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Evaluating the Suspended Sediment of Mahabad Dam Using Statistical Methods

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ABSTRACT

Dam construction is one of the methods for storing surface water. Estimating the service life and economic efficiency of dam is one of the most important cases in estimating the design of it. The most important problem that threatens the useful life of the dam is input sediment to reservoir. Life expectancy of a dam reservoir is measured with respect to the incoming sediments. Estimation of suspended sediment in rivers plays an important role in estimating the useful life of dams. Many methods such as statistical methods USBR (United States Bureau of Reclamation) and FAO (Food and Agriculture Organization) and moderate categories method are used to measure suspended. In this research the mentioned statistical and some other methods are used in Mahabad dam. By using sediment volume and the estimated flow rate Sediment loads is measured at different times in this method and its accuracy is estimated by correlation coefficient. The gained results show that the sedimentation estimates by using USBR and FAO with two correlation curves methods are useful and have more correlation coefficient.

KEYWORD

Suspended Load, USBR, FAO, Sedimentation, Erosion

INTRODUCTION

A) Background of Study:

Sedimentation includes phenomena like erosion, loading, sedimentation effect and sedimentation. These phenomena are natural and have existed through the earth life and have triggered its present form. Erosion and sedimentation depend on numerous factors like climate characteristics, region hydrology, vegetation, soil characteristics and so on. These phenomena are a part of evolutionary nature of the earth and can be affected by human activities and cause changing nature condition and result in natural disasters.

By cutting off the flow, dams and reservoirs change the normal course of water and sediments of system. Sediment particles are settled in the reservoir. That's why the reservoir causes reducing the water velocity in the reservoir. One of the most important effects of Erosion and sedimentations is reducing dam volume then its useful life is over. Depositing the sediments in the reservoir causes reducing the active storage and formation of delta-shaped in the reservoir inflow. When the reservoir is affected by large fluctuations in water surface, a large amount of the sediments enter the reservoir and this phenomenon causes endanger the reservoir performance and creating sediment masses in the reservoir and disruption in turbines operation and valves. Hence the construction and maintenance of dams and reservoirs requires that the designer and transfer relationships engineer knows the sediment comply with region conditions.

Due to the complexity of sediment transfer and numerous factors that are affected in this process, rivers erosion has different forms. In below, we consider about sediment transportation and types of the resulting erosion [1].

B) Various forms of sediment transport in rivers:

Basically, sediment materials are moved in two ways, Bed load and suspended load. Some factors as like as grading, grain density, water temperature, hydraulic flow and river characteristics are effective in sediment transport. Total load is total bed load and suspended load that is considered as river sediment load. The suspended load consists of two distinct parts, wash load and bed material suspended load. Washed load is fine-grained sediments that are eroded caused by rainfall from the catchment soils and enter

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waterways network. When a part of sediment grains come into a suspended state and transported by water course, the Bed material suspended load is formed. Bed material bed is composed of bed load and bed material suspended load and reagent the sediment materials derived from river bed.

Suspended load: One of the most important factors in suspending sediment grains is turbulence. As a result, sediment grains are separated from the bed and transmit while mixing the water stream.. Most of them are based on the ratio of shear (v_*)velocity to fall velocity of grains (w_0) for suspended.

Bed load: Bed load is a part sediment load transported by river moving into sliding, rolling or saltation state in bed (river bed). A formation mechanism of bed load was first considered by Duboys in 1879. According to Du Boys theory bed load is resulting shear stress of water flow and it increased with increasing bed load [2].

Bed material load: The total of bed load and suspended load is named bed material load. Although calculating bed load and suspended bed load by existing relations is possible, but most of the times its preferred using methods to calculate bed load directly. Equations that are applied for calculating the bed load are named overall load equations. Wash loads can`t be calculated by these equations.

Determining the bed material load began in the early 1950 by Einstein investigations [3, 4] and Several equations have been proposed by investigators so far. Range Grading used in determining not sticky bed material load of sediments, or sand and coarse grains in the bed. Cohesive sediment materials like rose and silt that are the origin of wash load are not considered in determining bed material load. Among the prominent characteristics of the bed material load is having specified sediment transport capacity following from the condition of hydraulic flow. With increasing flow rate (hydraulic index), the bed material load (load capacity index) also increases.

Total load: Total load is the resulting of catchment in sediment transport and Index of soil Stability, vegetation, land and Considerations relating to the conservation and utilization of rivers. Theoretically, it's possible to determine total load by transport equations. Thus, determining the wash load is possible only with sampling and determining concentration of the load. The Colby total method is the only method for determining total load in which the wash load is calculated with bed material load. Other available methods for determining the total load don't have necessary approach to calculate wash load and the bed material load is regarded as total load.

