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Gravitational Force and Sediment Transport Relationship: Case Study, Dujila Irrigation Canal, Iraq

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Abstract

Since Al-Dujila canal hasn't been maintained in recent years, deposits have built up and reduced its flow capacity, which may cause significant operational issues in the future. Moreover, the Dujili Regulator's operation has changed the river's shape and hydraulic properties. This study uses HEC-RAS software to assess the hydraulics of flow, effect of slope on the amount of sediment in the canal and sediment transport over a 57 km stretch in the Al-Dujila canal between the Kut dam and Wasit township. One-dimensional simulations of the flow in steady and unsteady states under various hydraulic conditions have been conducted. Also, a one-dimensional sediment transport model was created utilizing the estimated values of Manning roughness for the steady and unsteady states in the Al-Dujila canal, which were 0.025 to assess the sediment capacity in the canal. The data required to run the sediment transport model, which ran from January 2022 to June 2022, was gathered through a series of field measurements. The observations that were put into practice included samples of the suspended load and bedload. Then, a number of laboratory experiments were carried out to gauge the river bed's soil composition and sediment concentration.

Keywords: Sediment Transport, HEC-RAS, Manning coefficient, Slope effect

الخلاصة: ادت عدم الصيانة في قناة الدجيلي خلال السنوات الماضية الى تراكم الرواسب مما قلل من قدرة تدفق قناة الدجيلي، والذي سيسبب في حدوث مشاكل تشغيلية كبيرة في المستقبل. وعلاوة على ذلك، فإن تشغيل ناظم الدجيلي قد أثر على الخصائص الهيدروليكية وكذلك على مورفولوجيا النهر. يهدف هذا البحث إلى تقييم هيدروليكية الجريان وانتقال الرواسب في قناة الدجيلي لمسافه ٥٧كم بين سدة الكوت وناحية واسط باستخدام برنامج HEC-RAS. قد تم محاكاة الظروف الهيدروليكية المختلفة في كل من الحالة المستقرة وغير المستقرة للجريان في بعد واحد. كما تم تطوير نموذج أحادي البعد لانتقال الرسوبيات لتقدير كمية الرواسب في النهر، بأستخدام قيم خشونة مانينغ المحسوبة للحالة المستقرة وغير المستقرة في الدجيلي التي كانت 0.025.تم إجراء سلسلة من القياسات الميدانية لجمع جميع البيانات اللازمة المستخدمة لمحاكاة نموذج نقل الرواسب الذي استمر من يناير ٢٠٢٢حتى يونيو ٢٠٢٢. وشملت القياسات المأخوذة عينات من حمولة القاع والرسوبيات العالقة. ثم أجريت عدة فحوصات مختبرية لتقييم كل من تركيز الرواسب وتكوين التربة لمجرى النهر

1. INTRODUCTION

One of the basic requirements for the progress, development and maintenance of civilization is access to abundant and economical water supplies So Water conservation has crucial, and river flow conditions must be analyzed to detect water consumption in the different seasons of the year by expect total demand and lowering the likelihood of both drought and floods. Most studies on the simulation of river flow parameters used physical and numerical models. The phenomena of sediment movement and hydraulic flow can be understood by numerical modeling. These models useful resources for planning and assessing engineering projects, ensuring the most effective use of water resources, and forecasting extreme events so that a warning can be given. To support the creation of the simulation model. To recreate the realistic phenomena, numerical models (1D to 2D to 3D) have been developed in recent years, because they are simple to calculate and calibrate, long river lengths can still be successfully predicted using 1D models since they can be computed quickly and only require a modest amount of hydrologic data for calibration and validation [1-3]. Assert that the variabilities alter when the peak flow occurs [4]. HEC-RAS is a helpful tool for modeling runoff based on the channel's morphology [5]. Sediment transport is routinely simulated using the HEC-RAS 1D model. Version 4.0 of HEC-RAS was the first to include calculations for 1D sediment movement [6]. The hydraulic properties of soil are influenced by interactions with a variety of different variables, including atmospheric, biological, hydrological, and geomorphological influences [7]. The HEC-RAS model was used to simulate the erosion and deposition in river reaches and reservoirs across a number of iterations [8]. Evaluated the mobility of silt for the Euphrates using 1D-dimensional HEC-RAS, Heet River to Haditha, they double-checked a ton of studies that calibrated the models using this form of sediment transport model calibration. Comparing the computed water surface elevations yielded the observed and appropriate Manning coefficient value (WSE) [9]. Developed a sediment transport model for the Karun River that faithfully depicts the river's present characteristics over a period of five years. Their model was used to identify significant locations as well as places that were at risk from erosion or deposition. Using a 1D dimensional hydraulic and sediment transport model [10]. The model was calibrated and validated using unsteady flow prior to predicting the hydro-morphological behavior of the river reach during the course of the study period A 2D analysis was suggested to forecast the lateral morphological alterations [11].

