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Analysis of the Impact of Removing Meander on Shear Stress and Energy Line Slope by Hec-ras: A Case Study in Krishan Meander of Karun River

Iraj Rezapour[1*], Mahmoud Shafaei Bajestan[2], Suse's Poor[3]

[1] Hydraulic Structures, Department of Civil Engineering, Kish International Branch, Islamic Azad University, Kish, Iran

[2] Department of Hydraulic Structures, Shahid Chamran University, Ahvaz, Iran

[3]Hydraulic structures, Shahid Chamran University, Ahvaz, Iran

[*]E-mail: asozapor@yahoo.com

Abstract

Changes and displacements caused by natural or synthetic factors in the track of geometric characteristics of the river is the logical result of river systems' reaction to establishment of a new balance between erosion and deposition process. In this research, the impact of removing Krishan meander on the shear stress and energy line slope of Karun river flow in Ahvaz interval was studied by hec-ras software in two states. In the first state, the current status of Karun river and in the second state Krishan Meander in the downstream of Ahvaz were ignored and shear stress and energy line slope were compared in two states. By comparing two states, it was concluded that ignoring Krishan Meander, average shear stress and energy line slope increased and the increasing level enhanced with the increase of flood discharge. Shear stress increase also reduced the probability of formation of sedimentary hills in city range.

Keywords: shear stress, energy line slope, hec-ras, shortcut

Introduction

Changes and displacement caused by natural or artificial factors occurs in the path and geometrical characteristics of the river, logical consequence of the river systems' reaction is to establish a new balance between erosion and deposition process. Thus, making organizations and involvement in the rivers' systems requires recognizing specific rules governing them and prediction of river's reaction before doing anything else. Studies of rivers' morphology evaluate the impacts of different actions on the behavioral performance of rivers both qualitatively and quantitatively and thus enable the detection of instability factors and applying appropriate protective measures and engineering actions will be carried out in advance. Among the goals of improving rivers is to reduce flood levels in a range of river. This is carried out by increasing the permeability of waterways and flood plains by reforming and stabilizing the river and includes all works leading to path reformation (removing meander), widening, deepening cross-regulation, adjustment of flow depth and longitudinal slope, bed roughness coefficient change, removing superfluous obstacles in the path of the flow stream and stabilization of river beds.

The purpose of this study was to measure the effect of creating a shortcut on the bed shear stress and energy line slope of river meanders in alluvial bed. Therefore, Karun River is a permanent river, a part of it was selected in the alluvial bed with a lot of twists. Existence of some twists reduces energy line slope, shear stress reduction, flow rate reduction and increase in the deposition process in the Karun River. On the other hand, the area under study in this research is located in a residential, commercial and strategic zone that doubled the need to review the energy line slope and shear stress of Karun River in Ahvaz. Thus, by studying downstream meanders of Karun River, the impact of these natural constructs is analyzed. The first comprehensive study about deposition of the river was conducted by Kheiroallah (1991) and was done in order to organize this river for flood pass with the least deposition. Javaheri et al. (2005) studied the return of meander circles in Karun river and analyzed sensitive points of the river regarding deposition and erosion and represented some strategies for reducing erosion in sensitive points specially around pumping stations and reservoirs on Karun river. Abbasi (2007), using a neural network model QNET- 2000 concluded that, with regard to the capacity of suspended sediment passing through the stations of Ahvaz and Farsian, this interval of Karun river has deposition. Azarang et al. (2009), by using a one-dimensional model of CCHE, tried a hydraulic and sedimentary simulation of Karun river in Ahvaz-Farsian interval and modeled hydraulic and sedimentary condition of the river. Maghrebi (2010), by comparing MIKE FM21and CCHE2D models in simulation of flow pattern in the arc range of Karun river, showed that both software qualitatively stimulate the flow pattern in the area under study but there are differences in the results obtained from modeling both software which derives from the method of solving equations and different capabilities of these two software.

Yeganeh and Shafaie Bajestan (2012) studied a section of Karun river in the downstream of Ahvaz city by SMS software and according to a hundred-year-old river discharge, water level and flow rate were calculated at the available arch sections.

Materials and methods

Area under study

Karun river is one of the largest and longest rivers in Iran and the Basins of the Persian Gulf and Oman Sea and gathered waters of a large area of Iran and led to the Persian Gulf. The length of Karun river is about 890 kms and its basin area is about 62,570 km² and its annual water is estimated 22 billion cubic meters, according to the Ahvaz gages stations.

