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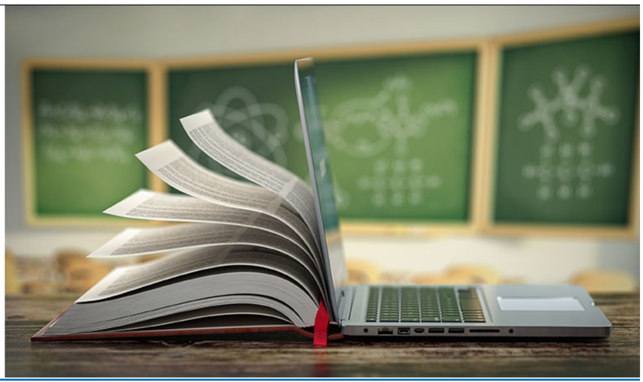

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Trend of bed load material and bed load transport in Sungai Kenau for year 2013 until 2020

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Abstract. A study was carried out to determine the trend of bed load material characteristic and bed load transport rate in Sungai Kenau at Sungai Lembing, Kuantan, Pahang between year 2013 until 2020. Sediment is a material that can be moved and deposited to the new location through the river. This study will be focusing in bed load transport as it is the key component to determine the sediment transport rate in the river. Two sampling station have been chosen to measure the bed load transport in year 2013 until to 2020. Schocklitsh and Duboys equation was used to predict sediment transport load and it was compared with measured sample from Helly-Smith equipment. The collected sample was analysed to determine the trend of bed load material and bed load transport in Sungai Kenau for year 2013 until 2020. According to Duboys calculation the highest bed load transport rate is Sample 1 with 0.013220 lb/sec and the lowest is on Sample 5 with 0.002310 lb/sec both of the samples are taken on the same station but on the different day. Meanwhile according to Schocklitsh calculation the highest bed load transport rate is Sample 7 with 3.79374 lb/sec and the lowest is on Sample 5 with 1.98018 lb/sec both of the samples also taken on the same station but on the different day. It can be sure that the higher flow rate of the river the higher bed load transport rate. It can be obtain that according to Wentworth Scale the median grain size in Sungai Kenau were between 0.68 mm to 2.6 mm where the bed material can be classified as coarse sand to the very fine gravel.

1. Introduction

Rivers plays and provided many important things that human needed. History show that the first human civilization started near the river as the river provides food, transport and shelter. A river, that commonly freshwater is a watercourse that flowing towards ocean, lake and another river. Water from the river is a basic natural resources and very essential in many human activities. Most of the human economic activities are located in the river basin as it provided placed for agriculture industry, hydro power generation, navigation, tourism, mining and irrigation. Even human are also having threat with the flood problem, siltation, sand deposition and bank erosion of river [1]. The process of sediment transport is referred when there is water flowing down on a slope in river channels that contain erodible bed that may scour the loose particle inside the river bed such as sand, rock and organic material the moved it to the downstream [2]. Sediment particle can be defined as whenever there is contact between the moving fluids with erodible bed and the local shear stress exerted by the flow to the boundaries of the channel is strong enough to disturb and immersed the friction force and the weight factor of the bed material [2]. The velocity of the flow, the particle size, and the relative densities of the sediment and the fluid will recognize whether the bed material moves as bed or suspended load [3]. Over a pass few decades researcher start to notice that mechanism of sediment transport in open channel is the one of the branches of modern alluvial hydraulic subjected to in depth investigation. The sediment transport study is to create an estimation of the amount of sediment material with only specific flow can carry, thus this attract a number of researcher to investigate about this issue such as Colby (1964), Englund-Hansen (1967) and Einstein (1950) have proposed graphical and analytical procedure to calculate the sediment discharge in the stream. Study of sediment transport is very important in hydraulic construction such as planning and design water reservoir, river training and bed deformation, sediment yield estimation for river basin, design and maintenance of stable irrigation channels and beach erosion and coastal sediment transport [3]. Sediment can be classified in the three forms which is suspended load, bed load and solution load [4]. Sediment characteristics can greatly affect the rate and pattern of the river condition. There are some factor that can affect the condition of the river bodies such as the chemical composition of sediment, particle size, fall velocity and any other factors. One of the most important properties when study about moving sediment, is particle size [5]. Particle size can greatly effects the calculation of the transport rate and bed material. As the solid particles has various type of size and classification when moving along the natural stream or any water bodies thus this classification has been recorded and accepted by the organization and widely used as the source of information by hydraulic engineers [6]. Human activities near the river such as mining, housing and facilities construction is one of the factor that contribute to the increasing rate of sedimentation. Increasing rate of sediment rate inside the river will cause the river become shallow thus will lead to other problem such as flooding and destroy habitat. The moving sediment can give negative impact to the water quality in water bodies as it act as transport mechanism of hazardous material such as heavy metal, pesticides and organic material this also known as contaminated sediment [7]. This hazardous material can give effect to the environment and human.

