University of Baghdad
College of Engineering
JE
JOURNAL OF ENGINEERING

Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 3 Volume 26 March 2020

Chemical, Petroleum and Environmental Engineering

Flow Characteristics Of Tigris River Within Baghdad City During Drought

Bushra Ibrahim Asaad*
B.Sc. water Res. Engineering
University of Baghdad / College of Engineering
bushraibraheem7@gmail.com

Dr. Basim Sh. Abed
Assistant Professor
University of Baghdad / College of Engineering
bassim.shabaa@coeng.uobaghdad.edu.iq

ABSTRACT

The main source of water supply in Iraq is the surface water, especially Tigris and Euphrates Rivers and their tributaries. In the recent years there was a great drop in the water levels of Tigris River within Baghdad City which had affected the operation of twelve water supply projects located on the banks of Tigris River in Baghdad City, due to significant climate changes, and the expansion of hydraulic construction (dams) and implementation of new irrigation projects in Turkey, these factors have greatly reduced the water flowrates of river by about 46%. In the present study the flow characteristics of Tigris River within Baghdad City was studied, the reach involved was about 49km in which it represents the urban zone beginning from the north of the Baghdad City at Al-Muthana Bridge to the confluence of Tigris River with the Diyala River south of Baghdad, using steady flow one-dimensional hydraulic model to achieve raising of water levels within this reach during drought periods. This model was implemented using HEC-RAS software.Three sets of observation data were used to calibrate the model to estimate suitable Manning roughness coefficient (n) considering the root mean square error (RSME) as an accurate indicator. The results showed that n of value 0.032 for the main river bed and 0.040 for flood banks of the river gave the best results with minimum RMSE of 0.076. Several treatments were suggested such as construction of barrage, inflatable weir, and the use of obstruction for the purpose of raising water levels. Moreover, selection of the suitable site of these treatments or hydraulic structures was studied, as well as their cost was analyzed. The results show that the proper solution for maintain the required water levels that ensure continuous operation of water supply project was the construction of an inflatable weirs, due to low initial cost, simplicity of operation, their ability to inflate and deflate quickly and easily to prevent upstream flooding, and offering a high level of control and easy method for recapturing water.

Keywords: inflatable weirs, hydraulic modelling, drought periods, drought.

---

*Corresponding author

Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2020.03.07

Article received:16/3/2019
Article accepted:28/4/2019
Article published:1/3/2020

خصائص جريان نهر دجلة داخل مدينة بغداد خلال الشحة

بشرى ابراهيم اسعد مهدي
بكلوريوس هندسة موارد مائية
كلية الهندسة /جامعة بغداد

الدكتور باسم شبع عبد
استاذ مساعد
كلية الهندسة /جامعة بغداد

الخلاصة

تعتبر المياه السطحية المصدر الرئيسي لإسالة الماء في العراق، لاسيما نهري دجلة والفرات وروافدهما. شهدت السنوات الأخيرة انخفاضا كبيرا في مستويات المياه في نهر دجلة داخل مدينة بغداد مما أثر على تشغيل اثني عشر مشروعًا لإسالة الماء تقع على ضفاف النهر وذلك بسبب التغيرات المناخية الكبيرة ، والتوسع في الانشاءات الهيدروليكية (السدود) وتنفيذ مشاريع الري الجديدة في تركيا ، أدت تلك العوامل إلى انخفاض تدفق مياه النهر بنسبة 46٪.

تم في هذا البحث دراسة خصائص تدفق نهر دجلة داخل مدينة بغداد ، لطول مقطع يصل إلى حوالي 49 كم والتي تمثل المنطقة الحضرية التي تبدأ من شمال مدينة بغداد عند جسر المثنى إلى نقطة التقاء نهر دجلة مع نهر ديالى جنوب بغداد ، باستخدام نموذج هيدروليكي أحادي البعد للجريان المستقر لرفع منسوب المياه في هذه المناطق خلال فترات الجفاف. تم تنفيذ هذا النموذج باستخدام برنامج HEC-RAS.

تم استخدام ثلاث مجموعات من بيانات الرصد لمعايرة النموذج لتقدير معامل خشونةماننغ (n) المناسب مع اخذ متوسط جذر مربع الخطأ (RSME) كمؤشر للدقة. أظهرت النتائج أن (n) بقيمة 0.032 لقاع النهر الرئيسي و 0.040 لضفاف الفيضان في النهر أعطت أفضل النتائج مع ادنى قيمة لـ RMSE وهي 0.076.

كما تم اقتراح العديد من المعالجات لغرض رفع مناسيب المياه مثل (**اقامة سدة، انشاء سد المطاطي، او استخدام العوائق)** لغرض رفع مناسيب المياه. علاوة على ذلك ، تم دراسة اختيار الموقع المناسب لهذه المعالجات أو المنشأت الهيدروليكية وكذلك تم تحليل كلفتها.

خلصت النتائج إلى أن الحل المناسب للحفاظ على مناسيب المياه المطلوبة التي تضمن التشغيل المستمر لمشاريع إسالة الماء هو بناء السدود المطاطية (القابلة للنفخ) ، وذلك بسبب انخفاض التكلفة الأولية وسهولة التشغيل وقدرتها على الامتلاء والتفريغ بسرعة وسهولة منع طفح المياه ، والسماح بتنظيف السد ذاتيا من الترسبات والحطام .

الكلمات الرئيسية: نهر دجلة، السدود القابلة للنفخ، مناسيب المياه، اقتراح المعالجات، المنشات الهيدروليكية، فترات الجفاف، التدفقات.

1. INTRODUCTION

Water supply projects are one of the most essential engineering infrastructures in all countries around the world. If the water levels in the river fall below the operational standards of these projects, they cannot be operated and cannot ensure the continuous production of drinking water for citizens. So, it is necessary to maintain the minimum water levels required to ensure the continuous operation of these projects located on the Tigris River within Baghdad City. **Fig.1** shows the location of the water supply projects on the Tigris River within Baghdad City**. Table 1** illustrates the general description of the water supply projects and the operational water levels for each project

To control the flow of water in rivers, streams, and canals it is essential to establish hydraulic control structures such as barrages, and inflatable weirs. Inflatable weirs, which are the modern types of weirs, also called rubber weirs, are long flexible tubes inflated with air or water or air/water, anchored to a concrete base and abutments, **Fig.2, (Nasser,2002)**. This type of weirs have been used for 60 years in rivers as low-level control structures used for raising water levels in streams for diverting water to domestic, irrigation, or industrial canal, but installations have risen as an abatement. In open canals, they are commonly used to raise the water level or to increase water storage. The interest in inflatable weirs is rising because of the ease of placement and construction; such structures can be utilized at sites where traditional structures are too costly and take long time to construct **(Nasser, 2002).**

There were many studies interested in studying the flow characteristics of the Tigris River within Baghdad City, but the present study will be concerned about drought periods and the decreasing of water levels, which affect the continued operation of the water supply projects. In recent years, the water levels in the river reduced within the study reach due to lack of water releases by the neighboring countries, especially Turkey.