Mathematical Model

In order to do hydraulic calculations, HEC-RAS one-dimensional model for a full network of channels is designed. The model consists of three components of one-dimensional hydraulic analysis for the calculation of water surface profile at steady-state flow, simulation of unsteady flow and calculation of sediment transport in moving boundary. The components of steady flow have the capability to model water surface profiles in subcritical, supercritical and mixed flows.

To run the software in viable terms, the following conditions should be satisfied :

Flow is persistent: The flow is gradually varied except in hydraulic structures such as bridges, culvert and spillways. In these places, since varied flow may occur, momentum equation is used.

The flow is one-dimensional: River or canal gradient is low, and it is often suggested that the slope is less than 10%. Since all conditions in this research are valid, the software should be applied in the condition of stable flow (under this condition, the water level profile is calculated by energy calculation) because the main purpose of the analysis is under condition of flood peak and since the path under study is long, the varied flow is gradual and the conduit slope is about 2 to 5 per ten thousand.

It should be noted that if the fast changing flow is dominant like in hydraulic jump, energy loss is not computable and in this situation, momentum equation is used to calculate water level profile. That, here dominant relations were not mentioned.

Sample of the study

In order to stimulate hydraulic flow of Karun river, geometric, hydraulic information of the river by HEC-RAS is required. In the geometric section of the schematic figure of river plan, cross-sections of the river, meaning roughness coefficient opening and narrowing coefficients were attributed to the model. In this research, a 75.3 km interval from Karun river was considered from Zargan to Farsian including 155 cross sections. In figure 1 of schematic plan 1 of Karun river in Zargan river in the Zargan – Farsian interval was shown before removing meander.

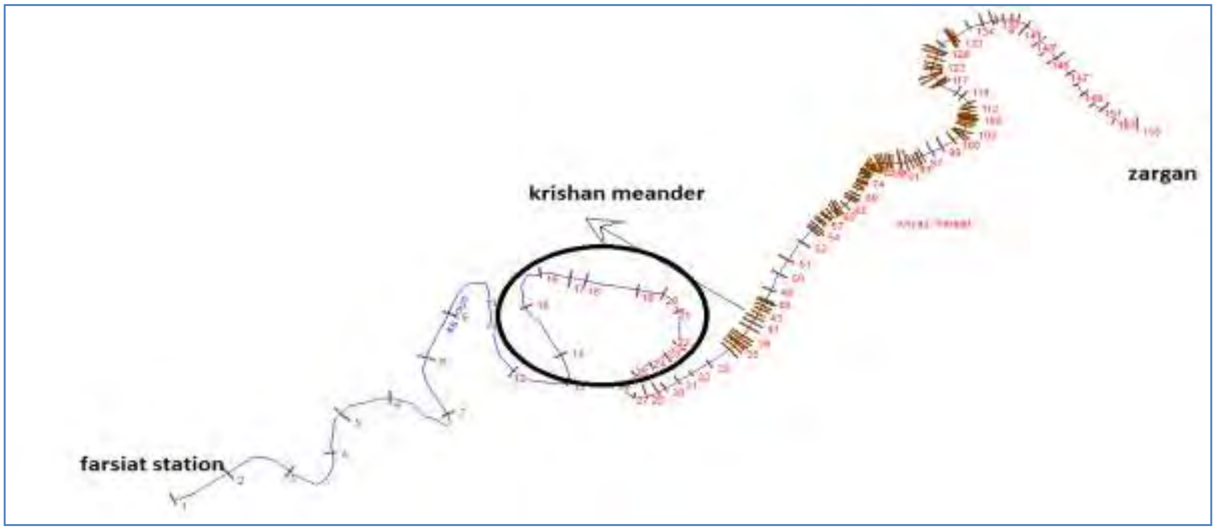

Figure 1: Schematic plan of Krishan meander on hydraulic flow in Karun river,

This meander was removed whose schematic plan is shown in figure 2.

