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Full Length Article

Sensitivity Analysis and Study of the Strength Relations in Fixed and Mobil Riverbeds

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ABSTRACT
The Roughness coefficient has a decisive role in determination of hydraulic parameters such as flow velocity and boundary shear stress which adds to the importance of this Issue. Despite all the research which has been going on, on the roughness coefficient there is no certain relation to calculate the exact value of it and it is only experimental methods which are being used. This paper attempts to provide a better understanding of some relations as well as using relations to estimate the roughness coefficient passing in open channels using Software (HEC-RAS). to achieve that we will study the simulation of the hydraulic behaviour in the flood zones of different return periods and The height of the water at various points along the river 'Siahrood', in Guilan Province ,Iran and sensitivity analysis of parameters influencing roughness coefficient.
***KEYWORDS**: Manning roughness coefficient, turbulent flow, laminar flow, fixed bed, moving bed*

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INTRODUCTION

Urban areas are so vulnerable to flooding and damages directly and indirectly. These damages among others includes the destruction of houses and other structures, disruption of communication lines, railways, runoff conveyance canals and roads,… which may cause loss of many human lives[21].
Flood zoning as a managerial method when facing flood, now is widely used. Although by structural manner in flood control estimating discharge and balance of water is possible before happening flood, and by directing, deviating and controlling floods by proper structures, the damages can be decreased, These methods are in special status in flood control, its function has not been satisfactory during the recent decades and experts believe that if structural manners are combined with non-structural manners, it can minimize the flood damages .
When first actions were done with digital elevation model analysis for hydrology uses, but the connection between hydraulic models and GIS returns to 80's and 90's. The most important actions in this field which is done basically and used all over the world, was applied by Maidment and Olivera in Texas University [23].
Correia et al [5] tried to zone and analyze the flood danger in flood plains along with urban development. They used Geographical Information System and hydrology and hydraulic models to evaluate flood danger decrease by controlling land use.
Johnson et al [10] used HEC-RAS model to estimate and determine the limits of wet lands in 10km of Wyoming River in America. By using the mentioned model, they drew the profile of the river water level, deviated water to a new basin and determined the border location with and without deviation with similar scale, then predicted in deviation period, all the area flooded with discharge of 283.3 l/s, dwindled from 167.2 Hectares to149.7 Hectares. The researchers believe the foresaid method is a valuable one to determine the rate of deviation effects on riverside wet lands.

Johnson and Strickland [10] have used HECRAS model to predict and determine the wet lands along 10 kilometers of Wyoming River in North America. Using this model, they have drawn the profile of water surface and through diverting the water to a new tank and a set of boundary conditions with and without the diversion of a similar scale. They found that, with diversion, the area under the flow with 283.3 liters per second flow rate reduces from167.2 to 149.7 hectares. They believe that this is avalid method to quantify the effect of diversion on wetlands along the rivers.
Islam et al [8] drew the flood danger map for Bangladesh by using remote sensing data taken from the flood which happened in 1988. These researchers drew the flood danger map for three rivers in Bangladesh and submitted to the executive department and government to plan.
Lin et al [13] studied the watershed zoning in North Carolina on the basis of best management practices and introduced it as a very useful function in watershed management.
Moramarco et al[15] tried to model rain-flood in Tiber City of Italy and modeled the flood of 1998 by using a distributaries model. Then, they used a flood 2D model for hydraulic modeling. The results showed an increase in a50-year flood height up to 2.3m in urban areas.
Zeinivand [26] tried to zone the flood danger of Seylakhor River in Lorestan Province by applying HEC-RAS Model. He found that this model has a high efficiency in calculating water level profile.
Safari [19] tried to zone flood danger of Neka River in Mazandaran Province by applying HEC-RAS Model. Hefound that this model has a high efficiency in calculating water level profile and flood zoning.
Kresch et al [12] after the 1998 flood disaster in Honduras, decided to plot a Fifty years flood inundation map for Olanchiner River in Honduras. Using GIS and HEC-RAS mathematical models for 243 cubic meters per second flow rate corresponding to the 50-year flood, they performed hazard zonation of the flood.
Whiteaker et al [24] using Map-to-Map modeling, ARC GIS 9, and HEC-RAS have created flood inundation zoning map from rainfall data on Rosillon Greek basin, Texas. It is worth mentioning that, Map-to-Map model is a method which calculatesa polygon layer of flood zone from rainfall data. This method allows the user to crate flood zone maps andthe possibility of predicting the real time of flood.
Papen Berger et al (2005), investigated uncertainty in unstable flows with combination of one dimensional HEC-RAS model and GLUE. The modelwas run with different Manning's Roughness Coefficients (from 0.001 to 0.09) and the results were compared with flood inundation and out put hydrograph. They also investigated the effect ofvariations of Manning's coefficient on weighted coefficients of numerical method and concluded that,using values less than 1 is not useful and suggested the use of implicit scheme with a weighted value of 1.Domestic studies have more focused on determining the flood-proneness of different basinsusing hydrological modeling and flood zoning using hydraulic models.
Sadeghi [18] combined HECRAS model and GIS in order to zoning of flood in Dar Abad River concluding the efficiency of mentioned approach for flood zoning.
Bambai Chi et al [3] analyzed unstable flows of dams' failures using HEC-RAS model. Abdollahi [1] investigated water surface profile using HEC-RAS model. Azari et al (2009)combined HEC-HMS and HEC-RAS models in GIS in order to simulate the flood. Zandniya[25] compared characteristics of flows in fixed-bed conditions using both HEC-RAS and BRI-STARS models and evaluated the substrate variations ofcoarse grained rivers with BRI-STARS.
Samii et al [20] in a paper modified the Karun River from MollaSany to Ahvaz using HEC-RAS. Jalali Rad [9] performed partial flood zoning of urban basins of Tehran. He used GIS, ARC View,and HEC-RAS and concluded that, GIS has good capability for flood zoning. Heydari[6] with emphasis on Qaranqo River's basin management investigated geological, climatologically, geometrical, soil science, hydrological and sediment data and concluded that, an artificial imposition on the river underwent changes and shows turbulence and anomalous and complex behavior. He has concluded that, through accurate and scientific recognition of performance and behavior of basin, we can control and moderate the risks, confusions and changes.
Nikfal[16] using HEC-GEORAS software performed flood zoning of Karun River. In this project, satellite images of flooded are provided and had compared with areas which have been flooded in the model. The results were used in economic analysis of flood damages and calculations of expected losses in flood-prone areas of Khuzestan plain.
Bilandi et al (2009) investigated the efficiency of HEC-RAS and HEC-GEORAS software in determining flood zone according to the available geographical and hydrometrical data along Karun River between MollaSani and Ahvaz.
Mesbahi[14] aiming to integrate ARC View software and HEC-RAS hydraulic models via HECGEORASannex, estimated flood zones with different return periods and compared results of the model with river flood. He found 13% error in estimating flood zone.

