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Assessing of the Morphology and Sediment Transport of Diyala River

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ABSTRACT

Diyala River is one of the important rivers that provide water for the Governorate of Diyala. In this research, the morphology and sediment transport of this river were studied using HEC-Ras software. The selected length of the river in the present study is 193 *km* and extended from Diyala Weir to the confluence of Tigris River and Diyala River. The fieldwork period extended from June 2020 till August 2020, where suspended-load and bed-load samples were collected and surveyed some cross-sections. The one-dimensional sediment transport model has been calibrated for five years, from 2014 to 2019. The results were compared with the measured cross-sections in 2019, and the suitable value of (maximum depth) was 120 *cm* for five years. The result of invert change from the simulation of the sediment model for real condition of the river from 2018 to 2019 ranged from0.2 *m* to 0.6 *m*.

Moreover, the daily and yearly sediment discharge was equal to 227.7 tons/day and 83531.93 tons/year, which were previous studies carried out on this river. While the simulating results of the imposed period as five successive flood years give an invert change values varied from -1.25 to 1.4 *m*. The river's capacity was improved by rising the riverbank level for parts of the reach and/or training of cross-sections for other parts.

Keywords: Diyala River, Capacity improvement ,HEC-RAS software, Sediment transport model.

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تقييم المورفولوجيا وانتقال الرواسب لنهر ديالى

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الخلاصة

نهر ديالى هو أحد الأنهار المهمة التي توفر المياه لمحافظة ديالى. أجري البحث الحالي لدراسة مورفولوجية وحمل الرسوبيات في هذا النهر باستخدام برنامج (HEC-RAS) وكان طول النهر المحدد في الدراسة الحالية يبلغ 193كم ويمتد من سدة ديالى إلى التقاء نهر دجلة ونهر ديالى. امتدت فترة العمل الميداني من حزيران 2020 حتى اب 2020، حيث تم جمع عينات الحمل العالق وحمل القاع، بالإضافة إلى مسح بعض المقاطع العرضية. تم معايرة نموذج نقل الرواسب أحادي البعد لمدة خمس سنوات، من2014 إلى 2019. قورنت النتائج مع المقاطع العرضية المقاسة في عام 2019 ، وكانت القيمة المناسبة (العمق الأقصى) 120 سم لمدة خمس سنوات .وقد تراوحت نتيجة تغير القاع عن محاكاة نموذج الرواسب للحالة الحقيقية للنهر من 2018 إلى 2019، من 0.2 *متر* إلى 0.6 *متر*. وعلاوة على ذلك، كانت التصاريف اليومية والسنوية للرواسب تساوي 227.7 *طن/يوم* و83531.93 *طن/ سنة* على التواليوالتي كانت اكبر من قيمتها في دراسة سابقة أجريت على هذا النهر. في حين أن محاكاة نتائج الفترة المفترضة (خمس سنوات فيضانية متعاقبة) تعطي قيم تغيير القاع تختلف من -1.25 إلى 1.4 م. وقد تحسنت قدرة النهر عبر اقتراح رفع مستوى ضفاف النهر لأجزاء منه و/أو تهذيب المقاطع العرضية للأجزاء الأخرى.

الكلمات الرئيسية :نهر ديالى, تحسين القدرة ,برنامج HEC-RAS, نموذج نقل الرواسب.

1. INTRODUCTION

The decreasing of flowrate in Diyala River, downstream of Diyala weir during the past dry years, after the flood of 1988, as well as the accumulation of sediment in the stream of the river for long periods due to the lack of maintenance in the river, led to a major change in the morphology of this river, which caused a reduction in the capability of the river to passes the flood waves. That issue presented clearly with the flood of 2019, which reflected the reduction of the flow capacity in Diyala River, especially within Baqubah City. Therefore, there is a very need for a study that must be carried out for the hydraulic analysis and estimation of the sediment load in the river to define their effects and reduce the risk of flooding in Baqubah City. Diyala River is the fifth branch of the Tigris River that consists of the confluence of the Sirwan and Tangro rivers in Darbandikhan Lake in the Sulaymaniyah Governorate in northern Iraq. Diyala River has a total length of 445 *km*. The selected length for the river in the present study was 193*km* and extended from Diyala Weir to the confluence end of Tigris River and Diyala River**, Fig.1**. Multiple studies used HEC-RAS software to simulate the sediment in the rivers and evaluate the sediment quantity. Some of the studies also used other methods to estimate the value of sediment accumulation within the rivers. This part will present these studies. **(Al-Ansari, et al., 1986)** estimated the suspended sediment quantity lower of Diyala River. The selected river reach of the river extended from the Hemrin reservoir to downstream of Diyala Weir with a length equal to 50 *km*. The period of sediment sampling extended from June 1984 to May 1985. The total number of the collected sediment samples from the Hemrin station was equal to 314 samples. The study results showed the value of annual suspended sediment quantity was equal to 64589 *tonnes* and the annual quantity of solute load was equal to 1.24 x 10^6 *tonnes*. The average value of daily sediment discharge was equal to 178.6 *tons/day*. While the mean value of monthly sediment discharge was 5335 *tons/month*, and the yearly sediment discharge was 64022.5 *tons/year* in Diyala River. **(Azarang, et al., 2015)** developed one-dimensional Version 4.1 of the HEC-RAS model to predict the reservoir dam's ability to protect the Karkheh River, located in Iran, by simulating erosion and sedimentation downstream of the river. The length of the Karkheh River is 94 *km* divided into 138 sections and the distance between cross-sections was 680 *m*, the period of sampling was 12 years from 2001 till 2013. According to the sediment results (Ackres-White, Larsen, and Engelund-Hansen) formulas had an accurate prediction of sediment transport and erosion in the Karkheh River since the Nash-Sutcliffe criterion values between 0.62 to 0.75. **(Mustafa, et al., 2017)** carried out a study to estimate the sediment transfer for the Euphrates River from the downstream of the Haditha dam to the Heet station by implementing the HEC-RAS software version 4.1, and model was calibrated and validated, the evaluated value of Manning Coefficient(n=0.033). The sediment load amount at the Heet city station was equal to (551,76 *tonnes/day*) which was considered to be less than the deposit value in a study measured in 1988 which was equal to (189,041 *tonnes/day*) because the discharge was increased in that area. **(Kayyun and Dagher, 2018)** reviewed the Tigris Rivers sediment analysis that was carried out using the HEC-RAS software version 5.03 for the area between the Saray station and the Muthanna bridge in the Baghdad City. The study used a sediment function called Lorsen Copeland, as well as a new equation for the river water surface level upstream and downstream of the river was developed. The study also included the river bed change estimated for the period 2012-2017, which was found to be equal to 0.39 *m* (sedimentation), 0.15(erosion) *m*. The average depth of erosion was 1 *m* from 2017 to 2040 when the discharge value was 461 m^3/sec. **(Daham, and Abed,2020)** used HEC-RAS, version 5.0.4 to develop a numerical model that simulates the transportation of sediment in the upstream part of the Gharraf River. The data from the ministry of water resources, hydrological and cross-sectional, were used to calibrate and verify the model for the range extended from Kut to Hay cities with a distance equal to 58 *km*. In addition to this, a 5-month field sampling was collected for suspended and bed loads from 7-2-2019, and samples were analyzed in the lab and the results were used to develop the model. The real sediment accumulation in the river was predicted in 2019, and the results of simulating the model for the year 2019, gave a value of accumulated sediment depth ranged from 2.5 *cm* to 0.5 *m*, whereas the depth of erosion ranged from -4 *cm* to -2 *cm*. The estimated quantity of sediment during one year ranged from 70 to 1008 *Tones/day*. To avoid sedimentation or erosion, lining of the selected river-stations with concrete or with grouted riprap respectively.

