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Evaluation and Development of the (Hilla – Daghara) Rivers System

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ABSTRACT

Shatt Al-Hilla branches from the left of Euphrates River, U/S Hindiyah Barrage, Iraq, and extends about 100 km. It branches at the end into Shatt Al-Diwaniya 112 km and Shatt Al-Daghara 64 km. The study aims to evaluate and develop (Hilla-Daghara) rivers system, which is included Shatt Al-Hilla and Shatt Al-Daghara. Fieldwork began from (26 October until December) 2020. M9, S5 devices, and the installed staff gauges were used to measure discharges and water levels, respectively. A one-dimensional model was developed for the study area by HEC-RAS, after calibration and verification by field measurements; the Manning's n of Shatt Al-Daghara is found to be 0.022. Five Scenarios were simulated to study the reach under the current conditions. It was found that the discharge capacity in Shatt Al-Hilla and Shatt Al-Daghara is 200 m^3/s and 50 m^3/s, respectively. Four scenarios were conducted for the development to improve the capacity of Shatt Al-Hilla to 303 m3/s and Shatt Al-Daghara to 75 m^3/s. Earthworks volume of development Shatt Al-Hilla and Shatt Al-Daghara are about (5.89 and 0.54) Mm^3, and its cost is (11.780 and 1.080) billion IQD respectively. Results of applied development show that Shatt Al-Daghara tail can pass discharge more than five m^3/s when Shatt Al-Daghara tail cross regulator that causes choking in the last reach of Shatt Al-Daghara is removed.

Keywords: Calibration, HEC-RAS 5.0.7, River Flow Modelling, Shatt Al-Hilla.

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تقييم وتطوير منظومة انهار (حلة – دغارة)

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الخلاصة

يتفرع شط الحلة من يسار نهر الفرات،عند مقدم سدة الهندية، في العراق بطول 100 كيلومتر, ويتفرع في نهايته الى فرعين هما شط الديوانية بطول 112 كم وشط الدغارة بطول 64 كم. تهدف الدراسة إلى تقييم وتطوير منظومة نهري (الحلة – الدغارة) والتي تشمل شط الحلة وشط الدغارة. بدأ العمل الميداني من (26 تشرين الأول حتى كانون الأول) 2020 واستخدمت أجهزة M9 وS5 والمساطر المثبتة لقياس التصاريف وتسجيل مناسيب المياه على التوالي. تم تطوير نموذج أحادي البعد لمنطقة الدراسة باستخدام HEC-RAS، فوجد بعد المعايرة والتحقق باستخدام القياسات الحقلية , ان معامل مانينغ لشط الدغارة هو 0.022، تمت محاكاة خمسة سيناريوهات لدراسة استيعابية المنظومة تحت الظروف الحالية، وجد أن استيعابية المنظومة تحت الظروف الحالية في شط الحلة وشط الدغارة تبلغ 200 م^3/ ثا و50 م^3/ ثا على التوالي. تم تنفيذ أربعة سيناريوهات أخرى للتطوير لزيادة سعة شط الحلة الى 303 م^3/ ثا وشط الدغارة الى75 م^3/ ثا. بلغت كميات الاعمال الترابية في شط الحلة وشط الدغارة حوالي (5.89 و0.54) مليون م^3 وتكلفتها(11.780 و1.080)مليار دينار عراقي على التوالي. أظهرت نتائج التطوير أن منطقة ذنائب شط الدغارة يمكن أن يمرر تصريف أكثر من 5 م^3/ ثا إذا تمت إزالة الناظم القاطع في ذنائب شط الدغارة والذي يسبب اختناقا في آخر منطقة من شط الدغارة.

الكلمات الرئيسية: HEC-RAS، شط الحلة، استيعابية التصريف، نموذج هيدروليكي أحادي البعد، معايرة.

1. INTRODUCTION

Water Resources Management is the process that helps people to work on managing the available water resources in the present and the future, reduces the risks of floods; also, it helps to supply the required water at the right time and in the right place **(Cosgrove and Loucks, 2015)**.
Euphrates River originates from the Eastern Mountains of Turkey and passes through the Syrian province; then, it enters Iraq at the city of Al-Qaim in Al-Anbar Governorate. The river passes through several governorates until the new Hindiyah barrage close to the town of Hindiyah, which was established for controlling the water levels of the Euphrates River and divert the flow into Hilla main Canal (Shatt Al-Hilla), Kifil main canal, Beni Hassan main Canal, and Hussayiniah main canal, also to generate hydropower, and facilitate the Navigation into Euphrates River.

(Agnihotri and Patel, 2011), studied the Tapi River, Surat, India, by using HEC-RAS software. The river cross-section development was proposed to improve the river's carrying capacity and reduce the risk of flooding. also, using the HEC-Geo-RAS flood immersion map of Surat city was done. **(Issac, et al., 2019)** used a hydraulic model of the Gurupura River in India that was selected by Issac to conduct a steady flow analysis used the HEC-RAS software to analyze the river flood and develop a flood inundation map of the river section. **(Wara, et al., 2019)** used the results from the HEC-RAS program to develop a rating curve for three water stations on two rivers in Kwale, Kenya. The data that was used in the model was established from cross-sections and information for hydraulic structures. The model was calibrated under an unsteady state and

using Velocity Current Meter and Doppler device (ADCP) to measure the discharge. **(Raslan, et al., 2020)** studied and proposed the required hydraulic solutions for the proposed new canal of the Bahr El-Baqer drainage by HEC-RAS Software. **(Talib, et al., 2019)** developed project water management for the Al-Kamaliya irrigation project, Karbala, Iraq by HEC-RAS to improve the operation of this project and choose the best irrigation scenario, and create a good database for project management. **(Shayea and Al Thamiry, 2020)** developed a one-dimensional hydraulic model of Euphrates River within Nasiriyah city, Iraq by the HEC-RAS software to simulate the discharge under the current conditions. The results after applying the developments showed that the capacity could become 800 m^3/sec in the short term and 1,300 m^3/sec in the long term. **(Sarmad, et al., 2020)** used the Doppler device (ADCP) to take field measurements, cross-sectional area, water discharge, and velocity of the Tigris River, U/S of the Amara Barrage, Iraq. The model was calibrated and validated to investigate an appropriate value for Manning's roughness coefficient.
The (Hilla-Daghara) rivers system is considered one of the essential and largest irrigation systems on the Euphrates River. The total length of the main streams of this system is 164 km. It has various branches and structures. For Shatt Al-Daghara, there is a lack of availability of any hydraulic study. Generally, this study is conducted to evaluate the hydraulic condition and the necessary improvement that will modify the capacity of the Shatt Al-Hilla and Shatt Al-Daghara.

