



## Effect of Tigris River's Stage on the Groundwater Level

Mustafa T. Al-Tahir<sup>a\*</sup>, Thair S. Khayyun<sup>b</sup>

<sup>a</sup> University of Technology, Baghdad, Iraq, [42135@student.uotechnology.edu.iq](mailto:42135@student.uotechnology.edu.iq)

<sup>b</sup> University of Technology, Baghdad, Iraq, [thshkhma@yahoo.com](mailto:thshkhma@yahoo.com)

\*Corresponding author.

Submitted: 05/07/2019

Accepted: 27/10/2019

Published: 25/07/2021

### KEY WORDS

Groundwater, Modeling, MODFLOW, GMS, Tigris River.

### ABSTRACT

*The research studies the effect of change of the Tigris River's surface stage on groundwater movement by building a three-dimension model using GMS model for a catchment area in Baghdad city. The model is built and calibrated by using the information of 16 wells for the year 2015. Three scenarios of river elevation stage are used when the stage elevation is maximum, average and minimum. The movement of groundwater according to the results was from the north-west to the Tigris River location. Also, the results show the velocity of groundwater in case of the minimum water surface level stage is greater than the other cases because of the high hydraulic gradient. The velocity of groundwater in layer one for all cases is very slow because of the low permeability.*

**How to cite this article:** M.T. Al-Tahir and T.S. Khayyun, "Effect of Tigris River's Stage on the Groundwater Level," *Engineering and Technology Journal*, Vol. 39, No. 07, pp. 1041-1051, 2021.

DOI: <https://doi.org/10.30684/etj.v39i7.442>

This is an open access article under the CC BY 4.0 license <http://creativecommons.org/licenses/by/4.0>

### 1. INTRODUCTION

Groundwater is a source of water in arid and semi-arid areas that can be used by the people who suffer from water scarcity, especially in remote areas. Groundwater can be used in the field of agriculture, industry, and many more human uses if a set of properties are available in a groundwater for the purpose that it is used for [1].

The groundwater modeling gives an obvious exemplification for a groundwater natural path and simplifies. The result of it ensures high reliability with saving the required thoroughness details.

Many studies by several researchers demonstrated that the outputs of groundwater modeling can be applied in Iraq for different purposes, for example : Najah , 2007 [2] developed a numerical model to simulate the water table levels in the Al-Jadreja Lake area. The result of running the model for a period of 4762 days, showed that the groundwater level was increased by 6.6m near the location of the lake. The rises in water table level were reduced step by step toward the east direction to 0.1 m at Al-Hurria plaza and diminish at the eastern border of the modeled area. Abbas, 2012 [3] suggested different scenarios to examine and reduce the groundwater table at the bottom of the sliding zone of the marl clay layer based on computer software known as Groundwater Modeling System (GMS). The simulation output found that the third scenario of ten wells, (15) days pumping period and (440) m.a.s.l. reservoir level is the best operation system for groundwater of the aquifer. Hussain,

2015 [4] developed a GMS model to study the predictive of the mathematical model of groundwater within Umm-ErRadhuma formation at the south-eastern part of AL- Anbar province. Results showed that the drawdown in GWL elevations ranged from (13) cm after running the model for a period of 5 days to (120) cm after running the model for thirty days. The drawdown values are concentrated near the wells' sites and it declines as it moves away from the sites of these wells. This reflects the nature of the water reservoir of the study area, which is characterized by high production where resulting compensation from the operation of the wells decline rapidly by the reservoir. Therefore, the values of the drawdown in its elevations appeared to be very low. The study also showed the possibility of drilling additional wells in this area depending on this model to be used in the future for different purposes. Basrawi, 2015 [5] used Arc GIS and GMS for drawing highly accurate estimating maps. Also, these models are used to define the salinity, type of the groundwaters, the general direction of their movement, the distribution values of transmissivity of upper aquifer, the amount of drawdown for these wells, and drawing map for the groundwaters depth zones. The results of this research illustrated that the salinity of the ground water in Baghdad Governorate ranges between fresh to Brine water in general, with the predominance of Chloridic water type and the presence of sulphatic in other places. The direction of the ground water movement is mainly from the north-west towards the south-east, with the presence of local movements in other directions. The transmissivity ranges between (50 – 350) m<sup>2</sup> / day in general, but these values decrease toward the east, especially east of the Tigris River as indicated by the level of draw down in the wells, which ranges between (2 – 10) m. The result reflects that the groundwater depth in Baghdad Governorate ranges between (2 – 50) m. The objectives of the study are to study the effect of change in Tigris river level on the direction of groundwater movement and the magnitude of the groundwater velocity. In this research, three scenarios of river elevation stage are used. These stages are maximum, average and minimum elevations.

