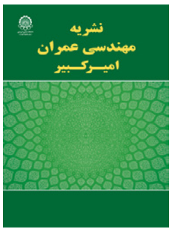


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# Assessment of bed load transport formula by using developed applied software (STE) (Case study: Chehel-chai,Khormaloo and Soosara rivers in Golestan province)

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**ABSTRACT:** Accurate estimation of flow and sediment discharges, as basic information, is important for many river engineering projects. To estimate bed load in the rivers, many experimental and semi-experimental equations have been developed but depending on the hydraulic conditions and sediment characteristics in each river, some of these equations may yield better results than the others. In this study, by developing an applied software, the abilities of 27 available equations for estimating bed load transport in rivers of Golestan province (Chehel-Chay, Khormaloo and Soosra), in which bed load is measured, have been evaluated. It should be noted that in this developed software quasi-two-dimensional models also can be used for computing velocity and sediment load distribution in cross section of the river. The software is also able to increase the accuracy of estimations by calculating calibration coefficients in the studied river. The results showed that by using the developed software, the best method for estimating bed load in the studied rivers is Yang's method. In this case, the percentage of discrepancy ratio between 0.5 to 2 for the rivers Chehel-Chay, Khormaloo and Soosra is 43.8%, 50% and 30.8% respectively. Also, using quasi-two-dimensional models, increases percentage of discrepancy ratio between 0.5 to 2 for the rivers Chehel-Chay, Khormaloo and Soosra by 6.3%, 6% and 8%, respectively. The results also showed that by calculating and applying a calibration coefficient, accuracy of methods can be improved for the studied rivers.

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## 1- INTRODUCTION

Hydraulic engineers have studied the sediment movements in rivers over the past two centuries, because the behavior of sedimentary materials is important in river hydraulics and its morphology. Sediment load estimation and creating an equation that can calculate the most accurate value has always been one of the most important issues in water engineering and hydraulic structures for better management of water resources. There has been a lot of researches in this field, but despite years of research, there is still no equation that can be used in various rivers and hydraulic conditions. In principle, creating such an equation is impossible because the hydraulic and laboratory conditions in which each equation is formed cannot be responsive to all areas and conditions. In order to obtain an equation that provides a better estimate, the conditions of the study area must be compared with the conditions and assumptions in which equations are formed. Therefore, due to the lack of existing a suitable software for evaluating different methods, and also for making calculations easier and increasing the speed and accuracy, as well as comparing the results, the need for a fast and accurate software feels in this field.

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## 2- METHODOLOGY

### 2-1- STE Software

The Sediment Transport Estimator (STE) software, developed and programmed by VB.NET language in Microsoft Visual Studio, provides the following abilities and features for its users:

- Save , load , edit and storing inputted data and calculated data in Microsoft Access files by type (.accdb)
- Ability to activate different methods for projects
- Ability to define different rivers with pictures and descriptions
- Ability to insert size fractions for each series of sediments in the project and calculate particle diameters automatically by applying polynomial and linear regressions.
- Ability to calculate discharge at different depths of flow and present stage-discharge curves for each defined river section using one-dimensional (mean velocity) Engelund-Hansen (1967) and Van Rijn (1984) models and a quasi-two-dimensional Shiono and Knight (1991) model [1], [2], [3].
- Ability to estimate sediment load including bed load, suspended and total load. Twenty seven methods of calculating bed load have been programmed in this software, ten methods are able to directly use size fractions. Seventeen Methods are able to calculate the sediment transport rate

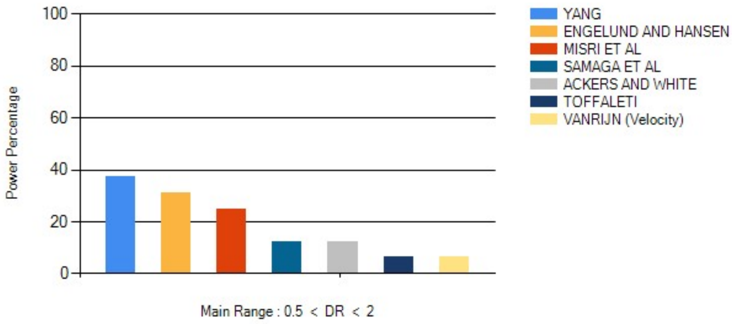


**Fig. 1. Percentage of discrepancy ratio for different methods in Chehel-Chay river**

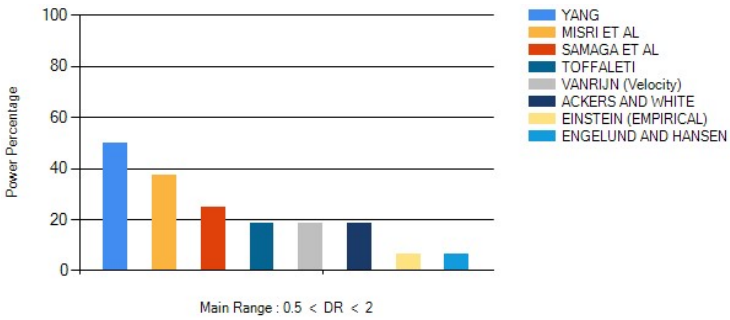


**Fig. 2. Percentage of discrepancy ratio for different methods Khormaloo river**

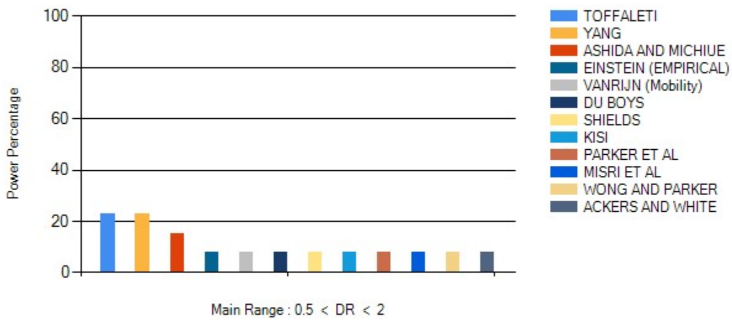


**Fig. 3. Percentage of discrepancy ratio for different methods in Soosra river**

across the river using the Shiono and Knight (1991) results.