2. STUDY AREA

Tigris River is extended along the central zone of Baghdad Governorate between Latitude 33°16′17″N to 33°25'32"N and Longitude 44°27′15″E to 44°20'46"E and it is the primary source of water for urban, industry, agriculture usages, and other uses within Baghdad City **(Mawlood, 2017).** The study reach included two gauging stations. The first station is near Al Muthana Bridge, namely North Baghdad (Al Muthana) gauging station, and the second is Sarai Baghdad gauging station, as shown in **Fig.1.** The cross-sections were surveyed by the Ministry of Water Resources at year 2008 (unpublished data). Many changes happened to these cross-sections due to scouring by flowing water and sediment deposition along the reach of the river during the past time, but the behavior of the river does not change, so these data can be taken as basic information to build the simulation model. The banks of the river faced various changes and a lot of excesses by digging and building constructions, as well as many contractions in the river cross-sections were done due to the construction of tourism projects on the left and right side banks of the river.

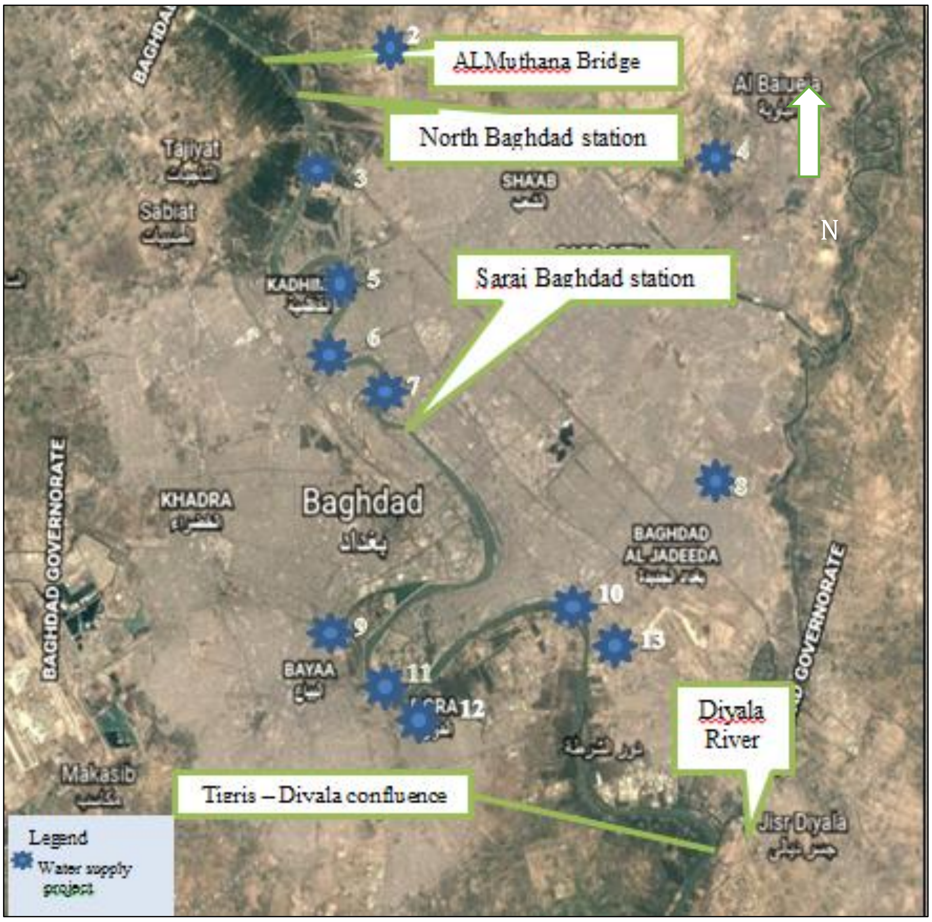

Figure 1. The reach of the study-Tigris River within Baghdad **(Google Earth).**

Table 1. Water supply projects located on the Tigris River in Baghdad.

No.	Name of Water Project	The project site	Min. level of the Tigris River (m.a.m.s.l.)
1	Al-Kharkh Water Project.	Tarmiyah	30**
2	Rasafa Water Project.	Boob Alshsham	29.5
3	Sharq Dijla Water Project.	Sabaa Abkar	28.47
4	Al Sadr Water Project.	Kasra Waeatash	28.5
5	Al Karama Water Project.	Utaifiyya	27.5

6	Al Wathba Water Project.	AlIwedhiya	27
7	Al Kadhimiya Water Project.	Al-Kadhimiya	26.9
8	Al Baladiyat Water project.	Al-Baladiyat	26.5
9	Al Qadissia Water project	Al Qadissia	26
10	Al Alwihda Water Project	Al Karrada	25.85
11	Al Jadiriyah Water Project	AL-Jadiriyah	25.75
12	Al Dora Water Project	Hay Alathuriyeen	25.60
13	Al Rasheed Water Project	AL-Rasheed Muaaskar	25.5

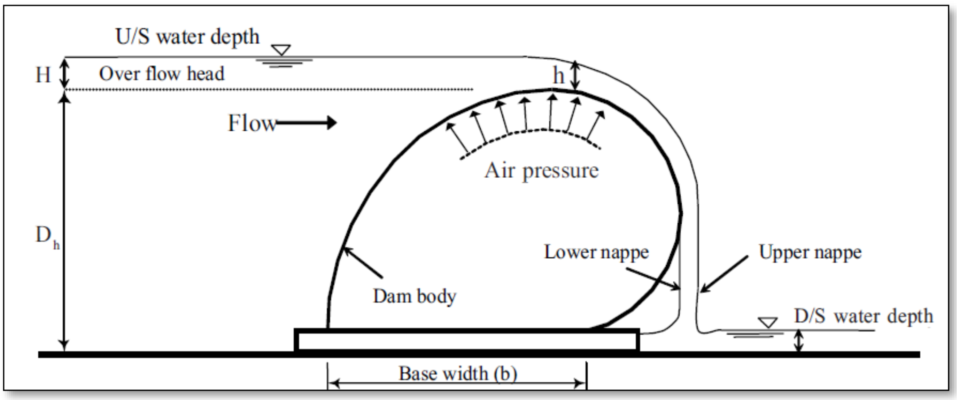

Figure 2. Flow over the air–inflated weir.