## 2. STUDY AREA

### 1. Location

Figure (1) shows the study area which is located between the latitude 33°13'52.05"N - 33°20'38.09" N, and the longitude 44°11'13.16"E- 44°30'32.49" E. The Tigris River divides Baghdad into two sectors for a separation of around 50 km. The direction of river flow is from northwest to southeast. Tigris river is the main source of water for domestic, irrigation and for industrial uses in Baghdad city [6]. The total area of the study region is about 361 km<sup>2</sup> (12.21 km x and 29.78 km) . The boundary of study area and the location of the observation wells are shown in Figure (2).

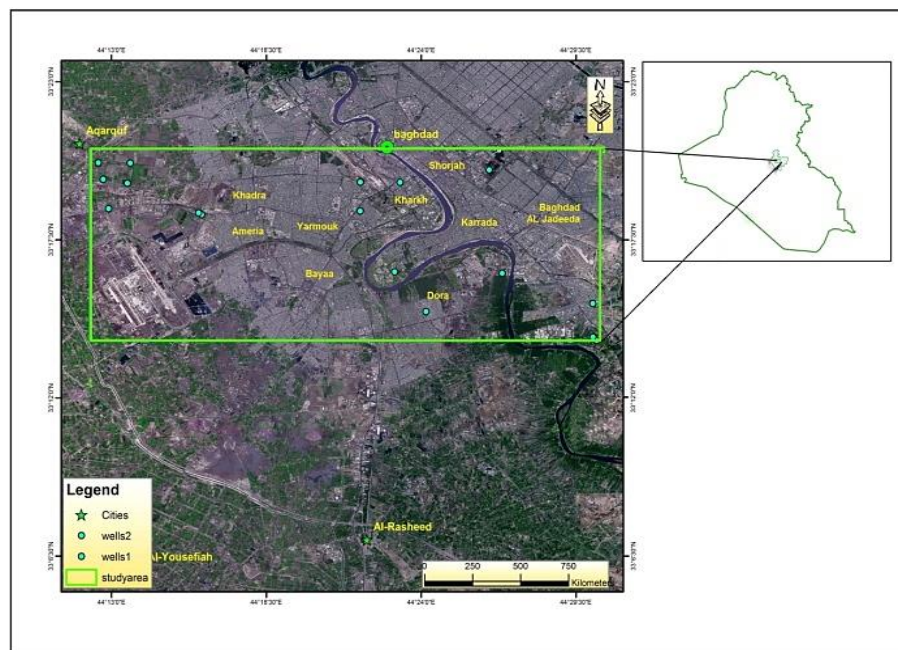


Figure 1: Study area.

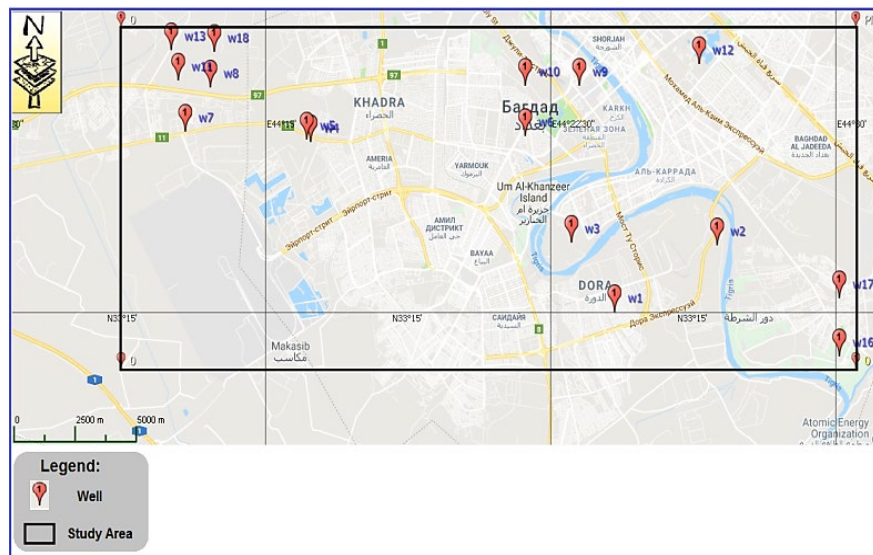


Figure 2: Location of observation wells

## II. Topography

Baghdad city is located along both sides of the Tigris River on the Mesopotamia Zone . The land on which the city is built is almost entirely flat and low-lying .The ranges of ground level elevations of Baghdad city are between (32 – 36 m.a.s.l) also the ground surface slope is about 0.1 m/km towards south, In this study the average elevation 34 m.a.s.l was used .