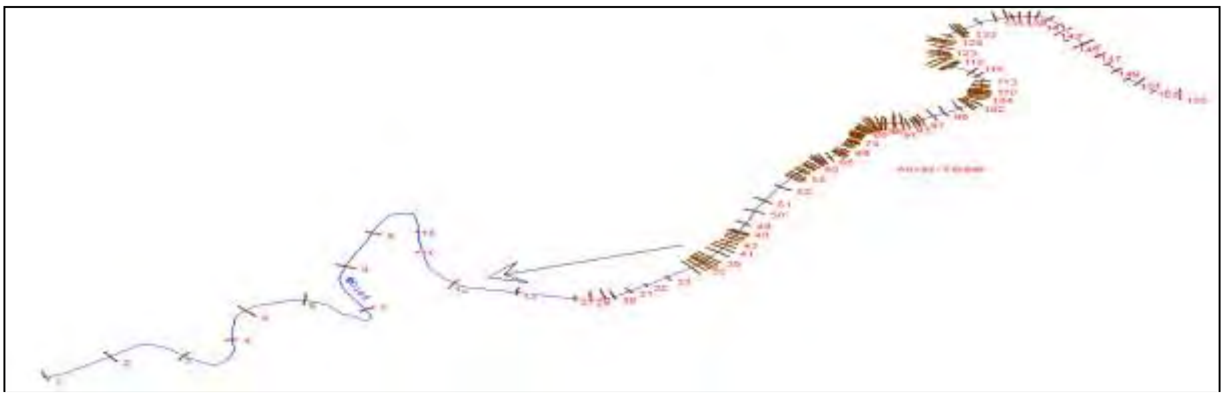

Figure 2: Schematic plan of Karun river after removing Krishan meander

After drawing a schematic figure of the interval under study in the two states (figure 1 and 2), different series of cross-sections were introduced to the model and the model was applied for the two following states.

The first state takes place before removing Krishan meander and in second state, Krishan meander was removed and the sections related to establishment of artificial shortcut were added to the model. Narrowing and opening coefficients represents the amount of energy loss as a result of flow section change.

Table 1: Discharges with different return periods in Ahvaz stations

Return period	2	10	20	50	100	200
	2560	4230	4700	5230	5590	5910

Recommended dosage for narrowing and disruption is according to the recommendations of hydraulic center of US military engineers in which 0.3 and 0.1 are used. Also, in order to estimate the amount of meaning roughness under condition of different cross sections, previous reports and experiences were used. At last, meaning roughness coefficient was taken into account to represent 0.35 model. In order to find discharges with different return cycles, a daily 30-year-old statistics of hydrometric station in Ahvaz city was used. The related statistics of discharge were evaluated using statistical software. The results are observed in table 1.

Also, regarding subcritical regimen of flow, discharge-easels curve of Farsian station is brought in figure 3.

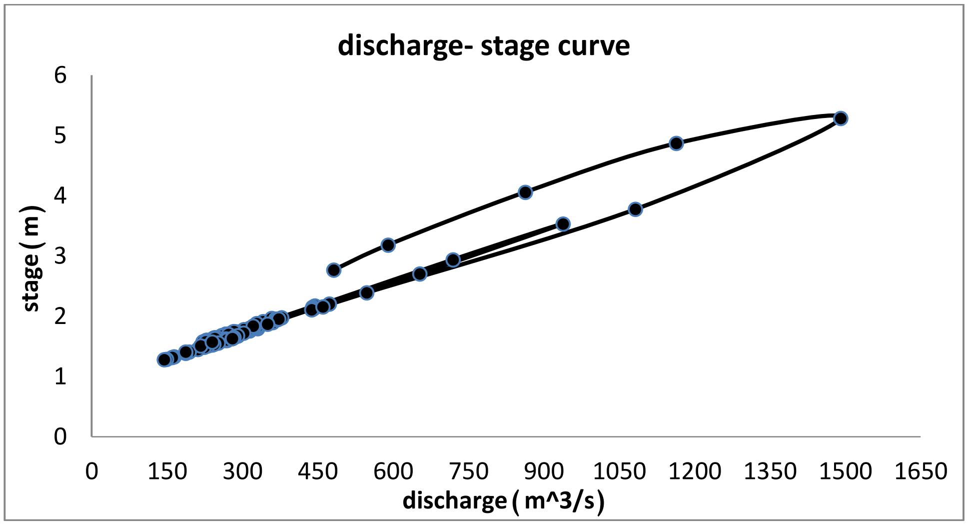

Figure 3: discharge-easel curve in Farsian station

Results and Discussion

After entering river plan and necessary data in the software, the model was applied in two states (first state without shortcut establishment and the second state with shortcut establishment). Also, the output results of the model were compared with each other.

Energy line level

Since removing Krishan meander in Ahvaz downstream leads to path shortening and finally path loss reduces, there is an increase in energy line slope leading to adecrease of water level and increase of average speed of flow and finally an increase in waterway in Ahvaz interval.