HEC-RAS model is a hydraulic model designed by Hydraulic Engineering Center of US military. In1964, the HEC-2 computer model was introduced in order to help Hydraulic engineers to in the field of river channels and flood plains.

The model has been rapidly developed as hydraulic analysis program and was used in the analysis of bridges and ports. Although the HEC-2 model is designed to use in central processor of large computers, but it can also be used in personal computers. In 1990, due to increased use of the Windows operating system, HEC-2software was upgraded to be used in this operating system and was named as River Analysis System(RAS). This graphical software was developed in Visual Basic and benefits computational algorithms of FORTRAN. HEC-RAS software, in addition to calculating one-dimensional profile of water surface instable rivers, it also is used for simulating unstable flows in rivers and calculating delivered sediment load. Moreover, the system is also capable of modeling flows below and above critical conditions as well as a combination of them for rivers composed from complete network of drainage channels, dendritic branches, or single branches of the river. Model results are used to evaluate the impact of flood and management of floodplains [22].

Roughness coefficient has a significant role in the determination of hydraulic parameters. Therefore, a more accurate estimate of it reveals the importance of understanding the affecting factors. Due to the widespread use of Manning formula, this research will investigate results of 12 relations in fixed riverbeds and one relation in moving riverbeds for Manning formula plus four relations to obtain the average value of roughness coefficient. Also, to determine the best relationship, Sefidrood's data has been used. In hydraulic models, Simulation of Siahrood's (one of the Sefidrood's branches) hydraulic behavior in the occurrence of floods with different return periods are considered. By using Geographic Information System, geometry data of riverbed were simulated and then the statistical analyses were performed. By entering these data into HEC-RAS, the results of the flood zones, speed, water depth, etc., obtained at different return periods.

MATERIAL AND METHODS

In HEC-RAS model, in order to calculate flow rates in rivers, following equations are used:

$$\frac{\partial A}{\partial t} + \frac{\partial \phi Q}{\partial X_C} + \frac{\partial (1-\phi) Q}{\partial X_f} = 0 \qquad \textbf{(1)}$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial X_C}\left(\frac{\phi^2 Q^2}{A_f}\right) + \frac{\partial}{\partial X_f}\left(\frac{1-\phi^2 Q^2}{A_f}\right) g A_c \left(\frac{\partial z}{\partial X_C} + S_C\right) g A_f \left(\frac{\partial z}{\partial X_f} + s_f\right) = 0 \ \textbf{(2)}$$

$$\phi = \frac{K_C}{K_C + K_f}, \; k = \frac{A^{\frac{5}{3}}}{np^{\frac{2}{3}}} \textbf{(3)}$$

$$S_C = \frac{\phi^2 Q^2 n_C^2}{R_C^{\frac{4}{3}} {A_c}^2}, S_f = \frac{(1-\phi^2) Q^2 n_f^2}{R_C^{\frac{4}{3}} {A_f}^2} \textbf{(4)}$$

Where,

Q is total flow rate of the river, Ac, Af is cross-sectional area of the channel and flood plain,X_c, X_f is river length,P is circumference of the areas affected by the river,R is hydraulic radius, n is Manning's roughness coefficient, and S is slope of the river.The values of Ø are obtained from dividing flow rate between river channels and floodplain which is function transitional value of K_c, K_f.

Table 1. Investigated relationships in fixed riverbed

Relationship's Name and Year	Relationship	Parameters	Description
Strickler	$n = c.k_s^{\frac{1}{6}}$	C is equal to 0.0342 for calculating velocity and stone size in designing stile with ks = d 90 and for natural channels with ks = d 50 in this study, this definition is used for c. C is equal to 0.038 to calculate the passing flow of stile channel with ks = d 90 C is equal to 0.0342 for natural sediment with ks = d 90, In all cases, ks, is in feet.	Hard Bed

Keulegan	In the fully turbulent current: $C = 32.6log\left[\frac{12.2R}{k}\right]$ In the laminar flow: $C = 32.6log\left[\frac{5.2R_n}{k}\right]$	$R_n = \frac{4RV}{v}$ *V:current's average speed* R_n:*Reynolds number* *v: Kinematic viscosity of water*	Hard Bed
Iwagaki	In the turbulent current: $C = 32.6log\left[\left(\frac{R}{k_s}\right)10^{A_r g^{0.5}/32.6}\right]$ In the laminar flow: $C = 32.6log\left[\left(\frac{R_n g^{0.5}}{4k_s}\right)10^{A_s g^{0.5}/32.6}\right]$ In transition zone: $C = -32.6log\left[\frac{4k_s}{R_n g^{0.5} 10^{A_s g^{0.5}/32.6}} + \frac{k_s}{\left(R10^{A_r g^{0.5}/32.6}\right)}\right]$	$A_r = -27.058log(F + 9) + 34.289$ $A_s = -24.739log(F + 10) + 29.349$ F is the Froude number and the data are in8> F> 2/0. $\frac{(R_n/C)}{(R/k_s)} > 50$	Hard Bed
Simons &Senturk (1976)	$n = 0.047d^{1/6}$	*d is bed's particles' diameter in feets*	
Henderson (1966)	$n = 0.034d^{1/6}$	*d is bed's particles' diameter in feets*	
Raudkivi (1976)	$n = 0.042d^{1/6}$	*d is bed's particles' diameter in feets*	
Garde&Raju (1978)	$n = 0.039d_{50}^{1/6}$	*d is bed's particles' diameter in feets*	
Subramanya (1982)	$n = 0.047d_{50}^{1/6}$	*d is bed's particles' diameter in feets*	
Chin & Mai	$n = \frac{d_{65}^{1/6}}{19} = 0.052d_{65}^{1/6}$	*d is bed's particles' diameter in feets*	
Meyer-Peter & Muller (1948)	$n = 0.038d_{90}^{1/6}$	*d is bed's particles' diameter in meters*	
Marion et al.(1998)	$n = \frac{d_{90}^{1/6}}{26}$	*d is bed's particles' diameter in meters*	
Lane &Crlson (1953)	$n = 0.026d_{75}^{1/6}$	*d is bed's particles' diameter in inches*	

