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"SUSPENDED SEDIMENT TRANSPORT FORMULA FOR THE UPSTREAM OF AL-BETERA REGULATOR"

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Abstract

In this study, the researcher suggest a new formula for the estimation of suspended sediment discharge for a reach of Tigris River located upstream AL-Betera regulator, Maysan province-Iraq. For this purpose, a number of in-site observations made; many samples were taking from the river during each observation, these samples filtered and the suspended sediment concentration and the average concentration recorded. In addition, for each observation, the river discharge measured using the ADCP technology. A total number of seventeen observations recorded. The formula developed by dimensional analysis and general regression among effect parameters, water density (ρw), solid particles density (ρ_s), water viscosity (ν), particles diameter (d_{50}), gravitational acceleration (g), water velocity (V) and depth of flow (D). A good agreement between the formula and the observed data achieved depending on the value of coefficient of determination R^2.

Key Words: Suspended sediment, new sediment formula, ADCP, Al-Betera Regulator

1. Introduction

Sediment is comprised of solid particles of mineral and organic material that transported by water. In river systems, the amount of sediment transported controlled by both the transport capacity of the flow and the supply of sediment. The "suspended sediment load" refers to the fine sediment that carried in suspension and this can comprise material picked up from the bed of the river (suspended bed material) and material washed into the river from the surrounding land (wash load). The wash load is usually finer than the suspended bed material. In contrast, the "bed load" comprises larger sediment particles that transported on the bed of the river by rolling, sliding or saltation. Most rivers will transport sediment in each of these "load" forms, according to the flow conditions [1].

Since natural rivers are subject to constant erosion and sediment transport processes, the study of sediment transport mechanisms and transport capacity of stream flows is considerably important in river hydraulics and geomorphology. Sediment transport and sedimentation in rivers have serious consequences including formation of sediment bars and reduction of flood sediment transport capacity, affected dams lifetime and their reservoir capacity, severe erosion of hydro-mechanical facilities and damaging field and water structures, sedimentation at flow channels, and other hydraulic problems. In addition, considering the principles of river material extraction and transported sediments by river flow in design of river structures, the study of various methods to predict river-sediment transport rate seems to be necessary.

Therefore, there is a need to establish a certain formula that can applied to study reach, which must derived depending upon the local boundary and hydraulic conditions of the study reach.

2. Region of Study

The reach of study is a 4.25km part of Tigris River in Al-Amarah city (south of Iraq), Maysan province upstream Al-Betera regulator. Its location is between latitudes 31.33°N and 31 49°N and longitudes 47.09°E and 46.52°E. Fig. 1 shows the study reach location.

