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A Hydraulic Model for Identification of Surface Friction Coefficient for Euphrates River within Al Muthanna Governorate, Iraq

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ABSTRACT

This study presents results of a developed hydraulic model to the surface friction roughness (Manning's coefficient) for the Euphrates River along 110 km within Al Muthanna Governorate, Iraq. Hydraulic modeling was used a tool for determination of surface friction coefficient. A typical value of surface friction roughness for open natural channels ranges between 0.025 to 0.04 was used as an initial input data for HEC-RAS hydraulic model. while in this study the calculated value of the surface roughness was compared with those observed and it was found to be in best agreement with the modeled when using value is 0.04.

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Introduction

Simulations of flow in rivers require an evaluation of the river flow resistance that generally is related with roughness value which can be described by Manning’s coefficient, (n). So, it requires obtaining an exact value of this coefficient. This is of essential step in any open channel flow study. The roughness coefficient may consider as the most sensitive parameter in developing hydraulic models for predicting water surface profile [1]. It is difficult to measure (n) directly from field observation and therefore it needs to be estimated. Several factors affect the estimation of this coefficient for a natural channel. These factors were namely; surface roughness characteristics, vegetation, channel irregularity, flow conditions etc., [2, 3].

Different methods for determination of (n) were investigated by a number of researchers. Ramesh et al. determined roughness value in open channel system using an embedded optimization method, with constraints in boundary condition, using wide rectangular channel with the same characteristics of large natural channels in India [4]. The optimal problem solved using complex method, depending on optimal model and it was applied on the flow of complicated channel network in the lower reach of the Yangtze River in China [5].

The roughness value of Parit Karjo channel in Malaysia was estimated using Manning's equation and flow rate of the channel was also calculated by mean-section method. It was found that roughness value ranges from 0.04 to 0.48 [6].

Abdul Hameed presented four methods to estimate roughness coefficient (Manning's, Bajorunas, Einstein, and Kennedy) for Euphrates River at Falluja regulator in Iraq [7]. Then it was noticed that Einstein and Bajorunas methods gave results closer to the reality than the others.

Nowadays, quick advancement in computer technologies and numerical techniques speed up the development of hydraulic modeling. These techniques for constructing surface profiles of the natural open channel, such as river, were developed [8]. HEC-RAS software is one of much software adopting for hydraulic modeling. This software is used successfully in modeling surface water profile. HEC-RAS was used by a number of researchers. Parhi has developed HEC-RAS flow model to calibrate river roughness for flood flow of years 2001, 2003 and 2006 [1]. He used Nash and Sutcliffe efficiency test for comparison between simulated and observed flow hydrographs and found that best estimate (n) value to be 0.029. Doherty used HEC-RAC model calibration to estimate channel roughness value for developing rating curves in large alluvial channels Western Australia [9]. Timbadiya et al. depended on HEC-RAC model to calculate different values of roughness, using single value for upper and another value for lower reaches of the Tapi river in India [10]. Researchers took root mean square error (RMSE) for comparison between simulated and observed water surface elevations. Parhi et al. estimated Mannnig’s value along the Mahanadi river in Odisha, India by simulation of flood flow for years 2003 and 2006. They used HEC-RAS model and found an optimum single roughness value to be 0.032 [11].

Hameed et al. applied HEC-RAS flow model for assessment of (n) in Al-Hilla River, Iraq [12]. The best agreement value between observed and computed hydrographs was (0.027) for whole river.

Hameed [13] identified (n) in Al-Kufa river, Iraq by developing HEC-RAS flow model calibration, and predicted a value of roughness as (0.032), which also represents the best agreement between observed and computed hydrographs.

In this study HEC-RAS was used to estimate (n) for Euphrates River within Al-Muthanna area, Iraq, located 270 km south of Baghdad.

HEC-RAS works only on one-dimensional flow. Although one dimensional flows do not actually exist in natural flow of rivers, Steffler and Jin defined the conditions where such flow can be used [14]. One-dimensional water surface profile for steady flow in natural and artificial channels can be computed by solving one-dimensional energy equation from one cross section to the next. When water surface profile rapidly varied, the solution switches to the momentum equation [15]. No studies are available regarding evaluation of roughness for Euphrates River in Al-Muthanna, Iraq. This study aims at developing a HEC-RAS model to steady flow of Euphrates in Al-Muthanna Iraq, and estimating the value of roughness coefficient.