2. STUDY AREA AND DATA

The Dujila canal is located on the right side of the Tigris River and on the left side of the Al-Gharaf River, which extends from (32◦ 10‘- 32◦ 30‘ N) latitudes to (45° 50’ – 46° 20’ E) longitude (see Figure 1. The total area covered by this project is 155986 hectare (irrigated and non-irrigated lands). The estimated flow via the canal is 42 m^3/s. The Al-Dujila canal runs for 57 kilometers from Kut city to Wasit township The study's chosen reach begins in Kut dam and ends to Wasit township shakha 13.

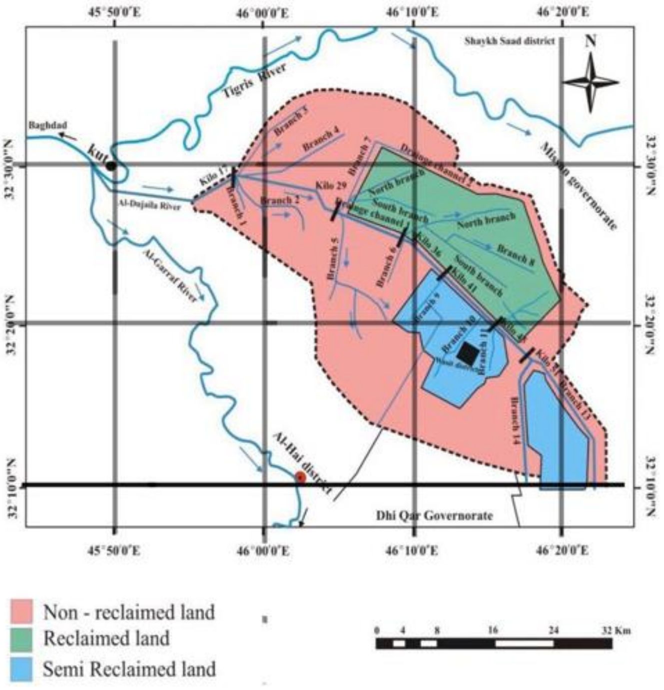


Figure 1 Location Map of the study area, (Directorate of Water Resources in Wasit, Ministry of Water Resources, 2010).

3. METHODOLOGY

To precisely replicate the sediment data analysis of a specific canal reach, the HEC-RAS 5.0.1 model needs a specific set of input data. Data on temperature, sediment/sediment load series, discharge, and gage height were all required. Calculating the water surface profiles is done to obtain the geometric information needed for 1D flow consideration. The HEC-RAS 5.0.1 model was created. Sediment analysis in HEC-RAS 5.0.1 uses 1D hydraulic characteristics based on sediment continuity analysis, sediment deposition analysis, and bed change analysis to calculate erosion. The simulation of sediment transport requires information on quasi-unsteady flow. The steps for pre-processing data and establishing the computational domain are described in the generic numerical modelling approach.

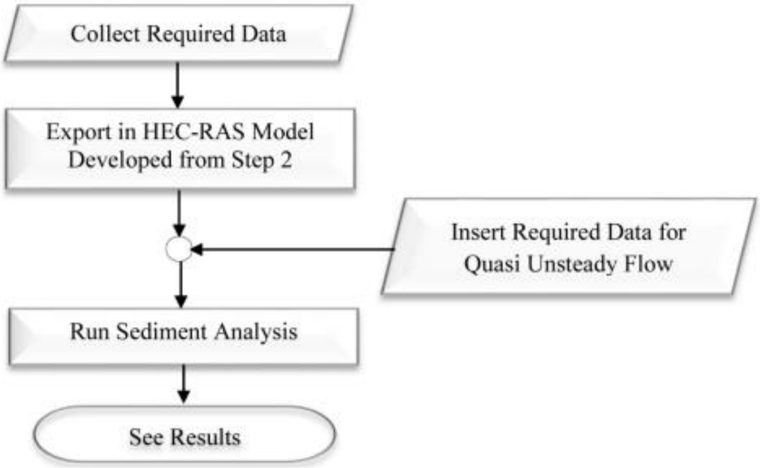


Figure 2 Simulating the sediment transport model

Geometric and hydrological data are acquired. The geometry of the canal segment as well as the border conditions upstream and downstream must be taken into account while doing a flow modeling with HEC-RAS. Additionally, the cross-sectional area, water speed, and canal release of each of the 57 sections of the Dujila Canal were calculated using the ADCP (acoustic Doppler flow profiler) tecniq SonTek Canal Tracker Surveyor (installed on a boat) The levels of each stretch of the Dujila canal were measured along 57 different sections using a level instrument. used the Van Veens grab to collect duplicates of canal bed models. In total, there were fifty-seven cross-sections encountered along the journey, as illustrated in Figure 3. Every cross-section was placed every 1 kilometer throughout the 57 kilometers of the canal.