C) Erosion and its variants:

Degradation erosion is an effective phenomenon in determining sediment load of rivers. If the sediment feed rate in river is less than its load capacity, the sediment material in the bed is eroded and carried along with the water. Eroded sediment of the bed is determined by following equation that is known as continuity equation or mass equation:

$Q_{sd} = Q_{sp} - Q_{st}$ (Equation 1)

In which $Q_{st}$is sediment feed of river (from upstream range and branch connected to the river) in time period. $Q_{sd}$is eroded sediment in bed and bank. $Q_{sp}$is the carried load by river that is transport capacity and is determined by sediment equations. According to the up equation that is based on transmission capacity on rivers, are known factors of wash load materials (total load minus the bed load). Different factors are effective in rivers erosion including construction of dams and input sediment trapping to reservoir, water withdrawal from rivers, removal of materials, reducing the level of flow resulted from bridge construction, protective structure and organization can be named. In the following we are presented the types of erosion in the river.

Local scour: The local scour arises by diversion of flow lines and the occurrence of Eddy formation. These types of erosion can observed around the base of the bridge of the nose drain, river bend, slipped out of the rock, down the overflows and structures within the river route. Local scour leads to the formation of Scour Hole and local sunken in the river bed.

General scour/ degradation: Sweeping the floor and you fall in the river bed are called general scour. Different natural and human factors are involved in occurring the general scour as like as dam construction, reducing river cross, material removal, flooding, prolapse water levels in seas and lakes estuaries, changes in land use, loss of sediment supply, protection and stabilization of the river bed and banks.

Bank erosion: A part of sediment load of rivers is resulted from bank erosion. Edgaard reported in his studies sediment load resulted from bank erosion of the Sacramento River, 60% of total annual sedimentation.

Effective factors in bank erosion are: erosion on the outer arc of rivers, banks erosion, widening the arterial rivers, gully erosions in rivers bank, claw laundering and mass infusion of banks, erosion resulted to hydraulic tensions (direct collision course with banks), cross section of the river, destroying the vegetation in banks. The amount of sediment load resulted from banks erosion can be estimated with annual erosion rate.

D) Literature Review:

Maknalizadeh in his research [5], considered the total sediment of the main branch of the river Karkheh Dam Karkheh based on USBR and FAO methods. Comparison of two methods of Karkheh dam reservoir with sedimentation rates resulted from hydrographic operations in one year showed that FAO method consisted with the situation better.

In 2012, Makvandi by using USBR and FAO along with average and classification of rates and also statistical division in low and high water months, computed sedimentation in Elam dam. He used daily discharge current and sediment discharge of hydrometric stations. His researches show that a special method cannot be used in calculating the annual brings of suspended sediment. It was shown that the proper method for calculating input sediments to reservoir is combined method of USBR and

classifieds for discharges by using statistical breakdown to low high months [6].

In 2010, Maknalizadeh analyzed the sedimentation process and the amount of sediment transported on dam reservoirs based on USBR and FAO. Also, he did this analysis on Karkheh dam. The results revealed that the used method in his research can be used as an analytic strong analyst tool in order to predicting the total sediment entering the reservoir and also for calibration and verification the sediment mathematical models used in planning and sustainable maintenance of employed Hydraulic structures [7].

In 2012, Ebrahimi et al. considered and compared the USBR and FAO methods in the years following the depth of the issue in Ekbatan dam different years. He concluded that the FAO method by using the correlation between the two curves, the answer is closer to the figure of the depth issue [8].

In 2007, Pedram in a research calculated input sediments to Zayandehrood reservoir dam by using hydraulic and sample statistical breakdown and compared it with real results. He concluded that estimating sediment by using average data and statistical breakdown method in form of dry and wet months has the highest correlation coefficient [9].

MATERIALS AND METHODS

A) Case Study:

Lake Urmia catchment: This catchment has been placed in west north of Iran and is surrounded by north part of mount Zagros, southern slopes of the Mount Sabalan, northern, western and eastern slopes of the Mount Sahand. All rivers in this catchment flow to the Lake Urmia. The catchment is located between east longitude geographic coordinates of 44° 7ˈ to 47° 53ˈ and 35° 40ˈ to 38° 30ˈ in the northern latitudes. It has an area of 1 square kilometer and around 35147 Km^2 of it are mountains, 9569 Km^2 of it are plains and foothills and 7150 Km^2 is the lake Urmia. This catchment is divided into eight sub catchment that one of them is Mahabadchay- Godarchay in east south of the Lake Urmia. MahabadChay has composes of two main branches, namely Beytas and Kowter, and a small branch called Dehbekr.

