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Quantitative Evaluation to the Sediment Load at a Part of Euphrate River in Center of Iraq

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ABSTRACT

Estimates sediment transport in Iraqi Rivers are essential for effective rivers management, particularly when delivery rates is potential threat to environment and ecological systems. Therefore, this research was performed for estimating sediment transport rates in a certain reach from Euphrates River downstream Al Hindiyah Barrage and examine the stat of Entrainment Rate Esi of bed sediments under a unsteady stream flow. In spite of complexity and the difficulty of conducting measurements, the sediment load were measured with satisfactory perfection to achieve acceptable results for monitoring this river reach. The acoustic Doppler current profiler (ADCP) technique were used to measure velocity distribution, cross section profiles, and using (Helley-Smith) sampler to collect bed load samples from twenty cross sections downstream Al Hindiya Barrage. The investigation of suspended sediment concentration in vertical profiles has consisted of using an Entrainment rate relation (Esi), also for evaluating materials concentration near the bed and the upward, the vertical distribution of material particles was examine in the water column. The measurement results are clarified that there are many regions of river covered with high sedimentation, but the suspended load is prevalent mode of transport with average value 97.313%. The observed suspended sediment yield in the river reach was ranged from 386.645 ton/day to 6588.58 ton/day during the drought condition and low level of water discharge and may change with discharge change. While bed load yield ranged between 0.270 ton/day to 5.394 ton/day. The investigation is represented a non-equilibrium condition in sediment transport is prevalent circumstance in channel system. It is tested the relation of Ei against limited grain-sizes data and skin shear velocity U*skin then analyzed the regression. The result is shown that near-bed entrainment, evaluated at 15% of the flow depth, decreases with the ratio of settling velocity to skin-friction shear velocity due to its role in determining bed load-layer concentrations. The fit relation for R2 = 0.48 and correlation r = -0.55 are shown that outstanding an association between maximal flow resistance and sediment diffusivities, this is probably because bed-form prompt by turbulence flow which caused nonlinear dependence.

Keywords: Euphrates river, entrainment rate, sediment transport, skin-shear velocity, particle Reynolds number.

INTRODUCTION

Most of rivers transported sediment with their streams periodically or ultimately, and then deposit materials in river bed or floodplains for creating new formation to riparian lands (Cheng, 2016; Hughes and Croke, 2011).Typically, the suspension materials that transported with running water is played a decisive role in river dynamic system where sediment can identify lowlands and builds landscapes (Bettes 2008; Khullar et al., 2010). In another view, the natural sediment that locally eroded from the bed and riverbanks and transport by stream power can increase sedimentations in downstream regions by increasing bed load availability (Diplas, et al., 2008).The change in morphology of fluvial river is as a result of complex interaction between series of physical processes such as; sediment transport, flow variation, and bed deformation (Cheng, 2016; Simon, 2006; Gorczyca et al., 2020) Therefor, estimating sediment transport from field investigation are essential for constructing significant view for effective management strategies (Rickenmann, and Recking 201; Mays, 2010).

In this context, Euphrates River is one of the main rivers in Iraq, and availability of sediment defines its stability, formation, and the ecological system (Al-Ansari et al., 2018).Sediment processes are caused serious variation in hydraulic, and morphologic river regime due to fluctuation in flood and drought series which create more deterioration in spite of maintenance process have been improved and lay into practice (Salih et al., 2020).

Some of notable problems of sediment conditions in Euphrates river are recognized by a change in river regime and the stability, a large variable in flow rate, and sequence of animated and fixed beds. Also, the risk of increasing sedimentation leads of build up more bars and islands and more bend and meanders (Sissakian et al., 2018). In view of this crisis, a lot of studies have outlined the reasons of morphological evolution to some sections of rivers as a response to the sediment transport process. The evaluation has predominantly has been based on one or two indicators. The literatures have displayed the disturbances in discharge and sedimentation rates are complicated and are not fully understood. This is because reiterating of sediment transporting has affected by many factors some of which are extremely complex and can affect river regime (Khassaf and Al-Rahman, 2005; Sulaiman et al., 2021). But No field survey or bathymetry survey supported by Satellite images is performed for Euphrates river in center of Iraq to identify sources of sediment issues or other factors which can stimulate of building a disturbance the inner and outer of banks, as well as caused dissimilarity of cross-sections along river watercourse. So, the aim of this study is quantified the sediment rate that transported in a section of Euphrates river which could effect river regime from the shape, direction, and depths of flow, and evaluated a distribution of suspended load in each water column of studied cross -section. Besides investigate how can the magnitude of hydraulic forces effective on river bed by calculating whether Entrainment rate (Esi) in the bed for different size fractions have related with fluid forces acting on them. Achievement of the study aim requires of conducting assessment field survey to identify and evaluate the characteristics of sediment and their spatial distribution along the study reach. This could help to construct appropriate view to the river behavior under specific conditions, or how can hydrological condition as results of disturbances in drought and flood events can effect hydrodinamic characteristics.

