Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 3 Spl Issue III 2014: 20-27
©2014 Academy for Environment and Life Sciences, India
Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

Full Length Article

Determining the Best Method for Estimating the Bed Load through HEC-RAS Model (A Case Study for Taleghan Dam)

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ABSTRACT

One of the objectives of river engineering science in sediments studies is to estimate the amount of sediments and to access appropriate methods of estimating sediment transport capacity of the rivers. In order to design river engineering operations, different mathematical models such as HEC-RAS model can be used. In this case, the first step is to stimulate hydraulic conditions of the flow which can be fulfilled by applying the geometric features of the river and flow hydraulic through the abovementioned model. The present research has estimated the amount of input sediment to the reservoir of Taleghan Dam through mathematical model of HEC-RAS and has determined the best method for estimating the bed load among the seven methods of aforementioned model. Using the required data of the model such as geometric shape of the river, data relating to sedimentary materials of the river, data relating to hydrology or river flow, as well as hydraulic conditions of upstream and downstream system and implementing it, the annual amount of input sediment to the dam reservoir was determined through the sediment statistics of Cling station (upstream) and Lushun station (downstream). Then the floor load obtained from the observed data was compared to the results of seven models. The results showed that the best performance belonged to Wilcok method so that according to hydrometric stations data, in the period between 1980 and 1994 the amount of floor load was about 0.734 million tons per year and according to Wilcock method it was estimated to be 0.635 million tons.

Keywords: HEC-RAS model, Taleghan Dam, bed load, flow hydraulic

Received 28.04.2014 Revised 02.05.2014 Accepted 23.06. 2014

INTRODUCTION

Usually, based on the slope and cross section of the river, sediments transport capacity of the flow is changing and other solid materials are added to or subtracted from the flow. In mountains, due to steep slope of the river and flow discharge, sediment transport capacity is high and a part of river bed is eroded along with the washed sediments of the basin and these materials will enter the flow. In plains, the slope decreases, sediment transport capacity decreases as well and thus the transported solid materials are deposited with regard to sediment transport capacity of the flow [5].

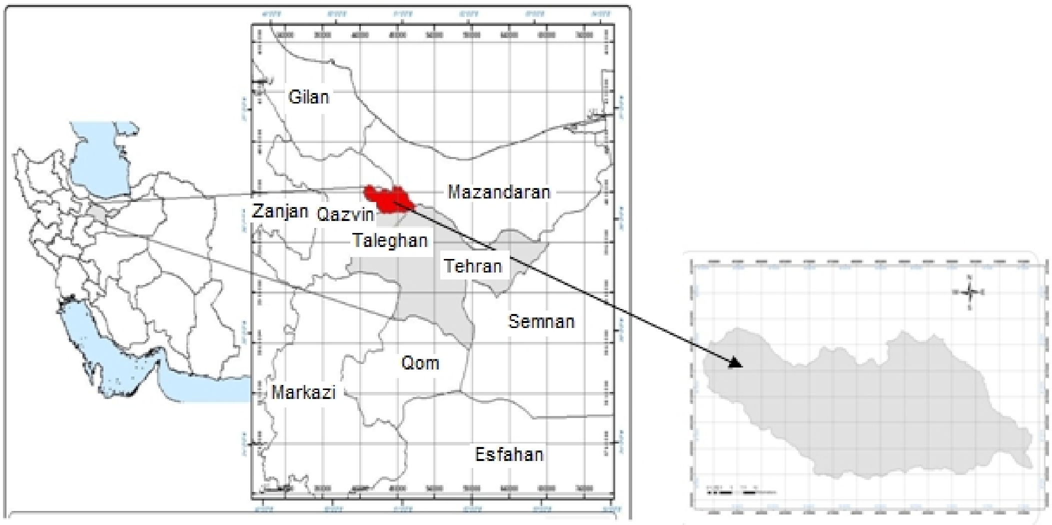
Sedimentation and erosion in different parts of the river may cause different problems such as changing the path of river flow, destroying bridges and other hydraulic structures, flood penetrating farmlands and industrial areas, and destroying residential areas. Bridge spans and underpasses clogging and their destruction through the water pressure resulting from the raise of water level at upstream of these structures in turn cause a new wave of flood which in some cases could be stronger than the original wave. This could enhance the flood dame, too. In present research, the amount of sediments deposited in the dam reservoir has been estimated using HEC-RAS mathematical model. Foreign and domestic researchers who have conducted studies in this area directly and indirectly are Li [23], Bates [21], Horritt [21], Adam [20], Knebl [22], Abrishami [2], Al Yasin [1], Taloori [5], Rangzan [15], Hosseini [8], Kazemi [17], etc.

