Estimation of Sediment Quantity Upstream of Al-Yaa'o Regulator

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Abstract

In this research, the modeling of sediment transport was performed and the transporting amounts of total material load were estimated in the upstream of Al-Yaa'o channel regulator located on the Euphrates river in the central of Iraq, the region of Al-Qadissya. The study-reach is five kilometers upstream Al-Yaa'o regulator; seventeen cross-sections were chosen along the area of study. These sections represent of the hydraulic variables and characteristics of sediments transported.

For the purpose of estimating the real and accurate amount of total sediment discharge, technical dimensional analysis has been used to find the relationship to calculate the transition sediment discharge that fit with the hydraulic conditions and properties of bed materials in the Euphrates river in the extension fact at the upstream of Al- Yaa'o regulator. A new formula was obtained and compared with six well known formulas.

Key words: Sediment Transport, River Bed Degradation, Measurements

الخلاصة

تناول هذا البحث إجراء نمذجة الرسوبيات المنقولة وتقدير كميات حمل مواد القاع في مقدم ناظم اليعو الواقع على نهر الفرات في وسط العراق ضمن ناحية القادسية. وكانت منطقة الدراسة بطول (5) كم باتجاه مقدم الناظم ،حيث تم اختيار سبعة عشر مقطعا عرضيا على امتداد منطقة الدراسة، وتمثل هذه المقاطع مواقع المتغيرات الهيدروليكية وخصائص الرسوبيات المنقولة.

إن تخمين كمية حمل القاع بشكل حقيقي تطلب استخدام تقنية التحليل ألبعدي من اجل التوصل إلى علاقة لحساب انتقال الترسبات تتلائم مع الظروف الهيدروليكية وخصائص مواد القاع في نهر الفرات ضمن الامتداد الواقع في مقدم ناظم اليعو .تم التوصل إلى معادلة جديدة وقورنت مع الصيغ الستة المعروفة.

الكلمات المفتاحية: نقل الرسوبيات، تآكل قاع النهر، نظام مقاييس

List of symbols

B,W= Width of the rever.
C_s= Concentration coefficient in the sediment transport function.
C_t, C_v= Total sediment concentration.
D_{50}= Particle size for which 50 percent by weight of the sediments is finer.
G= Acceleration of gravity.
Gs, Sg= Specific gravity.

Introduction

Rivers and channels are considered to be important resources for water supply, irrigation, navigation, water power generation and other public uses. The presence existence and movement of sediment causes many problems. The deposition and erosion of solid material of the beds and banks of channel increases bed deformation, which in turn will reduce the depth of water in some places and reduce the ability of the water way for navigation or hydraulic purposes. However, the raising of the river bed by the deposited materials increases the flood range to a great extent, **(Khassaf and Addab, 2011)**.

There is a number of equations to compute the total sediment load. Most of these equations have some theoretical and empirical bases. They were derived under very limited conditions of flow and sediment characteristics. All of them have shown good results when used to compute the sediment load for conditions similar to those under which they were derived. On the other hand, very poor results are obtained when they were applied for different conditions.

Description of Study Reach

Al-Yaa'o channel regulator is an important project of irrigation in the south of Najaf province in the middle of Euphrates region within Fifty km to the southeast of

Najaf city, in the region of Al-Qadissya, a branch of the left side of Al-Meshkhab river, and downstream of it, on the Euphrates. It was constructed on Kifil-Shenafiyah branch. The study region is located between longitude E 44°29'5.5" to E 44°30' 38.25" and latitude N31°42 30" to N 31°44' 44.46",**(Abbas, 2013)**. **Figure(1)** shows reach study location.