## III. Geology

The study area located at the flood plain, that consists of Pleistocene, Quaternary deposits and Holocene deposits. The thickness of this deposits is more than 250 m as depicted from the geological map, Jassim and Goff, (2006).Holocene deposits represent the mainly component of Mesopotamian Plain. They consists of alternating and complex sequence of silt, clay, gravel and sand. The mountains of Zagros-Taurus were the main source for the covering soil which transported by the Tigris and Euphrates rivers. After that they deposited at the flood plain of river Buday (1980). In the unstable shelf of the Arabian Plate, predominantly within the Tigris Subzone of the Mesopotamian Zone was Baghdad district located byBuday and Jassim (1987), [7].

## IV. Climate

The climate of the Baghdad city is mostly arid to semi-arid, with clear impact of the Mediterranean climate on the territory. It is portrayed by dry and sweltering summer, and cold with moderate downpour winter. As indicated by the meteorological data provided by for the years (1981 – 2000), the yearly mean precipitation was about 140 mm, the yearly relative humidity is about of (45 – 46) %, the yearly evaporation is around 3300 mm, the yearly mean temperature its about 23° C and the yearly mean wind speed ranges from (3 – 3.5) m/sec [5].

## 3. METHOD AND MATERIALS

### I. Groundwater modeling

TheGroundwater Modeling System (GMS) is a complete graphical user environment for performing groundwater simulations. The system consists of interface of program to appear the graphical user , as the number of analysis codes such as MODFLOW, MODPATH and MT3DMS.This program was developed by Aquaveo and it was designed as a comprehensive modeling environment. Many tools are provided in this program to assist in the building of the model , they indicate the buildup of mesh and grid, also to site's characterization, and post-processing[8].

## II. Groundwater Flow Equation

The general governing equation solved by Modflow:

$$\frac{\partial}{\partial x} \left( k_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left( k_y \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left( k_z \frac{\partial h}{\partial z} \right) = S_c \frac{\partial h}{\partial t} + W$$

where;  $x, y, z$ : Cartesian coordinates, (L) along the hydraulic conductivity axes  $k_x, k_y, k_z$  (L/T);  $h$ : Head of groundwater pressure, (L);  $W$ : the volumetric flux per unit volume, (T<sup>-1</sup>);  $S_c$ : Specific storage for the porous medium (L<sup>-1</sup>); and  $t$ : Time (T) [9].

## III. Input Data

The study area is divided into 49 rows and 120 columns, at each layer in **Fig. 3**, the size of each cell (250 x 250) m. according to the information, the number of the layers on this model is three layers, silty clay is a top layer of thickness of 10 m (fine and medium) sand at the medium and bottom layers respectively, with a thickness of 4m and 20 m respectively. The Modflow in steady state condition was used.



Figure 3: Grid size.

The properties of the soil's layers for aquifer of the study's area were given to the model as shown in Table I.

TABLE I: Lithological data of all layers

Layer no.	Soil type	Hydraulic conductivity (k) (m/sec)	Effective porosity (kN)
1	Silty clay	$5 \cdot 10^{-9} - 1 \cdot 10^{-7}$	0.42 – 0.68
2	Fine sand	$2 \cdot 10^{-7} - 2 \cdot 10^{-4}$	0.01 – 0.39
3	Medium sand	$9 \cdot 10^{-7} - 5 \cdot 10^{-4}$	0.16 – 0.46

In this paper, all model boundaries are considered as a constant head for the steady state condition, the other cells at the grid of model were represented variable head, as in **Fig. 4**. The minimum, average and maximum water levels of the Tigris River (27.6, 29.15 and 30.70 m.a.s.l) respectively were used which represented the observation for the period from the year 2000 to 2015 [10]. These stages were used in all the river's mesh in the model because the stages reading was not available along the Tigris River's reach. The model was run for each value.

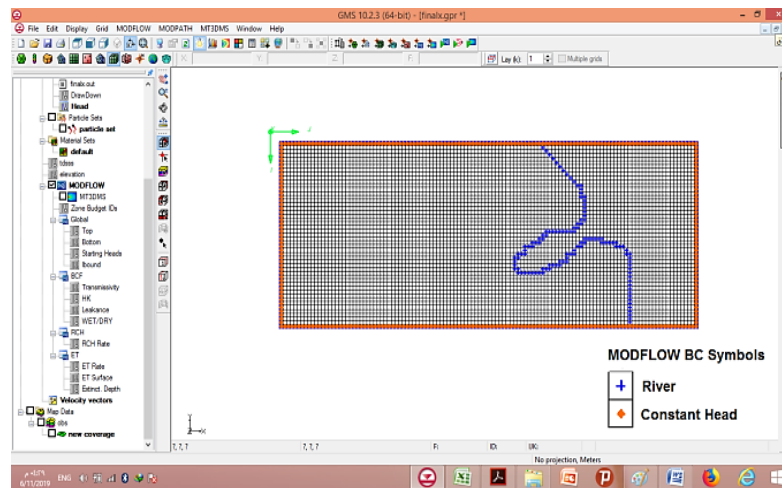


Figure 4: Boundary condition

#### 4. RESULTS AND DISCUSSIONS

##### I. Calibration and Validation

The manual calibration is used during the calibration of the model by adjusting the hydraulic conductivities. The values of the hydraulic conductivities after calibration are 0.0008, 17 and 40 m/day for the three layers.  $R^2$  (the coefficient of determination), ME (mean error), MAE (mean absolute error) and RMSE (root mean square error) were used as an indicator for the evaluation of the model's performance.