1.1 Research Objectives

There are three objective has been obtain from this research which are to identify the Characteristic of sediment in Sungai Kenau at Sungai Lembing,to identify the sediment concentration effect toward the environment and lastly is to calculate bed load transport rate using the Duboys and Schoklitsch equations.

1.2 Scope of Study

This research is conducted on September 2013 until February 2020. The location of study area is in Sungai Kenau at Sungai Lembing, Kuantan, Pahang. The scope of study in this research is about effect from the human activities near the river to the sedimentation rate at Sungai Kenau that are currently facing problem due to mining and housing development activity. All of this activity can contribute to the increasing of sedimentation rate in the river and will give worse effect to the river ecosystem at Sungai Kenau. The increase in water demands causes more conflict between the human system and the river ecological system [8]. Figure 1 show the view of Sungai Kenau at station 1 for sampling datawhile Figure 2 show the view of Sungai Kenau at station 2 for sampling data.


Figure 1. Station 1 in Sungai Kenau. **Figure 2.** Station 2 in Sungai Kenau.

2. Study Area

The study was conducted at Sungai Lembing, Kuantan, Pahang. It was concentrated on the bed load transport of the collected data at the selected station. The study locations are located at coordinates of 3.9146° N, 103.0327° E near the Sungai Lembing food court. This location was selected because Sungai Lembing was once a famous mining site in peninsular Malaysia. It was the largest tin mining site in 1990 to 1998. Sungai Lembing is a one of river bodies in Kuantan district, while Sungai Kenau is one of the branches of Sungai Lembing. Even though the tin mining activities at the site doesn't active anymore, the tailing from the mining site still can give effect to the river body morphology and ecosystem near them [9].

3. Methodology

Comparing between four year which is year 2007, 2013, 2019 and 2020 will show the bed load transport rate using the bed load equation and Helly-smith equipment in Sungai Kenau at Sungai Lembing. Two sampling point represent the difference between the bed load transport and bed load particle in each sample. The required data that collected on site are bed material sample and flow characteristic of the river such as width, depth and velocity of the flow. The sample then stored and dried in the oven for 24 hours. Sieve analysis test was conducted by divided the sample into 500 grams for each sample and put it on mechanical shaker about 15 minutes. The sizes of sieve trays used in this research were 10.0 mm. 6.3 mm, 5.0 mm, 3.35 mm, 1.18 mm, 0.6 mm, 0.3 mm, 0.15 mm and 63µm. Each type of sediment represents the different size that characterise from the Udden Wentworth class [10] table as reference of sediment particles classification. All the data that obtain from the laboratory and on-site measurement are important to calculate the bed load transport. Helly-Smith equipment was used to determine the measured bed load transport immediately in the site. Figure 3 shows the flow chart of methodology from the sampling until data evaluation