SITE DESCRIPTION

The river reach is a part of a mainstream of Euphrates River in center of Iraq. The reach is started with about 554 m downstream Al Hindiyah Barrage from site 605 + 550 km and end at site 630 + 00 km downstream Karbala water intake project. The riparian area is conceived to be one of the main region of the sedimentary alluvial plain that Euphrates River flow through (Al-Mimar et al., 2018; Najm et al., 2020) as illustrated in (Figure 1). location was chosen because of; 1) the critical effect of Al Hindiyah Barrage, 2) continuous erosion and sedimentation process, and 3) points bars and islands were considered one of the manifestations formative within the stream. The imbalance of river activity from one region to another led to disparity in the shapes, areas and lengths of sedimentations. The river is feeding with sediment from upstream natural sources at flooding periods (e.g hill slope, gullies and tributaries). It has contributed of increase sediment yield and suspension yield as a differ in geological pattern of Euphrates river between upstream and downstream. The soil erosion mainly took place on the plateaus slope and sediment accumulated in river (Al-Ansari et al., 2019; Sulaiman et al., 2019a.). This significantly relative with the considerable contribution of surrounding watershed area,and specified proportion of gullies with absence of vegetation cover in most around drainage areas (Al-Ansari, et al., 1988; Afan, et al., 2016).The high eroded of sediment from the major tributaries each year can be associated with rainfall by erosion of agricultural and urban land or erosion of channel (Afan, et al., 2016).

FIELD SAMPLING

A fieldwork was performed between Sep 2022 to Dec 2022 to collect data from 20 cross-sections along the study river reach. Most locations of samples were identified where there are obvious problems in these sites. The samples are collected where human activities can expedite and decelerate entire sediment to stream flow or invert the natural

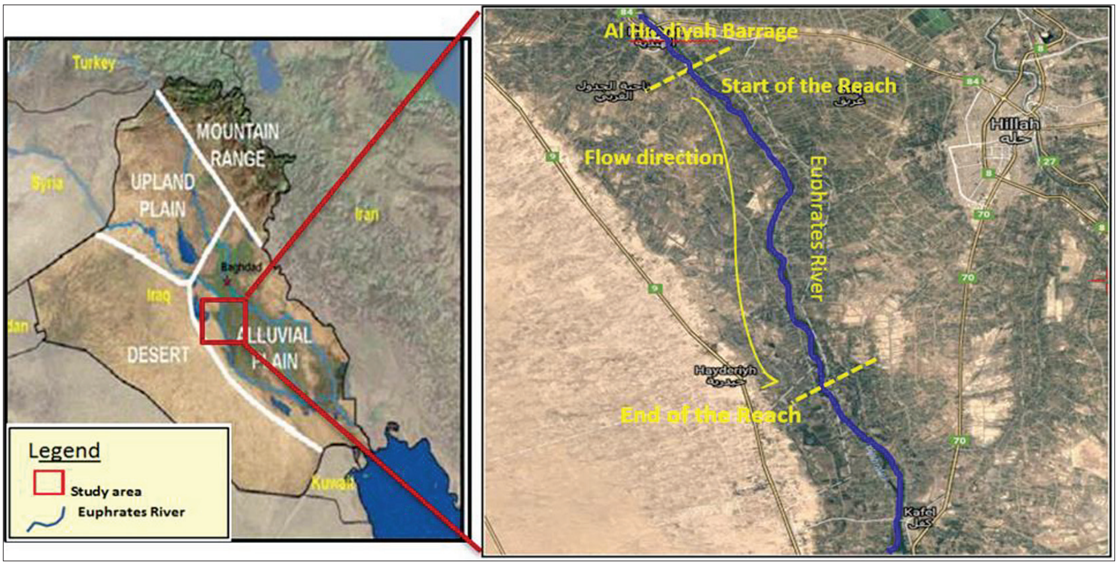

Figure 1. Map of Iraq (left), and the location of the reach along Euphrates River (right) (Landsat Image Google Earth)

behavior of dynamic stream boundary system around study area such as: banks cavity, steep banks, falling banks, alternative bars, native vegetation, aggradation and degradation of channel,agriculture farms and urban areas, which produce sediments, and the change in channel width deposits are prominent as a source. The distribution of cross-sections through studied river reach are shown in (Figure 2). The work consisted several campaigns with using some tools and devices to collect samples from each cross section, besides provided some maps, aerial photographs, and used Google earth technique. These data are included measuring suspended load, bed load, flow velocity, water temperature, depth and width of river. Then, laboratory tests have performed for material analysis. The ADCP surveyor device positioning has done by using kinematic GPS, the both have contact a laptop to register the data by a software system. Suspended load and ground load estimates were obtained using the following methods.

Suspended load

Sediment sampling was conducted by consider as much as possible coordinates are identical with each cross-section to reduce the possible imprecision in measurement. The GPS-72 has used to localize sampling points and check the distance has taken during leveling method. In field sampling, it collected with about 164 samples of suspended load and to minimize the error of measurements, these samples mixed carefully to get homogenous samples to be ready for testing in laboratory. The suspension material is measured as two types, the total suspended solids (TSS), and suspended sediment concentration (SSC), which are differ in methods of measuring. The first type of mesuring technique is using Grabbing-bottle method which samples bring out by dipping a bottle into the river when water levels approaching low current (Collins and Walling, 2004). The bottle sampler shown in (Figure 4) as especially designed to obtain required samples in each site at low level of water, where suspended sediment is uniformly distributed along the vertical and horizontal planes are fine < 0.063 mm. This technique is applicable in any situation by using small boat, or using nearest bridge for sampling or by using wading. The sampler contains of one liter a plastic bottle with an inlet nozzle of 8 mm in diameter to inlet water, and 5 mm diameter as air outlet with plastic tube and a valve to dominate the entering (water sediment) mixture into the grab bottole, it has a metal body for weight encloses plastic bottle for retaining the sample. The system of sampling begins by lowering the sampler in the water to reach needed depth and keeping the nozzle closed by locked the tube outlet. The process contiued untile the water enters the bottle, then the nozzle opened for the air inside the bottle start to run away by the tube and the water entering to the bottle from other plastic tube. When the bottle is filled with water the sampler drag out of the river. This method is used at any distance from water surface column from 10–15 cm of the bed.

