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Utilizing of shields factors for sedimentation movements and drainage channels at the middle of Iraq (as a case study)

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ABSTRACT

The shields factor seems to be a non-dimensional quantity which is utilized to determine the commencement of sediments movement in channels. This study intends to analyze sediments movement in channels of drainage and irrigation in Iraq by utilizing these characteristics as a determinant, and to establish a suitable formula to describe this impact in estimating sediments discharge. Based on seasonal unpredictability of the data, the field and laboratory work was completed across a 36-month period from January 2015 to January 2018. The soil texture was silty sand with a little clay amount, and the specific gravity magnitudes of the soil specimens vary from 2.66-2.73. Furthermore, the Shields factor magnitudes (θ) for movement were greater comparison with the critical magnitudes (θcr) in all channels; sediments transmission has been situated along the channels, according to the research. Using the Shields factor, two logarithmic formulas have been devised to quantify sediments discharge. The Flowing in irrigation channels has a correlation magnitude of 0.9007, whereas the Flowing in drainage channels has a correlation coefficient of 0.644. This demonstrated that the shields factor and sediments transport in irrigation channels had a significant degree of association. The drainage channels, on the other hand, have a significantly lower degree of correlation. This reflects the requirement to design a routine maintenance schedule for certain channels and to ensure that hydraulic Flowing criteria are met.

Keywords: Shields factor, Sedimentation Movements, Drainage Channels, Iraq

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1. Introduction

Sediments is a mixture of inorganic and organic components that may be taken away by snow, wind, or water. Whereas the word "sediments" is often utilized to refer to soil-based mineral matter (such as sand, silt, and clay), it also refers to decaying organic compounds and inorganic biogenic material. The most of mineral silt was created by weathering and erosion, while organic sediments is prepared by decaying stuff like algae and detritus. Where the particles with diameter equal to 0.000195 cm or less is called clay, while particles with diameter equal to 0.15 cm or more is called coarse sand. On the other side, large boulders, may be classed as silt throughout floods or other great-flowing event since they are transported downstream. Several bodies of water include sediments, which would be a naturally occurring substance that may be altered by human causes [1]–[4]. The transportation of inorganic and organic particles via water was found as sediments transportation. The greater the Flowing, the more sediments are moved in general. Water Flowing might well be powerful enough to suspend particles in the water column or just propel them downstream along the channel's bottom. Transported sediments could include mineral resources, chemicals, and pollutants, and also organic material. Sediments conveyance is also known as sediment loading. The total load includes the majority of the particles going as wash loading, suspended loading, and bedload [5], [6]. Geologic, geomorphic, and biological causes all contribute to sediments. In any given canal, the volume, substance, and size of carried sediments is a total of these factors. Glacial silt is frequently carried in rivers with headwaters from mountain ranges, whereas a body of water surrounding by swampland would be overwhelmed by rotting organic waste. Sediments transfer isn't always reliable. It was, in reality, susceptible to ongoing modification. Other external variables may affect sediments transport, in addition to variations in sediments load caused by biological components, geomorphology, and geology. Changes in human impact, meteorological events, water level, and water Flowing may all affect sediments transfer.

Figure 1. Sediments carried downstream with water Flowing

The Shields factor seems to be a dimensionless factor that encapsulates the multiple elements that combine to cause motion on a sediments bed. Many students struggle to comprehend these (and most other) dimensionless numbers, despite the fact that they are critical to comprehending sediments movement and deposition controls. I provide such a dynamic, interactive formula that displays locations on the Shields graph, enabling students to investigate the various factors that influence motion initiation [1], [7], [8]. Predicting the Flowing intensity during which sediments movement starts is a basic challenge in sediments transport. This requirement for incipient movements is often described in terms of shear stress (critical or threshold), that I'll refer to as τ_{oc}. The issue may be seen as either the smallest shear stress available to transport a specific particle or the maximum grain size that a specific shear stress could transport. Geologists refer to the latter as competency. Since the Flowing still has not become a two-phase Flowing, all the ideas and methods of sediments-free Flowing—what is known as rigid-boundary hydraulics—must still applicable. Incipient movements must be one of the easiest issues in sediments transport. Even in the simplest of difficulties, nevertheless, comprehension is far from full, which should alert you to several ways and formulae in the research that claim to deal with proven sediments movement [9]. The threshold velocities of big size boulders (15 to 45 cm) in the Blue Creek mountainous river in the United States were examined by [10]. In the summer and autumn of 1967, 36 natural boulders of different shapes and sizes have been painted bright red, tagged with a float, and put in a research obtain in the Blue Creek in which near-bed velocities might be monitored near to the labeled rocks. The water depth is around 1 and 1.2 meters. The rapid floats' movement has been characterized as the start of motion. Helley also includes field data from [11] equivalent observations. Turowski, et al., [12] investigated the transportation of stones and boulders in the Erlenbach mountain stream, a minor stream in the canton of Schwyz, Switzerland, exhibiting step-pool morphology. Three rare occurrences occurred, rearranging the previous step-pool morphology partially or entirely. Sediments movement rates at a selected discharge and total sediments output were greater for around a year or more after the incidents. Observations of boulder movement and stepping destruction have been utilized to infer channel stability for the most recent incident, which occurred on June 20, 2007. Throughout the 2007 incident, stones having average diameters=135 cm and assessed weights with higher than 2.5 tons shifted. Boulders with diameters ranging from 50 to 65 cm have been observed to be completely mobile at peak circumstances, with average velocities with about 3 m/s (discharge= 5 m3/s, average width of Flowing=4 m, and average depth of Flowing =120 cm). Mueller, et al., [13] investigated the bed-load transportation's threshold bed-shear stress (θcr) of pebbles and boulders in several mountain streams with D50 magnitudes ranging from 0.025 to 0.21 m. (Idaho, USA). The non - dimensional bed-shear stress even at a low non - dimensional reference bed-load transportation rate of 0.002 is specified as the θcr value. The reference transportation rate was thought to reflect Flowing levels just great sufficiently start mobilizing silt from the bed surface. Mountain streams have been known for their diverse particle size distribution, which includes regions of finer, more mobile silt and massive, more stationary rocks stacked in cascades or steps. Fine sediments may be mobilized by annual snowmelt and stormFlowings, whereas boulders have been moved in occasional, greater floods or debris