The objectives of this research are to develop a one-dimensional hydraulic model and simulate the flow under the current conditions for multiple scenarios by using HEC-RAS 5.0.7 software, and the required development to increase the discharge capacity of the Shatt Al-Hilla and Shatt Al-Daghara to satisfy the study of strategy for Water and Land Resources in Iraq, 2014 which is conducted by the Iraq Ministry of Water Resources in Iraq.

2. DESCRIPTION OF THE STUDY AREA

The study area extends between the governorate of Babil and Qadisiyah, as shown in **Fig.1**. It is considered an important system that supplies water to most irrigation projects in Diwaniya and Babil. The total agricultural land irrigated from this system is 128900 hectares. The most important parts of this system are described below.

2.1 Shatt Al-Hilla

In its current condition, Shatt Al-Hilla is the old path of the Euphrates River before it turned into its new path at the end of the last century. Branches in their current position from the left of the Euphrates River, upstream Hindiyah Barrage, and its length about 100 km. Shatt Al-Hilla extends through the Babil governorate and parts of the Qadisiyah governorate until Al-Daghara Head Regulators Group. The normal discharge of Shatt Al-Hilla ranges between 150 to 200 m^3/s. It is hoped to develop and expand Shatt Al-Hilla to be able to pass a maximum discharge of 303 m^3/s study of strategy for Water and Land Resources in Iraq SWLRI, 2014. Shatt Al-Hilla branches at the end into two branches, right branch Shatt Al-Diwaniya, left branch Shatt Al-Daghara. Control of water quantities and levels in Shatt Al-Hilla carried out by the Shatt Al-Hilla Head Regulator, Cross Regulator at the station (53+400) km, and Cross Regulator at the station (78+200) km, also the Head Regulators for all streams branching from the right and left of Shatt Al-Hilla. Irrigation on the Shatt Al-Hilla through Thirty-five streams branched from the Shatt Al-Hilla, most of them are unlined.

2.2 Shatt Al- Daghara

Shatt Al-Daghara is the left branch of Shatt Al-Hilla, located on 482299 m, Easting, and 3566681 m, Northing on UTM coordinates system. The length of Shatt Al-Daghara is about 64 km. The design discharge of Shatt Al-Daghara is 75 m^3/s. Control of water quantities and levels in Shatt Al-Hilla carried out by the Shatt Al-Daghara Head Regulator and four Cross Regulators at the station (19+060, 30+900, 43+400, and 63+970) km, nineteen streams are branched from Shatt Al-Daghara. Five of these streams are only unlined, and they are controlled by the head regulators installed on them.

3. FIELDWORKS

The ADCP (Acoustic Doppler Current Profiler) M9 device was used to measure the discharge as shown in **Fig.2** and using the staff gauges at the points to record the water levels. The monitoring sites were determined according to the location when the discharges are changed, as well as the presence of level measuring staff gauges and the availability of a measuring boat or the availability of a nearby bridge for ease of measurement. **Table 1** presents the locations and coordinates of the monitoring point.

The importance of fieldwork is to collect the necessary data for evaluating the system and investigating the hydraulic system within the study area. The data is used to prepare the hydraulic model using HEC-RAS software and calibrate Shatt Al-Daghara. The details are described in the following points.

1- The fieldwork started from the downstream end of Shatt Al-Hilla, by measuring the discharge and water level at this point and measuring the discharge and water level downstream the head regulator of Shatt Al-Diwaniya and Shat Al-Daghara. Three observations were made in this area, as presented in **Table 2**.

2- The discharge and water level measurement in the Shatt Al-Daghara was made of four sets of five sites along the Shatt Al-Daghara reach, as presented in **Table 3.**

Table 1. The locations and coordinates of the monitoring point.

River	Location	Station	UTM coordinates ,m	
			X, Easting	Y, Northing
Shatt Al-Hilla	Shatt Al-Hilla tail	99+750	482677	3567419
Shatt Al-Daghara	Shatt Al-Daghara H.R	00+200	482266	3566561
	Al-Jawean	19+150	496386	3555747
	Al-Fadilia	31+000	506694	3555150
	Al-Tharima	43+500	517572	3550268
	Shatt Al-Daghara tail	63+000	535096	3541401