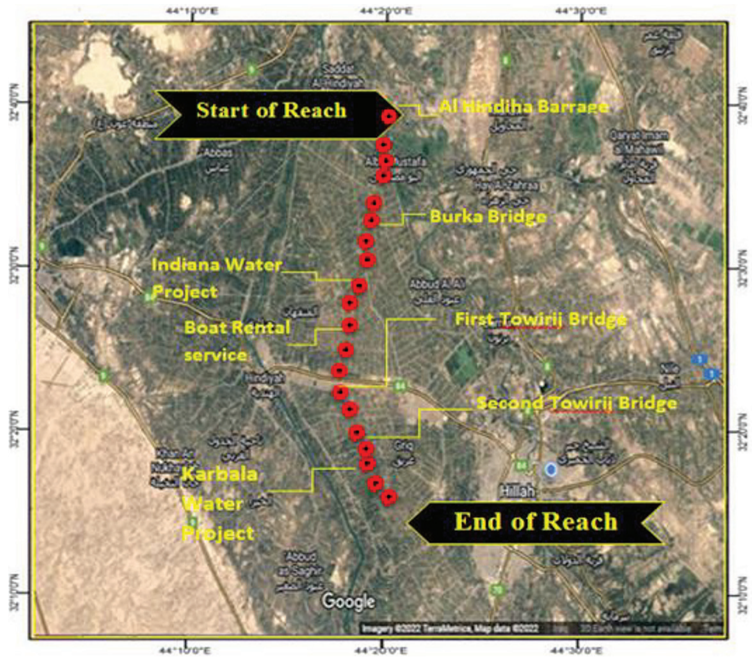

Figure 2. Locations of sediment sampling cross-sections along river reach

The location of each sampling point in lateral distance were chosen at distances (1/4 W, ½ W and ¾ W) of width of channel W at each cross section is represented in (Figure 3) considered from left to right bank. At each point, two to three samples were taken vertically at three locations 0.2 D, 0.6 D and 0.8 D, where D is the depth of water column (Figure 3). The hydraulic measurements for suspended sediment concentration were carried out by different methods based on each cross section, type of sediment transported and depth of water (Ali, and Dey, 2017a).

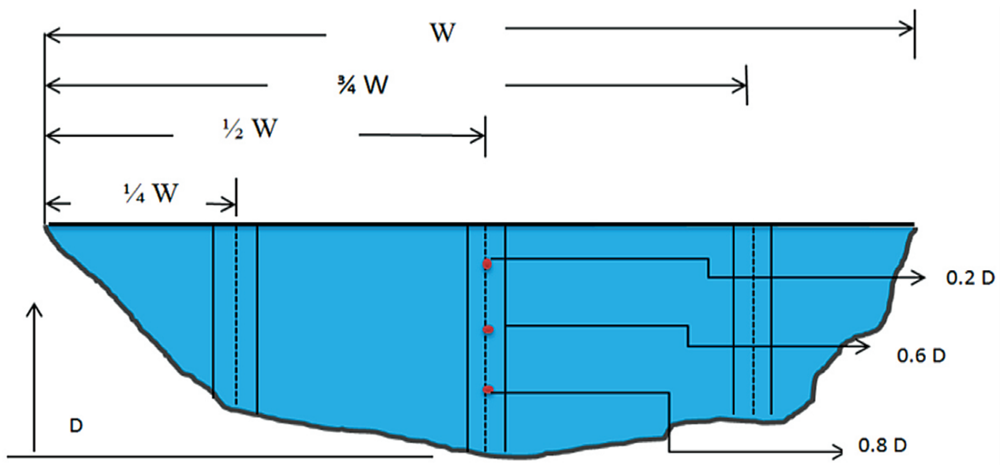

Figure 3. Diagram of sampling points longitudinally and vertically distance

Figure 4. Sampling devices to measure suspended load

If there is a difficulty in sampling in some sites because high current of flow and sediment, another sampler is used, the (US-AP 63) devices is used to collect suspended sediment at vertical profiles in deep and large width (Figure 4). The sampler was guide by a boat with a motorized and manual US-GS B-reel and provided with a valve and 48-volt battery connected to the B-reel that opened and closed when triggered. The sampler consist plastic bottle of 1 L capacity to collect water and sediment at time between 30 and 120 seconds according on the flow rate. This device is preferred apparatus when sampling deep rivers (i.e. > 4.5 m). After samples collection in the field, each of sediment sample was processed using traditional filtration method to obtain suspended-Sediment concentration according guide of (Interagency Committee on Water Resources, 1963). The collected samples were filtered in 47 mm of Whitman microfiber glass filters with opening size of 1.6 µm installing in filtration set to compute total sediment concentration. The filter papers are weighted before filtration, and after filtration, Its used a precise balance of 4 decimal digits of the gram to weight. The papers are dried for 15 min at 70 °C. Then the dried papers is snipped to the filter funnel and carefully wetted with distilled water. In graduated cylinder, a volume of 1000 ml of sample has measured and the cylinder washed out into the filter funnel with distilled water (Owens, 2005). It is accelerated the filtration rate by a vacuum pump linked with flask. After finishing filtration, the papers is dried and weighed again; the difference between two weights of papers divided by the volume of two weights gives the suspended sediment concentration.

