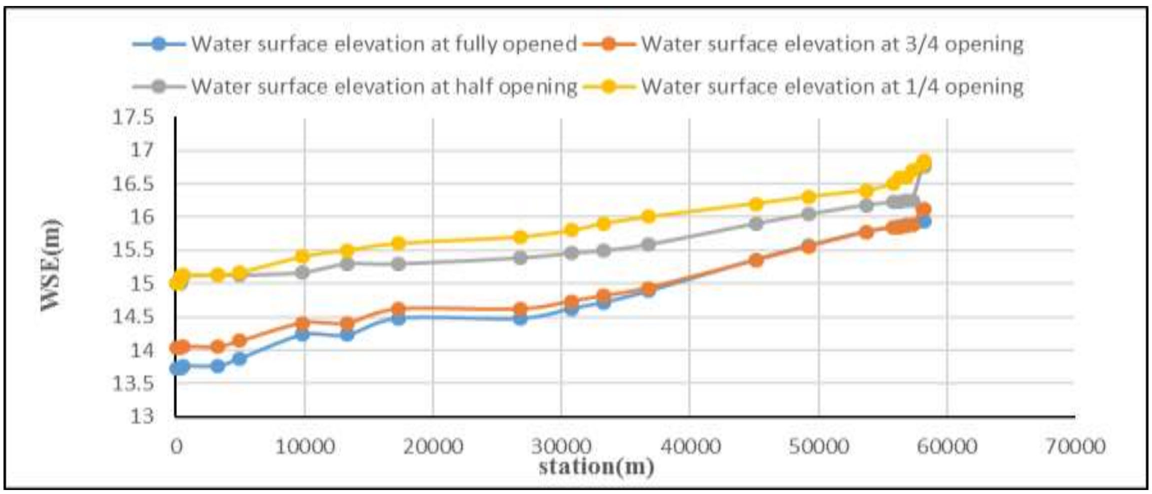

Figure 6. c.WSE in m, when flowrate =190-200 m^3/s.

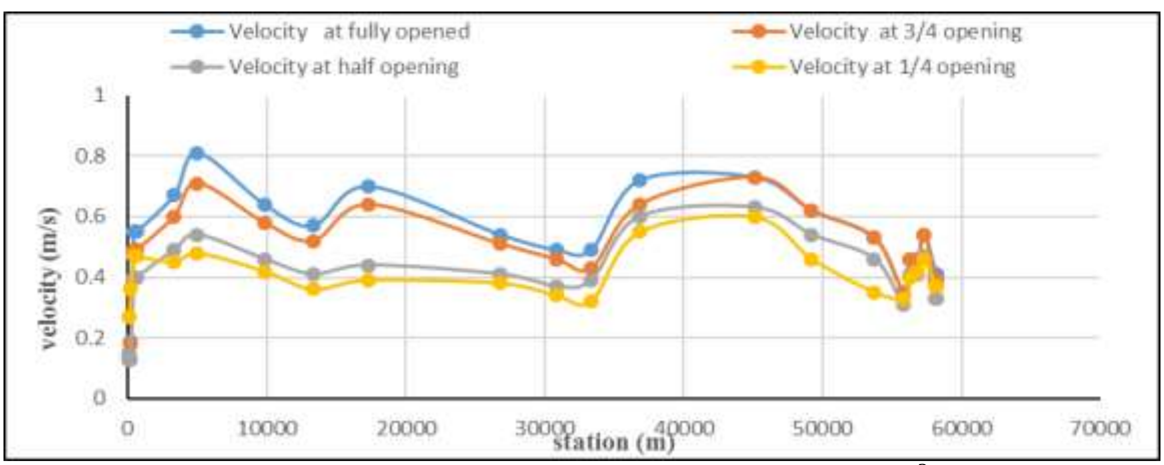

Figure 6. d. Velocity in m/s, when flowrate =190-200 m^3/s.