The main objective of the present study is to simulate a one-dimensional sediment transport model of the lower reach of Diyala River by implementing HEC-RAS software (5.0.7) since there was no previous study concerned with developing a numerical model to estimate sedimentation in the lower part of this river, as in **Fig.1.**

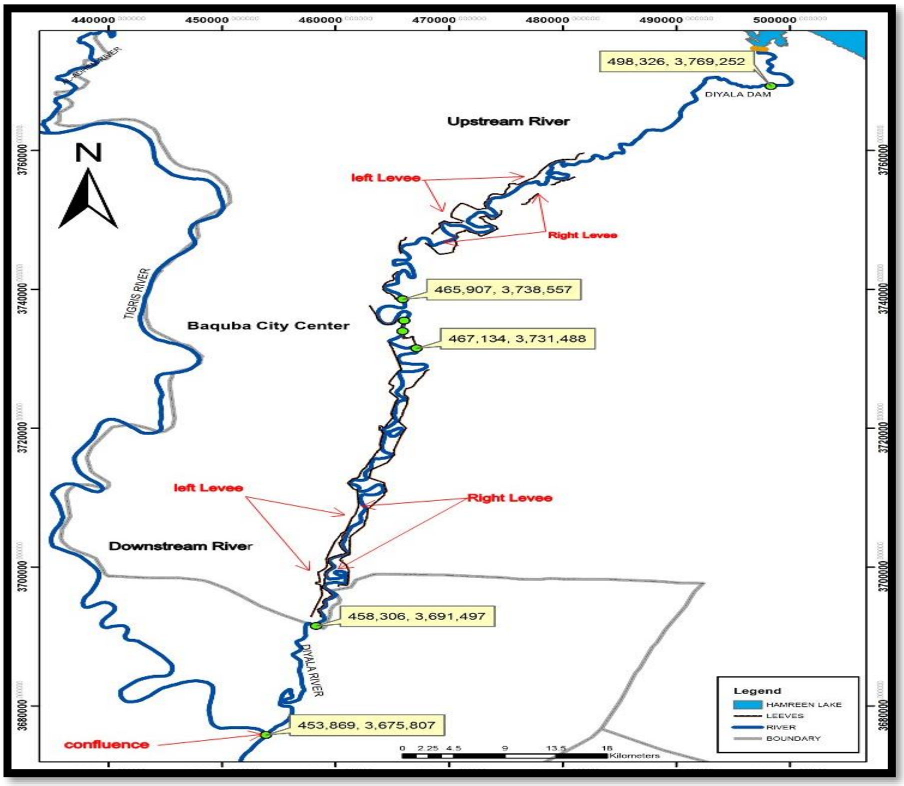


Figure1. The map of the Diyala River, ARC-MAP(10.2).

2. INPUT DATA AND THE SELECTED BOUNDARY CONDITIONS

The HEC-RAS software (5.0.7) was released in the United States in 2016 to study natural river analysis by "the Army Corps of Engineers". **(Daham, and Abed,2020).**

2.1. One-dimensional Steady Flow Model

The one-dimensional analysis model was developed by applying accurate formulas. The current study begins at a station 10,000 *m* when the Diyala river passes into the lower Diyala Weir and ends at a station 203,000 *m*, at the junction with the Tigris River.

The cross-sectional data used during the simulation were calculated by (Ministry of Water Resources from 2014 to 2019). The selected distance between every successive cross-section ranges between 100 *m* and 1*km*. The one-dimensional steady-state model has been calibrated and validated, and the values of the estimated values of Manning roughness for the steady-state were 0.028 and 0.045 for the mainstream and the flood plains of Diyala River, respectively. While (**Mustafa, et al., 2016)** found that the Manning roughness value for the mainstream of the Diyala River was 0.027, **and (Asaad and Abed, 2019)** found it is equal to 0.032 for the mainstream of the Tigris River and 0.040 for the floodplain**.**

2.2. One-dimensional Quasi Unsteady Flow

Several sediment transport models had been developed using the quasi-unsteady flow method and by selecting flow series as a boundary condition upstream of Diyala River. To begin with, the model that simulated Diyala River during the period from 1/2/2014 to 1/2/2019, for 67 months, with a time interval of 730 hours, and the discharge rate ranged from (1 to 601) m^3/s, the purpose of developing this model is to evaluate the suitable value of the (d max., which refer to maximum securing depth that may occur along the river) by testing several values of (d max.) to calibrate the sediment transport model.

The other models used the same values of flowrates that represent Diyala River during the high flow condition that ranged from(15 to 601) m^3/s and 192 m^3/s as average. Still, the simulation was during different periods: one, two, three, four, and five years. The selected type of boundary condition at the end of the Diyala River was the normal depth with the value of energy slope was evaluated from the river profile and equal to 18 *cm/km*. Also, the temperature value in this study was 20° C which was measured during the field measurements period (The period in which sediment samples were gathered from the river).

2.3. The Sediment Transport Model

Before the sediment transport model can be performed, very critical data must be entered. These include a file of flow geometry, a file for the chosen method of flow, a quasi unsteady flow method, and a file of the sedimentation details. This sediment data file has a transporting function, and the transport function was chosen in this study was "Laursen-Copeland' since Diyala River has a bed type of clayey silt. Also, it contains boundary conditions; the rating curve boundary condition calculates the sediment flowrate and includes the following information: the sediment flowrate, the water discharge, and the upstream grain distribution curve. In this study, the rating curve boundary condition was selected for the upstream of Diyala River that used the data collected during the period of field observation that extended from June 2020 till August 2020. Fifteen samples of suspended sediment were collected, and three sample sets of suspended load at the upstream part of Diyala River were considered as the inputs of deposit concentration discharge at the upstream of the study reach (at C.S . No. 39.97, station 10000 *m*). At the same time, the total number of bed-load samples was five which the analyzing results of these bed samples were used as input data of particle size distribution curves in the sediment file. **Fig. 2** shows the particle size distribution curve for the upper part of the river.

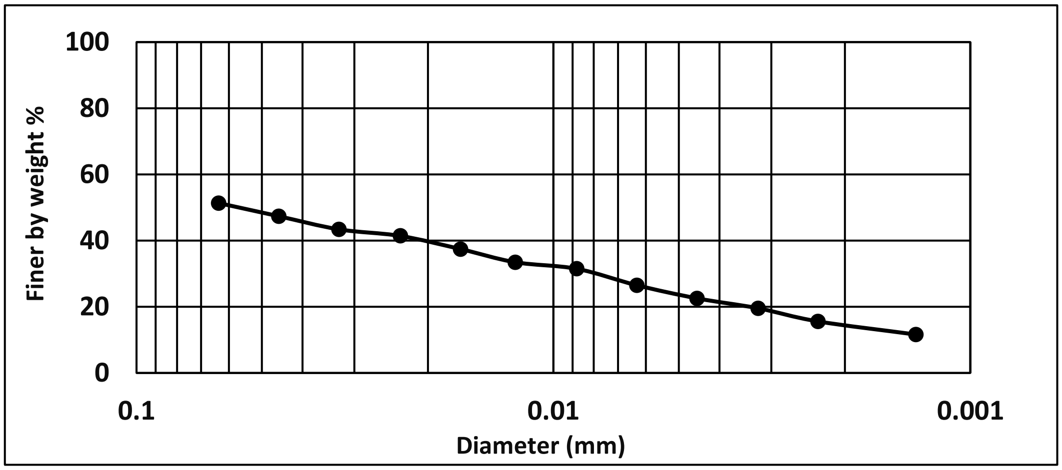


Figure 2. The grain size distribution at the upper part of Diyala River.