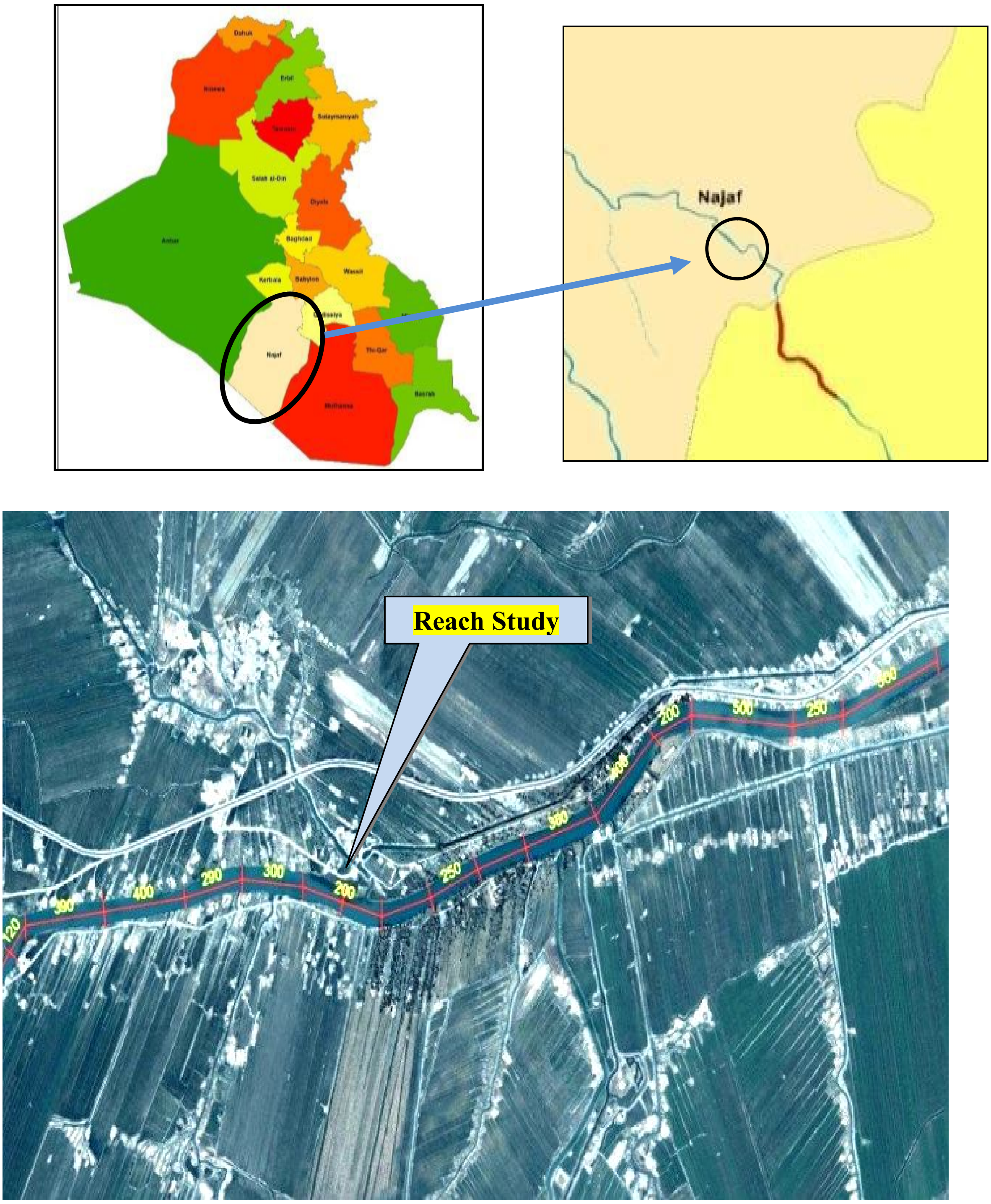

Fig. 1: Reach study location

Field Measurement

In this research, the data used for hydraulic and sediment characteristics were collected from 17 sections in the Euphrates River distributed along the study area upstream of Al- Yaa'o channel regulator. The collected data were discharge, velocity, cross-sectional area, and observed suspended sediment load from the field measurements. The flow depth in study reach ranged from (1 to 4.5) meters, with flow ranging from (21.09 to 44.54) m3/sec.The flow velocities ranges from (0.106 to 0.341)m/sec and the median sediment size (0.216) mm for the bed material composition was observed.

The bottom samples were obtained using a device (Van Veen Sample), which was manufactured by the researcher in addition to sampling the mixture (Water-Sediment) by using a factory device. Also, the hydraulic variables were found using (Acoustic Doppler Current Profile) device, **(Abbas, 2013)** .

