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STUDY THE 1D QUASI UNSTEADY FLOW IN SIMULATING OF SEDIMENT TRANSPORT IN GALING RIVER BY USING HEC-RAS

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ABSTRACT

Sedimentation comes from the sediment transport, which involved the rock, gravel, sand, silt, clay and other natural sources where it is caused by the erosion in the river. In my study, it is essential to make a research about the physical of the Galing River that can influence the simulating of sediment transport rate where can effect of Urban Land Uses and Stream-water. River bed changes, prediction in this study leans post uses 1D modelling sediment provided by Hydrologic Engineering Canter's River Analysis System (HEC-RAS). This software allows performing one-dimensional quasi unsteady flow and sediment transport calculations. The data of cross section, flow discharge and sediment data are collected to run this software (HEC-RAS 4.1). Through this software we can the simulation the sediment transport pattern. There are 3 total bedload data that are used which is 0.1777 tonnes/m-day, 2.275 tonnes/m-day and 7.760 tonnes/m-day while the slope is 0.0001383. The result are predicting about a year and half with computation increment is 1 hour. The result shows that there are many sediment transport occur and it is compared to others method.The result of each approach, Meyer-Peter Muller method shows that there many locations that occur the erosion and sedimentation. The erosion occurs at the 150m, 700m and 1800m from the downstream while the sedimentation formed at station 7 and 16 where 600m and 1100m from downstream. The Toffaleti method show that the erosion that occurs same with Meyer-Peter Muller method which is 150m, 700m and 1800m from downstream. The sedimentation that formed only at 1 location which is at station 7 where 600m from downstream. The Laursen method shows that the erosion has occurred in many locations which is 150m, 700m, 1150m and 1800m from downstream while the sedimentation that formed are same with Meyer-Peter Muller method.

ABSTRAK

Pemendapan datang dari pengangkutan sedimen yang melibatkan batu, batu kelikir, pasir, kelodak, tanah liat dan lain-lain sumber semula jadi di mana ia disebabkan oleh hakisan dalam sungai. Dalam kajian saya, adalah penting untuk membuat penyelidikan tentang fizikal Sungai Galing yang boleh mempengaruhi simulasi kadar pengangkutan sedimen di mana boleh memberi kesan daripada Tanah Bandar Penggunaan dan air laju. Perubahan dasar sungai, ramalan dalam kajian ini bersandar pos menggunakan 1D pemodelan sedimen disediakan oleh River Sistem Analisis hidrologi Kejuruteraan Canter ini (HEC-RAS). Perisian ini membolehkan melaksanakan kuasi aliran dan pengangkutan sedimen pengiraan satu dimensi. Data keratan rentas, kadaralir dan data sedimen dikumpul untuk menjalankan perisian dalam (HEC-RAS 4.1). Melalui perisian ini kita boleh melihat simulasi corak sedimen yang terhasil. Terdapat 3 jumlah data beban dasar yang digunakan iaitu 0,1777 tan metrik / m-hari, 2,275 tan metrik / m-hari dan 7.760 tan metrik / m-hari manakala kecerunan adalah 0,0001383. Hasilnya meramalkan kira-kira satu setengah tahun dengan kenaikan pengiraan adalah 1 jam. Hasilnya menunjukkan bahawa terdapat pengangkutan sedimen banyak berlaku dan ia dibandingkan dengan kaedah lain.Keputusan setiap pendekatan, kaedah Meyer-Peter Muller menunjukkan bahawa terdapat banyak lokasi yang berlaku hakisan dan pemendapan. Hakisan tersebut berlaku pada 150 m, 700 m dan 1800m dari hiliran manakala pemendapan yang terbentuk di stesen 7 dan 16 di mana 600m dan 1100m dari hiliran. Kaedah Toffaleti menunjukkan bahawa hakisan yang berlaku sama dengan kaedah Meyer-Peter Muller iaitu 150m, 700m dan 1800m dari hiliran. Pemendapan yang ditubuhkan hanya di 1 lokasi iaitu di stesen 7 di mana 600m dari hiliran. Kaedah Laursen menunjukkan bahawa hakisan yang telah berlaku di banyak lokasi yang bermula dengan 150m, 700m, 1150m dan 1800m dari hiliran manakala pemendapan yang membentuk adalah sama dengan kaedah Meyer-Peter Muller.