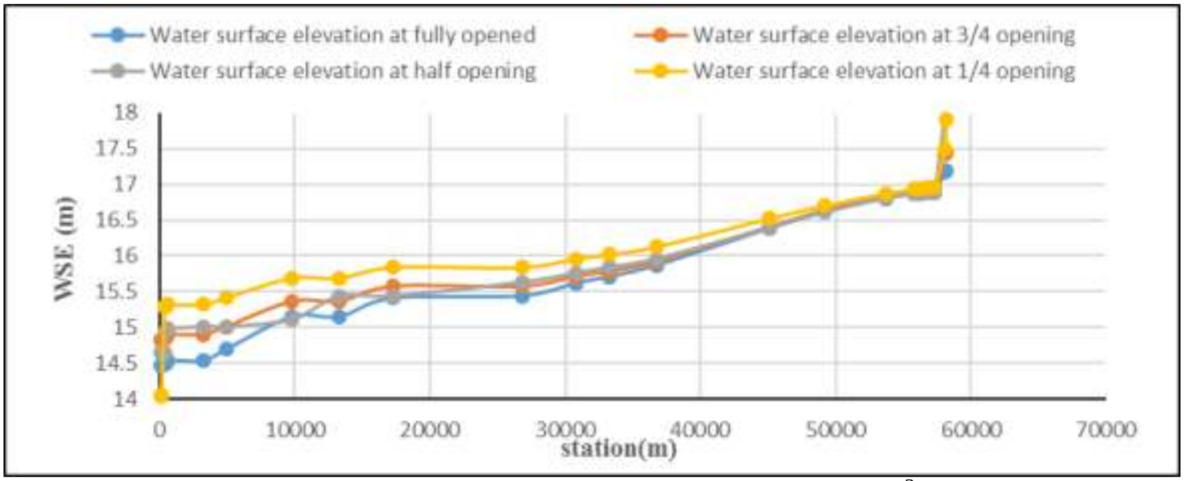

Figure 6. e.WSE in m, when flowrate =290-300 m^3/s.

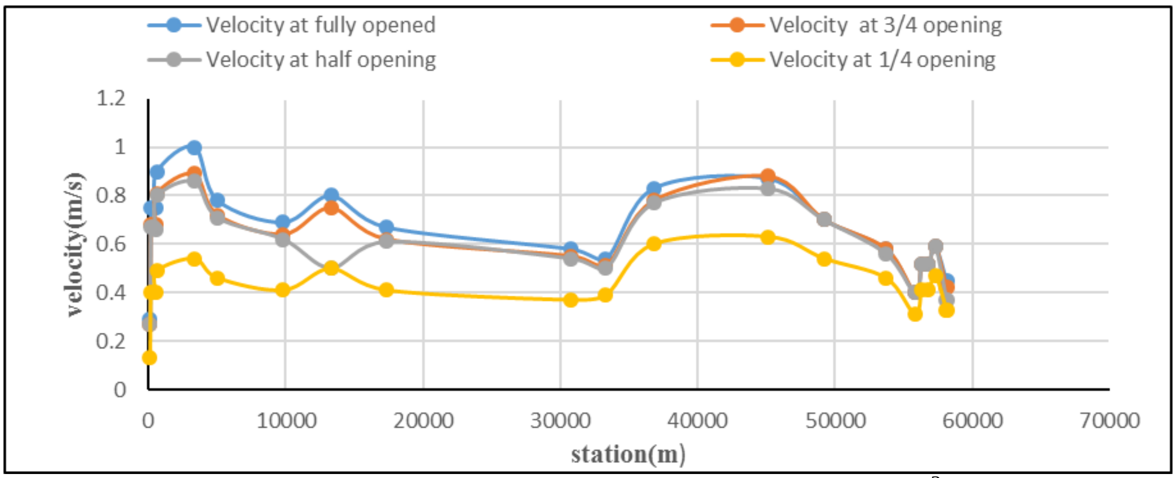

Figure 6. f. Velocity in m/s, when flowrate =290-300 m^3/ s.