MahabadDam: Mahabad is located dam on the Mahabad River. It has been constructed at longitude 45° 46ˈ east and latitude 36° 42ˈ north approximately one kilometer northwest of Mahabad city with population of 200 thousand people and is the flow main controller of main branches of the Mahabad River. The Dehbekrrivers and valleys Beytas meet in 600 meters upstream of the dam site and form the Mahabad dam. Generally, Mahabadriver flows from west to east direction and has excavated the relatively symmetrical valley of dam site with hill slope around 30 degrees deposits during the second and third geological periods. Mahabad dam is of gravel and dirt core and open overflow type. Its height is 46.5 meter. The length of crown is 700 meter and its overflow capacity is 1550 cubic meter per second. The annual adjustable water volume is 195 Million Cubic Meters (M.C.M.) cultivation is 20000 hectares and installed power is 6000 KW. According to statistics, from 1969, the maximum, minimum and average of flow during statistical periods are in order 275.30 m^3/sec, 0.00 m^3/sec and 9.12 m^3/sec. The normal volume is 19 M.C.M and the crown volume is 230 M.C.M.

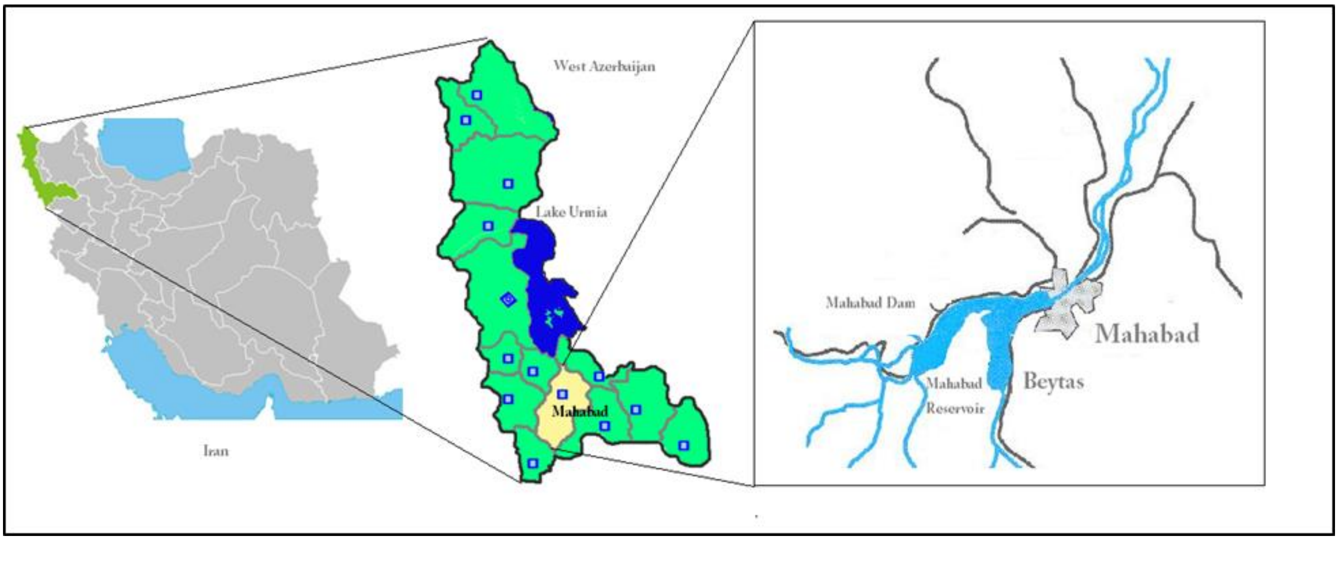
Input and output stations of Mahabad dam: Mahabd dam has two input and one output stations. The input station is called Kowter and Beytas and the output station is GerdYaghoub.

Kowter station: this station was established in 1970 with 45° 42ˈ longitude coordinates and 36° 41ˈ latitude coordinates on Kowterriver. Also it has ashal and Teleferik bridge. The station altitude is 1382 meters and square of the field is 415 Km2.

