

Chemical, Petroleum and Environmental Engineering

**Effect of Tail Regulators on the Flood Capacity of Euphrates River
at Annassiriyah City**

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ABSTRACT

Euphrates River extends about 125 km within the study area located in Annassiriyah City, Dhi Qar Governorate, Iraq. The impact of the seven hydraulic structures on the discharge capacity of the Euphrates River needs to be considered. The main objectives of this research are to increase the discharge capacity of Euphrates River within Annassiriyah City during flood seasons and study the impact of these hydraulic structures on the river capacity by using HEC-RAS 5.0.3 software. Five scenarios were simulated to study the different current condition of Euphrates River within Annassiriyah City. Other additional four scenarios were implemented through river training to increase the river capacity to 1300 m³/s; it is the flood of 100 year return period. The results of the current condition showed that the maximum discharge capacity of Euphrates River within Annassiriyah City is just 300 m³/s. The results of applied improvements show that the capacity can reach 1300 m³/s when Al Chibayish Weir was hypothetically removed from the river system. Additionally, the river capacity will be reduced to 600 m³/s when Al Chibayish Weir is considered. It was concluded that the 100-year flood discharge cannot be achieved without removing Al Chibayish Weir from the river system.

Keywords: Euphrates River, Annassiriyah City, HEC-RAS, Flood, Tail Regulators

تأثير النواظم الذيلية على أستيغابية نهر الفرات الفيضانية في مدينة الناصرية

الخلاصة

يمتد نهر الفرات حوالي ١٢٥ كم داخل منطقة الدراسة التي تقع في مدينة الناصرية، محافظة ذي قار في العراق. يتطلب التحري عن تأثير المنشآت الهيدروليكية الذيلية والواقعة مؤخر مدينة الناصرية على استيعاب نهر الفرات في الناصرية. تهدف هذه الدراسة لتحديد استيعابية نهر الفرات الحالية وزيادتها ليستوعب موجات الفيضان ودراسة تأثير النواظم الذيلية وسدّ الجبايش الغاطس على سعة النهر باستخدام برنامج HEC-RAS 5.0.3. تمت محاكاة خمسة سيناريوهات لدراسة واقع الحال لنهر الفرات داخل مدينة الناصرية. كما تم تنفيذ أربعة سيناريوهات لزيادة استيعابية نهر الفرات من خلال تهذيب النهر

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Peer review under the responsibility of University of Baghdad.

<https://doi.org/10.31026/j.eng.2020.01.05>

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Article received: 30/12/2018

Article accepted: 2/3/2019

Article published: 1/1/2020



الى ١٣٠٠ م٣/٣ . أظهرت نتائج واقع الحال أن أقصى تصريف لنهر الفرات داخل مدينة الناصرية حالياً هو ٣٠٠ م٣/٣. كما تبين نتائج التطويرات أن استيعابية النهر ستصل ١٣٠٠ م٣/٣ في حالة إزالة سدّ الجبايش الغاطس بشكل افتراضي من نظام النهر. فضلاً عن ذلك ، فإن استيعابية الفرات ستقل ٦٠٠ م٣/٣ بوجود سدّ الجبايش الغاطس. وقد وجد أن استيعابية النهر المنشودة لا يمكن تحقيقها بوجود سدّ الجبايش الغاطس.

الكلمات الرئيسية: نهر الفرات , مدينة الناصرية, HEC -RAS , فيضان , نواظم ذيلية

1. INTRODUCTION

Euphrates River is originating from the Eastern Mountains of Turkey and passes through the Syrian territory. It enters Iraq territory at Al Qaim City, in Al Anbar Governorate. The river passes through several provinces until it reaches Dhi Qar Governorate. Euphrates River extends about 125 km within the study area which starting from Annassiriyah City till Al Chibayish Village, west of Dhi Qar Governorate. Before 2010, Euphrates and Tigris rivers are joint at Al Qurna City in southern Iraq to form Shatt Al Arab. Since 2010, Euphrates River did not reach to Al Qurna City any more due to the construction of a weir, at the end of Al Chibayish Village. The impact of the hydraulic structure on the discharge capacity in the Euphrates River should be studied. These hydraulic structures are Al Chibayish Weir, Al Hafar, Ekeakaa, Glaween, Baniseaeed, Bani Hasan, and Um Nakhlaa Regulators. They are named as tail regulators, and they were constructed in 1953 except Glaween Regulator which is constructed at 1970. The tail regulators are located downstream of Annassiriyah City, near Suq Al Shuyukh Village.

The lack of maintenance and the accumulation of sediment in the mainstream of Euphrates River and at the upstream of the tail regulators during the last three-decades reduced the discharge capacity of the main channel of Euphrates River. This will increase the flood risk in Annassiriyah City. Therefore, the hydraulic analysis is required to evaluate flood risk of Euphrates River in Annassiriyah City and find the possible solution(s).

There is a lack in the studies that related to study the current discharge capacity of the reach of Euphrates River within Annassiriyah City. (**Consulting Engineering Bureau, 2017**), prepared a report “Dhi Qar Combined Cycle Power Plant: Hydrological Study”. This study aimed at evaluates the flood risk of the nearby Euphrates River and to provide groundwater and weather conditions data and their analysis. The Power Plant is located just to the west of Annassiriyah City at 613397 m, Easting and 3433966 m, Northing in UTM coordinate system. The site of the plant was about 500 m from the right bank of Euphrates River. Based on the hydraulic analysis of river reach which was 23 km by using HEC RAS Software, it is found that the maximum current capacity of the reach Euphrates River within Annassiriyah city was 300 m³/s. At this discharge, all water levels were lower than the left and right levees levels of the river. Exceeding the discharge value of 300 m³/s, the water levels were higher than the left side levee which threatens the left part of Annassiriyah City. However, the right side part of Annassiriyah City, at the site of the power plant lies, was safe up of 500 m³/s.

