University of Baghdad
College of Engineering

Journal of Engineering

journal homepage: www.joe.uobaghdad.edu.iq

Volume 29 Number 3 March 2023

Roughness Coefficient in Euphrates River Reach between Haditha Dam to Ramadi Barrage

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ABSTRACT

Accurate computation of the roughness coefficient is important in the studies of open channel flow. To measure and identify the hydraulic characteristics of the flow system, the model simulation is necessary to study and get the results of the hydraulic properties to specify the Manning coefficient of the Euphrates River. In this study, the reach is extended along the Euphrates River from Haditha Dam to Ramadi Barrage with a distance of 169km. The HEC-RAS model was implemented to simulate the flow within the study reach. The geometry of the river was represented by more than two hundred cross-sections surveyed in 2013 and 2021. The model was calibrated using some observed discharges at the Heet gage station for records of the last five years. The Model was validated using five sets of observed water levels in different cases of manning coefficient in the model. The Root Mean Square Error (RMSE) was used for comparison of the model results. Results of the model showed that the roughness coefficient value for this reach is 0.026 for the river bed and 0.030 for the River bank. These values gave the best coincidence between the simulated and observed values of water levels.

Keywords: HEC RAS, RMSE, Manning coefficient, Euphrates River.

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Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2023.03.08

Article received: 12/12/2022
Article accepted: 01/02/2023
Article published: 01/03/2023

تحديد معامل الخشونة لنهر الفرات من سد حديثة لغاية سدة الرمادي

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الخلاصة

يعتبر تقدير معامل الخشونه مهم لأي دراسة تتعلق بالجريان في القنوات المفتوحة , من خلال معرفة الخصائص الهيدرولوجية للجريان. تناولت هذه الدراسة اختبار معاملماننك لامتداد نهر الفرات بين سد حديثة وسدة الرمادي بطول 169 كم من خلال تطوير نموذج هيدروليكي أحادي البعد بأستخدام برنامج HEC–RAS لنمذجة جريان الماء في النهر وباستخدام اكثر من مئتي مقطع للنهر تم مسحها بين سنة 2012 و2021. تمت معايرة النموذج باستخدام بعض التصاريف المرصودة لاخر خمس سنوات في محطة قياس مدينة هيت حيث تمت مقارنتها بمجموعه من المناسيب وبأستخدام قيم مختلفه من معامل ماننك. اشارت نتيجة المعايرة بأن أقل معدل للجذر التربيعي للخطأ في المناسيب المقاسة والمقدرة يساوي 0.267. بينت النتائج بأن استخدام معامل ماننك 0.026 لقاع النهر من سد حديثة ولغاية سدة الرمادي و 0.03 للمجرى الفيضاني لكل الامتداد.أعطت هذه القيم أفضل تطابق بين قيم المناسيب المرصودة والمقدرة.

الكلمات الرئيسية: نهر الفرات، نموذج HEC–RAS ، معامل ماننك ، معدل الجذر التربيعي للخطأ.

1. INTRODUCTION

The Euphrates River is one of the largest rivers in southwestern Asia. The river originates from the Taurus Mountains in Turkey. The Euphrates River flows to the southeast and joins its many branches before passing through the Syrian borders. In Syria, the Euphrates is fed by Al-Bleekh and Al-Khabur Rivers. After that enters the Iraqi border at Anbar province from Al Qaim city and passes through several Cities before it entered Ramadi city. The headwater of the river is at an elevation of about 3000 m.a.m.s.l. and its ends at Al Qurnah at a level of a few meters above the mean sea level. The basin of the Euphrates River is about 444000km^2. The Euphrates River passes within Iraqi provinces for a length about of 1160 km. Haditha Dam and many regulators have been built along the reach of the Euphrates River in Iraq **(Al-Ansari, et al., 2018).**