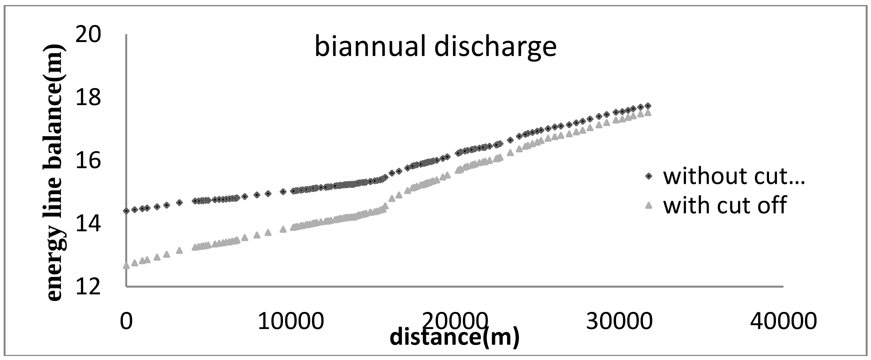

Figure 4: energy line balance in two states in Ahvaz interval in discharge with biannual return period

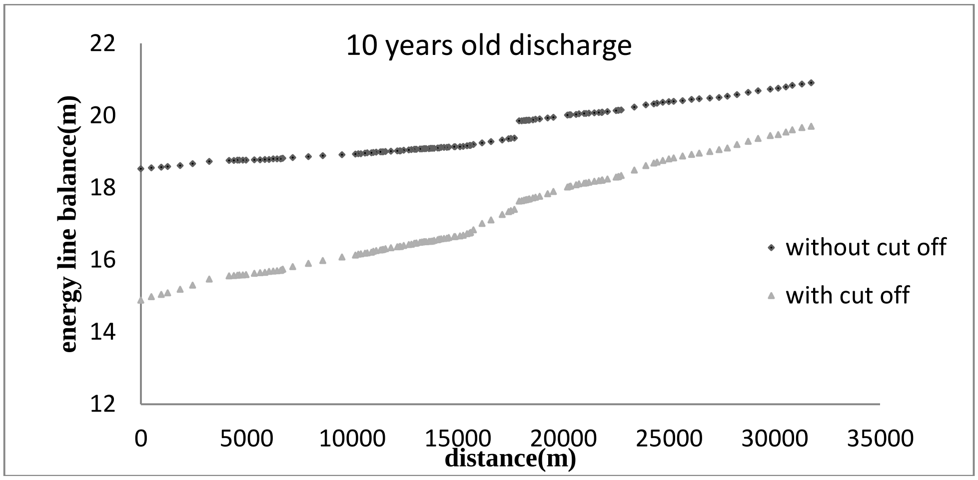

Figure 5: Energy line balance in two states in Ahvaz interval in discharge with 10 years old return period

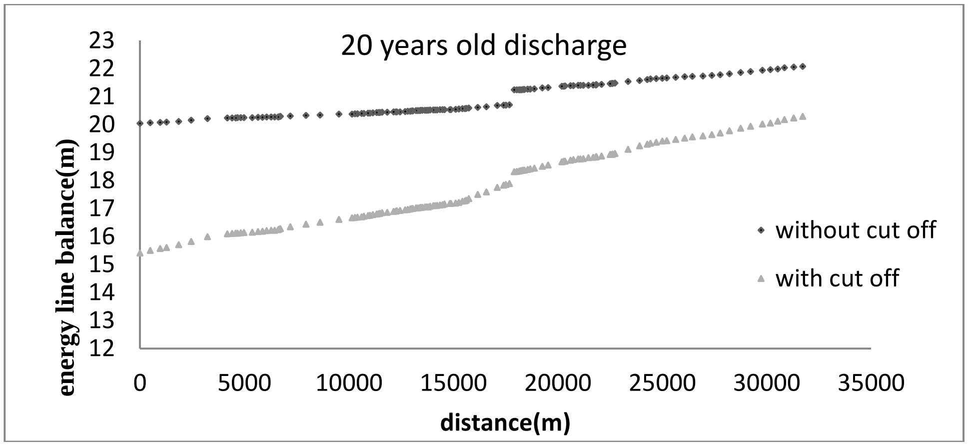

Figure 6: Energy line balance in two states in Ahvaz interval in discharge with 20 years old return period