The objectives of this research are to develop a one-dimensional hydraulic model to predict the water levels in Euphrates River within Annassiriyah City during floods and study the impact of tail regulators as well as specify the significant regulators that will cause choking in Euphrates River. Moreover, increase the discharge capacity of Euphrates River by river training of its mainstream to 1300 m³/s to achieve the requirements of the study of Strategy for Water and Land Resources in Iraq, 2014 conducted by Ministry of Water Resources.

2. DESCRIPTION OF THE REACH OF EUPHRATES RIVER UNDERSTUDY

Fig. 1 shows a general view of the layout of the reach of Euphrates River under study. The study reach of Euphrates River runs within Dhi Qar Governorate, south of Iraq. After Al Muthanna Governorate, Euphrates River enters Dhi Qar Governorate. The reach understudy of Euphrates

River extends about 125 km within the study area and starts before Annassiriyah City, located at 606517 m, Easting and 3437873 m, Northing in UTM coordinate system, till the weir at end Al Chibayish Village, its located close to Al Basra Governorate border having a UTM coordinates of 705345 m, Easting and 3426361 m, Northing. After Al Fadlia Village, located at 636367 m, Easting and 3423325 m, Northing on UTM coordinate system, Euphrates River branch into several branches. These branches are called Glaween and Al Safha rivers. Al Safha River is then divided into two branches, Ekeakaa, and Bani Hassan.

Additionally, Um Nakhlaa and Beni Seaeed are branches of Euphrates River downstream Suq Al Shuyukh City. Um Nakhlaa canal is considered as the main feeder of Al Hammar Marsh. Beni Seaed and Beni Hasan branches are met with Euphrates River at Beni Seaed Village, located at 650165 m, Easting and 3417411 m, Northing, and Al Tar Village located at 658014 m, Easting and 3422050 m, Northing, respectively. AL Modimaa River is the confluence of Glaween and Ekeakaa branches. It meets with the Euphrates River at Al Fahud Village located at 666153m, Easting, and 3424812m, Northing on UTM coordinate system. Six tail regulators were constructed downstream Annassiriyah City. Al Hafar Regulator is the biggest hydraulic structure in the study area. Details of these six regulators are presented in **Table 1**. Furthermore, during 2010, a weir was constructed in Al Chibayish Village on the mainstream of Euphrates River to raise the water levels to feed the central marshes and to control the discharges of Euphrates River within the Al Chibayish region at its upstream. According to the data provided by Center for the Restoration of Iraqi Marshes and Wetlands, Al Chibayish Weir was operated during 2010, it has a width of 50 m, a length of 25 m, a side slope of 1:10, and the level of its crest and side levees are 1.75 and 4 m.a.m.s.l., respectively.

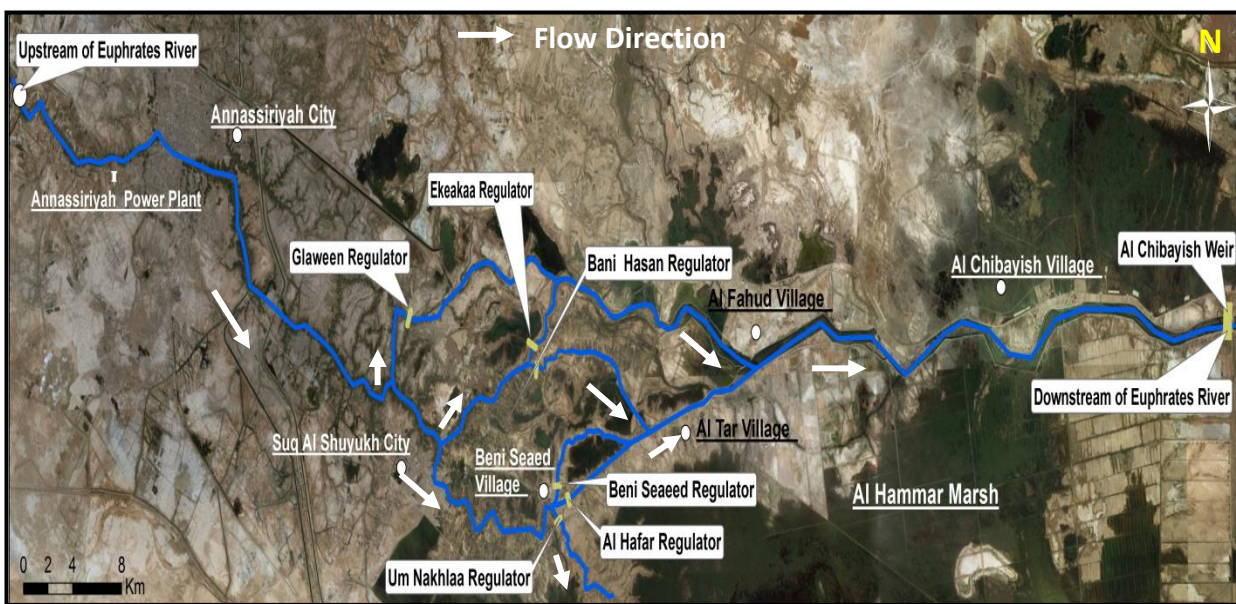


Figure 2. General layout of reach of Euphrates River under study showing tail regulators, by ArcGIS 10.2 , ESRI.

Table 1 . The hydraulic information for the six tail regulators.

Regulator	Glaween	Ekeakaa	Al-Hafar	Bani Hasan	Bani seaeed	Um-Nakhlaa
Date of Construction	1970	1953	1953	1953	1953	1953
Design Discharge, m ³ /s	250	300	500	100	100	50
Number of Gates	4	5	7	3	3	2
Dimensions of Gates, <i>m</i>	5*4*	8*5	8*5	5*4	5*4	5*4
Sill level, <i>m.a.m.s.l</i>	1	-0.5	-0.5	0.5	0.5	0.5
Width of Peirs , <i>m</i>	0.8	0.9	0.9	0.8	0.8	0.8
Type of Gates	Radial					Sluice
lock Navigation	Yes					No

* width*height

3. SIMULATION BY USING HEC-RAS SOFTWARE

The well-known HEC-RAS software was used to simulate the flow of the reach of Euphrates River within Annassiriyah City under different conditions.