2.4. Main Governing Equations for Sediment Transport

There are basic equations developed by **(Brunner and Gary, 2016)** about the deposit transportation within the river. First of all, the equation of continuity of sediments;

$$-\frac{\partial q_s}{\partial \mathrm{X}} = (1-\lambda_p)\, b\, \frac{\partial \eta}{\partial T} \qquad \mathbf{1}$$

Where: b=the width of the river-bed, *m*. η= the river-section height, *m*. λ_p= porosity,dimensionless . q_s= deposit quantity rate, *tones/day*. The second equation is the Laursen-Copeland sediment transportation formula :

$$c_m = 0.01\, \gamma\, \left(\frac{d_s}{\mathrm{D}}\right)^{1.167} \left(\frac{\tau_0}{\tau_c} -1\right) f\left(\frac{u^*}{\omega}\right) \qquad \mathbf{2}$$

Where: γ = specific weight of water, *kg/m³*. d_s= median diameter of deposit particles, *mm*, D = the effective flow depth, *m*. τ_0= shear stress of river-bed, *pa*. τ_c =the critical shear stress of river-bed, *pa*. ω=fall speed of sediment particle, *m/s*.u^* = the shear speed,*m/s* . c_m =the sediment quantity, *tones/day*.

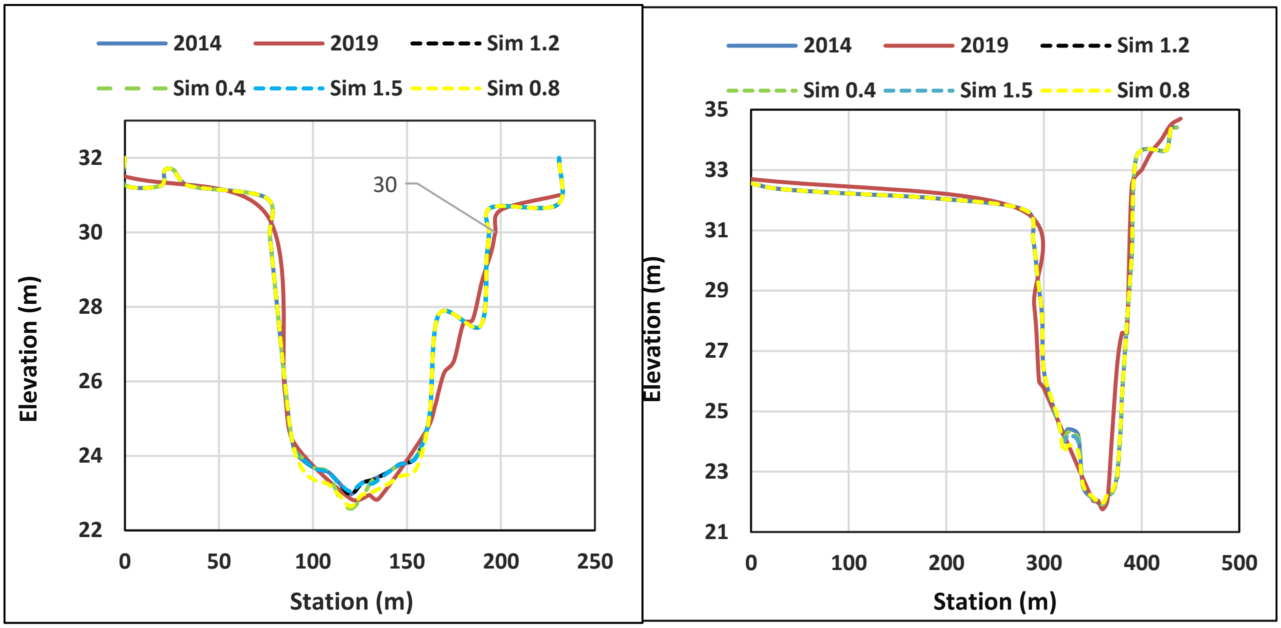
3. THE RESULTS OF SEDIMENT MODEL SIMULATION

The calibration and validation of the sediment transport model are considered the most important procedure to check the accuracy of the sediment model to simulate the actual morphology conditions of Diyala River and present the river state during actual and hypothetical cases.

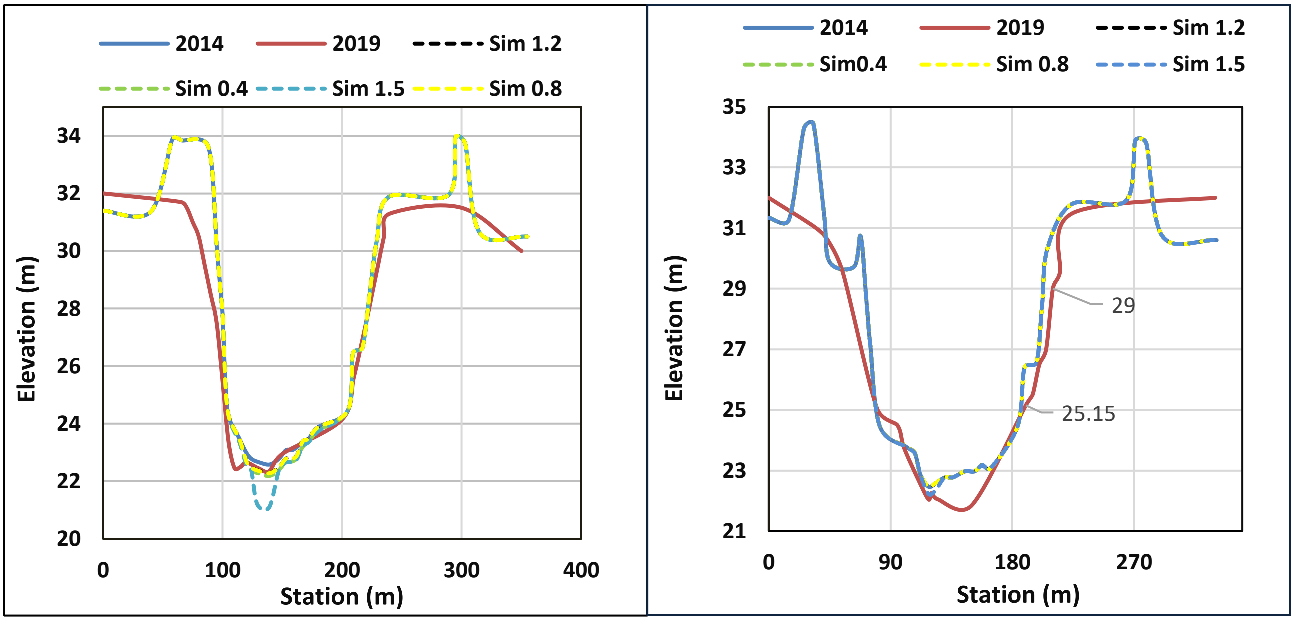
3.1. Calibration and Validation of the Sediment Model

The one-dimensional sediment transport model was calibrated by analysis of several values of maximum sediment accumulation depth along the river per unit time, which were equal to (40 *cm*, 80 *cm*, 120 *cm*,150 *cm*). The model was simulated for the period from 1/2/2014 to 1/2/2019 initially by inputting the cross-sections observed by MoWR in 2014 in the model, and then the model was simulated for five years, to 2019, using real values of flowrates ranging from (1 to 601) m^3/s that conducted during those five years. The measured cross-sections by MoWR in 2019 were compared with the resulting cross-sections from the simulation of the sediment model for five years till 2019 to evaluate the suitable value of (maximum depth). Nine stations were chosen to observe the effect of sediment accumulation or erosion in those cross-sections for calibration of the sediment model. The results of calibration showed that the suitable (max. depth) value that represents the river during five years was 120 *cm* since, in this value, the measured cross-sections converge with the simulated cross-sections and produce a value of RMSE equal to 0.2 *m* and the value of the R^2 was equal to 0.87. **Fig. 3** shows some of the calibrated stations along the river.