The observation of the hydraulics heads of 16 wells for 2015 were used for calibration and 9 wells for 2016 for validation. The ( $R^2$ ) for the straight line of the observed head versus the calculated head for all the three cases of Tigris River stage was greater than 0.89 and it was considered to be very good. The statistical results are shown in Table II. Figures (5a,b and c) show the comparison between the computed and the observed hydraulic heads for the wells at 30.7, 29.15 and 27.6 m.a.s.l respectively to the calibration process. Figures 6a, 6b and 6c show the comparison between the computed and the observed hydraulic head for the process and for the wells which were used for the validations processing. The difference between the observed and calculated hydraulic head for the groundwater elevation (calibration and verification process) was due to unknown of the seasonal time of the groundwater head in the observation wells. These data were during the year 2016 only.

TABLE II: Statistical analysis of the observed and simulated data

Water river stage	Parameters	MODFLOW results
Maximum water surface elevation (30.7) m	Mean error	0.586
	Mean absolute error	0.599
	Root mean square error	0.782
	$R^2$	0.893
Average water surface elevation (29.15) m	Mean error	0.618
	Mean absolute error	0.631
	Root mean square error	0.805
Minimum water surface elevation (27.6) m	$R^2$	0.897
	Mean error	0.65
	Mean absolute error	0.663
	Root mean square error	0.831
	$R^2$	0.898

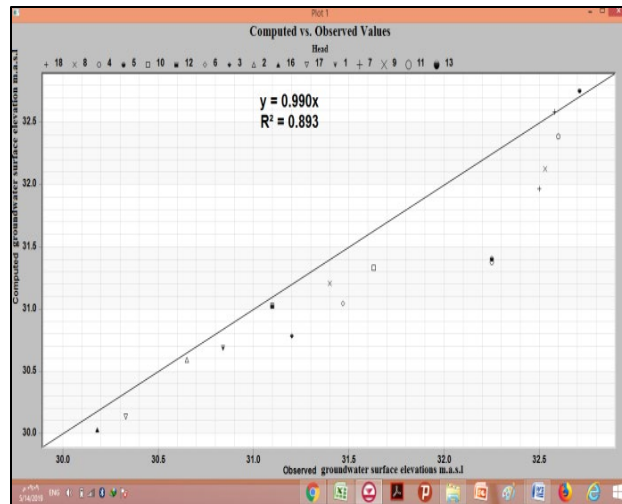


Figure 5a: Comparison between the computed and the observed hydraulic heads wells at 30.7 m.a.s.l river stage (Calibration process)

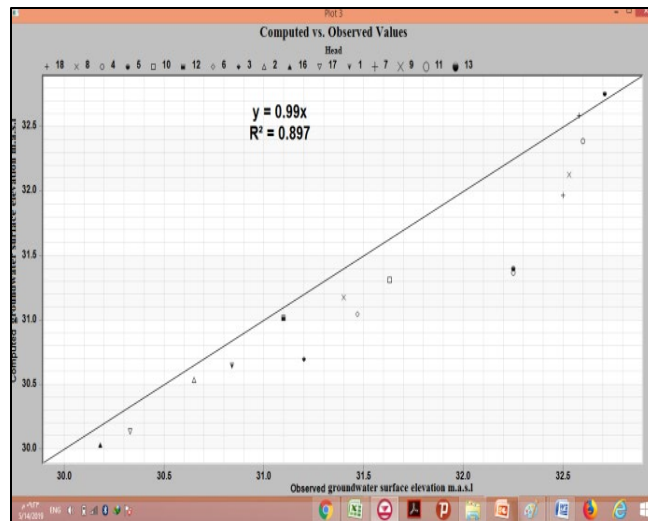


Figure 5b: Comparison between the computed and the observed hydraulic heads wells at 29.15 m.a.s.l river stage (Calibration process)