Data of 350 cross sections of 250 to 1000 m apart of the mainstream of the reach of Euphrates River and its branches within Annassiriyah City were provided by **(the General Authority for Surveying of the Ministry of Water Resources, 2012)**. Bathymetrical survey of the Euphrates River and its branches within Annassiriyah City was conducted during 2012. These cross-sections were used in modeling of the reach by using the HEC RAS software. Bathymetrical survey of the branches was conducted to just a few kilometers downstream their regulators. The lack of survey data of the cross-sections of branches of Euphrates River leads to consider only the part of the reach with survived cross-sections. **Fig.2** shows the schematic diagram of the simulated flow network of Euphrates River and the boundary conditions used in the simulation.

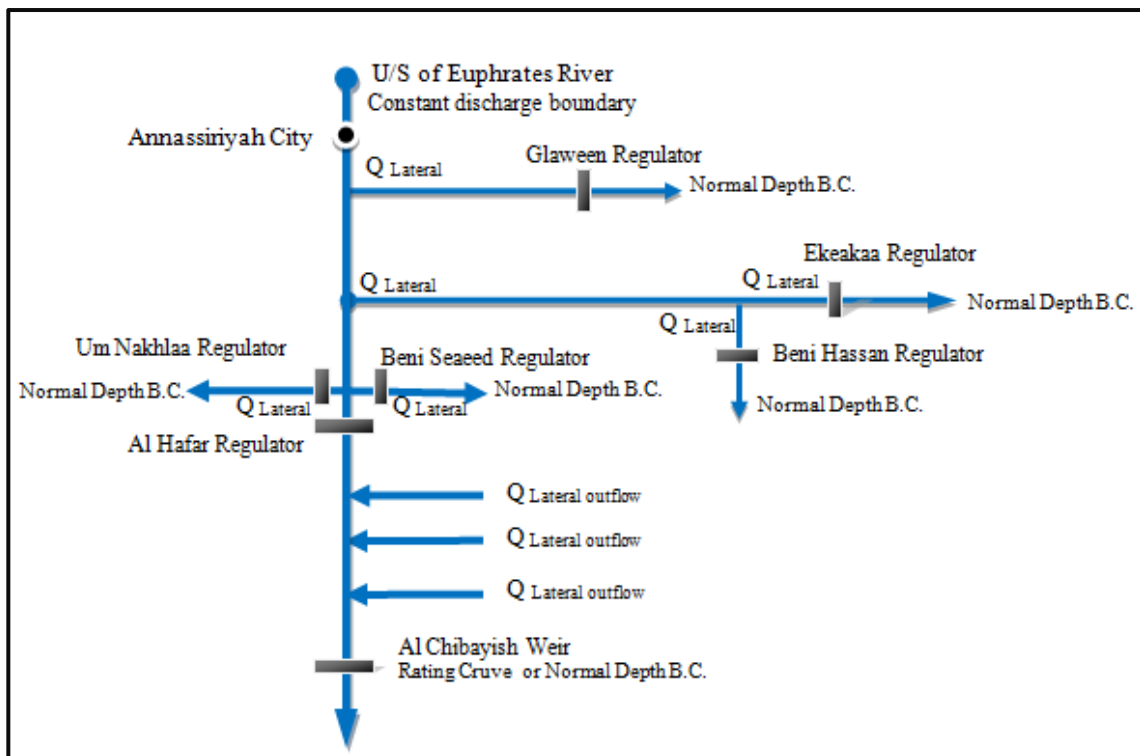


Figure 2. Schematic diagram of the simulated Euphrates River and its boundary conditions.



Different values of discharge were assumed at the upstream boundary of the reach. These discharges vary between 1300 and 100 m³/s with an interval of 100 m³/s. The upper limit represents the sum of the capacity of the tail regulators, while, the lower limit is the minimum discharge within the records. A normal depth was adopted at the downstream end as a boundary condition of the reach of Euphrates River. In the case of simulation Al Chibayish Weir at the downstream reach, the rating curve of the weir was used instead of the normal depth.

A normal depth as a boundary condition at the end of the reach of each branch, that is at the last survived cross-section. The rating curves of all tail regulators are not available. Therefore, an assumption was made to estimate the discharge through each branch by multiplying the incoming discharge at the upstream end Euphrates River by a factor. This factor is the ratio of the design discharge of the regulator to the sum of the design discharges of the branches, which is 1300 m³/s. Selecting a Manning’s n for a natural stream is not easy unless some observed water levels, gauged data, are available to determine the Manning coefficient by calibration, **Akan, 2006**. One station gauge existed on Euphrates River within Annassiriyah City, and its rating curve was not adopted to calibrate the model due to the effect of the operating of the tail regulators on the mainstream of Euphrates River and its branches downstream Annassiriyah City. Therefore, the values of Manning's n estimated from previous experimental studies for similar stream conditions were used as guides in selecting n values, **Chow, 1959**. Manning coefficient values of the main channel of Euphrates River and its floodplain were estimated to be 0.03 and 0.04, respectively.

4. SIMULATION SCENARIOS

Two sets of scenarios were simulated as shown by **Table 2**. The first set includes five scenarios were implemented to simulate the water levels of Euphrates River under the current conditions. The second set includes four scenarios with improved conditions of the reach of Euphrates River by the training of its main channel. The gates of all the tail regulators are simulated as fully opened in all scenarios.

Table 2. Description of the scenarios.

