DETERMINING THE STAGE-DISCHARGE CURVE AND CHANGING IT INTO A REGRESSION EQUATION USING HYDRAULIC SOFTWARE

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ABSTRACT
Constant measurement of the rivers flow in normal conditions is difficult and costly and in flood risk condition it is perhaps impossible due to the measurement problems and probable risks. Therefore, in hydrometric stations through continuous reading of the scale and finding the relationship between stage-discharge, the flow rate is obtained for the times when the measurement is not done. Stage-discharge relationship is a kind of flow resistant equation which is used to determine the flow rate when the hydraulic radius or depth, channel shape, slope, bed material characteristics, and temperature are known. The present research was conducted to determine stage –discharge relationship in the Dez River at different stages. First of all, the needed data were collected including cross sections, hydrological data, hydrometric stations data, etc at the Dez River. After collecting the data, the associated hydraulic models were implemented. The models used in this research are HEC-RAS and MIKE11 software which are important software in river engineering sciences.

Keywords: *hydrometric station, rivers, flood risk, hydraulic model.*

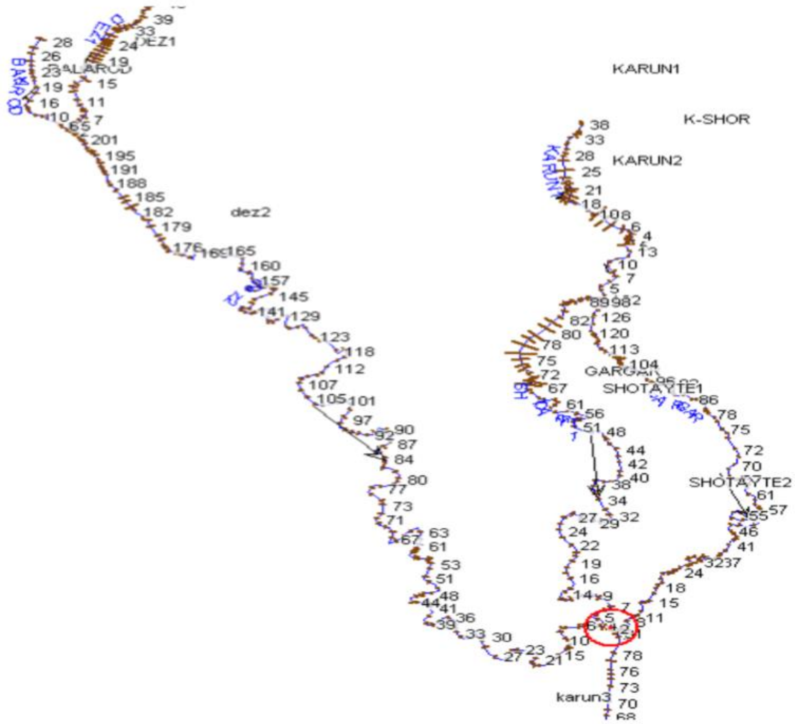
1. INTRODUCTION

Knowing the river behavior and being aware of its changes are the necessary prerequisites of the river management and doing hydraulic and hydrometric studies is necessary in this regard. Stage-discharge relationship is a kind of flow resistant equation which is used to determine the flow discharge when hydraulic radius or depth, channel shape, slope, bed material characteristics, and temperature are identified. The curve is used as the basic information for various hydrological calculations, hydraulic calculations of river sediments and channels with soil beds. Moreover, it is also used for boundary conditions in computerized models to calculate the flow profile. Constant measurement of the rivers flow in normal conditions is difficult and costly and in flood risk condition it is perhaps impossible due to the measurement problems and probable risks. Usually, through several simultaneous measurements of flow discharge and the corresponding stage in a hydrometric gauging station, it is possible to achieve a simple relation between the river flow and water surface elevation. Stage-discharge relation is determined empirically for the parts of the river where there are gauging stations and is only applicable for those sections and within the measured range. Sanders et al. [1] and Sobey [2] in a research began to route the rivers using numerical models. In a research entitled " Comparing physical habitat conditions in forested and non-forested streams" in Texas University, Andam [3] studied speed changes and Froude Number in these two types of river using HEC-RAS model and HEC-GeoRAS attachment and compared the effect of vegetation on regime and physical behavior of the flow and concluded that application of HEC-RAS model can provide appropriate numerical values for the researchers to study the regime and other hydraulic characteristics of the river flow. Randall and Edward [4] in a research project compared the effect of bridge piers with different number and base diameters on water rejection and the flood depth.