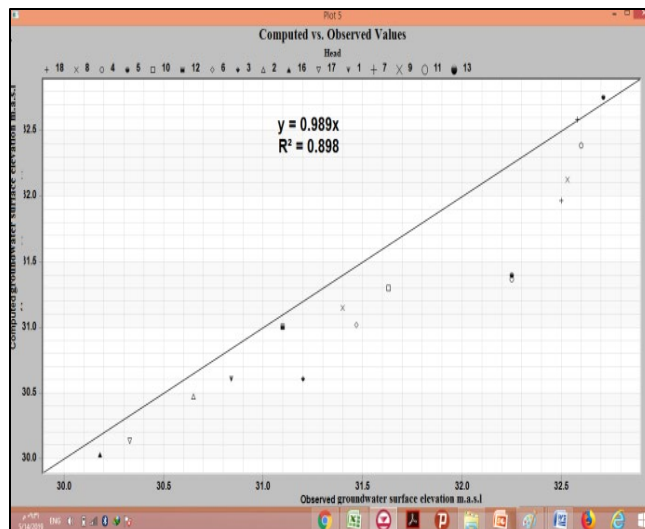


Figure 5c: Comparison between the computed and the observed hydraulic heads wells at (27.6 m.a.s.l) river stage (Calibration process)

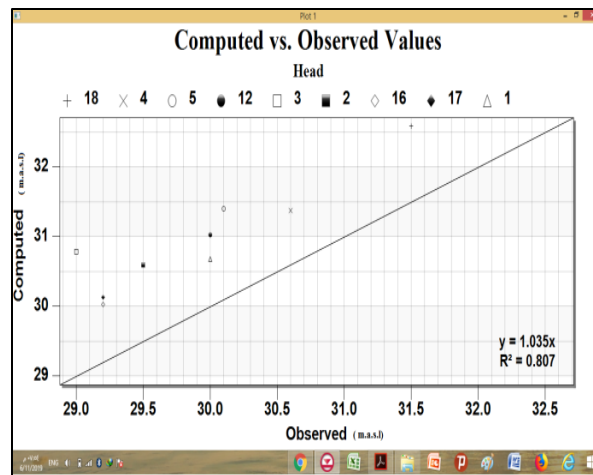


Figure 6a: Observed and calculated hydraulic head of the wells at 30.7 m.a.s.l river stage (validation process)

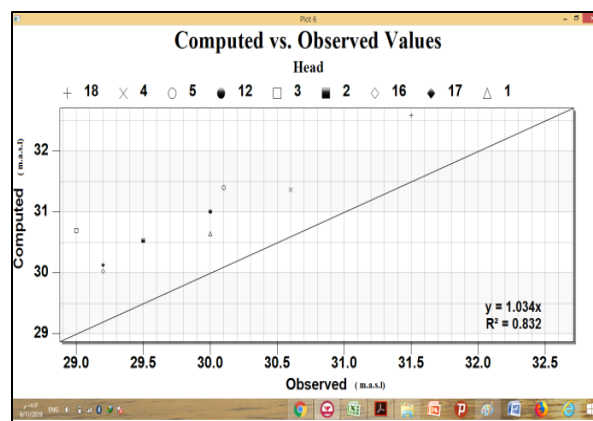


Figure 6b: Observed and calculated hydraulic head of the wells at 29.15 m.a.s.l river stage (validation process)

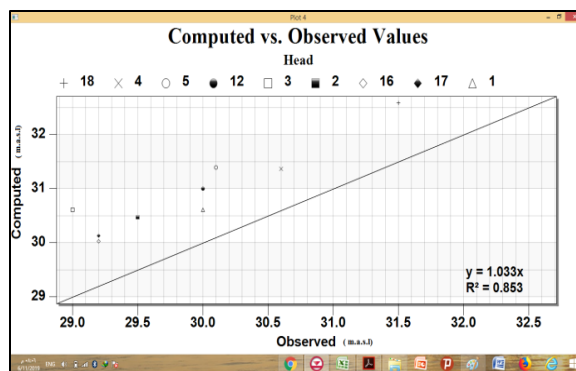


Figure 6c: Observed and calculated hydraulic head of the wells at (27.6 m.a.s.l.) river stage (validation process)

**II. Groundwater Flow:**

The contour lines of the equipotential of the groundwater flow in the first, second, and third layer for the maximum, an average and minimum water surface level of the Tigris River are shown in Figure (7-a-b and c) Figure (8-a-b and c) and Figure (9-a-b and c) respectively. The values of hydraulic head are illustrated as the following:

1- For the maximum water surface elevation (30.7 m.a.s.l) , Fig. (7-a-b-and c) , the head was 33 m.a.s.l at the western boundary of the study area .This value gradually changed towards Tigris River

until it reaches the smallest head value of ( 30 m.a.s.l) at the eastern boundary of the study area. The groundwater movement was towards the river because the movement of groundwater was from the high to low head. The groundwater flow Velocity in layer one was very slow .The velocity in this layer was (8 x10<sup>-8</sup>)m/day. For the layers two and three the velocity of groundwater was 0.0017 and 0.004 m/day respectively.