Area of the study

Euphrates River crossing Al- Muthanna territories through five towns which are Al Hilal, Al Majid, Al Samawa, Al Khidhir, and Al Drajae, as shown in Fig.1. In this reach, the river runs approximately 110 km from the north border of Al-Muthanna with Diwaniyah Governorate to the south border with An-Nasiriya Governorate. Euphrates River within this area serving the agricultural purpose and provision of drinking water. This river is irrigating around 250,000 hectares.

For the purpose of this study, the field observations that were used for analysis and modeling were provided by the Department of Water Resources in Al-Muthanna, Iraq.

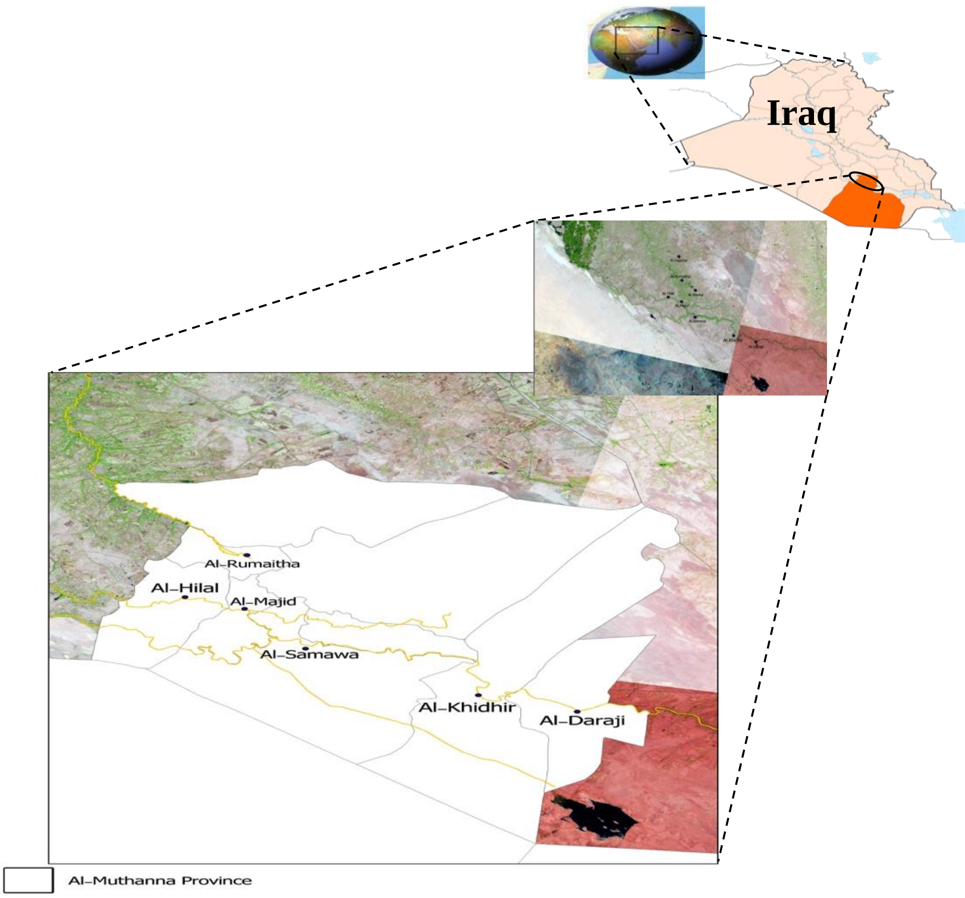


Figure 1: Map of Al- Muthanna showing the extend of Euphrates River

Steady Flow and HEC-RAS Model Development

The most important parameters for the HEC-RAS hydraulic model are geometric and flow data. The geometric data have been developed by drawing the river system schematically with flow direction. This was done using the button of river reach of the HEC-RAE adopting the method explain in details in software manual [15]. Fig. 2 shows the schematic diagram of geometry of the Euphrates River within the area of the study along with the locations of cross-sections as appeared by the HEC-RAS model. Then, cross sections data including cross section coordinate, down reach length, Manning's n values, main channel bank stations and contraction or expansion coefficients were entered via the cross-section data editor button on the same window.

All cross-section coordinates were defined by entering the river station and elevation points from left to right in sequence along river.

