1D SEDIMENT TRANSPORT MODELLING IN LANGAT RIVER BY USING QUASI UNSTEADY HECRAS

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ABSTRACT

The main purpose of this study is to study sediment transport characteristics at Langat River. Langat River is located in the state of Selangor and it is subjected to regular flooding. Sediment transport capabilities can be known by using Hydraulic Engineering Center's River Analysis System program (HEC-RAS). The appropriate data required to create the model. The data needed to use in HEC-RAS is cross sectional data and elevation data. HEC-RAS can create the sediment transport and hydraulic models. The sediment transport model will calculates sediment transport capacity with a number of available methodologies. In this research, HEC-RAS can show sediment transport. The HEC-RAS model can calibrate and gives the values of Manning's coefficients of roughness for the Langat River. HEC-RAS also can predict the changes of bed elevation. The model will conclude that there is a significant increase in river bed depth due to development, which means there is no change in flooding behaviour was detected in the short term. This paper will be focused only on bed load sediment. The result of 6 years stream flow shows there are some area had faced sediment transport and erosion of the river. By using the England Hansen function in HEC RAS had shown a little change in the river. From the simulation, the result shows the section that experienced sediment transport at station 943 (1.45km from the upstream part at Bangi) and station 959 (1.05km from the upstream part at Bangi), and station 972 (725m from the upstream part at Bangi) that experienced the erosion of river.

ABSTRAK

Tujuan utama kajian ini adalah untuk mengkaji ciri-ciri pergerakan pasir di Sungai Langat. Sungai Langat terletak di negeri Selangor dan kebiasaannya mengalami banjir. Keupayaan pergerakan pasir boleh diketahui dengan menggunakan programHydraulic Engineering Center's River Analysis System (HEC-RAS). Data yang sesuai diperlukan untuk membuat model. Data diperlukan untuk digunakan dalam HEC-RAS adalah data keratan dan data kedalaman sungai. HEC-RAS boleh menjangka pergerakan pasir dan model hidraulik. Model pengangkutan sedimen akan mengira kapasiti pengangkutan sedimen dengan beberapa kaedah yang ada. Dalam kajian ini, HEC-RAS boleh menunjukkan sedimen. Model HEC-RAS boleh menentukurkan dan memberi nilai-nilai pekali Manning ini kekasaran bagi Sungai Langat. HEC-RAS juga boleh meramalkan perubahan ketinggian dalaman. Model ini akan membuat kesimpulan bahawa terdapat peningkatan yang ketara dalam kedalaman dasar sungai akibat pembangunan, yang bermaksud tidak ada perubahan dalam tingkah laku banjir dikesan di masa pendek. Kertas ini akan memberi tumpuan hanya pada beban dasar sedimen. Hasil 6 tahun aliran sungai menunjukkan terdapat kawasan ada yang dihadapi pengangkutan sedimen dan hakisan sungai. Dengan menggunakan fungsi England Hansen di dalam HEC RAS telah menunjukkan sedikit perubahan dalam sungai. Berdasarkan keputusan simulasi, hasil menunjukkan keratan rentas yang mengalami pengangkutan sedimen adalah di stesen 943 (1.45km dari bahagian hulu di Bangi) dan stesen 959 (1.05km dari bahagian hulu di Bangi), dan stesen 972 (725m dari bahagian hulu di Bangi) yang mengalami hakisan sungai.

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LIST OF SYMBOLS

C_m	sediment discharged concentration
G	unit weight of water
D	mean particle diameter
τ_0	bed shear stress due to grain resistance
τ_w	critical bed shear stress
$f(\frac{u}{\varpi})$	function of the ratio shear velocity to fall velocity
X	sediment concentration, in parts per part
G_{gr}	sediment transport parameter
s	specific gravity of sediments
d_s	mean particle diameter
D	effective depth
u_*	shear velocity
V	average channel velocity
n	transition exponent, depending on sediment size
c	coefficient
F_{gr}	sediment mobility parameter
A	critical sediment mobility parameter
g_s	unit sediment
γ	unit weight of water
γ_s	unit weight of solid particles
d_{50}	particle size of which 50 % is smaller
C_t	total sediment concentration
ϖ	particle fall velocity