Scenario	Description
Scenarios with the current condition	
C 1	Euphrates River with all hydraulic structures.
C 2	Euphrates River without any hydraulic structure
C 3	Euphrates River with all tail regulators but without Al Chibayish Weir.
C 4	Euphrates River without any tail regulator but with Al Chibayish Weir.
C 5	Euphrates River with Glaween, Ekeakaa, Bani Hasan, Bani seeed and Um Nakhlaa Regulators
Scenarios with improved condition	
Im 1	Euphrates River without any hydraulic structure
Im 2	Euphrates River with all hydraulic structures.
Im 3	Euphrates River with all tail regulators but without Al Chibayish Weir.
Im 4	Euphrates River without any tail regulator but with Al Chibayish Weir.

The first set includes five scenarios that are coded by **C1**, **C2**, **C3**, **C4**, and **C5**. **C1** scenario represents case of modeling Euphrates River with all tail regulators and Al Chibayish Weir. **C2** scenario is implemented when the tail regulators and Al Chibayish Weir were hypothetically removed from the river system. **C3** scenario is implemented when Al Chibayish Weir is hypothetically removed from the river system and the tail regulators are considered. Moreover, when all the tail regulators were hypothetically removed from the river system but Al Chibayish Weir is considered, **C4** scenario is implemented. Finally, **C5** is implemented in order to study the effect of Glaween, Ekeakaa, Bani Hasan, Bani Seaeed and Um Nakhlaa Regulators on the mainstream of Euphrates River when Al Chibayish Weir and Hafar Regulator were hypothetically removed from the river system.

The second set includes four scenarios of the improved condition of the cross-sections of the reach of Euphrates River that is coded **Im1**, **Im2**, **Im3** and **Im4**. Firstly, **Im1** scenario is implemented when Al Hafar Regulator and Al Chibayish Weir were added in the hydraulic model of the river system while **Im2** scenario is implemented when Al Hafar Regulator and Al Chibayish Weir were added in the hydraulic model of the river system. Moreover, **Im3** scenario is implemented when Al Hafar Regulator is taken into consideration in the hydraulic model without Al Chibayish Weir. Finally, **Im4** scenario is implemented when Al Hafar Regulator was only hypothetically removed from the river system.

5. RESULTS AND DISCUSSION

Fig. 3 shows the longitudinal section of the reach of Euphrates River that includes the water levels profile, the river bed level, Al Hafar Regulator, Al Chibayish Weir and sides levees levels at three rates of discharges 300, 400 and 500 m³/s under the **C1** scenario. It is clear that the discharge of more than 300 m³/s makes most of the levees are overflowed. The right levees at upstream of Euphrates River till station 20+000 km will be safe up to 500 m³/s. While the left levees will be flooded and threaten the left side of Annassiriyah City at the same distance. However, levees between Al Hafar Regulator and Al Chibayish Village will be safe up to 500 m³/s. Al Chibayish Weir affected on Euphrates River almost 50 km length on its upstream side. As a result, the maximum discharge capacity in Euphrates River under the current condition is 300 m³/s.

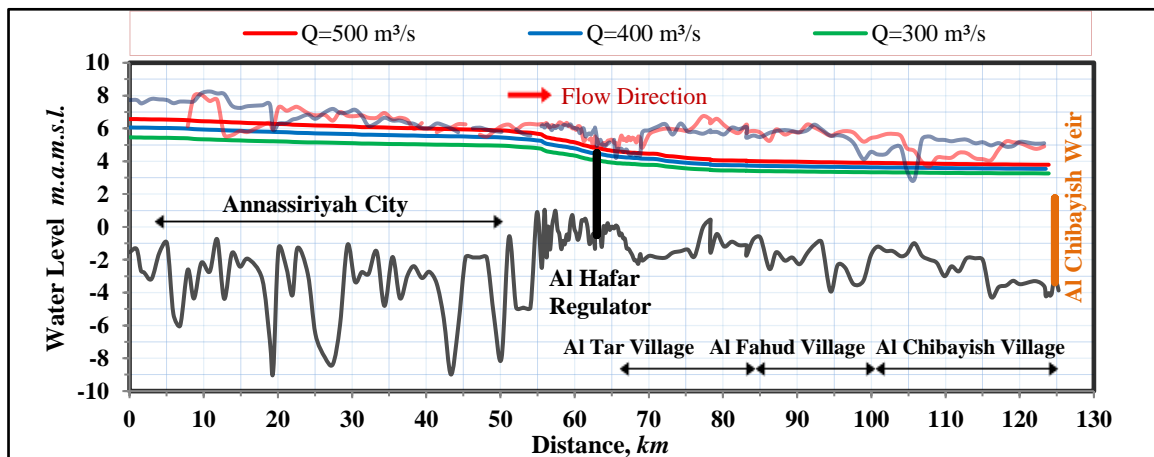


Figure 3 . Water levels profile of Euphrates River in **C1** scenario.

The results of the water levels of **C2** scenario are shown in **Fig. 4**. The maximum discharge capacity of Euphrates River within Annassiriyah City is 300 m³/s. As compared with **C1** scenario,

Al Chibayish Weir has no significant effect on Annassiriyah City and its effect is limited to Chibayish Village.

The results of the water levels of the **C3** scenario are shown in **Fig. 5**. The water levels of the Euphrates River are lower than the longitudinal levees elevation along the reach at $300 \text{ m}^3/\text{s}$. On the other hand, Al Hafar Regulator can pass the discharge of $400 \text{ m}^3/\text{s}$ as a flood wave at upstream of Euphrates River while the actual discharge passing is $154 \text{ m}^3/\text{s}$ through its gates. As a result, the maximum discharge at this scenario is $300 \text{ m}^3/\text{s}$. Moreover, the other tail regulators are safe at the discharge of $300 \text{ m}^3/\text{s}$.

The results of the water levels of **C4** scenario are shown in **Fig. 6**. The maximum permissible discharge of the reach of Euphrates River is also $300 \text{ m}^3/\text{s}$. On the other hand, the water level at Annassiriyah City is 5.43 m a.m.s.l while at Al Chibayish Weir is 3.26 m a.m.s.l . It should be noted that Al Chibayish Weir has no significant effect on Annassiriyah City and its effect is limited to Chibayish Village and extends to Al Tar Village. Moreover, Al Chibayish Weir serves marshes lands located on the right side of Euphrates River during drought seasons but will be choked the flow within the river during flood seasons.