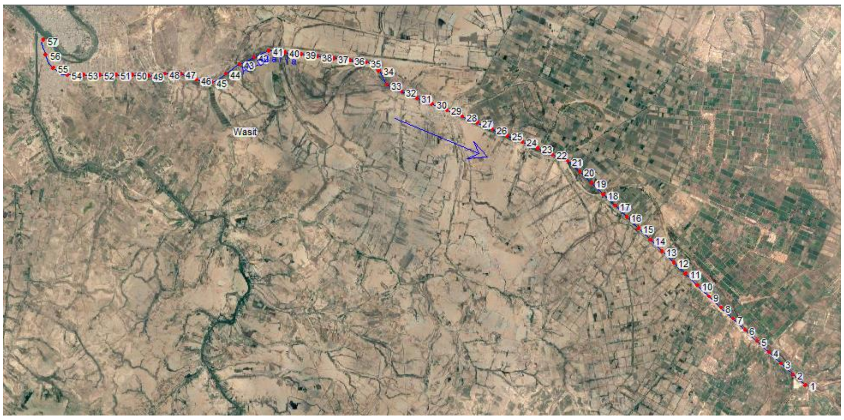


Figure 3 Google Earth satellite view of the Al-Dujila Canal's upper reaches.

Surveying works are shown in the Figure 4, 5 and 6

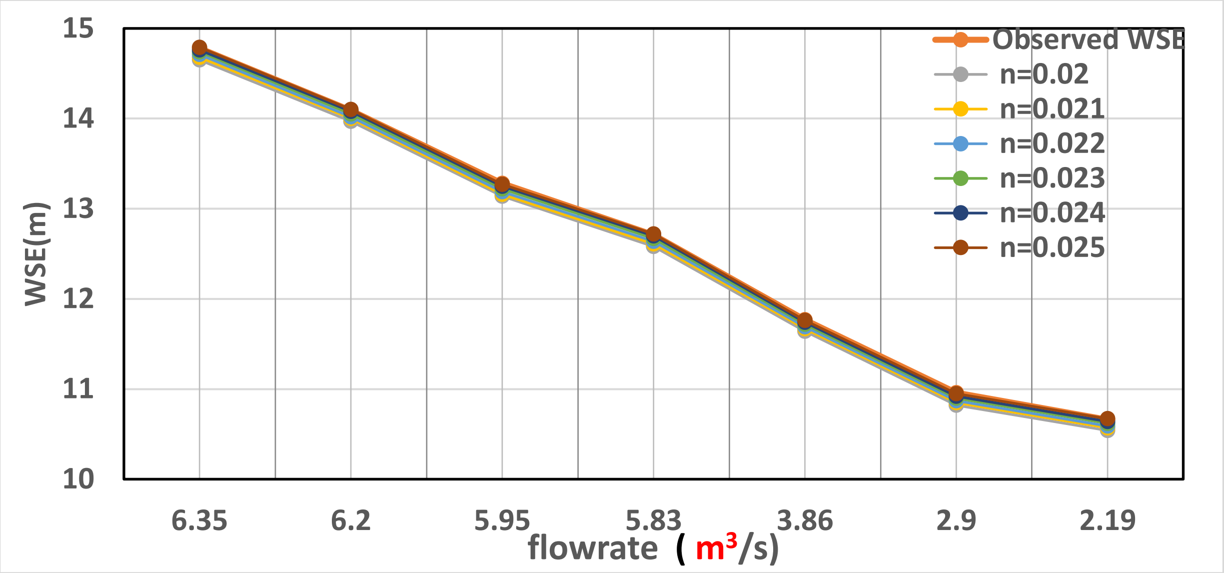
Figure 4 Survey work using Level and the boat to survey the inside of the canal.

Figure 5 Survey work using a level device.

Figure 6 Measuring the discharge and velocity of each section along the channel using ADCP.

The Manning's roughness coefficient (n) for the Dujila Canals is projected to fall between 0.02 and 0.03 in this simulation model. The anticipated level at 0.025 was the closest to the measured values, as shown in Figure 7, when the manning coefficients were investigated at 11 different values ranging from 0.02 to 0.03. The model is consistent with values of (n) produced by (n = 0.025).