Haditha Dam was constructed for storage purposes and to produce electrical power, and some regulators were carried out for irrigation purposes and control the flood-like Ramadi Barrage and Al-Warrar regulator representing flow in open channels like rivers need an estimation of the resistance of river flow which is generally related with roughness value, this value can be simulated by Manning's coefficient (n). So, it requires obtaining the best value of this coefficient that can give the most accurate simulation for the river flow **(HEC-RAS User Manual, 2021).** This is an essential step in any simulation in an open-channel system. The manning coefficient can consider important sensitive properties in generating hydraulic models for computing the profile of the water surface. It is not easy to specify the roughness coefficient (n) directly from field measurements, and therefore, it is required to be estimated. Some factors affect the estimation of this coefficient for a natural channel. These factors were namely; surface manning coefficient like the irregularity of the channel, vegetation, the conditions of the flow, etc.

Different methods for computing the roughness coefficient were conducted by some researchers. **(Hameed and Ali, 2013)** worked on a hydraulic model to estimate the roughness coefficient of the Shatt Al-Hilla River. In this study, the HEC-RAS software was applied to simulate the unsteady flow in the Shatt Al-Hilla River to predict the roughness coefficient value through the calibration procedure. The study reach started from the head regulator of Shatt Al-Hilla to Glyuen canal, and five irrigation canals branched from the left side of the reach (Mahaweel, Khatoniya, Fandiya, Neel, and Babil). The data were collected for the period between 20 August 2008 and 12 September 2008 were used for the calibration and verification of the model to estimate the coefficient. The model was calibrated with varied values of the manning coefficient from (0.025 to 0.03). The study result indicated that the suitable value of Manning's coefficient (n) is (0.027), which is giving good agreement with the observed and computed hydrographs. **(Parhi, 2013)** conducted a hydraulic model using HEC RAS software to specify the manning coefficient for the Mahanadi River in Odisha in India. It was found that from the model simulation the value of Manning's coefficient "n" can be used for Khairmal to the reach between Mahanadi and Barmul is 0.029. The study verified that there is an error of about 5.42% in computing the flood discharge in the model observed in 2006 by applying the manning value with (0.029).

(Hatzigiannakis, et al., 2015) conducted research to study the changing of the Manning roughness coefficient in the river Strymonas in Northern Greece. This study aims to specify the difference in the coefficient of roughness (n) with distance and time. The study was carried out within the river Strymonas. This river extends into the Serres plain in the Northern part of Greece. The velocity measurements and the geometric properties had been conducted in three different locations along the river. The results of the measurements appeared that the variation in the Manning coefficient along the three locations in the river with the discharge and the depth of flow in each section. **(Al. Khuzaie, et al., 2018)** carried out a one-dimensional model to compute Manning's Coefficient of the Euphrates River. The study area covered the reach of the Euphrates River which is pass through Al Muthanna Governorate, the length of the study's reach extends about 110 km and passes through five towns which are (Al Majid, Al Khidhir, Al Hilal, Al Drajae, Al Samawa). The model was carried out using HEC-RAS software, and the input data of Manning's coefficient for open channels at an initial value between 0.025 and 0.04. The model was calibrated by operating for different flow rates from 51.67 m^3/sec to the maximum of 148.39 m^3/s upstream of the river through May 2017. The result of the study referred that the roughness coefficient is equal to 0.04 which is the best coincidence with the model.

Generally, this study is carried out to estimate the roughness coefficient (n) for the Euphrates River along with the distance from Haditha Dam to Ramadi Barrage. The study reach of the river is with long of 160 km in length and there is a lack of data about the manning coefficient (n) in this reach.

2. THE STUDY REACH

The part of the Euphrates River reach is located from Haditha Dam to Ramadi Barrage, as shown in **Fig. 1.** The length of the reach is about 160 km long. Haditha Dam and Ramadi Barrage are the main structures that control the flow of the Euphrates River within the study area. The level of the levee of the Euphrates River downstream of Haditha Dam is close to 110 m.a.m.s.l. This level of the levee gradually decreases to 54 m.a.m.s.l. at Ramadi Barrage, The longitudinal slope of the water surface within the study reach is approximately 30 cm/km.