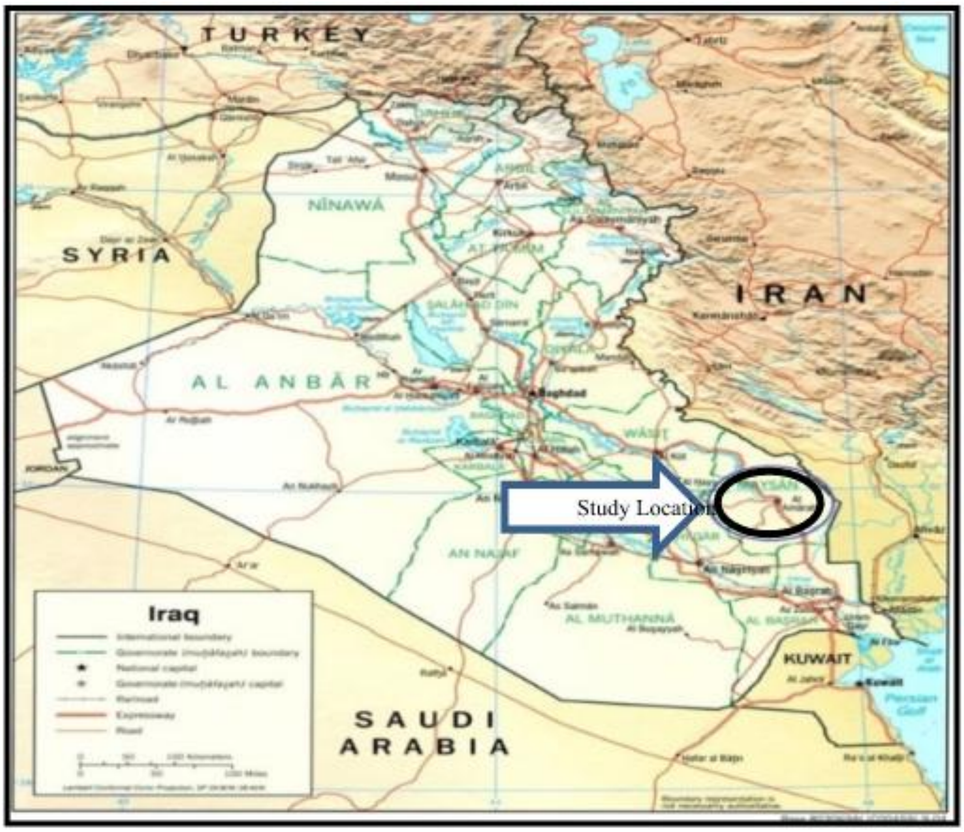

Fig. 1, Study Reach Location

Velocity Measurements and Distribution

Seventeen cross-sections, Fig. 2, considered along the reach. At each section, bed elevation, top width, water level, area of cross sections, water velocity and discharge measured using the ADCP technology. SonTek river tracker surveyor; Fig. 3 and Fig. 4; and its software version 4.3 used for this purpose. These measurements tabulated in Table 1.

Fig. 2: Transect Sections Locations

Fig. 3: SonTek River Surveyor ADCP

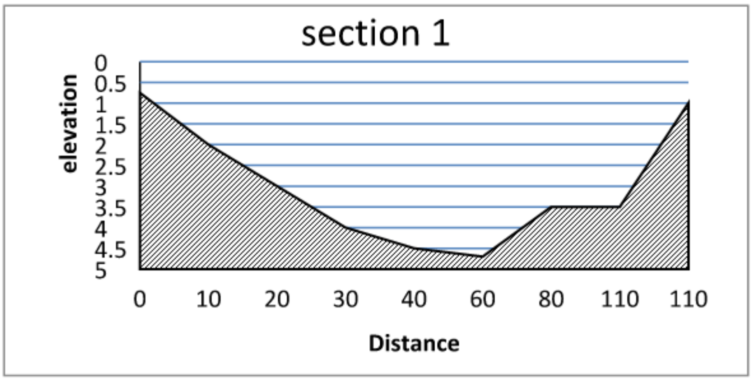

Fig. 4: Geometry of Section No.1 using the ADCP

3. Suspended Sediment Concentrations

Suspended sediment concentration measured and recorded to determine how much sediment entrained in the stream flow. Depending on the desired degree of accuracy of the measurements, the number and location of sampling verticals should selected. The common methods in use given and briefly discussed by the Interagency Committee on Water Resources [2]. In this study, the sampling verticals chosen at ¼, ½ and ¾ of the width of stream at each cross-section. This procedure was very convenient and more practical for study reach; three samples taken at each vertical at three depths 0.8d, 0.6d and 0.2d, where d is the depth measured from water surface. Nine samples in each transect section. Once suspended sediment samples collected, the samples were filtered using filter papers. The filters used had a pore size of 0.45µm and pre-dried for 15 minutes in an oven at 105 °C. The weight of the filter paper measured prior to filtering. The amount of water filtered also measured. After the sediment filtered out of the sample, the sediment and filter paper placed on a dish, placed in an oven, and baked for 24 hours at approximately 105 degrees Celsius to remove water from the sediment. After 24 hours, the filter paper with sediment removed from the oven and weighed. The mass of sediment could then be determined by subtracting the initial filter weight from the weight of the dried sediment and filter. Once the weight of the sediment and the volume of water filtered were determined, the following equation used to calculate the suspended sediment concentration [3].

$$\textit{Sediment Concentration}\ (Cs) = \frac{\textit{Mass of Sediment}(M)}{\textit{Volume of Water}\ (v)} \qquad \dots (1)$$

Where Cs in ppm or mg/l; M in mg and v in liter.

4. Bed Materials Sampling

One bed material sample taken for each section in study reach. The samples taken using Van Veen's grab. For sample taking from the bottom surface the "Van Veen's grab" is a very useful tool. It can easily handle and gives in many cases quite good samples. During the descent to the bottom, the two buckets held in open position by the means of a hook. When the grab hits the bottom, the tension on the hook released and the hook is disengaged. When the line is hoist, the buckets close automatically.

Sieve analysis and specific weight done for each bed sample, Fig. 5. The procedure listed in ASTM D_{854} and AASHTO T_{100} followed in the determination of specific gravity of bed sediments materials. The average value of specific gravity for all sections was (2.68).