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d	Diameter,
τ	Boundary Shear Stress
ρ	Fluid Density
τ'_*	Dimensionless Shear Stress
τ^0	Critical bed shear stress
q	Dimensionless Sediment Transport Parameter
Q	Transport Sediment Load
V	Velocity
u	Initial velocity
G	Acceleration of Gravity
C	Concentration sediment
q_b	Transport rate of bed load per unit width
u_b	Product of the bed layer particle
δ_b	Bed layer thickness
C_b	Bedload Concentration
T	Time
λ_p	Porosity of active layer
B	Width of channel
n	Channel Elevation

x	Distance
Sg	Specific Gravity
Y	Depth
s	Slope
U_y	Flow velocity
$f\left(\frac{u}{\hat{w}}\right)$	Friction of the ration shear velocity to fall velocity
C^n	Sediment discharge concentration

ABBREVIATIONS

HECRAS	Hydraulic Engineering Centres River Analysis System
JPS	Jabatan Pengairan dan Saliran

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF RESEARCH

Sediment transport is the movement of solid particles that are usually caused by a combination of the gravity force, the lift force, the drag force and extra friction due to the collisions that acting on the sediment transport. Among the materials involved in this transport sediment is rocks, gravel, sand, silt, clay and many more where it is caused by corrosion. Sediment transport can occur in lakes, rivers, oceans and everything that involves the movement of water. But many of sediment transport in rivers occur because many high cliffs and soil erosion from upstream to downstream. Sediment transport is very important to understand on how the river works because it is the set of process that mediates between the flowing of water and the channel boundary.

The sediment transport that through in a river channel determined by three fundamental controls which is capacity, sediment simply and competence. For the capacity, it is referring to the maximum amount of sediment of a given size that stream can transport in traction as bed load. The capacity depends on channel gradient, discharge and caliber of bed load. A bed load method is presented which enables the computation of the bed load transport as the product of the station height, particle velocity and bed load concentration (Van Rijn, 1984). In sediment supply, it more refer to the amount and size of sediment that suitable for the transportation process of sediment. It only achieved if the supply of the caliber of sediment is not limiting. Competence depends on the larger size or diameter of sediment particle or grain the flow is capable of moving. Physical reasoning leads to dimensionless groupings of the variable which are different for coarse sediment and fine sediment because of dissimilar of transport. (Ackers, Feb 27 1974).

Galing River is the one of the river in Pahang that is high potential to be affected by flood. This Galing River is located in Kuantan, Pahang. One of the factors of flooding is sedimentation that comes from the sediment transport. In my case study, I do a research about the sediment transport at the Galing River that to know the simulation of sediment using the HEC-RAS software in 1D Quasi Unsteady Flow. In this Galing River, there are much sedimentation of the rock and other substance that causes by the sediment transport.

1.2 PROBLEM OF STATEMENT

The worst natural in Malaysia is experiencing the flooding. Galing River is one of the rivers that are in Kuantan, Pahang that often floods. This problem can be related to sediment transport problems because there is a lot of the sedimentation that causes by the sediment transport. The nature of the sediment is the most important process in human environment. Sedimentation almost occurs in river, lake and sea. The sedimentation may pertain to objects that have a variation of size, ranging from the huge rock to suspension of pollen particles. This sedimentation problem can cause disruption to the village and the area. This will cause a lot of damages and problems. River bed changes prediction in this study uses 1D sediment leans post modelling provided by HEC-RAS 4.1. Through this software we can know the simulation of the sediment transport at this river.

1.3 OBJECTIVES

The objective of this research is to determine the simulation of the sediment transport at Galing River which is can cause the flooding. There are objective for this project:

- To identify the pattern of the sediment transport deposition.
- To Quantifying the sediment volume in future.
- To determine the channel design and sediment potential.