Ninety cross sections were distributed along the river. Fig. 3 demonstrates sample of cross sections as well as all information required by the cross-section data editor. After the geometric data are defined and saved, data of discharge was entered for calculation process and finalizing the model creation. All data for geometry and discharge had been furnished by Department of Water Resources, Al- Muthanna, Iraq.

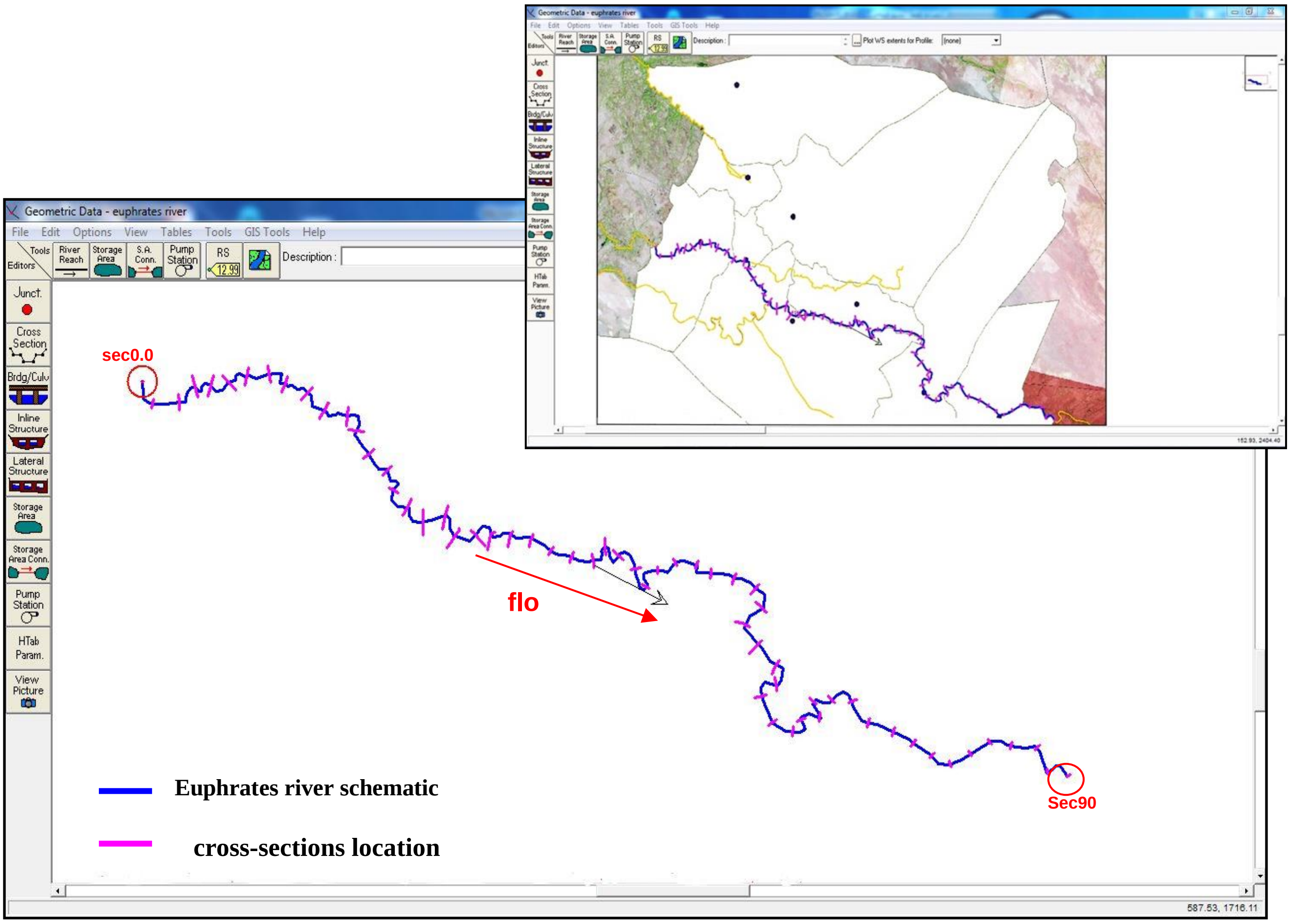
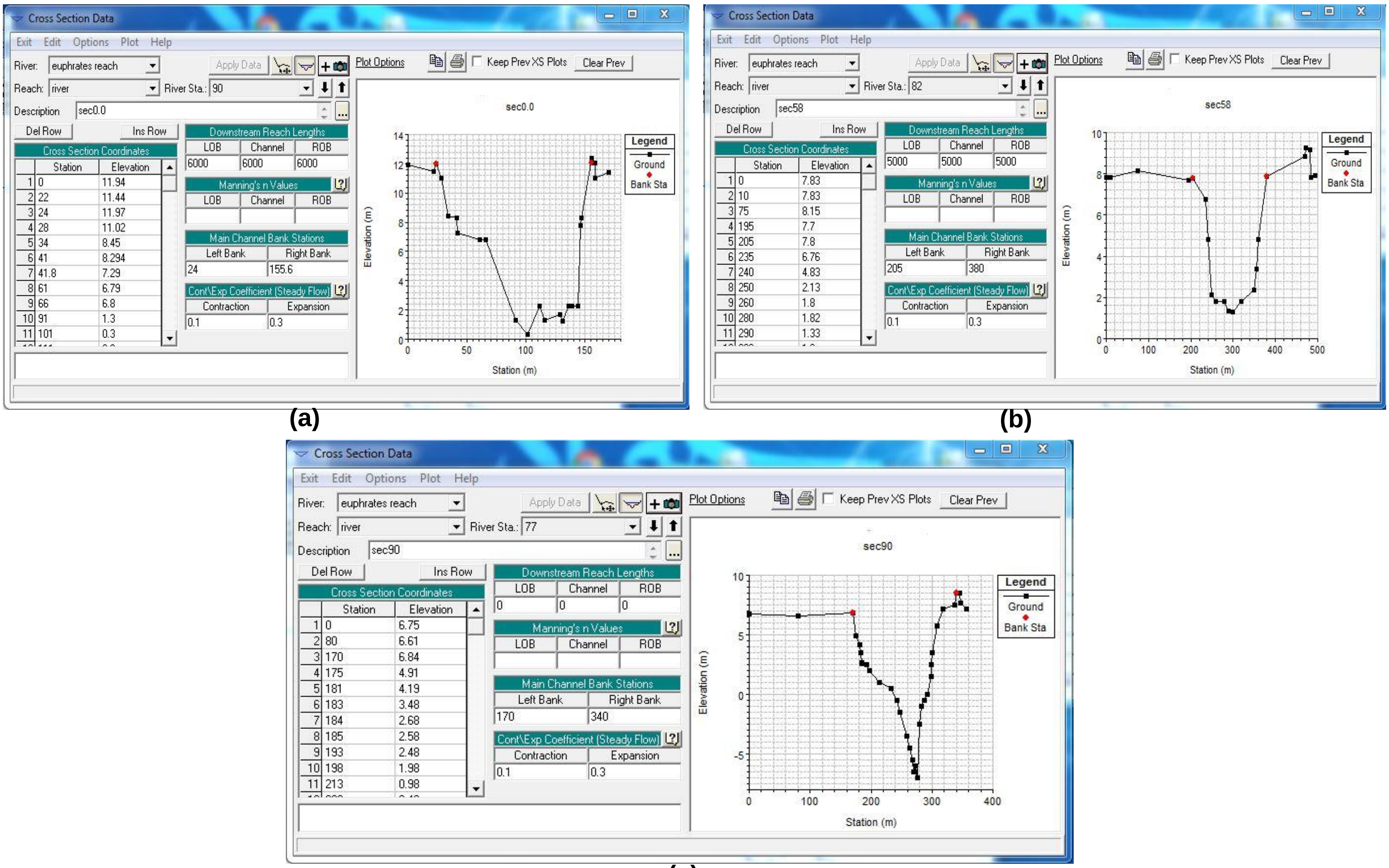