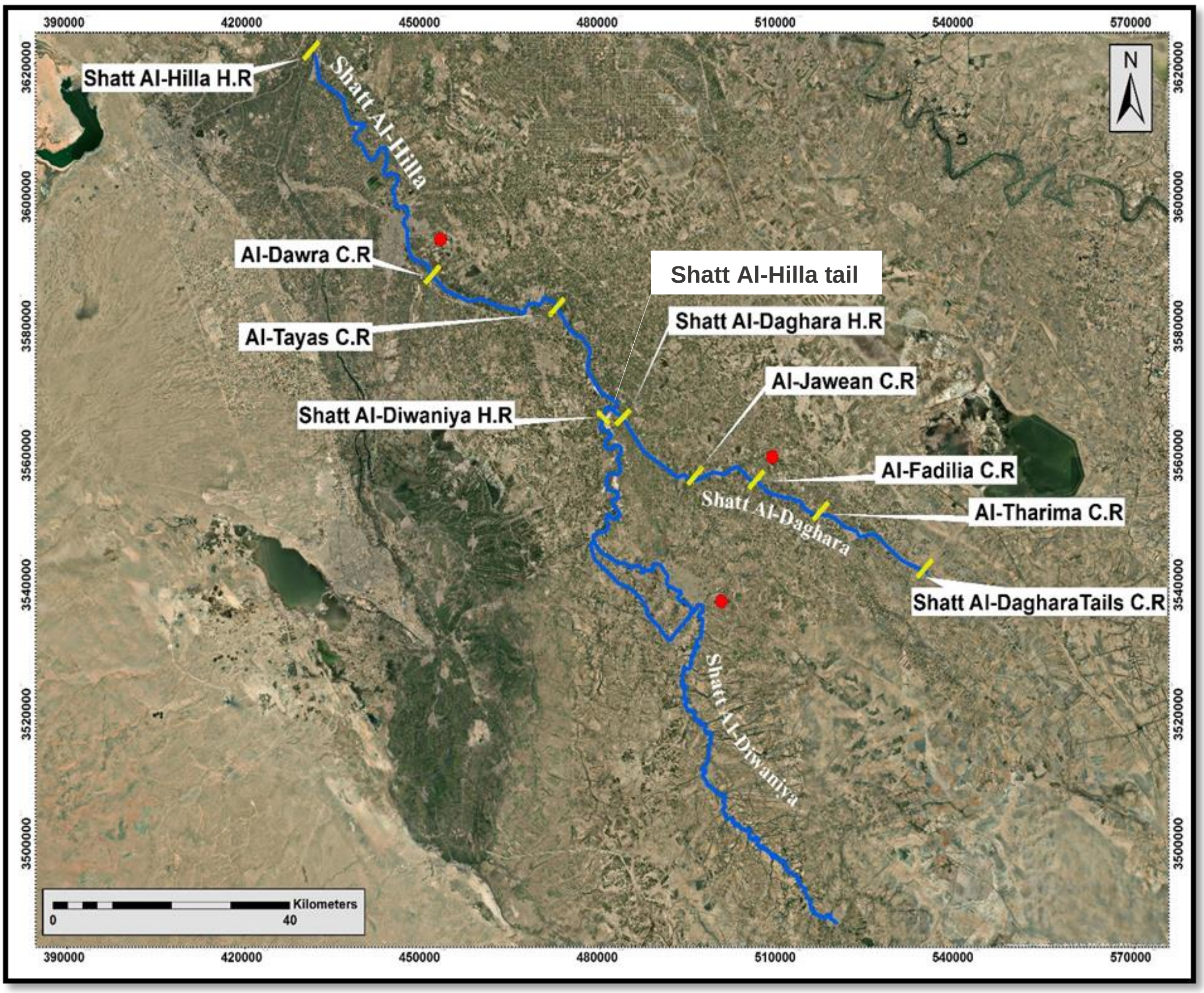

Figure 1. General layout of study area, by ArcGIS 10.2, ESRI. Condition.

a) M9 Device

b) S5 Device

Figure 2. Snap shots for the Device used for the measurement of the discharge.

Table 2. The field works data of the Shatt Al-Diwaniya Diversion Canal reach.

Set	Date	Station					
		Shatt Al-Hilla tail 100+000		D/S Shatt Al-Diwaniya H.R 00+300		D/S Shatt Al-Daghara H.R 00+200	
		Q m^3/s	W.L *m.a.m.s.l*	Q m^3/s	W.L *m.a.m.s.l*	Q m^3/s	W.L *m.a.m.s.l*
1	26/9/2020	104.15	23.75	60	23.70	25.18	22.85
2	9/10/2020	92.89	23.65	65	23.80	33.82	23.12
3	18/11/2020	97.21	23.70	55	23.58	29.5	22.91

Table 3. The field works data of the Shatt Al-Daghara reach.

Set	Date	Station *Km*									
		D/S Shatt Al-Daghara H.R 00+200		Al-Jawean 19+150		Al-Fadilia 31+000		Al-Tharima 43+500		Shatt Al-Daghara tail 63+000	
		Q m^3/s	W.L *m.a.m.s.l*	Q m^3/s	W.L *m.a.m.s.l*	Q m^3/s	W.L *m.a.m.s.l*	Q m^3/s	W.L *m.a.m.s.l*	Q m^3/s	W.L *m.a.m.s.l*
1	2/10/2020	27.5	22.85	21	20.55	16.5	19.25	6	18.5	5.5	16.1
2	12/10/2020	37	23.1	27	20.9	20	19.65	7	18.75	6	16.13
3	23/11/2020	16	22.6	12	20	9	18.6	4	18.1	3	15.63
4	29/12/2020	30.2	22.95	22	20.6	17.6	19.35	7	18.55	6	16.12

4. DEVELOPING THE HYDRAULIC MODEL

The software presented by the United States Army Corps of Engineers is used to analyze the river system. The HEC-RAS 5.0.7 software was used to simulate a one-dimensional steady-state gradually varied flow of the study area under different conditions. Five hundred forty-six cross-sections for Shatt Al-Daghara of 100 m apart and 395 cross-sections for Shatt Al-Hilla of 250 m apart were used in the hydraulic model; the data were provided by the [Directorate of Water Resources in Diwaniya and Babil]. The boundary condition is the constant discharge at the upstream and the normal depth at the downstream.

5. RESULTS AND ANALYSIS

In this section, the results will be reviewed and analyzed of flow capacity of Shatt Al-Hilla and Shatt Al-Daghara; the analysis includes the calibration and verification of the Manning's n for Shatt Al-Daghara and the current and modified discharge capacity of the reach.

5.1 Calibration and Verification

Determination of Manning's n coefficient is important in open channel flow calculations; the variance in this factor has a clear effect on the calculations of discharge, depth, and velocity. Due to the absence of any previous hydraulic study on the Shatt Al-Daghara, the determination of the Manning's n coefficients is very necessary. Measured field data were relied on in determining the Manning's Coefficient (n) of Shat Al- Daghara through calibration and verification by HEC-RAS software. As For Shatt Al-Hilla, due to the lack of suitable conditions for conducting field measurements, therefore, the latest previous research was dependent on determining the Manning's Coefficient (n) and showed that the most appropriate value for Manning's Coefficient (n) for Shatt Al-Hilla is 0.023 (Basim, 2020). As for the flood plain of the study areas, there are no levees , as well as no observational data was obtained in which the water reaches a level higher than the level of the banks. Therefore, Manning's coefficient, n for the flood plain in the HEC-RAS model, was fixed with a value of 0.035 for Shatt Al-Hilla and Shatt Al-Daghara, according to the values of n recommended by "Open Channel Hydraulics" **(Chow, 1959)**.

The Root Mean Square Error, RMSE, was used to test and compare the simulated and the observed water levels that are:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(S_i - O_i)^2} \quad (1)$$

N= number of data,

S_i = Simulated water level, *m.a.m.s.l.*

O_i = observed water level, *m.a.m.s.l.*

Many trial runs of the HEC-RAS simulation model were carried out using different values of Manning's coefficients during the calibration. The process was conducted using sets of data obtained from field works. **Table 4** shows three sets of data for Shatt Al-Daghara observed discharge and water level, simulated water level by using Manning's coefficient of 0.022, and RMSE, whose minimum value of 0.077m is obtained in set no.1. The results of the verification process showed a very good agreement between the observed and computed water levels with an RMSE of 0.062 m for Shatt Al-Daghara, as presented in **Table 5**.