Hosseini et al. (2009) did some research on the Kharrud River and the Abharrud River. They stimulated and investigated hydraulic conditions and studied sedimentation distribution along the river path and identified proper spots and places for removing sediment throughout the studied rivers. Finally, they estimated the rate of passing sediments during 37-year simulating period through extracting the amount of changes in floor level of each section of the river. According to changes trend of sedimentation in the river, the most appropriate period to remove sediments from the river was recommended to be between December and April [7]. In a research on the Jajrud River and the Taleghan River, Kazemi (2008) studied the bed load and suspended load through some equations and simulated the flow via HEC-RAS in the aforementioned rivers. He concluded that in both rivers Schoklitsch equation was the best equation for estimating the bed load and Bangold equation in Taleghan and Einstein equation in Jajrud were appropriate for estimating the suspended load. The present study aims to investigate sediments deposited in the lake of Taleghan dam since its construction until now and to determine the best method for estimating suspended load within HEC-RAS model.

MATERIALS AND METHODS

Characteristics of the Studied Area

Taleghan Watershed in Alborz province (110 km northeast Tehran) in located in the altitudes of Central Alborz which is adjacent to Ghazvin Province in west and Mazandaran province in north. It is located between two watersheds of Karaj and Alamut. The area of this watershed is about 1325 km^2 which is located at latitudes 36°5'20" and 36°11'15" N and longitudes 50°45'00" and 51°11'15" E in maximum and minimum heights of 4400 and 1790 m above the sea level. The studied area is the lake of Taleghan Dam.



Map 1: National and provincial location of studied area

Table 1: Technical specifications of Taleghan reservoir dam

Type of dam	Soil with clay core
Crest elevation	1789 m above the sea level
height above river bed	103 m
height above foundation	109 m
crest length	111 m
crest width	12m
body size	14.8 m m^3
type of spillway	Open chute
spillways capacity	2500 m^3
watershed area	960 km^2
average annual rainfall	615 mm
average annual discharge of Taleghan River	16.3 m^3/s
Maximum elevation of reservoir water level	1780 m above sea level
Reservoir volume	420 m m^3
Useful volume of reservoir	329 m m^3
Reservoir area	12.0 km^2
Total annual discharge	460 m m^3