There is one lateral outflow along the study reach called Al-Warrar canal which is located 500 m upstream of Ramadi Barrage, this outflow protects Ramadi city from the danger of flood. The reach of the study includes five valleys that feed the Euphrates River in the rainy season. These valleys are (Haditha, Al-Baghdadi, Sahiliya, Al-Marj, and Al-Mohammadi). The maximum discharges of these valleys are presented in **Table 1**, **Farhan and Al-Thamiry, 2020.**

Table 1. Detailed information for inflow and outflow tributaries through the reach under consideration (**Farhan and Al-Thamiry, 2020).**

Station Km	Tributary	Type
13+500	Haditha Vleys	inflow
53+500	Al Baghdadi – Valleys	inflow
95+000	Sahiliya Valley	inflow
98+500	Al- Marj Valleys	inflow
125+000	Al -Mohammadi Valleys	inflow
168+000	Al -Warrar canal	outflow

Figure 1. The reach of the Euphrates River from Haditha Dam to Ramadi Regulator.

3. THE NUMERICAL MODEL

The widely-used software that was a product from the United States Army Corps of Engineers- Hydrologic Engineering Center's River Analysis System, HEC-RAS 6.1, has been implemented for analyzing and simulating the flow in rivers, lakes, and any open channels. This software is also too much effective in simulating water quality and sediment transport. The steps of determining the gradually varied flow unsteady and steady-state in a one-dimensional model with HEC-RAS Software depend on the standard step method to get the energy grade lines and water-surface levels. It is a refined solution of open channel hydraulics principles equations, such as the flow resistance equation, the continuity equation, the energy equation, and the Froude Number. Descriptions and details of the standard step method that is applied in HEC-RAS software can be found in HEC-RAS User manuals, U.S. Army Corps of Engineers, 2021.
The required data to generate a model of the steady and unsteady flow in the HEC-RAS software are including complete cross-sections along the study reach, information on discharges and water levels at the boundary, the Manning's coefficient of roughness. The details of the results will be presented in figures or tables including cross-section details and longitudinal profiles, in addition to other components of the results.

4. RESULTS AND DISCUSSION

The roughness coefficient (n) is varying along the river according to the condition of the flood plain and channel. These conditions are known as stage-discharge, surface roughness, channel irregularity, and vegetation. The value of manning (n) will be large at high stages when the banks are grassy and rough, however, the Manning coefficient decreases when the flow rate gradually increases (**Chow**, **1959)**.
Different values of the roughness coefficient (n) were estimated for the flood plain and the main channel to trail and analyze their influence on the water surface level. These values vary between 0.020 and 0.030. Two flow rates were used in the sensitivity analysis that is 200 m^3/s and 1200 m^3/s discharged from Haditha Dam.
Figs. 2 and **3** show the results of sensitivity analysis for the Euphrates River within the study reach. The water level elevation gained with various values of roughness coefficient (n) and for a discharge of 200 and 1200 m^3/s, respectively. With some runs of the model in HEC-RAS software, the sensitivity results showed that the variation between the site records and the determined water surface in the model can be raised depending on the records data at Heet gage station which is located in Heet city. This city is far about 110 km downstream of Haditha Dam, and 50 km upstream of Ramadi Barrage, the analysis appeared that when the flowrate is 200 m^3/s, the average water level is raised by about 0.03 m as the Roughness Coefficient (n) is increased at the step of 0.001 within the range of (0.020 to 0.030), and at a flowrate of 1200 m^3/s the water level is increased 0.06 m at the step of 0.001 within the range of (0.020 to 0.0030).