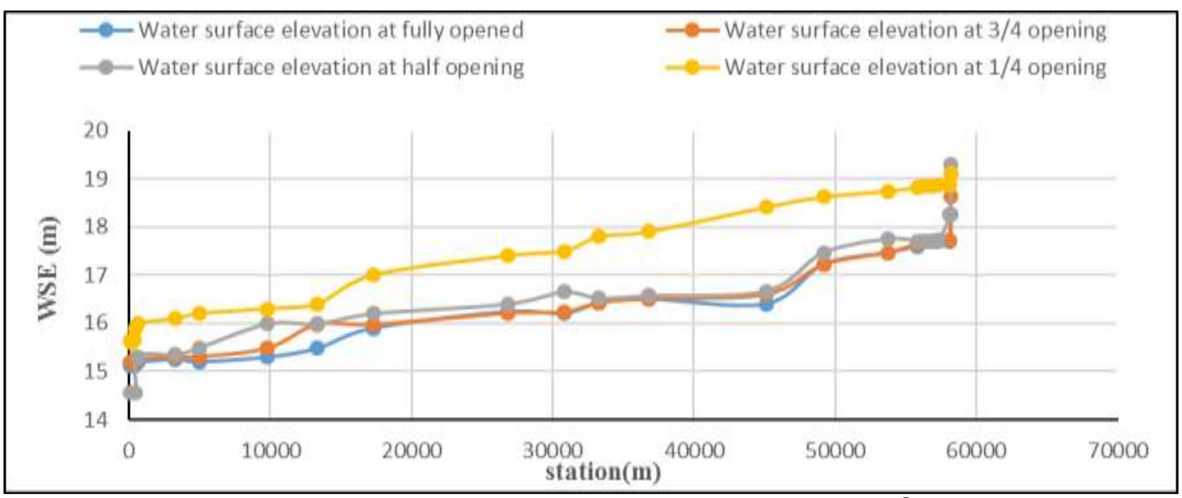

Figure 6. g.WSE in m, when flowrate =340-350 m^3/s.

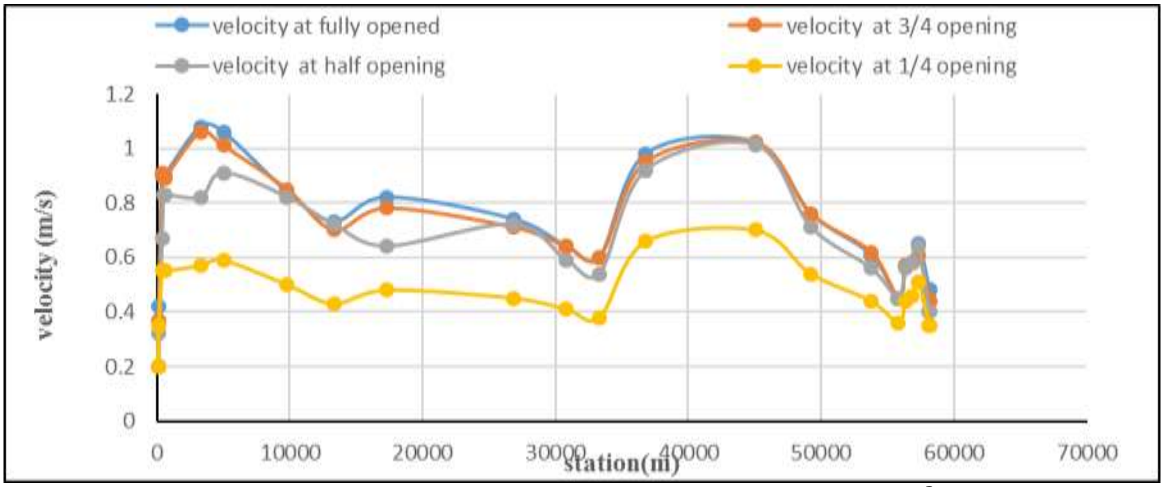

Figure 6. h. Velocity in m/s, when flowrate =340-350 m^3/s.