Figure 7 Calibration of steady-state flow model in the reach of study



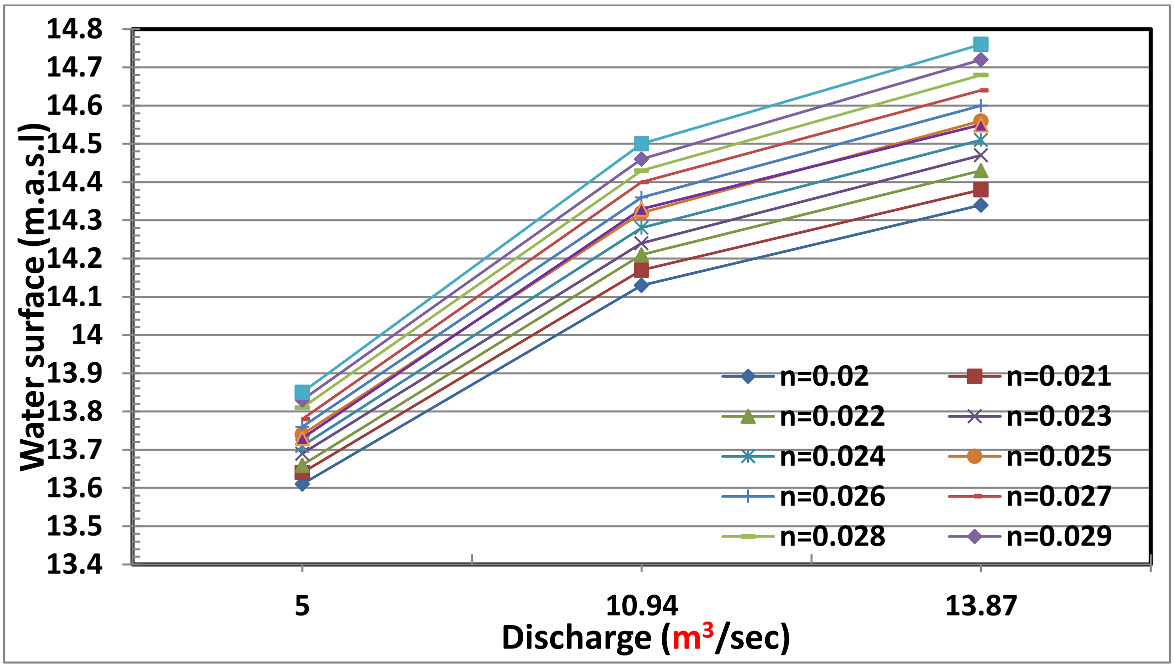


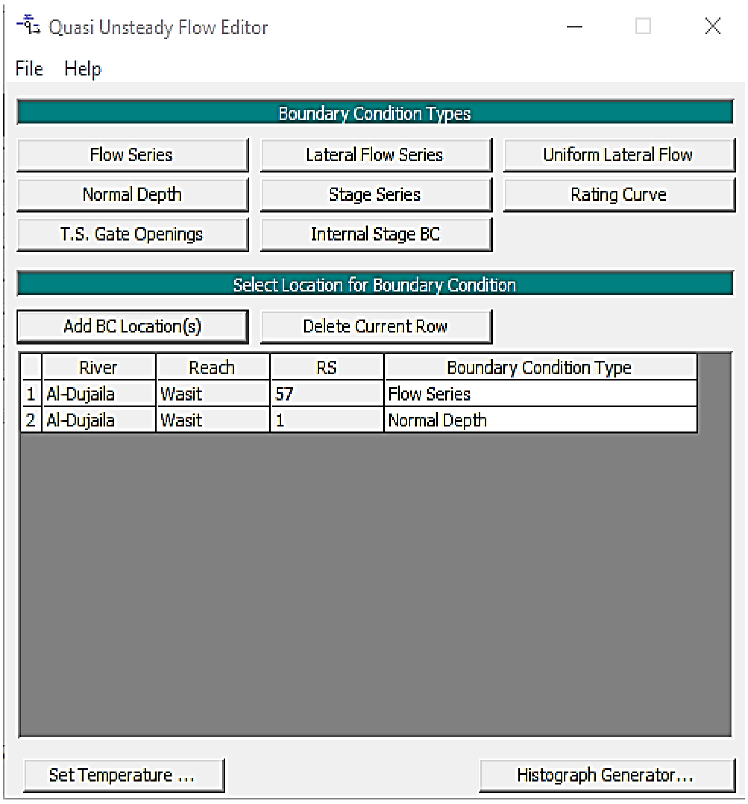
Figure 8 Calibration of unsteady-state flow model in the reach of study for the period from January to March in 2022 at Dujila Head Regulator

Table 1 Calibration Results' Statistical Test.