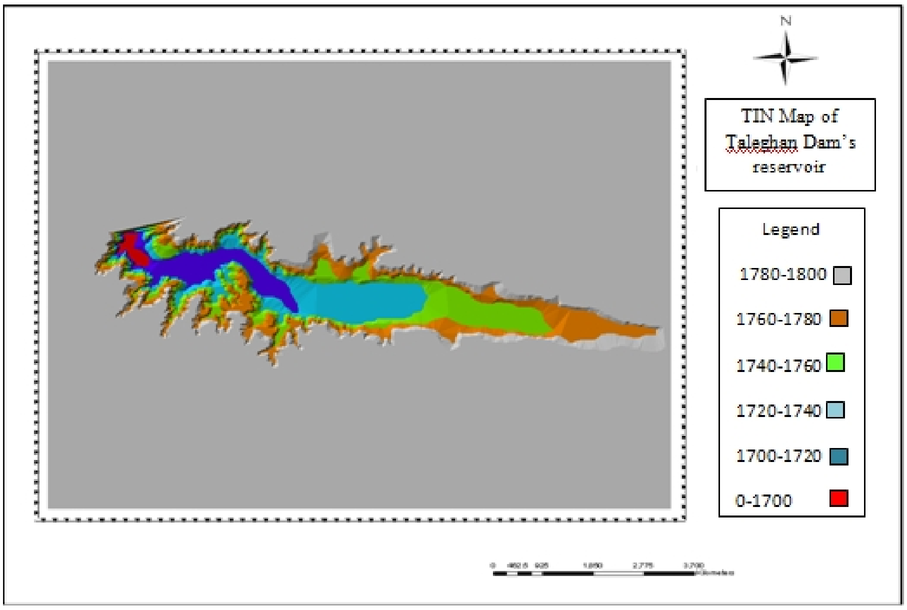
Required Data and Information

In studies related to estimating sediments of the rivers through HEC-RAS model three kinds of information are required including information relating to geometric shape of the river, river sediments, river hydrology or flow as well as hydraulic conditions of upstream and downstream system which will be explained in the following.

The required data for implementing the model include:

- ❖ Topographic profile and drainage plan, topographic map (1:50000) of Taleghan watershed (cross of Taleghan dam's lake)
- ❖ Geometric features and cross sections of the river and the distance between them at a scale of 1:50000
- ❖ River discharge values
- ❖ Roughness coefficient values of the river in each interval
- ❖ Times series and boundary conditions of the region (such as discharge curves- upstream and downstream scale, input hydrographs and flood discharge values)

In order to facilitate and accelerate the studies and application of relevant model, geometric and cross sections of the river can be extracted through the use of GIS system and application of digital elevation maps (DEM) of the region, extracted from topographic maps.



Map 2: TIN Map of Taleghan Dam's reservoir

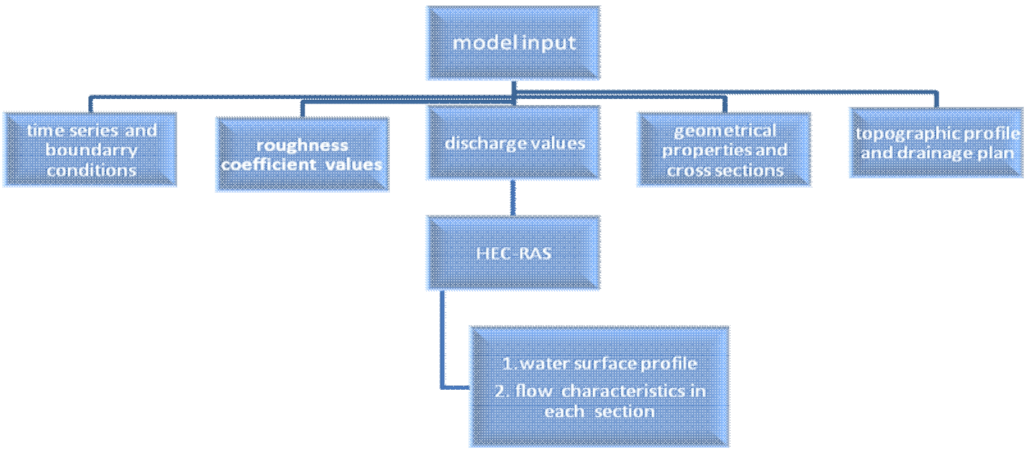


Figure 1: chart of HEC-RAS model

MATERIALS AND METHODS

HEC-RAS is able to calculate bed load by means of 7 methods. Calculating methods of sediment transport which are used in new version of HEC-RAS model are as the followings:

- Ackers-white (1973) transport function
- England –Hansen
- Copeland's (1996) modification of Laursen's Relationship (Copeland and Thomas, 1989)
- Moyer – Peter and Muller (1948)
- Toffaletti (1966)
- Yang's (1973) stream power for sands
- Wilcock

❖ Ackers-White (1972) equation attempts to present relationships for calculating sediment transport capacity of the rivers through dimensional analysis. These relationships are presented based on three dimensionless numbers including the function of sediments transport capacity, mobility index and dimensionless size of the particles.