Figure 2: Euphrates schematic and Locations of cross-sections in the HEC-RAS model



(a) (b) (c)

Figure 3: Sample of cross sections; (a) cross section at upstream ;(b) cross section at distance 58 Km from upstream (c) at distance 110 Km from upstream

HEC-RAC Model Calibration and Validation

In order to make the steady flow HEC-RAS hydraulic model for Euphrates River more effective for predicting water flow, it has to be well calibrated and validated for more applicability and practicality. These processes need two independent sets of observed flow data. The first set is used to determine the value of roughness, while the second set is used to validate the accuracy of calibrated parameters [16] . This model was calibrated using the minimum observed flow during May 2017 (51.67 m^3/sec at the upstream end of the river at cross section No. 0.0). The calibration was performed by comparing the results obtained via the model with the observed surface water data.

Based on literature review, the initial value of n was selected from Chow, 1959 [2], Henderson, 1966 [17] and Gupta, 2007 [18]. Department of Water Resources in Al-Muthanna do not have any estimation for roughness coefficient for the river. According to Fenton, 2002, the typical value of n for natural irrigation channels is 0.025 [3], while Chow, 1973 suggested n value between (0.025 to 0.033) for clean open channel [19, 20]. BWRD, 1998 study on flow of Iraqi natural rivers, estimated that the value of n may vary between 0.025 and 0.034 [21]. When specifying roughness values for open channels, depth of flow should be considered. If the flow occurs only in bed channel, n values for main channels should be determined separately from banks [22]. From aforesaid above, the roughness calibration of the HEC-RAS hydraulic model was performed using single values of n applied along main channel of the river starting from 0.025, at an increment of 0.005 and ending at 0.04.

After the estimation of initial value, the surface roughness was changed until the differences between observed data and simulation results became nearly equal to zero. Hence, the results of the steady flow HEC-RAS model for different values of n were compared with the observed water surface profile as presented in Fig.4.

To provide a measure of accuracy, the root means square deviation (RMSD) was applied between observed and computed water surface elevation at each cross-section, as presented in equation (1).

$$RMSD = \sqrt{\frac{\sum_{i=1}^{t}(h_i - h_{ci})^2}{t}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

hi is the measured water surface elevation in meter,

hci is the computed water surface elevation at each cross section in meter,

i is the identity number of the cross section, and

t is the total number of cross sections.

Table 1 shows (RMSD) values of the calibration results. It was found that the best match between observed and computed profile occurs when using value of 0.04. For verification, another sets of flow measurements data have been used during March 2017, with maximum flow rate of 148.39 m3/s at cross section No. (0.0), and the simulated results was compared to the actual water surface profile as shown in Fig 5. The same RMSD value were obtained for this round (0.04) leading to conclude the best agreement between the field and calculated profiles as shown in table (2).

Table (1). The smallest values of RMSD for calibration results.

Flow rate m^3/sec	Roughness value (main channel)	Calibration results (RMSD)
51.67	0.025	2.5
	0.03	2.4
	0.035	1.8
	0.04	1.6

Table (2). The smallest values of RMSD for validation results

Flow rate m^3/sec	Roughness value (main channel)	Validation results (RMSD)
148.39	0.025	2.2
	0.03	2.1
	0.035	1.7
	0.04	1.1

From Fig 4 and 5, with various roughness values selected, the calculated profile becomes close to the observed generally within the distance from the mid reach to the final point of the river at the exit point. This fact can be noticed with no effects from the period and value of flow.

Conclusions

HEC-RAS software is one software that can be adopted for hydraulic modeling. So, this software can be used successfully in modeling surface water profile. A hydraulic model performed on the Euphrates River along its reach with Al- Muthanna province at 270 km was performed using HEC-RAS modeling. The roughness coefficient, gives the best agreement with the model when the roughness coefficient equals to 0.04.