The sediment transport model was validated by selecting another five stations using the best value of (max. depth), which was 120 *cm* for five years. Also, the resulting cross-sections from simulating the model for five years, till 2019, were compared with measured cross-sections in 2019, and the results indicate acceptable values concerning the RMSE and determination coefficient, the values were equal to 0.1 *m* and 0.87, respectively. **Fig .4** shows some of the validated stations along the river.

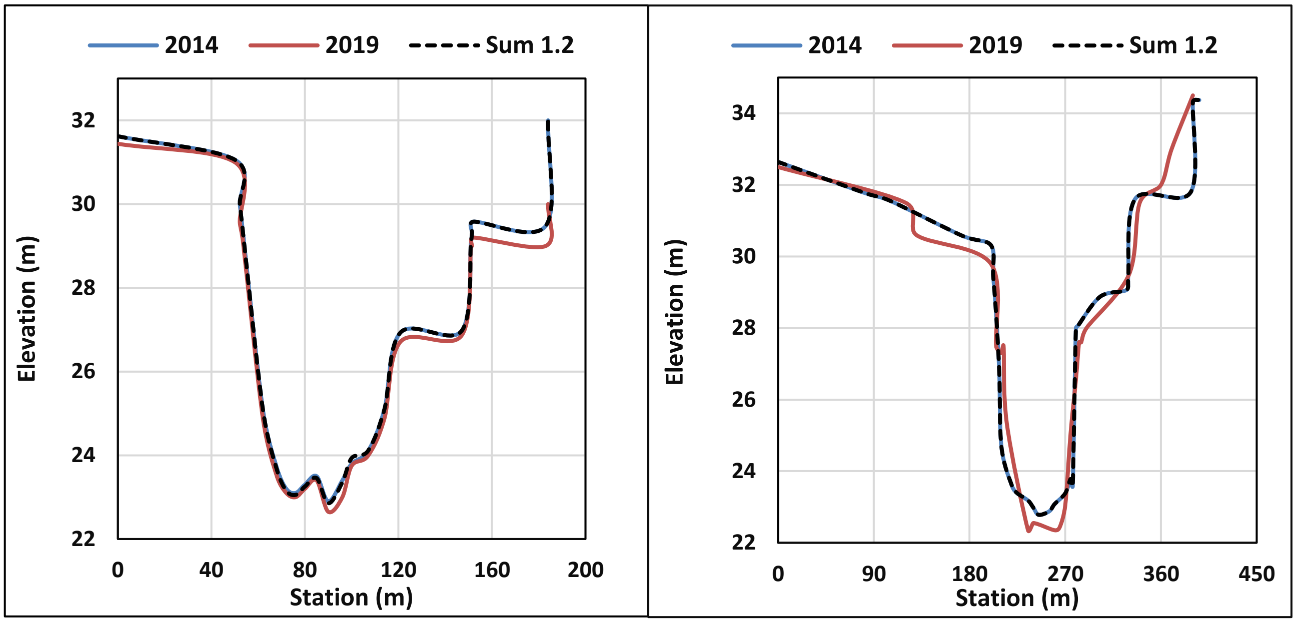


A: C.S= 3.7.Sta 190+500 **B:** C.S= 2.71.Sta 194+00



C: C.S= 1.95. Sta 198+500 **D:** C.S= 1.94.Sta 198+750

Figure 3. The calibration of the one-dimensional sediment transport model.



A: C.S= 3.8.Sta 190+250 **B:** C.S= 2.7.Sta 194+250

Figure 4. The validation of the one-dimensional sediment transport model.

3.2. Simulating the Sediment Transport Model

After the sediment transport model had been calibrated and validated, a few scenarios were simulated to represent the Diyala River real condition using the actual flowrate values. Also, hypothetical scenarios have been carried out by taking the same real flowrate values from 2018 to 2019 but simulated at different periods. This section will present the analysis of these developed models that show the effect of sedimentation and erosion along the river and predict the sediment and erosion effects for future events. The used values of flowrates in the simulation of all sediment models ranged from (15 to 601) m^3/s that represent Diyala River during the normal and high flow conditions, measured from October 2018 to October 2019 by MoWR. The first model simulated the actual state of the Diyala River during the period extended from 1/10/2018 to 1/10/2019, shown in **Fig.5.**

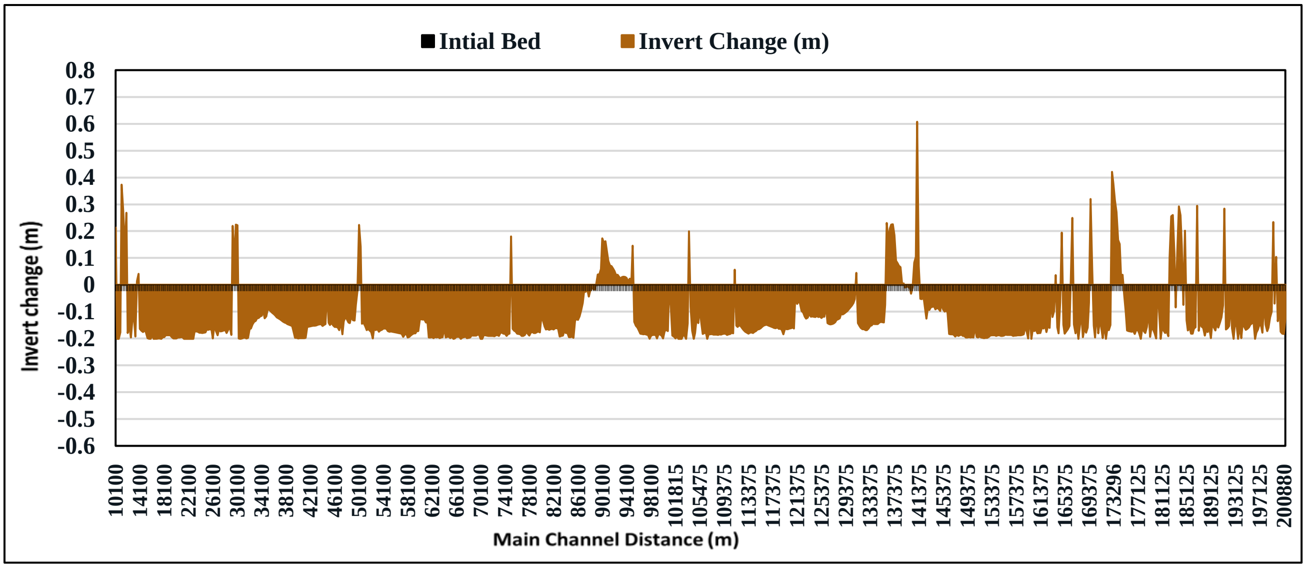


Figure5. The cumulative invert change along the river for one year (1/9/2018-1/9/2019).