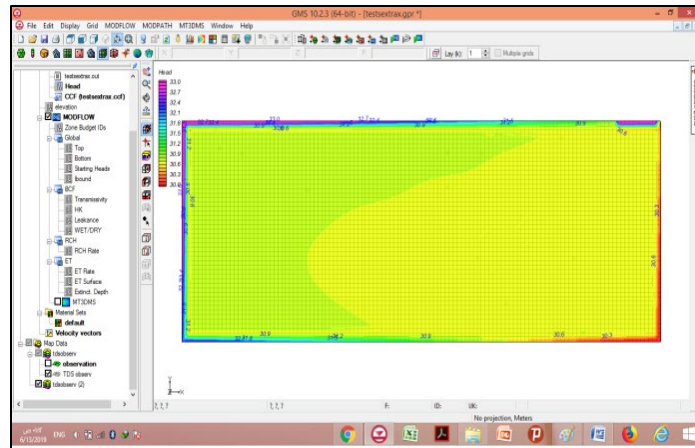


Figure7a: Contour map of the equipotential lines for maximum river stage (30.7 m.a.s.l) of layer1

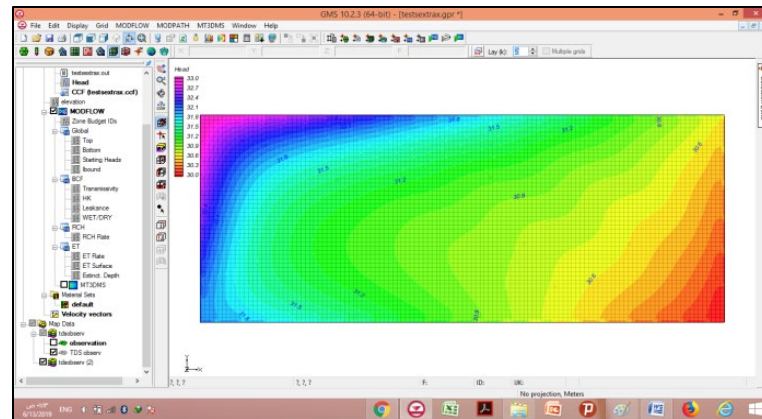


Figure 7b: Contour map of the equipotential lines for maximum river stage (30.7 m.a.s.l) of layer2

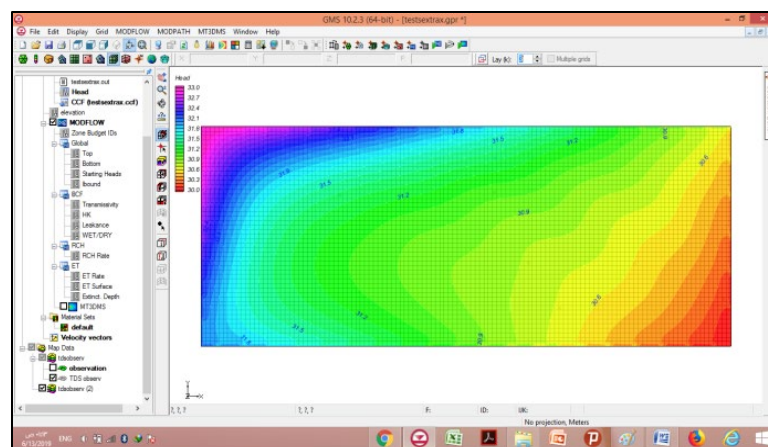


Figure 7c: Contour map of the equipotential lines for maximum river stage (30.7 m.a.s.l)of layer3

2- For the average water surface stage at the river (29.15 m.a.s.l), Fig. (8-a-b and c) , the value of the hydraulic head was33 m.a.s.l at the west boundary in the study area while the smallest head value was ( 29.158 m.a.s.l) at the area near the river. The groundwater flow Velocity in the layer one was very slow.The velocity in this layer was 1.224x10<sup>-7</sup> m/day. For the layer two and three were 0.0026 and 0.00612 m/day respectively.



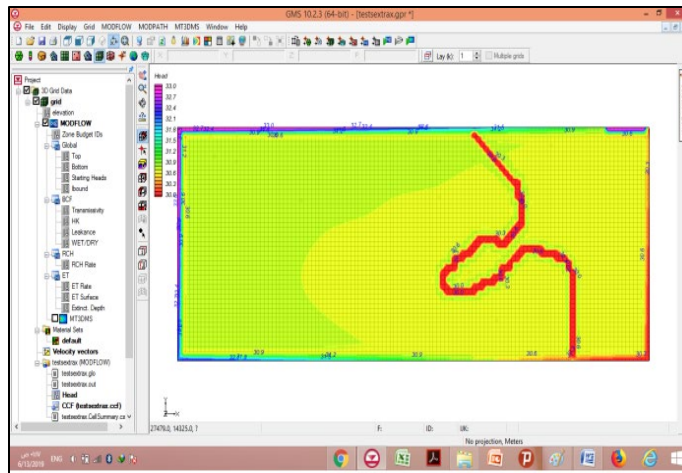


Figure 8a: Contour map of the equipotential lines for average river stage (29.15 m.a.s.l) of layer1