Table2. Brownlie relationship in moving riverbed

Relationship's Name and Year	Relationship	Parameters	Description
Brownlie	For the lower current regime: $n = \left[1.6940 \left(\frac{R}{d_{50}} \right)^{0.1374} S^{0.1112} \sigma^{0.1605} \right] .0.034 (d_{50})^{0.167}$ For high current regime: $n = \left[1.0213 \left(\frac{R}{d_{50}} \right)^{0.0662} S^{0.0395} \sigma^{0.1282} \right] .0.034 (d_{50})^{0.167}$ Transition relationship: if the slope is greater than 006/0, the current is always higher. Otherwise, the transition is associated with the particle.s Froude number: $F_g = \frac{V}{\sqrt{(S_g - 1) g d_{50}}}$ $F'_g = \frac{1.74}{S^{1/3}}$	*R: hydraulic radius in terms of ft, d50: particle's size in terms of ft S: bed slope σ: geometric standard deviation from composition of deposition* $\sigma = 0.5 \left(\frac{d_{84}}{d_{50}} + \frac{d_{50}}{d_{16}} \right)$ * If F'g ≥ Fg, the flow regime is low, F'g<Fg the flow regime will be high. * Fg particle Froude number, V the flow velocity, Sg specific gravity of sediment particles..	

Effective Factors in determining roughness coefficient

The most important factors which influence accurate calculation of the Manning roughness coefficient are:

1- Type and size of material that make riverbeds and sides.
2- Shape of the channel

Accordingly Cowan (1956) suggested the following formula to calculate the value of "n":

$$n = (n_b + n_1 + n_2 + n_3 + n_4) m \quad \textbf{(5)}$$

Where:

n_b :The basic amount of " n" for a straight channel, uniform and flat with natural material, n_1: Correction coefficient for correcting surface's irregularities,n_2: Correction coefficient for changes in shapes and channel's cross-section's size,n_3: Correction coefficient for obstacles, n_4: Correction coefficient for Herbal conditions and flow, m: Correction coefficient for channel's bend.

The calculated values of this relationship are used in adjacent and average conditions, thus it needs less corrections than basic values of Chow (1959).

Methods to obtain the average roughness coefficient

Horton Method or Einstein:

$$\bar{n} = \frac{\left(p_1 n_1^{1.5} + p_2 n_2^{1.5} + ... + p_N n_N^{1.5}\right)^{2/3}}{p^{2/3}} \quad \textbf{(6)}$$

Where:

$\bar{n}$: The mixed value of "n" for the section, p_N: Wet perimeter of the N cross-division, n_N: value of "n" in the N cross-division, N: Amount of Divided cross-sectional areas , P: Total Wet perimeter in cross-section

Colbatch and Los Angles relationships:

$$\bar{n} = \frac{\left(a_1 n_1^{1.5} + a_2 n_2^{1.5} + ... + a_N n_N^{1.5}\right)^{2/3}}{A^{2/3}} \quad \textbf{(7)}$$

$$\bar{n} = \frac{\left(a_1 n_1 + a_2 n_2 + \ldots + a_N n_N\right)}{A} \quad (8)$$

Where:
a_N: The last continuous area with the divided region n, A:The total area of the cross section

Total Force Method

This method is based on equality of the total resistance force and sum of resistance forces in each region of flow. Thus, the value of mixed n will be like below:

$$\bar{n} = \frac{\left(p_1 n_1^2 + p_2 n_2^2 + \ldots + p_N n_N^2\right)^{1/2}}{p^{1/2}} \quad (9)$$

RESULTS AND DISCUSSION

Simulation of riverbed and adjacent lands (The central line, Sides of the river, Floodways)

In order to simulate riverbed conditions and river's flood plain plans of Siahrood's River with 1:1000 scale have been used. Initially these plans were geo referenced in AutoCAD. After being digitized were imported into Arcview(GIS). And the necessary corrections for the height points were done in Arcview. In the next stage related TIN of riverbed and flood plains were made by this software. Then by using an extension HEC-GeoRAs, river's path and its sides and cross sections were simulate. Cross-sections by navigation of Siahrood River's path were considered to introduce river's morphology. In this case, those mentioned factors were carefully studied and applied. In Figure (1) to (3) geometry simulation of the riverbed and adjacent lands (3Dmodel, the central line of river, Sides, Flooding ways) are shown.

