River Restoration Through Bank Stabilization Using FLUVIAL-12: Case Study of Raia River, Ipoh, Perak

AHMAD DARUS, *River Engineering Section, Department of Irrigation and Drainage, Malaysia, Jalan Sultan Salahuddin, 50626 Kuala Lumpur, Malasysia*

AMINUDDIN AB. GHANI, *Deputy Director, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

NOR AZAZI ZAKARIA, *Director, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

ROZI ABDULLAH, *Research Associate, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

CHANG CHUN KIAT, *Research Officer, REDAC, Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

ABSTRACT
River restoration defined as the return of a degraded river ecosystem to a close approximation of its remaining natural potential. Many types of practices such as dam removal, levee breaching, modified flow control, bio-engineering methods for riverbank erosion control are useful on channel construction. A tension exists between restoring natural fluvial processes and ensuring stability of the completed project. Sediment transport analyses are a key aspect of design since many projects fail due to erosion or sedimentation. Existing design approaches range from relatively simple ones based on river classification and regional hydraulic geometry relations to more complex two- and three-dimensional numerical models. This paper outlined the application of mathematical model (FLUVIAL-12) for assessment of hydraulic analysis in the form of one-dimensional flow and sediment transport computations in achieving bank stability.

1 Introduction

The term "river restoration" is often erroneously used to refer to any type of river corridor manipulation. In this paper, "restoration' refers to the return of a degraded ecosystem to a close approximation of its remaining natural potential (U.S. Environmental Protection Agency, USEPA 2000).

Generally, river restoration will focus on four approaches that will improve water quality, that is improving the quality of stormwater entering the river, maximizing the quantity of the urban river riparian corridor, stabilizing the riverbank, and improving the habitat within the river. Riverbamk erosion is the removal of sediment from the banks of the river. It occurs when the amount of shear stress is at or exceeds that which is required to entrain sediments as shown in Figure 1, (i.e. critical shear stress).

Erosion is always occurring as a natural process in rivers (see Figure 2); however, rates of erosion can be altered by a variety of factors including land use practices and changes in riparian vegetation.

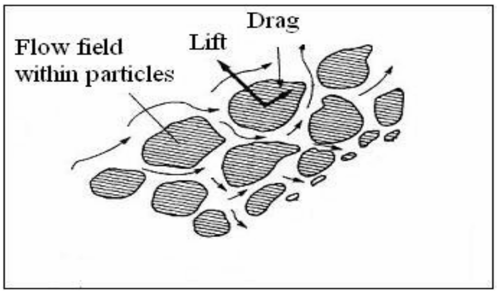

Figure 1 Detachment and entrainment process of particles (Hemphill, 1989).

Altered rates of erosion can cause adverse impacts to aquatic habitat and organisms. Within naturally meandering channels, helical circulation flow patterns erode particles from outside mender bends and deposit them on downstream point bars on the inside of meander bends. Once sediments are entrained they are transported varying distances. Deposition occurs when rivers no longer have the energy to carry particles. This erosion and deposition pattern results in rivers moving laterally across floodplains (i.e. lateral river migration).

Figure 2 Riverbank erosion (Chanson, 1998).

The process can result in the creation of beneficial aquatic habitat features such as cut banks under overhanging vegetation and root masses. At low rates of erosion, aquatic habitat features are lost and gained as part of the natural erosion process, and aquatic organisms can acclimate and adapt to this. Erosion can, however, adversely impact aquatic habitat features by removing bank vegetation through accelerated lateral river migration.

At accelerated rates of erosion, more habitat features may be lost than gained or degraded at such rates that aquatic organisms cannot acclimate or adapt. Similarly, entrainment of bed materials (vertical migration) can result in beneficial habitat features such as scour pools if the bed scour is confined to a localized areas. However, large-scale accelerated erosion of bed materials can result in adverse impacts to aquatic organisms by incising channels which eliminates both bed material and undercut banks.

2 Raia River study area

Raia River, which is nearby to town of Ipoh, went through significant changes in, a 2.8 km reach (see Figure 3 & 4) during the 1996 floods. The study reach has a smaller wide and steep natural configuration; the slope and bed material size decrease in the downstream direction; the bed material varies from coarse sand (d_{50} = 1.40 mm) at the upstream end to fine sand (d_{50} = 1.00 mm) downstream.

Figure 3: Flood event at Simpang Pulai in 1996 (Courtesy from DID Kinta /Batang Padang, 1996).

The mathematical model FLUVIAL-12 was used to stimulate the changes during the 1996 flood. This hydrograph which produced the maximum discharge was used in the calibration process. Graf's equation for bed-material load was used in computing the sediment discharge. Channel roughness in terms of Manning's n was selected to be 0.045 in consideration of channel irregularity and the riverbank wascovered with vegetation.