d_m	median particle diameter
S	energy gradient
ν	kinematics viscosity
g_{ssl}	suspended sediment transport in the lower zone, in tons/day/ft
g_{ssM}	suspended sediment transport in the middle zone, in tons/day/ft
g_{ssU}	suspended sediment transport in the upper zone, in tons/day/ft
g_{sb}	bed load sediment transport in tons/day/ft
g_s	total sediment in tons/day/ ft
M	sediment concentration parameter
C_L	sediment concentration in the lower zone
g_s	unit sediment transport rate in weight/ time/ unit width
k_r	roughness coefficient
k'_r	roughness coefficient based on grains
γ_s	unit weight of the sediment
g	acceleration of gravity
d_m	median particle diameter
R	hydraulic radius
S	energy gradient
ϖ	particle fall velocity
s	specific gravity of particles
d	particle diameter
β	direction of motion
θ	surface topography
λ	angle of streamflow direction
a_θ	surface topography

$\eta_\wp$ excess shear

LIST OF ABBREVIATIONS

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

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF RESEARCH

Flood can be determined as one type of disaster in world. The disaster of flood can be effect of residential and population surrounding. Flood damage also one effects of flood disaster in Malaysia from Malaysian statistics. Sediment is coarse occurring by the material that formed by affected which is erosion, weathering and transporting. Sediment in rivers is generally transported by the water.

Mostly, the impact of compaction, erosion deposition and transportation of the sediment can caused sedimentation occur. The changing of the flood carrying capacity that effected by sedimentation, can lead to flood water damage to surrounding area. Consequently, there is essential for us to realize the basic principles of sediment transport.

From basic principles of sediment transport, we can guess the fluvial processes found in natural rivers and stream through modelling. It could be a physical model in alter scale, duplicate, miniature, or enlarged or a numerical model with the support of computer software. In this study, HEC RAS is one of the software that can help and use to reach the objectives.

1.2 PROBLEM OF STATEMENT

Malaysia is a tropical country and flood is always happening in urban and rural areas. For example, Hulu Langat is a popular flash flood in Selangor. In the normal depth of rainfall at Langat is 60mm but sometimes the rainfall depth exceeding 200mm. This project will be focused on Sungai Langat, Selangor. The concepts of sediments is a particular interest in drainage design, sand and gravel mining which happens due to force. Not all rivers transport sediment and not all channels are formed in sediments. For this project will be used quasi unsteady flow HEC RAS. The function of HEC RAS is used in creating the hydraulic and sediment transport models. Quasi unsteady flow is one of model in HEC-RAS software. In HEC-RAS, quasi steady flow will show approximates a continuous hydrograph with a series of a discrete steady flow profiles. For sediment transport, there are three steps in HEC-RAS that are flow duration, computation increment and mixing time step.

1.3 OBJECTIVES

The main objectives of this research are to determine the sediment transport at Langat River that can cause flood disaster in that area that includes Bangi, Putrajaya, and Kajang. Below is another objective for this project.

- To understand how Langat River work in the intermediate process between the flow of water and the channel boundary.
  - Flow of hydraulics capacity in Langat River can be change before and after normalization.
- To know Langat River morphology using 1D sediment transport analysis.
  - 1D sediment models is the study of the longitudinal profiles of the cross section properties of flow and sediment transport in Langat River.
- To determine the channel design and analysis, and sediment potential.

1.4 SCOPE OF STUDY

A study area of this project is at Sungai Langat, Selangor. This project is to study sediment transport characteristics at Sungai Langat. The selected data likes rainfall and cross sectional data needed to ease the process of hydraulic and catchment area. A software computer such as HEC RAS will be used to predict the changes of bed elevation. The sample of sediment will be analyzed in the laboratory to determine the particle shape and roundness.

HEC RAS Quasi unsteady flow model also will be showing the results for the estimation of energy slopes. This sediment transport will be focused in bed load only. The study is about 2km of Langat River near with Jalan Bangi and Jalan Reko.

