

Natural Stable River Section Design Using Fluvial-12



AHMAD DARUS
Engineer, Drainage and Irrigation Department (DID), Malaysia



PROF. MADYA DR NOR AZAZI ZAKARIA
Director, River Engineering and Urban Drainage Research Centre (REDAC), Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Seberang Perai Selatan, Pulau Pinang, Malaysia



PROF. MADYA DR AMINUDDIN AB. GHANI
Deputy Director, River Engineering and Urban Drainage Research Centre (REDAC), Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Seberang Perai Selatan, Pulau Pinang, Malaysia



PROF. MADYA DR ROZI ABDULAH
Lecturer, School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Seberang Perai Selatan, Pulau Pinang, Malaysia

ABSTRACT

Sediment transporting capacity, curvature effects as well as composition of channel bed and bank materials need to be considered by the engineer during the design process of natural channels. Neglecting these effects would normally result in instability problems because channel morphology usually changes with time.

Mathematical model (FLUVIAL-12) has gradually become popular in designing stable sections because it is more economical compared to physical model. The model is capable of predicting instability effects such as riverbed changes due to erosion and sedimentation during flood, thereby providing the necessary information for the design or bank protection work. In this paper, the application of FLUVIAL-12 for Raia River shows that the study reach can be preserved to its natural characteristics provided that the river bank should be covered with natural protection which produce the flow resistance to the value of Manning's $n = 0.045$.

Keywords: Stable River Design, Sediment Transport, River Modelling, FLUVIAL-12, River Conservation

1.0 INTRODUCTION

1.1 Characteristics of Natural Rivers

Materials comprising the beds of alluvial rivers have an important influence on river geometry. Bed slopes at the headwaters of rivers are steep, and the bed material is relatively coarse. In general, both river slope and bed material sizes decrease in the downstream direction.

Figure 1.0 shows bed material of Rio Grande River range in size from boulders

and cobbles to silts and clays, generally decreasing in a downstream direction. On the Rio Grande, median particle size decreases from 0.5 mm at Otowi, New Mexico, to 0.14 at a point 200 miles downstream.

Figure 2.0 shows natural river exhibiting non-uniform bed materials at different locations along the river course. It's imperative to maintain these natural features of the river to preserve the river equilibrium.

1.2 Bank Materials

Bank material normally changes with distance along a stream. It is important to note that banks are generally not composed of uniform materials throughout their height, but rather are stratified with layers of gravels, silts, sands and clays.

Riverbanks may generally be classified as cohesive, non-cohesive, and stratified (composed of layers of materials of different size, permeability, and cohesion characteristics).

1.3 Definition of Stable Section

Lane (Chang, 1988) presented an excellent definition of stable or regime channels as follows;

"A stable channel is an unlined earth canal for carrying water, the banks and bed of which are not scoured by the moving water and in which objectionable deposits of sediment do not occur."

Thus from the definition, small amount of erosion and deposition may occur within river channels but for a long period of time, bank and bed will attain toward stability.

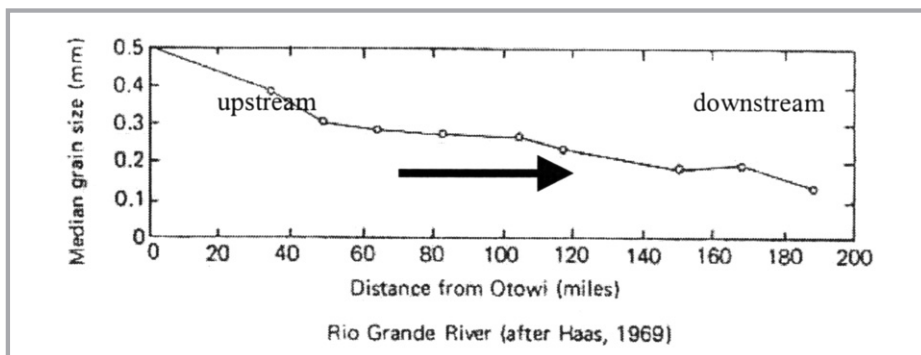


Figure 1.0: Grain Size Degradation of Rio Grande River (Peterson, 1986)



Figure 2.0: Natural River Exhibiting Non-Uniform Bed Materials (8th January 2003)

2.0 MATHEMATICAL MODEL (FLUVIAL-12) FOR CHANNEL DESIGN

The FLUVIAL-12 (Chang 1980, 1982, 1984, 1985, 1986, 1988, 1990) model has been formulated and developed for water and sediment routing in natural and man-made channels.