Number of (n) calibrated	Value of (a)	RMSE
1	n=0.02	0.1302
2	n=0.021	0.1019
3	n=0.022	0.0776
4	n=0.023	0.1251
5	n=0.024	0.0251

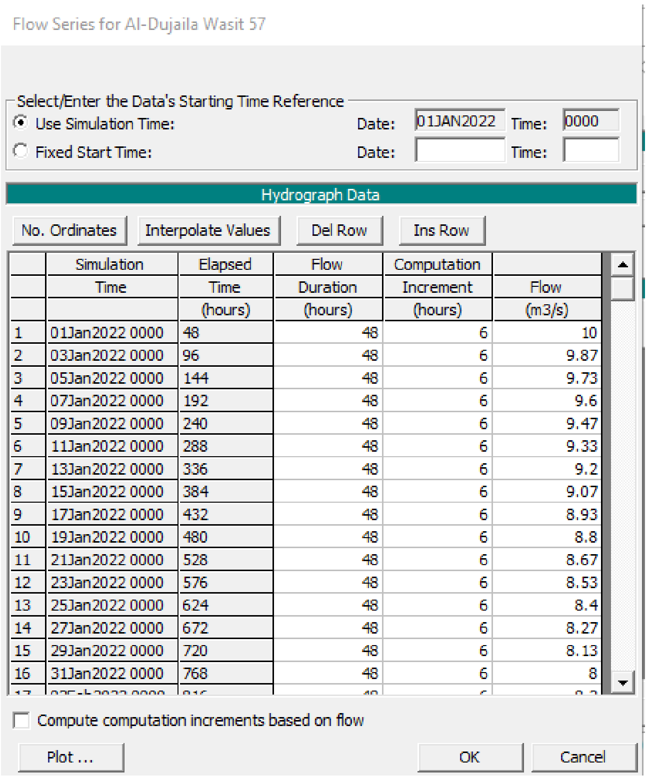
A statistical test on the recorded data must be used to validate the calibration technique. The RMSE test is used. The (RMSE) values from the statistical test for the calibration findings are also included in Table 1. These figures are derived from a comparison of the calculated and observed phases.

When it comes to quasi-unsteady flow, there are many alternatives. The flow series boundary condition, shown in Figure 8, was chosen as the upstream boundary condition, and the measured flowrates of the Al-Dujila Canal were then entered into the first model. (1/1/2022 to 1/6/2022) and were measured by MoWR during the field sampling period, with values ranging between (8 and 11 m^3/s) Figure 9. The temperature measured during the sediment sampling was 15°C, and the typical depth and energy slope value for the boundary conditions for canals were 7 cm/km. This served as the quasi-unsteady model's input data.



	River	Reach	RS	Boundary Condition Type
1	Al-Dujaila	Wasit	57	Flow Series
2	Al-Dujaila	Wasit	1	Normal Depth

Figure 9 Window of boundary conditions for quasi-unsteady flow.



Select/Enter the Data's Starting Time Reference

● Use Simulation Time: Date: 01JAN2022 Time: 0000

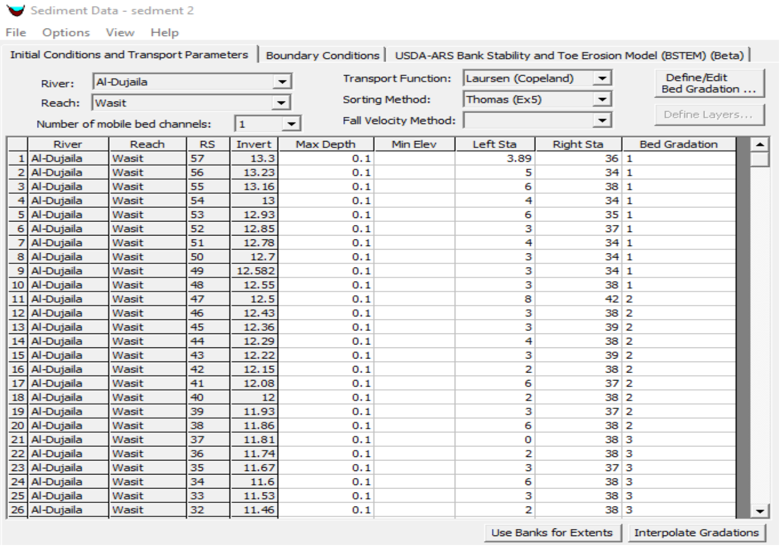
○ Fixed Start Time: Date: Time:

	Simulation Time	Elapsed Time (hours)	Flow Duration (hours)	Computation Increment (hours)	Flow (m3/s)
1	01Jan2022 0000	48	48	6	10
2	03Jan2022 0000	96	48	6	9.87
3	05Jan2022 0000	144	48	6	9.73
4	07Jan2022 0000	192	48	6	9.6
5	09Jan2022 0000	240	48	6	9.47
6	11Jan2022 0000	288	48	6	9.33
7	13Jan2022 0000	336	48	6	9.2
8	15Jan2022 0000	384	48	6	9.07
9	17Jan2022 0000	432	48	6	8.93
10	19Jan2022 0000	480	48	6	8.8
11	21Jan2022 0000	528	48	6	8.67
12	23Jan2022 0000	576	48	6	8.53
13	25Jan2022 0000	624	48	6	8.4
14	27Jan2022 0000	672	48	6	8.27
15	29Jan2022 0000	720	48	6	8.13
16	31Jan2022 0000	768	48	6	8

☐ Compute computation increments based on flow

Figure 10 Values from the Window of Flow Series.