3. CALIBRATION AND VERIFICATION OF THE MODEL

A one dimensional and steady flow HEC-RAS model was calibrated using three sets of observation flow data for periods in the year of Low flow, Normal flow and High flow within different flowrates ranged between 322 and 1300 m^3/s at the upstream of the studied reach at the North of Baghdad (Al Muthana) gauging station.The Root Mean Square Error (RMSE) test was used to calibrate the steady flow model where it was used for comparison of the computed water levels by the model for each of the values of Manning roughness coefficient (*n*) with the observed water levels according. The (*n*) values were defined in the simulation program, and different values were obtained for the water levels. The results showed that Manning roughness coefficient (*n*) of value 0.032 for the main channel and 0.040 for banks of the river gave the best results with minimum (RSME) of 0.076 for calibration results, as shown in **Fig.3.**

Then, the suitable *n* was used in the verification of the model using other sets of data for Low flow, Normal flow and High flow started on August 2014, October 2015 and March 2013 with different flowrates ranges of 330.8 to 400, 500 to 800, 818 to 1220 m^3/sec at north of Baghdad, respectively at (Al Muthana) gauging station, **Fig. 4.**

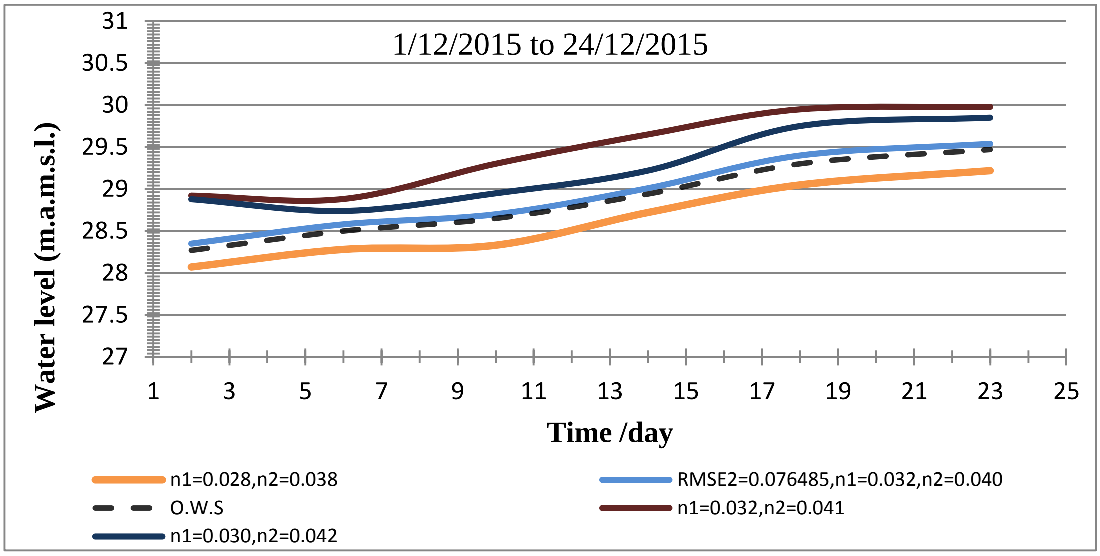

Figure 3. Calibration comparison between computed and observed water levels at the station of Sarai Baghdad for (Q=534 to 800m^3/s).

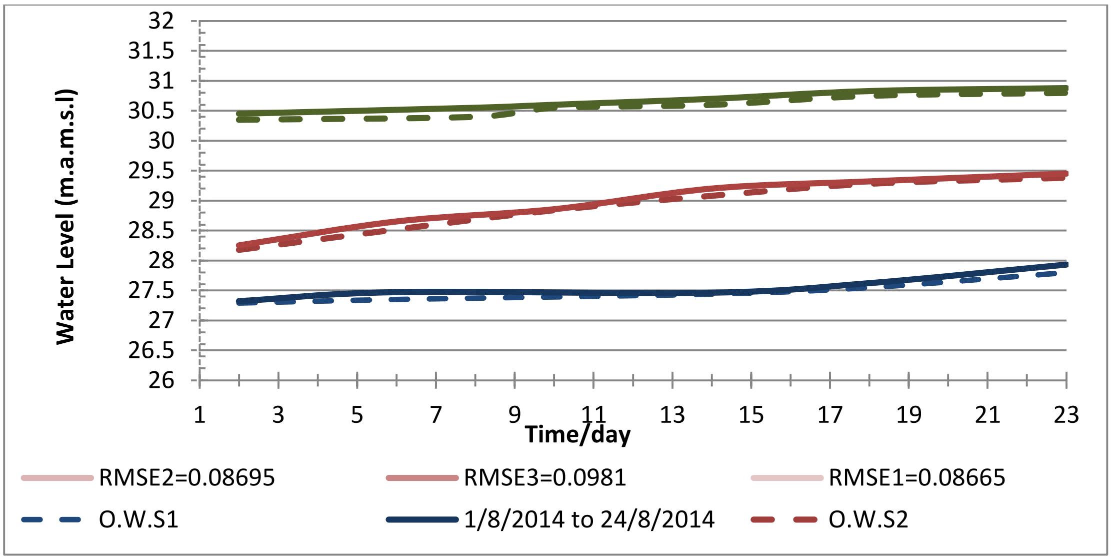

Figure 4. Verification comparison between computed and observed water levels for the three periods at Sarai Baghdad gauging station.

4. SELECTION OF BEST LOCATION OF STRUCTURE

Through studying the river section, it's very important to select the best location which meets the technical specifications required for the constructing the safe hydraulic structures such as, suitable foundation, materials needed for the construction should be easily available either locally or in the near vicinity, diversion works during the construction, morphology of the river valley, and geotechnical conditions. The proposed location of the structures or treatments is at 4 kilometers upstream the confluence of Tigris River with Diyala River. Its coordinates are 33°08´58″N- 44°23´45″E m between cross-section 13 and 14, **Fig. 5.**

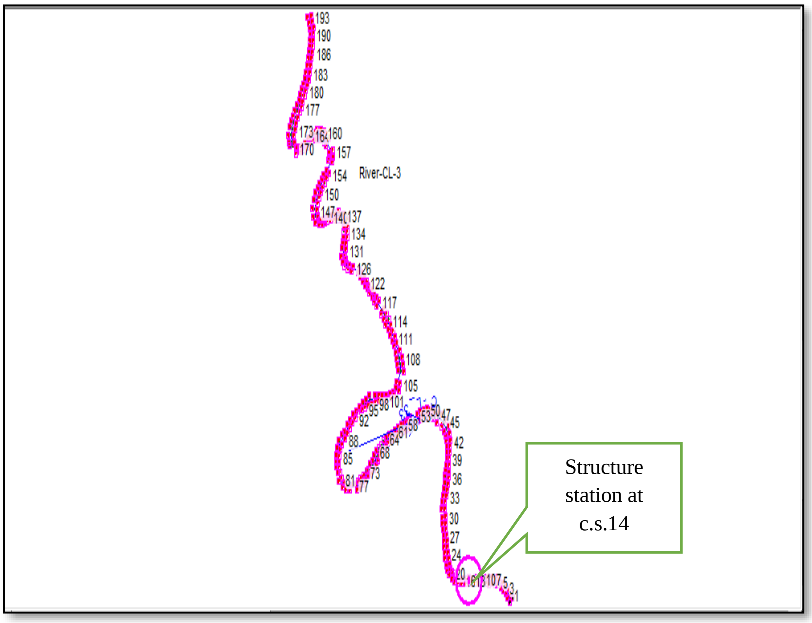

Figure 5. Proposed location of the suggest structure or treatment on the Tigris River.

5. SIMULATION RESULTS BEFORE USING TREATMENTS

The water surface profiles of Tigris River within Baghdad City before treatments for low flow case (Q=150) m^3/sec during the drought period, **Fig.6**, were computed using the HEC-RAS simulation model.

