River Confluence Model: Flow Depth Estimator (RICOMOD)

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Introduction

The overflow of water in the river is mainly caused by the heavy rain and inefficient structure of the drainage system especially at its channel junction will make it become worse. At the junction when two rivers combine is defined as river confluence. In this confluence mixing of flow from upstream and lateral stream happens and if the depth of the downstream cannot hold a certain amount of water, this can damage the riverbank and flood can happen. To avoid overflow of water after the confluence junction, it is necessary to predict the maximum depth at the channel before the junction. When this phenomenon happens, field measurement incurs higher cost and time consuming.

Therefore, a mathematical model, that is cheaper and simpler, would be an alternative approach for flood mitigation. This derived model, namely RICOMOD, is implemented by MATLAB software to provide a user-friendly tool for the results analysis. This model could assist the Department of Irrigation and Drainage (JPS) in its decision making regarding the suitable depth ratio to avoid flooding rivers, computing the amount of river flow rates, and validating the results achieved by the experiment methods.

Model Formulation

The schematic layout and geometric details used, are shown in Figure 1 below. The water is assumed to flow from branch channel (channel 1 and channel 2) to the main channel (channel 3). Q is the flow rate of the water flow, b is the bottom width of the channel, θ is the angle of the branch channel to the axis of the main channel, y is the flow depth of the water flow, T is the top width of the cross-sectional area of the water, z is the side slope value of the channel and α is the side slope angle of the channel from the horizontal line. Every parameter with subscripts 1, 2, and 3 indicate the parameter that belongs to channel 1(upstream), channel 2(lateral stream), and channel 3 (downstream) respectively.

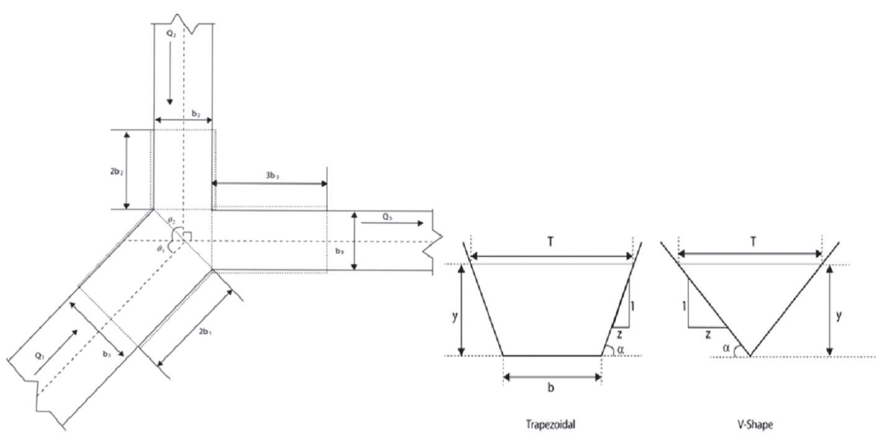

Figure 1: Schematic Layout of Combining Flow Type Junction and Geometric Details of the Typical Trapezoidal and V-Shape Cross Sectional Area

By applying the continuity equation and momentum principle, and by considering the assumptions that have been made in which friction is neglected and a horizontal smooth junction is assumed, therefore, the general equation of the behavior of water flow at combining channel junctions was proposed and defined such as in Table 1 (Refer: Shahari et. al, 2021)

Table 1: The General Equation of the Behavior of Water Flow

	The General Equation of the Behaviour of Water Flow at Combining Channel Junction
Trapezoidal	$(1+2k_3)\left[\frac{1}{2}\left(y_r^2-1\right)+\frac{k_3}{3}\left(y_r^3-1\right)\right]$ $=F_3^2\left(1+k_3\right)^2\left[1-\frac{(1+k_3)}{y_r}\left\{\frac{q_r^2}{\left(b_{r2}+k_3y_r\right)}\cos\theta_2+\frac{\left(1-q_r\right)^2}{\left(b_{r1}+k_3y_r\right)}\cos\theta_1\right\}\right]$
V-shape	$\frac{1}{3}\left(y_r^3-1\right)=\frac{1}{2}F_3^2\left[1-\frac{1}{y_r^2}\left\{q_r^2\cos\theta_2+\left(1-q_r\right)^2\cos\theta_1\right\}\right]$

Simplification of the General Equation in the form of Polynomial equations is given in Table 2.