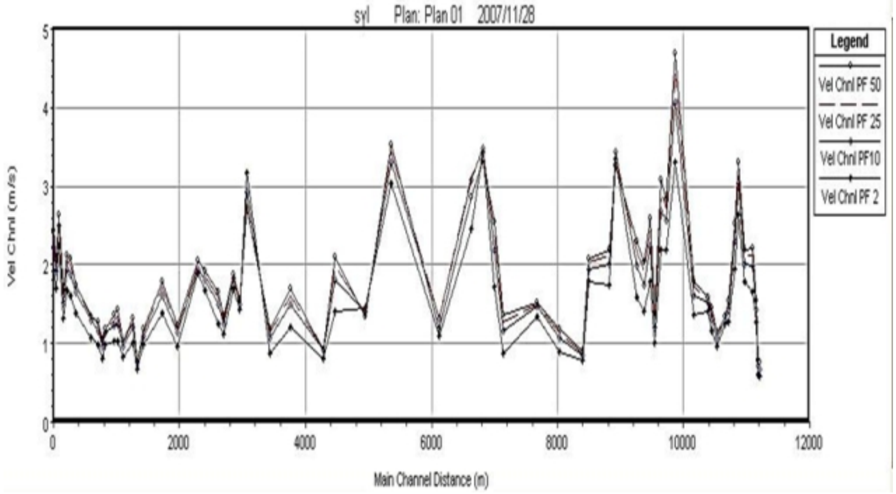

Figure 1. Changes in water velocity in the main channel of the river at different return periods

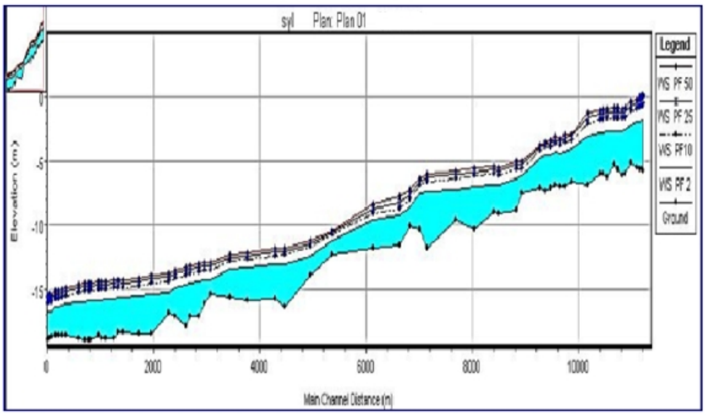

Figure 2. Longitudinal profile of river and height of water in the different return periods

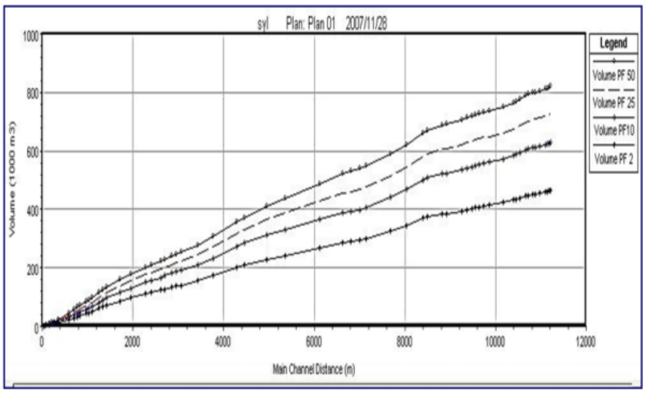

Figure 3. Changes in volume of flood water of Siahrood River in the different return periods

By running the model in HEC-RAS we aim to simulate the hydraulic behavior of the river and computing speed, water depth and breadth of different return periods. A summary of the results are presented in the following tables and graphs.

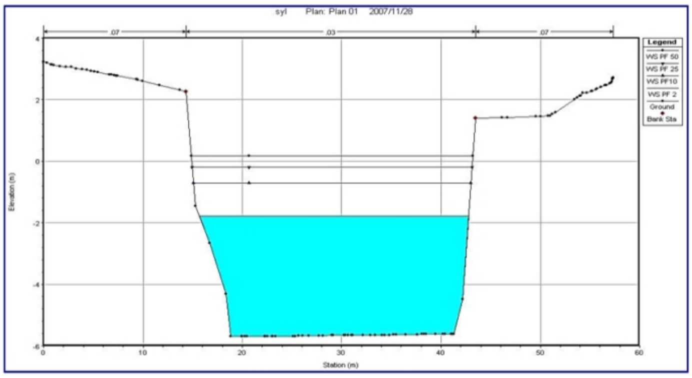

Figure 4. Cross section number 1 Siahrood River and height of water in the floods with return periods of 2,10, 25 and 50 years old

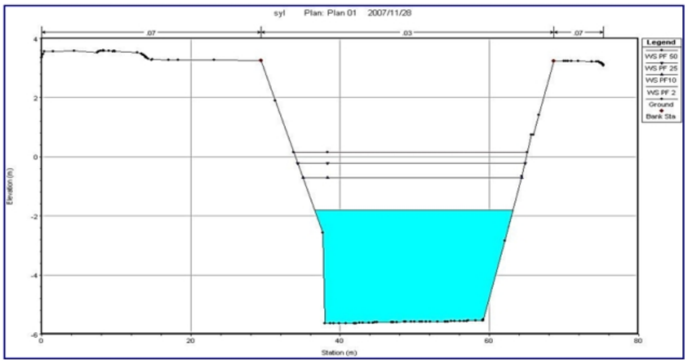

Figure 5. Cross section number 2 Siahrood River and height of water in the floods with return periods of 2,10, 25 and 50 years old

Introduction region of Data Acquisition

The Desired range is total path of Sefidrood River from beginning in Manjil's dam to the end in the mouth of the Caspian Sea. In other words, it is limited to the Caspian Sea from the north, to the Amarlu Mountain from the south, to the basin of the river that entrances Anzali Lagoon from the west, and to the Shamrud's basin from the East. Sefidrood River's used data was retrieved from reorganization Plan's report of this river that was provided by DOE (Department of Energy).