Figure 6. The results of the one-dimensional unsteady flow hydraulic model

4.3. The Result of Two- Dimensional Unsteady State Condition

The purpose of using a two-dimensional model is to simulate the discharge scenarios in two directions to specify the peak and low regions where the velocity and the water surface are maximum and minimum respectively. After using the optimal manning roughness for unsteady state and entering discharge 100 to 350 m^3/s, the result of the Two-Dimensional model represents When the discharge is varied between 100 to 200 m^3/s, the water surface elevation ranged from 13 to 15m and the velocity values ranged between 0.1-0.4m/s, **Fig.7**.While values of WSE when the discharge ranged between 200-300 m^3/s were 13-17m and the obtained velocity values were ranged between 0.22-0.5m/s, **Fig.8.**And the simulation results for discharge ranged between 340 to 350 m^3/s showed that the values of WSE equal to 15-18m and for velocity equal to 0.22-0.5m/s, **Fig.9.**

Table3 shows the comparison of the obtained results between a one-dimensional and Two-dimensional hydraulic model.

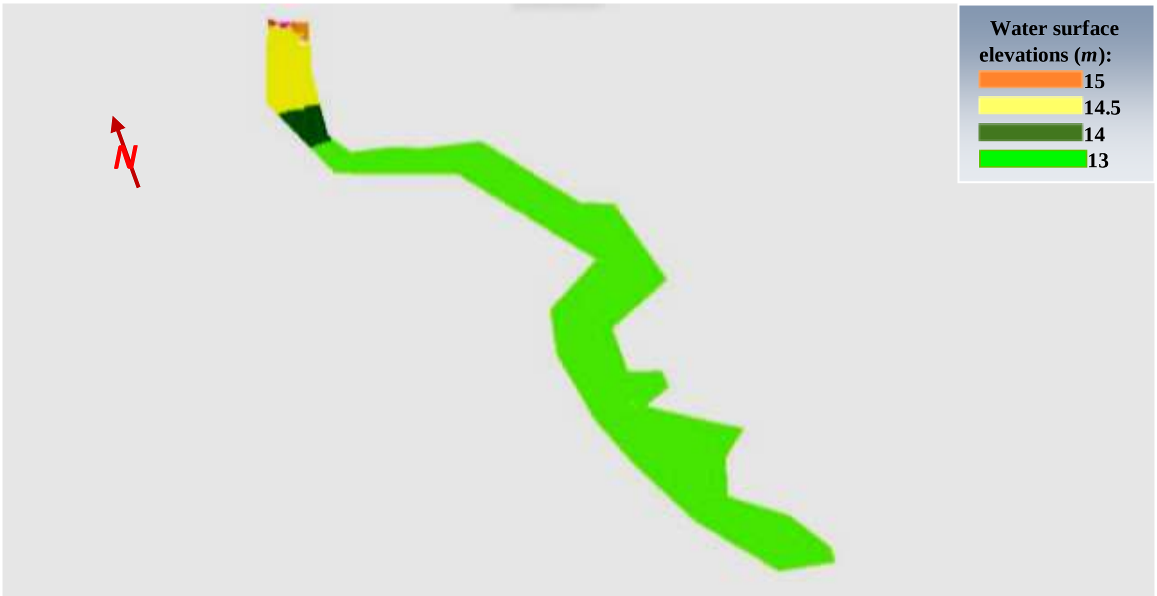

Figure 7. a. Water surface elevation in Gharraf River.