❖ England and Hansen equation have resorted to dimensionless relationship of shear force and also the coefficients obtained via laboratory research and in order to ensure the above relationships, used the statistics of observed sediments which were available and concluded that the equations did not present good and acceptable results for particles smaller than 0.15 mm due to too many limitations.

❖ Laursen equation by means of data obtained in laboratory experiments not only extended laboratory results and the statistics obtained from three small streams, but also obtained a formula experimentally. Some of the parameters in this formula are presented graphically.

❖ Meyer-Peter-Muller equation: the first experimental formula was presented by Meyer-Peter-Muller in 1948. This formula is based on the extending experimental results obtained through laboratory results in terms of using rectangular section streams with coarse bed materials. It has been presented to estimate the sediments transport capacity in the rivers whose bed materials are sand and gravel. Here a simple equation is obtained based on processing and analyzing available data which is still being used.

❖ Toffaletti equation (1968-1969): by extending Einstein's equations, Toffaletti has presented some equations to calculate sand sediments transport capacity in rivers in details and by distributing transport capacity from the bottom up to the surface of water. The sum of sediments transport capacity in this method can be calculated with regard to the size of particles and corresponding percentages in three lower, middle, and upper parts of water flow. However, since the abovementioned equations are obtained through experimental data and collected statistics they cannot be used for all the rivers and it can be concluded that their results are acceptable for particle with diameters larger than 0.625 mm and they have some limitations for particles with smaller diameters.

❖ Yang Equation (1972): Yang was the most successful researcher who could present sediments transport equations for the rivers based on flow theory and who could find some relationships between sediments concentration and unit of flow energy. In 1973, by reviewing previous works and using correlation analysis, Yang could obtain a dimensionless equation for sediments transport capacity. He found a relationship between the bed load of materials and the rate of dissipation of flow energy and presented an equation for estimating the load of bed materials and stated that in steady and uniform flow, there is no change in kinetic energy and energy dissipation rate is due to changes in potential energy. He called the velocity × channel slope as the Unit Stream Power. Since the sediment is transported solely due to the conditions of turbulent flows, the total amount of deposition is directly related to unit stream power. Yang and Molinas (1982) showed that there should be the following relationship between total rate of sediment and unit stream power using the basic principles governing turbulent flows.

Log CT = M + N log VSws

In which, M and N are dimensionless parameters that depend on features of flow and sediment and $_{ws}$ is the falling velocity of sediment particles Coefficients of M and N have been obtained based on experimental data and regression analysis.

❖ Wilcock equation

In 1977, Wilcock used sediment transport observations in four streams and a studied flume to estimate the amount of carrying sand and used two common formulas of shear stress of sand and gravel in his equation.

$$W_i^* = \frac{(S-1)gq_{bi}}{f_i \rho_s \left(\tau/\rho\right)^{1.5}}$$

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$$S = \rho_s / \rho$$

ρ_s is the sediment weight, ρ is specific weight of water, g is gravity force,

q_{bi} is the rate of sediment transport in mass unit within a time, f_i is the amount of i, t is the shear tension of sand and gravel.

Considering seven equations for estimating sediment in HEC-RAS model, it is necessary to compare the results of implementation of each of these equations with the results of measured sediments in stations, so that the best equation which has the closest respond to the gauging station of the area in estimating sediments could be selected. Hydrometric station of Glink which drains a watershed of 805 km^2 is upstream of the dam and hydroelectric power plant of Taleghan, and hydroelectric station of Lushun with an area of 4797 km^2 is located at downstream of the dam. According to the statistics during 1970 to 1984, the mean annual rate of suspended sediment discharge is 0.678 million tons at Glink hydrological station and the coefficient of sediment transport is 842 t/km per year. The mean annual rate of suspended sediment discharge is 6.42 million tons at Lushun station and the coefficient of sediment transport is 1801 t/km per year. The input sediment to the dam is obtained by comparing the sediment transport coefficients of these two hydrological stations. Therefore, the mean annual rate of input sediment to the lake of dam by counting the coefficient of 10% as the floor load is 0.734 million tons.