Beytas station: another branch of the Mahabadriver is Beytas river. This station was established in 1965 with 45° 42ˈ and longitude coordinates and 36° 41ˈ latitude coordinates on Beytasriver. The station altitude is 1424 meters and square of the field is 203 Km2.

One of the essential problems of sediment statistics in the named input stations of Mahabd dam is lack of sampling in flooding condition in spring. Dehbekr is another branch leads to MahabadChay.

Fig.1. Status of the Mahabad river catchment area.



Tab 1: evaluating the information of the studied station in Mahabad dam

Stations Name	Statistical years of daily discharge	Statistical years of water discharge and sediment discharge	Number of samples CM	Number of samples CM, CF	Minimum and maximum of daily discharge (m3/sec)		Minimum and maximum of corresponding water discharge (m3/sec)		Minimum and maximum of sediment concentrations (gr/lit)	
					Min	Max	Min	Max	Min	Max
Kowter	1971-1993	1969-1977	117	233	0	134.5	0.17	125.1	3	5.4
Beytas	1963-1993	1969-1986	87	209	0	54	0.04	66.8	0	4.6

B) Methods for calculating suspended load:

Suspended sediment transport is a function of flow hydraulic condition and physical specifications of sediment grains. From hydraulic view, sediment grains are separated from bed by lift force resulted from turbulent phenomenon and is transported in suspended form. This part of sediment material in river flow is called bed suspended load. The rate of bed suspended load is hydraulic condition function and its value increases with increasing discharge and it reduces significantly in low discharges.

The concentration of the suspended load obtained from the cohesive sediments (fine-grained) or wash load, are not affected by hydraulic flow and transport capacity is not true for these loads. In natural condition, transported suspended load by rivers are combination of bed suspended load and wash load and due to the different mechanisms governing their transmission, methods for the determination of each are different. Below are the details of the determining suspended load.

The general stages in this study to estimate the suspended sediment load in the main branches of the basin are as follow:

1. Extraction of suspended Sediment Rating Curves for each hydrometric station of the main branch, using the measured flow and sediment flow with relations between FAO and USBR
2. Depicts the flow duration curve using flow rates in appropriate time periods
3. Calculate the mean flow rate corresponding to the probabilistic classes of flow duration curve
4. Calculation of sediment transport from the station using a flow rate obtained from the previous step, using sediment rating curve
5. Calculate the volume of suspended sediment in a submerged state (in cubic meters per year)
6. Compares the results obtained in both FAO and USBR

C) Calculations of suspended load in terms of statistics:

One of the proper procedures for determining the suspended load is using recorded statistic in hydrometric station sites. In these stations besides measuring flow discharge (Q), water samples to determine sediment concentrations (C) are prepared and after transferring to laboratory, suspended load concentrations are determined. The information is part of common statistic of rivers and it is available through related organizations like water regional organizations, Basic Studies of Water Resources (enterprise resource management). Sampling and determining concentrations by using point method and accumulation in depth. After determining the suspended sediment load (C) of river, Qs is determined by the following relations and is recorded as a part of suspended sediment statistic:

$$Q_s = 0.0864\ Q_d \qquad \text{(Equation 2)}$$

In this relation;
Q_s: Suspended sediment load (ton per day),
C: Average concentrations of suspended load (mg in liter) and
Q_d: Is daily discharge (m^3/sec).
Because limited number of data measurement will be available and these data are base of determining daily, monthly and annually sediment load; different methods can be used, as like as, Sediment Rating Curve (SRC) and flow duration curve known as United States Bureau of Reclamation (USBR).

Sediment Rating Curve (SRC):

Considering the discharge statistic and sediment in hydrometric stations in statistical periods:

The sediment rating curve is drawn by statistical data Q_s and Q_d .These information are a part of river assessments program and in any hydraulic station, during measuring the daily discharge flow, the suspended material concentrations and daily sediment tonnage are measured. In order to drawing the sediment rating curve a statistical period of several years is used. Annually, sampling and determining average concentrations (C) and daily discharge flow are performed simultaneously several times. Daily sediment tonnage (Qs) is calculated by equation 1.