Adib et al. [5] in a research extracted the stage-discharge curve in tidal rivers using artificial neural networks. This research aims to determine the stage-discharge curve and to change it into regression equations in the Dez River which is a major river in Iran.

2. INTRODUCTION TO THE STUDY AREA

Dez River located in Khuzestan Province and which is one of the main branches of the Karun River and helps the drainage system in vast areas of the provinces of Lorestan, Chahar Mahal va Bakhtiari, Isfahan, and Khuzestan (Figureure 1). This river whose main source is in Sarband Arak and Aligoudarz and Oshtorankooh Valleys, joins Khuzestan Plain above Dezful and enters Karun in Band Ghir. Since the Dez River is one of the most important rivers in iran, the present research has been conducted on this river.



Figureure 1. Dez River Geometry Introduced in HEC-RAS software

3. MATERIALS AND METHODS

In order to carry out the present study the required data including cross sections, hydrological data, and hydrometric and hydraulic stations information were collected from the relevant organizations such as Khuzestan Water and Power Organization. Then HEC-RAs and MIKE 11 hydraulic models were used. The models calibration was determined at a specific time interval based on stage-discharge information and also the roughness coefficient of the river bed which was picked based on the field work. After modeling by means of hydraulic software and determining the desired parameters, in order to verify the feasibility and accuracy of the data the artificial neural network model of Alyuda was used. Finally, the output of hydraulic software was changed into regression equations using SPSS[1] software.

One of the major parameters in running the cited hydraulic models is the Manning Coefficient which in natural rivers and channels with fixed beds depends on the size of bed materials, and in alluvial channels the bed form is usually shaped through the movement of floor materials and will in turn influence the roughness. The roughness coefficient values for the studied area are presented in Table (1).

Table 1. Manning Coefficient within the Range of the Research for the River

Left side	Bed	Right side	range
0.035	0.032	0.035	Manning Coefficient

The results of comparison of HEC-RAS and MIKE11 mathematical models are shown in Figureure (2). The results obtained through running the two models are consistent with each other. The minor differences of the results are related to the solution methods of equations via the two kinds of software. In order to minimize the error percentage in estimating the depth and water surface changes the artificial neural network of Alyuda was used. Since in this research the depth of the desired flow was to be determined, the effective parameters had to be identified first. The effective parameters of flow discharge, width of water surface, floor slope, roughness coefficient were identified. In order to use Alyuda model, the data should be provided for the model through the note pad software. After entering the data, the model was implemented. In this research, Multilayer Perceptron artificial neural network was used.

[1] Statistical Processor for Social Science

The network was assessed with 1, 2, 3 hidden layers and 2, 3, 4, 5, 6, and 7 neurons each time in the hidden layer (by considering four neurons in the input layer). Moreover, the Logistic Function was considered as the stimulating function and momentum term, learning rate and maximum iterations in the network were respectively selected as 0.8, 0.01, and 10000. The maximum iteration of 10000 was selected because different repetitions experiment showed that at higher iterations, the correlation coefficient (r) of the network training was high but the correlation coefficient of network testing was relatively low, and conversely, in lower iterations than 10000, the correlation coefficients for both training and testing were relatively low. For each conFigureuration after training the network the root mean square of errors and the correlation coefficient were recorder. The summary of the results of the best neural network conFigureuration for various outputs and stations are presented in Tables 2-4. In theses tables, the sensitivity coefficient of each input parameter for each conFigureuration is recorded, as well.