RESULTS

After preparing the data relating to geometric shape of dam reservoir in GEORAS software at GIS environment and entering all required date into HEC-RAS model which was described in details in previous chapter and its implementation the following results were obtained.

A. Cross section of Taleghan dam's reservoir: after entering data into the model at geometric data-sediment part it is possible to observe the determined sections on the dam reservoir (34 sections) and cross profile of each section relating to 2009 which is prepared based on the satellite image of that year.

B. Estimation of the sediment in Taleghan dam's reservoir: the rate of sediment in Taleghan dam's reservoir was estimated via HEC-RAS model and through the use of mentioned methods in new version of this model, and the results of each method were presented separately. Finally, by comparing the obtained results of the model with real annual amount of input sediment to dam's reservoir, the closest result to reality was suggested among the results of available methods for estimating sediment in Taleghan dam.

Estimating Reservoir's Bed Load by Ackers-White Method

Through applying HEC-RAS model and selecting Ackers-White method, the model has been implemented and the sedimentation trend in reservoir's sections has been shown in the diagram.

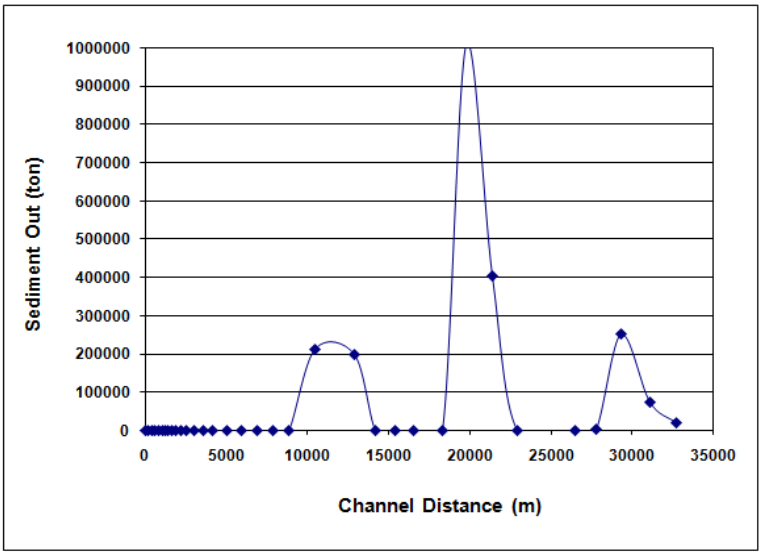

Diagram 1: Sedimentation trend of bed load in different sections of dam's reservoir via Ackers-White method

- **Estimating the Amount of Sediment of Taleghan Dam's Reservoir in HEC-RAS Model via England-Hansen Method**

The results of this method were estimated in HEC-RAS model and illustrated in diagram 2.

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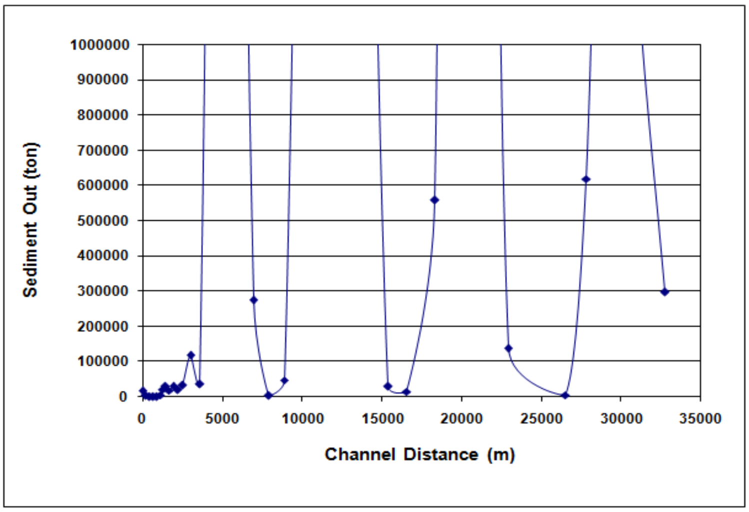