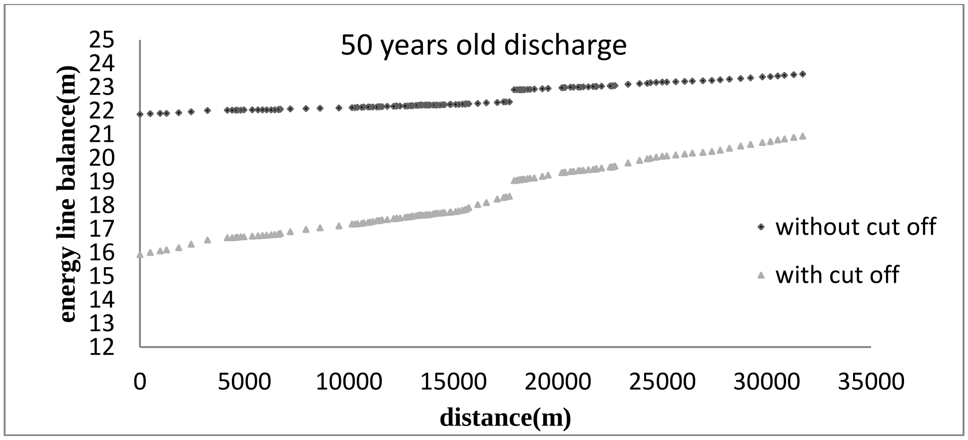

Figure 7: Energy line balance in two states in Ahvaz interval in discharge with 50 years old return period

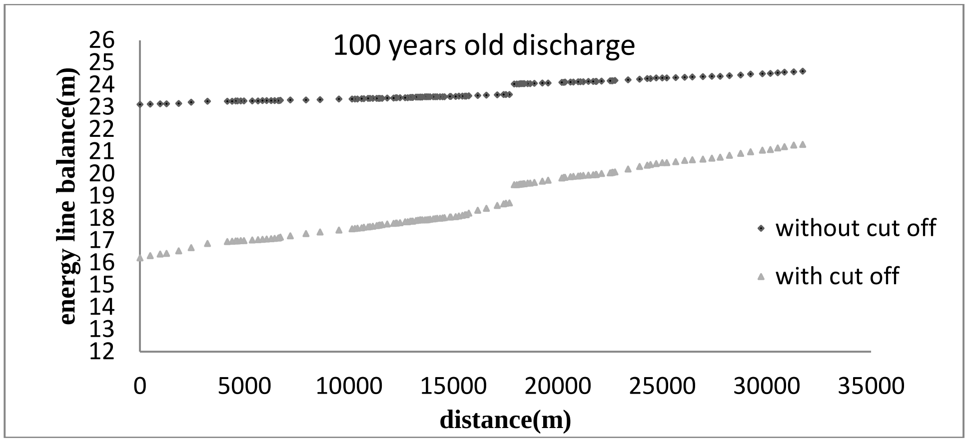

Figure 8: Energy line balance in two states in Ahvaz interval in discharge with 100 years old return period

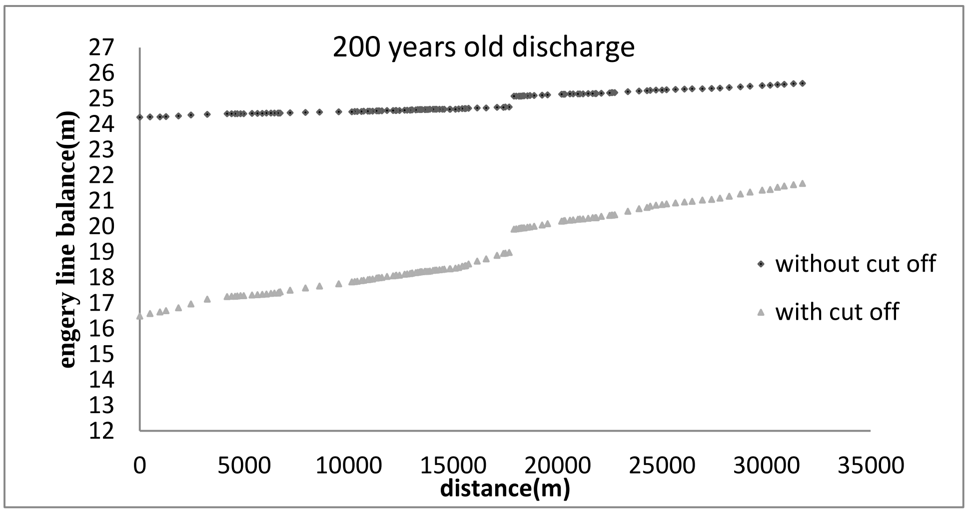

Figure 9: Energy line balance in two states of Ahvaz interval in discharge with 200 years old return period

In order to check the balance of energy flow in the cases listed in Table 1 in two states, energy line balance from the beginning of interval upstream under study up to the beginning of shortcut about 32 km will be studied. Figures 4 to 9 shows energy line balance in cases of table 1 in two states.