5. Sediment Discharge In Study Reach

Suspended sediment transport rate (discharge) may computed from the following equation [3 and 4]

$$Q_s = C\,Q \qquad .... (2)$$

Where: Q_s = Sediment discharge (kg/sec).

C= Average concentration of suspended sediments (mg/lit).

Q = Water discharge (m^3/sec).

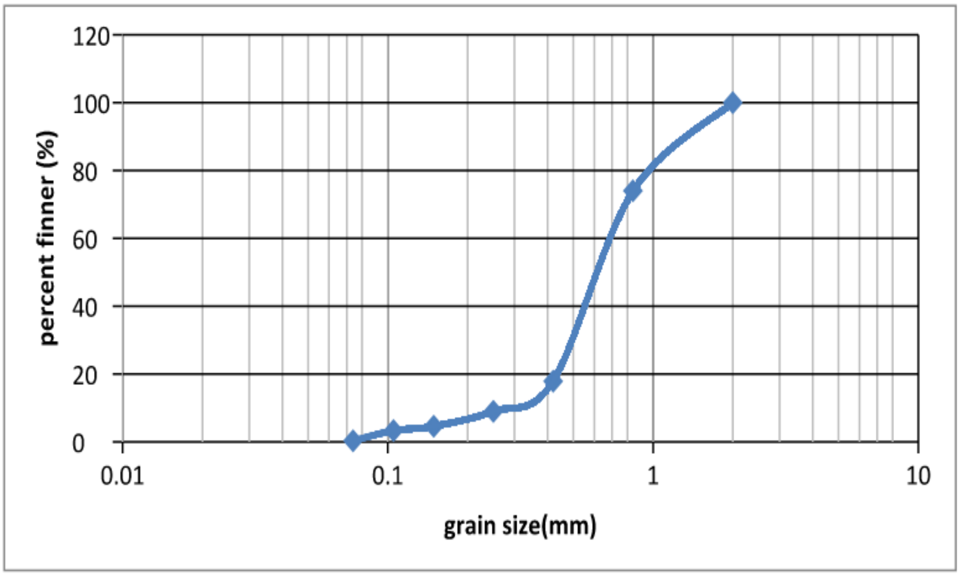

Fig. 5: Average Sieve Analysis for All Section

6. Development of Formula

The Buckingham π theorem is one of the approaches that researches used in developing general total sediment. Based on the theorem, the proposed influential parameter is the general form of the intensity of the bed material load,

$$\mathbf{Q_t = \emptyset(V, D_*, D_{50}, Ws, u_*, \rho w, \rho s, \theta, D)}$$

$$\mathbf{Or\ F(Q_t, V, D_{50}, Ws, u_*, \rho w, \rho s, D_*, \theta, D)} = \text{constant}..........[3]$$

The number of primary dimensions involved is 3,i.e, m= 3 (**M,L,T**). The total numbers of variables are 10. Therefore , the number of π – terms is(7)

Thus, F(π1, π2, π3, π4, π5, π6,π7) = constant. The results of the analysis are shown in table [1]

Table [1] : π parameters

π	1π	2π	π3	4π	5π	π6	7π
Parameter	$Q_{t/\rho_{w\,V\,D^2}}$	D*	θ	Gs	V/Ws	V/u*	D/D_{50}

The final form of the equation has to be determined by the conducting of the regression analysis on the observed data. The regression analysis was conducted and be found by using the following formula.

$$Q_t = \rho_w V D^2 (D_*)^{-0.8912} (\theta)^{0.4393} (G_s)^{7.465} (\frac{V}{W_s})^{0.9132} (\frac{V}{u_*})^{-0.2425} (\frac{D}{D_{50}})^{-1.856} \ldots [4]$$

D* = particle parameter =$[(Gs-1)g/\vartheta^2]^{\frac{1}{3}} D_{50}$

$\theta = Shield\ parameter = u*^2/(Gs\text{-}1)gD_{50}$

Q_t= Total sediment load (kg/sec),

ρ_s= *Density of sediment*(kg/m^3),

ρ_w=Density of water (kg/m^3) ,

D_{50}= Median grain size (m),

=Shear velocity (m/sec) u*

V = Mean velocity (m/sec),

Ws = fall velocity of particle (m/sec),

D = Depth of water (m),

ϑ= Kinematics viscosity (m^2/sec)

The coefficient of determination of equation (4) was found to be equal (R^2=0.787)

Figure (6) shows a relationship between the predicated and the observed values of sediment discharge for 17 sections.