Flowings. The huge, comparatively stationary granules cause turbulence and interrupt the Flowing. Many scholars have investigated the influence of environmental and hydrological factors on the amount of sediments loading. Sediments Flowing in irrigation canals has been the subject of several studies in Iraq. Salah, et al., [14] documented and examined the sediments distribution in the Musayib project channel; Al–Delewy [15] investigated the variables influencing the onset of sediments transport in the channels of irrigation and their relationship to the Shields chart. The association between sediments particle size and bed loading on the irrigation channels' bottom is clarified in [16]. The influence of sediments particle size and movement on the sediments loading volume in the channels of irrigation has been characterized in certain research [17]. In [18], they performed thorough research on the impact of hydraulic factors including sediments grain diameter and bed shear stress on bed sediments loading calculation, as well as the impact of sediments grain's shape factor, Flowing velocity, and sediments reference concentration on suspended sediments load calculation. By investigating the non-dimensional assessment the turbulent energy rate to the Flowing depth in channels, and by having to prepare mathematical coefficients that involve these factors to determine the density of sediments loading, some of that investigations demonstrated the impact of Flowing energy dispersion on the sediments distribution. [19], [20] have developed statistical models and developing a model to study the sediments' distribution and movement, as well as the impacts of multiple factors including Flowing shear stress, settling velocity, and sediments grain diameter.

1.1. The aim and objective of the investigation

The current investigation goal is to observe whether the shields factor can be utilized to predict sediments Flowing. In addition to the investigation of relationships between the shields factor and other hydraulic factors of Flowing in these channels, the investigation also included the preparation of a suitable formula to describe the impact of utilizing this variable on determining the sediments discharge in the channels drainage and irrigation in Iraq. This research was being done in Iraq's Middle area, in drainage and irrigation systems.

2. Research methodology

2.1. Investigation zone

The current study is being place in Iraq's central area. The research region is between 32 and 33 degrees north latitude and 44 to 45 degrees east longitude (Figure 1). Because the study region is described by sedimentary soil with a diverse range of hydraulic requirements and water resources, it was selected for this investigation. And Table 1. demonstrates the details of channels in each of selected locations such as Bottom width, Mean depth, Area of section, Channel slope, and Hydraulic radius.

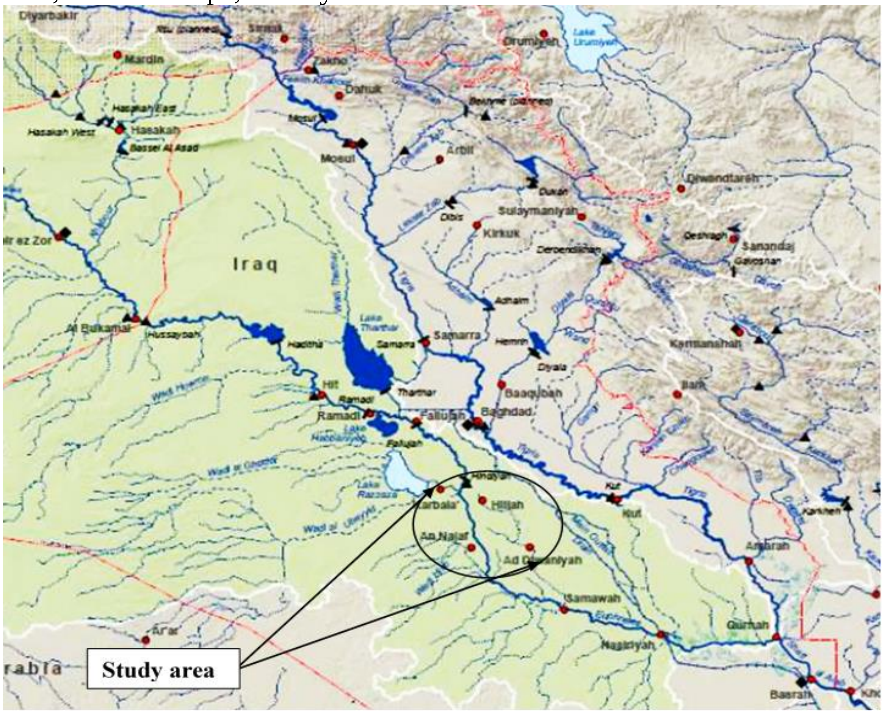

Figure 1. The investigation Zone in the middle of Iraq

Table 1. Channels Details

Channel Type	Channel name	Bottom width, B (m)	Mean depth, d (m)	Area of section, A (m2)	Channel slope, S (cm/Km)	Hydraulic radius, R (m)
Irrigation	Al-Mahaweel	10.5	1.55	18.67	15	1.255
	Al-Nile	4.5	1.1	6.16	18	0.809
	Babil	6.4	1.3	10.01	12	0.993
	Al-Ameer	6.7	1.7	14.28	17	1.24
	Al-Musaib Project	19.47	2.88	64.36	13	2.289
	Al-Musaib Project 2	19.26	2.33	50.3	14	1.945
	Al-Musaib Project 3	18.9	1.8	37.26	15	1.553
	Shatt Al_Hilla	48	6.78	325.41	8	5.286
Drainage	Yosifiya	20	4.973	107.709	10	2.550
	Yosifiya 2	20	4.747	124.919	10	3.03
	Mahmoodiya	20.5	4.329	109.212	10	2.74
	Mahmoodiya2	20.5	4.976	144.935	9	3.39
	Sowira	20.8	4.211	119.185	8	3.312
	Sowira 2	20.8	6.298	168.223	8	3.866
	Km 360	21.2	6.5	222.3	7	4.422
	Km 398	20.4	5	139.5	9	3.63

2.2. Shields factor mathematical model

The Shields factor, also known as the Shields criteria or Shields number, is a nondimensional number utilized to determine when sediments begins to move in a fluid Flowing. It's a nondimensionalization of a shear stress that's usually written as τ∗ or θ. Albert F. Shields created this factor, which is known as the later Shields factor. The Shields formula's major factor is the Shields factor. It is provided by [21].

$$\tau_* = \theta = \frac{\tau}{(\rho_s - \rho)gD} \qquad (1)$$

whereas: τ is a shear stress dimensional;
ρ is the sediment's density;
ρs is the fluid's density of the;
g is gravity acceleration;
D is a sediment's particle diameter.