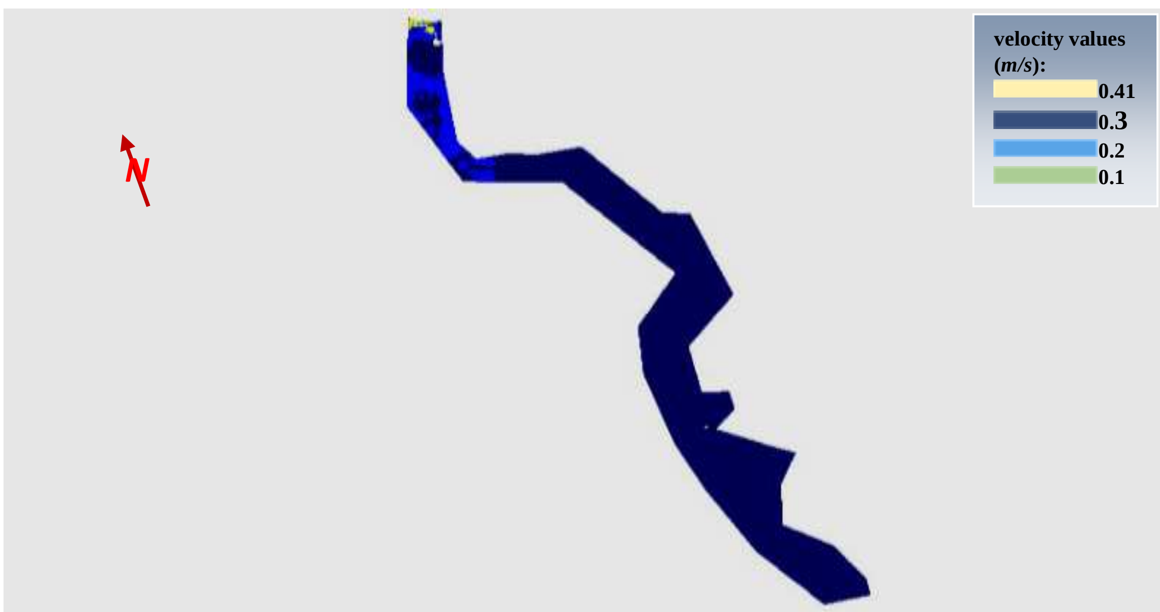

Figure 7. b.velocity in Gharraf River.

Figure 7. Results of the 2D simulation model with Q=100-200m^3/s, for the upper reach of Al-Gharraf River.

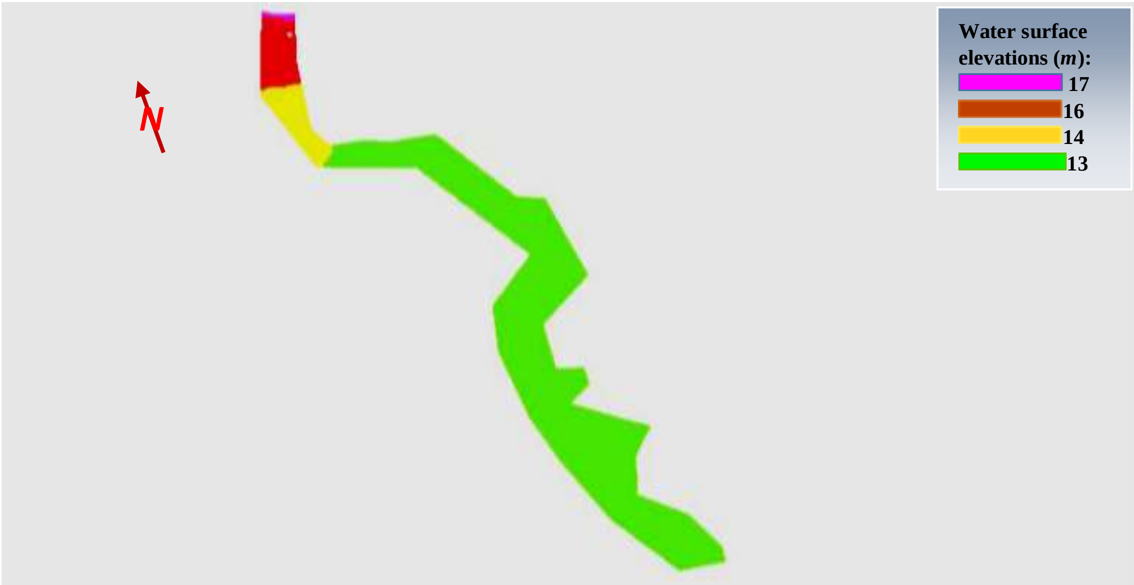

Figure 8. a. Water surface elevation in Al- Gharraf River.