Table 2. The results summary of the best Neural Network ConFigureuration for flow depth parameter in 50km away from the end

Sensitivity coefficient parameters (percent)				Root Mean Square Error(RMSE)		Correlation coefficient (r)		best network conFigureuration	Qualitative parameter
Roughness coefficient	bed slope	Discharge	Width of the water surface	Training	Test	Training	Test		
15.97	24.25	35.82	23.96	0.027294	0.074431	0.90	0.85	*4-5-1	depth
11.77	24.98	39.04	24.21	0.02828	0.03070	0.91	0.87	4-3-3-1	depth
14.36	20.14	37.23	28.27	0.00969	0.01731	0.88	0.85	4-6-6-1	depth

Table 3. The results summary of the best Neural Network ConFigureuration for flow depth parameter in 100km away from the end

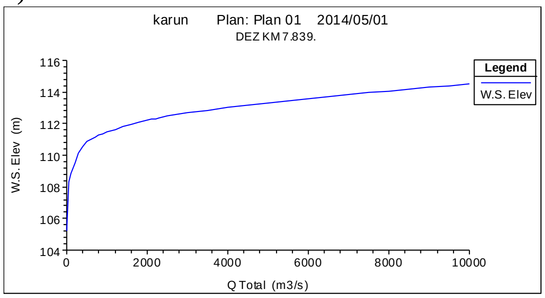
Sensitivity coefficient parameters (percent)				Root Mean Square Error(RMSE)		Correlation coefficient (r)		best network conFigureuration	Qualitative parameter
Roughness coefficient	bed slope	Discharge	Width of the water surface	Training	Test	Training	Test		
26.18	29.23	17.26	27.33	0.01166	0.02872	0.82	0.74	4-3-1	depth
11.40	44.30	24.06	20.24	0.07194	0.03857	0.84	0.80	4-4-4-1	depth
16.18	32.43	17.34	34.05	0.010865	0.05026	0.70	0.65	4-3-1	depth

Table 3. The results summary of the best Neural Network ConFigureuration for flow depth parameter in 150km away from the end

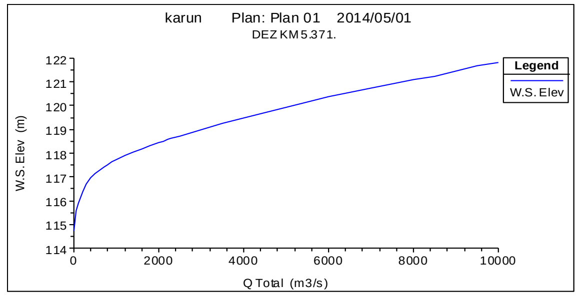
Sensitivity coefficient parameters (percent)				Root Mean Square Error(RMSE)		Correlation coefficient (r)		best network conFigureuration	Qualitative parameter
Roughness coefficient	bed slope	Discharge	Width of the water surface	Training	Test	Training	Test		
25.92	31.12	19.31	23.65	0.02963	0.05093	0.93	0.94	4-3-3-1	depth
26.11	24.53	22.29	27.07	0.04412	0.0655	0.95	0.73	4-2-2-1	depth
27.40	31.60	18.45	22.5	0.04483	0.00991	0.87	0.92	4-3-3-1	depth

Figureure 2. Comparison Chart of the Results of Hec-Ras and MIKE 11Software

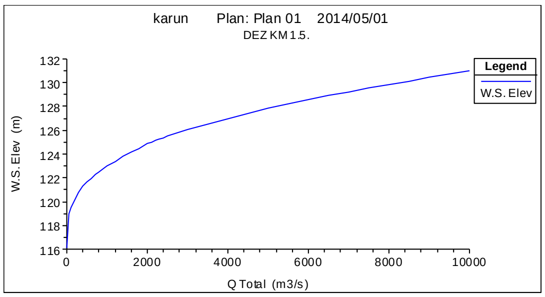
In the next stage, the results of hydraulic modeling of the studied river are presented as a curve (Figureure 3, 4, 5, 6, 7).



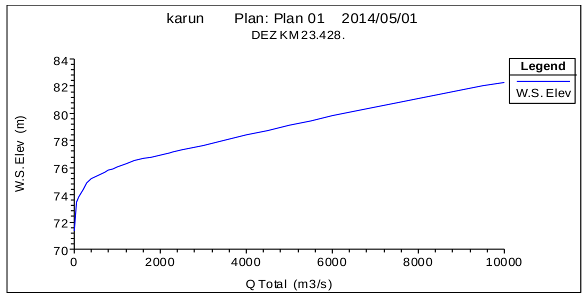
Figureure 3. Stage discharge curve at the end of 7839 km