According to the above figures, removing Krishan meanders leads to the reduction of energy line balance in Ahvaz zone which intensifies by increasing flood discharge. It means that in huge floods, the impact of removing meander on energy line balance of Karun river in Ahvaz is more observable. The balance slope of energy line is in fact the same energy line slope. Thus, the average slope of energy line along interval under study in two states is observed in the following table.

Table 2 indicates the average slop of energy line in Ahvaz interval for two states. In the first state (the natural state), increasing the flood exchange of average slope of the energy line declined which happens because of the entrance of flow to the plain flood of the river.

In general, by removing Krishan meander in downstream Ahvaz, the average slope of energy line increases.

Table 2: Percentage of energy line slope increase by establishing shortcut in the interval under study with exchanges in different returns

Return period	Biannual		10 years old		20 years old		50 years old		100 years old	
State	first	second	first	second	first	second	first	second	first	second
Average slope Energy In the interval under study (percent)	0.000105	0.000152	0.000075	0.000152	0.000064	0.000154	0.000054	0.000158	0.000047	0.000161
Proportion of the second state to the first one	1.45		2.02		2.4		2.94		3.4	

But, this increase is strengthened by the increase of return period as in biannual discharge removing meander leads to a 1.45 times increase of energy line slope and in 100 years old discharge, the average slope of energy line increased up to 3.4 times. That, the desired result is achieved.

Average shear stress

Since shear stress of flow has a direct relation with erosion and deposition in open ducts, it is necessary to study it. Shear stress for the states (with or without shortcut) is shown in the following figures.