The results of water levels of **C5** scenario are shown in **Fig. 7**. It was found that the maximum discharge passing through the gates of regulators, Ekeakaa is $300 \text{ m}^3/\text{s}$, Beni Seaed is $100 \text{ m}^3/\text{s}$, Um Naklaa is $50 \text{ m}^3/\text{s}$, Glaween is $136 \text{ m}^3/\text{s}$, and Beni Hasan is $90 \text{ m}^3/\text{s}$. Moreover, Glaween and Beni Hasan Regulators and their branches must be maintained to carry their designs discharges

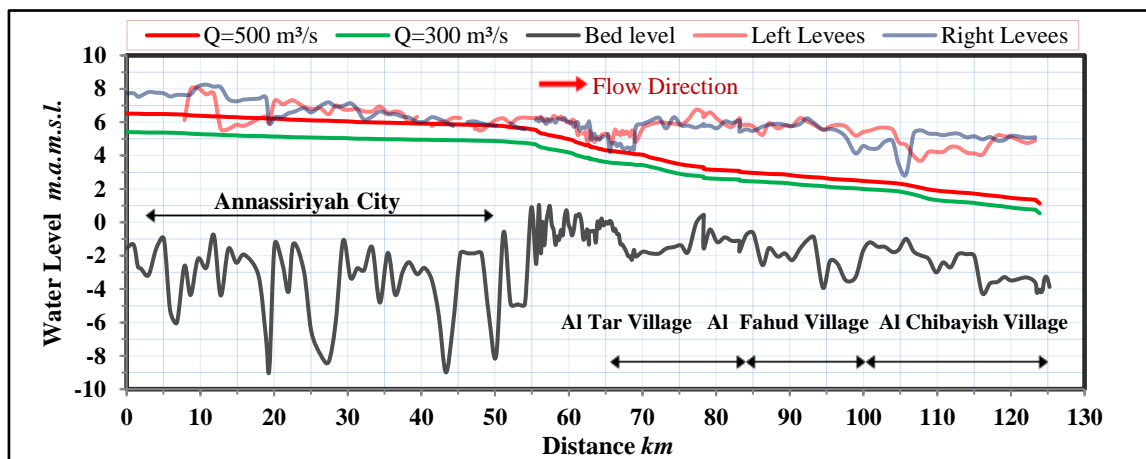


Figure 4 . Water levels profile of Euphrates River in **C2** scenario.

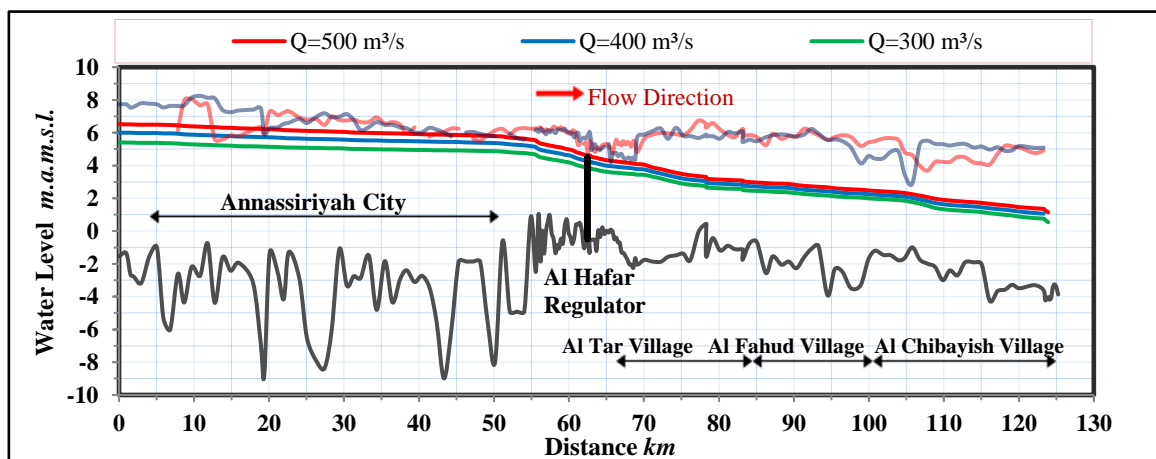


Figure 5 . Water levels profile of Euphrates River in **C3** scenario.

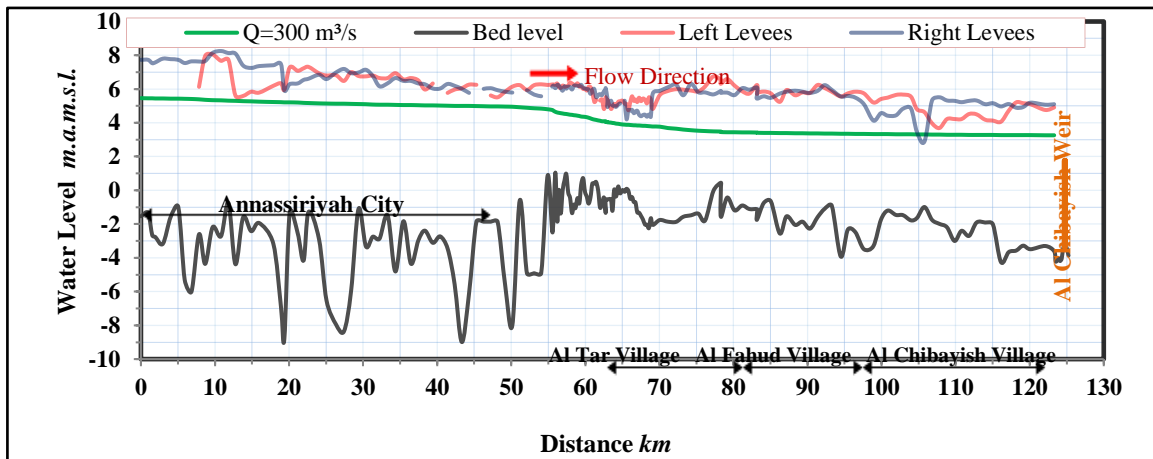


Figure 6 . Water levels profile of Euphrates River in C4 scenario.