Table 2: The New General Equation of the Behavior of Water Flow for Trapezoidal & V-Shape Channel

	The New General Equation of the Behaviour
Trapezoidal	$r_t\left(y_r\right)=f.y_r^5+g.y_r^4+h.y_r^3+i.y_r^2+j.y_r+l$ where, $r_t\left(y_r\right)=0,$ $f\left(k_3\right)=\frac{k_3^2}{3}\left(1+2k_3\right),$ $g\left(k_3,b_{r1}\right)=\left[\frac{b_{r1}}{3}+\frac{1}{2}\right]\left(k_3\right)\left(1+2k_3\right),$ $h\left(k_3,b_{r1}\right)=\frac{b_{r1}}{2}\left(1+2k_3\right),$ $i\left(k_3,F_3\right)=\left(-k_3\right)\left[\left(\frac{k_3}{3}+\frac{1}{2}\right)\left(1+2k_3\right)+F_3^2\left(1+k_3\right)^2\right],$ $j\left(k_3,b_{r1},F_3\right)=\left(-b_{r1}\right)\left[\left(\frac{k_3}{3}+\frac{1}{2}\right)\left(1+2k_3\right)+F_3^2\left(1+k_3\right)^2\right],$ $l\left(k_3,F_3,q_r,\theta_1\right)=F_3^2\left(1+k_3\right)^3\left(1-q_r\right)^2\cos\theta_1$
V-Shape	$r_v\left(y_r\right)=\frac{2}{3}y_r^5+i.y_r^2+l$ where, $r_v\left(y_r\right)=0,$ $i\left(F_3\right)=-\left(\frac{2}{3}+F_3^2\right),$ $l\left(F_3,q_r,\theta_1\right)=F_3^2\left(1-q_r\right)^2\cos\theta_1$

Graphical User Interface Model

The RICOMOD is performed using a MATLAB solver as shown in Figure 1 below. The model attempts to determine the depth ratio of channel 1 (upstream) to channel 3 (downstream). The left-hand side is the first part of the system where the system displays a platform that allows the user to manually input the values for physical constant, bottom width, Froude number, flow rate and angle. The calculate button will calculate the value of the polynomial equation based on the input values. The approximate button will calculate the maximum depth ratio. For example, with 0.5 amount of flow rate (Q) from lateral stream (C2) to downstream (C3) can uphold water with a maximum depth ratio of 1.0461 from upstream (C1) to downstream (C3). This software can give information for understanding the river flow as well assist engineers in designing the river confluence. This software allows us to quickly see the effects of changes in various parameters on the input and see how it influences the output.

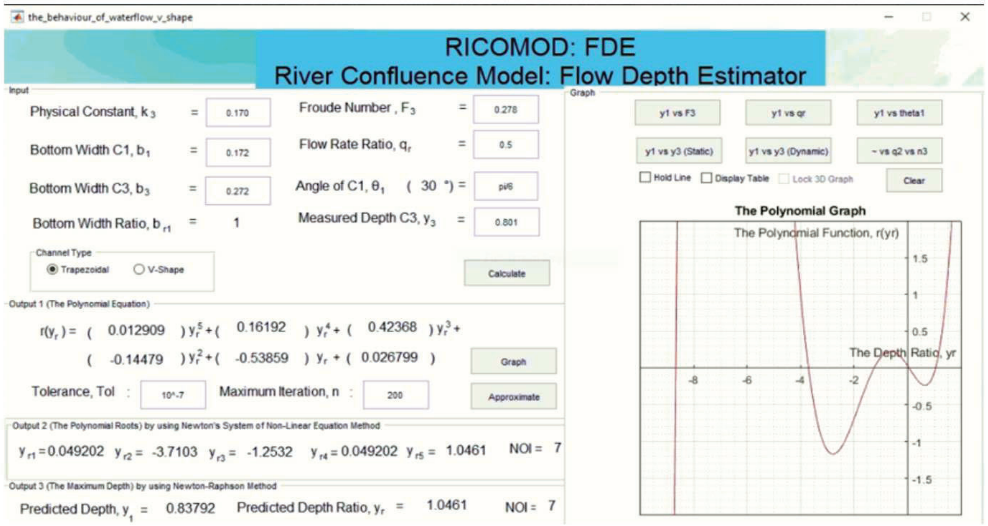

Figure 1: Interface of The Behavior of Water Flow

The Results

The general equations of open-channel flow for the types of trapezoidal and V-shaped cross-sectional channels have been developed in the form of polynomial equations with degree five by considering two branch channels that unite, forming a single main channel. The modified equations consist of five parameters, which represent both physical and flow characteristics of the water. The parametric investigation has been carried out to understand the interdependence of some of the responding variables, where the Froude number gives the greatest impact on the water flow depth. Furthermore, the rate of increase of depth flow for the trapezoidal channel is higher than the V-shaped channel as the Froude number and flow rate ratio increase. Therefore, the trapezoidal channel is recommended to avoid water overflow in the combining open-channel flow. Nevertheless, this study relates only to combining open-channel flow. Thus, the modified equation of dividing flow for trapezoidal and V-shaped channels may be considered for future research.

References

[1] Nor Azni Shahari, Nor Arif Husaini Norwaza, Iskandar Shah Mohd Zawawi, Nurisha Adrina Mohd Kamarul, Aimi Said "Numerical Investigation on the Behavior of Combining Open-Channel Flow" *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 23, no. 2, pp. 1110-1119, 2021