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# Evaluation and Comparison Different Methods of Preparation of Sediment Rating Curve in Telezang Station of the Dez River

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**Abstract:** For preparation of sediment rating curve, different methods developed by researchers. But selection of a suitable method is a very complex problem. For this purpose, results of these methods must be compared with observed data. In this research, it made used of observed data in Telezang station of the Dez River. This station locates at upstream of the Dez dam. Several suitable soft wares were applied for determination of sediment rating curve. These soft wares can determine sediment rating curve without simplification of problem. This subject increases accuracy of results to an acceptable limit. The applied methods in this research are empirical methods at logarithm coordinates, mathematical optimization methods at Cartesian coordinates, the artificial neural network method and the genetic algorithm method. The results of genetic algorithm method are more accurate than results of other methods. Also the time of running of genetic algorithm method is suitable for determination of sediment rating curve. This research can guide engineers and designers for selection the best method of determination of sediment rating curve.

**Key words:** Genetic algorithm method, Artificial neural network method, Telezang station, The Dez River, sediment rating curve.

## INTRODUCTION

Erosion and sedimentation are serious problems in water resources management. Sedimentation fills reservoir dams, irrigation channels, dikes and marshes rapidly. Also it can bury cities, villages and farms by new sediment. At resulting sedimentation and erosion harm to national economy of countries very extremely.

For estimation of sediment load, hydrologic and hydraulic methods are applied. Hydrologic methods make used of sampling and practical measurement of data for prediction of the value of sediment load of watershed. Hydraulic methods are function of hydraulic characteristics of flow and can calculate sediment transport but they can not predict the value of sediment load of watershed. Hydraulic methods show maximum capacity of sediment transport in rivers but its concurrency is impossible. There fore measured sediment discharge is often less than calculated sediment discharge by hydraulic methods.

In the other hand hydraulic methods need to value arrival sediment to watershed as upstream boundary condition. For calculation the value of arrival sediment to watershed, hydrologic methods are applied for analysis observed data in upstream of watershed. Arrival sediment to watershed is introduced to hydraulic methods as a sediment rating curve.

Researchers utilized of regression models for extraction discharge- sediment discharge relation (Wang and Linker, 2008; Sadeghi *et al.,* 2008; Gao, 2008; Ganju *et al.,* Achite and Ouillon, 2007; Lenzi *et al.,* 2006; Crowder *et al.,* 2007; Arabkhedri *et al.,* 2009).

A number of researchers applied artificial neural network for determination of sediment rating curve (Paratal and Cigizoglu, 2008; Jain, 2001). Also researchers made used of genetic algorithm for this purpose(Aytek and Kisi, 2008). Scientists exploited sediment rating curve by neuro-fuzzy and neural network approaches (Cobaner *et al.,* 2009; Ulke *et al.,* 2009).

But they compared accuracy of these methods for determination of sediment rating curve.

In this research, different methods of determination of sediment rating curve are studied. By comparison results of these methods, the best method is determined.

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***The Dez River:***

Two main branch of the Dez River are the Sezar River and the Bakteari River. After the Dez River passes from mountain region in the north of Dezful and Andimeshk cities, it arrives to Khuzestan plain. The direction of flow is from north to south in the Dez River. This river connects to the Karun River in Bandgeer at 40 Km north of Ahvaz (the center of Khuzestan province). The great Karun River is developed by connection of two rivers. Then, the great Karun River goes toward Ahvaz and Khorramshahr cities. The length of the Dez River is 250 Km from the Dez dam to Bandgeer.

The Dez River is a meandering river after passing from the Dez dam. Then, this river passes from the regulation Dez dike and the diversion Dez dike. The length of the Dez River is 39 Km from the Dez dam to division Dez dike (the local of getting water for Dez irrigation network). The Dez River converts to a wide branched river at downstream of dikes. The maximum width of branches of the Dez River and islands between them are 4 kilometers.

Because suspended sediment of flow deposits in the reservoir of Dez dam, flow has intense ability for erosion in the downstream of dam. Therefore bed load consists of rubbles and coarse gravels at distance Dezful to Bonehsefer in south of Hafttapeh. At Bonehsefer, wide branched river converts to meandering river and coarse bed load converts to fine bed load. Location of the study area is shown in figure1.

***The Research Methodology:***

Estimation of arrival sediment to the river (by using of sediment samples of hydrometric stations):
Sediment of river divides to two categories. Bed load and suspended load are ingredients of total sediment load. The total sediment load is often boundary condition of sediment transport models. In gotten sediment samples, Separation of suspended load from bed load is very difficult. Hydrologic methods can determine total bed load of watersheds. But these methods simplified problem. This subject decreases accuracy of results very much. For improvement of accuracy of results, it is necessary that stochastic methods are applied. Then results of stochastic methods are introduced to sediment transport models.