To run the sediment transport model, data must be entered into the geometry file, the flow file with the chosen quasi- or unsteady flow type, and the sedimentation information file Figure 10. The sediment data file contains details on the canal station, a transport function, bed gradation, maximum depth or minimum elevation, sorting procedures, fall velocity techniques, and boundary conditions.



River: Al-Dujaila

Reach: Wasit

Number of mobile bed channels: 1

Transport Function: Laursen (Copeland)

Sorting Method: Thomas (Ex5)

Fall Velocity Method:

	River	Reach	RS	Invert	Max Depth	Min Elev	Left Sta	Right Sta	Bed Gradation
1	Al-Dujaila	Wasit	57	13.3	0.1		3.89	36	1
2	Al-Dujaila	Wasit	56	13.23	0.1		5	34	1
3	Al-Dujaila	Wasit	55	13.16	0.1		6	38	1
4	Al-Dujaila	Wasit	54	13	0.1		4	34	1
5	Al-Dujaila	Wasit	53	12.93	0.1		6	35	1
6	Al-Dujaila	Wasit	52	12.85	0.1		3	37	1
7	Al-Dujaila	Wasit	51	12.78	0.1		4	34	1
8	Al-Dujaila	Wasit	50	12.7	0.1		3	34	1
9	Al-Dujaila	Wasit	49	12.582	0.1		3	34	1
10	Al-Dujaila	Wasit	48	12.55	0.1		3	38	1
11	Al-Dujaila	Wasit	47	12.5	0.1		8	42	2
12	Al-Dujaila	Wasit	46	12.43	0.1		3	38	2
13	Al-Dujaila	Wasit	45	12.36	0.1		3	39	2
14	Al-Dujaila	Wasit	44	12.29	0.1		4	38	2
15	Al-Dujaila	Wasit	43	12.22	0.1		3	39	2
16	Al-Dujaila	Wasit	42	12.15	0.1		2	38	2
17	Al-Dujaila	Wasit	41	12.08	0.1		6	37	2
18	Al-Dujaila	Wasit	40	12	0.1		2	38	2
19	Al-Dujaila	Wasit	39	11.93	0.1		3	37	2
20	Al-Dujaila	Wasit	38	11.86	0.1		6	38	2
21	Al-Dujaila	Wasit	37	11.81	0.1		0	38	3
22	Al-Dujaila	Wasit	36	11.74	0.1		2	38	3
23	Al-Dujaila	Wasit	35	11.67	0.1		3	37	3
24	Al-Dujaila	Wasit	34	11.6	0.1		6	38	3
25	Al-Dujaila	Wasit	33	11.53	0.1		3	38	3
26	Al-Dujaila	Wasit	32	11.46	0.1		2	38	3

Figure 11 The window of inputs of sediment data.

4. RESULTS AND DISCUSSION

HEC-RAS was used to apply a hydraulic typical sample to a 57 km section of the Dujila Canal (n). Due to the roughness coefficient (n) of 0.025, there is a reasonable balance between the actual and anticipated water levels.

To select the most effective sediment transport equation, a sediment study was carried out after model calibration. In terms of data matching with field measurements, Laursen-Copeland equation, one of seven transport equations available in HEC-RAS, produced the best results. Therefore, another simulation using the Laursen-Copeland equation is chosen.

After the calibration and validation procedures have been finished, to model the current sedimentation conditions in the AL-Dujila Canal utilizing the gathered field data, the outcomes of sample testing, and the hydraulic data that were measured during the field measurement period 1/1/2022 to 1/6/2022. Figures 11 depict the Al-Dujila Canal's cumulative impacts of sedimentation over that time.