Table 4. Comparison between the observed and simulated water levels using the calibrated Manning's coefficient of 0.022 for Shatt Al-Daghara.

Set number	Station *km*	Q m^3/s	W.L *m.a.m.s.l.*		RMSE
			Observed	Simulated n=0.022	
1	00+200	27.5	22.85	22.83	0.077
	19+150	21	20.55	20.65	
	31+000	16.5	19.25	19.29	
	43+500	6	18.5	18.47	
	63+000	5.5	16.1	15.97	
2	00+200	37	23.1	23.11	0.123
	19+150	27	20.9	20.89	
	31+000	20	19.65	19.45	
	43+500	7	18.75	18.59	
	63+000	6	16.13	16.03	
3	00+200	16	22.6	22.44	0.189
	19+150	12	20	20.23	
	31+000	9	18.6	18.88	
	43+500	4	18.1	18.17	
	63+000	3	15.63	15.5	

Table 5. Comparison between observed and simulated water surface profiles during verification of the calibrated Manning's coefficient for Shatt Al-Daghara.

Set number	Station *km*	Discharge m^3/s	Water surface elevation *m.a.m.s.l.*		RMSE
			Observed	Simulated	
4	00+200	30.2	22.95	22.91	0.062
	19+150	22	20.6	20.69	
	31+000	17.6	19.35	19.34	
	43+500	7	18.55	18.51	
	63+000	6	16.12	16.03	

5.2 Current Capacity of Shatt Al-Hilla

As mentioned previously, irrigation on the Shatt Al-Hilla is carried out through streams scattered along the reach. To assess the capacity of Shatt Al-Hilla capacity under the current conditions, different values have been imposed for the discharges downstream of the head regulator of Shatt Al-Hilla. These discharges range from 150 m^3/s up to the maximum design discharge of 303 m^3/s, with the maximum consumption of the streams branching from Shatt Al Hilla. In the first case, as presented in **Table 6,** the maximum discharge that can be accommodated within the Shatt Al-Hilla under the current condition is less than 200 m^3/s. In the second case, as presented in **Table 7,** when the discharge was increased to more than 200 m^3/s and reached the design discharge, it is clear that Water Surface Elevation reached the banks level and flooding occurred in Shatt Al-Hilla, as shown in **Fig. 3 and 4.** The water surface elevation along the reach of Shatt Al-Hilla for the discharge 200 m^3/s and 303 m^3/s, respectively. In the third case, the discharges were released, which were imposed in the first and second cases, while reducing the consumption efficiency of the stream branches from Shatt Al-Hilla to 80% of the design discharge for them as presented in **Table 8.**

Table 6. The suggested discharge with the maximum consumption of the Shatt Al-Hilla streams, first case.

Station	Discharge in Shatt Al-Hilla *m^3/s*						Streams Discharge 100% *m^3/s*
00+000	150	160	170	180	190	200	-
00+000 to 9+210	135	145	155	165	175	185	15
26+330 to 32+575	116	126	136	146	156	166	19
39+420 to 53+053	98	108	118	128	138	148	18
56+350 to 74+850	69	79	89	99	109	118	30
78+550 to 93+600	46	56	66	76	86	95	23
92+890 to 98+500	25	35	45	55	65	74	21

Table 7. The suggested discharge with the maximum consumption of the Shatt Al-Hilla streams, second case.

Station	Discharge in Shatt Al-Hilla *m^3/s*		Streams Discharge 100% *m^3/s*
00+000	250	303	-
00+000 to 9+210	235	288	15
26+330 to 32+575	216	269	19
39+420 to 53+053	198	251	18
56+350 to 74+850	169	222	30
78+550 to 93+600	146	199	23
92+890 to 98+500	125	178	21

Table 8. The suggested discharge with reducing the consumption efficiency of the streams branches from Shatt Al-Hilla to 80% of the design discharge, third case.

Station	**Discharge in Shatt Al-Hilla m^3/s**						**Streams Discharge 80% m^3/s**
00+000	150	160	170	180	190	200	-
00+000 to 9+210	138	148	158	168	178	188	12
26+330 to 32+575	123	133	143	153	163	173	15
39+420 to 53+053	109	119	129	139	149	159	14
56+350 to 74+850	85	95	105	115	125	135	24
78+550 to 93+600	67	77	87	97	107	117	18
92+890 to 98+500	51	61	71	81	91	101	16

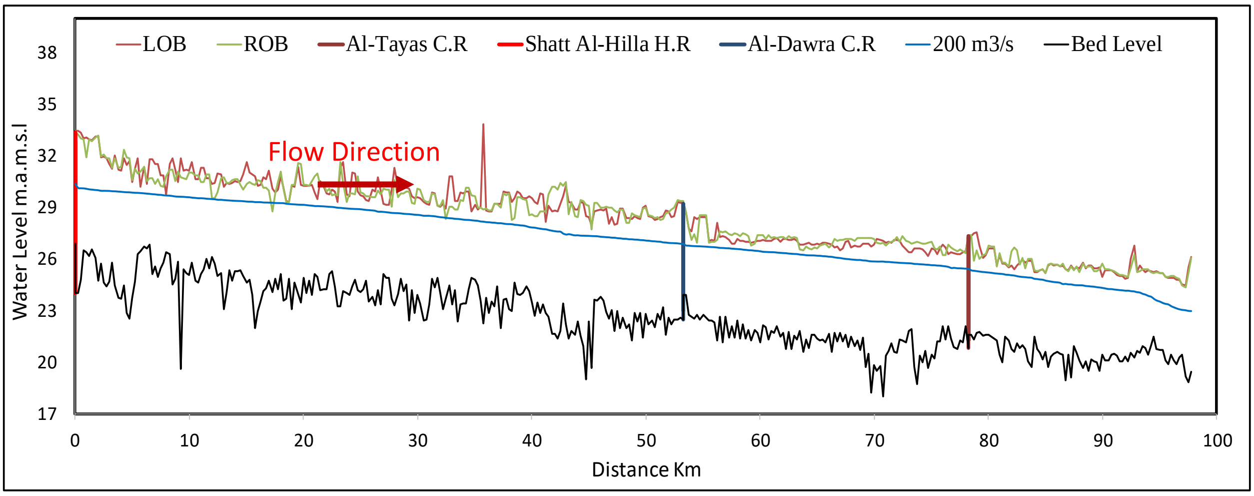

Figure 3. Water surface elevation along Shatt Al-Hilla under current condition with a discharge of 200 m^3/s in the first case.