Bed load

The bed load is directly measured using sampler designed as a copy to Van-Veen grab device of size 3.14 L with approximate weight roughly 5 kg used to extract bed load sediment (Figure 5). A Van-Veen grab sampler consists of two pails with two levers into their ends which are spread like an open scissor stay in an open situation until lowering sampler into water. After touching river bed to catch samples at measured time then brought up for weighting. The levers and pails are locked by pulling a lift cable and unlocked on hitting the ground. After collected many samples, they are mixed well to get homogenous samples and to reduce the error of measurements. Some processes of sampling is illustrated in (Figure 5).

The samples of bed load are taken according to the length of section for established different classes of grain sizes to the river bed. There are some obstacles and difficulties prevent to obtain samples for all channel length, thus samples of bed load are collected from the same cross sections those considered for sampling suspended load to conduct sizes analysis distribution.

In deep depths or when the level of water was rise, a direct traps sampler (Helley-Smith) device an identical as the pressure-difference samplers for bed load sampling (Figure 5). This device consist of frame, an open metal body 15.24 cmx 15.24 cm with intake through which water and sediment pass in. The sampler has an entrance nozzle with opening area 19 cm^2 and this area is expansion with ratio of exit with 1.40. The mesh bag to collect grains with 46 cm long is attached to the rear of the nozzle assembly with a rubber "O" ring. The sampler is usually constructed of stainless steel and aluminum, is equipped with tail fins. The sampler is connected with a steel cable or chain and reel to be lowered into river water. This sampler was used by lowering a cable from the bridge, because the work need for heavy efforts (e.g. first and second Tuwiraj Bridge, Hindiyah Bridge, etc). The extracted samples were individually conserved in class bowls, then they treated with 1 mL of 0.4 g/liter copper sulphate solution to minimize of organic material to growth. Then, they marked with a sticker including all information about the time, date and location then transported to the laboratory by box covering with ice to prevent of organic growth. Then the air dried, sieved, and weighed by size fractions.Finally, the bed and side materials were analyzed according to (ASTM D 854-92), where samples are dried in an oven under 70 °C for 48 hours. Then, its weighted for obtaining particles distribution which is carefully classed into a number of sizes. The soil is broken as small sizes as possible then sieving through a set of sieves meshes by a mechanical shaker. The data are varied in sizes, the size above > 0.074 mm has been determined by sieving analysis. The portion of the fine particles 0.075 mm to 0.0002 mm are later analyzed using the (Hydrometer-151H). The fine soil particles are scatter by saturated the soil in a dispersing agent, and by fast stirring to neutralize the change between the soil particles. this test is done depend on (ASTM D 422-63).

Figure 5. Sampling bed load material

ESTIMATING ENTRAINMENT RATE OF UNIFORM SEDIMENT

The dimensionless entrainment rate (ESi) of sediment from granular, loose beds materials to be shift up and away from prime stable balance situation. It has to be a activity of water forces acting on a river bed protect with soft sediment and the features of the bed material itself. From relationship obtained in the literature for estimating the entrainment rate of sediment into suspension case, the formula set down by Smith and McLean 1977 (Smith and Mc Lean 1977; Gray, et al., 2000. 24) executes better when tested set of data. In this work a formula to Smith and McLean is applied for available datasets of Euphrates river that had flow depth D, averaged flow velocity V, bed material grain-size ds channel bed slope S. A river dataset which supply a grain-size and the analysis was reflect only grain size coarser than 65.5 µm like sand particle. According Smith and McLean (1977) the evaluation for independent parameters from known dependencies with dimensionless entrainment rate has given by:

$$ESi = \frac{0.65\,\gamma_0\,S_0}{1+\gamma_0 S_0} \quad (1)$$

S_0 is a normalized shear stress given by:

$$S_0 = \frac{\tau*_{skin} - \tau*c}{\tau*c} \quad (2)$$

$$\tau*_{skin} = \frac{\tau_{skin}}{(ps-p)ds} \quad (3)$$

$$\tau_{skin} = \rho u*_{skin} \quad (4)$$

$$u*_{skin} = \sqrt{g\,HskS} \quad (5)$$

where: $Hsk = 2ds$, S is channel bed slope and; V_0 is a constant equal to 2.4×10^{-3}; the $\tau*c$ is calculated with Brownlie (1981) as following:

$$\tau*c = 0.22\ Rep\ \ 0.6 + 0.06 \times 10 - 7.7\ Rep - 0.6 \quad (6)$$

where: $\tau*c$ is a critical Shields stress associated with the initiation of sediment motion.

The particle Reynolds number (*Rep*), this factor may be also estimated with the skin-friction component of shear velocity $u*_{skin}$ as given below:

$$Rep_{skin} = \frac{u*_{skin}\ ds}{v} \quad (7)$$

The reference height is equal to $\alpha_0 \times \tau*skin - \tau*c \times ds + ks$, and $\alpha_0 = 26.3$, and *ks* is equal $2ds$ for uniform grain distribution.

RESULTS AND DISCUSSION

The data collected from field work to each cross section and main parameters computed are discussed as following.