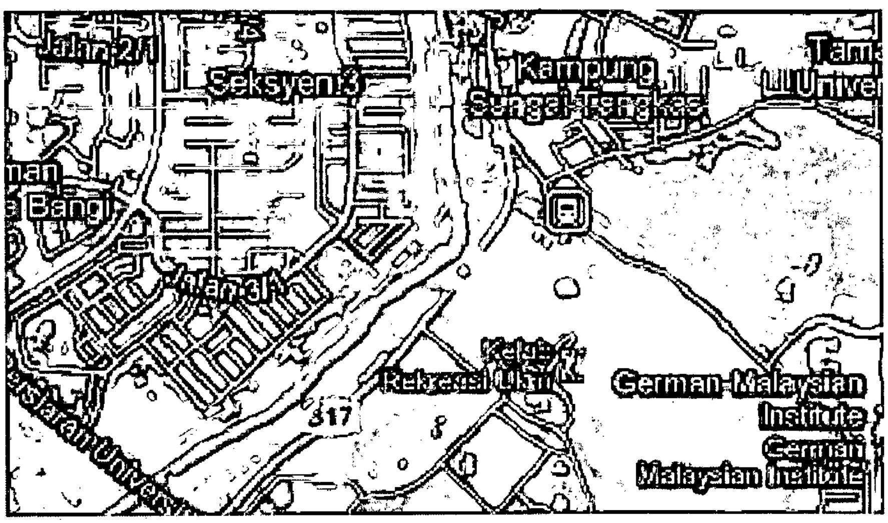

Figure 1.1: Layout Sungai Langat 2km

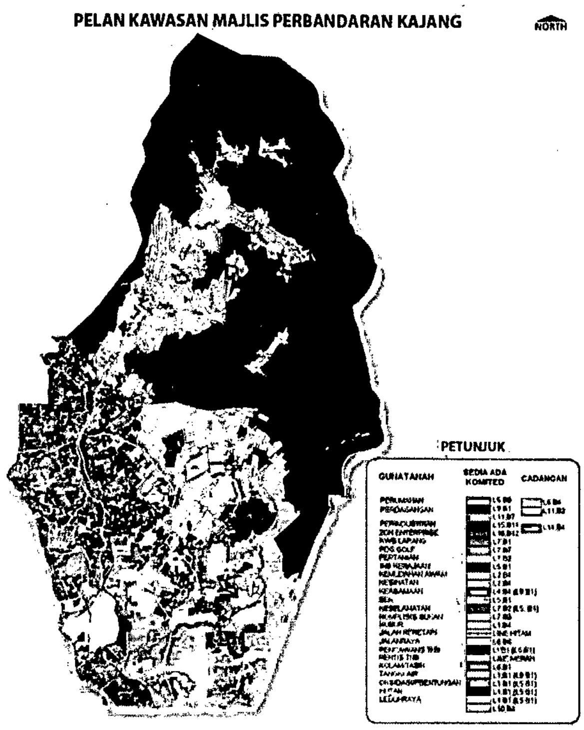

Figure 1.2: Landuse map Kajang

1.5 SIGNIFICANCE OF STUDY

By using an existing data will the scope of research in preparing a model of Sungai Langat. Besides that, to get the grain size or known particle size distribution of bed load sediment, need to collect from river to be used as a sample. Moreover, by the result of river bed modelling, we can arrange some hydraulic structure such as sand trap.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The river always changing, the change in channel characteristics upstream and downstream is caused by modified river channel. The streams are powerful erosive agents in moving material from their bed and banks. Streams also store huge amount of sediment on lakes and ocean basins. The headwaters of stream usually steep slopes and cut a deep V-shaped valley. Commonly, the flows of headwater are rapids and waterfalls. In transfer zone, there are low elevation streams change and flow down more gentle slopes. Sediments can be classified as lithogeneous sediments, biogeneous sediments, and hydrogeneous sediments. The characteristics of sediment are texture, grain size, colour, organic content and others.