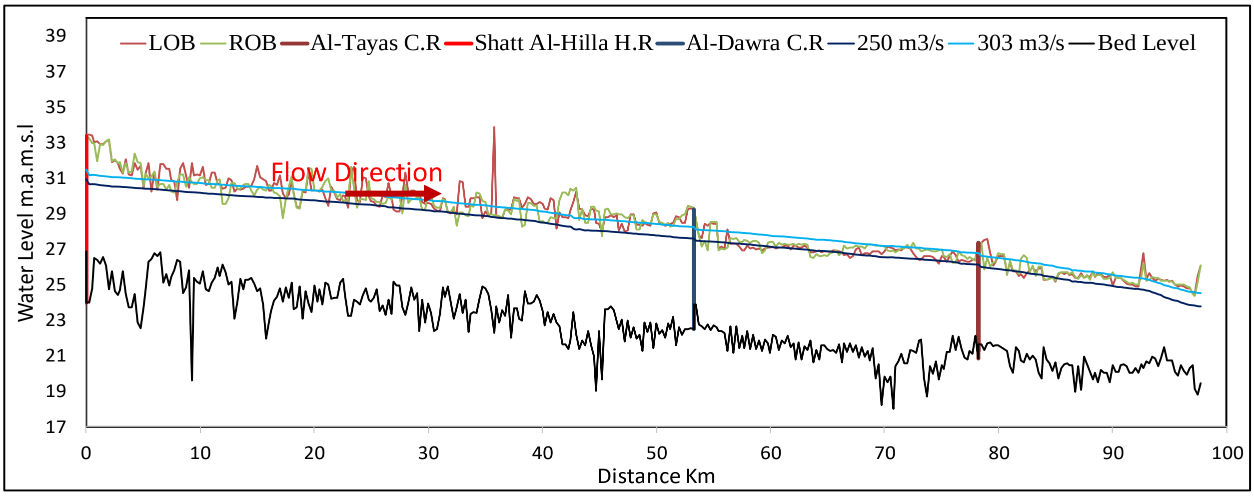

Figure 4. Water surface elevation along the reach of Shatt Al-Hilla under current condition for a discharge of 303 m^3/s, second case.

It was found that the capacity of Shatt Al-Hilla in the third case becomes 190 m^3/s, as shown in **Fig. 5.** This scenario was imposed to improve the capacity of Shatt Al-Hilla in receiving the high discharge in case the streams of Shatt Al-Hilla were not able to pass their design discharge.

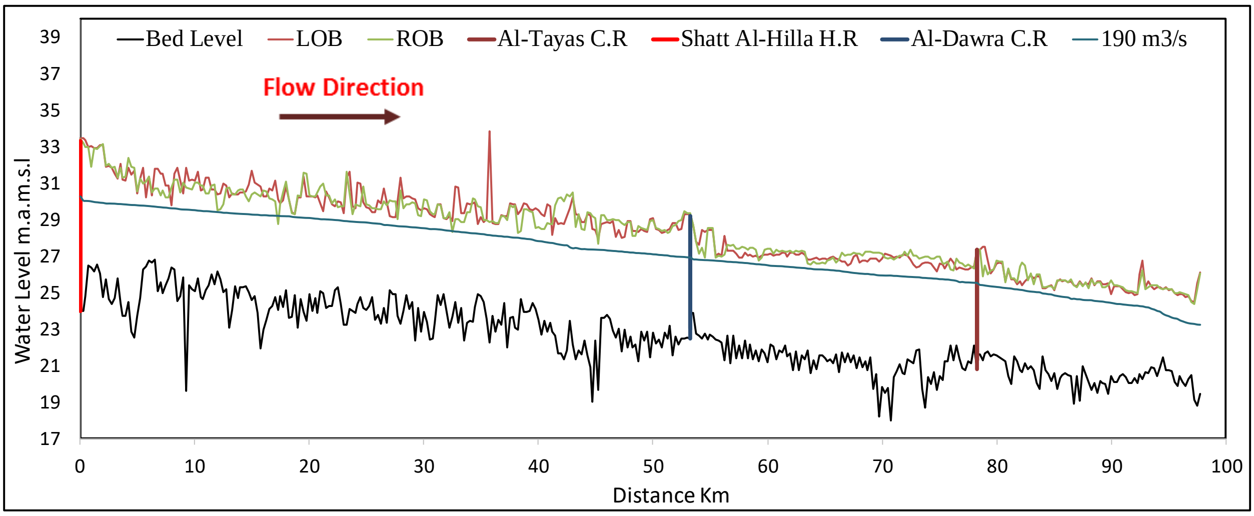

Figure 5. Water surface elevation along the reach of Shatt Al-Hilla under current condition for a discharge of 190 m^3/s, third case.

5.3 Development of Shatt Al-Hilla

It was previously mentioned that released discharge in Shatt Al-Hilla cannot exceed 200 m^3/s, which is lower than the current and future agriculture requirements in the Babil and Qadisiyah Governorate. The development of the Shatt Al-Hilla includes increasing the current discharge from 200 m^3/s to 303 m^3/s by river training and raising the banks level in different locations. Also, there is a benefit from the operation of the cross regulators at station (51+000) km and at station (74+000) km in irrigation. By using the streams on both sides of Shatt Al-Hilla in case Shatt Al-Hilla is not able to prepare the streams, and in case of failure to achieve the required water levels. After carrying out the required development of the cross-sections of Shatt Al-Hilla and conducting the scenario by releasing the maximum discharge of 303 m^3/s in Shatt Al-Hilla without operating the two cross regulators, meaning that the gates are fully open, Shatt Al-Hill became able to accommodate the discharge 303 m^3/s with the presence of a freeboard of 1 m, as presented in **Fig. 8.** The Earthworks volume of these cross-sections is about 5.89 million m^3, and its cost is 11.780 billion IQD.