- This software is able to receive the observed sediment load from user and calculate the discrepancy ratio and calculate a score for each method in 6 ranges of discrepancy ratio which are defined by user.
- There is an ability in this software that can improve the method's accuracy in the studying river by calculating a coefficient that named calibration coefficient.

## 2-2 Shiono and Knight Model

Many 2D mathematical models have been presented so far by various researchers. Shiono and Knight (1991) for the first time presented a mathematical model for calculating the velocity distribution in cross section of the river. This simple model, obtained by integration of the Navier-Stokes equation under steady flow conditions with the effects of secondary flows. The velocity distribution in width of the river can be modelled as follows:

$$\rho g H S_0 - \rho \frac{f}{8} u_d^{\,2} \sqrt{1+\frac{1}{s^2}} +$$

$$\frac{\partial}{\partial y}\left\{ \rho \lambda H^2 \left(\frac{f}{8}\right)^{1/2} u_d \frac{\partial u_d}{\partial y} \right\} =$$

$$\Gamma = \frac{\partial H\left(\rho \overline{UV}\right)_d}{\partial y}$$

Where, ρ is the volume mass of water $\left(\mathrm{Kg}/\mathrm{m}^3\right)$, g is gravity $\left(\mathrm{m}/\mathrm{s}^2\right)$, H depth of flow (m), $S_0$ is longitudinal bed slope, $f$ is Darcy-Wiesbach friction coefficient, $u_d$ average velocity in

**Table 1. Recommended methods for estimating bed load with calibration coefficients**

| River | Equation | Calibration coefficient | $0.5 < R < 2$ | | Mean R | |
|---|---|---|---|---|---|---|
| | | | MV | SKM | MV | SKM |
| Chehel-Chay | Yang | 0.95 | 38 | 44 | 11 | 13 |
| Soosra | Yang | 0.95 | 23 | 31 | 10 | 12 |
| Khormaloo | Misri et al | 0.46 | 56 | 56 | 1.08 | 1.01 |

**MV:** Mean Velocity (one-dimensional)
**SKM:** Shiono and Knight Model (quasi-two-dimensional)

depth $\left({}^{m}\!/_{s}\right)$, s is the lateral slope of the canal or river, λ is the coefficient of turbulence viscosity, Γ is the phrase of secondary flows and the width of the cross section at which the velocity must be obtained.

### 2-3- Data collection

The present study data are used from the results of Haddadchi et al. (2011) in which there are 16 series sampling for Chehel-Chay River, 16 series for Khormaloo river and 13 series for Soosra river [4].

## 3- RESULTS AND DISCUSSION

Fig 1 shows the variation of percentage of discrepancy ratio range of 0.5 to 2 for different bed load transport formula. The results show that Yang method can predict the bed load by 40%, Engelund-Hansen by 30% and Misri et al by 25% for Chehel-Chay river. By using Shiono and Knight model, accuracy has improved in Yang method from 37.5% to 43.8%.

Fig 2 shows the variation of percentage of discrepancy ratio range of 0.5 to 2 for different bed load transport formula. The results show that Yang method can predict the bed load by 50%, Misri et al by 38% and Samaga et al by 25% for Khormaloo river By using Shiono and Knight model, accuracy has improved in Misri et al method from 38% to 44%.

Fig 3 shows the variation of percentage of discrepancy ratio range of 0.5 to 2 for different bed load transport formula. The results show that Yang method and Toffaleti method can predict the bed load by 23% and Ashida-Michiue by 15% for Soosra river. By using Shiono and Knight model, accuracy has improved in Toffaleti and Yang method from 23% to 31%.

Calibration coefficients has been calculated for the studying rivers using STE software ability. The results are as Table 1.

## 4- CONCLUSIONS

In this study, the accuracy of 27 equations of the most common bed load estimation equations using one-dimensional and quasi-two-dimensional models has been evaluated in three rivers Chehel-Chay, Khormaloo and Soosra. results show that:

1. Yang, Toffaleti, Misri et al, Samaga et al, Ackers-White, Engelund-Hansen, Meyer-Peter and Muller, and van Rijn equations respectively, give more appropriate results than the other equations. Yang Method Calculate 42% of the whole data (data from three rivers) within the range of discrepancy ratio 0.5 to 2, which yields the best results for the rivers in the study area using mean velocity (one-dimensional) calculations.
2. By using quasi-two-dimensional models, the percentage of discrepancy ratio between 0.5 to 2 for Chehel-Chay, Khormaloo and Soosra rivers increases by 6.3, 6, and 8%, respectively. By applying the calibration coefficient 0.95 for Yang results in Chehel-Chay and Soosra rivers and the calibration coefficient 0.46 for results of Misri et al in Khormaloo river the accuracy of bed load estimations improves.

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