Figure (2) shows the distribution of the sections along the search area. A summary of data used in the study is presented in **Table (1).**

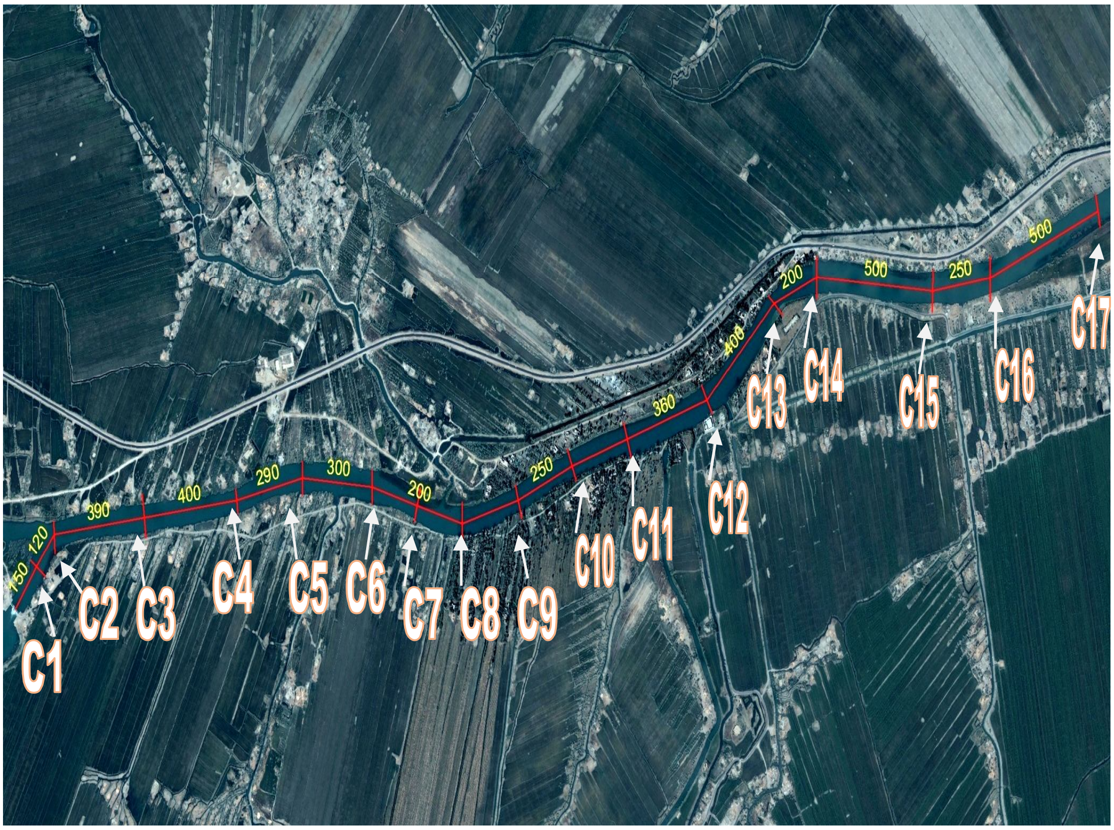

Table 1: Primary data and parameters

Sec. No	1	2	3	4	5	6
	37.33	22.97	25.99	40.62	25.18	39.43
	0.217	0.112	0.106	0.252	0.168	0.208
	2.684	2.7	2.667	2.684	2.673	2.680
	0.205	0.220	0.195	0.190	0.225	0.230
	172.10	205.3	244.90	161.40	149.80	189.60
	2.013	3.362	3.407	1.960	1.985	2.212
	85.51	61.07	71.88	82.35	75.47	85.72
w_s (m/sec)	0.032	0.038	0.03	0.03	0.29	0.04
υ (m^2/sec)	$1.21*10^{-6}$	$1.18*10^{-6}$	$1.16*10^{-6}$	$1.15*10^{-6}$	$1.14*10^{-6}$	$1.13*10^{-6}$
Sec. No	7	8	9	10	11	12
	42.33	44.54	60.51	53.25	41.76	42.97
	0.247	0.244	0.341	0.313	0.278	0.259
	2.69	2.95	2.66	2.70	2.66	2.68
	0.195	0.225	0.22	0.232	0.230	0.234
	171.70	182.80	177.60	170.00	150.20	166.10
	1.754	2.331	1.882	2.002	1.847	1.922
	97.87	78.43	94.39	84.93	81.32	86.43
w_s (m/sec)	0.031	0.042	0.04	0.046	0.044	0.046
υ (m^2/sec)	$1.12*10^{-6}$	$1.1*10^{-6}$	$1.09*10^{-6}$	$1.08*10^{-6}$	$1.08*10^{-6}$	$1.07*10^{-6}$
Sec. No	13	14	15	16	17	
	38.74	41.93	38.59	22.03	21.09	
	0.204	0.271	0.221	0.118	0.106	
	2.668	2.690	2.70	2.660	2.70	
	2.865	1.788	2.250	2.463	4.533	
	189.60	154.50	174.70	187.10	199.50	
	2.864	1.788	2.250	2.463	4.533	
	66.21	86.41	77.64	75.97	44.01	
w_s (m/sec)	0.055	0.048	0.030	0.035	0.040	
υ (m^2/sec)	$1.06*10^{-6}$	$1.06*10^{-6}$	$1.05*10^{-6}$	$1.04 *10^{-6}$	$1.0*10^{-6}$	