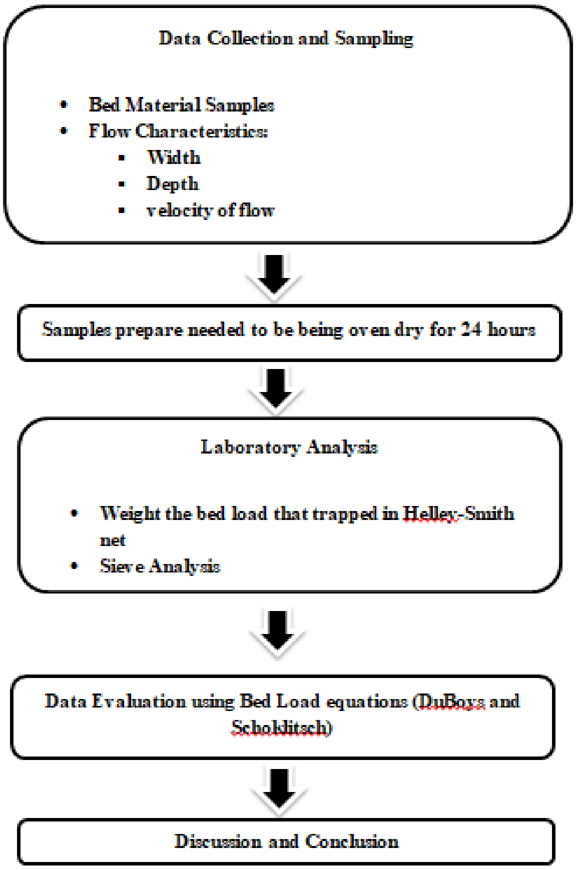

Figure 3. The flow chart of methodology

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4. Results and Discussions

Figure 4 shows the Particle size distribution curve in Sungai Kenau for each sample. The particle size distribution of each sample of bed load material that taken in Sg.Kenau are plotted after doing sieve analysis test. From the figure above shows the particle size distribution of each sample taken. From the graph it shows that the median grain size d_{50} is 0.68 mm for Sample 1 on 4th September 2013, 1.9 mm for Sample 2 on 5th September 2013, 1.6 mm for Sample 3 on 13th March 2016, 1.4 mm for Sample 4 on 16th March 2016, 2.1 mm for Sample 5 on 13th November 2019, 2.4 mm for Sample 6 on 13th November 2019 and for Sample 7 and 8 on same day which is 21st February 2020 the median grain size is 2.6 mm. The table 1 shows the median grain size in Sungai Kenau were between 0.68 mm to 2.6 mm where the bed material can be classified as coarse sand to the very fine gravel. The bed load material characteristic and size can greatly influence the bed load transport.

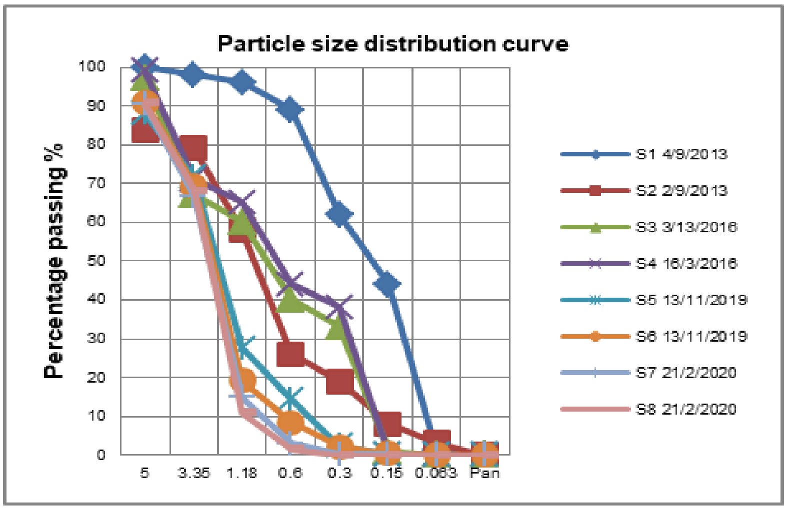

Figure 4. Particle size distribution curve

Bed load material are classified according to the classification on Udden-Wentworth scale based on range of each sediment or bed load material class. In the Udden-Wentworth scale there is a detail about the size range of sediment that already named in the class such as (boulder, cobble, pebble), for the sand type (very coarse sand, medium sand, fine sand) and for the finer sediment (silt, clay, mud). The bed load material size and type classification are very important because it will affect the value of bed load transport rate.

Table 1. The Soil classification using Wentworth Scale based on median grain size d_{50}

Date	d_{50}	Wentworth class
4th September 2013	0.68	coarse sand
5th September 2013	1.9	very coarse sand
13th March 2016	1.6	very coarse sand
16th March 2016	1.4	very coarse sand
13th November 2019	2.1	very fine gravel
13th November 2019	2.4	very fine gravel
21st February 2020	2.6	very fine gravel
21st February 2020	2.6	very fine gravel

4.1 Bed load Discharge Equation

Bed load transport or bed load discharge can be determine using two different bed load equation which is Schocklitsch and Duboys equation. This method is known as prediction method

4.1.1 The Duboys equation

The formulation in predicting sediment discharge has been started since 1879 by Du Boys who is introduce the tractive force approach in his bed load sediment formula. Duboys (1879) introduced the tractive force or bed shear stress which was an entirely new concept. DuBoys (1879) developed the following formula

$$g_s = \psi\tau_o[\tau_o - \tau_c] \tag{1}$$

4.1.2 The Schoklitsch equations

From analysis of the experimental data of Gilbert (1914), Schocklitsh (1914) showed that the non-uniform nature of shear stress distribution in a channel cross section. Because of the average shear stress in Du Boys model is a poor criterion for the determination of bed load transport rate.

