1-D Shallow water model for industrial practice

Application to the River Romanche

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Context

The Romanche, a river in the French Alps, is currently facing large changes. A new hydropower facility is being built in order to replace older power plants. For this project, as well as for many others around the world, it is important to be able to simulate quickly and efficiently the behavior of the river under a range of discharges corresponding to some human or natural inputs.

1-D models have low computational costs. In order to reach appreciable precision, equivalent 1-D cross sections were generated from previously calibrated 2-D steady simulations. This approach leads to richer information than local 1-D measures, based on validated data.

1-D shallow water model

A first steady solution can be obtained thanks to (Kroger et al. 2011):

$$\frac{\partial \Omega}{\partial t} + \frac{\partial Q}{\partial x} = \frac{\partial Q}{\partial x} = qL$$

Saint-Venant equations are used for time solving:

$$\left\{ \begin{array}{l}
\frac{\partial \Omega}{\partial t} + \frac{\partial Q}{\partial x} + \frac{\partial Q}{\partial x} = qL \\
\frac{\partial Q}{\partial t} + \frac{\partial Q}{\partial x} + g\Omega \left( \frac{\partial Z}{\partial x} + J \right) = gQL,
\end{array} \right.$$  

where $\Omega$ is the cross section area, $Q$ is the discharge, $qL$ is the lateral input discharge, $u$ is the velocity in the direction of the cross section, $\Omega$ is the gravity acceleration, $Z$ is the elevation of the free surface, $J$ is the friction slope and $\eta$ is a coefficient which allows to take into account or not the velocity of the lateral discharge. The domain is discretized using finite volume method; MacCormack is used as fraction law (Machado et al. 2011), $k$ being the characteristic size of the bottom roughness, $a$ the hydraulic radius and Re the Reynolds number.

For $k/Re < 0.05$ For $0.05 < k/Re < 0.15$ For $k/Re > 0.15$

$$\frac{\Omega}{Q} = 1,963 \left[ \frac{k}{Re} \right]^{-1} \quad \frac{\Omega}{Q} = 182,8 \left[ \frac{k}{Re} \right]^{-1} \quad \frac{\Omega}{Q} = 4,98 \left[ \frac{k}{Re} \right]^{-1}$$


References:


Model fitting

Fitting is performed upon downstream hydraulics. Several Goodness-of-Fit factors can be computed: NSC, index of agreement, $R^2$, etc.

Optimization methods:

1. Scanning N-dimensional space of parameters
2. Simulated Annealing Method (heuristic)

Optimization over:

(a) Roughness in several zones of the river
(b) Tuning factors on the wet perimeter formula

Integration into Simulink

Fortran or C codes can be integrated into Matlab or Simulink (D-Functional). Fast computing routines can be used in a user-friendly environment.