2.2 RIVER EQUILIBRIUM

River equilibrium can be elaborated as a balancing process with stream physical adjustments that to control stream channels. The stream channel can be deposited because of the water flows and movement sediment. Incoming and outgoing water discharge and sediment load will express or show an equilibrium alluvial channel.

When balance incoming and outgoing sediment will change cross sectional and then the channel geometry also will be changed. For instance, river bends may reach equilibrium condition between the rate of erosion on the outside bank and the rate of sedimentation on the point bar. In a broad sense, the cross-sectional geometry of a meandering channel is in equilibrium (Pierr V. Julien, 2002).

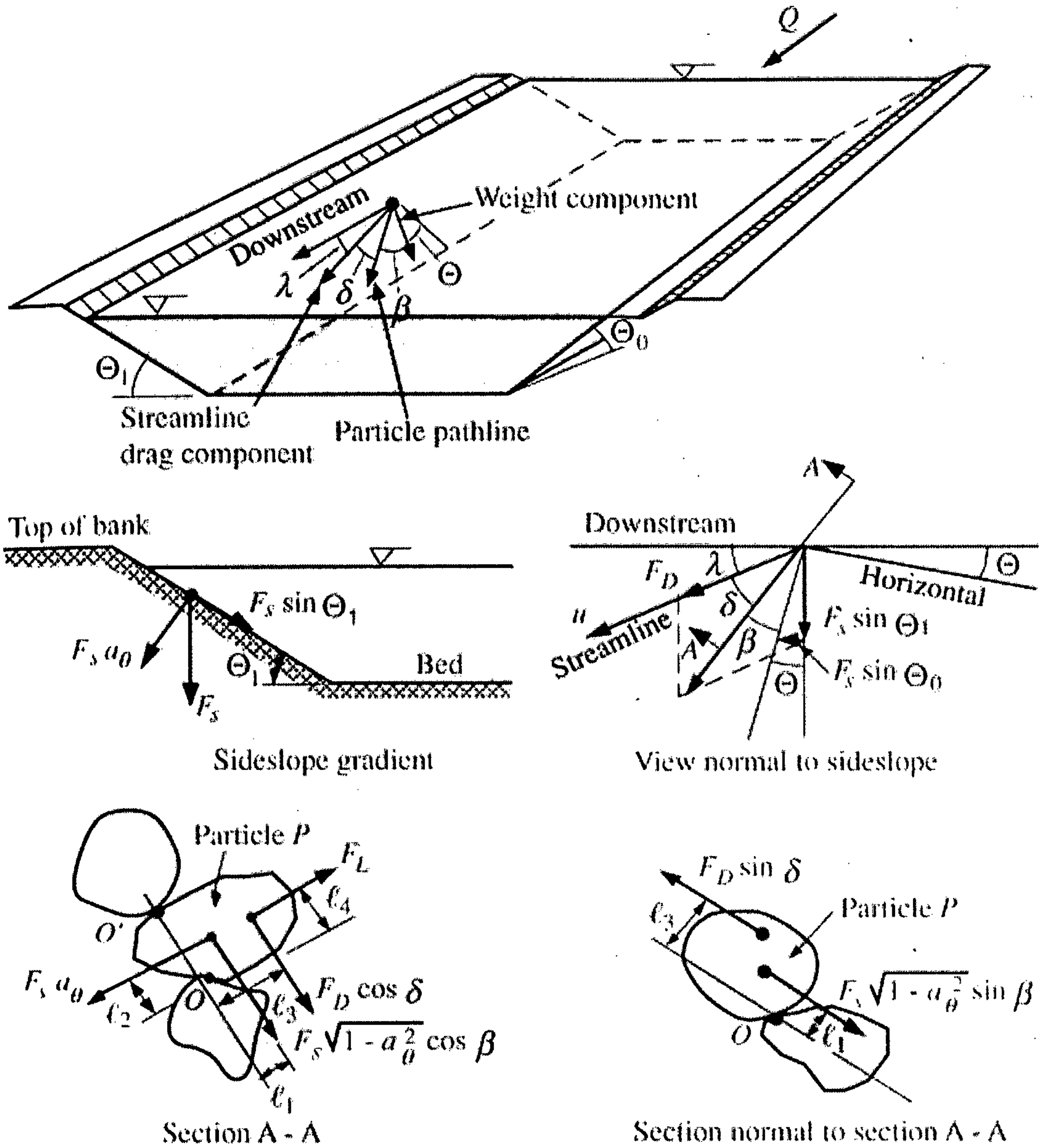

Figure 2.1: Particle stability analysis (Pierr V. Julien, 2002).