Briefly, this model, for a given flood hydrograph, simulates time and spatial variations in flood level, sediment transport, and bed topography (Figure 3.0). In the prediction of river-channel changes, scour and fill are tied in with width variation and the effect of secondary currents under the changing channel curvature. In the model, scour and fill are computed on the basis of longitudinal imbalance in sediment discharge.

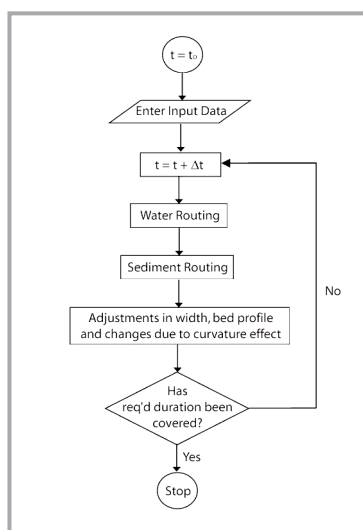


Figure 3.0: Flow Chart Showing Major Steps of Computation for FLUVIAL Model (Chang 1988, 1993)

3.0 METHODOLOGY

3.1 Case Study of Raia River

Raia River is an important tributary of Kinta River. It has a catchment area of 192 km² covering the areas in Ipoh and Kinta Valley. Figure 5.0 shows Raia River study area started at Kampong Tanjung Bridge (Ch. 2800m) and extends upstream for a distance of about 2.8 km.

3.2 Study Procedures

Simulations using the FLUVIAL-12 mathematical model carried out by using

In this paper, FLUVIAL-12 was applied to Raia River reach near Ipoh. The aim of the study is to identify the best effective geometry natural section (Darus, 2002). Comparison with the Simons & Albertson Regime method (Chang, 1988) is also made (Figure 4.0).

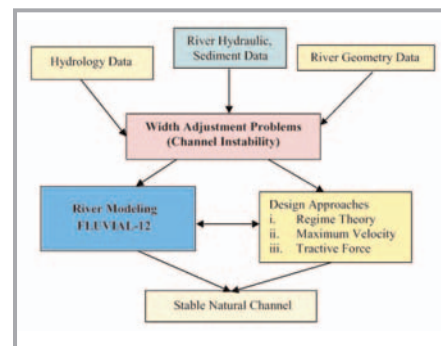


Figure 4.0 Methodology for Identifying, Analyzing and Modeling Instability Problem (Darus, 2002)

several input data such as hydrograph and rating curve obtained from DID. Bed and bank material as well as cross sections profiles at selected gauging stations shown in Figure 6.0 were taken for comparison with the simulated results. Cross sections used in the simulation process were obtained from a DID survey plan in 1999.

4.0 DESIGN CONFIGURATION OF RAIA RIVER

4.1 Selected Cross Section

An appropriate cross section was identified and selected to convey maximum discharge and furthermore the important task is to minimize the

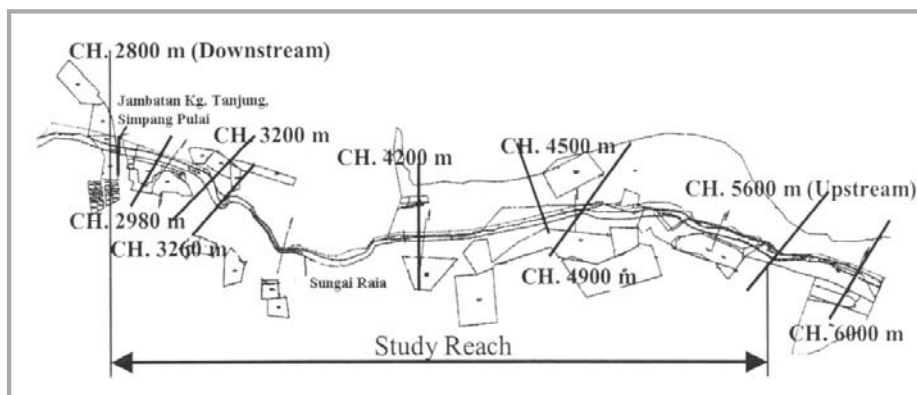


Figure 6.0 : Study Reach of Raia River (Darus, 2002)