Table 3. Sections' Characteristics

Section	Area	Perimeter	Radius	Slope	Froude	Q	V
1	87.09	75.0589	1.16	0.0016	0.43	122.980	1.593
2	98.85	69.0289	1.431	0.00445	0.365	122.240	1.267
3	88.829	73.5189	1.2079	0.0048	0.424	122.980	1.221
4	82.705	95.6689	0.864	0.00215	0.493	122.970	1.597
5	84.099	89.125	0.943	0.00329	0.474	122.950	1.390
6	87.959	77.7149	1.131	0.00315	0.44	122.980	1.542

7	99.209	76.0800	1.304	0.00234	0.349	122.930	1.277
8	97.715	66.5449	1.4680	0.00329	0.328	122.970	1.200
9	93.129	65.1139	1.429	0.00631	0.372	122.980	1.320
10	68.919	92.9339	0.741	0.01681	0.629	122.950	1.530

Combining and comparing the presented methods

This section has divided the river into three parts, two parts Wall and one part riverbed, the roughness coefficient of the Wall parts were investigated by fixed riverbed's relationships and the roughness coefficient of the central part was investigated by Brownlie method.In Presented Tables Speed in terms of meter per second and flow in terms of cubic meters per second are calculated .Furthermore, according to the given explanations about Determining of Correction coefficients and existing tables and numbers, the average total of this coefficients in each panel of each section was obtained approximately 0.024 ,and 1.15 for correction coefficient of bending.

Table 4. Manning coefficient obtained from 13 methods in the 4 combined methods for the entire path

Method	n(Los)	n(Col)	n(T.F.)	n(Hor)
Keulegan	0.05175	0.05225	0.05347	0.05244
Strickler	0.04766	0.04843	0.05052	0.04888
simons-senturk	0.04770	0.04863	0.05129	0.04927
Henderson	0.04765	0.04834	0.05023	0.04874
Raudkivi	0.04766	0.04844	0.05046	0.04885
garde&raju	0.04767	0.04847	0.05060	0.04892
Subramanya	0.04770	0.04865	0.05124	0.04924
meyer-peter &muller	0.04769	0.04858	0.05095	0.04909
Marion	0.04769	0.04860	0.05100	0.04911
lane & Carlson	0.04769	0.04856	0.05083	0.04902
chin &mai	0.0477 0	0.04864	0.05117	0.04920
Iwakagi	0.04761	0.04816	0.04951	0.04838

Tables (5) and (6) are related to the analysis of obtained flows compared to the measured flow of the entire path and different sections. As shown in Table (4) is observed that Meyer-Peter & Muller relationship combined with Brownlie relationship by using mixed method "Total Force" offers the best response for the whole path.

Table 5. The difference of obtained flows from experimental methods with measured flows for the entire path

Method	Q(Los)	Q(Col)	Q(T.F.)	Q(Hor)	Q(Con)
Keulegan	-1.59%	-2.54%	-4.77%	-2.90%	15.03%
Strickler	6.84%	5.14%	0.79%	4.17%	13.15%
Simons-Senturk	6.76%	4.71%	-0.71%	3.35%	17.20%
Henderson	6.88%	5.33%	1.38%	4.47%	17.71%
Raudkivi	6.84%	5.13%	0.91%	4.24%	14.16%
Garde&Raju	6.82%	5.07%	0.64%	4.08%	13.40%
Subramanya	6.75%	4.68%	-0.63%	3.41%	13.58%
Meyer-Peter & Muller	6.78%	4.81%	-0.06%	3.73%	13.26%
Marion	6.77%	4.79%	-0.15%	3.68%	12.81%
Lane & Carlson	6.78%	4.86%	0.18%	3.87%	13.01%
Chin & Mai	6.75%	4.69%	-0.48%	3.50%	13.54%
Iwakagi	6.95%	5.73%	2.85%	5.25%	12.82%

In Table (6) the second section in the range between 5% has the most response between all sections and the mixed method " Total Force" has the most response between mixed methods, while this method has more dispersal response than other methods in sections (has response in 4 sections)

Table 6. Number of flows obtained from experimental methods with difference less than 5% with the measured flows at different sections

Sec	Q(Los)	Q(Col)	Q(T.F.)	Q(Hor)	Total
1	11	9	0	7	27
2	0	8	12	11	31
3	0	0	9	0	9
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0

7	0	0	0	0	0
8	0	0	8	0	8
9	0	0	4	0	4
10	0	0	0	0	0
Total	11	17	33	18	79

According to average measured flow and calculated flows can be realized that StricklerandRaudkivi relationships combined with Brownlie relationship by using Total Force Method in second section has the nearest values (Respectively 122.78 and 123.12 cubic meters per second) to the average measured flow(122.89 cubic meters per second). Calculated Manning roughness coefficients for them are equal to 0.05097 and 0.05087 and average velocity of flow is equal to 1.3829 and 1.3857 meters per second. Furthermore, we can say that the Total Force Method is the best combined method between introduced combined methods. In the following presented charts represent the obtained Manning roughness coefficient and flow for the whole path that have been achieved from experimental methods in any of combined methods. Figure (6) and (8) represents the obtained Manning roughness coefficients are for the whole path.

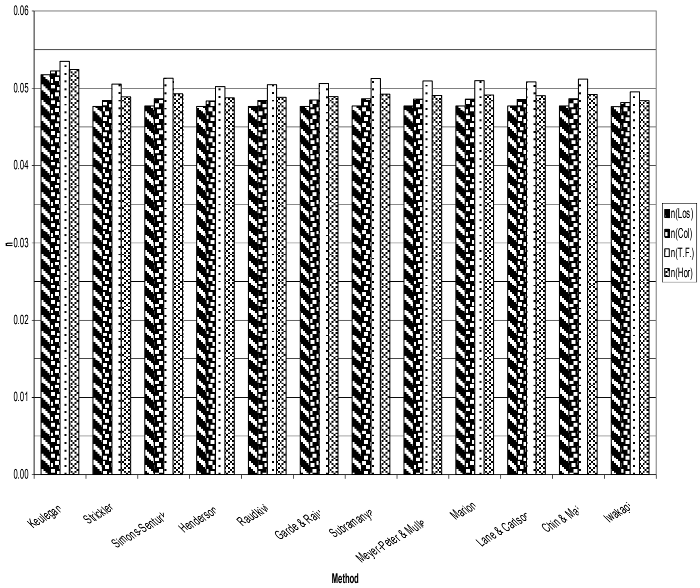

Figure 6. Comparison of the Manning roughness coefficient obtained for the entire path from experimental methods