The Shields chart is still the most often utilized criteria for sediments incipient motion. Nevertheless, because of its implicit nature, applications are cumbersome. This technical note creates an explicit description of the Shields chart by employing Guo's logarithmic matching approach twice, allowing the essential Shields factor to be computed directly from sediments and fluids properties without resorting to any error and trial process or iteration. The logarithmic matching algorithm is utilized in a more advanced way in this example [22].

For no motion $\tau < \tau_{cr}$ (2)
For bed load transport $\tau_{cr} \le \tau \le \bar{\tau}_{cr}$ (3)
For bed and suspended loads transport $\tau > \bar{\tau}_{cr}$ (4)

Whereas: bed shear stress is τ, critically shear stress for initial grain movement is τ_{cr}, critically shear stress for initial suspended grain is $\bar{\tau}_{cr}$.

The Shields chart depicts the association between the critical Shields factor and the hydraulic characteristics of the Flowing at the channel's bottom that are given in sediments particle Reynolds numbers. The particles' Reynolds number is determined by the shear velocity magnitudes and the particles' diameter. Once the movement Shields factor magnitude exceeds a critical Shields factor, the sediments grain begins to move, as demonstrated in the following formulas:

$$\theta_{cr} = \frac{U_{*cr}^2}{(s-1)*g*d_{50}} = \frac{\tau_{cr}}{(s-1)*\rho*g*d_{50}} \qquad (5)$$

$$\mathrm{Re}_* = \frac{U_{*cr}*d_{50}}{v} \qquad (6)$$

$$\theta = \frac{U_*^2}{(s-1)*g*d_{50}} = \frac{\tau}{(s-1)*\rho*g*d_{50}} \text{ with } U_* = \sqrt{gRS} \qquad (7)$$

$$U_* > U_{*\mathrm{cr}} \qquad (8)$$

$$\tau_b > \tau_{bcr} \text{ with } \tau_{bcr} = \rho * U_{*\mathrm{cr}} \qquad (9)$$

$$\theta > \theta_{cr} \text{ with } \theta_{cr} = \frac{U_{*cr}^2}{(s-1)*g*d_{50}} \qquad (10)$$

Whereas: Shields factor for non-dimensional movement is θ, Shields" factor for non-dimensional critically movement is θ_{cr}, non-dimensional grain Reynolds number is Re_*, shear velocity is U_* m/s, critically shear velocity is $U_{*\mathrm{cr}}$ m/s, shear stress is τ N/m2, critically shear stress τ_{cr} n/m2, kinematics viscosity is v m2/s, average grain diameter is d_{50} (m). Therefore, the next formulas have been considered as a mathematically model to describe the beginning of the sediments movement.

Actually, [23] observed that the inclusion of $U_{*\mathrm{cr}}$ in both axes of the shields chart makes it impossible to implement. As a result, Madsen devised a new factor to replace Reynolds number in the horizontally plane of the diagram, as seen in (Figure 2). This graph shows the relationship between the critical shields factor in the Y-axis and a new factor in the X-axis, the sediments-fluid factor S_*. The following formula yields the S_* magnitude.

$$S_* = \frac{d_{50}}{4v}\sqrt{(s-1)gd_{50}} \qquad (11)$$

S_* magnitude is calculated using this method. Utilizing (Figure 2), the estimated magnitude was utilized to measure the critical Shields factor θ_{cr} amount that will aid in defining particle movements velocity and the potential of particle deposition at the Flowing cross-section.

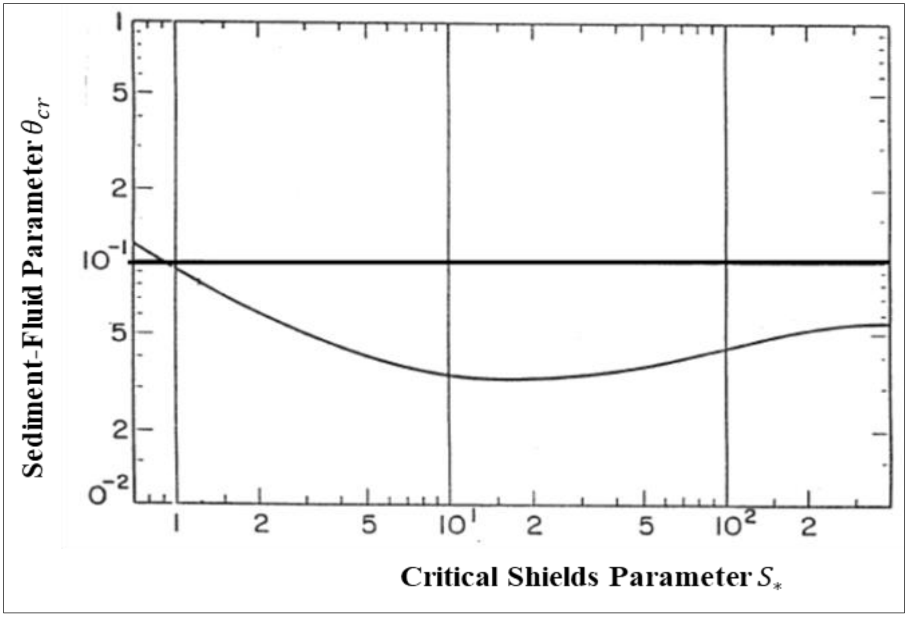

Figure 2. Relationship Between the Sediments-Fluid factor θ_{cr} and Critical Shields factor S_*

3. Fields works

Based on seasonal fluctuation of the data, fields research was conducted in the middle area of Iraq in several channels of drainage and irrigation over 36 months from January 2015 to January 2018. Various river discharge amounts and hydraulic properties distinguish these channels. The Shatt al-Hilla, Musayib project channel, tiny irrigated channels branch from the Shatt al-Hilla, and different spots on the major drainage channel Al-Masab Al-Aaam were chosen for this research, as indicated in (Figure 1).

3.1. Flowing discharge in drainage and irrigation channel

On the selected channels, Flowing discharge measurements were made utilizing a current meter measurements to determine the Flowing velocity. To complete the testing job, one location has been chosen in each channel. This location must be defined by the appropriate criteria in order to provide a good overall picture of the hydraulic characteristics for every channel. Flowing velocity may be calculated using current meter data by multiplying this number by the cross sectional area, and the result could be utilized to calculate the whole discharge within every channel or drainage system.