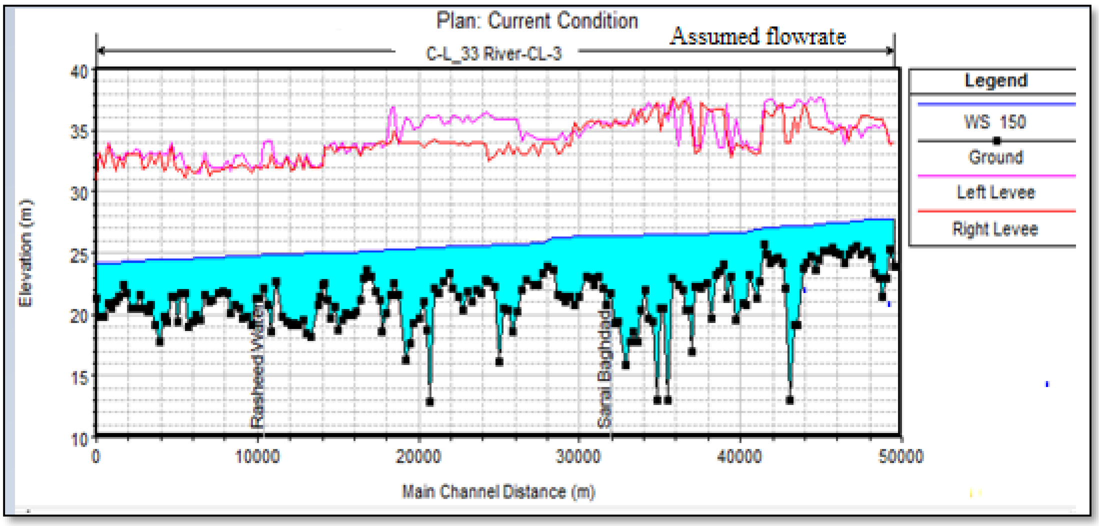

Figure 6. Longitudinal profile of Tigris River within Baghdad City before treatments during drought period for discharge of 150 m^3/sec.

From **Fig. 6**, it can be noticed that when the flowing discharge of the river is Q=150 m^3/sec, (before treatment) low water surface elevation of 24.75 m.a.m.s.l. will be attended (at the station 43), which is insufficient for operation of many water projects, for example Al Rasheed water project operates at a water level of 25.5m. While the predicted water surface elevation for the discharge of Q=300m^3/sec, which represents the upper limit of low flowrates before treatment, was 25.20m, which is still below the required water surface elevation for the operation of the Al Rasheed water project.

6. RESULTS OF THE CONSIDERED SCENARIOS FOR RAISING WATER SURFACE ELEVATION

For the purpose of raising the water surface elevation of Tigris River to a minimum level that ensures a continuous operation water supply projects especially during drought periods, one of the following suggestions may be proposed to be placed at a distance upstream the confluence of the Tigris River with the Diyala River after Al-Rasheed water project. Moreover, Several scenarios will be suggested and tested using HEC-RAS model to check the suitable scenario. These scenarios can be summarized as follows:

6.1 First scenario: Using a Barrage

The simulation results of using HEC-RAS model were tested for different discharges through the operation of the hydraulic models and including the suggestions or treatments for raise the water surface elevations, during drought periods which ensures and providing the minimum water surface elevations that meet the requirements for continuous operation of the water supply projects in the study region. The proposed barrage will be assumed for different cases of flowrates, namely (150, 1300, and 2500) m^3/sec, which represent the low flow, max normal flow, and flood flow conditions. These cases were tested with a barrage having different number of gates (5, 10, and 15). However, each case was implemented to study of the first treatment (scenario), the model was run according to different discharges.

- The First Case a Barrage with five gates (Q=150, 1300, and 2500 m^3/sec).
- The Second Case, a Barrage with ten gates Q= (150, 1300, and 2500 m^3/sec),
- The Third Case, a Barrage with fifteen gates Q= (150, 1300, and 2500 m^3/sec).

Figs. 7 through **12** show the results of different operation cases of the simulation model, for different flowrates. While **Table 2** illustrates the water surface elevations obtained from the run of the simulation model for the cases mentioned above.

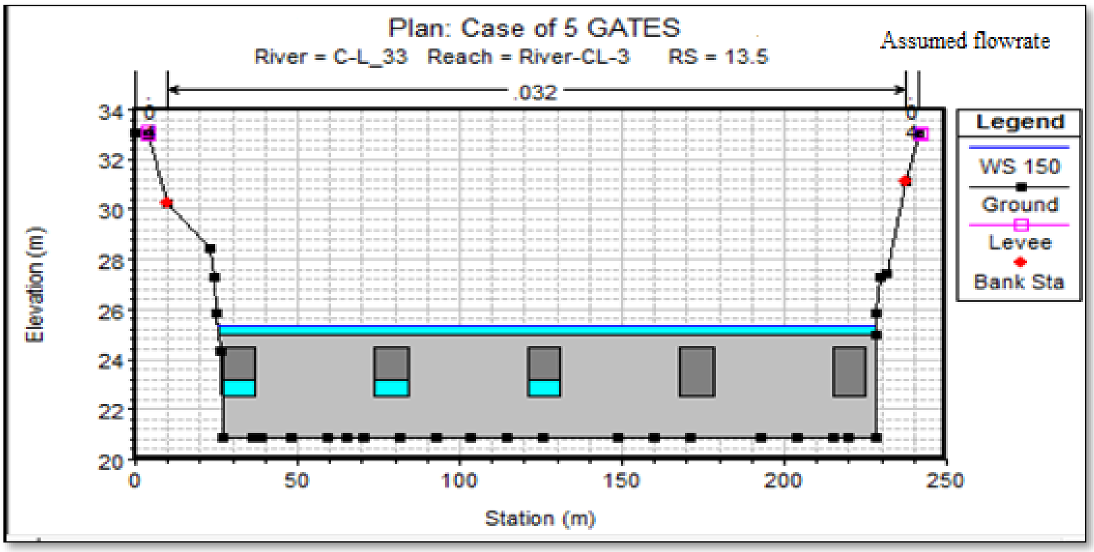

Figure 7. Barrage with five gates, three gates opened with a height of 0.7m and at discharge of 150 m^3/sec.