Determining the exponential relationship and drawing sediment rating curve:

Necessity of determining the exponential relation of sediment is due to the limited observational statistics in which the simultaneous measurement of Qs and Q are performed only for limited days during a year. Within a year, several times referred to the hydrometric station, discharge measurement flow and sediment sampling

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operations are performed by an expert team. The remaining days of the year, it is necessary to determine the correlation between Qs and Q, the sediment tonnage for non-statistics days is calculated.
The general sediment exponential equation is as follows:

$$Q_s = aQ_d^b \qquad \text{(Equation 3)}$$

In which a and b are in order coefficient and exponent of the equation and Q_s andQ_d have been defined before.
Range of suspended sediment load is very index due to comply with hydraulic regulation and varies from 12 tons per day to almost 5 million tons per day. Important factors in intensifying the daily sediment tonnage change range are soil instability, mountain topography, and lack of vegetation that increase the erosion rate of soil and has occurrence of strong flows.
FAO: In order to increasing the accuracy of the results of sediment rating curve, FAO adjustment method has been proposed. In this method coefficient a in equation 3 is supersede by $\overline{Q_s} a = \bar{Q}_d$ in which $\bar{Q}_s$is average of daily measured sediment load and $\bar{Q}_s$ is average of measured daily discharge during statistical period. In FAO method the adjusted curve has a similar and parallel slope with the gained curve from fitting the exponential curve that passes a point with average coordinate of total discharge $\bar{Q}_d$and total average of suspended load of samples of desired station$\bar{Q}_s$.
Determining daily, monthly and annually sediment tonnage: Determining the temporal changes of the suspended sediment load is important from different aspects. In planning and operation of river resources projects, it is necessary to determine concentrations and daily sediment tonnage. Moreover, determining monthly and annually sediment is necessary in order to evaluating operation of dam reservoirs, improvement of rivers road, sand removal and other numerous cases.
Determining daily sediment tonnage: after determining rating curve and its exponential equation, the sedimentation table is adjusted due to the daily discharge statistic (Q_d), and for each water year (365 days), sediment tonnage is calculated from the following equation:

$$Q_{si} = aQ_{di}^b , \quad i = 1,2,3, \dots ,365 \qquad \text{(Equation 4)}$$

In which:
Q_{si} : Daily sediment tonnage,
Q_{di} : Daily discharge and I is the index of day from 1 to 365 for a water year. In order to determining the daily sediment, firstly, it is necessary that daily statistical discharge be determined. Setting the table of daily sedimentation and discharge is performed for each water year and a several years statistical period. Such data as basic input data in the study of sediment behavior of rivers and how they influence, the engineering effort required. Along with the daily sedimentation, daily concentrations (C_i) can be calculated by $Q_s$and $Q_d$the following equation:

$$C_i = 11.5741\, Q_{si} / Q_{di} \ , \quad 1=1,2,3,..365 \qquad \text{(Equation 5)}$$

Forming the discharge table and daily sedimentation for each water year prepares the current consideration of flow regime (annual hydraulic flow) and sediment regime (annual sedimentation hydraulic) of the river.
Determining monthly sediment tonnage: Amount of monthly sediment is calculated by sum of daily sedimentation (Qsi). Monthly sediment for months October to September is for each water year is calculated by the following equation:

$$Qsm_{i,j} = \sum_{i=1}^{M} Qs_{i,j} \qquad \text{(Equation 6)}$$
$$i = 1,2,3, \dots ,12 \quad j = 1,2,3, \dots , N, M = 30(29,31)$$

In which:
$Qsm_{i,j}$:Monthly sediment in month is i and in year is considered by y (ton),
$Qs_{i,j}$: Daily sediment tonnage in considered month is j,
M is the index of day numbers during a month and y in the number of water days (1 year to N).
Determining annual sediment tonnage: Annual sediment is the transferred sediment load in a water year and the sum of daily sediment is gained by the following equation:

$$Q_{syk} = \sum_{i=1}^{365} Qs_{i,k}, k = 1,2,3, \dots ,12 \qquad \text{(Equation 7)}$$

In which:
Q_{syk}: Annual sediment load for water year k (ton),
N: the number of water years.
In engineering affairs, along with sediment caliber for a year, it is needed that transported average of annual sediment of statistical period be determined. Also, the average of monthly sediment transported of statistical period is of basic data for study purposes. Average load of monthly sediment is gained in statistical period.

$$\bar{Q}_{sm,j=\sum_{i=1(}^{365} Q_{sm,k/N})j} \qquad \text{(Equation 8)}$$

In which:
$\bar{Q}_{sm,j}$: Average of monthly sediment for the month (ton),
$Q_{sm,k}$: Monthly sediment load in water years from 1 to N. j is month index from 1 to 12.
Average annually sediment load in statistical period can be calculated by the following equation:

$$\bar{Q}_{sy=\sum_{k=1}^{N} Q_{sy,k/N}} \qquad \text{(Equation 9)}$$

In which $\bar{Q}_{sy}$annual suspended sediment load in considered statistical period (ton) and other parameters have been defined before. In order to determining annual average sediment load it is necessary that the monthly and annual sediment quantity in different water years in statistical periods be calculated. Also, according to the performed relation average of the sediment load is determined. Performing the changes of monthly and annually sediment load by diagram is a part of data analysis of sediment

statistics and introducing annual and monthly regime of rivers.