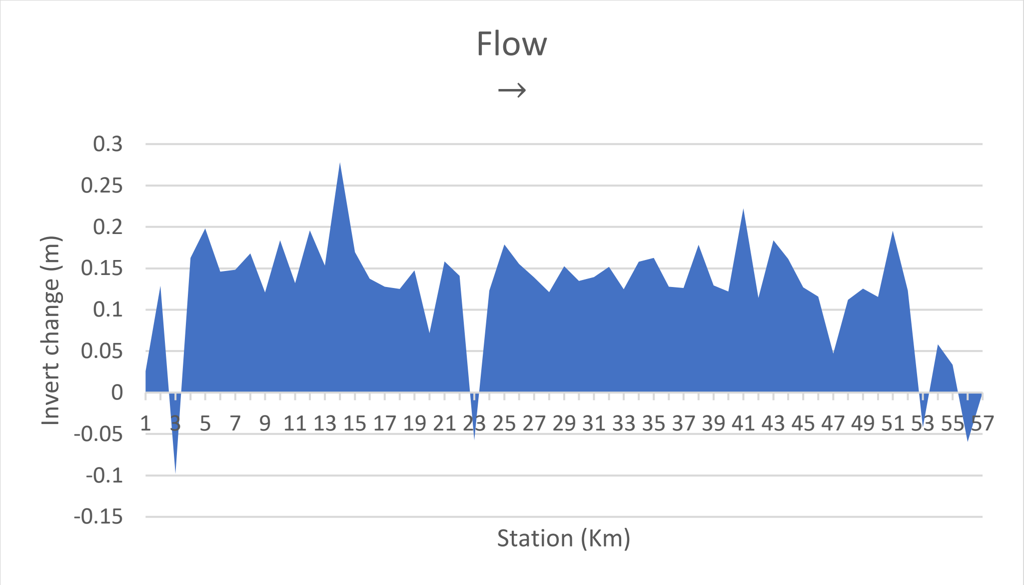


Figure 12 Accumulative changes of invert bed depth along the reach of the canal for the period (1/1/2022to 1/6/2022).

The invert change is the variation between the initial bed level and the anticipated bed level from the simulation model. Positive indicators imply sedimentation, while all negative signs in the tables and figures show erosion. The maximum sedimentation occure upstream of Dujila head regulator, at cross-section No. 13, with a depth equal to 27 cm, and the minimum sediment accumulation occurs downstream near Kut township at cross-section No.54, with a deposit depth of 5cm, scouring depths ranged between (5-8cm) during the time period studied. The sediment discharge was ranged between 5 to 36 tones/day.

The model has been testing several values of slope to find out the effect of slope on sediment transport the result was of increased sedimentation when the slope is reduced and decreased sedimentation when the slope is increased. The natural slope of the canal equal to 0.٠٠٠٠٧. Figure 13 and14 shown change in sedimentation with change in slope

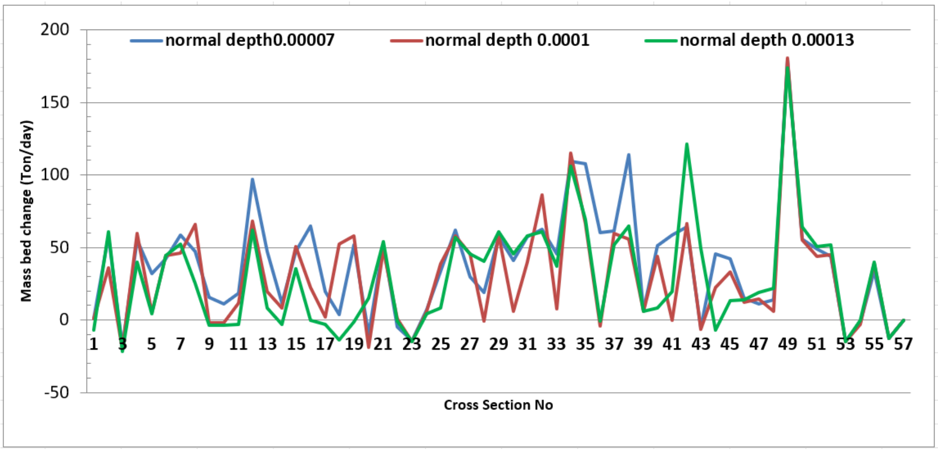


Figure 13 Show the change in sedimentation in the case of increasing slope.

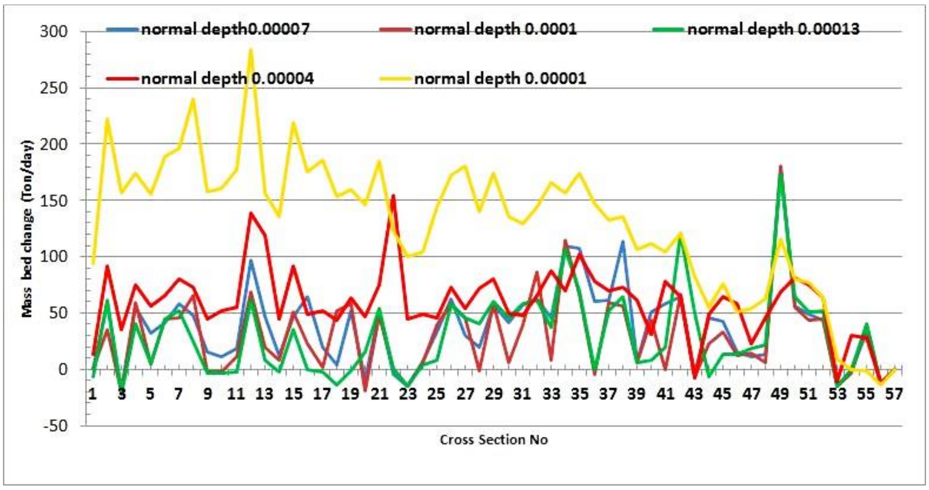


Figure 14 Show change of sedimentation in the case of decreasing and increasing slope.