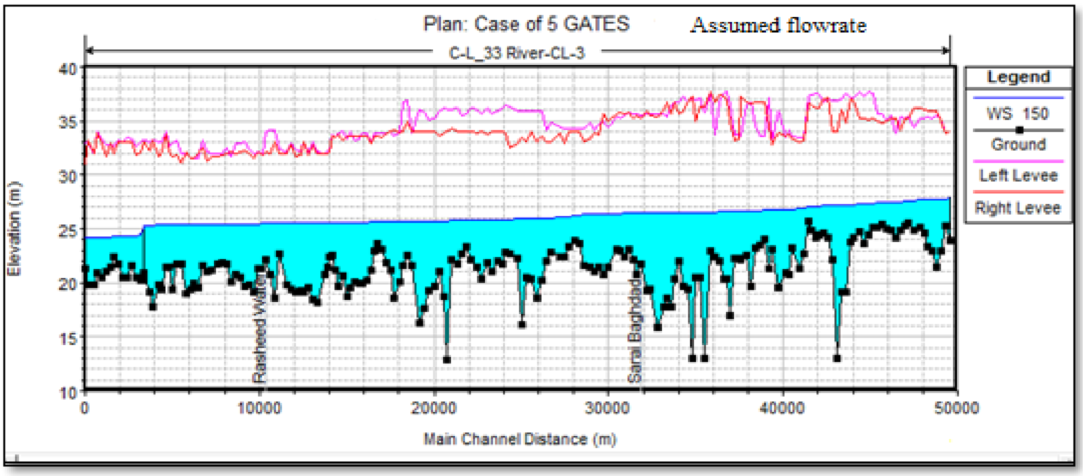

Figure 8. Longitudinal profile of Tigris River within Baghdad City, Q=150 m^3/sec with the proposed Barrage.

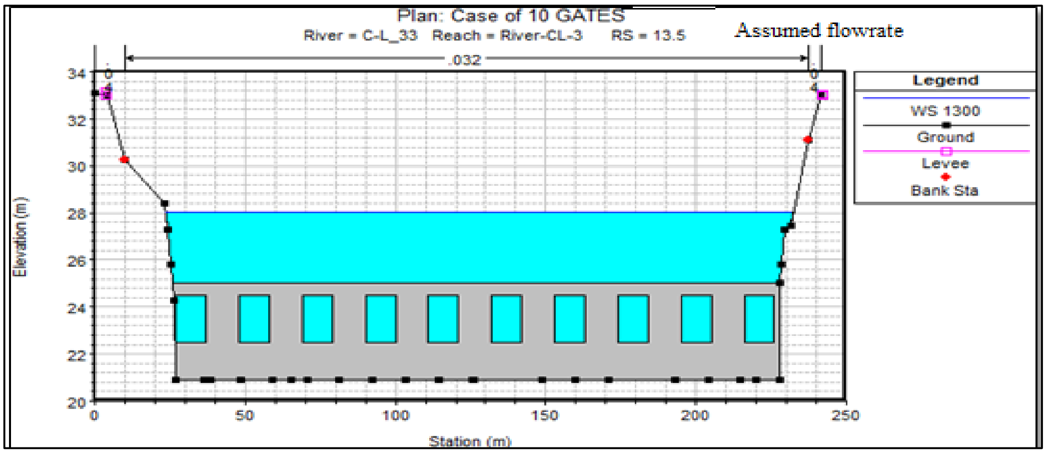

Figure 9. Barrage with ten gates, fully opened, Q=1300 m^3/s.

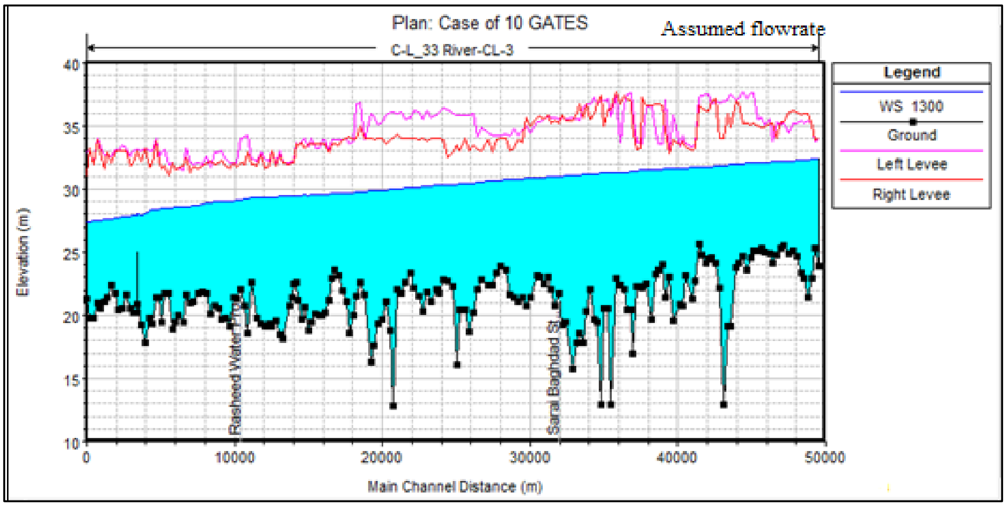

Figure 10. Longitudinal profile of Tigris River within Baghdad City, Q=1300 m^3/sec, with the proposed Barrage.

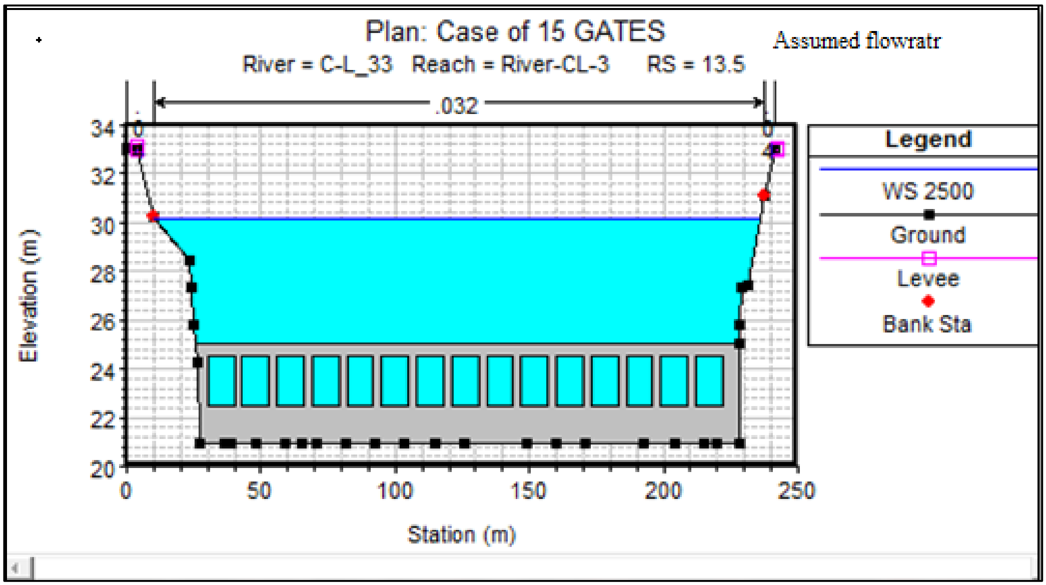

Figure 11. Barrage with fifteen gates, fully opened, Q=2500 m^3/s.