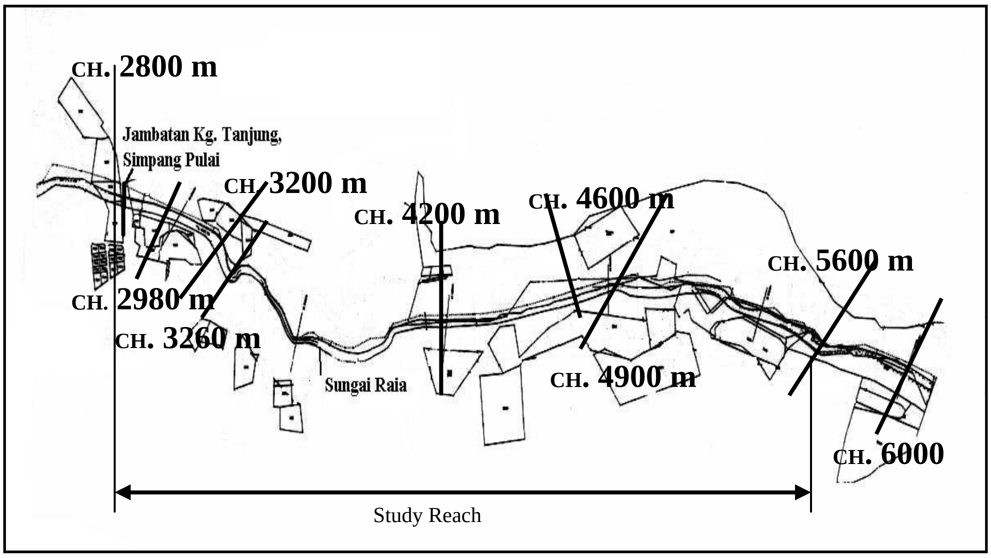

Figure 4 Raia River Study Area (Courtesy from DID Kinta /Batang Padang, 2001).

This study was made to predict the appropriate bank profile for channel geometry with related to slope gradient. Also type of bank protection is significantly important for channel designs but the establishment of initial slope profile with encompasses the type of bank material is really needed.

3 Simulation results

Parameters used in the simulation process are as follows;

a) Different design bank profile were used in the simulation process ranging from side slope of z = 2.0, z =1.5 and z = 1.0. The purpose of these processes is to identify which bank profiles produce the best natural profile that has minimum erosion and sedimentation in the channel.
b) Comparison of two bank erodibility factor of Fh = 1.0 and Fh = 0.5 were also used to established the various changes occurred at the bed and bank section.
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.

Simulation results shown in Figure 5 and 6 are used to describe the fluvial processes and also the changes in bank profile during the peak discharge using the design hidrograf of year 2020, Q_{100}. These predicted bank results are compared with measurements made at several gaging station on 9 February 2002. The simulated results shows that the bank for z = 2.0 is closely related with the measuremnet results.

In a bend, the flow curvature tends to be more unstable and thus create a fully developed transverse circulation flow as it approach the channel curvature (see Figure 5). At this particular section especially at all bend which are critical to bank erosion, special attention of bank protection by using bio-engineering materials needs to be considered.