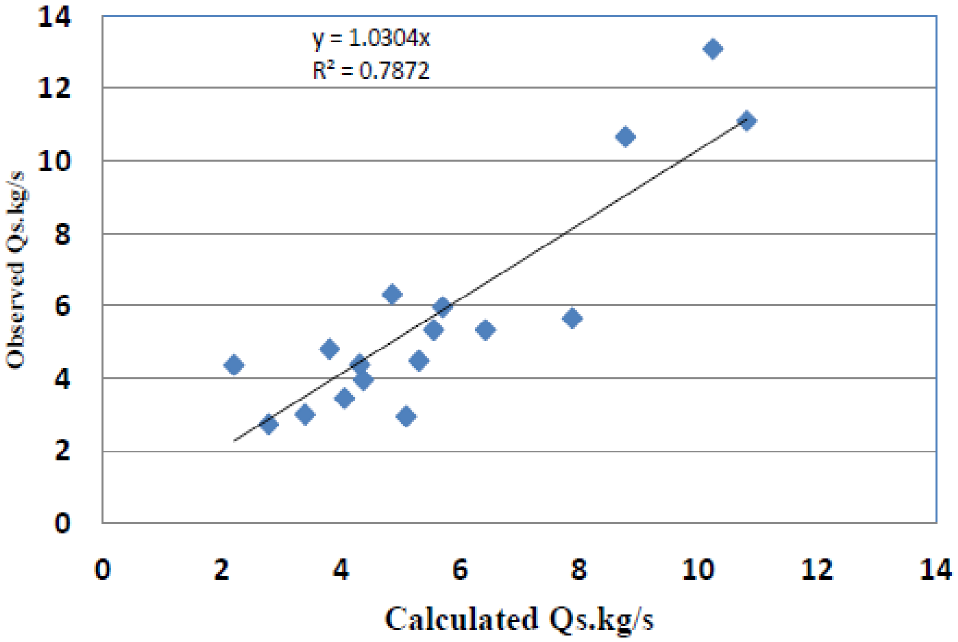

Fig.(6):Relationship between calculated and observed sediment discharge.

7. Existing Total Load 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, whereas the other combines the two modes of transport and tracks only the total load [4]. Table (2) shows the summary of the sediment discharge variables by the researchers and the predicted and observed values of sediment discharge are presented in table (3).

Table (2): A summary of sediment parameters

Author	Input parameters used
Ackers-White	d_{50}/h , V/U_* , γ_s/γ , C_s , ν
Yang	$V\,S/W_s$, V/u_* , $W_s\,d_{50}/\nu$
Van Rijn	$\frac{(V-V_{cr})}{(G_s-1)\,g\,D_{50}}$, $\frac{D_{50}}{H}$, $\frac{d(G_s-1)\,g}{\nu}$
Ariffin	R_h/d_{50} , U_*/W , U_*/V , $V/g\,D$
Jasem	$\rho\,W\,R_h$, V/W , R_h/d_{50} , $\nu/w\,R_h$, $Gs\,B/R_h$

Table (3): The calculated and observed values of sediment discharge for 17 cross-sections of river reach in (kg/sec)

Sec. No	Ackers	Yang	Van Rijn	Ariffin	Jasem	Observed	Calculated
1	0.44	0.26	1.37	4.89	10.68	6.316	4.86
2	0.88	0.61	2.63	10.15	13.98	4.382	4.313
3	0.55	0.29	1.48	6.19	9.32	4.369	2.202
4	3.27	1.5	9.31	16.06	18.72	2.95	5.095
5	2.21	0.8	10.41	9.21	15.29	5.652	7.885
6	2.10	0.41	1.83	9.86	9.07	4.483	5.314
7	0.98	0.44	4.51	8.38	12.02	5.338	6.426
8	4.35	1.01	8.61	14.54	15.46	3.95	4.378
9	0.41	0.21	0.43	6.86	6.77	10.67	8.782
10	1.42	0.36	1.27	6.88	8.29	5.97	5.708
11	0.67	0.56	3.73	7.58	12.86	11.11	10.819
12	3.40	0.66	3.89	10.88	11.75	13.1	10.252
13	0.12	0.08	0.08	4.5	4.08	5.339	5.555
14	4.62	1.38	17.04	11.89	21.88	3.455	4.061
15	5.43	1.43	21.25	13.98	19.04	4.806	3.811
16	0.85	0.52	1.41	10.77	10.91	2.73	2.783
17	2.04	0.59	5.16	10.38	11.24	3.005	3.395

8. 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.