The invert change is the initial bed level minus the simulated bed level. If the results are negative, it means erosion. Otherwise, it means sedimentation. When simulating the actual condition of Diyala River for one year, the invert change values ranged from -0.2 *m* to 0.6 *m*, the maximum deposition depth value was equal to 60 *cm*, at station 141 *km*, located downstream of Diyala River. At the same time, the deposition depth value upstream of the river was equal to 38 *cm*. Also, the values of erosion depths along the river profile were ranged between 5 and 20 *cm*.

The second model was a hypothetical model which simulated the Diyala River during a period extended from 1/10/2018 to 1/10/2020, using the same flowrate values, shown in **Fig.6.**

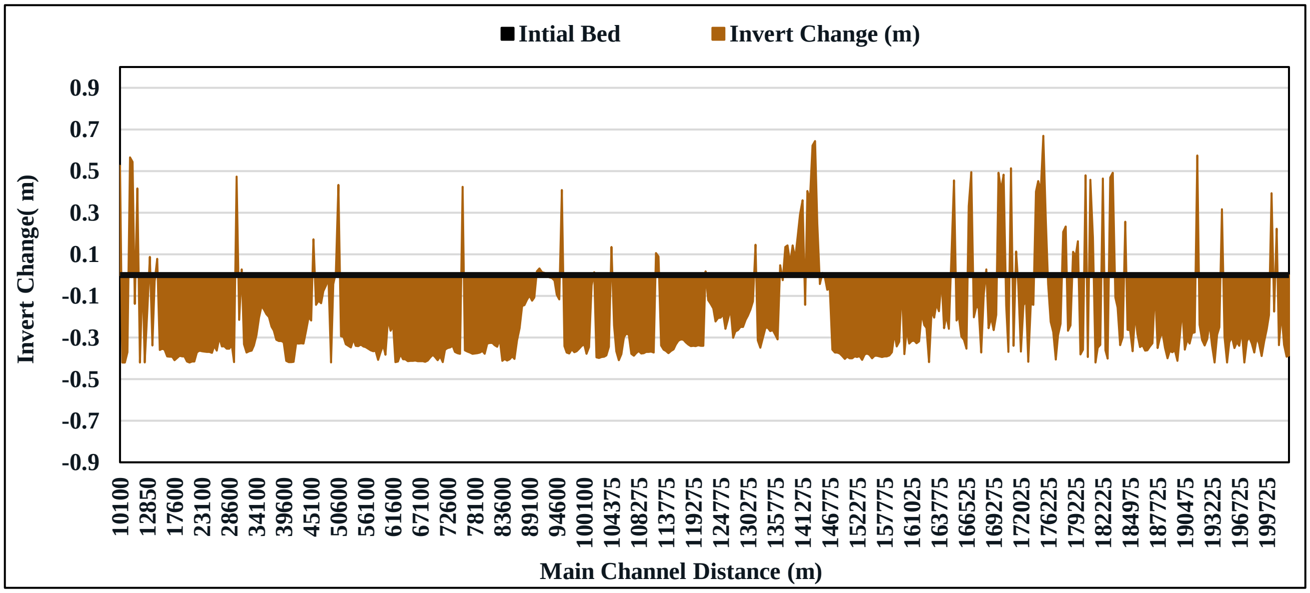


Figure 6. The cumulative invert change along the river for two years (1/1/2018-1/1/2020).

Fig. 6 shows the invert change values when simulating the Diyala River for two years. The invert change values ranged from -0.4 *m* to 0.66 *m*. The maximum deposition depth value was equal to 66 *cm* at station 175 *km*, located downstream of Diyala River, and the sedimentation depth value for upstream of the river was equal to 55 *cm*. Moreover, the erosion depth values along the river ranged from 10 *cm* to 40 *cm*.

The third model was hypothetical that simulated the Diyala River for the imposed period as five successive flood years, and the period was from 1/10/2018 to 1/10/2023, **Fig.7**.

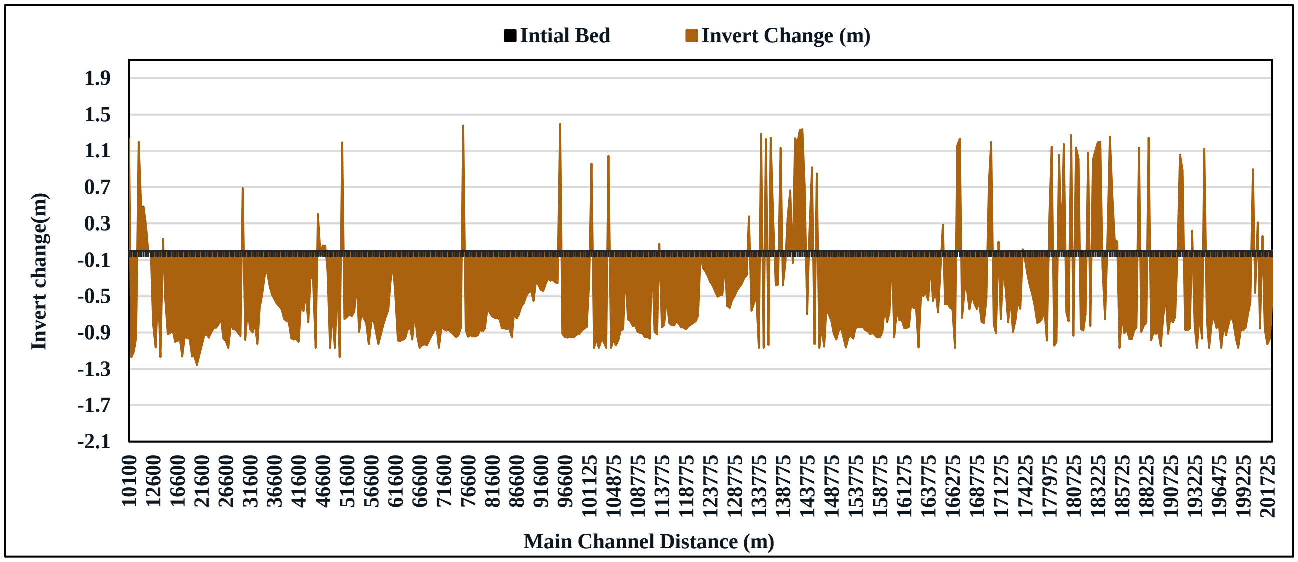


Figure 7. The cumulative invert change along the river for five years (1/1/2018-1/1/2023).

Fig.7 shows the cumulative invert change along Diyala River for five years; the invert change values varied from-1.25 to 1.4 *m*. The value of maximum sediment depth was 1.4 *m*, which was located in the center of the river, at station 94 *km*, and the deposit depth value upstream of the river was equal to 1.2*m*. The erosion depth values were ranged from 10 *cm* to 1.25 *m*.

3.2.1. Sediment quantity in Diyala River

The sediment transport model was operated by using hydraulic information for the year (2018-2019) to calculate sediment discharge in the Diyala River, and the results of the model were indicated in **Table1.** These results of the present study were compared with a previous study **(Al-Ansari, et al., 1986).** There was a difference between the results of the two studies. This was due to the large climatic changes and shortage of water over the years, the selected methods of managing the water resources between Hamreen dam and Derbandikhan, and water releases from the Diyala Dam, etc. These factors led to the increase in the rates of erosion and deposition as well as the change in the longitudinal slope of Diyala River that varied from 11 *cm/km* **(Al-Ansari, et al., 1986)** to 18*cm/km* from the present study.

Table 1. Sediment discharge in Diyala River for the period from 2018 to 2019.