3.2. Analysis of soil size in drainage and irrigation channel

Soil specimens were taken from the investigated area's channels and drains. In each cross-section, three specimens have been taken. A specimen is collected from the cross-sectional area’ss centre, while the others are obtained from either side. The three specimens were taken in order to acquire an accurate distribution of sediments particles. The distribution of sediments grains have been investigated using a categorization system depending on the soil grains size. The research also identified the requirements needed to compute the sediments discharge volume.

3.3. Amount of sedimentation in channels of drainage and irrigation

Utilizing a device bottle kind specialized for that purpose, many water specimens have been obtained to measure silt content. The conventional procedure for calculations was utilized, and the cross section has been split into multiple pieces. Specimens have been obtained at various depths in the water, and one specimen was chosen for every Flowing discharge. For certain channels, two specimens have been acquired for the testing to account for seasonal differences in data investigation over the winter and summer seasons. The sediments amount at every testing site is computed by multiplying the amount magnitude of every segment by its area and after that obtaining the results. The sediments amount rate of every quantity discharge per site at each channel has been determined by dividing the collection result by the entire area of cross section. The ppm unit of measurement has been utilized to measure amount. Table 2 shows the silt amounts in the water channels**.**

Table 2. Sediments grains properties

Channel name	**Sediments Concentration ppm**	**Particle Diameter (mm)**		
		d35	d50	d65
Al-Mahaweel	185	0.078	0.115	0.21
Al-Nile	182	0.069	0.1	0.195
Babil	168	0.063	0.095	0.19
Al-Ameer	181	0.078	0.115	0.21
Al-Musaib Project	172	0.060	0.091	0.186
Al-Musaib Project 2	184	0.052	0.081	0.152
Al-Musaib Project 3	197	0.028	0.062	0.097
Shatt Al_Hilla	202	0.073	0.12	0.31
Yosifiya	231	0.085	0.152	0.286
Yosifiya 2	277	0.11	0.214	0.339
Mahmoodiya	286	0.098	0.218	0.335
Mahmoodiya2	317	0.126	0.236	0.36
Sowira	304	0.1	0.211	0.336
Sowira 2	339	0.142	0.242	0.383
Km 360	388	0.148	0.244	0.385
Km 398	326	0.1	0.206	0.33

4. Field works results and analysis

4.1. Bed channels’ requirements and soil texture

The findings of soil particle size that are reported in Table 2, reveal that particle diameter sizes are converging. The soil texture seems to have been silty sand with a minor amount of clay, according to the soil categorization. Soil specimens had specific gravity values ranging from 2.66-2.73. The Percentage fine soil particles-size was ranged (d65=0.0097-0.0385 cm, d50=0.0062-0.0237 cm, d35=0.0028-0.0148 cm, according to soil analysis. Furthermore, soil categorization revealed an increase in the width of soil particles in drainage channels when comparing to irrigation channels. This is due to drainage water carrying various chemical pollutants and agricultural land soil erosion.

4.2. Shields factor as a determinant for sediments movement

In irrigation channels, their magnitudes varied from (2.976 -7.680), whereas in drainage channels, they ranged from (7.600 to 13.420). The findings have been shown that sediments movement occurs in the hydraulic transitional Flowing (500 ≥ Re ≥2), implying that the sediments particle size thickness seems to be the similar to that of the viscous sub Flowing layer, resulting in critical Shields factor magnitudes close to 0.032 (min limitation), which agrees with the result obtained by critical Shields factor magnitudes close to 0.032 (min limitation) [18]. The findings in (Figure 3) revealed that the protective factor magnitudes (θ) of sediments movement have been bigger than the critical magnitudes of the (θcr) placed inside the transmission, and sediments migrated down the channels' length with little influence on the Flowing quantity. Moreover, (θ) magnitudes in the irrigation canals were nearly 10 times larger than (θcr) as shown in Figure 4. The Shatt al Hilla canal was the exception, with shield factor magnitudes of 26 times in channels of irrigation and 19 times in channels of drainage. As a result of these findings, the sediments load seems to be in movement and transitioning thru the Flowing channels' section, implying that the channels' cross-sections had to change as a results of sedimentation and erosion processes in accordance with the hydraulic conditions of the channels, implying that these channels will indeed require more frequent maintenance to maintain Flowing requirements.