The figure describe about the particle stability analysis. According to (Pierr V. Julien, 2002), the lift force is defined as the fluid force normal to the embankment plane whereas the drag force is acting along the plane in the same direction as that of the velocity field surrounding the particle. Below is the equation for direction motion of sediment particle. The particle orientation depends on the surface topology, stream flow direction, and particle characteristics.

$$\beta = \tan^{-1}\left[\frac{\cos(\lambda-\theta)}{\frac{\sqrt{1-a_\theta^2}}{N\eta_0 \tan\varphi}+\sin(\lambda+\theta)}\right] \quad (2.1)$$

where,

β	= direction of motion
θ	=surface topography
λ	=angle of streamflow direction
a_θ	= surface topography
η_o	= excess shear

2.3 RIVER DYNAMIC

Many factors likes' soil type, vegetation type and coverage, land use, climate and weathering can be influenced for sediment production. The sediment that flows into the fluvial system will be transported within the system, which can cause flooding plains.

After that, the local conditions of the river can be affecting the movement of sediment. The river has the ability or energy to transport the amount and size of sediment that relate with to sediment transport capacity. The velocity and depth of water moving through the channel are the key components to control the sediment transport capacity. Dissolved, suspended and bed load are 3 types of sediment load in rivers. While dissolved and suspended load are important components of the total sediment load; in most river systems, the bed load is what influences the channel morphology and stability (Kondolf, 2002).

Concentrate on bed load; it is made up of sand, gravel, cobbles and boulders. Bed load is transported by rolling, sliding, and bouncing along the bed of the channel (Allan, 1995). Theoretically, river system can be divided into three zones headwaters, transfer zone, and depositional zone. Same as river system, fluvial system also can be divided into three zone that is erosion, transport and sedimentation. The upper zone that is erosion be classified as an erosion of bed material caused by waterfalls and others.

Other than that, the lower zone also can be classified as a net sedimentation and channel geometry. Channel geometry can be changed by the higher or increase sediment load and flow discharge. The **Figure 2.2** shows three zones in fluvial system.