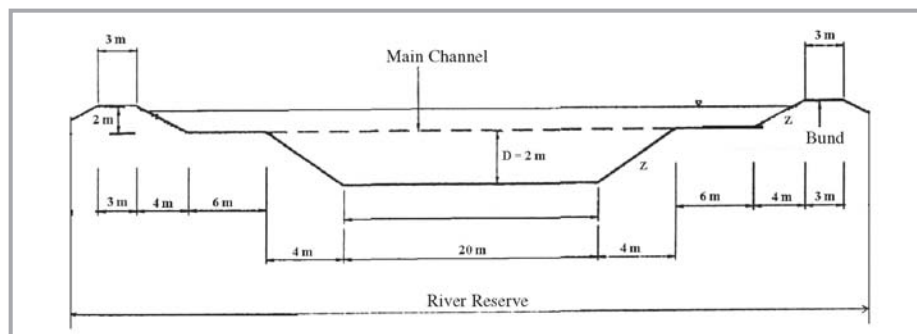


Figure 7.0 : Selected Cross Section Design for Raia River

instability problem. Due to inadequate river reserve at site, the cross section as shown in Figure 7.0 was adopted (uniform for all cross section).

4.2 Hydrology

a). Hydrograph

Figure 8.0 shows the predicted hydrograph based on land use until 2020 that was used for the design process (Darus, 2002).

b). Flow Rating Curve

The rating curve for the simulation process was derived from the downstream section using Manning’s formula (Figure 9.0)

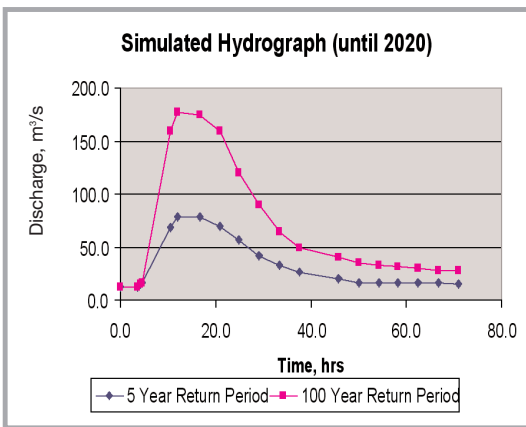


Figure 8.0: Simulated Hydrograph Until 2020 for Raia River (Darus, 2002)

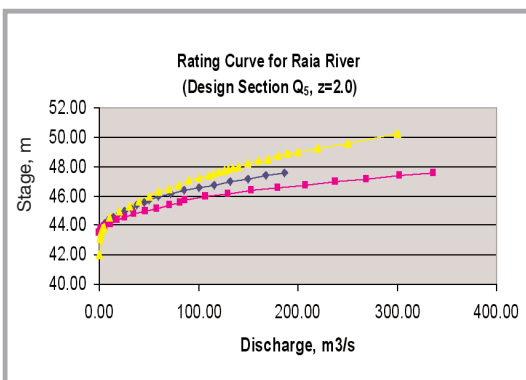


Figure 9.0: Rating Curve for Raia River at CH2800 m

4.3 Bed Material

Bed material samples from each section, i.e. downstream and upstream of design reach were used for the simulation process (Figure 10.0). Each sample is divided into five size fractions, and the size for each fraction is represented by its geometric mean diameter. The mean size of the bed material decreases toward downstream showing the natural characteristics of the Raia River at the study reach.

4.4 Bank Material

Sample of bank materials for each station, left and right bank was taken at mid-point between bed and water level. The characteristics of these sample associated with bank cover will determine the erodibility factor F_h value for each particular river section.

The presence of vegetation along the river banks once more shows the natural characteristics of the study reach.