Month	Mean water flowrate, Q, m^3/s	Day	Sediment discharge, Qs, ton/day	Sediment discharge, Qs, ton/month
Jun	104.16	30	45.40	1362.14
July	93.29	31	35.00	1085.06
Aug.	49.99	31	14.73	456.68
Sep.	93.29	30	51.92	1557.73
Oct.	19.16	31	46.52	1442.13
Nov.	19.16	30	14.98	449.67
Dec.	96.44	31	785.20	24341.23
Jan.	396.28	31	1097.62	34026.28
Feb.	396.28	28	326.42	9139.78
March	310.64	31	95.70	2966.77
April	601.16	30	91.09	2732.79
May	394.60	31	128.11	3971.60
Average	214.54	30	227.72	6960.99

The used values of flowrates to simulate the actual condition in the Diyala River were measured by MoWR from Jun 2018 to May 2019 and ranged from 19 to 601 m^3/s.The results showed that the daily sediment quantity varied from 14.73 to 1097.6 *tons/day*, and the average value of daily sediment discharge was equal to 227.7 *tons/day*. In contrast, the monthly sediment quantity values ranged between 449.6 and 34026 *tons/month*, and the mean value of monthly sediment discharge was 6961 *tons/month*. The yearly sediment discharge was 83531.93 *tons/year*. The flow rate values in the Diyala River ranged from 4 to 441 m^3/s that measured from Jun 1984 to May 1985 **(Al-Ansari, et al., 1986)**. The value of the daily sediment quantity varied between 1.5 to 561.5 *tons/day*, and the average value of daily sediment discharge was equal to 178.6 *tons/day*. The monthly sediment quantity values ranged between 45 and 15723.8 *tons/month*, and the mean value of monthly sediment discharge was 5335 *tons/month*. The yearly sediment discharge was 64022.5 *tons/year* in Diyala River from 1984 to 1985.

When comparing the present study and the previous study conducted by **(Al-Ansari, et al., 1986),** this study has larger values concerning the daily, monthly, and yearly sediment quantity, which were equal to 227.7 *tons/day*, 6961 *tons/month*, and 83531.93 *tons/year* respectively. These values in previous studies were 178.6 *tons/day*, 5335 *tons/month*, and 64022.5 *tons/year*, respectively.

4. IMPROVING THE DISCHARGE CAPACITY OF DIYALA RIVER WITHIN BAQUBAH CITY

The one-dimensional steady-state flow model was simulated with a flowrate value equal to 1300 m^3/s to increase the capacity of the river to endure the maximum flood wave. The model simulation results are presented in **Fig. 8** shows the longitudinal profile of the river before the treatment.

The flooded parts of the river within Baqubah City were divided into three parts to apply the required treatment. The first part was located upstream of the river reach in north of Baqubah City (from station 70 *km* to station 102 *km*), with a length equal to 32 *km*. The elevation of both sides of the river banks was increased at different parts of the reach distance. This solution was chosen since the dredging process is so difficult in this region of the river. The treatment of this part of the river is illustrated in **Table 2.**

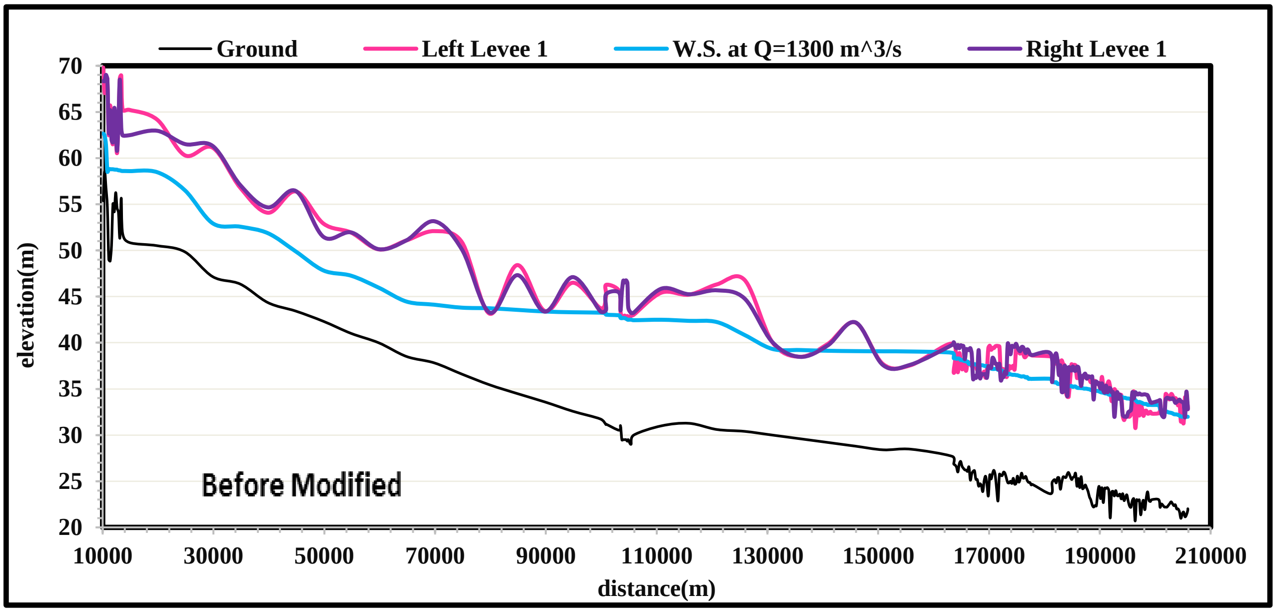


Figure 8. The longitudinal profile of the Diyala River before the treatment.

The second part was in the center of Baquabah City. The area was located between station 100 *km* and station 108 *km* with a length of 8 *km*. This region is considered the most important part that needs to be treated since this part is located at the center of the city with a high population, and there are many buildings and bridges along the selected reach of the river. For that reason, the applied treatment for this part is the combination of both dredging and increasing the elevation of some parts of the levee from the left side to pass the maximum flood discharge within this reach. **Table2** illustrates the treatment results for increasing the elevation of the riverbank for the selected station in the center of Baqubah. **Table3** illustrates the dredging treatment of the stations located in the center of Baqubah City. The third part was located downstream of Baqubah City between station 108 *km* to station 172 *km*, with a total length of 64 *km*. The elevation of both sides of the riverbank was increased to treat this part of the river because there was a levee on both sides of the river. The treatment of the downstream part of Baqubah City is presented in **Table 2.**

Table 2. Increasing elevations of the riverbank for selected stations within Baqubah City.

C.S	Sta1	Sta2	Dis	L.Levee	R.Levee	Location
27	80000	85000	5000	1.5	1.5	U/S of Baqubah
25	90000	95000	5000	1	1	U/S of Baqubah
22	99000	100000	1000	-	1.5	Center Baqubah
17	126000	131000	5000	0.25	0.25	D/S of Baqubah
16	131000	136000	5000	1.75	1.75	D/S of Baqubah
15	136000	141000	5000	0.25	0.5	D/S of Baqubah
13 to 12	146000	156000	10000	2.5	2.5	D/S of Baqubah
7.9-7.28	162500	172250	9750	1.5	1.5	D/S of Baqubah

Table 3. The dredged stations in the center of Baqubah City.