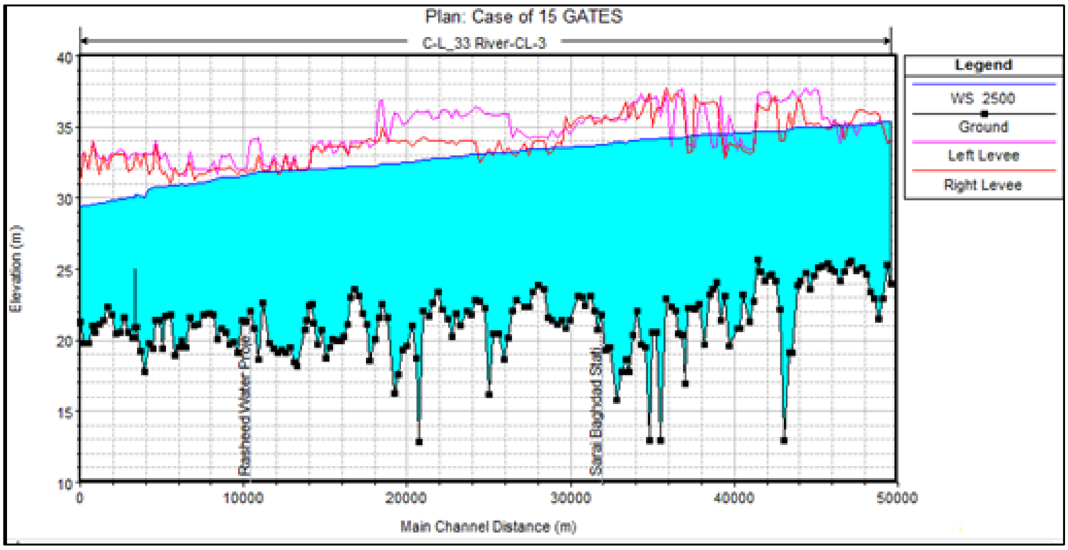

Figure 12. Longitudinal profile of Tigris River within Baghdad, Q=2500 m^3/sec, with the proposed Barrage.

Table 2. Simulation Results of the first scenario: (Barrage) on Tigris River at Baghdad City.

Proposed Solutions	Gate Dimensions	Sill Invert , m.a.m.s.l.	Operation , Q= 150 m^3/s		W.L (m.a.m.s.l.)
			No. of Open Gates	Opening Height , m	Al Rasheed Water Project
Barrage with 5 Gates	2*10	22.5	3	0.7	25.5
Barrage with 10 Gates	2*10	22.5	3	0.7	25.5
Barrage with 15 Gates	2*10	22.5	3	0.7	25.5
Proposed Solutions	Gate Dimensions	Sill Invert , m.a.m.s.l.	Operation , at Q=1300 m^3/s		W.L at
			No. of Open Gates	Opening Height , m	Al Rasheed Water Project
Barrage with 5 Gates	2*10	22.5	5	2	29.23
Barrage with 10 Gates	2*10	22.5	10	2	29.23
Barrage with 15 Gates	2*10	22.5	15	2	29.24
Proposed Solutions	Gate Dimensions	Sill Invert , m.a.m.s.l.	Operation , at Q=2500 m^3/s		W.L at
			No. of Open Gates	Opening Height , m	Al Rasheed Water Project
Barrage with 5 Gates	2*10	22.5	5	2	31.75
Barrage with 10 Gates	2*10	22.5	10	2	31.76
Barrage with 15 Gates	2*10	22.5	15	2	31.77

Results of the first scenario show that the longitudinal profile of Tigris River within Baghdad City, tested with a barrage having different number of gates (5, 10, and 15), for flowrates, Q=1300 m^3/sec, and fully opened gates the water surface elevations in the Al Rasheed water project is 29.24 m.a.m.s.l, and an overflow happened. While the case when a flowrate Q= 2500 m^3/sec, and fully opened gates of the three cases of the barrage as shown in **Fig. 12**, the longitudinal profile of Tigris River within Baghdad city and the water surface elevations in the Al Rasheed water project is 31.76 m.a.m.s.l, with considering of levees raising due to overflow happened in different locations which imposed earthworks.

6.2 Second Scenario: Inflatable Weir

The second scenario was implemented to study Inflatable Weir and the model was run for a discharge of 150 m^3/sec that represents minimum expected flowrate during drought periods, the other discharge cases would be considered with emptied weir. When discharge is 150 m^3/sec, the proposed inflatable weir must be with crest level is 24.7 m.a.m.s.l. to raise water surface elevation that ensures the minimum water surface elevation required for operating the water stations, as shown in **Fig 13.**

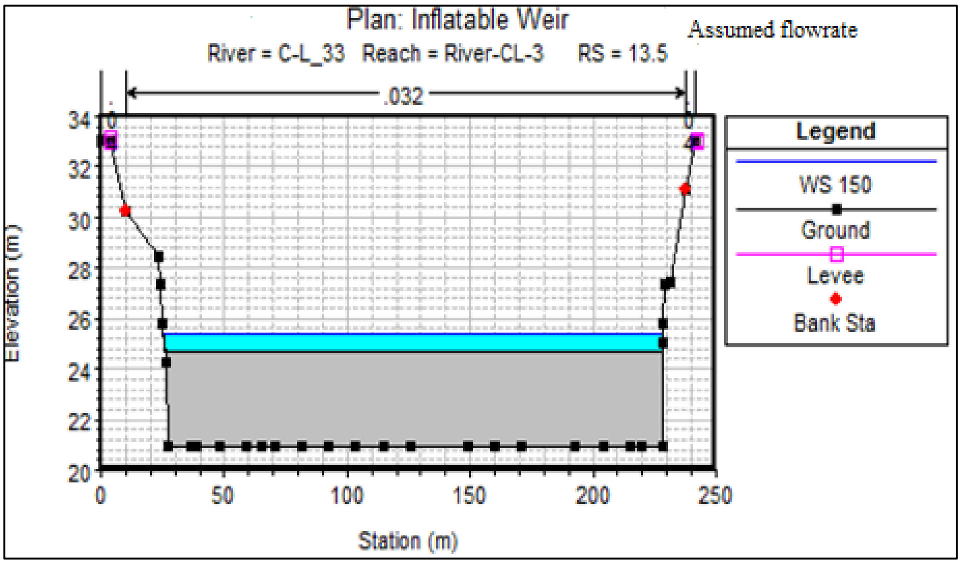

Figure 13. Inflatable weir, Q=150 m^3/sec, with crest level=24.7 m.a.m.s.l.

Fig.14, presents the longitudinal profile of the Tigris River within Baghdad City, Q = 150 m^3/sec after installing the inflatable weir, it was found that when a crest level is 24.7 m.a.m.s.l, the water surface elevation in the Al-Rasheed water project will be 25.5 m.a.m.s.l, which is the minimum water surface elevation required to operate the project. The results also show that the longitudinal profile of Tigris River within Baghdad City when the inflatable weir was emptied for flowrates Q = 1300 m^3/sec, the water surface elevation in the Al-Rasheed water project is 29.40 m.a.m.s.l, and an overflow happened. While the case when a flowrate Q = 2500 m^3/sec, and emptied the inflatable weir. **Fig.15** shows the longitudinal profile of Tigris River within Baghdad City while inflatable weir was emptied during flood period for Q = 2500 m^3/sec, the water surface elevation in the Al-Rasheed water project is 30.76 m.a.m.s.l. considering banks raising due to overflow that happens in different locations, which required earthworks.