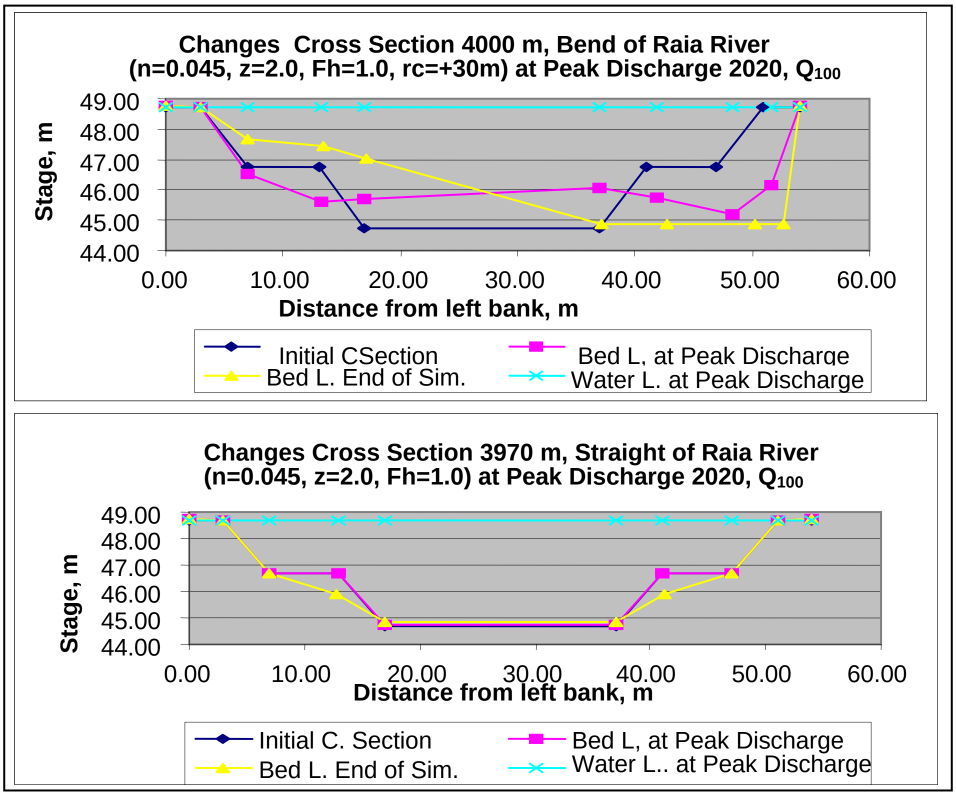

Figure 5 Comparison of Cross Section 4000 m and 3970 m Of Raia River (n=0.045, Fh=1.0, z=2.0) at Peak Discharge 2020, Q_{100}.

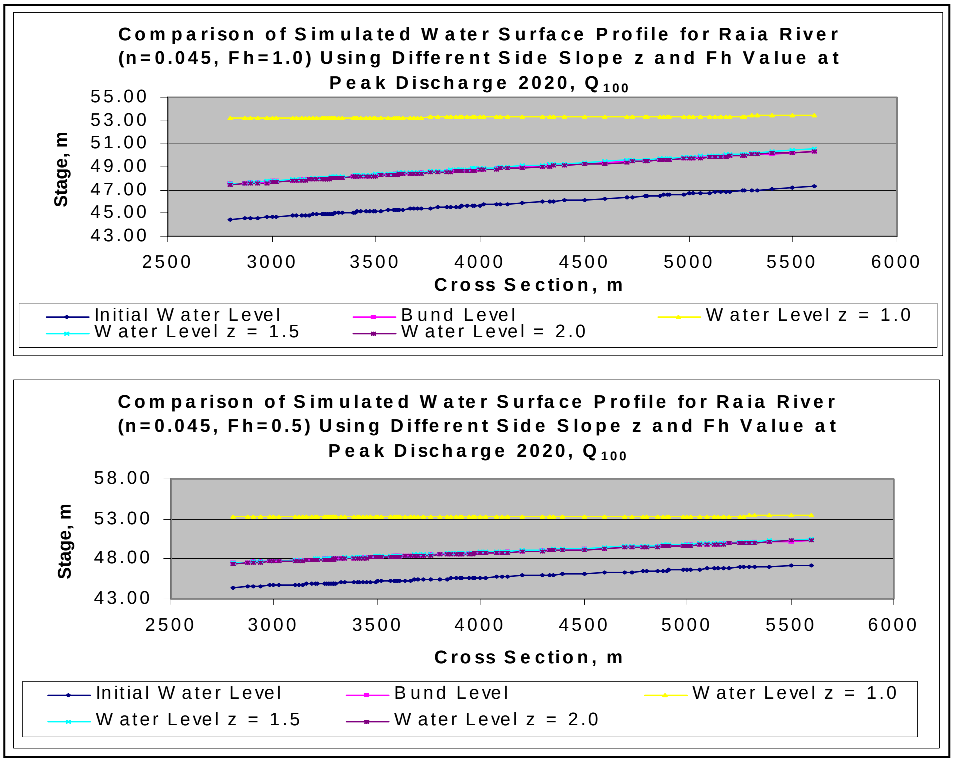

Figure 6 Comparison of Simulated Water Surface Profile of Raia River (n=0.045) Using Different Side Slope z and Fh Value at Peak Discharge 2020, Q_{100}.

4 Discussion and conclusion

Although the number and scope of stream restoration projects are increasing, designs for these projects are often weak in hydraulic engineering. Attempt of using a more powerful, user-friendly software tools such as FLUVIAL-12 are needed for this type of work. Sensitivity analysis and expert advice should be integral parts of such software.

These simulated results show that the riverbank of Raia River can still be maintained as natural condition. Futhermore strengthening of the riverbank can still be carried out by using bio-engineering materials which will provde significant habitat and water quality improvement.

Moreover general public should be educate on these subject as to promote the necessity of a more natural river form.

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