Flow duration curve: Flow duration curve is often used in order to determining discharge duration of rivers for given flow of determined flow. In order to drawing the flow duration curve it is necessary that after choosing the statistical period, the given amount of daily flow be sorted decreasingly for consecutive years and then by classifying them in different classes, the given amount of flow and their occurrence probability for each class be determined. The flow durable curve is drawn by using these specifications. There are different methods for estimating sediment in a field. Designers have selected one of these methods and by using it estimated the sediment of a field in upstream.

U.S.B.R method: In this method was first proposed by Soil Conservation Service (S.C.S) of the USA, then it was formulated by U.S.B.R that was applied in most of the civil plans related to water and soil. The mentioned method that is called flow duration curve method is according to regarding a complete period of discharge flow statistic of rivers and shows the discharge abundance of water and sediment. The sediment rating curve contains drawing all measured sediment discharge during the recorded statistical period against the values of water discharge in coordination and by determining the line of best of benefit that is ordinarily performed in equivalent form of (Equation 10).

$$Q_s = aQ_w^b \qquad \text{(Equation 10)}$$

In U.S.B.R method, the recorded data in corresponding measurement Q_s and Q_w are transmitted to Bi- Logarithmic the line of best of benefit based on Methods of list Squares is passed through them. So, a relation between Q_s and Q_w is derived as follow which is called sediment rating curve:

$$Q_s = aQ_w^b \qquad \text{(Equation 11)}$$

In which, constant coefficient of equation a and b are in order distance of meet location of line of benefits with vertical axis to origin point and slope of line of benefits.

Measuring the suspended load of river and its corresponding volume pass is performed limitedly. Also, amount of $Q_s$is generally estimated by the quantity number of Q_w.

Volume passing the river is very different. Therefore, using of one or some numbers as average discharge of river and estimating suspended load due to it is not correct. U.S.B.R offers using of durable flow curve. This curve which is known as discharge duration curve is gained by accumulative draw of river discharge in relation to gained time. In fact, it is a method for estimating the hydrometer potential of river with definite occurrence probability. By using this curve and due to the statistic of river discharge for different probabilities, the amount of gained water from the rivers is estimated. Also, this method shows the percentage of times in which the river discharge is equal or greater than a definite amount in recorded statistical data.

FAO method: statistically, in U.S.B.R method, because of using data logarithm method in calculating sediment rating curve, so the data distribution around the best of benefit line is asymmetric and distance between upper (best of benefit line is asymmetric and distance between upper insurance limit and regression line is more than the lower insurance limit.

This issue causes that in each Volumetric Transition, the estimated suspended load Q_w is close to minimum amount. Also by setting the Average Volumetric Transition in sediment rating equation, during the statistical period Q_w, average suspended load Q_s is gained during this period.

In this unique occasion, the data distribution is more in dried and semi dried regions. Due to this fact, in order to adjusting the numbers and closing the estimated amounts, using the sediment rating curve to gained amounts is recommended by FAO method. In sediment water- discharge equation, coefficient a´ is used instead of a by the following relation:

$$\acute{a} = \frac{Q_s}{Q_w^b} \qquad \text{(Equation 12)}$$

Other calculations are exactly like U.S.B.R method. In other words, this is the adjusted form of U.S.B.R method.

RESULTS

From the revenue starting in 1970 until now, bathometry has been performed three times in years 1976, 1988 and 1994. Due to the statistic, for three periods 1970-1976 and 1976-1988 and the whole revenue, hydraulic method tests have been performed that results are in tables (2) and (3).

In annual bathymetry report in 1976, annual average sediment has been reported 1.6 million tons. Also, in annual bathymetry report in 1988, annual average sediment has been reported 2.6 million tons. On the average, the annual average sediment can be considered 2.1 million tons for whole revenue.

According to the tables (2) and (3), We notice that none of these used methods could perform a number close to number gained from bathymetry in order to finding the reason, all stations and neighboring fields were considered. After the investigations, it was revealed that concentrations of the measured sediment in neighboring fields are more than sampling concentrations for Mahabad stations. Also, it was shown that the problem was related to sampling and time of sampling. Samplings done in flooding occasions are less than in non-flooding seasons. Due to the quick slope of the region and mountainous area, the bed load is supposed 40%.