Determinations of sediment rating curve at logarithm coordinate:

Sediment rating curve shows relation between discharge of flow and sediment concentration. Sediment concentration (erosion rate) has a direct relation with discharge of flow. General form sediment rating curve is:

$$Q_S = aQ_W^b \tag{1}$$

Where:

$Q_W$: Discharge of flow (CMS)

$Q_S$: Weighted discharge of sediment (Ton/Day)

a, b: Constant coefficient

For preparation of sediment rating curve, correlated sediment concentration to each discharge of flow must be measured. The earned points should be shown on a sheet with logarithm coordinate. Horizontal axis of this sheet is $Q_W$ and vertical axis of this sheet is $Q_S$. At the end, the best trend line is determined by the least square method. This line shows discharge- sediment discharge relation. The equation of this line:

$$\log Q_S = \log a + b \log Q_W \tag{2}$$

Although this method is simple but it plays down to low discharges in determination of discharge-sediment discharge relation. This method emphasizes on high discharges that occur in flood times while duration of flood is negligible at comparison with non flood times. For determination of constants of equation1, optimization methods are applied. Objective function of these models is:

$$Objective : Min \sum_{i=1}^{N} (Q_{Sobs} - Q_{Scal})^2 \tag{3}$$

Where:

$Q_{Sobs}$: Observed sediment concentration (Ton/Day)

$Q_{Scal}$: Calculated sediment concentration by equation1 (Ton/Day)

N: The number of gotten samples of sediment concentration

Selection of the best method concerns to consumed time for discovering of optimum solution, the value of objective function and convenience of using of method. If optimization method can find value of global optimum, the value of objective function will minimum. But some of methods find local optimum and they can not find global optimum.

Determinations of sediment rating curve at Cartesian coordinate:

Because of disadvantages of using of logarithm coordinate, designers and engineers often make used of Cartesian coordinate. But fitting of an exponential relation on data is very difficult in Cartesian coordinate. For fitting of relation, it must be applied optimization tool of mathematical soft wares or spreadsheets programs. In this research made used of MATLAB and EXCEL soft wares. Objective function is equation3 in this method.

Selection of error function:

The numbers of samples of discharge of flow and sediment concentration are not sufficient. Also accuracy of preparation of samples is very low. Samples were prepared in non flood times. On the other hand variation of sediment concentration occurs in small time steps. Therefore sediment rating curve can not predict concentration of sediment in short time periods (for example one day). On the other word comparison between daily observed sediment concentration and calculated sediment concentration by sediment rating curve can not prove accuracy of sediment rating curve. Fitness between daily observed sediment concentration and calculated sediment concentration by sediment rating curve is not important. While calculated sediment concentration by sediment rating curve in long term periods (for example one year) should fit to observed sediment concentration. Results of the best relation have the most fitness with yearly observed sediment concentration. Accuracy of observed sediment concentration in Telezang station can be evaluated by the volume of deposited sediment in the reservoir of the Dez dam. The Dez dam was constructed in 1963. The volume of reservoir of the Dez dam was determined by hydrographic action in 1973 and 2002. The trapping coefficient of reservoir was estimated 84%. A part of arrival sediment to reservoir is produced by erosion of areas between Telezang station and reservoir of the Dez dam. The value of this sediment must be computed. Difference between this value and arrival sediment to reservoir of the Dez dam is arrival sediment to Telezang station. The procedure of calculation of average of volume of yearly arrival sediment to Telezang station is shown at follow.

***The Results of Task 8 Report Are:***

The percentage of sediment of the Dez River from connection point of the Sezar River and Bakteari River to reservoir of the Dez dam is 16% of total arrival sediment to reservoir of the Dez dam. The area of the Dez watershed, Telezang station watershed, Tangpang Sezar station watershed and Tangpang Bakteari station watershed are equal to 17360, 16213, 9410 and 6432 $Km^2$ respectively. The area of watershed between Telezang station and reservoir of the Dez dam is:

$17360-16213=1147\ Km^2$

The area of watershed between connection point of the Sezar River and Bakteari River and reservoir of the Dez dam is:

$17360-(9410+6432)=1518\ Km^2$

Area of between Telezang station and reservoir of the Dez dam is 75.5% of area of watershed between connection point of the Sezar River and Bakteari River and reservoir of the Dez dam.

$1147/1518*100=75.5\%$

The percentage of sediment of the Dez River from Telezang station to reservoir of the Dez dam is 12.1% of total arrival sediment to reservoir of the Dez dam.