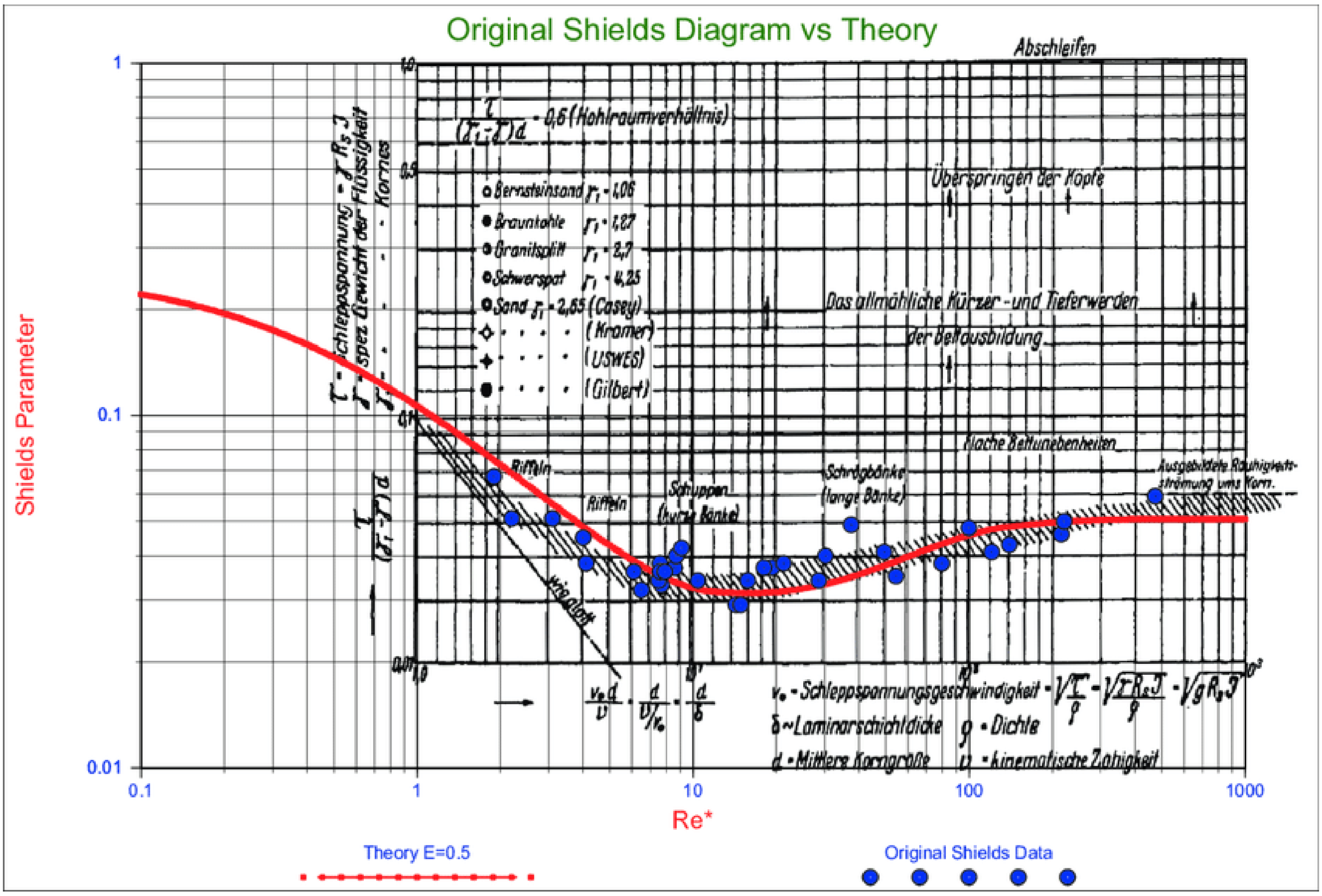

Figure 3. Comparison between the Location of θ Magnitudes with θ_{cr} in Shields Chart

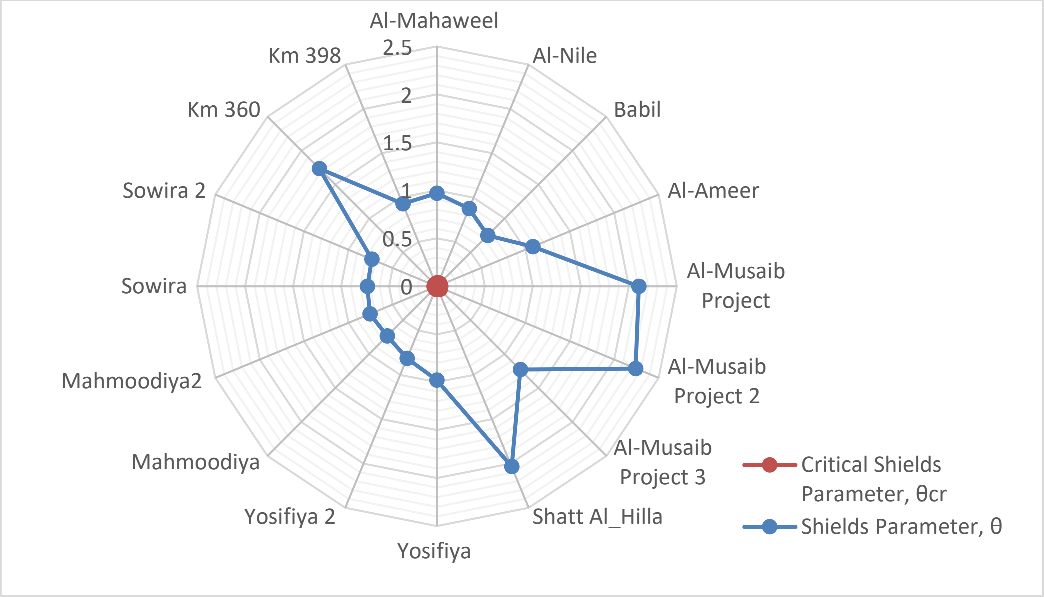

Figure 4. The differences Between θ and θcr magnitudes for various Locations

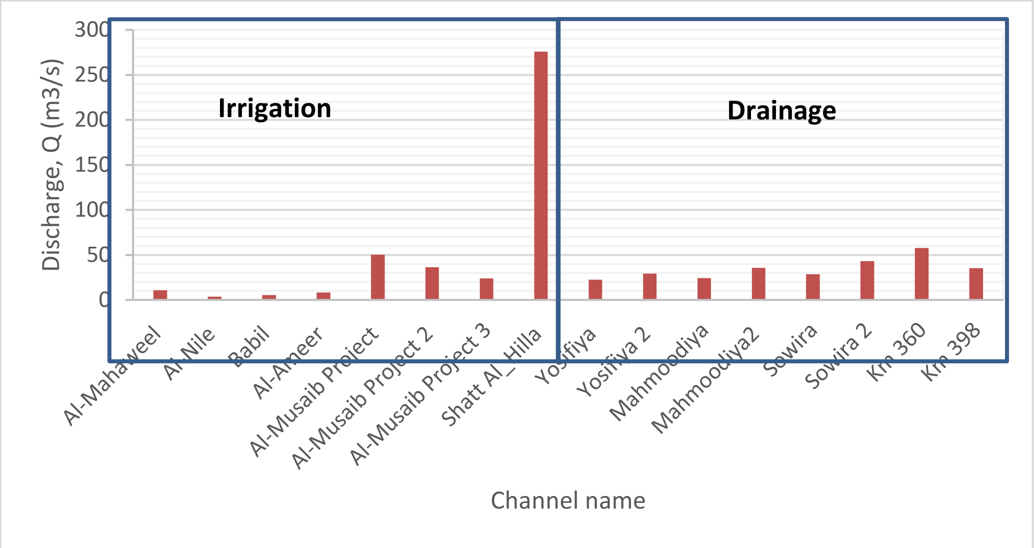

Figure 5. The differences Between Drainage and Irrigation Discharges for various Locations