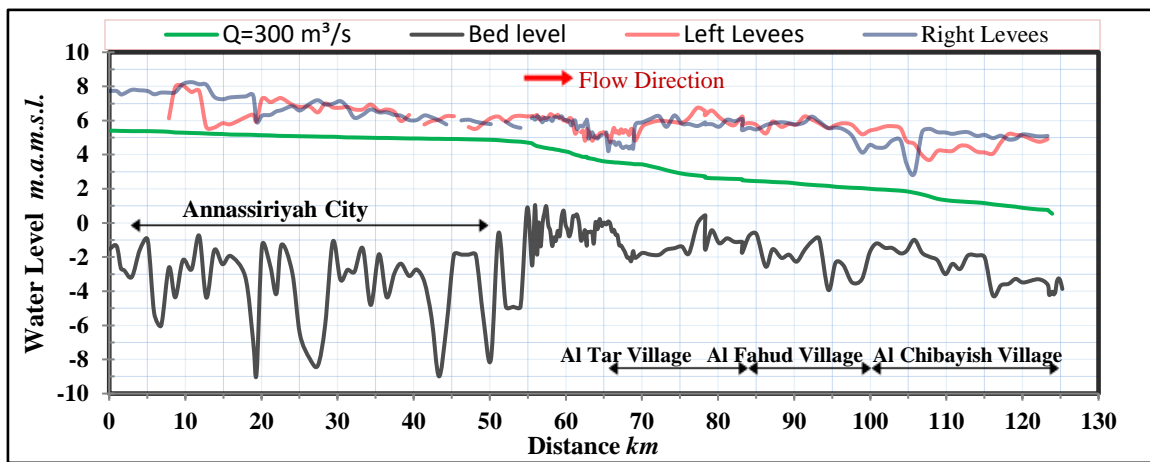


Figure 7. Water levels profile of Euphrates River in C5 scenario.

Fig. 8 show the original and modified cross-sections of Euphrates River every 10 km. The improvement of the mainstream of Euphrates River is applied to its cross-sections that cause choking to the flow in the river reach. A trapezoidal shape was adopted to these cross-sections. The improvement extends longitudinally from upstream of Euphrates River at 0+000 km till Al Chibayish Village at 111+150 km. The cut volumes of these cross-sections are about 114.26 million m^3 , and its cost is 228 billion IQD.

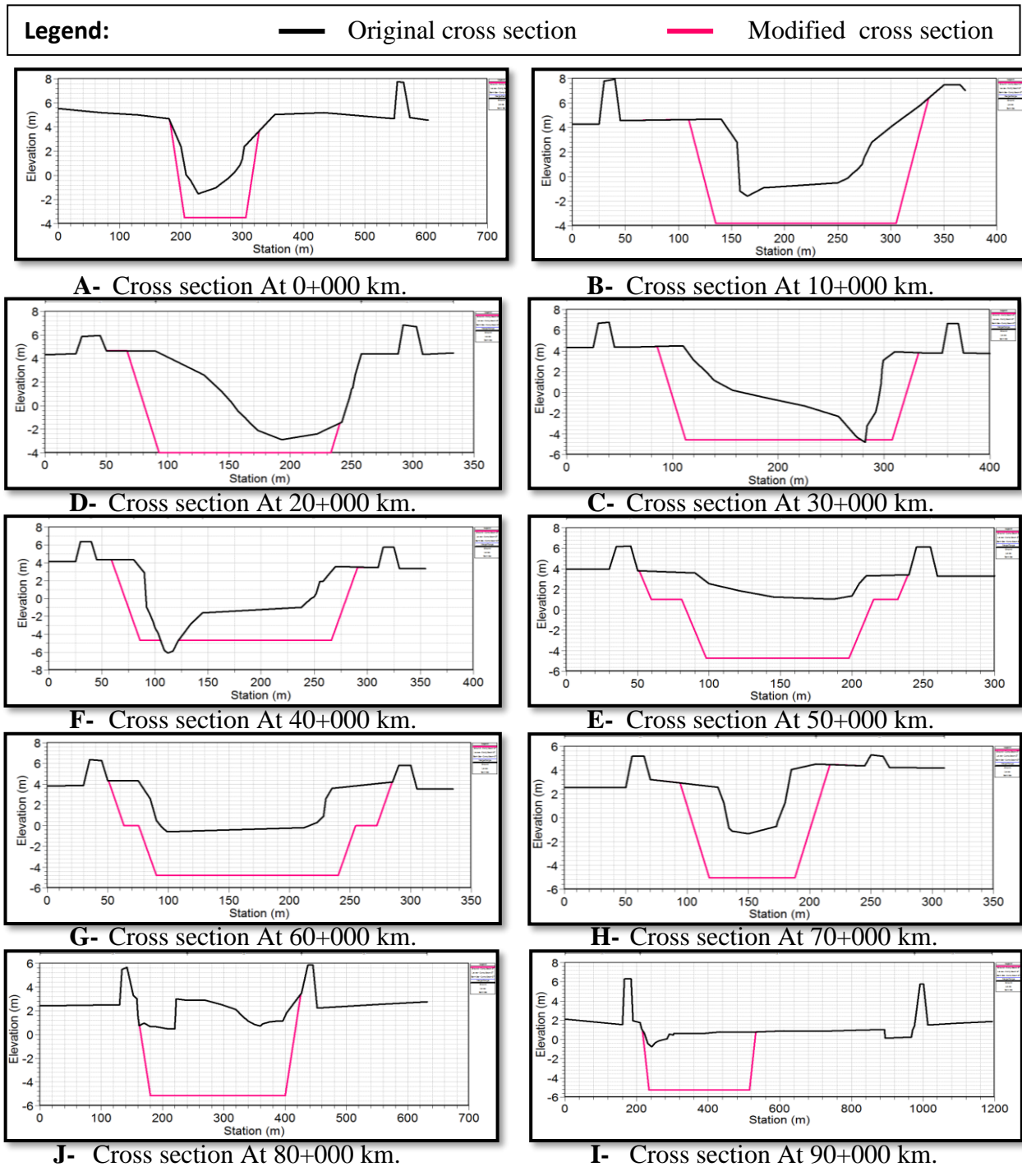
The results of the floodwater levels of Im1 scenario are shown in Fig. 9. It is found that the maximum discharge capacity of the Euphrates River is 1300 m^3/s .