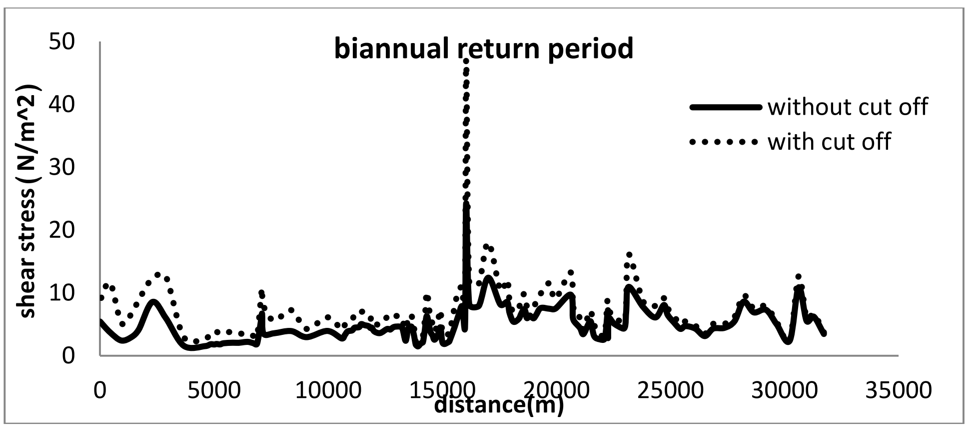

Figure 9: Average speed of the flow in two states for biannual discharge

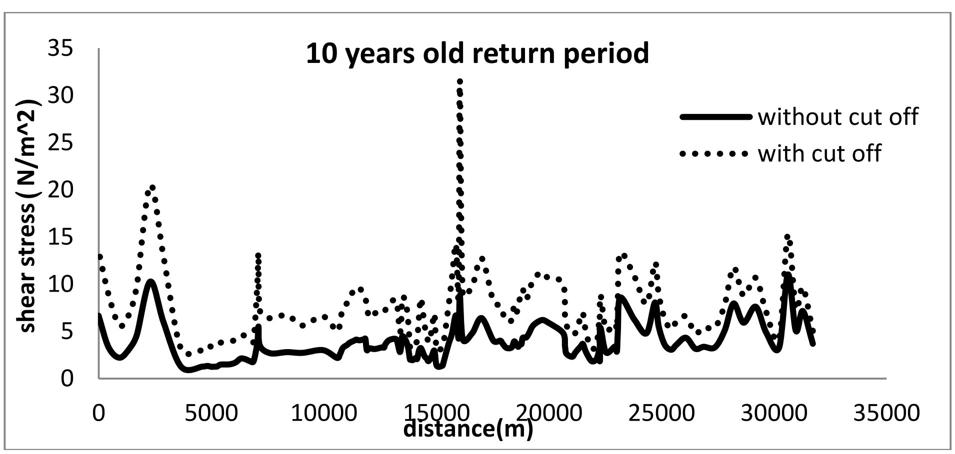

Figure 10: Average speed of the flow in two states for 10 years old discharge

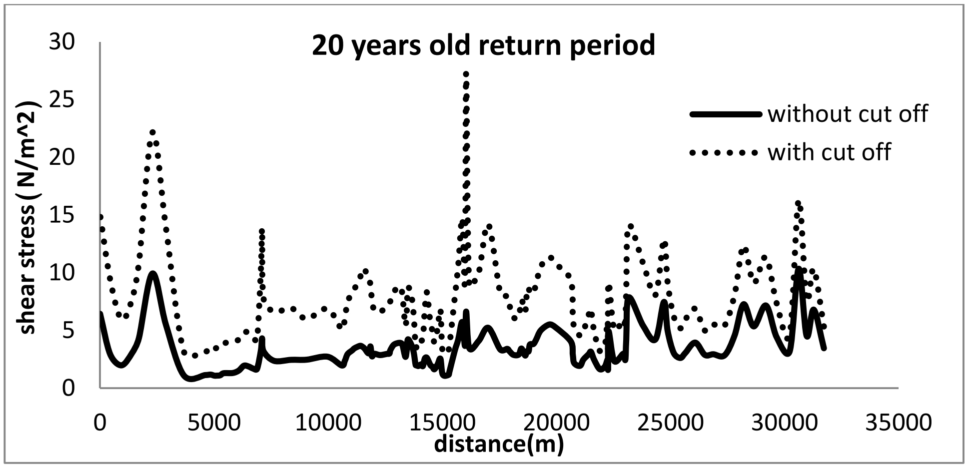

Figure 11: Average speed of the flow in two states for 20 years old discharge

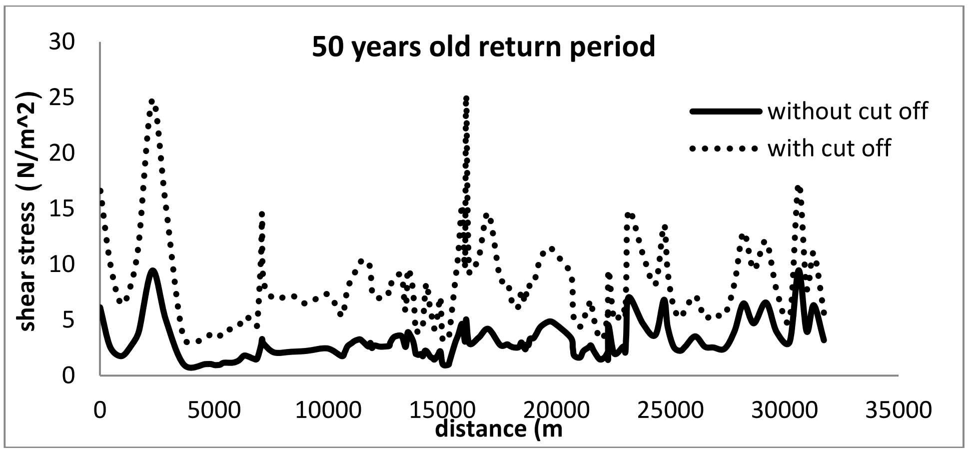

Figure 12: Average speed of the flow in two states for 50 years old discharge

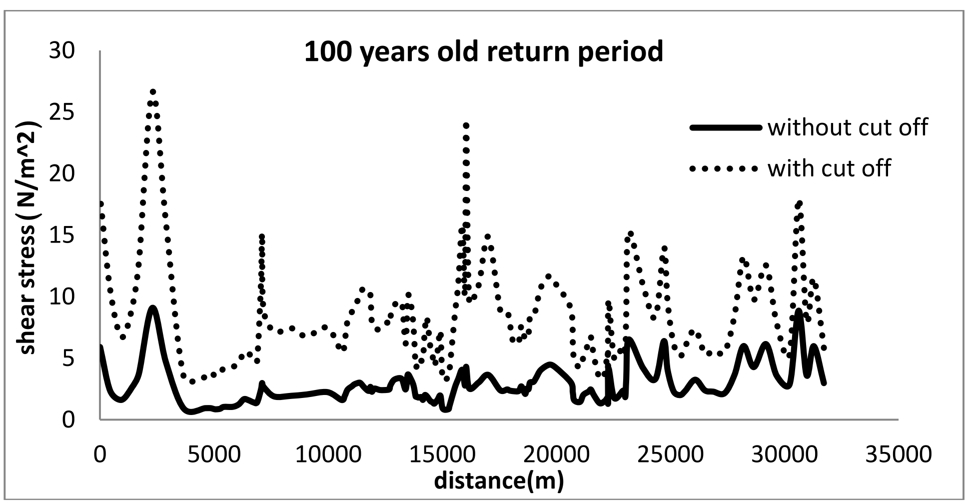

Figure 13: Average speed of the flow in two states for 100 years old discharge

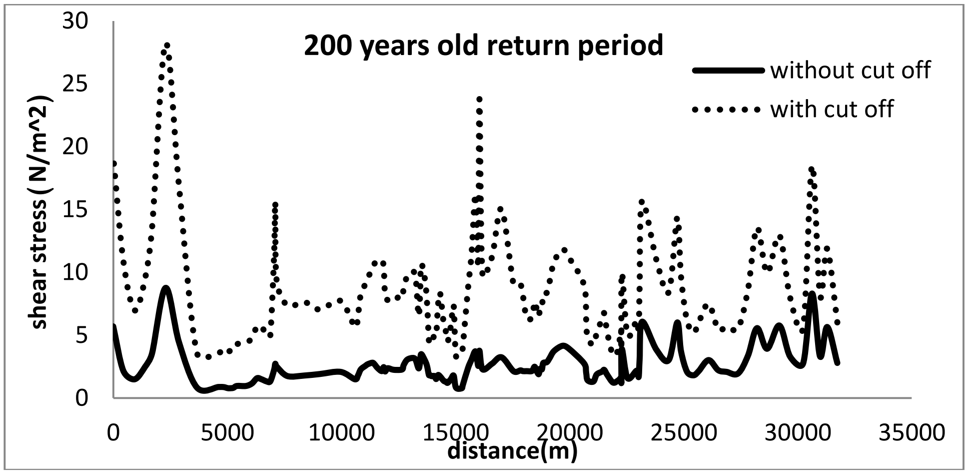

Figure 14: Average speed of the flow in two states for 200 years old discharge

According to figures 9 to 14, removing Krishan meander causes an increase in average shear stress in Ahvaz interval, indicating an increase in flood discharge, which shows a raising trend. Consequently, an increase in shear stress in Ahvaz interval leads to an avoidance of sediment leakage as a result of islands formed around the urban area and with regard to form is not appropriate for the urban zone and in case of dredging in the new condition (removing Krishan meander) is not formed anymore and annual dredging costs of Karun around Ahvaz city is not expensive. With regard to the importance of the problem, a selected section at the center of Ahvaz is studied. The following table indicates average shear stress changes with removing meander.

Table 3: Percentage of shear stress increase in two states at the center of Ahvaz

Return period	**biannual**		**10 years old**		**20 years old**		**50 years old**		**100 years old**		**200 years old**	
state	first	second	first	second	first	second	first	second	first	second	first	second
(average) (N/m^2)	3.56	5.59	2.68	6.37	2.37	6.6	2.07	6.9	1.89	7.15	1.76	7.36
Percentage of increase of average shear stress (%)	0.67		1.38		1.78		3.34		2.78		3.18	