1.4 SCOPE OF STUDY

I will make a research upon Galing River, which is located in Kuantan, Pahang. The study will be about the sedimentation hydraulic engineering subject. In sedimentation, we knew that there are temporal and spatial pattern of sediment erosion and its deposition. Therefore, there will be some river bed change to know about the simulation of the sediment transport. My study needs me to use HEC-RAS 4.1 to the proposed model of sediment transport of the river in this research. HEC-RAS 4.1 was used to know the river bed changes prediction of 1D sediment modelling. The sample of sediment will be analyzed in the laboratory to determine the size and its roundness. This sediment transport will be focused on the bed load. In this process, the cross section data, rainfall data and sediment model data are needed.

1.5 SIGNIFICANCE OF STUDY

Using this existing data, the sample of Galing River should be prepared. This because to get the grain size of sample that suitable or particle size bed load of sediment. This sample is important to know the pattern of sediment erosion and deposition.

CHAPTER 2

LITERATURE REVIEW

2.1 SEDIMENT TRANSPORT AND PROPERTIES

2.1.1 Sediment Size and Transport Rate Computation

The most important properties during the sediment moving are particle size. It can affect the computation of transport rate of bed material that moving along the nature stream that usually not in same size. It covers more of soil types and size characteristic of sediment transport. **Table 2.1** is a summary of the classification size of sediment material that normally found in the river. In order to estimate the transport rate of a mixture of non uniform sediment material in a natural stream, one can:

I. Analyze the adequate number that representative the bed material sample to know the particle size of all samples
II. Average size (mean diameter) is introduced for each fraction.
III. Sediment mixture is divided into number of size fraction with smaller variation in size.
IV. The transport rate for each fraction individually have to calculate.

This procedure, in fate is the more rational method which has been used by several investigations, including Toffaleti (1969) and Einstein (1950). However, by using this fraction calculation makes the computational procedure longer.

Another method that an introduced representative of particle size of the whole bed material sample and use this characteristic to calculate the total bed load. This approach simplifies the calculation that causes the lack of accuracy. Ackers and White (1973), Rijin (1984) that used this approach. A number of important sediment sizes are defined as follows:

d_{50} - particle diameter (usually equivalent sieve diameter) for each 50% by weight of the The material is finer.

$d_{16, 35, 65, 84, 90}$ - Particle size with similar definitions as that for d_{50}.

Table 2.1: Classification of sediment particles

Type of particle	Size, mm
Boulders	
-Very large	4096-2048
-Large	2048-1024
-Medium	1024-512
-Small	512-256
Cobbles	
-Large	256-128
-Small	128-64
Gravel	
-Very coarse	64-32
-Coarse	32-16
-Medium	16-8
-Fine	8-4
-Very fine	4-2
Sand	
-Very coarse	2-1
-Coarse	1.0-0.5
-Medium	0.5-0.25
	0.25-0.125
-Fine	0.125-0.062
-Very fine	

Silt	0.062-0.031
-Coarse	0.031-0.016
-Medium	0.016-0.008
-Fine	0.008-0.004
-Very fine	
Clay	0.004-0.002
-Coarse	0.002-0.001
-Medium	0.001-0.0005
-Fine	0.0005-0.00024
-Very fine	

2.1.2 Fall Velocity

The fall velocity concept is fundamental to any discussion of erosion and sediment transport. In the area of sediment transport, fall velocity has a significant role in the movement of suspended sediment. When the solid particle is falling through a fluid, due to viscosity and turbulence, force arises that resist settling. Since the resisting force strengthens as velocity increase, the particle will achieve the speed where the gravitational force is balanced by the frictional drag and after its fall at a constant velocity which is called as a fall velocity.

In majority, the sediment transport theories of fall velocity are required in moving of sediment-water in the fluid. The fall velocity problem depends on the presence of turbulent fluctuation and concentration gradient. Upward and downward component of turbulent velocity will give an effect to terminal fall velocity. This effect is more to fine particles and strongly related to the intensity of the turbulence. The relation between the turbulent and size of particles is the important factor that should be considered. If the particle size is small compared to the smaller turbulent, it will tend to follow the turbulent fluctuation and may hardly reach a constant velocity.