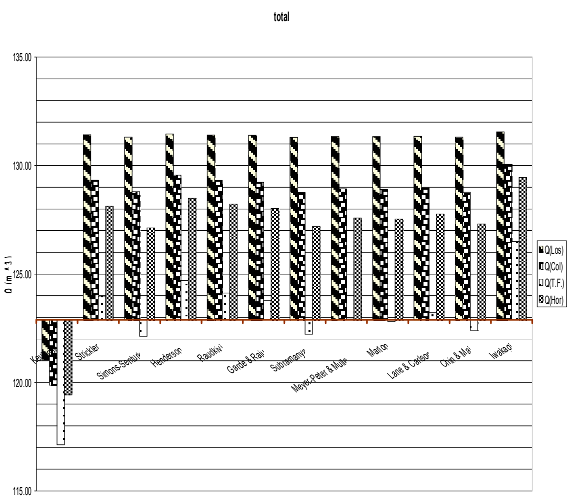

Figure 7: Comparison of obtained flow values for the entire path of experimental methods using combination methods

As can be seen in Figure (6) roughness coefficients that have been obtained from Keulegan Method in combination with the Brownlie relationship in combined methods are more than other relationships' responses. Figure (7) shows difference between the achieved flow and measured flow in whole path (Main sensing axis in this Charts is measured flow).

As it's obvious, Keulegan relationship's responses combined with Brownlie relationship in different combined methods are less than measured flow. Can be understand from this chart that Strickler, Raudkivi, Meyer-Peter & Muller and Marion relationships combined with Brownlie relationship by using Total Force method have the best answer. One of the common methods to estimate Manning roughness coefficient for beds that covered by herbal is SCS method. In 1947 roughness coefficient curves released for five types of herbal covers by US Department of Agriculture according to the following relationship, so with the values of velocity, hydraulic radius and recognition of types of herbal covers this relationship can be used to determine SCS roughness coefficient.

$$n = \frac{CR^{\frac{1}{6}}}{a+19.97\log\left(R^{1.4}S^{0.4}\right)} \quad \textbf{(6)}$$

Where:

n: Manning roughness coefficient , C: Unit correction coefficient (it's value is 1 for British system and 1.2 for Metric system) , R: hydraulic radius (Feet or meter) , a: Coefficient for classification of plant in SCS method, S: Channel's slope ($\frac{ft}{ft}$or$\frac{\square}{m}$).

Note: Classified covers are shown in experiments. Also they are green and generally uniform.

Note: This relationship does not response in small amounts of [$R^{1.4}S^{0.4}$] , Therefore it is suggested to use maximum roughness coefficient (it means 0.5) when relationship results are more than 0.5 or less than zero .

Factors that directly affect this method are: bed's slope, hydraulic radius and Coefficient for classification of plant in SCS method.

Sensitivity analysis

General used terms in Sensitivity analysis of introduced relationship are:

Value of bed's slope and hydraulic radius was considered 1 for fixed state. Also classified herbal coefficient was considered 41 for fixed state. It means averaged maximum and minimum values were considered.

A) Change in slope: Considered Range of changes for riverbed's slop is 0.00001to 0.08, an increase in slope creates a downward trend in value of Manning coefficient, of course the slope of the trend is fixed for the riverbed slopes of 0.0015 to 0.005. Meanwhile earlier changes are still not fixed. This trend can be seen in Figure (8).

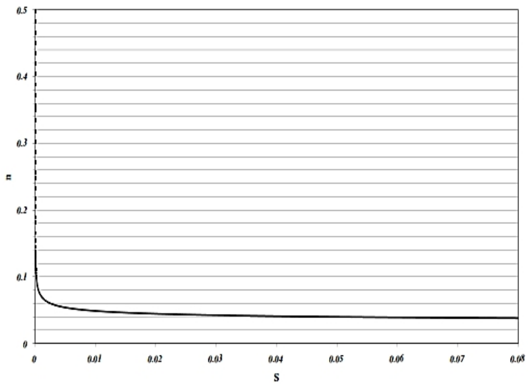

Figure 8. The influence of slope's changes on Roughness coefficient in the SCS method

In addition in Figure (9) , Figure (8)'s values shows change's percent of "n" to change's percent of riverbed's slope, While primary spots on the right side of the diagram and its endpoints are on the left. With this explanation, as can be seen in the figure differences percentage tend towards zero and leads to a convergence.

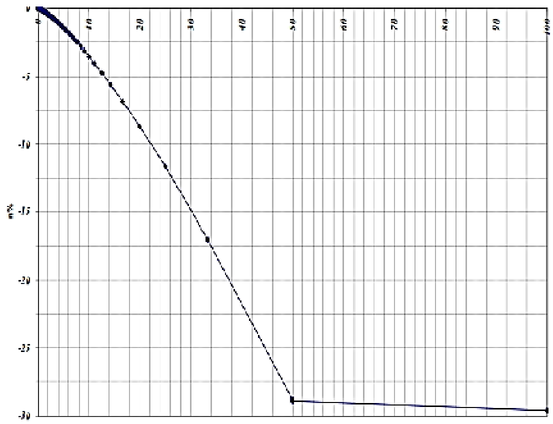

Figure9. Change's Percentage of bed's slope and its impact on Manning roughness coefficient

To most obvious change in "n" in range of 0.001 to 0.002 slope is shown in Figure (9). The trend observed in Figure (9) represent that the relationship is more sensitive to riverbed's slope and it needs more precision in determination in this range.