C.S	Bottom. Width(m)	Top. Width(m)	Channel Depth(m)	Side Slope	Cut Area(m^2)	Cut Volume(m^3)
21.8	100	147	12	2	391	97750
21.7	75	125	13	2	325	89456
21.6	100	180	12	2	373	87313
21.5	100	166	12	2	389	95260
21.4	75	167	13	2	237	78180
21.3	75	140	13	2	385	77716
21.2	75	119	13	2	405	98686
21.1	75	126	13	2	380	58848
21.0	75	126	13	2	311	172698

When the treatment was applied at the flooded regions, the capacity within Diyala River has reached a value equal to 1300 m^3/s and the value of freeboard equal to 1 m according to the criteria of the Bencol Engineering Consulting Office of the Ministry of Water Resources. **Fig. 9** shows the longitudinal profile of Diyala River after the treatment**. Fig. 10 and Fig. 11** show some of the treated cross-sections.

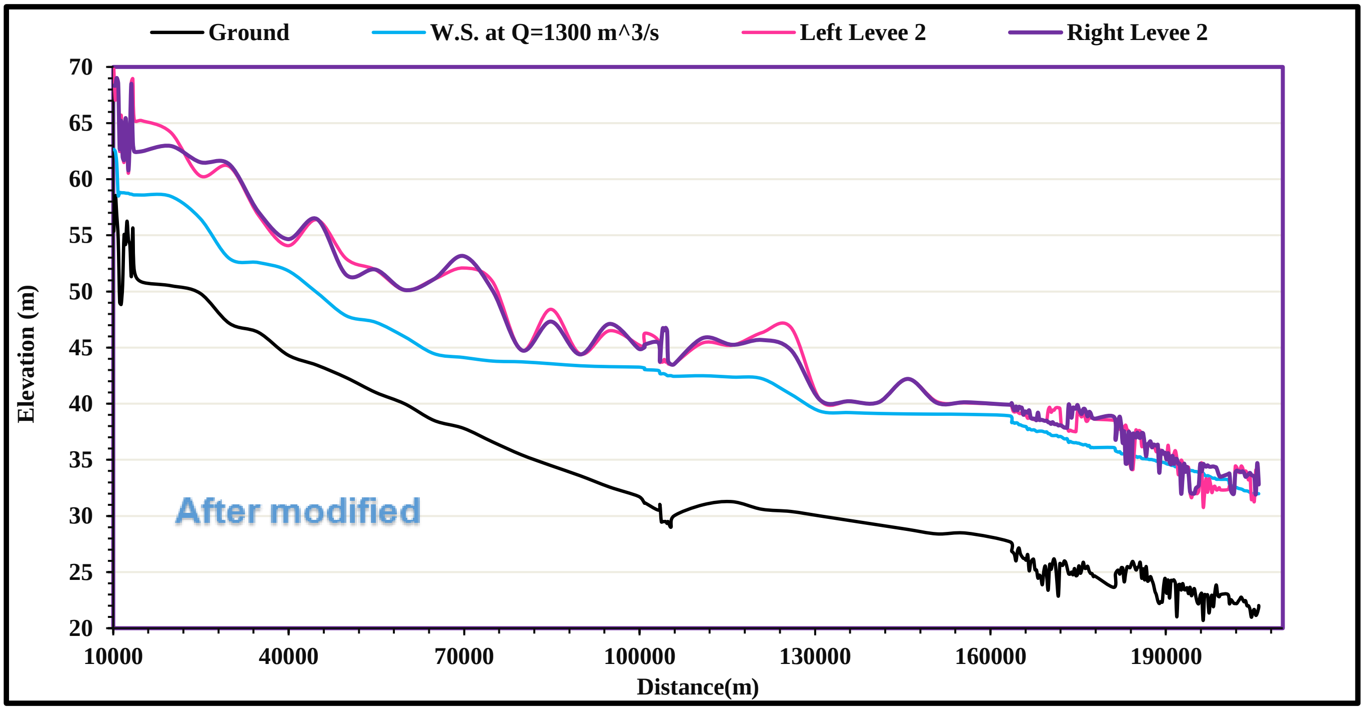
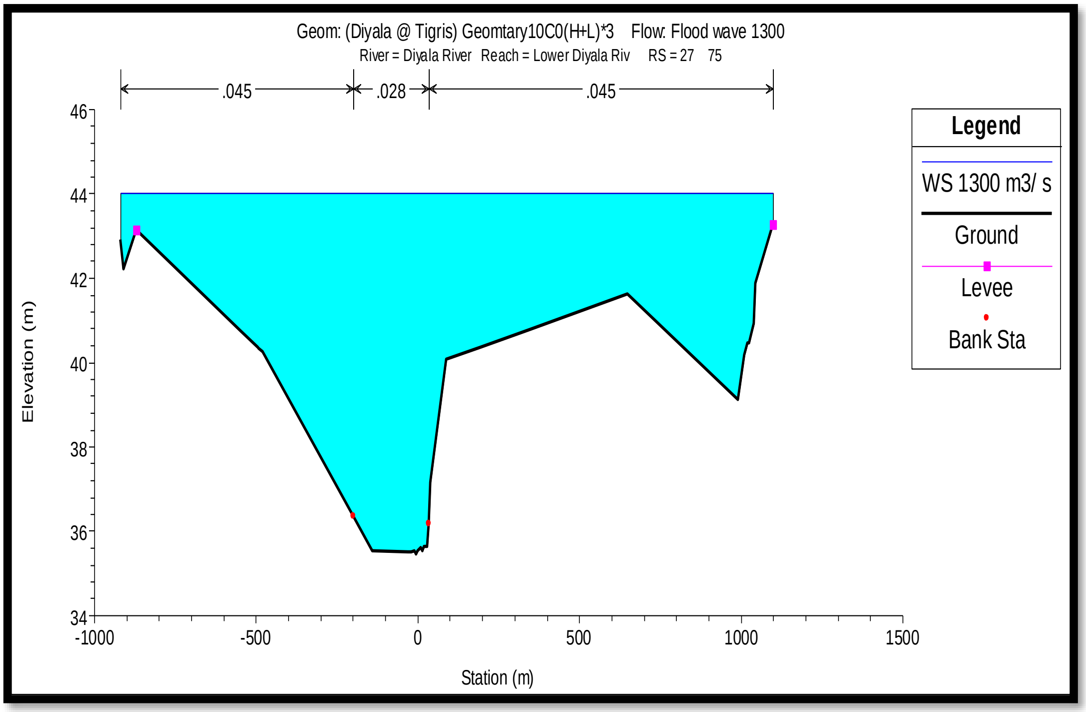
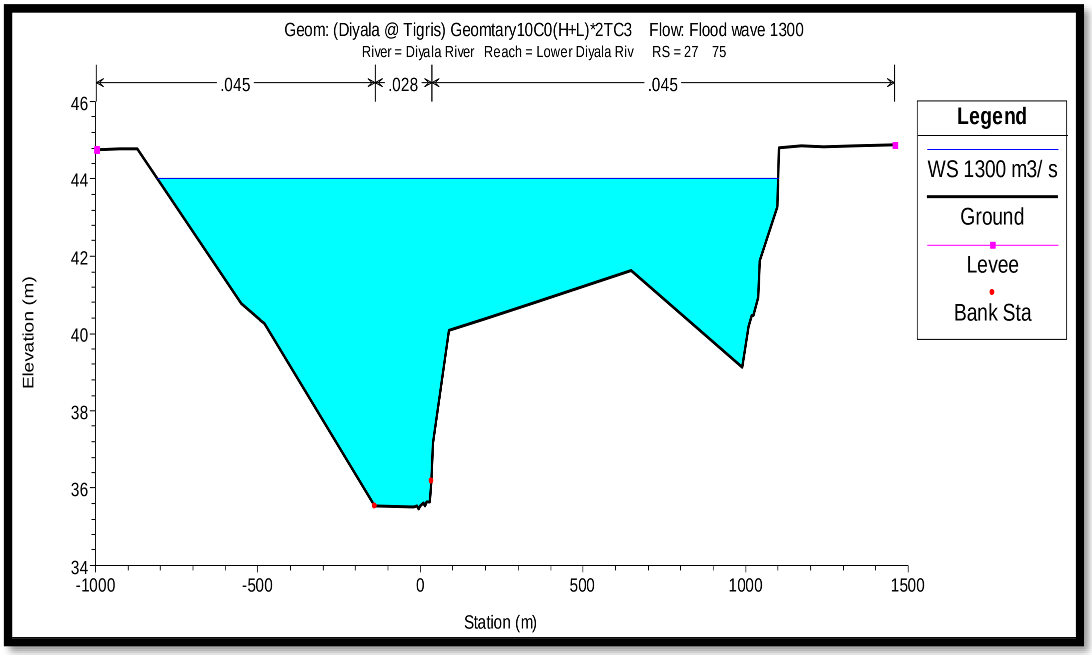