Diagram 2: Sedimentation trend of bed load in different sections of dam's reservoir via England-Hansen method

- **Estimating the Amount of Sediment of Taleghan Dam's Reservoir in HEC-RAS Model via Copeland's 1996 modification of relationship (Copeland and Thomas 1989) by Larsen**

The results of this method were estimated in HEC-RAS model and presented in diagram 3.

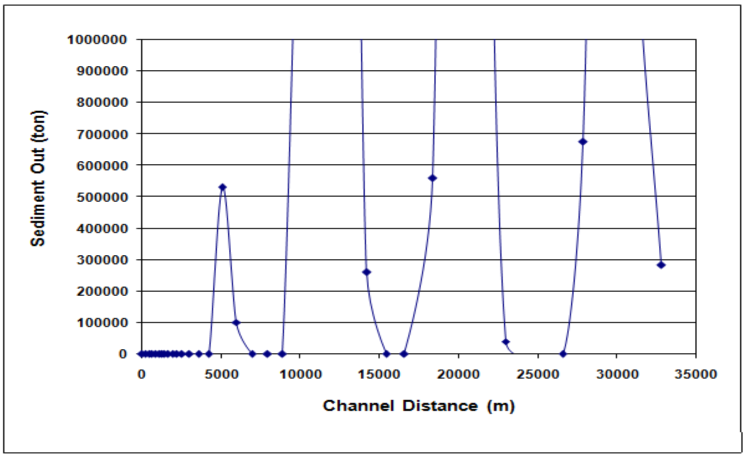

Diagram 3: Sedimentation trend of bed load in different sections of dam's reservoir via Larsen method

- **Estimating the Amount of Sediment of Taleghan Dam's Reservoir in HEC-RAS Model via Moyer-Peter and Muller (1984) Method**

The results of this method were estimated in HEC-RAS model and displayed in diagram 4.

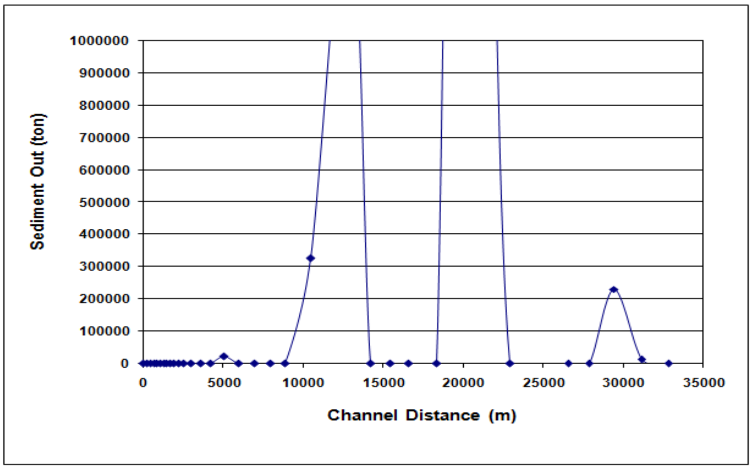

Diagram 4: Sedimentation trend of bed load in different sections of dam's reservoir via Moyer-Peter and Muller method

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- **Estimating the Amount of Sediment of Taleghan Dam's Reservoir in HEC-RAS Model via Toffaletti (1966) Method**

  The results of this method were estimated in HEC-RAS model and illustrated in diagram 5.