Sediment Transport Formulas

There are two general categories of sediment transport model equations used to simulate the movement of sediment in natural rivers.One set of transport model equations separates the total sediment load into suspended and bed load, where as the other combines the two modes of transport and tracks only the total load,**(Tianchun and Yong,2008).**The formulas used in testing were Inglis-Lacey,Yang,Fazle, Ariffin, Jasem and sharba. **Table (2)** is showing summary of the sediment discharge variables by the investigators.

Table 2 :Summary of sediment parameters

Author	Input parameters used
Inglis-Lacey (1968)	
Yang(1996)	
Fazle(1998)	
Ariffin(2004)	
Jasem(2012)	$\rho_w\ w_s R_h,\ V/w_s,\ R_h/d_{50},\ v/w_s R_h,\ G_s B/R_h$
Sharba (2014)	$Q_s/\rho_w\ w_s\ d_{50}^2,\ V/w_s,\ R_h/d_{50},\ U_*/w_s,\ B/d_{50},\ \rho_s/\rho_w,$

The meanings of each symbol are presented in list of symbol.

- **Inglis-Lacey formula**

The Inglis-Lacey formula was developed by Lacey and Inglis, by introducing the mean size and fall velocity of the bed sediment. The original Lacey regime relations were based on data from large stable irrigation canals. The formula itself is dimensionally homogeneous and it can be used with any consistent set of units, **(Inglis,1968)**.The actual expression used with the Inglis-Lacey approach to predict sediment transport is:

$$Q_t = 0.562\left(\frac{\sqrt[3]{v\,g}}{ws}\right)\left(\frac{v^2}{g\,h}\right)\left(\frac{\rho_w\,v^3}{g}\right) \qquad \text{............eq.(1)}$$

- **Yang's equation**

Yang et al. proposed modified Yang's unit stream power formula for a sediment-laden river. Computing the sediment concentration from,**(Yang *et al.*, 1996)**.

$$\log G_t = 5.16 - 0.153\log\left(\frac{w_s\ d_{50}}{v}\right) - 0.297\log\left(\frac{U_*}{w_s}\right) + [1.78 - 0.36\log\left(\frac{w_s d_{50}}{v}\right) - 0.48\log\left(\frac{U_*}{w_s}\right)] * \log\left(\frac{VS}{w_s}\right)$$

............eq.(2)

$$C_m = \frac{C_t G_s \times 10^{-3}}{G_s - (G_s - 1)(C_t \times 10^{-3})} \qquad \text{............eq.(3)}$$

$$Q_s = C_m \times Q_w \qquad \text{...........eq.(4)}$$

- **Fazle Karim Formula**

Fazle Karim in this analysis for developing the relation for total sediment discharge per unit width, **(Fazle,1998)** .The equation is:

$$\frac{Q_t}{\sqrt{g(Gs-1)d_{50}^3}} = 0.00139 \times \left[\frac{v}{\sqrt{g(Gs-1)d_{50}}}\right]^{2.97} \left(\frac{U_*}{ws}\right)^{1.47} \qquad \text{……..….eq.(5)}$$

- **Ariffin Formula**

Ariffin had derived her sediment transport equation based on regression. She had conducted tests on the robustness on the variables used in her equation, **(Ariffin, 2004).** Her proposed equation is:

$$C_v = 1.156 \times 10^{-5} \left(\frac{R_h}{d_{50}}\right)^{0.716} \left(\frac{u_*}{ws}\right)^{-0.975} \left(\frac{u_*}{v}\right)^{0.507} \left(\frac{v^2}{g\,H}\right)^{0.524} \qquad \text{…….…...eq.(6)}$$