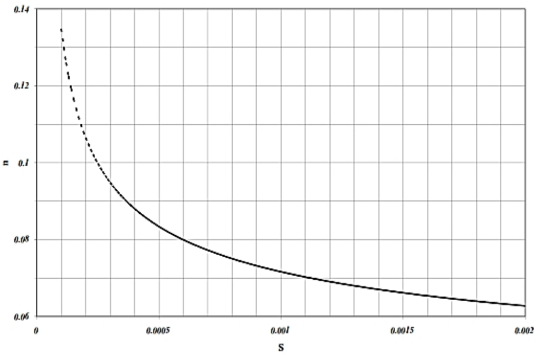

Figure 10. Changes in the slope from one 0.0001 up to 0.002 and mode of effects on Manning roughness coefficient

B) Change in hydraulic radius: Considered Range of changes for this parameter is 0. 1to 20.According to the chart (4) increasing the hydraulic radius will cause a decreasement in value of Manning coefficient. While, this effect continues to a radius of 13.8 m (the minimum obtained value) for the roughness coefficient and then the roughness coefficient curve increases with a light slope. This process can be easily seen in Figure (5), where the ranges of 0.025 to 0.0285 are examined. In addition, the results (roughness coefficient) change in the range of 0.025 to 0.028 for radius 1.5 m and more. For better visibility of this process, in this diagram the range is spread out to hydraulic radius of 200 m.

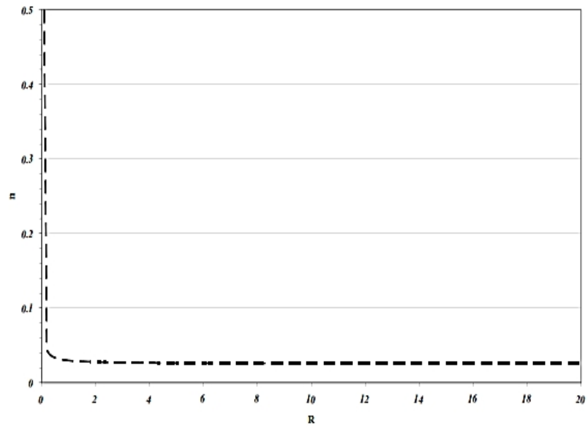

Figure 11. The influence of Hydraulic radius's changes on Roughness coefficient in the SCS method

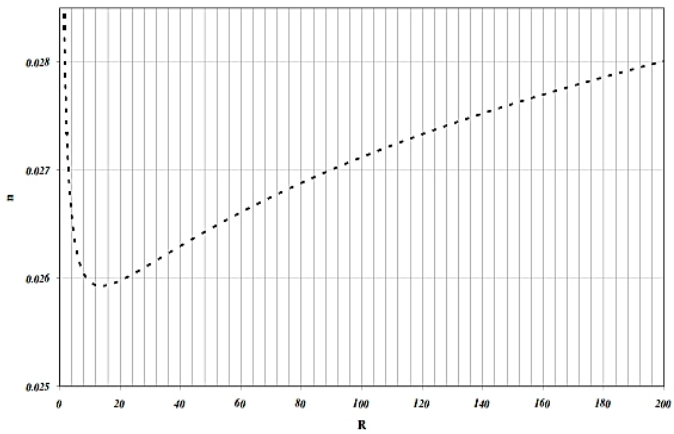

Figure12. The influence of Hydraulic radius's changes on Roughness coefficient in the SCS method (in the hydraulic radius from 4 to 200)

In the Figure (13) the process of percentage change in the hydraulic radius and the process of percentage change in Manning roughness coefficient are compared. Generally, we can understand process of reducing the hydraulic radius values causes a downward trend in variation of roughness coefficient values. Moreover, the slope of changes of these two parameters are not equal, this disparity in percent of change are caused by their different powers. It should be explained that the beginning and end of curves, show high values compared to other values. As can be seen in this diagram, from variations of sections 5 and 6 and more , variation percent of Roughness coefficient is reached below 10 percent (-0.1)and variations of sections 8 and 9 is reached below 5 percent (-0.05), that show reduction of influences in roughness coefficient of the high values of hydraulic radius of this parameter.

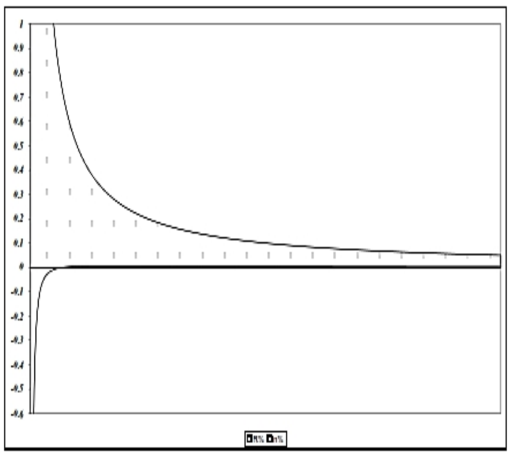

Figure 13. Change's Percentage of Hydraulic radius and its impact on Manning roughness coefficient

C) Simultaneous change of slope and hydraulic radius: In here the study will focus on changes of Manning roughness coefficient by change of the hydraulic radius in some certain amounts of bed's slope. Considered slopes are 0.0001, 0.007, 0.003, 0.04, 0.01 and 1. In addition, the hydraulic radius's ranges have been considered from 0.1 to 20. Figure (14) shows reaction between SCS relationship in defined terms. This chart shows the difference between roughness coefficient in the various radiuses and bed's slopes.The greater Bed's slope gets, the values of roughness coefficient get smaller and hydraulic radius begins at smaller values.

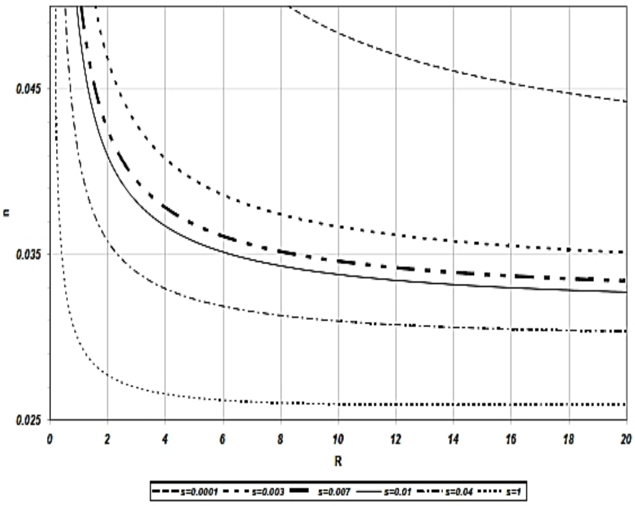

Figure 14. The amount of Manning roughness coefficient's changes with the hydraulic radius's changes in the various slope (in the more limited range of hydraulic radius)

As in the Figure (15) is observed when the Bed's slopes values are close, the slopes of the curves are approximately equal. Furthermore, in the Bed's slopes less than 0.0001 to 1, decreasing trend of roughness coefficient slightly turns into an increasing trend Of course this increasing is negligible and starts from various hydraulic radius. Greater bed's slope gets, the turning point of the curve occurs at smaller values of hydraulic radius. For better visibility of this process, in this diagram the range is spread out to hydraulic radius of 200 m.