Variation in velocities and flow rate

The impacting of dimensionless variables in selected sites are presented in (Table 1). The estimation is to be also suitable for bends and meanders, for bending section in river, averaged velocities at the outer side are found to be lower than inner side contrary to straight channels, they are varied between 0.48 m/s and 0.68 m/s. The higher velocity can deposit more coarser sediment while low velocity deposit fine sediment and more spatial variability in sediment transport and bed composition. Mean velocities in the bends sites is varied from 0.4 m/s at low flow in inner side to higher than 0.7 m/s in outer sides at high flows with an average 0.532 m/s and mean velocities at islands between 0.32–0.65 m/s such as right side bars at 615 + 00 km, 617 + 00 km, 618 + 00 km, and 620 + 850 km. As one transport from river center towards the river corners and reduction

Table 1. The hydraulic parameters of cross-sections along river reach

Id	Cross section	Cross section area A (m^2)	Top width WT (m)	Av. width of water W (m)	Velocity V (m/s)	Disch. Q (m^3/s)	Slope S	Max. water depth (m)	Av. water depth (m)
1	605+554 Sec. 1	712.953	189.393	122	0.700	499.317	0.0001524	4.192	2.540
	605+554 Sect. 2	453.256	139.446	88	0.631	286.053	0.0001073	5.137	3.160
2	606+00	678.237	258.715	123	0.602	407.960	0.0000617	4.430	1.943
3	606+540	804.317	171.979	132	0.556	447.120	0.0000660	4.900	2.663
4	607+00	529.075	115.305	92	0.501	265.067	0.0000461	3.990	2.816
5	609+860	610.749	124.896	112	0.611	372.984	0.0000696	5.769	4.813
6	612+620 Sec. 1	175.996	55.792	41	0.469	82.542	0.0000212	2.144	1.929
	612+620 Sec. 2	291.522	92.174	68	0.516	150.309	0.0000204	3.854	2.828
7	615+670 Sec. 1	87.971	37.773	17	0.465	40.932	0.0000940	2.725	1.625
	615+670 Sec. 2	158.274	82.052	61	0.577	91.249	0.0000113	4.465	3.112
8	616+500 Sec. 1	170.681	67.476	42	0.465	79.333	0.000199	3.200	1.963
	616+500 Sec. 2	282.190	100.245	46	0.557	157.293	0.0000239	4.900	3.643
9	619+400	521.152	167.609	100	0.513	267.455	0.0000139	4.650	3.022
10	620+550 Sec. 1	259.847	75.366	60	0.450	116.983	0.0000342	4.627	2.663
	620+550 Sec. 2	17.249	28.969	20	0.400	6.893	0.0000015	3.505	2.048
11	622+450	265.488	156.515	55	0.431	114.425	0.0000076	7.432	4.875
12	623+240	634.195	155.403	124	0.540	342.275	0.0000317	4.800	3.099
13	624+680	673.085	187.526	130	0.548	368.851	0.0000433	4.310	2.404
14	625+300	600.167	134.523	205	0.470	282.187	0.0000185	4.300	3.493
15	626+200	691.337	156.495	84	0.635	438.999	0.0000824	5.150	3.407
16	626+860 Sec. 1	253.871	81.213	32	0.650	165.016	0.0000209	3.450	1.522
	626+860 Sec. 2	105.255	82.87	45	0.664	69.889	0.0000126	3.450	1.989
17	627+140	1007.94	222.119	214	0.657	662.217	0.0001415	6.727	4.913
18	628+000	586.255	129.87	76	0.602	352.926	0.0000697	5.983	3.697
19	629+ 000 Sec .1	131.248	54.102	36	0.565	74.155	0.0000168	2.550	2.006
	629+ 000 Sec .2	416.230	77.96	61	0.603	251.086	0.0000535	5.750	4.878
20	630+100	548.837	132.419	102	0.546	299.665	0.0000467	4.928	2.897

Note: Al Hindiyah Barrage at distance 605 + 00 km from Iraqi border; some stations splits into two cross section 1 and 2 because bars and islands.

in velocity are considerable. A decline is notable at the area of radial space from center of curving channel, in both trends in the outer and inner. The rate of lowering is more fast to the low levels of flow than for higher levels of flow. It can also observe that the low velocity level take place at intersection between the outer side and the bed of main channel. The flow rate measurements during work period is non-uniform. AL Hindiyah Barrage diverts a discharge of an average 499.317 m^3/s. The data shows fluctuation in records and significant increase in some sites. whereas the average discharge rate is declined from 272.701 m $^3/s$ from site 605 + 554 km to site 630 + 00 km, while there is a sharp fell in discharge records between 611 + 00 km to 618+00 km. There is a sudden increase after site 623 + 240 km to be 662.217 m^3/s in site 627 + 140 km in Towirij Bridge. After this, the fluctuation in annual discharge data is continued with a significant fell trend in level of records compared to the last sites. The reason of fluctuation in hydraulic parameters that Euphrates River is passed through nature of lands differ in topography, many agricultural lands, several cities and towns,represents the main reason to alteration the rate of flow (Sissakian, 2018). The flow rate measurements during work period are non-uniform. AL Hindiyah Barrage diverts a discharge of an average 513 m^3/s. The data shows fluctuation in records and significant increase in some sites. It is important to refer to the bed load discharges Qb which combined with suspended sediment discharges Qs by summing of both sediment discharges at each cross-section to estimate the total sediment loads Q_T along study reach of Euphrates river as shown in Table 2.