Taking into such condition, sampling statistics has estimated a method which has qualitatively and quantitatively estimated highest amount. That is FAO method by using average of classified statistic. Table 4, in summary shows the results of sediment calculations by using samplings information CM statistic.

Tab 2: Sediment calculation results by using hydraulic methods in Mahabad dam for period 1970- 1976 and 1976-1988.

Sediment calculation method		Name of station	Annual average of sediment (ton/year)			
			1970- 1976	sum	1976-1988	sum
USBR method	with a correlation curve	Kowter	35000	54000	50000	61000
		Beytas	19000		11000	
	with two correlation curve	Kowter	44000	88000	46000	60000
		Beytas	44000		14000	
	Clusters average limit	Kowter	92000	139000	49000	79000
		Beytas	47000		30000	
FAO method	with a correlation curve	Kowter	306000	417000	659000	803000
		Beytas	111000		144000	
	with two correlation curve	Kowter	65000	131000	75000	97000
		Beytas	66000		22000	
	Clusters average limit	Kowter	297000	374000	52000	98000
		Beytas	77000		46000	

Tab 3: Results of sediment calculations in Mahabad dam for whole operational period

Sediment calculation method		Name of stations	Annual average of sediment transported ton/year	
				sum
USBR method	with a correlation curve	Kowter	45000	65000
		Beytas	19000	
	with two correlation curve	Kowter	58000	98000
		Beytas	40000	
	Clusters average limit	Kowter	138000	192000
		Beytas	54000	
FAO method	with a correlation curve	Kowter	235000	401000
		Beytas	166000	
	with two correlation curve	Kowter	83000	143000
		Beytas	60000	
	Clusters average limit	Kowter	434000	515000
		Beytas	80000	
Ocular benefit method according to Co- concentrations lines		Kowter	82000	852000
		Beytas	769000	

Tab 4: Calculating sedimentation by using different methods and bathymetry results by using CM statistic

	Average annual sediment transported by hydrological methods ton/year								
	USBR method			FAO method			Daily method	Ocular Benefit Method According to Co concentration lines	Weight Average of Annual Sediment Through Bathymetry (m.ton/year)
	with a correlation curve	with two correlation curve	Clusters average limit	with a correlation curve	with two correlation curve	Clusters average limit			
1970- 1976	55000	894000	139000	417000	131000	374000	113000		1.604
1976-1988	62000	61000	79000	803000	97000	98000	119000		2.6
Whole period	65000	986000	193000	402000	143000	515000	127000	852000	2.1

Tab5: Results of the average annual sediment calculations by hydrological methods by using composing statistic of CM and CF for Mahabad dam (ton / year)

	USBR method			FAO method			Daily method
	with a correlation curve	with two correlation curve	Clusters average limit	with a correlation curve	with two correlation curve	Clusters average limit	
55-49	47000	63000	68000	189000	84000	81000	96000
67-55	62000	57000	79000	211000	82000	98000	66000
Whole period	57000	109000	148000	249000	176000	414000	122000

As a considerable number of samplings in the dam have been done by fixed point method, therefore estimation of sediment calculations by using hydraulic methods and by using composing of statistic and information of CM and CF were performed in studied dam. So, correlation relations between CM and CF were gained for any of the stations. Then by using these correlation relations that most of themhad acceptable regression coefficient, the information and statistic relating to the fixed points were changed in section dam samples. Those processes were performed for information and statistic like before. The results have been shown in table (5).

CONCLUSION

1. Life expectancy is the time it takes that the reservoir is full by input sediments or upstream water resources. These factors can be expressed as to the 3:

a. The lack of statistical years: according to the estimations and calculations were made in recent years, if number of years is significantly higher, social reality is represented p is estimated more attentively. Therefore, in estimating the sediment of a river, if the numbers of years of water discharge and sediment measurements exceed, estimated deposition estimate is closer to reality.

b. Failure to comply the standard criteria for sampling: sampler should have adequate accuracy in sampling of the standard rules. If the sampler not to do sampling correctly at any reason like lack of precision, skill and the necessary

facilities, it causes false figures for river discharge and ultimately lead to inaccurate estimates of sediment of a field. Regarding the considerable amount of sediment load of rivers (more than 70 percent) are loaded in flood and a flood may accorbe more than annual load, thus discharge measurements and sampling should be of great importance in flood times of flood. In summary, factors such as failure in method of sampling instructions, excessive concentration in sampling in lower discharge, taking more samples from the fix point and insufficient number of samples causes that the calculations to estimate the deposition not have sufficient accuracy.

c. Deselecting the accurate method in estimating the sediment of a field: there are different methods for estimating of sediment in a field that designers have selected one of these methods according to experts. By using this method they estimate sediment of a field in upstream. If a method is not selected correctly by an expert, sediment estimation in a field is incorrect.