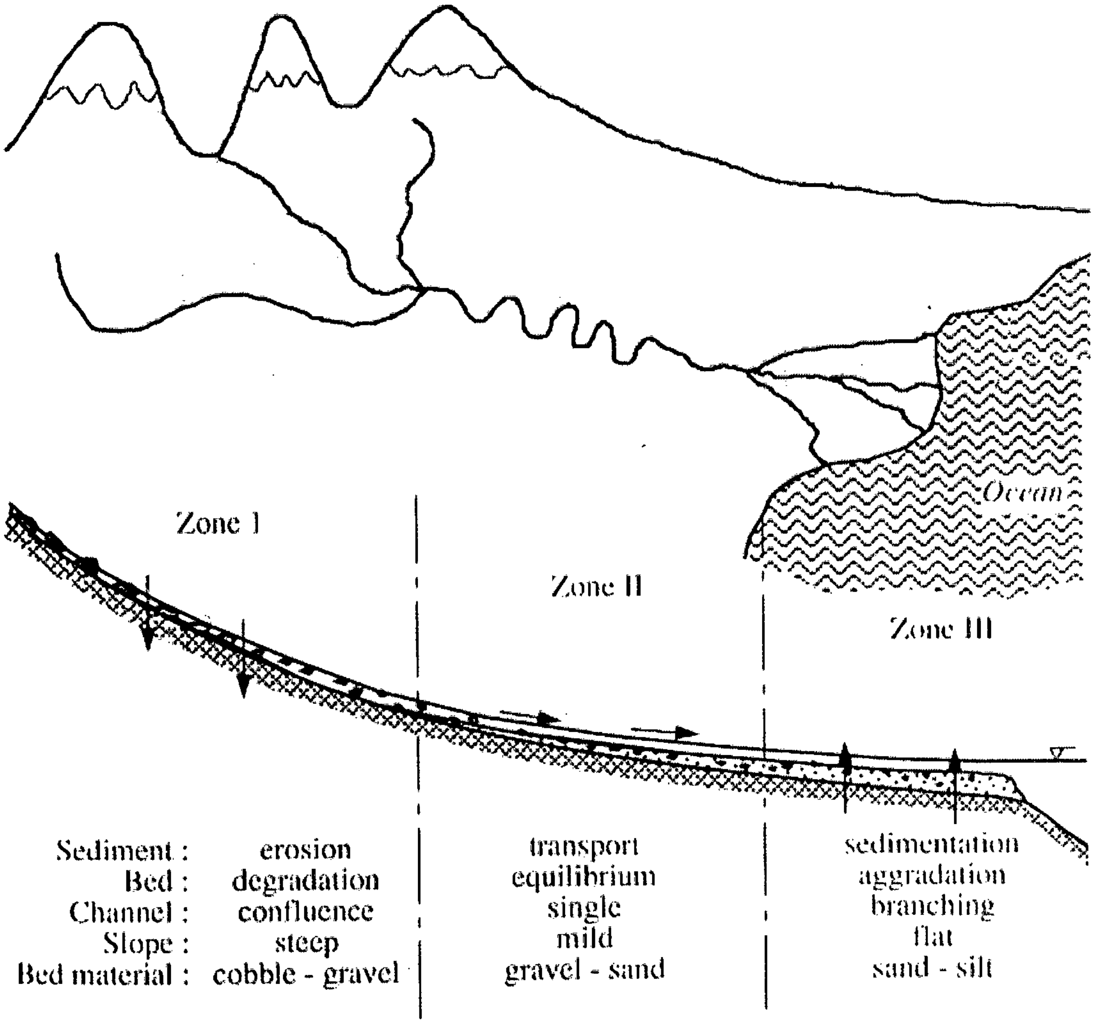

Figure 2.2: Erosion, transport and sediment (Pierr V. Julien, 2002)

There are four fluvial processes that may change the streams and rivers that can categorized as degradation, aggradations, channel widening and plan form change. Generally, degradation can be determined by the lowering bed elevation due to erosion. Channel degradation can be occur if there are increasing slope, increasing in flows, decrease in sediment, and flood plain access. **Figure 2.3** below shows the relationship between sediment load and channel geometry.