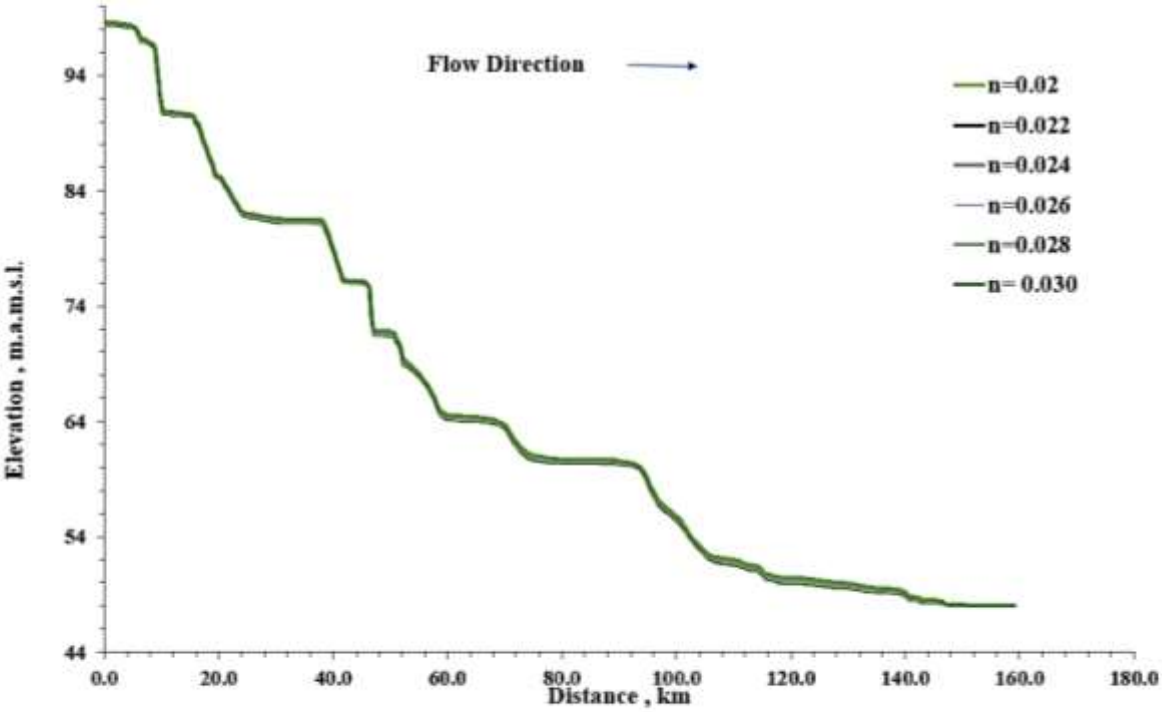

Figure 2. The water surface profile along the Euphrates River within the study area with different roughness coefficients (n) and a flow rate of 200 m^3/s.