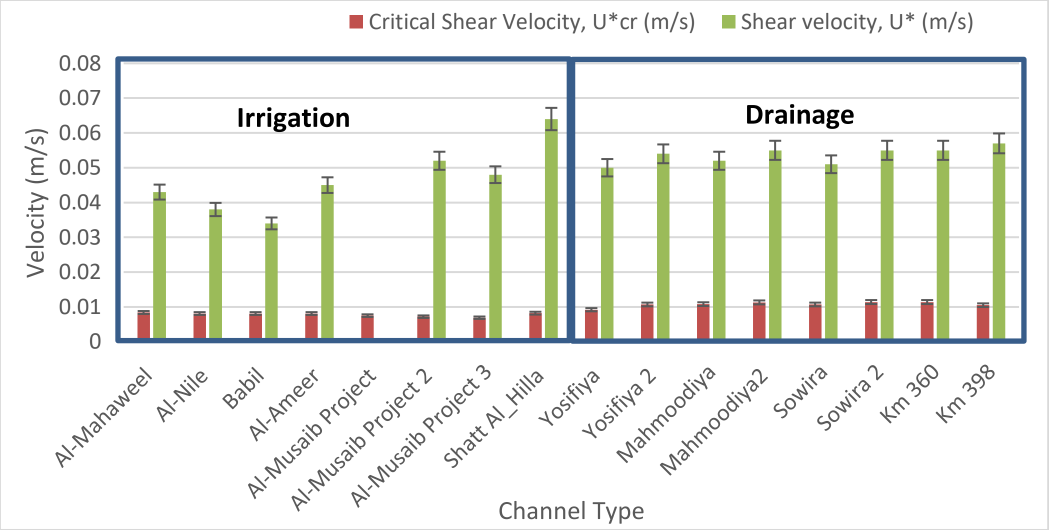

Figure 6. The differences Between Drainage and Irrigation Velocity for various Locations

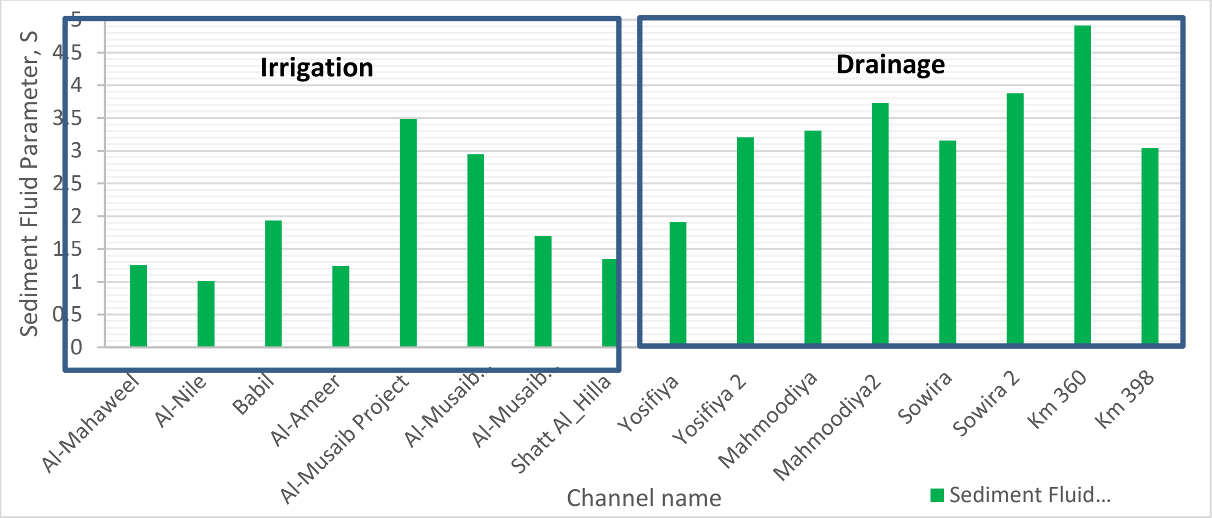

Figure 7. The differences between Drainage and Irrigation Sediments Fluid Factor for various Locations

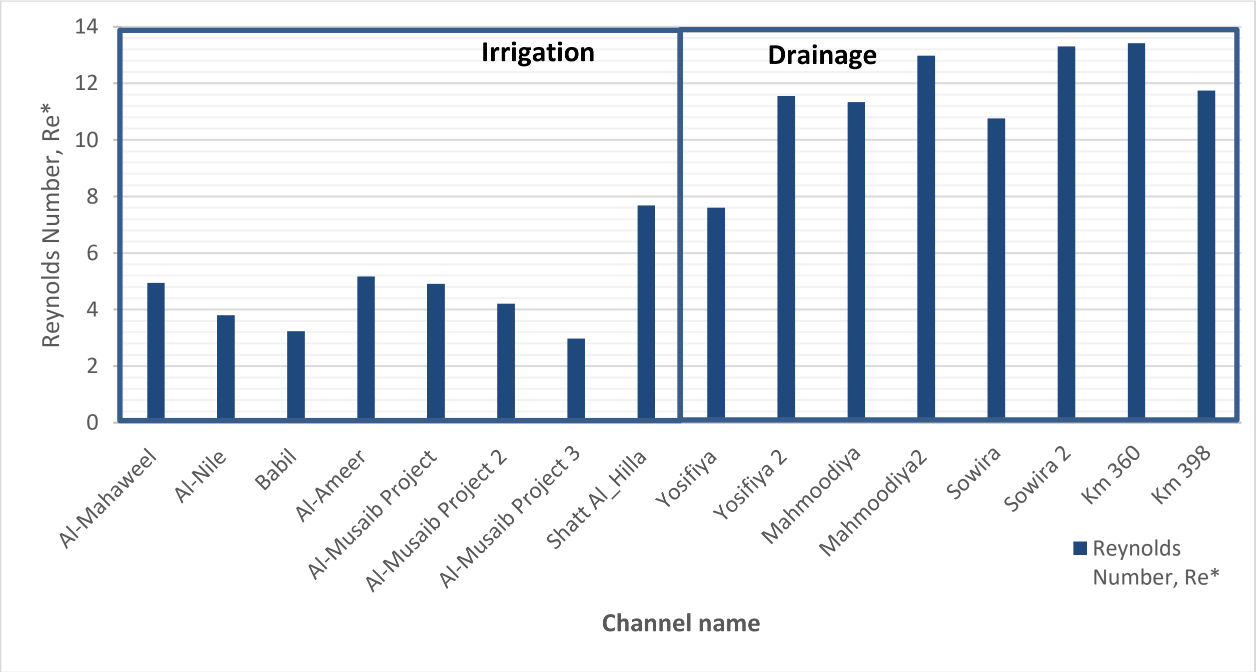

Figure 8. The differences Between Drainage and Irrigation Reynolds Number for various Locations