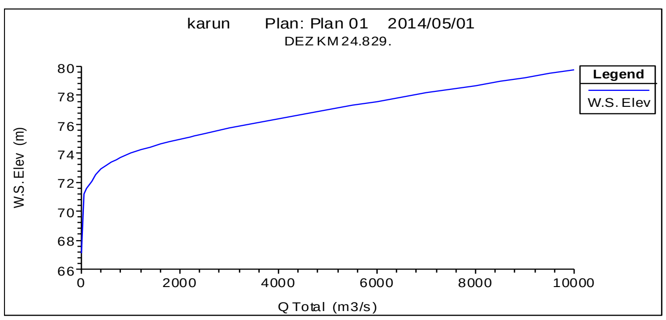
Figureure 4. Stage discharge curve at the end of 5371 km



Figureure 5. Stage discharge curve at the end of 1500 km



Figureure 6. Stage discharge curve at the end of 23428 km



Figureure 7. Stage discharge curve at the end of 24829 km

4. RESULTS AND DISCUSSION

The results of hydraulic simulation in the studied river show that two parameters of shear stress and energy grade line(E.G.L) are affected by many parameters and when the flow conditions change, each one of these parameters changes and the accumulation of changes cause large changes in shear stress. It can be concluded that this parameter is very sensitive to the changes of flow conditions. Different studies show that changes curve of energy grade line (E.G.L), shear stress, cross section, and flow velocity has a uniform trend towards the flow discharge changes which can be due to the following reasons:

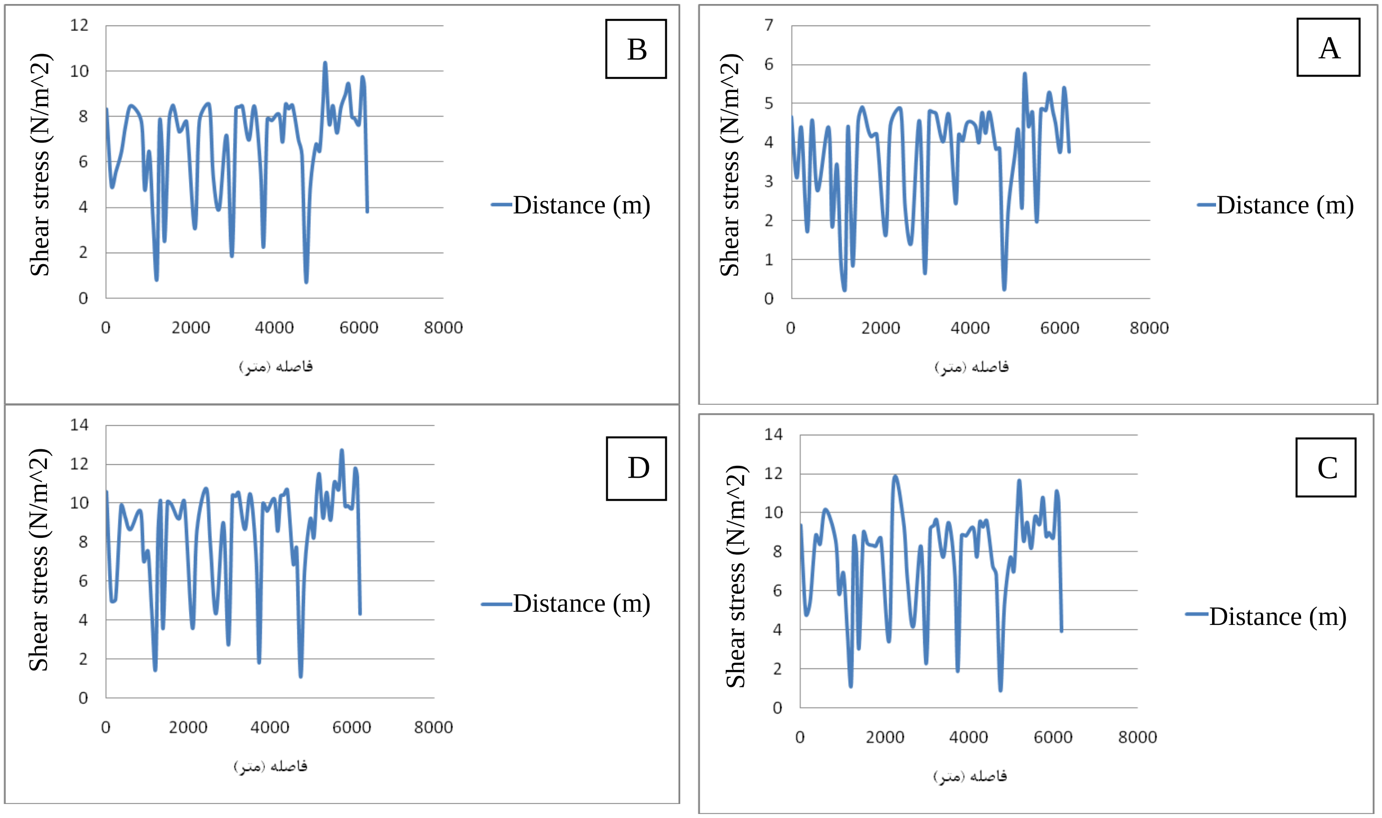
i) Changes of the flow discharge rate in the river at different return periods are not too high and as the discharge rate increases, the flow still moves in its main course and moves less towards the plain flood.