4.5 Simulation Process

The mathematical model, FLUVIAL-12 was employed to simulate and to identify the instability problem occurring in the design reach especially at the riverbank. A total of 89 cross sections were employed to represent the riverbed geometry. Graf’s equation for sediment transport was used for this sand-bed river. The parameters used in the simulation process are as follows:

- a) Different design cross sections were used in the simulation process ranging from side slope of $z = 2.0$, $z = 1.5$ and $z = 1.0$. The purpose of this process is to identify which section produces the best stable section that has minimum erosion and sedimentation in the channel.

- b) Comparison of two bank erodibility factor of $F_h = 1.0$ and $F_h = 0.5$ was also made to establish the various changes occurring at the section and bank.

- c) Roughness in terms of Manning’s n obtained from calibration results of 0.045 and 0.025 were used in the model process to identify the variation in the channel capacity.

5.0 SIMULATION RESULTS

Figures 11.0 and 12.0 demonstrate different methods of designing the

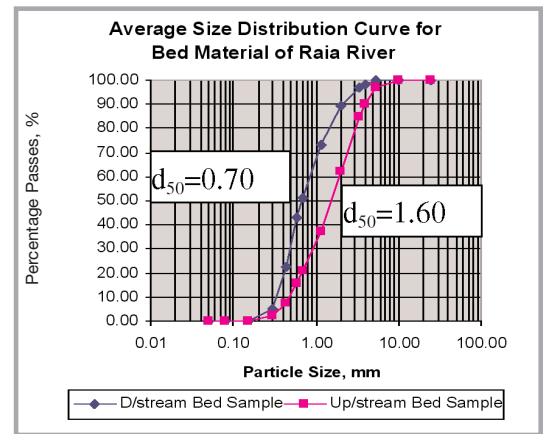


Figure 10.0: Average Size Distribution of Raia River Bed Material

natural stable channel and FLUVIAL-12 seem to produce and agree with the measured cross-section at site.

6.0 SUMMARY AND CONCLUSIONS

A mathematical model for water and sediment routing through alluvial channels was employed to simulate riverbed changes and the instability problem during a specified flow, thereby providing the necessary information for design or other bank protection work.

Simulated results show a cross section with a side slope of $z = 2.0$ is capable of carrying a maximum discharge of 177 m^3/s and also demonstrate minimum changes in bed level and a high degree of stability.

Simulated results also show that channel-bed scour is affected by the

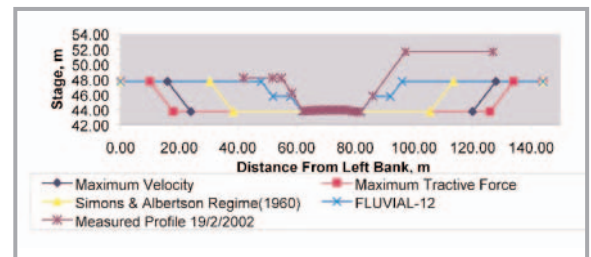


Figure 11.0: Comparison of Different Design Methods for Natural Stable Channel for Raia River (Darus, 2002)

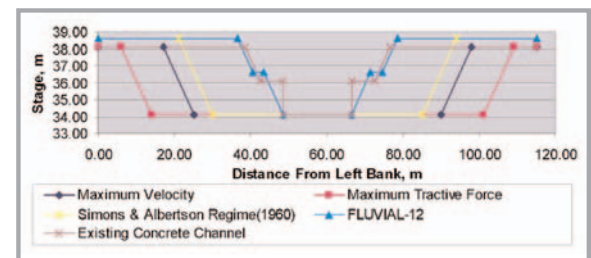


Figure 12.0: Comparison of Different Design Methods for Natural Stable Channel for Pari River (Darus, 2002)

channel curvature. The scour depth increases as flow enters a bend; maximum scour is generally reached at the bend exit, followed by a gradual decrease in transverse bed slope and scour depth with the decline in spiral motion.

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CONDOLENCE MESSAGE

With deep sadness, the Institution would like to announce the demise of IEM Council Member, **ALLAHYARHAM IR. MOHAMAD NIZAR BIN HAJI HASSAN (M 13444)** on **20th March 2004** and wish to extend our condolences to his family.

The Institution would like to thank him for his past support and contributions.