5. In fields that the statistic of both flooding and non-flooding occasions is available, comparing with the remained sediment, the estimated numbers by using FAO has higher level. The reason is that in this state, growing coefficient “a” and being affected on the estimation of maximum observed sedimentations (fig 2).

6. As the sampling statistic in many studied field is not considerable, the daily numbers doesn’t conform to reality. Also it can be said that the estimated amount by this method is less than the real amount. Thus, while qualitatively and quantitatively access desired statistic.

7. In Iran fields with present sampling situation, using U.S.B.R method by a single correlation curve is not recommended.

8. Therefore, performing systematic and comprehensive studies in relation to sedimentation phenomena, its procedure, estimating the amount of transposed sediments are essential for optimal benefit of water resources of dams.

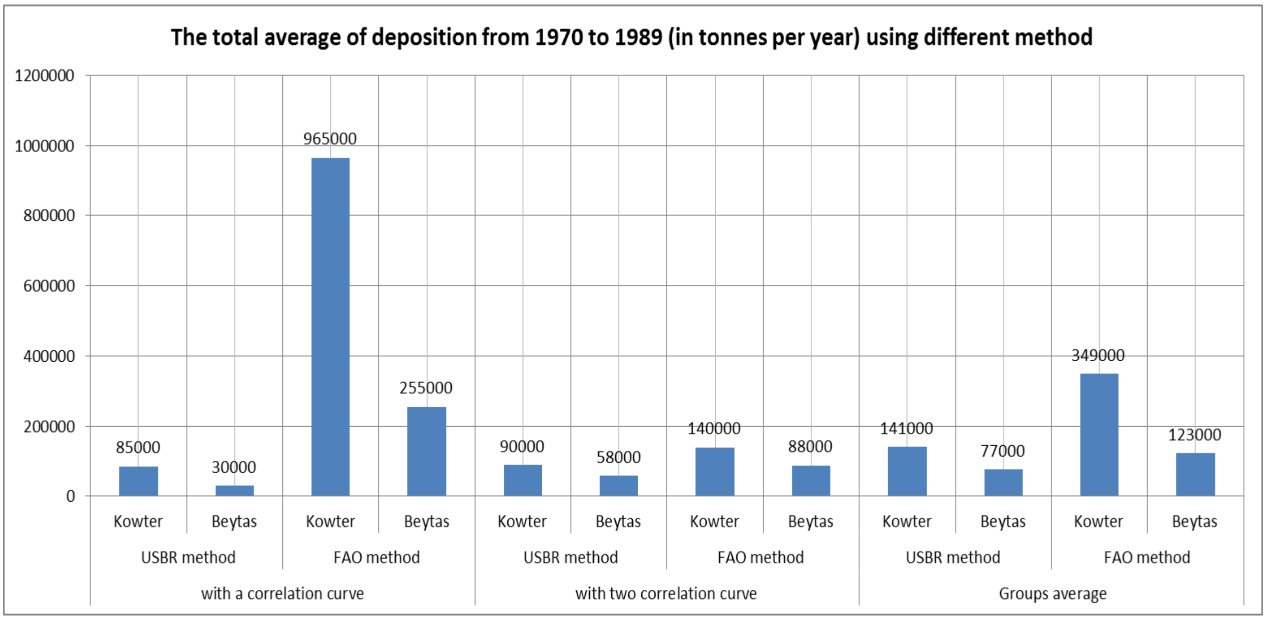

Fig 2. The total calculated sedimentation amount in whole period by different method (ton/year)

2. The amount of estimated sediment by the tested methods is more depended on accuracy, number, proper and uniform dispersion of samplings during the flooding and non-flooding days of a year.

3. Using composing statistic of fixed point and average point of (CM, CF) have resulted in more uniform consequences with the view to estimate amount.

4. In fields that sampling hasn’t been done I flooding occasions or their number is few, comparing with the remained sediment, the estimated sediment by using U.S.B.R is less. The reason is that in this state, the estimated number is more affected by least observed sediment (fig 2).

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