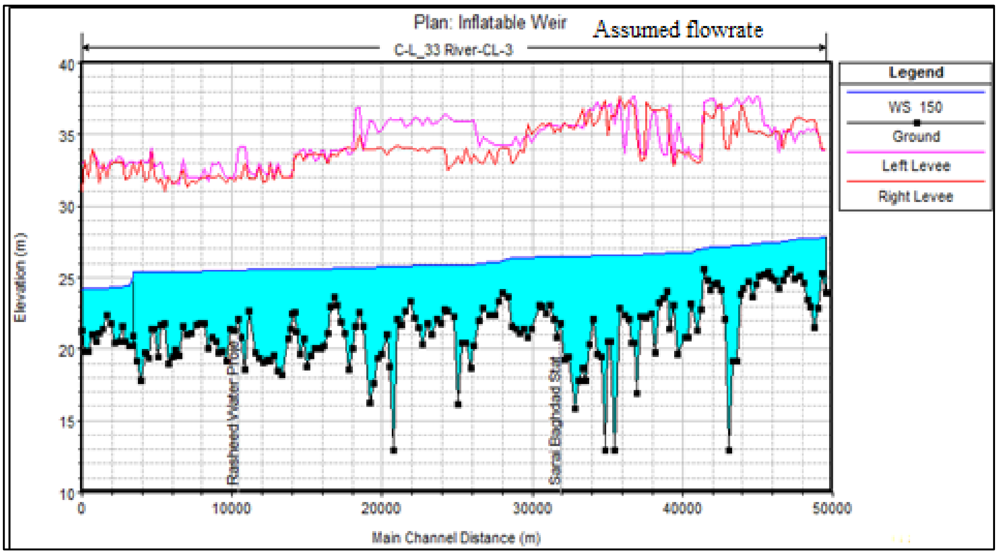

Figure 14. Longitudinal profile of Tigris River within Baghdad City, Q=150 m^3/sec with Inflatable weir.

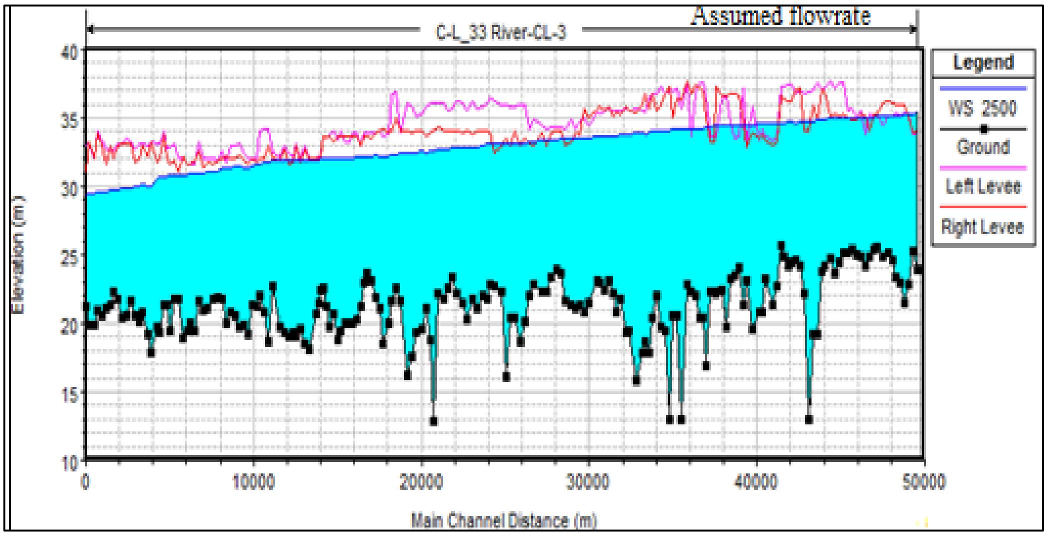

Figure 15. Shows the longitudinal profile of Tigris River within Baghdad emptied Inflatable weir, for Q=2500m^3/sec.

6.3 Third Scenario: Obstruction.

The third scenario was implemented to study the third treatment, the use of obstructions; the model was run for the discharge of 150 m^3/sec, with different gaps between one obstacle and another. **Fig.16** shows the results of the third treatment, a continuous obstruction along the cross-section with crest level of 24.7 m.a.m.s.l, was used, with dimensions of 2x3x190 m, which achieved the minimum water surface elevation required to operate the water projects was, 25.5 m.a.m.s.l.

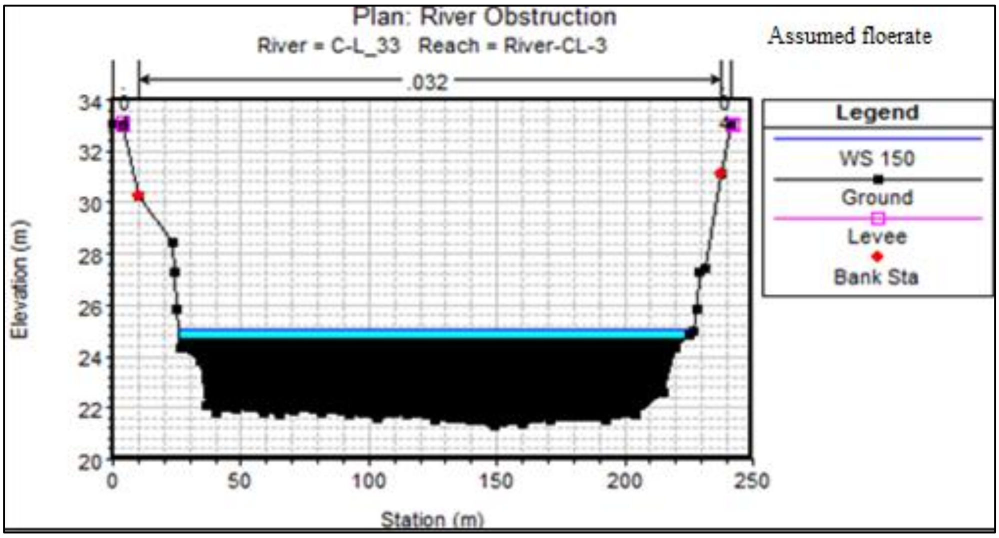

Figure 16. Show the third treatment obstructions.