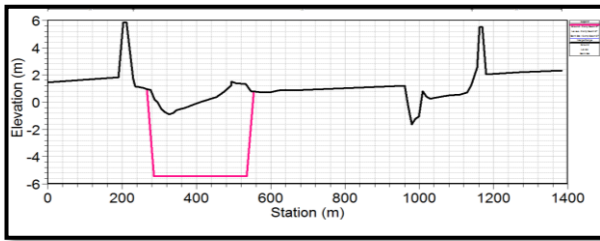
The results of the floodwater levels of Im2 scenario are shown in Fig. 10. It is clear that the river cannot carry 1300 m^3/s because of the high impact of backwater of Al Chibayish Weir on the reach. On the other hand, the flood water levels are lower than the longitudinal levees levels everywhere of the reach at 900 m^3/s . However, Al Hafar Regulator reduces the discharge capacity of Euphrates River to be 700 m^3/s .

Fig. 11 shows the flood water levels for Im3 scenario. Although Al Hafar Regulator considered, the maximum discharge capacity of Euphrates River is 1300 m^3/s . Moreover, the percentage of the discharge capacity of the Euphrates River of this scenario with removing Al Chibayish Weir is increased 46% comparing with Im2 scenario.

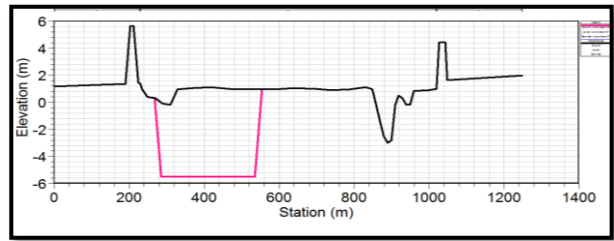


The result of the floodwater levels of **Im 4** scenario is shown in **Fig. 12**. It showed that the flood water levels are lower than the longitudinal levees levels everywhere of the reach at 900 m³/s. Therefore, Al Chibayish Weir has reduced about 30% of the discharge as compared with **Im3** scenario.





L- Cross section At 100+000 km.



K- Cross section At 110+000 km.

Figure 8 . The original and cross sections of Euphrates River after training in 10 km apart of its reach(from 0 to 110 km station) .

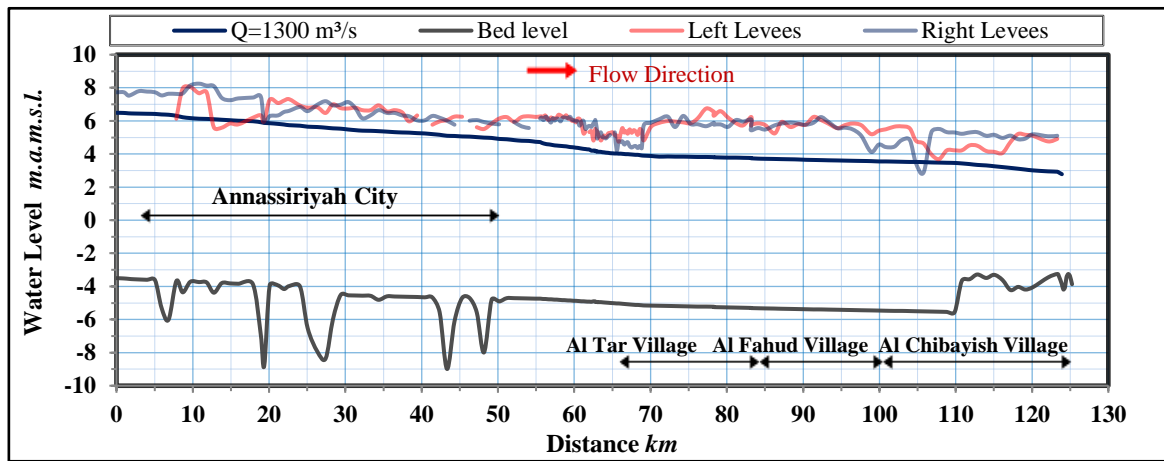


Figure 9 . Water levels profile of Euphrates River in Im 1 scenario.