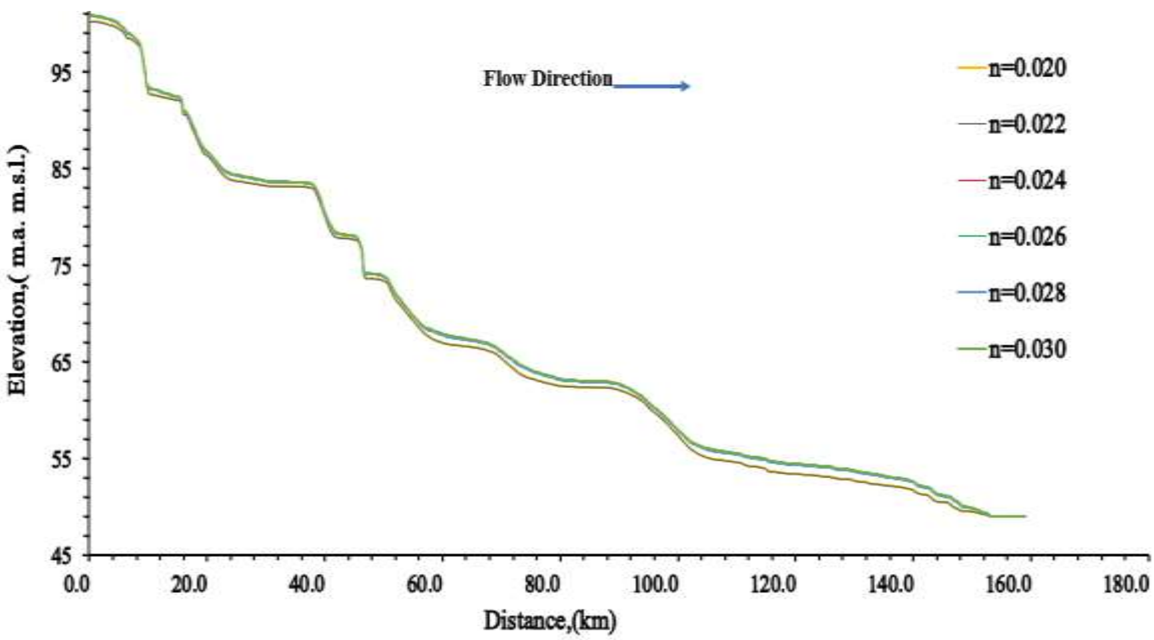

Figure 3. The water surface profile along the Euphrates River within the study area with different roughness coefficients (n) and a flow rate of 1200 m^3/s.

Table 2 displays the computed values of (RMSE) using various values of Roughness' coefficient (n) throughout the calibration process straight to the reach between Haditha Dam and Al-Ramadi Barrage. The process was operated by the data with a discharge varies from 200 m^3/sec to 1200 m^3/sec flows from Haditha Dam and for the data records along the study reach for the last five years at Heet gage station. The minimum value of RMSE was 0.267, it was gained when using Roughness coefficient (n) 0.026, for the reach (Haditha Dam –Al Ramadi Barrage). The flood plain of the whole reach under study was 0.030.

Table 2. RMSE results of calibration test.

Case No.	Part of the channel	Manning's coefficient "n" Haditha Dam-Al Ramadi Barrage	RMSE
C1	Main reach	0.022	0.367
	Flood plain	0.030	
C2	Main reach	0.024	0.297
	Flood Plain	0.030	
C3	Main reach	0.026	0.267
	Flood Plain	0.030	
C4	Main reach	0.028	0.308
	Flood plain	0.030	
C5	Main reach	0.030	0.390
	Flood plain	0.030	

The calibrated value of the roughness coefficient was verified using some discharges that were recorded in the Heet gage station as shown in **Table 3**, it appears that the water surface profile for the verification process. The results showed a good coincidence between the records data with the measured in the model in applying manning (n) as in (C3) with an RMSE of 0.267.

Table 3. Comparison among the simulated water levels with Roughness coefficients of 0.026.

Calibration Case No.	Discharge (m^3/s)	Water surface elevation, m.a.m.s.l.	
		Records	Simulated
C3	200	52.15	52.27
	375	53.02	53.08
	480	53.23	53.47
	600	53.72	53.92
	800	54.88	54.49

5. CONCLUSIONS

The HEC-RAS model is one of the common codes that can be implemented for hydraulic modeling. This model can be applied successfully in simulating the river flow and water surface profile. From the results of the hydraulic model of the Euphrates river from Haditha Dam to Ramadi barrage, it can be concluded the below:

1- The best agreement between the observed water surface with the computed in the model can be gotten with Manning's coefficient of (0.026) for the main channel, and (0.03) for the flood plain.
2- The results of the sensitivity analysis for low and high discharges showed that the average water level is raised by about 0.03m the roughness coefficient (n) is increased at the step of 0.001 within the range of (0.020 to 0.030).

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