4.3. Impact of shields factor magnitude on the sediments discharge

In this work, an association was established between the Shields factor and the sediments' fields discharge in channels of drainage and irrigation. Utilizing the Shields factor as a primary factor, a logarithm formula was already established to predict sediments discharge. This formula provides a good correlation coefficient magnitude between 2 factors (θcr) & (Qs/(ρs ((s-1) g d3)0.5), which is around 0.9007 for channels of irrigation and 0.6444 for channels of drainage as shown in Figure 9. The following are the logarithm formulas:

$$\theta_{cr} = 0.3783 \ln\left(\frac{Q_s}{\rho_s\sqrt{(s-1)gd^3}}\right) + 2.2732 \qquad (12)$$

By simplifying Eq. 12

$$\frac{Q_s}{\rho_s\sqrt{(s-1)gd^3}} = e^{\frac{\theta_{cr}-2.2732}{0.3783}} \qquad (13)$$

For the irrigation channels Eq. 13 will be as following:

$$Q_s = 2.46 * 10^{-3} \rho_s e^{2.64\theta_{cr}} \sqrt{(s-1)gd^3} \qquad (14)$$

The logarithms formula for drainage in channels were deriving as following:

$$\theta_{cr} = 0.2681\ln\left(\frac{Q_s}{\rho_s\sqrt{(s-1)gd^3}}\right) + 1.4089 \qquad (15)$$

By simplifying Eq. 15

$$\frac{Q_s}{\rho_s\sqrt{(s-1)gd^3}} = \frac{\theta_{cr}-1.4089}{e^{0.2681}} \qquad (16)$$

In order to use Eq. 16 for the drainage channels will be as following:

$$Q_s = 5.2 * 10^{-3}\, \rho_s\, e^{3.73\theta_{cr}}\sqrt{(s-1)gd^3} \qquad (17)$$

Whereas:

Q_s: Sediments discharge Kg / s.m (m3/ s.m),

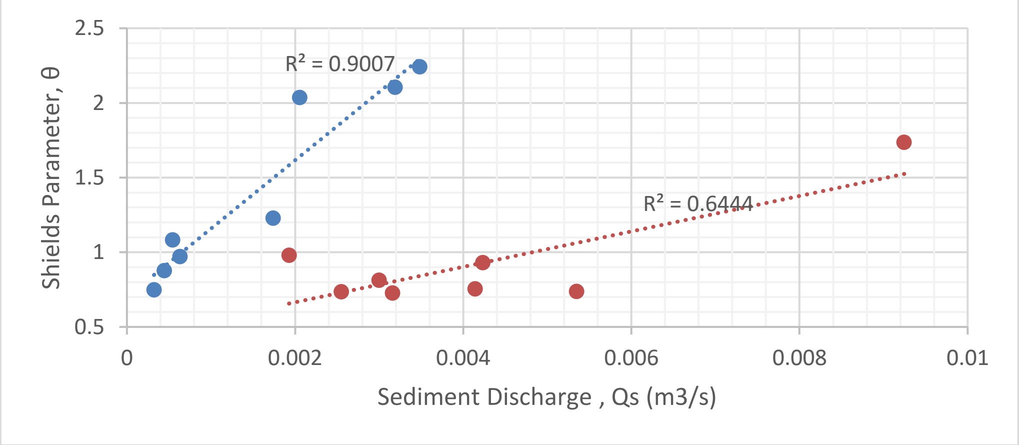

Figure 9. The Relationship between the Discharge and Shields Factor for the Sediments

All previous researches mainly concentrated on and explained the association between Shields factor and sediments movement in channels of irrigation, whereas current findings had also tried to explain the potential application of that association in drainage channels and irrigation channel interpretation. Because of the various mechanical requirements of the sediments and hydraulic factors of Flowing in drainage channels comparing to sediments condition and Flowing in irrigation channels, the findings demonstrated a limitation in applying this connection in these channels. As a result, a comprehensive research was conducted to illustrate the influence of the Shields factor on sediments transport and movement in drainage channels. Figure ten depicts the influence of the sediments-fluid factor (S*) on sediments discharge (Qs). With a correlation value of 0.7866 for Flowing in channels of irrigation and 0.6682 for Flowing in channels of drainage, a logarithmic connection appeared between these factors (S* and Qs). The examination of the relationships of factors in Figures 9 and 10 demonstrates the high level of confidence in the connection presented in Figure 9. It's because of the effect of interaction between the hydraulic factors of Flowing and the mechanical requirements of sediments particle on sediments discharge, while only the influence of sediments particle requirements emerges on sediments discharge in Figure (10) As a result, formulas (14 & 17) are utilized. More precision and trustworthiness in calculating sediments discharge in channels of drainage and irrigation, respectively. The correctness of such formulas in estimating sediments discharge is shown by their use in other channels.

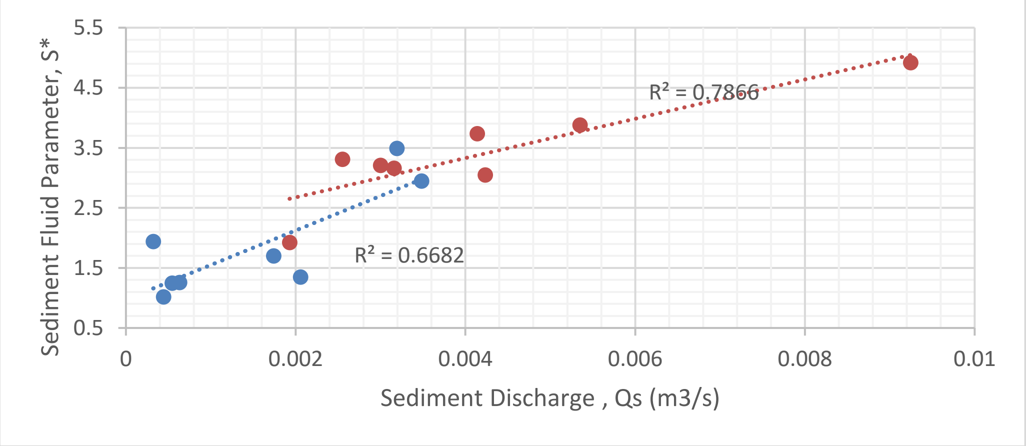

Figure 10. The Relationship between the Discharge and Fluid Factor for the Sediments