In table 3, we can see that by establishing a shortcut (removing Krishan meander), the average shear stress in every discharge in the chosen section has increased. Before establishing shortcuts, by increasing flood return period of average shear stress, there is a decrease and before establishing shortcut in biannual discharge, the shear stress equals to 3.56 N/m^2 and in the 200-year-old discharge, and this amount reaches to 1.76 (comparing shear stress in first states in the third raw of the table). The reason for shear stress reduction, with increase of flood discharge, is the dispersion of flood in plain's flood. By establishment of shortcut in each discharge, the shear stress increases as in biannual discharge 76 percent and in 200 years old discharge 3.18 percent increases.

Conclusion

Removing Krishan meander in the downstream Ahvaz greatly impacts flow hydraulic in Karun river around Ahvaz. As by establishing shortcut, the average slope of energy in Ahvaz zone significantly increases especially in flood discharge leading to a decrease in flow depth and increase of flow rate which is consistent with results of researches by Poor Asef et al (2009) and Azm et al (2013).

1. By removing Krishan meander, the highest average slope increase occurs at 200 years old discharge and its value compared to the natural state of the river is 3.4 times higher and the lowest increase also occurred in biannual discharge and the proportion of energy line slope increasing in this discharge is 1.45 times more.

2. Changes of shear stress is also increased by removing meander as the highest increase in 200 years old discharge is 3.18% and the lowest increase in the biannual discharge is 0.67%.

3. By increasing shear stress in Ahvaz interval with removing Krishan meander, the possibility of formation of sedimentary hills in the metropolitan area is reduced.

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