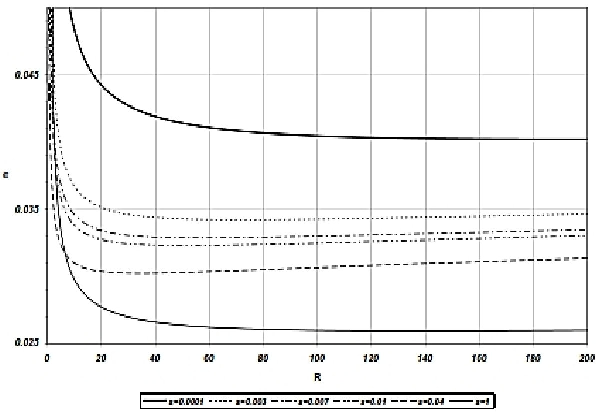

Figure 15. The Manning roughness coefficient changes with the hydraulic radius changes in the various slopes

D) Classification of vegetation cover coefficient in the SCS: Tested values in this case are numbers between 30 and 52 and results are shown in the Figure (16). According to the Figure (16) by increasing in classification coefficient, we have reducing in roughness coefficient.For better understanding of changes' process, variation Percentage of vegetation cover classification coefficient and its impact on roughness coefficient are shown in Figure (17).

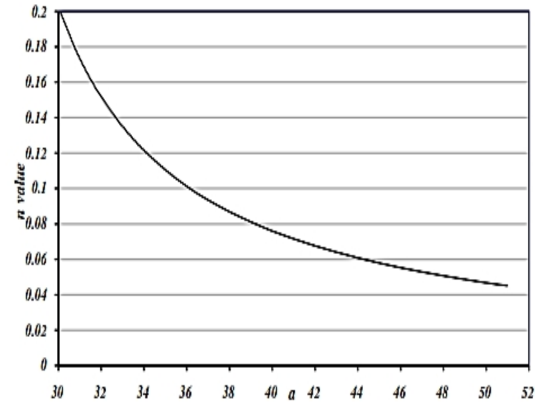

Figure 16. The influence of classification of vegetation cover coefficient's changes on roughness coefficient in the SCS method

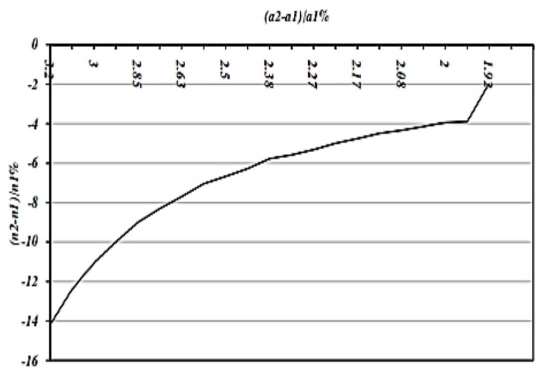

Figure 17. Comparison of percentage change of classification vegetation cover coefficient with changes of roughness coefficient in the SCS method

Pluralization

In summary, it can be picked that the bed slope's influence on roughness coefficient tends to zero at high values, while in low values it has high sensitivity. The sensitivity of this relationship at high values is less than its sensitivity at lower values to the hydraulic radius and finally from the charts can be realized that the most sensitive parameter of this relationship is coefficient of plant classification and then the bed slope that has more importance than hydraulic radius. In general, according to obtained charts and tables it can be concluded that by increasing parameter values mentioned in this relationship their impact on the results of relationship decreases and it shows that a decrease in response accuracy of this relationship. In fact low impact of the factors considered in this relationship and the lack of replacement by new factors demonstrates the weakness of this relationship in higher values of its effective parameters.Therefore, we should use other relationships to determine Manning roughness coefficients when the influence of some effective factors of the relationship is weak ,like some steep and large scale of open channels**.**

According to the presented results and review of achieved charts and hydraulic model of Sefidrud River and similar rivers can be taken that:

Keulegan relation combined with the Brownlie relationship has been answered just in the three sections in different methods, this is because absence of this relationship's conditions in other sections.Thus, generally results of this relationship are useless for investigation in this river.

Strickler relationship combined with Brown lie relationship by a combined method Total Force gives the best results to obtain flow in similar sections.

In addition, Meyer-Peter & Muller relationship combined with Brownlie relationship by a combined method Total Force gives the best response for entire path of rivers with similar characteristics.

Obtained results about the factors influencing roughness coefficient:

1. As seen in various relationships bed's roughness is a function of particles' shape, type and size. In most cases the greater the particle size and bed's surface irregularities and also bed's slope get, the roughness coefficient gets greater.
2. Increasing of changes in cross-section increases the value of roughness coefficient.
3. Increasing depth will decreases roughness coefficients.

4. Changes in flow and velocity will also change the roughness coefficients by impacting on the depth, area and wet perimeter of the duct and.....In case increasing the flow associated with increasing the depth will leading to a decrease in the roughness coefficient. Similarly decreasing the velocity associated with increasing the depth will leading to a decrease in the roughness coefficient. It must be mentioned that deceleration increases the deposition of suspended material that are contained in current; this issue itself requires studying in roughness of the bed form. Meanwhile increasing in roughness coefficient will reduce the depth, velocity and flow.

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