5. Conclusion

This study aimed to determine sediments movement utilizing this variable as a determinant, and it was conducted in channels of drainage and irrigation in middle areas of Iraq, obtaining the following results:

- The findings indicate that soil categorization relates to an increase in diameter of soil particle in channels of drainage as compared with irrigation channel locations, and soil texture seemed to be silty sand with a low clay rates that have specific gravity values ranging from 2.66-2.73.
- The transport of sediments in channels of drainage and irrigation occurs within the range of hydraulical transition Flowing ($500 \geq Re \geq 2$), which implies that the sediments particle size was uniform across all viscous Flowing sub-layers.
- In all of the analyzed channels, the shields factor magnitudes (θ) of sediments movement also seem to be bigger than the critical magnitudes of (θcr), and they are situated inside the transmission and movement region of sediments over the channels' length. In irrigation channels, the magnitudes of (θ) were generally 10 times larger than (θcr), while in drainage channels, they approximately 19 times more, and in the Shatt al Hilla, they were 26 times higher. Utilizing the Shields factor, two logarithmic formulas were devised to predict sediments discharge.
- In comparison to the state of Flowing and sediments in irrigation channels, the findings highlighted the inadequacy of the application of that association between shields factor and sediments transport in drainage channels.

6. Acknowledgement

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7. References

[1] A. J. Hussain and Z. S. Al-Khafaji, *Reduction of environmental pollution and improving the (Mechanical, physical and chemical characteristics) of contaminated clay soil by using of recycled oil*, J Adv Res Dyn Control Syst, (2020).

[2] Z. A. Hammood, Z. S. Al-Khafaji, and H. K. Al-Naely, *Evaluation the Water Quality for Water Bottles in Some Provinces in Iraq*, J Adv Res Dyn Control Syst, (2019).

[3] F. S. Abdulraheem, Z. S. Al-Khafaji, K. S. Hashim, M. Muradov, P. Kot, and A. A. Shubbar, *Natural filtration unit for removal of heavy metals from water*, in *IOP Conference Series: Materials Science and Engineering*, 2020.

[4] S. Al-Marri *et al.*, *Ultrasonic-Electrocoagulation method for nitrate removal from water*, in *IOP Conference Series: Materials Science and Engineering*, 2020.

[5] H. Al-Naely, Z. Al-Khafaji, and S. Khassaf, *Effect of opening holes on the hydraulic performance for crump weir*, Int J Eng, (2019).

[6] H. Al-Naely, A. Majdi, and Z. Al-Khafaji, *A study of the development of the traditional Crump Weir by Adding Opening Holes within the weir body*, (2019).

[7] Z. S. Al-Khafaji, Z. Al Masoodi, H. Jafer, A. Dulaimi, and W. Atherton, *The Effect Of Using Fluid Catalytic Cracking Catalyst Residue (FC3R)" As A Cement Replacement In Soft Soil Stabilisation*, Int J Civ Eng Technol Vol, (2018).

[8] Z. O. . Al-Masoodi, Z. Al-Khafaji;, H. M. Jafer;, A. Dulaimi;, and W. Atherton, *The effect of a high alumina silica waste material on the engineering properties of a cement-stabilised soft soil*, in *The 3rd BUiD Doctoral Research Conference*, 2017.

[9] Q. S. R. Marshdi, S. A. Hussien, B. M. Mareai, Z. S. Al-Khafaji, and A. A. Shubbar, *Applying of No-fines concretes as a porous concrete in different construction application*, Period Eng Nat Sci, (2021).

[10] E. J. Helley, *Field measurement of the initiation of large bed particle motion in Blue Creek near Klamath, California*. US Government Printing Office, 1969.

[11] R. K. Fahnestock, *Morphology and hydrology of a glacial stream--White River, Mount Rainier, Washington*. US Government Printing Office, 1963.

[12] J. M. Turowski, E. M. Yager, A. Badoux, D. Rickenmann, and P. Molnar, *The impact of exceptional events on erosion, bedload transport and channel stability in a step-pool channel*, Earth Surf Process Landforms, (2009).

[13] E. R. Mueller, J. Pitlick, and J. M. Nelson, *Variation in the reference Shields stress for bed load transport in gravel-bed streams and rivers*, Water Resour Res, (2005).

[14] E. A. M. Salah, T. A. Zaidan, and A. S. Al-Rawi, *Assessment of heavy metals pollution in the sediments of Euphrates River, Iraq*, J Water Resour Prot, (2012).

[15] A. Al–Delewy, *Computer aid for: All about the inception of sediment motion*, J Eng Dev AL Mustansiriya Univ Baghdad, Iraq, (2004).

[16] A. A. A. Al-Delewy, *The (d50) Criterion in Estimating the Bedload in Earthen Channels*, J Eng Sustain Dev, (2005).

[17] A. A. Ahmed, V. Vanaker, U. H. Ismael, and R. Al-Weslah, *Overview of sediment problems in Nile basin*. UNESCO, London, (2003).

[18] L. C. Van Rijn, *Simple general formulae for sand transport in rivers*, (2013), [Online]. Available: www.leovanrijn-sediment.com.

[19] K. Kheder, A. Ahmed, A. R. Ghumman, H. N. Hashmi, and M. Ashraf, *Sediment transport investigations using three dimensional numerical modeling in a large Canal: Marala Ravi Link Canal (Pakistan)*, Int J Sci &Engineering Res, (2014).

[20] I. S. Osman, B. Schultz, F. X. Suryadi, Y. Mohamed, and A. K. Osman, *Improving the operation and maintenance for better sediment and water management in Gezira Scheme, Sudan*, in *Proceedings of the ICID 21st International Congress on Irrigation and Drainage, Tehran, Iran, 15-23 October, 2011*, 2011.

[21] A. Shields, *Application of similarity principles and turbulence research to bed-load movement*, (1936).

[22] Z. Cao, G. Pender, and J. Meng, *Explicit formulation of the Shields diagram for incipient motion of sediment*, J Hydraul Eng, (2006).

[23] O. S. Madsen, *Sediment transport on the shelf*, Lect Notes Ralph M Parsons Lab Water Resour Hydrodyn Dep Civ Eng Massachusetts Inst Technol Cambridge, USA, (1993).