$0.755*16=12.1\%$

- The volume of deposited sediment is reservoir of the Dez dam from 1963 to 1973 is equal to 192 MCM.
- The volume of deposited sediment is reservoir of the Dez dam from 1973 to 2002 is equal to 425 MCM.
- The volume of deposited sediment is reservoir of the Dez dam from 1963 to 2002 is equal to 617 MCM.
- Specific weight of sediment of the Dez River is equal to 1100 $Kg/m^3$ (from task1 report, Pages 3-34).
- The weight of yearly sediment of the Dez River in Telezang station from 1963 to 1973 is equal to $20.6272*10^6$ Ton.

$(192*10^6\ m^3/10year/0.9)*(1-0.121)*1.1Ton/m^3= 20.6272*10^6Ton/year$

0.9 is trapping coefficient of reservoir of the Dez dam in primary years of construction of dam.

- The weight of yearly sediment of the Dez River in Telezang station from 1973 to 2002 is equal to 16.8692Ton.

$(425*10^6m^3/29year/0.84)*(1-0.121)*1.1Ton/m^3=16.8692*10^6Ton/year$

- The weight of yearly sediment of the Dez River in Telezang station from 1963 to 2002 is equal to 18.2105Ton.

$(617*10^6m^3/39year/0.84)*(1-0.121)*1.1Ton/m^3=18.2105*10^6Ton/year$

The calculated weight of yearly sediment by different methods is less than actual weight of yearly sediment. Because the most of sediment samples were gotten at non flood times, their sediment concentration is very less than sediment concentration in flood times. In this situation, sediment concentration at non flood times effects on sediment rating curve very much.

***Applied Optimization Methods for Determination of Sediment Rating Curve:***

a) SOLVER functions of EXCEL software:

SOLVER functions of EXCEL software make used of stochastic optimization algorithm. Using of this software is very simple. EXCEL software is often applied by hydrologists for determination of hydrologic parameters.

b) Genetic algorithm:

A great number of optimization methods can not find global optimum. Engineering problems have several local optimums. Optimization methods are sensitive to selection of starting point. If starting point is near to a local optimum, optimization method will converge to it. For determination of global optimum, optimization method must be applied several times with different starting points. This procedure increases time of solution very much. Therefore, using of suitable optimization methods that can reach to global optimum is necessary. A suitable method is genetic algorithm method. This method is not sensitive to selection of starting point. This method was developed by observation of natural phenomena. It makes used of stochastic selection and is conducted by stochastic popularization.

c) Artificial neural network:

Artificial neural network is a new method for solving of hydrologic and hydraulic problems. Artificial neural network have abilities as parallel proceeding, training ability, error endurably and popularization. Because of complexity of problem of determination of sediment concentration and effects of different parameters, artificial neural network is a suitable method for determination of sediment concentration.

The method of using of optimization models in this research:

a) The method of using of SOLVER functions of EXCEL software:

The method of using of these functions is explained in help of EXCEL software.

b) The method of using of genetic algorithm:

For using of genetic algorithm, MATLAB (Matrix Laboratory) software package and its genetic algorithm tool box were applied. MATLAB software is a suitable package for analysis vectors and matrixes. MATLAB can inverse matrix and multiply matrixes more rapid than other soft wares. Also application of this software is very simple.

Optimization by genetic algorithm is added to MATLAB7 and future versions. Genetic algorithm makes used of a fitness function. By improvement of generations and their members, fitness number of output of fitness function decreases.

The genetic algorithm tool of MATLAB is shown in figure2.

b) The method of using of artificial neural network:

For using of artificial neural network, MATLAB software package and its artificial neural network tool box were applied. This tool box is simpler, rapider and more perfect than other artificial neural network soft wares. MATLAB software makes used of feed forward network. Learning rule for feed forward network is the back propagation algorithm. The best algorithm of MATLAB software is Trainlm1. This algorithm has the highest convergence velocity and learning velocity. The artificial neural network tool of MATLAB is shown in figure3.

## RESULTS AND DISCUSSION

For evaluation and comparison results different methods that produce sediment rating curve, the least square method was applied. The results of different methods are shown in table1.

**Table1:** Results and the mean of square of errors of different methods

| Method | Constant (a) in Eq.1 | Constant (b) in Eq.1 | The mean of square of errors (%) |
|---|---|---|---|
| Fitting in logarithm coordinate by stochastic optimization | 1.0964 | 2.2 | > 100 |
| Fitting in Cartesian coordinate by stochastic optimization | 0.001243 | 2.7585 | > 100 |
| Fitting in Cartesian coordinate by genetic algorithm | 0.6388 | 1.4141 | 8.25 |

Because discharge of flow was only input to artificial neural network, this method produced unsuitable outputs. For using of artificial neural network, the number of arrival parameters to network should become more than one parameter. Also results of stochastic optimization are not unsuitable. Although results of this method in Cartesian coordinate are better than results of this method in logarithm coordinate.