5. CONCLUSION

The Dujila canal sediment simulation model was created between January 1 and July 1, 2022. The key findings of this study are as follows:

- The sediment discharge was accurately computed using the Lursien equation.
- There is an uneven distribution of sediment in the reach.
- Changing the slope of the channel causes a change in sedimentation.

The falling bed tendency must be taken into consideration before any hydraulic structure is built. Along with the effect of the bed shift, this model might also show how sediment dispersion across the reach affects the area. The predicted capacity of this model's sediment transfer could be helpful for long-term canal management. It will be beneficial to develop a more reliable model to forecast the sediment scenario in the future. For this, it would be necessary to use bed load and sediment load gradation data from additional reach cross-sections. In order to make informed decisions about water management, sedimentation analysis is crucial in determining the capacity of the canal reach, the nature of the canal, and the characteristics of the canal's morphology. In determining which canal engineering elements would best limit sediment erosion or deposition and, as a result, lower the danger of economic instability brought on by effects on bank infrastructure, policymakers and water managers would also profit from the study's conclusions. Stream bank stabilization may be one of the most efficient techniques to reduce erosion rates for such canal sections. Aquatic environments, such as those for fish, plants, macroinvertebrates, etc., will also require it. Sediment analysis studies are essential for hydraulic infrastructure such as dams, bridges, irrigation canals, and navigational needs. Therefore, in order to help the planning and management sectors make better and more sustainable environmental decisions, information on sediment properties is provided.

REFERENCES

1. Horritt, M., Bates, P. (2002). Evaluation of 1D and 2D numerical models for predicting river flood inundation. *Journal of hydrology*, ***268***(1-4), 87-99.
2. Panin, N., Jipa, D. (2002). Danube River sediment input and its interaction with the north-western Black Sea. *Estuarine, Coastal Shelf Science*, ***54***(3), 551-562.
3. Werner, M. (2001). Impact of grid size in GIS based flood extent mapping using a 1D flow model. *Physics Chemistry of the Earth, Part B: Hydrology, Oceans Atmosphere*, ***26***(7-8), 517-522.
4. Kalra, A., Sagarika, S., Pathak, P., Ahmad, S. (2017). Hydro-climatological changes in the Colorado River Basin over a century. *Hydrological Sciences Journal*, ***62***(14), 2280-2296.
5. Thakur, B., Parajuli, R., Kalra, A., Ahmad, S., Gupta, R. (2017). Coupling HEC-RAS and HEC-HMS in precipitation runoff modelling and evaluating flood plain inundation map. World Environmental and Water Resources Congress 2017,
6. Brunner, G. W., Gibson, S. (2005). Sediment transport modeling in HEC RAS. In *Impacts of global climate change* (pp. 1-12).
7. Ford, T. W., Quiring, S. M., Thakur, B., Jogineedi, R., Houston, A., Yuan, S., . . . Lock, N. (2018). Evaluating soil moisture–precipitation interactions using remote sensing: A sensitivity analysis. *Journal of Hydrometeorology*, ***19***(8), 1237-1253.
8. Moradinejad, A., Haghabi, A. H., Torabi, H., Jabari, A. (2014). Qara-Chai River sediment survey of the Markazi province numerical model HEC-RAS. 4. *International Research Journal of Applied Basic Sciences*, ***8***(10), 1628-1636.
9. Mustafa, A. S., Sulaiman, S. O., Al_Alwani, K. M. (2017). Application of HEC-RAS model to predict sediment transport for Euphrates River from Haditha to Heet 2016. *Al-Nahrain Journal for Engineering Sciences*, ***20***(3), 570-577.
10. Haghiabi, A. H., Zaredehdasht, E. (2012). Evaluation of HEC-RAS ability in erosion and sediment transport forecasting. *World Applied Sciences Journal*, ***17***(11), 1490-1497.
11. Nistoran, D. G., Ionescu, C., Pătru, G., Armaş, I., Omrani, Ş. G. (2017). One dimensional sediment transport model to assess channel changes along Olteniţa-Călăraşi reach of Danube River, Romania. *Energy Procedia*, ***112***, 67-74.