It's clear that in turbulent flow, the fall velocity should be related to the properties of turbulent as the particle characteristics. However the Rubey's formula gives the fall velocity irrespective to the turbulence intensity of the flow. The open channel flow experiences of Jobson and Sayre (1969) indicated an increase in the fall velocity of fine sediment due to the presence of turbulence. There is no quantitative estimation given to the variation of fall velocity with the intensity of turbulence.

Besides, the fall velocity in sediment transport particle natural stream depends on the simultaneous effects of several parameters that include the size, shape, concentration and specific gravity, concentration of suspended sediment, dynamic viscosity of fluid, temperature, velocity distribution and the turbulence intensity. The fall velocity can be determined accurately by considering the factor that can affect it. Other, accurate determination of fall velocity in sediment flow is not possible. Also, nothing range of uncertainties in the area of sediment transport estimation where prediction of 200% error is considered satisfactory, a complicated solution for fall velocity is not reasonable.

2.2 SEDIMENT TRANSPORT EQUATION

Bed load sediment is defined as the portion of the total load that moving causes by the sliding, rolling or stating that near the stream, the moving at velocities that less than the of the adjacent flow. Rock and gravel would fall into bad load categories, while sand-size particle could be transported depending on condition of flow and density of particles. There are many formulas that used in the bed load equation for sediment transport which is included:

- Meyer-Peter Muller
- B. Toffaleti
- Laursen
- Van Rijn

2.2.1 Meyer-Peter and Muller

Meyer-Peter and Muller develop an empirical equation for predicting bed load transport in open channel flow. Their theory is one of the most widely used bed load predictors. This is formulated that most that used:

$$q_{s*} = K_{MPM}(\tau_{*sk} - \tau_{*c})^{3/2} \quad (2.1)$$

or

$$q^* = 8(\tau^* - \tau^*_{crit})^{3/2}, \; \tau^*_{crit} = 0.047 \quad (2.2)$$

$$\tau_* = \frac{u_*^2}{(s-1)gD} \quad (2.3)$$

where:

τ = boundary shear stress

ρ = fluid density

q^* = sediment transport parameter

τ^* = dimensionless shear stress

This equation can be considered as Meyer-Peter-Muller relationship for prediction of the bed load transport rate. The parameter τ'_* called as dimensionless shear stress. The dimensionless sediment transport parameter, q^* has also been used subsequently by Einstein (1950) among the other investigation. Most of data that used in this Meyer-Peter-Muller formula were obtained from flow little or no suspended size load with sediment size larges than 2.0 mm diameter. So, it suggested that this procedure should be used for similar flow and sediment condition.

2.2.2 Toffaleti

Fred B. Toffaleti proposed an approach to predict the transport rate of the both bed and suspended load for individual size friction of the bed material. He test his model data sample from all types of river, small to large, under a full range of flow condition and from flume experiments conducted under widely varying flow and sediment size condition (Yang, 1991). One drawback of Toffaleti's formulation is relevant equation is not dimensionally homogeneous and is developed for system units.

In drawback of Toffaleti's bed load formulation, he used the simple product of sediment concentration and flow velocity at the upper edge of the bed load layer at $y=2d_i$, times the thickness of the bed layer $2d_i$ or

$$q_{bi} = (Ci)_{y=2di}\, u_{y=2di}\, 2d_i \tag{2.4}$$

where:

y = bed load layer

Ci = sediment concentration

U_y = flow velocity

d = thickness

Using this formula for computation of bed load is equivalent to one of the three this assumption:

I. Both sediment concentration and flow velocity are constant within the bed load layer and are equal to concentration and velocity at $y=2d_i$

II. The product of concentration and velocity is constant within the bed layer and is equal to $(Ci)_{y=2di}\, u_{y=2di}\, 2d_i$ and

III. Both $(Ci)_{y=2di}$ and $u_{y=2di}$ indicate their average value throughout the bed layer.

In Toffaleti's equation, there no independent calibration or verification of the individually bed load formula had been made. The procedure should be carefully used for predicting the transport rate for bed load, especially in those natural rivers where the flow is carrying the only bed load or major part of the moving material bed load such river with low energy gradient. In fact, Toffaleti only applicable to sand transport such particle in the range 0.065mm- 2.0mm which is mostly transported in suspension.