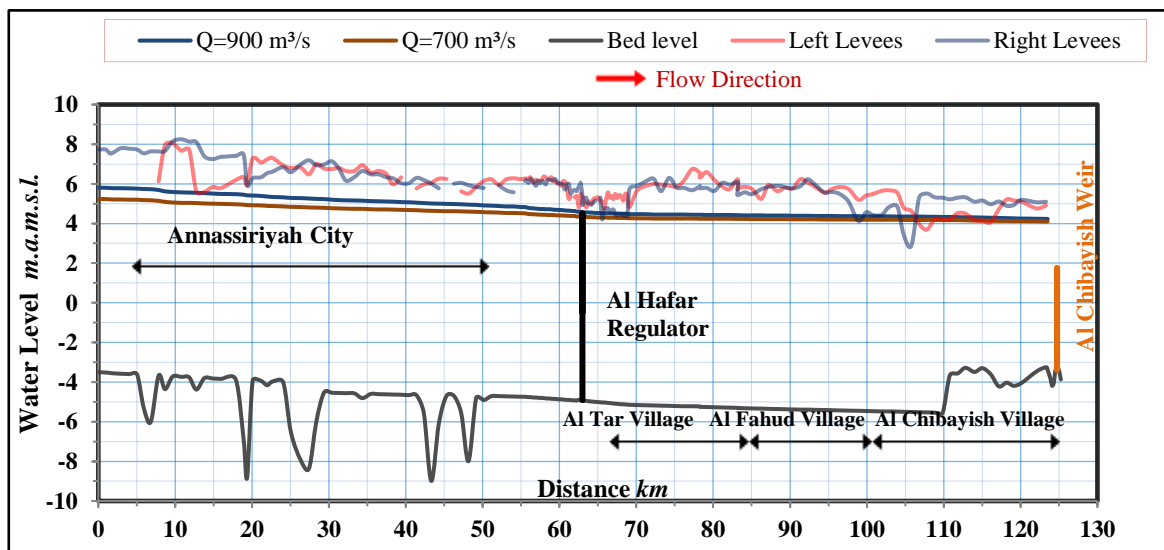


Figure 10 . Water levels profile of Euphrates River in Im 2 scenario.

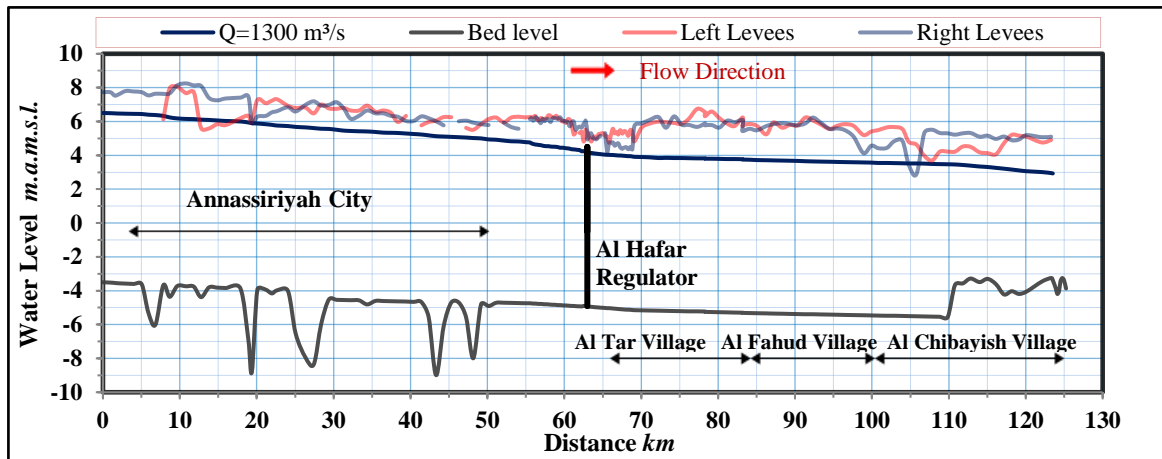


Figure 11 . Water levels profile of Euphrates River in Im 3 scenario.

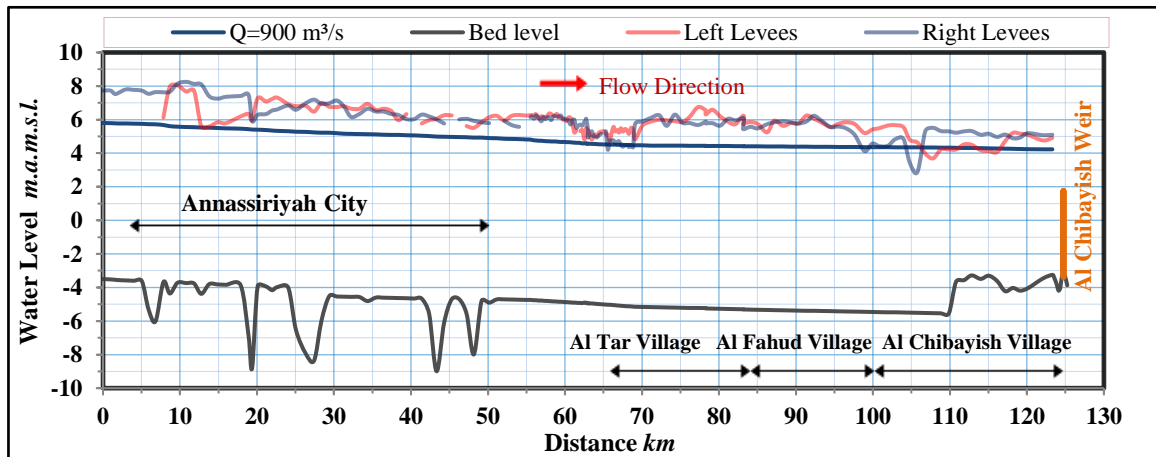


Figure 12 . Water levels profile of Euphrates River in Im 4 scenario.

6. CONCLUSIONS

Based on the analysis of the results, the following main conclusions are made:

1. The maximum current capacity of the reach of Euphrates River within Annassiriyah City is $300 \text{ m}^3/\text{s}$. This discharge remains unchanged even the tail regulators, and Al Chibayish Weir was hypothetically removed from the river system.
2. Ekeakaa, Glaween, Bani saeed, Bani Hasan and Um Nakhlaa Regulators have no significant effect on the water levels of the main channel of Euphrates River, and their effect is limited on their branches.
3. Al Chibayish Weir reduces the capacity discharge of the river to be $700 \text{ m}^3/\text{s}$ even after applying the improvement to the river cross-sections.
4. Euphrates River can carry $1300 \text{ m}^3/\text{s}$, it is a 100-year return flood after its cross sections are improved and Al Chibayish Weir is removed from the river system, or it must be improved by installing gates to reduce its effect and to increase its passes capacity.

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