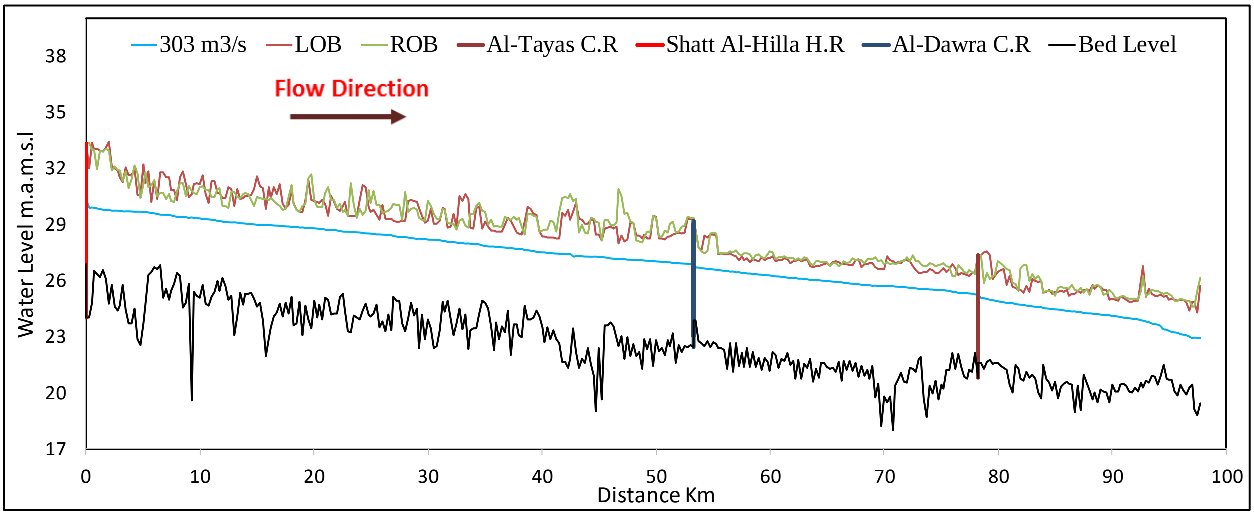

Figure 8. Water surface elevation along the reach of Shatt Al-Hilla with discharge of 303 m^3/s.

5.4 Current Capacity of Shatt Al-Daghara

The results of the present discharge capacity of Shatt Al-Daghara have been shown through three cases of the discharge as presented in **Tables 9, 10, and 11. Table 9** shows the first case representing the lateral outflow discharge consumption along Shatt Al-Daghara reach. The results showed that the capacity of the Shatt Al-Daghara under the current condition is 50 m^3/s. The maximum discharge that passes through a cross regulator at station (63+970) km is 5 m3/s, which causes choking in the last area of Shatt Al-Daghara from Al-Tharima C.R to Shatt Al-Daghara tail C.R. Many scenarios have been worked out in the case of the few discharges. A comparison was made between the water surface elevation in Shatt Al-Daghara and the bed level of the streams before the cross regulator. It was found that these streams can be operated without the need to operate the Shatt Al-Daghara tail cross regulator, so there is no need for the cross regulator to operate the streams that are located before the cross regulator**.** In the second case shown in **Table 10**, the discharge was increased to the design discharge of 75 m^3/s, also increased the discharges consumptions of the branches of Shatt Al-Daghara design discharge. It is clear that Shatt Al-Daghara under the current conditions is not capable of accommodating the design discharge, as the water level is higher than the level of the banks and flooding occurs in different locations, especially from station (10+000) km till station (19+000) km, the center of Al-Daghara district. From the on-site inspection of Shatt Al-Daghara, it was found that the 19 streams of Shatt Al-Daghara need maintenance, which includes cleaning and dredging to pass the design discharge. Hence, it was assumed that Shatt Al-Daghara only passes 85% of its design discharge in case of releasing the design discharge in Shatt Al-Daghara, as presented by the third case in **Table 11.** **Fig. 6 and Fig. 7** show the water surface elevation along the reach of Shatt Al-Daghara for the discharge of 50 m^3/s and 75 m^3/s, respectively.

Table 9. The suggested lateral out flow along Shatt Al-Daghara reach under the current condition for a discharge of 50 m^3/s, first case.

Station *Km*	**Discharge in Shatt Al-Daghara** m^3/s	**Streams Discharge** m^3/s
000+00	50	-
00+000 to 18+855	40	10
19+000 to 30+400	31	9
41+980 to 43+265	21	10
61+090 to 63+970	5	16

Table 10. The design discharge in Shatt Al-Daghara with the maximum consumption of the streams, second case.

Station *Km*	**Discharge in Shatt Al-Daghara** m^3/s	**Streams Discharge 100%** m^3/s
000+00	75	-
00+000 to 18+855	53	22
19+000 to 30+400	44	9
41+980 to 43+265	20	23
61+090 to 63+970	5	16

Table 11. The suggested discharge with reducing the consumption efficiency of the streams branches from Shatt Al-Daghara to 85% of the design discharge of 75 m^3/s, third case.

Station *Km*	**Discharge in Shatt Al-Daghara** m^3/s	**Streams Discharge** m^3/s **85%**
000+00	75	
00+000 to 18+855	56	19
19+000 to 30+400	48	8
41+980 to 43+265	29	20
61+090 to 63+970	15	13