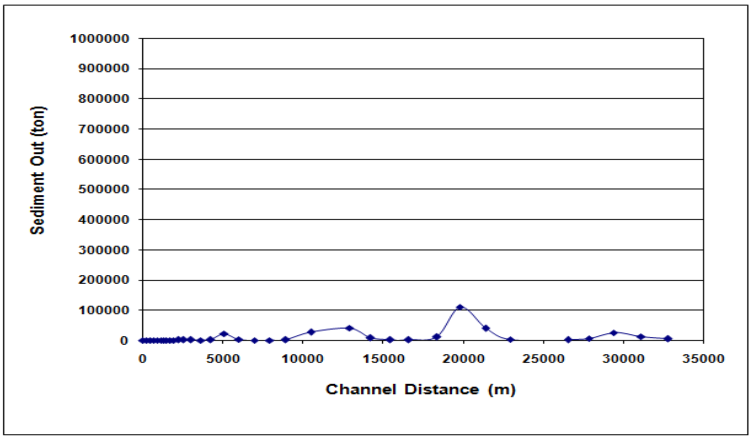

Diagram 5: Sedimentation trend of bed load in different sections of dam's reservoir via Toffaletti method

- **Estimating the Amount of Sediment of Taleghan Dam's Reservoir in HEC-RAS Model via Yang Method: Yang 's (1973) Stream Power for Sands**

The results of this method were estimated in HEC-RAS model and presented in diagram 6.

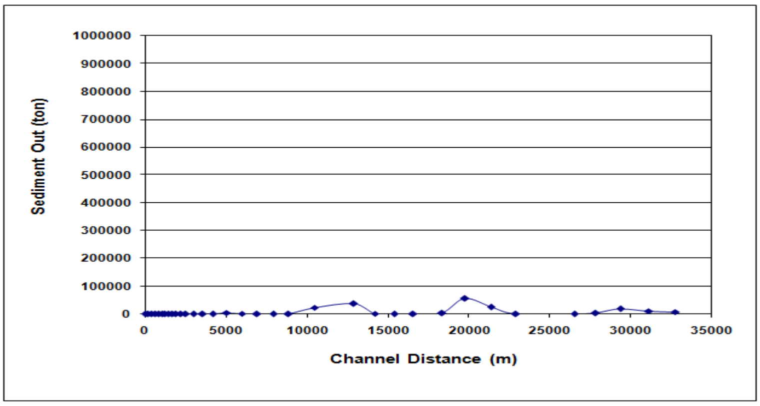

Diagram 6: Sedimentation trend of bed load in different sections of dam's reservoir via Yang method

- **Estimating the Amount of Sediment of Taleghan Dam's Reservoir in HEC-RAS Model via Wilcock Method**

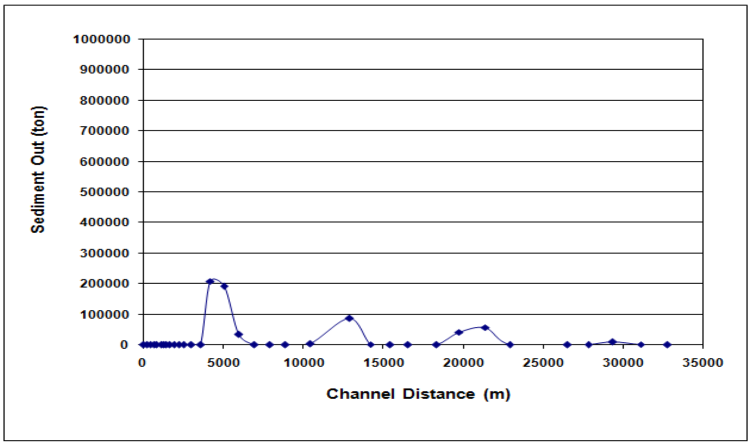

Diagram 7: Sedimentation trend of bed load in different sections of dam's reservoir via Wilcock method

DISCUSSION AND CONCLUSION

In this research the closest equation of estimating total sediment load in the applied model to the data of Glink station (the nearest station to dam) is relating to Wilcock method by sediments equal to 0.635

million tons per year. The results of other studied equations used in mathematical model are presented in Table 1. As it is observed, the range of changes of results is very wide, and with regard to various features of each one of the relationships, the obtained results are not so far-fetched.