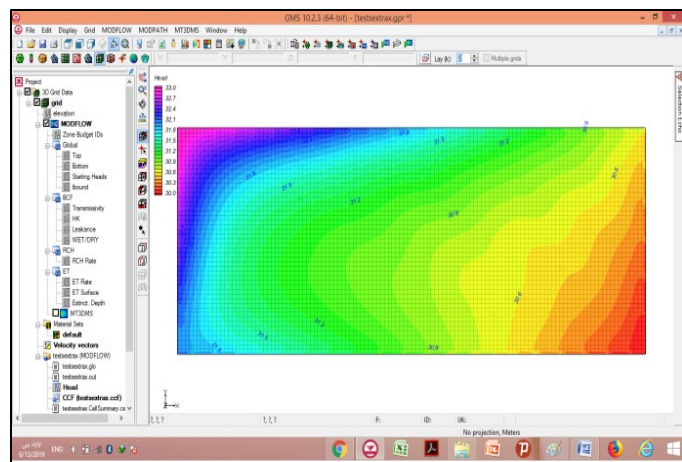


Figure 8b: Contour map of the equipotential lines for average river stage (29.15 m.a.s.l) of layer2

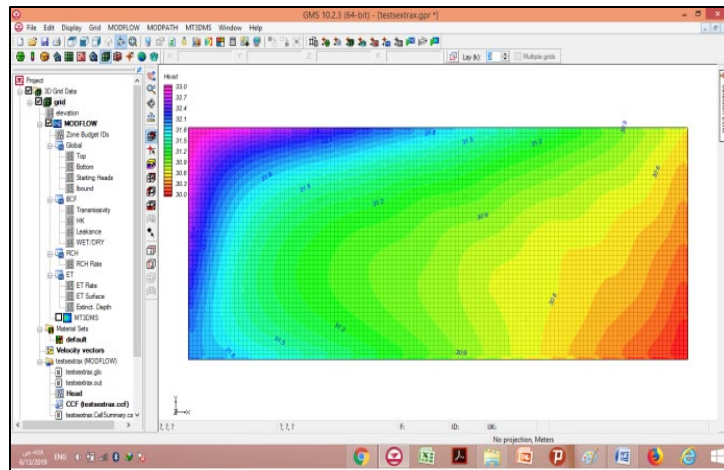


Figure 8c: Contour map of the equipotential lines for average river stage (29.15m.a.s.l.) of layer3

3-For the minimum water surface stage of Tigris River (27.6 m.a.s.l) Fig. (9-a-b and c) , the head value at the western boundary of the study area was 33 m.a.s.l while the smallest head value was ( 27.6159 m.a.s.l) at the area near the river. The groundwater flow Velocity in layer one is very slow .The max velocity in this layer was  $1.72 \times 10^{-7}$  m/day. For the layers two and three were 0.00365 and 0.0086 m/day respectively . It was shown that , the groundwater flow velocity was in an increase trend toward the river when the stage of water surface of Tigris River changed from high to low level due to the hydraulic gradient for the flow.

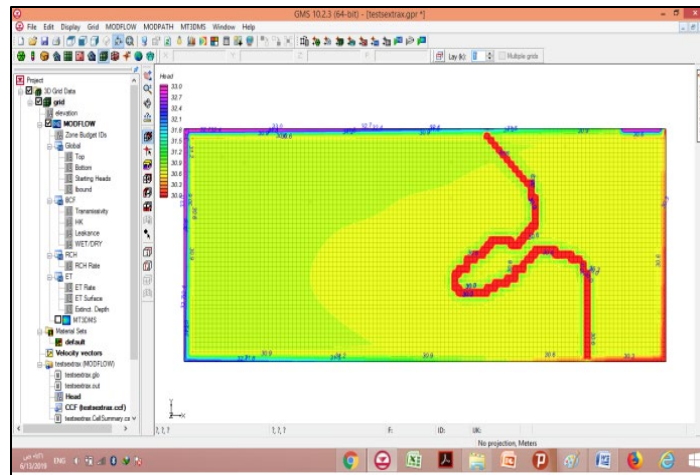


Figure 9a: Contour map of the equipotential lines for minimum river stage (27.6) m.a.s.l of layer1