$$g_S = \sum_{i=1}^{n} g_{si} = \sum_{i=1}^{n} i_b \frac{25}{\sqrt{D_{si}}} S^{\frac{3}{2}}(q - q_o) \tag{2}$$

4.1.3 The percentage different equations

Percentage different equation was use to compare the different value of the data between each sample.

$$\text{Percentage different} = \frac{V_{1-V_2}}{\frac{(V_{1+V_2})}{2}}\ x\ 100 \tag{3}$$

Table 2. Description of bed load equation

Name	Type	Size (mm)	Comment
Duboys	Bed load	0.01-4.0	The formula is not applicable for sand-bed streams that carry suspended load.
Schoklitsch	Bed load	0.30-5.0	It is a bed load formula that should not be applied to sand-bed streams that carry considerable bed sediments in suspension.

Table 2 shows the particle size range and explanation for Duboys and Schocklitsch equation. Both of the equation only applicable for particles size in the bed load and it not suitable for sand-bed stream.

Table 3. Bed load Discharge Result using Duboys and Schoklitsch

Date	Weather	Duboys (lb/sec)	Schoklitsch (lb/sec)
4th September 2013	Sunny	0.013220	2.54404
5th September 2013	Rainy	0.008300	3.31416
13th March 2016	Sunny	0.003620	2.30649

16th March 2016	Sunny	0.003960	2.84298
13th November 2019	Sunny	0.002310	1.98018
13th November 2019	Sunny	0.003070	3.04560
21th February 2020	Rainy	0.007890	3.79374
21th February 2020	Rainy	0.004460	3.30724

Table 3 shows the result of bed load discharge using Duboys and Schoklitsch equation. For Duboys equation, the highest and lowest discharge are 0.013220 lb/sec and 0.002310 lb/sec respectively. Meanwhile for Schoklitsch equation, the highest and lowest discharge are 3.79374 lb/sec and 1.98018 lb/sec respectively. The lowest value recorded for both equations is on Sample 5 date on 13th November 2019.

Table 4. Flow Rate versus Predicted Bed Load Discharge

Duboys (lb/sec)	**Schoklitsch (lb/sec)**	**Average Flow Rate (ft^3/s)**
0.013220	2.54404	3.55
0.008300	3.31416	5.289
0.003620	2.30649	0.997
0.003960	2.84298	0.981
0.002310	1.98018	1.040
0.003070	3.04560	1.692
0.007890	3.79374	1.003
0.004460	3.30724	0.604

Data on the Table 4 shows the relationship between flow rate and predicted bed load discharge using Duboys and Schoklitsch equation. Firstly for Duboys equation for sample 1 on 4th September 2013, the bed load discharge is 0.013220 lb/sec when the flow rate is 3.55 ft^3/s. then for sample 2 on 5th September 2013, the bed load discharge is 0.008300 lb/sec, when the bed load 5.289 ft^3/s. Sample 1 and 2 shows the highest flow rate due to rainy condition. The increasing upstream flow has increase the flow rate in the station. Sample 5 and 6 on 13th November 2019 shows the lowest bed load discharge which is 0.002310 lb/sec and 0.003070 lb/sec. the flow rate on that day also decrease than sample 1 and 2 which is 1.040 ft^3/s and 1.692 ft^3/s. Meanwhile for the Schoklitsch equation for Sample 1 on on 4th September 2013, the bed load discharge is 2.54404 lb/sec when the flow rate is 3.55 ft^3/s. for Sample 3 and 4 on 13th March 2016 and 16th March 2016 the bed load discharge are 2.30649 lb/sec and 2.84298 lb/sec 0.997 ft^3/s and 0.981 ft^3/s. Sample 3 and 4 has slower flower because the sample taken in sunny day. Then for Sample 7 and 8 on 21th February 2020 the bed load discharge are 3.79374 lb/sec and 3.30724 lb/sec when the flow rate are 1.003 ft^3/s and 0.604 ft^3/s. sample 7 and 8 show the highest sediment rate between all of the sample because the sample were taken after the rainy weather at the station even though the flow rate is the lowest, assumed that the bed material from the upstream already reached the station thus it can greatly affect the calculation.