The comparison between results of genetic algorithm method and observed data is shown in figure4.

The average of discharge of flow is 2900 CMS in the Dez River. For average of discharge of flow, the estimated weight of sediment by genetic algorithm is equal to 49900 tons/day ($18.2*10^6$ Tons/year) in Telezang station. This value is almost equal to observed data in Telezang station.


**Fig. 1:** Location of the study area

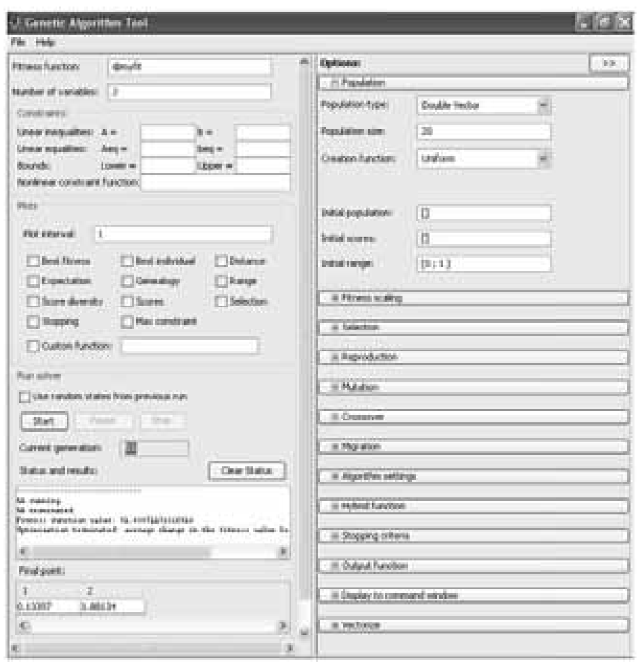


**Fig. 2:** The genetic algorithm tool of MATLAB

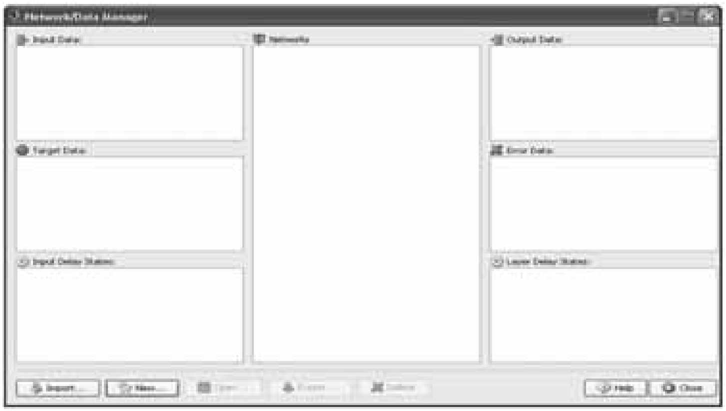

**Fig. 3:** The artificial neural network tool of MATLAB

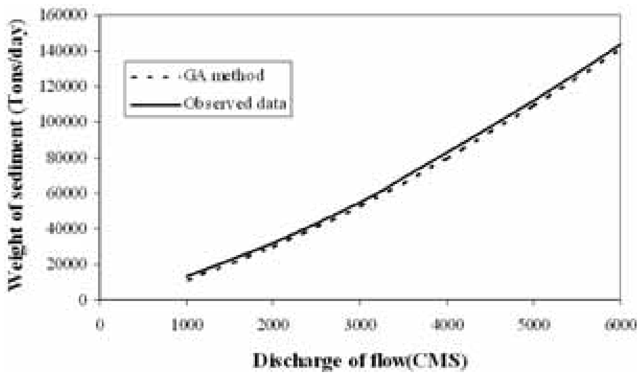


**Fig. 4:** The comparison between results of genetic algorithm method and observed data

***Conclusion:***

1- In this research, it was shown that genetic algorithm method is the most accurate method.

2- For using of artificial neural network method, arrival parameters to network should increases. A parameter (discharge of flow) is not sufficient for training of network. The parameters as sediment grain size, hydraulic parameters (velocity of flow, Froude number and etc.) and intensity of rainfall in flood times must be introduced to network.

3- For using of stochastic optimization, it is better that multi objective functions are applied. In addition to equation3, correlation coefficient must be considered as an objective function. In this case, correlation coefficient between calculated values and observed values have to converge to 1.

4- For better evaluation of ability of optimization methods, the number of observed data (especially in flood times) and their accuracy must increase.

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