- **Jasem Formula**

Jasem (2012) was studied the transportation of bed load and its entrapment have been estimated of up-stream Al-Abassiya Barrage, **(Jasem, 2012).** The equation is:

$$Q_s = \rho\, w_s\, R_h \left(\frac{V}{w_s}\right)^{1.5} \left(\frac{R_h}{d_{50}}\right)^{-0.5} \left(\frac{v}{w_s\, R_h}\right)^{0.43} \left(\frac{S_g\, B}{R_h}\right)^{0.67} \qquad \text{…….....eq.(7)}$$

- **Sharba formula**

Sharba (2014) was conducted to estimate the total amount of sediment load in Euphrates River upstream of Al-Shamia Barrage, **[Sharba (2014)].** The equation is:

$$Q_s = 32 \times 10^{-4}\, \rho_s\, w_s\, d_{50} \left(\frac{U_*\, v}{ws^2}\right)^{1.07} \left(\frac{R_h\, ws}{v}\right)^{0.33} (B) \qquad \text{……....eq.(8)}$$

Table (3) is showing the predicted and observed values of sediment discharge.

Table 3: Predicted and observed values of sediment discharge in (kg/sec).

Sec. No	1	2	3	4	5	6
Inglis-	9.95×10^{-4}	1825×10^{-5}	1.72×10^{-5}	2.34×10^{-3}	2.2×10^{-4}	5.33×10^{-4}
Yang	2.43	0.033	0.043	0.173	0.060	0.060
Fazle	1.92×10^{-4}	1.52×10^{-5}	2.10×10^{-5}	2.33×10^{-4}	5.5×10^{-5}	1.02×10^{-4}
Ariffin	1.82×10^{-2}	0.2×10^{-2}	0.186×10^{-2}	0.455×10^{-2}	2.53×10^{-3}	5.77×10^{-3}
Jasem	2.55	0.50	0.60	3.30	1.34	1.8
Sharba	1.043	0.42	0.484	0.932	0.63	0.84
Observed	3.42	1.17	1.21	5.62	1.38	2.29
Sec. No	7	8	9	10	11	12
Inglis-	2.2×10^{-3}	1.14×10^{-3}	7.88×10^{-3}	4.2×10^{-3}	2.62×10^{-3}	1.68×10^{-3}
Yang	0.170	0.20	0.351	0.20	0.150	0.134
Fazle	3.2×10^{-4}	1.6×10^{-4}	4.21×10^{-4}	2.5×10^{-4}	2.25×10^{-4}	1.45×10^{-4}
Ariffin	4.42×10^{-3}	6×10^{-3}	9.84×10^{-3}	9×10^{-3}	6×10^{-3}	6.4×10^{-3}
Jasem	3.50	2.50	4.62	3.80	2.83	2.53
Sharba	1.35	1.00	1.322	1.10	1.073	0.95
Observed	3.05	3.22	7.13	6.91	4.15	3.28

Sec. No	13	14	15	16	17	
Inglis-	2.68×10^{-5}	2.2×10^{-3}	9.92×10^{-4}	3.36×10^{-5}	9.22×10^{-6}	
Yang	0.066	0.150	0.0003	0.035	0.038	
Fazle	6.85×10^{-5}	2×10^{-4}	1.86×10^{-4}	2.4×10^{-5}	1.15×10^{-5}	
Ariffin	5.4×10^{-3}	6.34×10^{-3}	4.1×10^{-3}	3×10^{-3}	1.82×10^{-3}	
Jasem	1.20	2.90	2.80	0.78	0.50	
Sharba	0.82	1.02	0.94	0.50	0.40	
Observed	2.21	4.40	3.43	1.11	1.04	

Comparison of Formulas precision

With the intention of selecting the best formulas; there are two types of comparisons which are statistical relations and graphical comparison.

1. Comparison Using Statistical Relations

Two methods are used in this research to evaluate the performance of each formula through comparing the measured sediment discharge with predicted sediment discharge.

1.1. Discrepancy Ratio

To evaluate the difference between the measured and the predicted values, the discrepancy ratio was used as an error measure that is defined as **[Yang,(2006)]:**

$$\text{Discrepancy Ratio} = \frac{\text{computed qs}}{\text{measured qs}} \qquad \text{..........eq.(9)}$$

If the discrepancy ratio is equal to one, then the predicted value is identical to the measured value. If the discrepancy ratio is larger than one, then the predicted value will be overestimating,and if the discrepancy ratio is smaller than one,it will be underestimating.