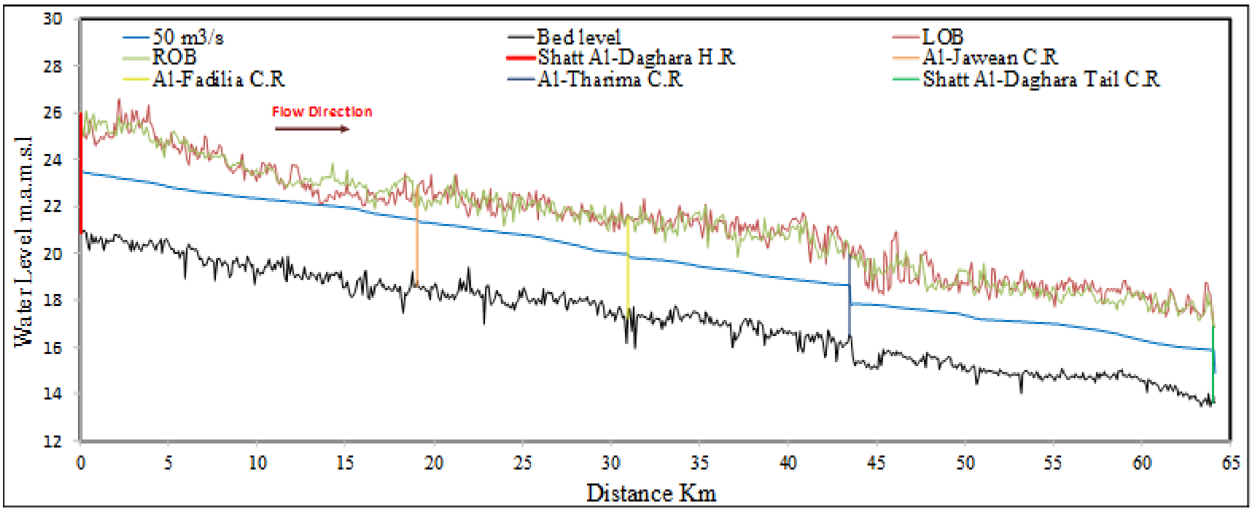

Figure 6. Water surface elevation along the reach of Shatt Al-Daghara under current condition for a discharge of 50 m^3/s, first case.

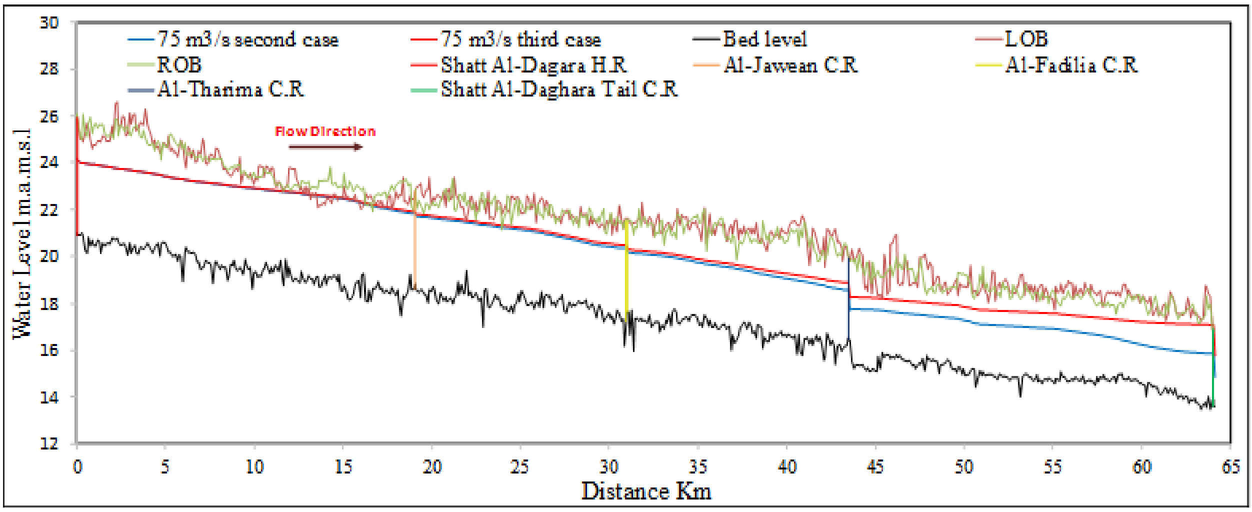

Figure 7. Water surface elevation along the reach of Shatt Al-Daghara under current condition for a discharge of 75 m^3/s, second and third case.

5.5 Development of Shatt Al-Daghara

The modification of Shatt Al-Daghara includes increasing the current capacity from 50 m^3/s to 75 m^3/s.The development included two cases. The first case was a modification of the cross-sections from station (13+000) km to (31+000) km and raising the banks level in some stations along Shatt Al-Daghara with released the discharge of 75 m^3/s in Shatt Al-Daghara, with the determination of the maximum consumption of streams, which are the design consumptions for them along the reach, as presented in **Fig. 9.** This case guarantees that the discharge 5 m^3/s reaches the Shatt Al-Daghara tail. Still, this discharge is not sufficient to operate all drinking water stations and at the same time irrigate the agricultural lands located in Shatt Al-Daghara tails. It is necessary to use a

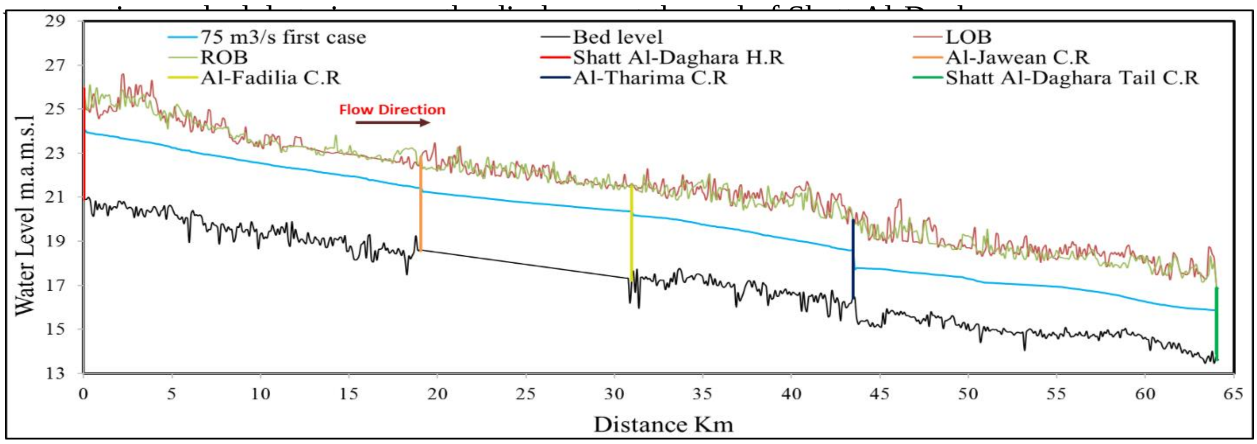

Figure 9. Water surface elevation along Shatt Al-Daghara for a discharge of 75 m^3/s, first case.