Figure 8. b.velocity in Gharraf River

Figure 8. Results of the 2D simulation model with Q=200-300m^3/s, for the upper reach of Al-Gharraf River.

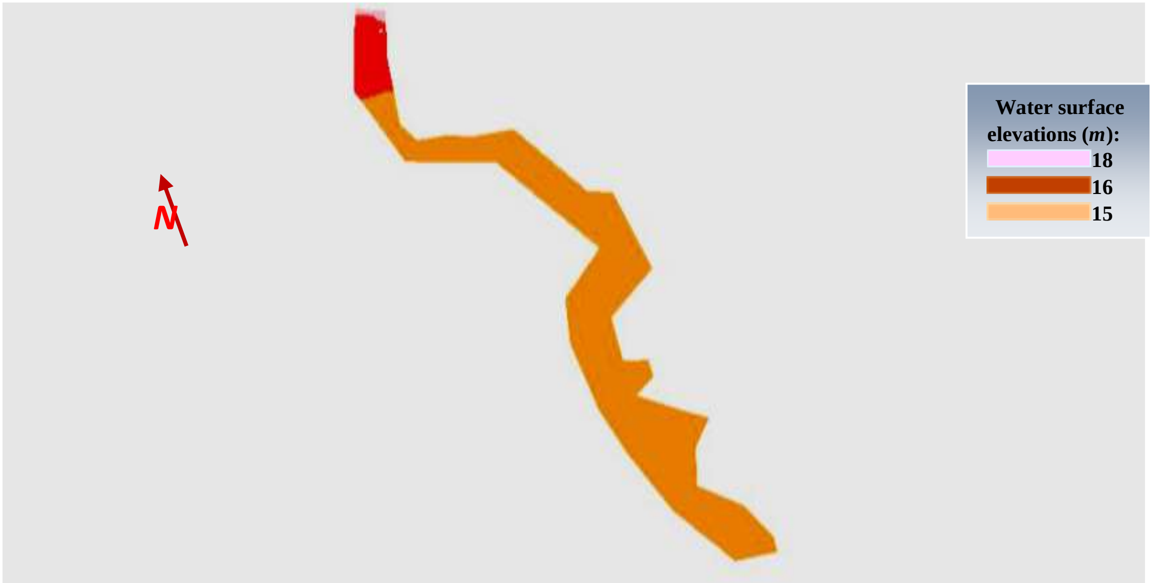

Figure 9. a. Water surface elevation in Al- Gharraf River

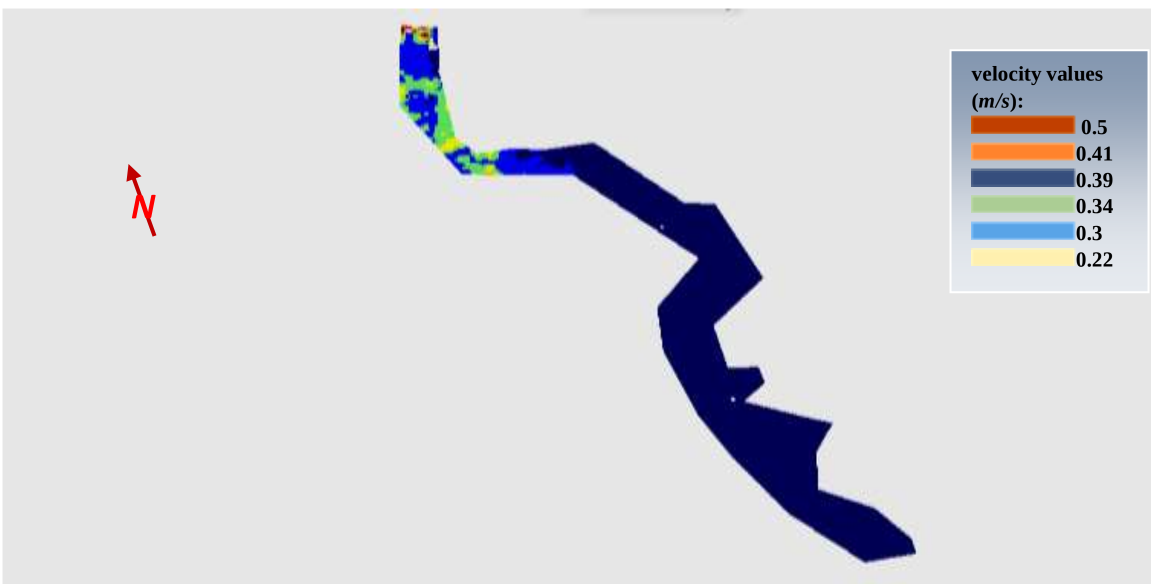

Figure 9. b.velocity in Gharraf River

Figure 9. Results of the 2D simulation model with Q=340-350m^3/s, for the upper reach of Al-Gharraf River

Table3. The differences between simulation results of 1D and 2D hydraulic models, with Q=100-350 m^3/s.

Flowrate Q m^3/s	One-dimension		Two-dimension		Measured WSE m	Measured Velocity m/s
	Average WSE m	Average V m/s	Average WSE m	Average V m/s		
100-200	15.14	0.36	14.13	0.24	14.3	0.25
200-300	15.36	0.38	15	0.35	15	0.34
340-350	17.84	0.5	18.82	0.44	18.75	0.5

5. CONCLUSIONS

This section will illustrate the important simulation results obtained, and specify the similarity and the differences between results of the one and two-dimensional simulation models of the unsteady state flow in the upper reach of Al-Gharraf River as;

1-The suitable value of Manning roughness was 0.025 that achieved good agreements between the predicted and measured results of velocities and water surface elevations values with minimum RMSE of 0.0967, and the coefficient of determination R^2 value equal to 0.998.

2- The flowrate less than 100 m^3/s was not enough to fulfill all the requirements of the branches of the River. When flowrate of 100 m^3/s is released from Gharraf Regulator it should open all gates of Hai regulator at a height of 1.4m, a quarter from the gate height. The releasing flowrates ranged from 340 to 350 m^3/s in one-dimensional flow modeling, the models have produced a water level values above the normal water level in the case of the quarter gate opening. Therefore the Gharraf Head Regulator shouldn't release these discharges while the gate opening of Hai Regulator is quarter