Table 5. Average velocity versus Predicted Bed Load Discharge

Duboys (lb/sec)	**Schoklitsch (lb/sec)**	**Average Flow Velocity (ft/s)**
0.013220	2.54404	0.420

0.008300	3.31416	8.250
0.003620	2.30649	0.231
0.003960	2.84298	0.412
0.002310	1.98018	0.831
0.003070	3.04560	1.169
0.007890	3.79374	0.632
0.004460	3.30724	0.558

Table 5 show the relationship between averge flow velocity and predicted bed load discharge. The lowest bed load discharge is Sample 5 on 13th November 2019 with Duboys equation 0.002310 lb/sec, Schoklitsch equation 1.98018 lb/sec and 0.831 ft/sec for velocity. The highest bed load discharge is Sample 2 on 5th September 2013 with 0.008300 lb/sec for Duboys, 3.31416 lb/sec for Schoklitsch and 8.250 ft/sec for velocity. This clearly shows that velocity of the river flow had great effect toward the bed load discharge. The higher the velocity the higher the bed load discharge.

Table 6. Percentage different between sample for Duboys, Schoklitsch and Average Flow Rate

Sample	Duboys (%)	Schoklitsch (%)	Average Flow Rate (%)
Sample 1 and 2	11.43	-6.57	-9.84
Sample 2 and 3	9.63	8.96	34.14
Sample 3 and 4	-2.24	-5.21	0.40
Sample 4 and 5	13.16	8.94	-1.46
Sample 5 and 6	-7.06	-10.60	-11.93
Sample 6 and 7	-21.99	-5.47	12.78
Sample 7 and 8	13.89	3.43	12.41

Table 6 shows the percentage different between samples for Duboys, Schoklitsch and average flow rate. As we can see in the table above the highest percentage value on all of the samples of Duboys, Schoklitsch and average flow velocity is Sample 2 and Sample 3. For Sample 2 and Sample 3 on the values of Duboys on 5th September 2013 and 13th March 2016 is 0.008300 lb/sec and 0.003620 lb/sec, the percentage different of Duboys between both sample is 19.63%, while for Schoklitsch equation for Sample 2 and Sample 6 is 3.31416 lb/sec and 0.003620 lb/sec, the percentage different of Schoklitsch between both sample is 8.96% and the average flow rate for Sample 2 and 3 is 8.250 ft/s and 0.231 ft/s , the percentage different of average flow rate between both sample is 34.14%.
The lowest different value for Duboys, Schoklitsch and average flow rate is Sample 5 and 6. For Sample 5 and Sample 6 on the values of Duboys on 13th November 2019 is 0.002310 lb/sec and 0.003070 lb/sec, the percentage different of Duboys between both sample is -7.06 %, while for Schoklitsch equation for Sample 5 and Sample 6 is 1.98018lb/sec and 3.04560 lb/sec, the percentage different of Schoklitsch between both sample is -10.60 % and the average flow rate for Sample 5 and 6 is 0.831 ft/s and 1.169 ft/s , the percentage different of average flow rate between both sample is -11.93 %. In this cases the data shows high different value on the sample even the sample taken on the same day. This prove that the distance between sampling station also can affect the result. In this study there are two sampling station which is at the upstream and downstream of Sg. Kenau.

Table 7. Comparison between Measured and Predicted Data

Schoklitsch (lb/sec)	Duboys (lb/sec)	Measured Bed Load (lb/sec)
2.54404	0.013220	N/A
3.31416	0.008300	N/A
2.30649	0.003620	N/A
2.84298	0.003960	N/A
1.98018	0.002310	N/A
3.04560	0.003070	N/A
3.79374	0.007890	0.01464
3.30724	0.004460	0.01261

Table 7 contain data for Predicted bed load using Schoklitsch and Duboys equation and Measured Bed Load. As shown in the table only data 7 and 8 are available this is because past researcher doesn't take part in using Helly-Smith bed load sampler. From that we can see using Duboys equation proven to give more accurate and same data with the measured bed load than the Schoklitsch equation. For Sample 7 and 8 on 21th February 2020 Duboys equation shows the bed load transport for that day is 0.007890 lb/sec and measured bed load shows 0.01464 lb/sec while Schoklitsch equation shows 3.79374 lb/sec. there are large gap between the data shows in Schoklitsch equation. As using measured data there are high possibilities to get false data due to human errors. Duboys equation also suitable to calculate bed load discharge in Sungai Kenau as it applicable for gravel type sediment**.**

5. Conclusions

In conclusion, based on the median grain size, the sediments or bed load material were classified as gravel type which is applicable for Duboys and Schoklitsch equation as the prediction method of bed load transport rate in Sg. Kenau. From the discussion it shows that the flow rate and river velocity give great influence on the bed load discharge as there are great comparison between the lowest and the highest flow rate of velocity on the data. In other word the higher velocity flow, the greater the bed load discharge. Sediment particle size also important to determine the size of material that take place inside the bed river. Increasing sediment rate in the river will cause flood problem and disturbance on natural habitat.

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