The total load is computed as minimum value 387.355 ton/day congruous to discharge rate of

Table 2. Suspended, bed and total load along Euphrates River reach

Id	Cross section	Discharge Q m^3/s	Suspended conc. C_{ave} ppm	Suspended yield QS tons / day	Bed material Sb g/30 min	Bed load Qb ton/ day	Qb/QS %	Total load Qt ton / day
1	605+540 Sec. 1	499.317	152.722	6588.583	90.433	5.394	0.0819	6593.977
	605+540 Sec. 2	286.053	149.444	3693.518	67.680	2.973	0.0805	3696.491
2	606+00	407.962	146.333	5157.914	58.533	4.862	0.0943	5162.776
3	606+540	447.124	170.778	6597.342	42.694	2.313	0.0351	6599.655
4	607+000	265.067	111.556	2554.818	35.222	1.279	0.0501	2556.097
5	609+860	233.459	140.889	2841.846	27.889	1.097	0.0386	2842.943
6	612+620 Sec. 1	82.542	141.111	1006.353	35.583	0.625	0.0621	1006.978
	612+620 Sec. 2	150.309	143.167	1859.258	12.450	0.361	0.0194	1859.619
7	615+670 Sec .1	40.932	109.333	386.645	59.602	0.709	0.1834	387.354
	615+670 Sec. 2	91.249	139.567	1095.866	12.341	0.319	0.0291	1096.185
8	616+500 Sec. 1	79.333	114.112	782.148	78.916	1.677	0.2144	783.825
	616+500 Sec. 2	157.293	121.556	1651.951	40.34	1.274	0.0771	1653.225
9	619+400	267.455	93.556	2161.894	23.389	1.235	0.0571	2163.129
10	620+550 Sec. 1	116.983	110.067	1112.481	44.027	1.045	0.0939	1113.526
11	622+450	114.425	88.222	872.196	22.056	1.087	0.1118	873.283
12	623+240	342.275	145.639	4306.915	13.412	0.656	0.1246	4307.571
13	624+680	368.851	109.778	3498.474	22.933	1.289	0.0152	3499.763
14	625+300	282.187	102.88	2508.309	63.133	2.675	0.0368	2510.984
15	626+200	473.566	143.778	5882.824	12.944	0.638	0.1066	5883.462
16	626+860 Sec. 1	165.016	69.330	988.465	28.434	0.727	0.0108	989.192
	626+860 Sec. 2	69.889	70.111	423.362	10.343	0.27	0.0735	423.632
17	627+140	662.217	124.111	7101.081	11.439	0.789	0.0638	7101.87
18	628+00	352.926	124.111	3784.491	28.472	1.165	0.0111	3785.656
19	629+00 Sec. 1	74.155	115.663	736.805	53.243	0.907	0.0308	737.712
	629+00 Sec. 2	251.086	103.567	2234.463	50.561	1.241	0.1231	2235.704
20	630+100	299.665	105.556	2732.945	67.538	3.028	0.0555	2735.973

Note: Total suspended solid ishcomputedhfor onlyh in hydraulic structure sites 605+540 km, 623+240 km, 624+680 km, 626+200 km, 627+14 0km and 629+00 km

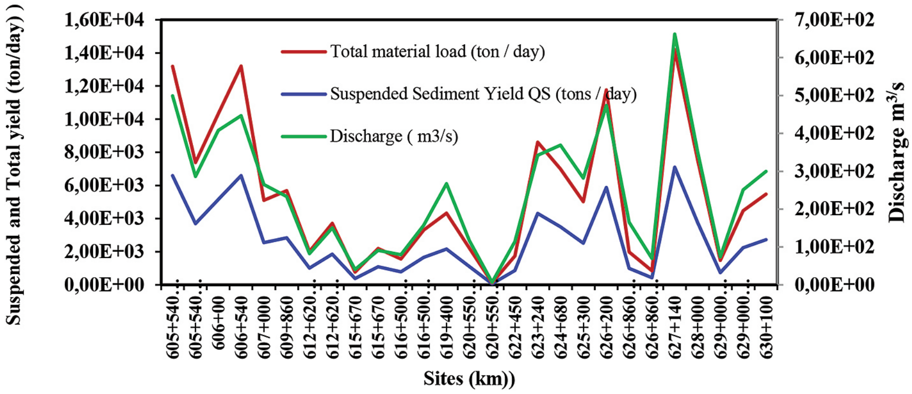

Figure 6. The distribution of suspended, bed and total load relation discharge along river reach

91.24 m^3/s and maximum value 7101.87 ton/day at site 627+140 km corresponding the discharge of 662.217 m^3/s. A relationship between cross section discharge, suspended and computed total sediment load is illustrated in (Figure 6). It is practically recognized that computed sediment load from different sites has given vastly different results from each other. The sediment load is declined clearly across the left side like between site 605 + 554 km and 606 +00 km, as well as between site 625 + 300 km and 630 + 00 km. Also the dredging activities between first Towirij Bridge and second Towirij Bridge are decreased sediment accumulation in this segment. While left side of site 606 + 00 km was hidden high accumulation of sediment and the velocity was in small value that inadequate to convey sediment from this position. The impact of bends, pattern of bed and a spiral flow rate was apparent on fall of convey materials to the sites 607 + 00 km, 609 + 860 km, 615 + 670 km, 612 + 620 km, 626 + 860 km, and 630 + 00 km.

The water if running from a narrow section of river to a shallower site or then the wider one. the flow velocity lead to be lower and consequently decreased the capacity of the reach like between 611 + 00 km and 613 + 00 km or under operation of removal the deposition for deepening the river sections. While in a bend where a greater of settling finer materials take place on the inner sides under action of the spiral flow; like in sites 609 + 860 km, 610 + 00 km, 617 + 00 km, and 622 + 00 km.

In general, the cross-sections having ratios of bed load to suspended load of the maximum percentage ratio was 0.21% and the minimum ratio was 0.01%. These ratios are referenced that suspended load can be prevailing on the sediment transport process, and the prospective interchange between the bed load and the suspended load depend on the hydro-morphological circumstance at each cross-section.