Figure 9. The longitudinal profile of the Diyala River after the treatment.

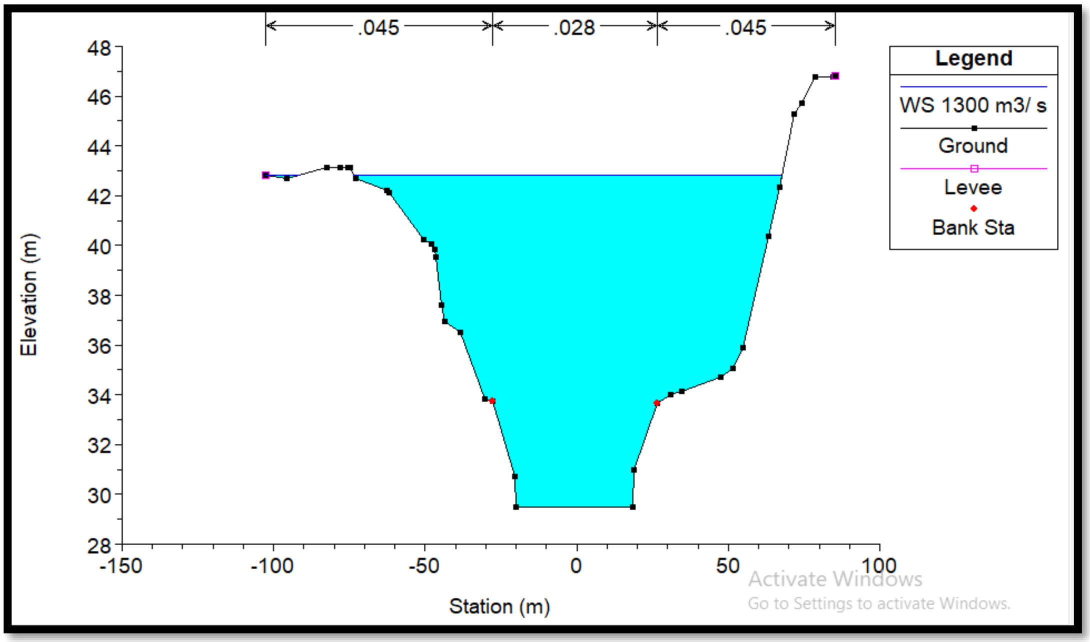


A: cross-section number 27 before the treatment.

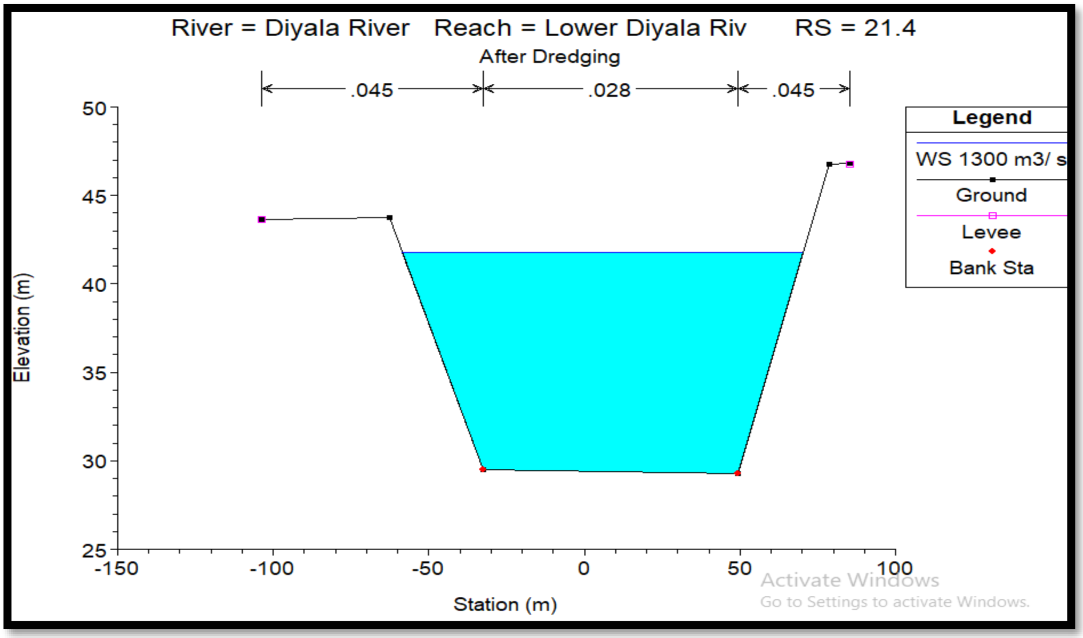


B: cross-section number 27 after the treatment.

Figure 10. The development for the river station upstream of Baqubah City, in (C.S 27).



A: cross-section number 21.4 before the treatment.



B: cross-section number 21.4 after the treatment.

Figure 11. The development for the river station center of Baqubah City, in (C.S 21.4).

5. CONCLUSIONS

From the obtained results of the present study, the following conclusions can be extracted

1. The calibration of the sediment transport model for five years shows that the maximum value of accumulated deposit depth along the river was equal to 120 *cm* for five years, which achieves an RMSE and the R^2 values of 0.1 *m* and 0.87, respectively.

2. The results of simulating the sediment transport model for representing the actual condition of the lower reach of Diyala River during the period extended from 1/10/2018 to 1/10/2019, the invert change values ranged from -0.2 *m* to 0.6 *m*
3. The simulation prediction results of the sediment transport model for the imposed period of Diyala River for five years present that the invert change values varied from -1.25 to 1.4 *m*.
4. The estimation of sediment loads for the actual condition in Diyala River from Jun 2018 to May 2019, the daily, monthly, and yearly sediment quantity, were equal to 227.7 *ton/day*, 6961 *ton/month*, and 83531.93 *tons/year*, respectively. These values were greater than the values estimated from previous studies due to climate changes in the region and their effects.
5. The flood issue of the river within Baqubah City was treated by simulating the model with a value of flowrate equal to 1300 m^3/s, and flooded parts were divided into three parts to apply the required treatment. The applied treatment for the first part located in the north of

Baqubah City increased the elevation of both sides of the river banks at some parts from the main distance. The applied treatment for the second part located in the center of Baqubah City was the combination of both dredging and increasing the elevation of some part of the levee from the left side. The applied treatment for the third part located in the south of Baqubah City increased the elevation of both sides of the river banks.

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