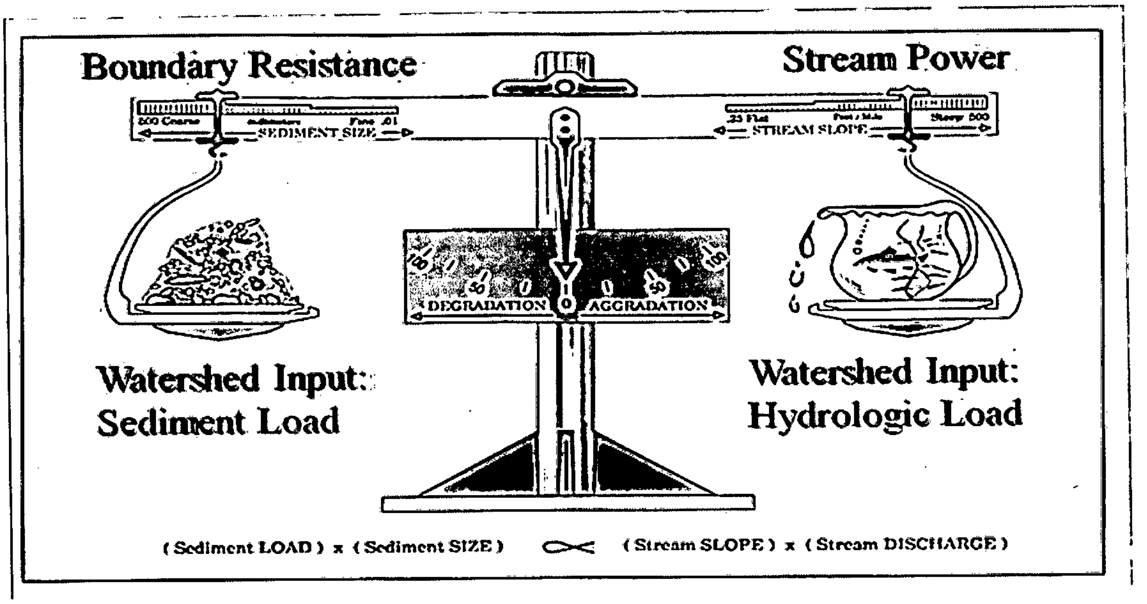

Figure 2.3: Lane's balance illustrating stream equilibrium conditions (Rosgen, 1996)

The erosion may occur quickly due to the higher storm water runoff. Channel degradation also causes the banks to become unstable and subject to failure (Pierr V. Julien, 2002). Moreover, freshly eroded, steep stream banks, gravel bars eroding on the downstream end and scour at bridge footings can show the effect of degradation. Figure below shows the channel degradation.