9. Comparison Using Statistical Relations

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

10. Mean Normalized Error

A mean normalized error was used in order to select the best formula since due to the high difference between predicted and measured sediment rates at various intervals[5]

$$MSE = \frac{100}{N} \sum_{n=1}^{n} |(S_o - S_c)/S_o| \qquad \ldots\ldots[5]$$

MSE is a Mean Normalized Error; S_o an observed sediment rate; S_c is a predicted sediment load and N is the number of the predicted values.

In this method, a lower statistical value (close to zero) shows a higher accuracy in the model performance.

Table (4) shows these results. This method gives a general evaluation for all results by each used formula[6,7].

Table (4): Comparison using Mean Normalized Error

Formula	Van Rijn	Ackers-White	Yang
	114%	62%	86.5%
Formula	Ariffin	Jasem	New formula
	127.4%	185.3%	20%

The new formula gave the Mean Normalized Error (MSE) equal to 20% as it is stated in the table (4). It is much less than the (MSE) for all the equations used in the comparison. Therefore the new formula produced good results to estimate the amount of bed material load in the study area.

11. Graphical Comparison

A graphical comparison is conducted on the formulas by calculating the deviation of predicted sediment discharges from measured or by means of discrepancy ratio as shows in figure (7). [8].

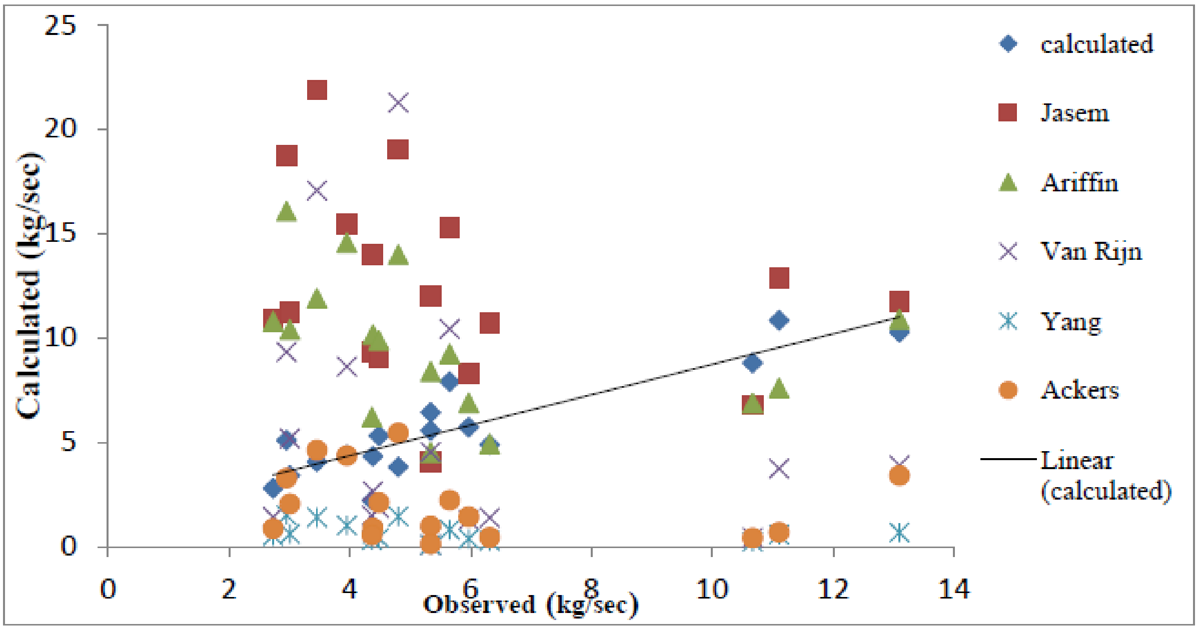

Figure (7): Comparison between calculated and observed sediment load by using all formulas

Figure (7) shows the extent of agreement between measured and predicted sediment discharges with respect to the new formula are very good. The scattering of the points is around the fit line.

12. Conclusion

This study presents the development and comparison performed to suggest a new sediment transport formula for the upstream of Al-Betera regulator.

According to the results obtained by this study, the following points concluded:

- The particle size distribution of sediment samples showed that the bed material river is composed of Sand, Silt and Clay. The large portion of bed material is sandy material, with median grain size from (0.5 to 0.9) mm.
- The observed suspended sediment discharge range in the study region was from (2.73) to (13.1) kg/sec, and by the new formula was (2.2) to (10.819) kg/sec.
- A new sediment transport formula developed in terms of dimensionless parameters.
- The new formula exhibited a good correlation between observed and calculated sediment discharge (R^2=0.78).

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