The discrepancy ratio is scheduled with the ranges (0.75-1.25), (0.5-1.5), and (0.25-1.75). The results are shown in **Table (4).**

Table 4: Comparison between the computed and the measured values.

Formula	*Discrepancy ratio*			*NO. data*
	Percentage of data in the range			
	0.75-1.25	0.5-1.5	0.25-1.75	
Inglis-Lacey	.....	......	.....	17
Yang	.....	5.88%	5.88%	17
Fazle	.....	......	.....	17
Ariffin	.....	......	.....	17
Jasem	41.2%	94.2%	100%	17
Sharba	.....	11.8%	76.5%	17
New formula	82.35%	100%	100%	17

1.2. Root Mean Squared Error

The root mean squared error (RMSE) value is a commonly used error measure. The sum of squares gives more weight to higher error values, and consequently higher error variances. The RMSE has the same units as the measured and calculated data.

Smaller values indicate better agreement between the measured and the calculated values, **(Scheaffer, 2011).**

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(S_o - S_c)^2}{N}} \quad \text{…………eq.(10)}$$

In which :S° observed sediment rate, S_c is predicted sediment load and N is the number of predicted values. The results are shown in **Table (5).**

Table 5: Comparison using Root Mean Squared Error

Formula	RMSE
Inglis-Lacey	3.73
Yang	3.5
Fazle	3.74
Ariffin	3.73
Jasem	1.33
Sharba	2.8
New formula	0.69

The modeling formulas were compared with the field results and the closest formula to the field results has been(Jasem),while (Fazle) formula has give quite poor, through various, statistical methods; other remaining formulas have given a poorly results than field values with a bit of convergence in some of these results.

2. Graphical Comparison

A graphical comparison is conducted on the six formulas and a new formula by calculating the deviation of predicted sediment discharges from measured or by means of discrepancy ratio. **(Jasem, 2012).**

Figure (3) shows the comparison between predicted sediment discharges of seven formulas and observed sediment discharge.

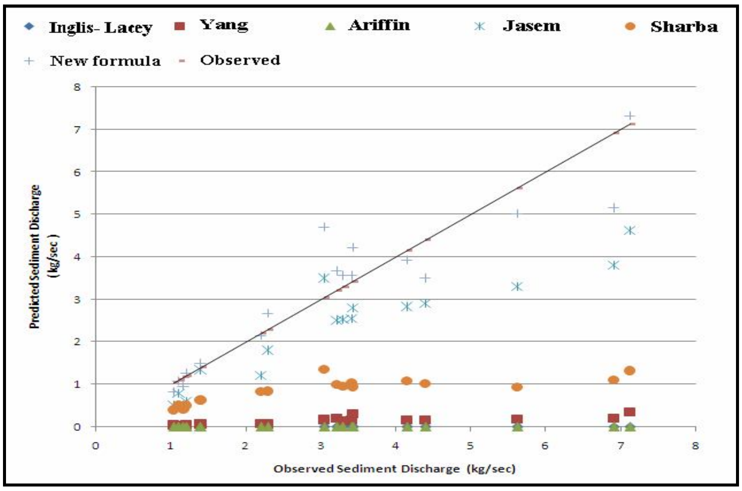

Fig. 3: Comparison between measured and computed sediment load by using six Formulas, new formula

Conclusions

Based on the results obtained in this study(Euphrates river up-stream of Al-Yaa'o channel regulator), The following conclusions can be made:

1. A new sediment transport formula has been developed in four terms.

$$Q_s = 4\times10^{-5}\,\rho_w\,Q_w\left(\frac{V}{W_s}\right)^{1.05}\left(\frac{T}{d_{50}}\right)^{-0.088}$$

formula is applicable under the following conditions:

- Flow velocity from(0.106 to 0.341) m/sec.
- Water discharge from(21 to 60.5) m^3/sec.
- Concentration of total load from (50.6 to 138.4) g/m^3.
- Median grain size from (0.183 to 0.254) mm.

2. six formulas used in the search to predict the total sediment load, the best performance were produced by Jasem formula followed by Sharba formula. The first one gave discrepancy ratio equal to 100% within the ranges (0.25-1.75) and RMSE equal to 1.33. While the second one gave 76.5% for the same ranges, and RMSE equal to 2.8.
3. The new formula is the best among other formulas as statistical methods proved. It also shows a good agreement between measured and predicted sediment discharge as the discrepancy ratio equal to 100% within the ranges from (0.5 to 1.5), and RMSE is equal to 0.69.

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