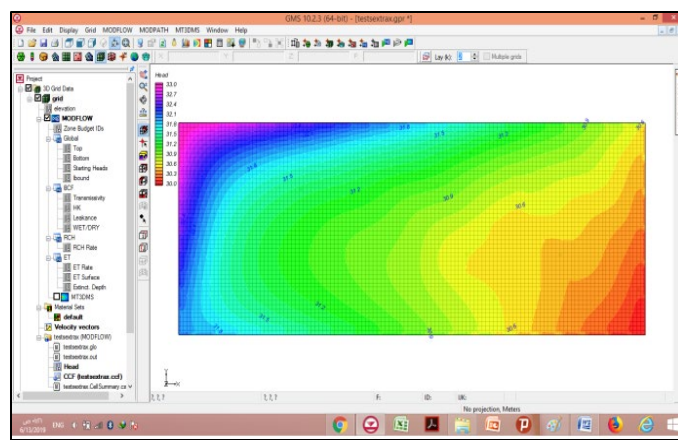


Figure 9b: Contour map of the equipotential lines for minimum river stage (27.6) m.a.s.l of layer2

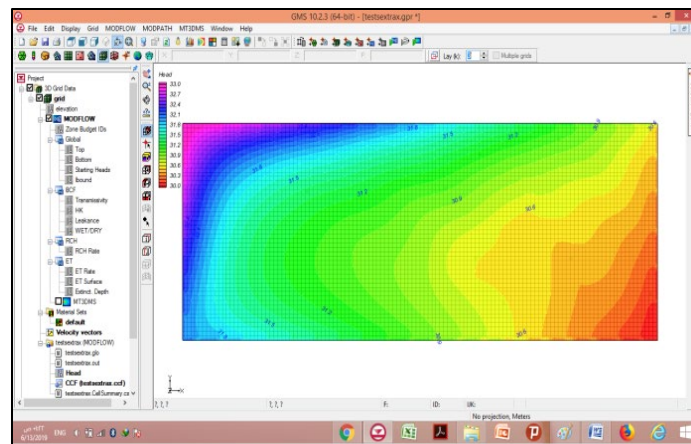


Figure 9c: Contour map of the equipotential lines for minimum river stage (27.6) m.a.s.l. of layer3

## 5. CONCLUSION

1. The direction of groundwater flow was from the northwest to the southeast for the study area.
2. The velocity of groundwater was low in all of the scenarios at the first layer.
3. The study is applied, for steady state condition only so a transient simulation must be recommended to appear during the alteration of aquifer hydraulic head with time; and that require more data with the change of seasons.
4. The values of the groundwater flow velocities for all of the water surface elevations scenarios were so close to the groundwater velocities for the aquifers as in [11]

5. It can be shown that the hydraulic gradient values of the groundwater flow for the scenario of Tigris River water surface elevation ( 27.6 m.a.s.l) , was highest than the other scenarios. Its value was ( $2.15 \times 10^{-4}$ ), so the velocity of groundwater flow was larger than the other scenarios.

## References

- [1] A.A. Satar, and H.A. Noor, groundwater in the Karkh district in Baghdad city, AL-Mostansiriyah j. arab int. stud., 56 (2017) 400-434. (in Arabic)
- [2] M. L. Najah, The Effects of Al-Jaderi Lake On The Groundwater Flow Pattern ,AL-TAQANI J., 21(2007) 152-164.
- [3] E. H. Abbas, Study of groundwater and slope stability for the right bank of derbendikan dam, MSc. Thesis, Building & Construction Dept., Univ. of Technology, Baghdad, Iraq, 2012.
- [4] T.A. Hussain, Simulation model of groundwater within umm-erradhuma formation in anbar province /western iraq, Iraqi J. Sci., 56 (2015) 3188-3202.
- [5] N.H. Al-Basrawi, J. H. Awad, and T. A. Hussain, Evaluation of the ground water in baghdad governorate / iraq, Iraqi J. Sci., 56 (2015) 1708-1718.
- [6] I. S. ALakaam, A study of some morphological characteristics of the Tigris River in the city of Baghdad, J. Coll. Educ. Women, 27(2016) 802-820.
- [7] S. M. Ali, Hydrogeological Environmental Assessment of Baghdad Area, Ph.D. Thesis, College of Science, University of Baghdad, 2012.
- [8] GMS User Manual (v10.2).
- [9] D. K. Todd, Groundwater hydrology, John wiley and Sons Inc, 3rd ed., New York, Ch. 3, 122-124, 2005.
- [10] S. K. Thair, Simulation of Groundwater Flow and Migration of the Radioactive Cobalt-60 from LAMA Nuclear Facility-Iraq, Mdpi J. Water, 10, 2018. <https://doi.org/10.3390/w10020176>
- [11] A. S. Mustafa , A. H. Abdulkareem and R. A. Saud , Simulation of groundwater movement for nuclear research center at al-tuwaita area in baghdad city, iraq J. Eng., 23 (2017) 94-107.