2.2.3 Van Rijn

(Rijn, 1984) derived his bed load equation from the product that the representative velocity of the bed load particle and concentration of sediment material in the bed layer. Rijn proposed a simplified procedure for computing sediment load. Rijn equation is large based on modification of existing equation using numerical and regression analysis technique with a large number of field and lab data. According to (Rijn, 2001), bed load consistsst of particle which moves along the bed of alluvial channel rolling. The transport rate of bed load per unit width q_b can be defined as the product of the bed layer particle u_b, the station height δ_b which can be regarded as the bed-layer thickness and the average bed load concentration C_b :

$$q_b = C_b u_b \delta_b \tag{2.5}$$

$$u_b = (gd_{50})^{0.5} 1.5T^{0.6} \tag{2.6}$$

$$\delta_b / d_{50} = 0.3d_*^{0.7} T^{0.5} \tag{2.7}$$

where:

q_b = transports rate bed load

u_b = bed load of particle

δ_b = station height

Rijn's (1984) model is the most comprehensive theory of sediment transport amongst all the all the recently published procedures. He proposed new or modified relationships for almost all the parameter involved in sediment transport including:

-Bed load transport rate

-Vertical distribution of suspended sediment concentration

-Diameter for non-uniform particle

-Fall velocity

He also suggests to the proposed expression of bed load concentration and transport rate that applied to the sand grains with diameter between 0.2mm and 2mm. However, in natural stream with high energy slope and bed load, mostly include the gravel particle which greater than 2.0mm diameter.

2.2.4 Laursen

Laursen method is a total load predictor. This function method is comprised a velocity, depth of flow, energy gradient, fall velocity and sediment characteristic of gradiation. The range of grain size of this method is about 0.011mm to 29mm. The general equation that used for this method to calculate the sediment transport is:

$$C^n = 0.01\left(\frac{d}{D}\right)^{\frac{7}{6}}\left(\frac{(\tau)}{\tau^\circ} - 1\right) f\left(\frac{u}{\hat{w}}\right) \tag{2.8}$$

Where:

C^n = Sediment discharge concentration

d = means particle diameter

D = effective depth of flow

τ = bed shear stress due to grain resistance

τ° = critical bed shear stress

$f\left(\frac{u}{\hat{w}}\right)$ = function of the ration shear velocity to fall velocity

2.3 HECRAS

2.3.1 Sediment Transport Modelling

HEC-RAS is capable to do modelling for a sediment transport, which is notoriously difficult. Therefore, modelling sediment transport is based on assumption and empirical theory that is sensitive to several physical variables.

2.3.2 Sediment Transport Calculation

Sediment transport simulation within HEC-RAS are based on a calculation of sediment on one-dimensional movable material from the river bed that causing scour or deposition over the modelling period time. Besides, the sediment transport through stream river and the two points which are bed load and suspended load that are depending on the parameter such as size of particle, water velocity and bed slope. In HEC-RAS, sediment routing is based on sediment equation:

$$(1-\lambda_p)B\frac{n}{t} = -\frac{Q}{X} \tag{2.9}$$

where:

λ_p = porosity of the active layer

B = width of channel (m)

n= channel elevation (m)

Q= transported sediment load (m^3/s)

x= distance (m)

t= time (s)

For the performing sediment transport capacity analysis and unsteady flow of the simulation have to be run first. Then HEC-RAS will automatically take the required hydraulic parameter from the unsteady output to be used in the sediment transport analysis.

2.3.3 Total Bed Load

The total bed load is important to run this software. It was calculated by manually as data discharges are given. There are three discharges of velocity to calculate the total bed load. The value of total bed load is key in before simulated can be done. The formulas below are used to calculate the total bed load.

$$\theta = [\frac{ys}{(sg-1)(D50)}] \tag{2.10}$$

$$f = \frac{2gSy}{V^2} \tag{2.11}$$

$$q_s = 0.1\left(\frac{1}{f}\right)\theta^{2.5}\, y[(Sg-1)gD50^3]^{1/2} \tag{2.12}$$

where:

Sg = Specific gravity
y_s = Depth
g = gravity
s = Slope
q_s = Total bed load