From estimation sediment load, it is noticed that major factors and processes controlling sediment yield are spatial and hydrological features of river and sediment deposition occurs in position where energy for transport is not enough to carry eroded sediments (Sulaiman et al., 2021). In addition, there is a direct connection between current power and the irregular behavior of sediment transport phenomena. The sediment cannot be moved for spacious distance, because low rate of flow which decrease the water guiding downstream and as a result a great amount will settle into rivers bank and the bed. A turbulent wave that may occur may result the materials to convey as a suspended load and then deposit as bed load at the end of time. This may be presence clarification to the reason for unexpected results in some of measurements results.

In over all, the watershed is considered a source as natural of homogeneous sediment yield and the material added to the river from the banks are appeared in the cross-sections variation.

The reason of the longevity and stability of deposits is varied with the time and some deposit in sites may be remobilized by next flood event, only to be deposited downstream(Al-Shahrabaly, 2008). The most of sediment may move in river during events of high intensity of rainfall which create runoff (Collins and Walling, 2016; Yuill and Gasparini, 2011). This variability may also be found through dry years, in spite of the fact that periods of higher drought characterize in the south and middle of Iraq, it can do occur under both conditions. Consequently, quantity of materials have deposited and stored within the watershed becoming a source of sediment

Table 3. Sediment entrainment condition for uniform sediment according Mc Lean and Smith (1977) formula

Ds mm	Shear velocity U^*_{Skin}	Shear stress τ_{skin}	Skin shear stress τ*skin	Particle reynolds number Re_P	Critical shear stress τ^*_C	Normalized shear stress S_O	Entrainment rate *ESi*
38.1	0.010668544	0.113817837	0.184727273	503682202	0.059994931	2.0790	0.003243315
35	0.006506191	0.042330519	0.074787879	282176801	0.059992824	0.2466	0.000384717
30	0.006229925	0.03881196	0.080345622	231595708	0.059991921	0.3335	0.00052028
26.67	0.004909216	0.024100404	0.055878788	162241385	0.059989998	0.0685	0.000106909
25.4	0.004924153	0.024247282	0.059030303	154985730	0.05998972	0.0159	2.49491 E-05
19.05	0.004669863	0.021807617	0.070787879	110236534	0.059987388	0.1800	0.000280872
18.85	0.003631951	0.013191068	0.043272727	84835534	0.059985243	0.2786	0.000434632
13.33	0.003643728	0.013276756	0.061575758	60200532	0.059981871	0.0265	4.14536 E-05
12.7	0.004162523	0.0173266	0.084363636	65506872	0.059982767	0.4064	0.000634085
9.42	0.002955332	0.008733985	0.057333333	34497179	0.059974683	0.0440	6.87041 E-05
4.699	0.002065111	0.004264684	0.056121212	12024730	0.059952366	0.0639	9.96891E-05
2.362	0.001651383	0.002727066	0.071393939	4833415.7	0.059917736	0.1915	0.000298791
1.315	0.000732225	0.000536154	0.025212121	1193155.2	0.059809839	0.5784	0.000902401
1.168	0.000778923	0.000606721	0.032121212	1127363.2	0.059803273	0.4628	0.000722101
0.54	0.000383579	0.000147133	0.016848485	256669.76	0.059550301	0.7231	0.001128157
0.58	0.000393218	0.000154621	0.016484848	282610.38	0.059266731	0.590960664	0.000921899
0.48	0.000277765	7.71535E-05	0.009939394	165213.47	0.058977404	0.082078521	0.000128042
0.415	0.00038106	0.000145207	0.021636364	195960.22	0.058598838	0.08906906	0.000138948
0.36	0.000499808	0.000249808	0.042909091	222962.61	0.05875869	1.299079658	0.002026564
0.295	0.000340076	0.000115652	0.024242424	124315.33	0.057494531	0.734362086	0.001145605
0.25	0.000324593	0.000105361	0.026060606	100555.52	0.057671038	0.474553755	0.000740304
0.167	0.00015773	2.48789E-05	0.009212121	32640.602	0.057419547	0.45325345	0.000707075
0.147	0.000389501	0.000151711	0.063818182	70949.91	0.059523728	0.701160546	0.00109381
0.121	0.000288944	8.34888E-05	0.042666667	43323.75	0.059380817	0.820444481	0.001279893
0.103	0.000326038	0.000106301	0.063818182	41613.254	0.059440636	0.612118207	0.000954904
0.092	0.000448316	0.000200987	0.135090909	51109.124	0.059482038	0.234832573	0.000366339
0.085	0.000145318	2.111 E-05	0.015272727	15396.113	0.059168319	0.516358269	0.000805519
0.074	0.00019043	3.626 E-05	0.03030303	17462.01	0.058383836	0.811855942	0.001266495
0.065	0.000181659	3.3002E-05	0.031393939	14631.76	0.05863168	0.15399774	0.000240236

available through sub-sequent rainfall events with adequate mobilize capacity to re-entrain and transport the sediment.