Table 1: the results of various equations used to select the best method in the studied area (Taleghan Dam)

Row	Method name	Qst
		mt/year
1	Statistics (station analysis)	0/734
2	Ackers_White	2/16
3	England_Hansen	54/1
4	Laursen	21/1
5	Meyer peter & Muller	9/4
6	Toffaletti	0/3
7	Yang	0/18
8	Wilcock	0/635

Accordingly, Wicock method is suggested as the best one for Taleghan River. In similar researches, the amount of estimated sediment by one of the 7 methods available in HEC-RAS software was highly consistent with the data of the studied areas stations. For instance, Hosseini (2009) in the research on Kharrud River concluded that the estimated suspended sediment in Rahimabad station. Located in Kharrud was about 1.69 million tons per year. By considering the coefficient of 20% as its floor load, the total output load from this station is estimated to be about 2 million tons per year and in this area, the closest equation of estimating total sediment load in applied model to the data of Rahimabad station, is relating to Yang method by sediments equal to 1.45 million tons per year. Hosseini (2009), Kazemi (2008), and Rangzan (2004) figured out results similar to the results of this research.

REFERENCES

1. Al Yasin, A. (2000). Engineering application of river in the rivers of Dez and Karun. Ministry of energy (Iranian national committee on large dams).
2. Abrishami, J., Hosseini, S.M. (1999). Open channels hydraulic. Astan-e Ghods-e Razavi Publications.
3. Ahmadi, H. (1998). Applied geomorphology, Vol. II, Tehran University Publications, 1st edition.
4. Ekhtesasi, M. (2005). Course booklet of wind erosion. Faculty of Natural Resources, Yazd University.
5. Taloori, A. (2004). Introductory principals of river engineering and organizing. Publications of Agricultural Research and Education Organization (Research Institute for Soil protection and Watershed). Publications of Agricultural Research and Education Organization (Research Institute for Soil Protection Watershed).
6. Ti Ti Dej, A. (2008). ARC GIS software tutorial. Publications of Northern University.
7. Hossein, S. A.; Habibi, M. 2006. Workshop of application of HEC-RAS mathematical model in river engineering operations. Islamic Azad University, Karaj.
8. Hosseini, S.A. (2009). Investigating hydrological conditions, sedimentation distribution conditions along the path of Abharrud and Kharrud rivers using HEC-RAS model (Research Institute for soil protection and watershed).
9. Jafarzade, A. (1992). Sediments control methods in irrigation and water distribution networks.
10. Dasturani, M. (2008). Course booklet of river engineering, Faculty of Natural Resources, Yazd University.
11. Rahbar Basir, A., Sadat Darbandi, A., Jabari, A. (2006). Flood hazard zonation with determining flood depth in the Narmab River in Golestan province. 7th international seminar on river engineering, Shahid Chamran University, Ahvaz.
12. Manual of sediment grading tests. (2003). State organization of management and planning, Issue no. 349.
13. A practical guide for field sampling of sediments in rivers and dams' reservoirs. (2007). State organization of management and planning, Issue no. 349.
14. River morphology studies guide. (2007). State organization of management and planning, Issue no. 349.
15. Rangzan, K. et al. (2004). Investigating changes at downstream area of Karkheh Dam before and after the dam construction using temporal images of Land sat. Shahid Chamran University.
16. Shafaei Bejistan, M. (1994). Sediment hydraulic. Shahid Chamran University, Ahvaz.
17. Kazemi, Y. (2008). Estimating the ratio of bed load to suspended load in the rivers of central Alborz (a case study for Jajrud and Taleghan rivers).
18. Kia, A., Bazazieh, N. (1985). Designing hydraulic structures. Vahabi, J. (1997). Flood hazard zonation using remote sensing and GIS and HEC-1 and MIKE11 software in Taleghan watershed. M.S. thesis, Tarbiat Modares University.
19. Hemati, M. (1993). Studying hydraulic problems of pools in terms of sedimentation in water structures, Tehran University.