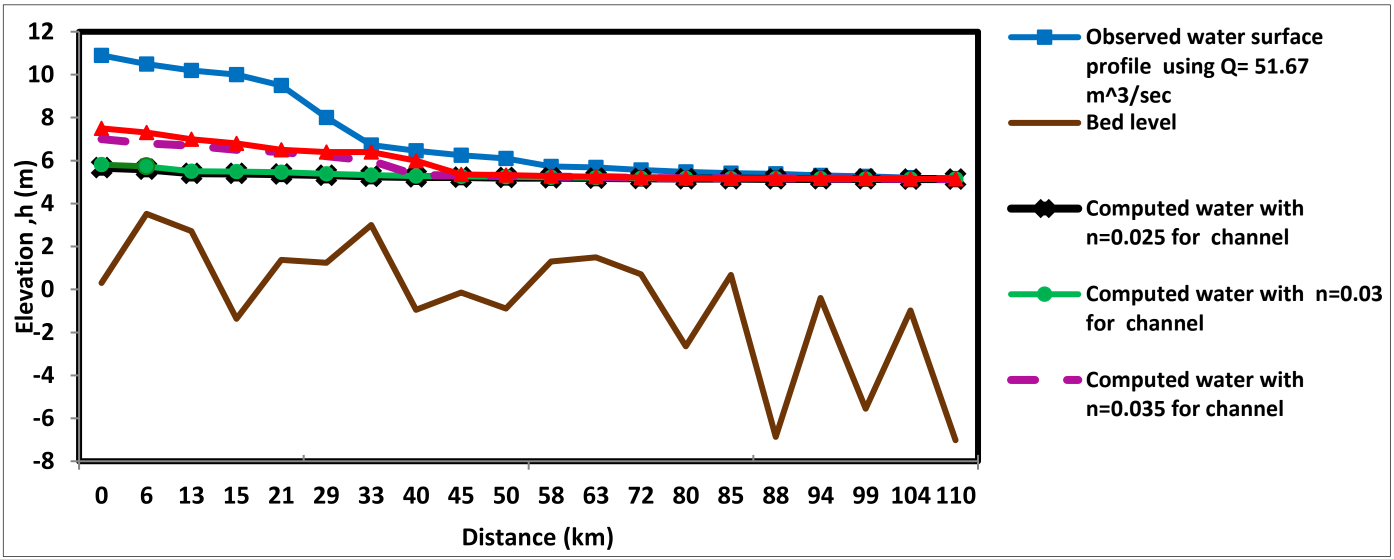


Figure 4: Water surface profile for Euphrates river for Q = 51.67 m^3/sec.

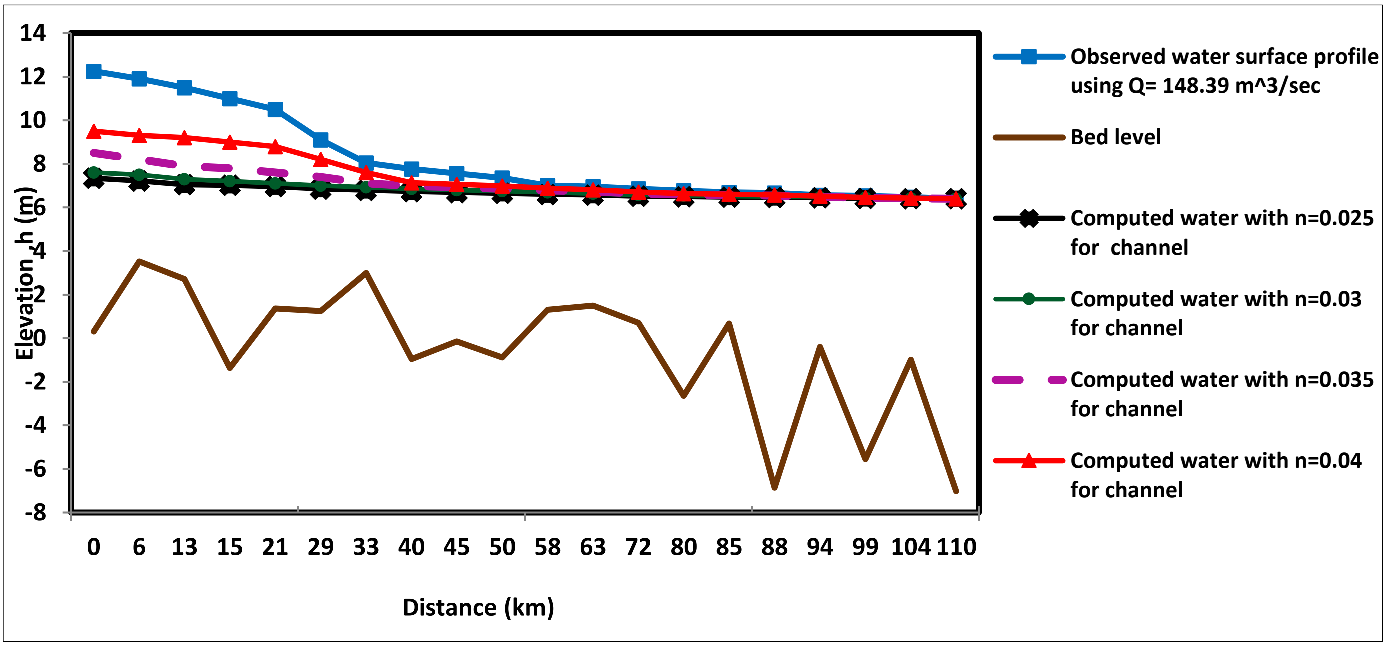


Figure 5: Water surface profile for Euphrates River for Q = 148.39 m^3/sec.

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