Response of bed to sediment entrainment

The flow alteration is the main character operate sediment entrainment rather than the forces of flow applied on sediment grains size. The details of tests results are indicated in Table 3, with set data including particles diameter, Rep is referred to the flow Reynolds number and depend on velocity in center of river, skin shear velocity U*skin, skin shear stress τ*skin, and dimensionless entrainment rate (ESi). In Figure 7 and 8 are arranged a relationship to isolate dependencies of entrainment rate by exerting a function for particles of materials ds and skin shear velocity U*skin respectively. The relation indicates $R^2 = 0.48$, that the entrainment based on particles size to the power -0.319 with correlation factor r = -0.55. The comparison also indicates a weak dependence on skin-friction shear velocity with $R^2 = 0.455$. The bed entrainment, assessed at 15% of the flow level reduction with skin-friction shear velocity under its role in determining bed load-layer concentrations. The higher amount of materials can diffusivities with larger flow resistance, like with bed-form that prompt by turbulence flow. The nature of sedimentary particles at their entrainment from river beds at their transport and

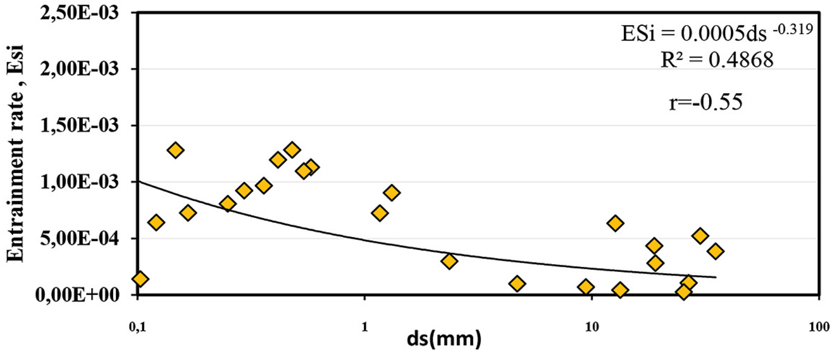

Figure 7. Sediment entrainment rate relation Grain-Size specific data

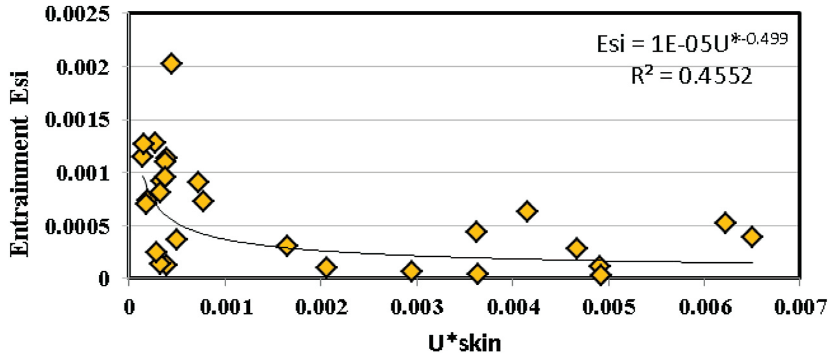

Figure 8. Sediment entrainment rate relation skin-friction shear velocity U^*_{skin}

their settling in the water. The size, shape, and composition of sedimentary particles profoundly impact their response to behavior in moving water (Table 3).

The amour layer is unstable and changed with the variation of flow conditions and entrainment rate is differ as larger or smaller degree according to the availability of appropriate sizes of sediment. Erosion the active layer includes removal of multi-granular masses either by the direct action of water stresses or cavitation-erosion. Grains dispersed into water under certain conditions, by the fluid viscosity and settle at a rate estimated by their size and excess of density. However, particles of sediment in bulk settle more slowly than when alone, as a consequence of particle interactions in the water. coarser grades are transported mainly as bed load, forming frequent touch with the bed (Dey, 2014).

CONCLUSIONS

The current work is examined the capacity of sediment transport and the state of their Entrainment rate Esi to a reach of Euphrates river under unidirectional stream flow. Besides the nature of sedimentary particles and their settling in the water. The results are indicated the following:

1. The Euphrates River is capable of transporting a considerable size of sediment depending on some factors such as size of sediment, shape of cross section, slope and amount of suspended load.
2. Physiographic character of the basin is principle factor of interruption fine sediment. Based on analysis this type of sediment is typically deposit because of small volume coarse sediment can transport from the upstream steep water through the channel to the low-gradient of river during floods.
3. The magnitude and timing of sediment-transporting are varied with the time and the space besides during flood events. The differences are obviously by Al Hindiyaha Barrage operation. In a cross section directly downstream of the Barrage, the deposition was greatest immediately following installation of the Barrage coupled with increase of channel complexity, sides bar and islands.
4. The sediment supply entering the study reach from upstream most likely remained unchanged at the selected locations which has persisted

to current times. Otherwise, sediment supply from land use has generally increased. The most influential alteration in the fluvial system has been the alteration in the other factors.

5. The dredging operation has changed channel geometry and allowed for greater conveyance for transporting more flow.
6. Fine sediment in bulk settle more slowly than when alone, as a consequence of particle interactions in the water. The coarser grains are transported mainly as bed load and close to the river bed, while the finer grains travels in suspension.
7. The channel bed entrainment is reduced with flow depth, and with U^*_{Skin} due to its role in estimating bed load concentrations. Greater relative sediment diffusivities for rivers with greater flow resistance, likely due to bed-form induced turbulence.
8. The amour layer is unstable with alteration of flow condition, and ESi is changed as larger or smaller level according to the availability of appropriate sizes of sediment.

Finally, there is always important part to be satisfied to fit the local conditions, spatially and temporally through using measured data to evaluate the respective coefficients, but unfortunately no reference data for sediment load to the study reach of Euphrates river are available whatsoever to evaluate the obtained results. So, we recommended for more field investigation to the Euphrates river stretch in future for more details and comparison the results to get more database for river management.

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