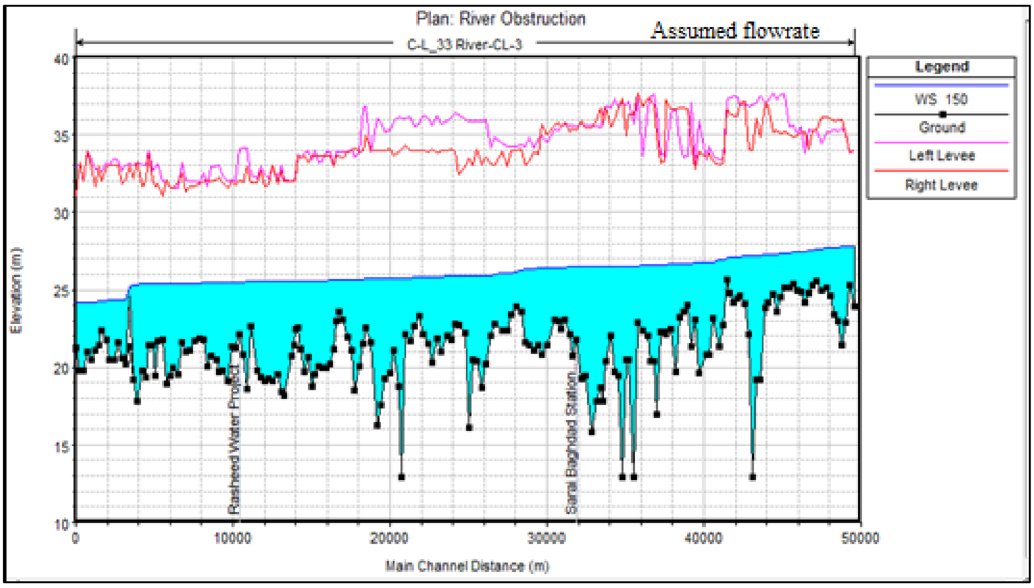

Figure 17. Longitudinal profile of Tigris River within Baghdad City, Q=150 m^3/sec, with continuous obstruction.

Figure 17 shows the longitudinal profile of the Tigris River within Baghdad City, with continuous obstructions with a discharge of Q=150 m^3/sec, the required water level was achieved. For the case of flood discharges 1300 and 2500 m^3/sec, with the use of obstruction, it was assumed that the obstruction was removed, so the cross-section would be as natural section and the flowrate will pass without any resistance, but the obstruction was not easy to remove in the case of flood, as well as the sedimentation results due to presence of that obstruction.

7. THE COST OF THE SUGGESTED TREATMENTS

The cost of using each of the considered treatment scenarios was calculated, based on the cost pricing criteria certified by the Rafidain General Company of Dam Contraction (RGCDC). These costs are listed in **Table 3**. It was obvious from this table that the third scenario has the minimum cost, when the obstruction was used, but for feasibility of operation and to prevent sedimentation process upstream the proposed treatment, the second scenario of Inflatable weir is more applicable due to ease of blowing and discharging these types of weirs, allowing for the cleaning of deposited mud, keeping of the cross-section of the river, the cost of construction is not high comparing with obstruction treatment, and the great benefit in reducing pollution, when the Inflatable weir was used.

8. CONCLUSIONS

A steady one-dimensional hydraulic model and the simulation of river flow characteristics for the Tigris River within Baghdad City were implemented using HEC-RAS software to specify the best suggestion or treatments for raising the water levels in the river during drought periods with the least cost. From the present study the following conclusions can be listed:

1. Results of calibration and verification of the one-dimensional hydraulic model that implemented by HEC-RUS software defines the feasible value of Manning's (*n*) was equal to 0.032 for the main river bed, while it is 0.040 for the banks of the river.
2. Results of implemented treatment by using a barrage, with different numbers of gates (5,10, and 15), sufficiently raise the water surface elevations in the river to the minimum required level to operate water supply projects, but the construction of barrage, firstly will be of high cost in addition to the operation and maintenances costs, secondly the barrage will affect the performance of the river to convey the flood flows and will damage the city during these flows.
3. When inflatable weirs used, with Q=150 m^3/sec, the crest level of inflatable weirs is 24.7 m.a.m.s.l., sufficient achieve the minimum level is to operate the Rasheed water project 25.5 m.a.m.s.l. On the other hand, for a high flowratesof 1300, and 2500 m^3/sec, there was no need to raise the water level, so the inflatable weir would be deflated, and that river returned to the normal state of flow with open cross-section.

4. The best solution for raising water levels of the Tigris River is by using the inflatable weirs because of the low initial cost, simple operation, and low maintenance requirements, they have no obstruction to the flow, their ability to inflate and deflate quickly and easily to prevent upstream flooding, as well as offering a high level of control and easily method for recapturing water, self-cleaned of the deposited silt and accumulated debris. Thus, they are of great benefit in the abatement of pollution.

Table 3. Cost of the proposed treatment or hydraulic structures maintenance, after (RGCDC).

No.	Scenarios Description	Cost of Banks Raising (IQD)	Cost of River Training (IQD)	Cost of the Suggested Hydraulic Structure + cost of gates (IQD)	Total cost (IQD)	
First Scenario	A barrage with 5 gates (1)	339,484,000	74190000	2,175,000.000	2,588,674,000	
	(2)A barrage with 10 gates	329,484,000	74190000	2,975,000,000	3,378,674,000	
	(3)A barrage with 15 gates	319,484,000	74190000	3,775,000,000	4,168,674,000	
Second Scenario	Inflatable Weirs	339,483,958	74190000	393,673,958	550,000,000	963,673,958
Third Scenario	The Obstructions	329484000	74190000	403,674,000	25,650,000	429,324,000

REFERENCES

- **Arrar, A. N., (2018)**. Hydraulic Simulation of Gharraf River Between Kut and Hay City", M.Sc. Thesis, College of Engineering, University of Baghdad.
- **Abdullah Ali Nasser Alhamati1, Thamer Ahmed Mohammed, Abdul Halim Ghazali, Jamalodin Norzaie, and Karim Khalaf Al-Jumaily (2005).** Determination of Coefficient of Discharge for Air-Inflatable Weirs Using Physical Model . Suranaree J. Sci. Technol. 12(1):19-27.
- **Ali, A. A. (2013).** Morphology of Tigris River inside Baghdad City, Ph D., Lulea University
- of Technology, Lulea, Sweden.
- **Al-Samurai, A.A.J.K., (2004).** Hydraulic Performance of Tigris River Flow Between Samara Barrage Station And Sarai Station In Baghdad City, M. Sc. Thesis, University of Technology, Baghdad, Iraq.
- **Mawlood, I.A., (2017)**. Assessment of Tigris River Pollution within Baghdad City using Geomatic Techniques, Ph D. Thesis, University of Technology, Baghdad, Iraq.
- **Nasser A. A., (2002)**. Investigation and Analysis of Inflatable Dams, M Sc. Thesis, University of Technology, Baghdad, Iraq.
- **Guo R., (2006).** Territorial Disputes and Resource Management. A Global Handbook. New York.
- **AL Doury S. S. S., (2008).** Modification of Some Hydraulical Problems of Diyala Weir, M Sc. Thesis, University of Technology, Baghdad, Iraq.
- **Al-Ansari, N., Ali, A. A., Al-Suhail, Q., & Knutsson, S**., (2015). Flow of River Tigris and its Effect on the Bed Sediment within Baghdad, Iraq, Open Eng.2015(5). pp.465–477, DOI 10.1515/eng-2015-0054.
- **Iliev, V., & Nikolov, N. (2016).** Validation procedure for numerical model of hydraulic inflatable dam under pulse load. Science Engineering and Education Journal,1(3), pp.3-10.