ii) The roughness coefficient of the flow rates over 50 years is different from the roughness coefficient of the flow rates less than 50 years and due to the alteration of roughness coefficient, the changes trend of mentioned parameters is slower in flow rates over 50 years.

iii) Since the Dez River is a coarse-bed and steep slope river, running the hydraulic model for the base flow will have lots of computational errors and the results of the model won't be reliable. Therefore, the results of the hydraulic model of the base flow are neglected.

According to the results of hydraulic simulation in the studied river, the changes range of water level, velocity, and the other hydraulic parameters was determined and a brief analysis of the results is presented here.

Examining depth-distance curves at different return periods shows that the changes trend of energy grade line (E.G.L) along the course is almost uniform except in some cases where the energy grade line (E.G.L) has increased instantaneously and has changed non-uniformly which is due to sudden change of bed slope which is very steep in this distance and increases the flow rate and consequently increases the height of energy. In depth-distance curve the depth of water flow increases slowly from upstream towards downstream which is due the decrease of the river bed slope that increases the depth of water flow in the cross section of the river main flow. In order to show the results of stage-discharge calculations as regression equations SPSS software was used.



Figureure 8. Distance-shear stress curve of the river in return periods A)2-year B)25-year C) 50-year D)100-year

Table 5. Derived Stage-Discharge Equation in 50 km of Final Conclusion

Range discharge $\left(\frac{m^3}{s}\right)$	Equation derived
0-20	$H = 0.02Q + 0.08$
20-40	$H = 0.04Q + 0.06$
40-60	$H = 0.07Q + 0.04$
60-80	$H = 0.08Q + 0.05$
80-100	$H = 0.1Q + 0.07$

Table 6. Derived Stage-Discharge Equation in 100 km of Final Conclusion

Range discharge $\left(\frac{m^3}{s}\right)$	Equation derived
0-20	$H = 0.015Q + 0.07$
20-40	$H = 0.035Q + 0.043$
40-60	$H = 0.065Q + 0.042$
60-80	$H = 0.073Q + 0.05$
80-100	$H = 0.12Q + 0.02$

Table 6. Derived Stage-Discharge Equation in 150 km of Final Conclusion

Range discharge $\left(\frac{m^3}{s}\right)$	Equation derived
0-20	$H = 0.025Q + 0.04$
20-40	$H = 0.055Q + 0.05$
40-60	$H = 0.068Q + 0.02$
60-80	$H = 0.086Q + 0.03$
80-100	$H = 0.2Q + 0.067$

5. CONCLUSION

Having information about the flow discharge is essential for water resources planning and management, flood prediction, storage operations and other engineering affairs of the river.

Since the daily measurement of the rivers flow in normal conditions is a costly, time-consuming process and sometimes impossible in flood risk conditions, most of the flow discharge data is obtained by converting the height of measured water into the flow discharge by the flow rating curve which makes the flow discharge measurement feasible and inexpensive. Therefore, in the present research the stage-discharge relationship of the Dez River was determined by mathematical models. In summary, the results of the research are as the following:

a. Among the parameters affecting the flow depth toward the end of the river, the flow discharge has the highest effect on the flow depth.

b. There is a good consistency between the results of HEC-RAS and MIKE11 software.

c. Since the flow is subcritical, the flow regime is mainly affected by the downstream flow.

6. REFERENCES

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