In the second case, the modification included-modifying the cross-sections from station (13+000) km to (31+000) km and raising the banks level in some stations along the reach of Shatt Al-Daghara, as well as removing the Shatt Al-Daghara tail cross regulator at station (64+000) km.After the last cross regulator at station (64+000) km, Shatt Al-Daghara is branched into many branches. The total discharges of these branches are not precisely defined but ranged between (10-15) m^3/s (Directorate of Water Resources in Diwaniya), but in recent years the absence of required discharges, the problems of water distribution, and the spread of informal outlet prevented the required water rations from reaching Shatt Al-Daghara tail. It was limited to operating water drinking stations and a few agricultural areas. In the second case, the discharge of 75 m^3/s was released, and a water rations program was made. The consumption of the streams was reduced in a way that guarantees the discharge of 15 m^3/s reaching the end of Shatt Al- Daghara. **Figures 10 and 11** show the water surface elevation of a discharge of 75 m^3/s, in the presence and absence of a cross regulator at station (64+000) km, respectively. The Earthworks volume of these cross-sections is about 0.54 million m^3, and its cost is 1.080 billion IQD.

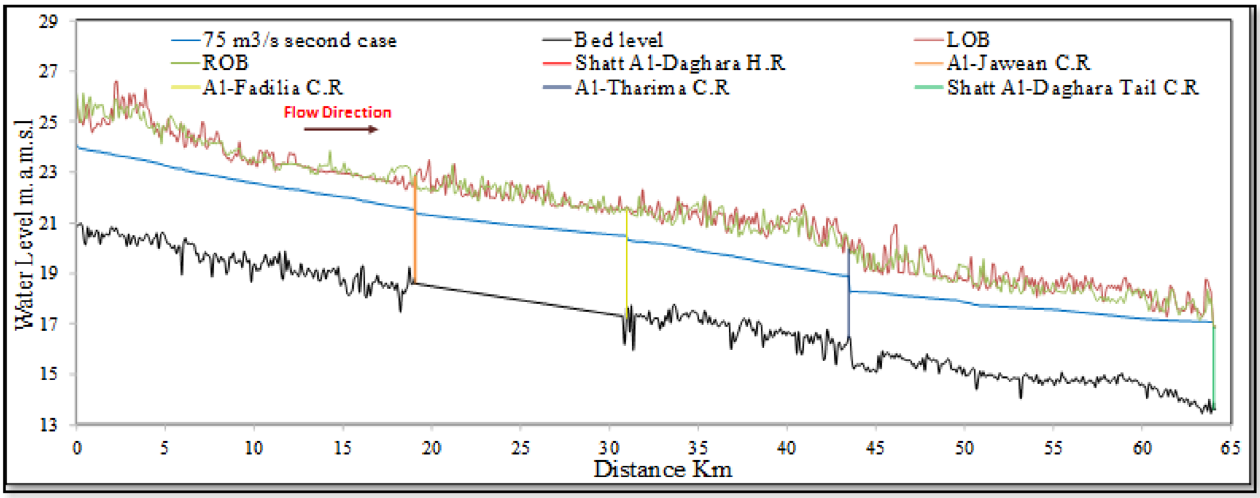

Figure 10. Water surface elevation of a discharge of 75 m^3/s, with cross regulator at station (64+000) km.

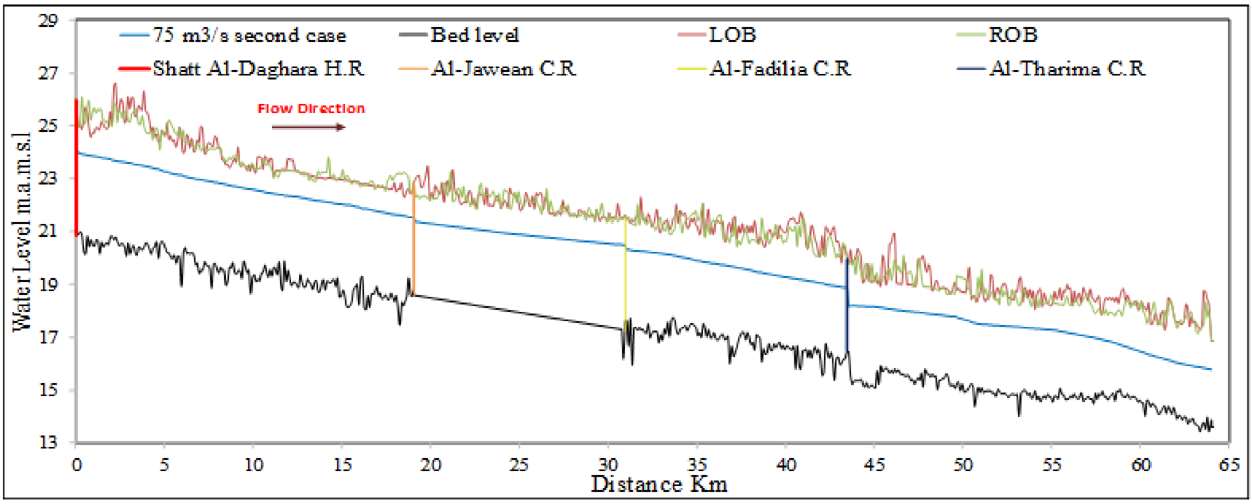

Figure 11. Water surface elevation of a discharge of 75 m^3/s, without cross regulator at station (64+000) km.

6. CONCLUSIONS

By analyzing the results, the following main conclusions were drawn.

1. It was found that Manning's coefficient for Shatt Al-Daghara reach is 0.022.
2. Under the current conditions, the maximum discharges of Shatt Al-Hilla and Shatt Al-Daghara are 200 m^3/s and 50 m^3/s, respectively.
3. The development of the Shatt Al-Hilla includes increasing the current discharge from 200 m^3/s to 303 m^3/s through river training and raising the bank levels in different locations.
4. The cross regulator of Shatt Al-Daghara at station (64+000) km could not pass a discharge of more than 5 m^3/s. This discharge is less than the water requirements for agriculture and drinking water. Also, it was found that streams before the cross regulator can be operated without the need to operate cross regulator.
5. After implementation of the improvements, the current capacity of Shatt Al-Daghara increased from 50 m^3/s to 75 m^3/s, and this has been done by modifying the cross-sections from station (13+000) km to (31+000) km and raising the bank levels and removing the cross regulator at station (64+000) km.

NOMENCLATURE

LOB = Left Over Bank, m.a.m.s.l.
ROB = Right Over Bank, m.a.m.s.l.

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