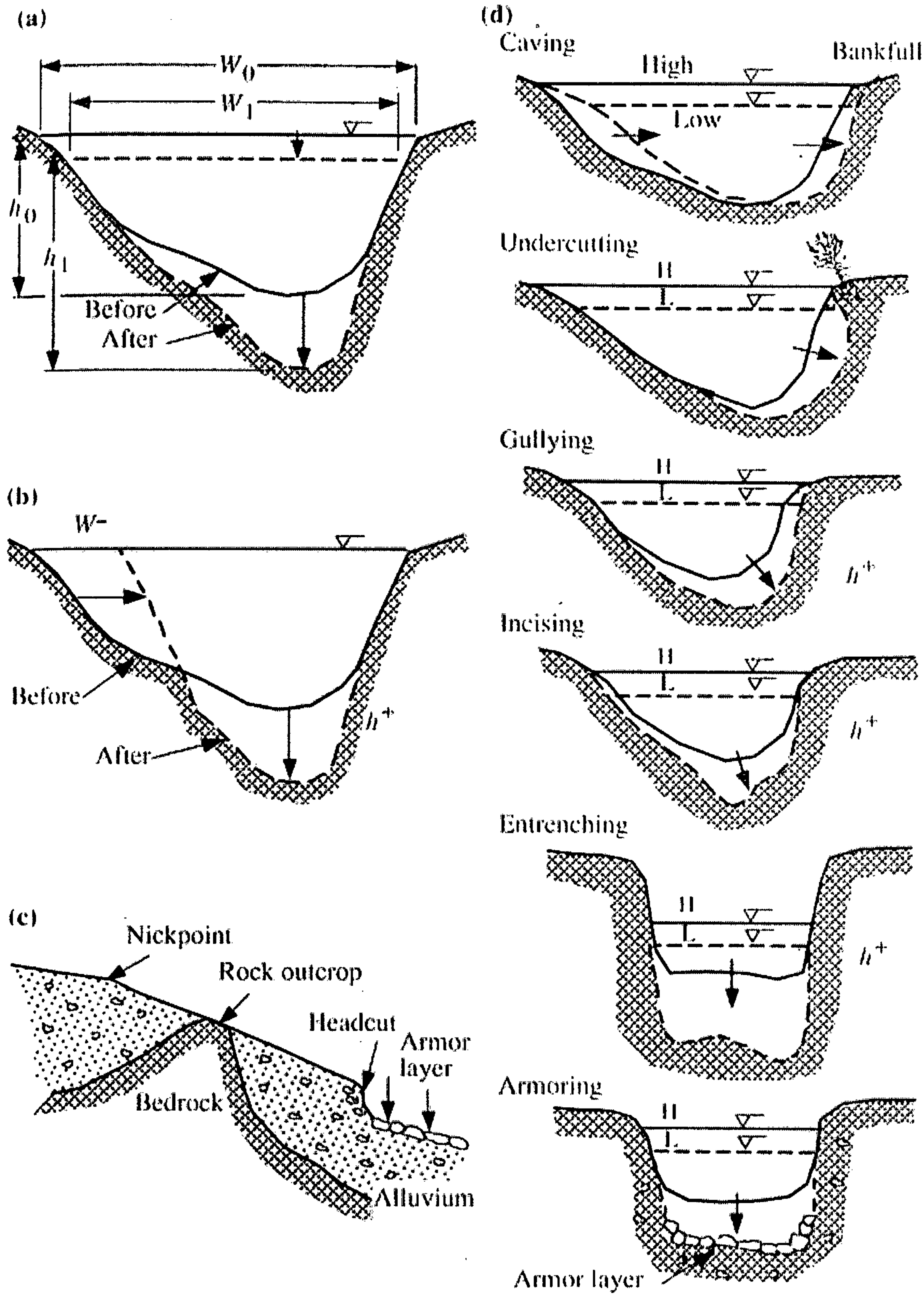

Figure 2.4: Schematic of riverbed degradation (Pierr V. Julien, 2002)

Next, the increasing of bed elevation through an accumulation of sediments also known as aggradations. The decrease in flow discharge and increase of sediment load is the effect of channel aggradation due to human work that can caused the narrowing the stream such as bridge, fill encroachment and culvert.

2.4 HEC-RAS

2.4.1 Quasi Unsteady Flow

Generally, unsteady models can be used to stimulate unsteady fluvial processes as well as steady and quasi-steady processes. The boundary condition between upstream and downstream can be choosing for equilibrium sediment. Maximum erodible depth, sediment formulas, sediment sorting method and fall velocity method need to require the sediment transport analysis.

2.4.2 Sediment Transport Modelling

Sediment modelling is the system that can utilize a measured sediment model to guess regional and long term trends. HEC-RAS now includes the framework with which to perform mobile boundary, sediment transport modelling (HEC-RAS Reference Manual). 1D sediment models usually used in the simulation of long term sedimentation process in long channels. Sediment transport modelling is used in stable channel. That's mean the stream should be either erosion or deposition.

2.4.3 Sediment Transport Function

There are several types of formula used in sediment transport that are accepted and utilized in this field. The processes of sediment transport are from soil erosion to the sediment transport, and then sedimentation. There are some formulas which HEC RAS used in sediment transport capacity such as Laursen-Copeland, Acker and White, England Hansen, Yang, Toffaleti, and Meyer-Peter Muller

2.4.3.1 Laursen- Copeland

Laursen method is a total sediment load predictor. This function is comprised of mean channel velocity, depth of flow, energy gradient, fall velocity and the sediment characteristics of gradation. The range of relevant particle size is from 0.011mm to 29mm. The general equation stated as:

$$C_m = 0.01\gamma \left(\frac{d_s}{D}\right)^{7/6}\left(\frac{\tau_o}{\tau_w}\right) f\left(\frac{u_0}{\varpi}\right) \tag{2.2}$$

where:

C_m	= sediment discharged concentration
γ	= unit weight of water
D	= mean particle diameter
τ_0	= bed shear stress due to grain resistance
τ_w	= critical bed shear stress
$f(\frac{u}{\varpi})$	= function of the ratio shear velocity to fall velocity

2.4.3.2 Acker and White

The mobility and transport rate of sediment can be determined by applying dimension analysis. Acker and White is the equation that compiled of particle size, mobility and transport. The general equations are represented by:

$$X = \frac{G_{gr}\, s d_s}{D\left(\frac{u_s}{V}\right)^n} \tag{2.3}$$

$$G_{gr} = C\left(\frac{f_{gr}}{A} - 1\right) \tag{2.4}$$

where:

X	= sediment concentration, in parts per part
G_{gr}	= sediment transport parameter
s	= specific gravity of sediments
d_s	= mean particle diameter