3-The results show that the 2D model was more accurate than the 1D model due to good agreement of these results of average WSE that range between 14.13-18.82 m and velocity range between 0.24-0.44 m/s, with the measured values of average velocity, 0.25 to 0.5 m/s, and water elevation, 14.3 -18.75 m. The RMSE value between the results of the 2D simulation model and the measured results was 0.032 for the velocity and 0.1 for water surface elevations and R^2 value equal to 0.99 for WSE and 0.978 for velocities. While the RMSE values for one-dimensional model results were 0.66 and 0.06 for WSE and v respectively. And the R^2 value for WSE was 0.92 and 0.91 for the velocity.

4- The resolution of the used Dem in Two-Dimensional model after it been modified using the bathymetry of the cross-sections was 12 m. Therefore it accurately specifies the sites of the values of velocities and WSE, which helps to make the necessary decisions of treatments required to avoid the problems that occur in these sites.

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NOMENClATURES

A	area of the section,m^2
C_F	the friction coefficient for channel bed, dimensionless
f	coriolis parameter, dimensionless
g	gravity acceleration ,m/s^2
H	water surface elevation,m
q	The discharge in the cross-section, m^3/s

Q	The total discharge, m^3/s
S_0	the slope of the bed, dimensionless
S_F	friction gradient, dimensionless
t	time, second
u	velocity component in x-direction,m/s
v	velocity ,m/s
V	velocity component in the y-direction,m/s
X	horizontal axis, dimensionless
Y	water elevation, m
y	vertical axis, dimensionless
z	bed elevation,m

GREEK SYMBOLS

α	velocity coefficient, dimensionless
vt	the coefficient of eddy viscosity, dimensionless