Universidad de Zaragoza

# Simulation of steady flow in channels with Canalflowmodel

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# 1 CONTENT

# 2 INTRODUCTION

The purpose of this practice is to approach the modelling of free surface flows using simple tools for the mathematical modelling of free surface flows with a mainly one-dimensional character.

There are different tools that provide different useful characteristics for the modelling of this type of flows. An example of a tool is **canalflowmodel** (http://canalflowmodel.net). One of the main advantages of this model, in terms of its use, is the possibility of saving the information in the cloud through a ticketing system. As we will see in practice, this is done by modifying the name of the project, which is normally given by the concatenation of a generic identifier and an identifier provided by the user. Another advantage of the model is its numerical robustness, since, as we will see, it shows good behavior in all types of regimes, regime changes and other common phenomena in modelling.

Therefore, it is proposed to carry out a set of tasks that are summarized in the following points:

- Modelling convergence to stationary flow in **simple channels, section changes and slope changes**. We will emphasize the importance of the boundary conditions.
- Modelling transient flow in simple channels, s**ection changes and slope changes**. We will emphasize the importance of the initial conditions.

The program numerically solves the differential equation system of mass conservation and motion averaged over the wet section using finite volumes:

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0 \tag{1}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+gA\frac{\partial h}{\partial x}=gA(S_0-S_f) \tag{2}$$

Where $(A, Q)$ are the wetted cross-sectional area and the flow through it respectively, h is the maximum water depth in each section A and g is the gravitational acceleration. The right-hand terms in the equation of motion are the bed slope $S_0$ defined as the derivative (with a minus sign) of the bed elevation $z_b$ in the x-direction and the slope of friction loss that we will formulate with Manning's law as a function of the roughness coefficient n and the hydraulic radius $R=A/P_m$ with $P_m$ being the wet perimeter.

$$S_f=\frac{n^2Q|Q|}{A^2R^{\frac{4}{3}}} \tag{3}$$

## 1.1 CHANNEL WITH CONSTANT SLOPE

A new project will be generated which will include a channel with a rectangular section ($A=bh$, $P_m=b+2h$) and a constant slope as shown in figure 1.

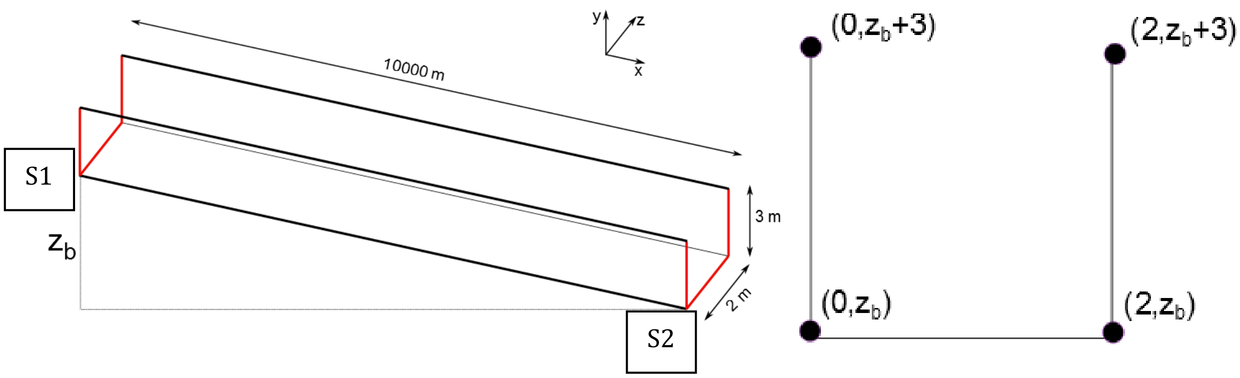


*Figure 1 Channel sketch (left) and section sketch*

The section geometries S1 and S2 are the same except for the origin associated with the dimension of the section itself which is defined by the $z_b$ dimension calculated for each of the channel configurations using the data shown in table 1 (assuming $z_b$ =0 for section S1).

| Configuration | $S_o$ | n |
|---|---|---|
| **C1** | 0.0001 | 0.012 |
| **C2** | 0.0001 | 0.022 |
| **C3** | 0.001 | 0.012 |
| **C4** | 0.001 | 0.022 |
| **C5** | 0.0001 | 0.012 |
| **C6** | 0.0001 | 0.022 |

*Table 1 Channel configurations*

Although section S2 is the same for all configurations, the tables representing section S1 must be constructed by hand from $z_b$ for each channel configuration in Table 1.

In order to generate a configuration to model the proposed configurations it is necessary to follow the following steps:

1. Go to canalflowmodel.net and press **Customization**
2. The length, the number of sections and the number of points defining the sections are defined in the **Reach** panels:
   a. In the Section properties (**Properties** button) select the required number of sections defining the channel and the maximum number of points required. In this case, 2 sections and 4 points per section. Caution It is important to take into account that every time the number of points or the number of sections is modified, the values entered in the sections become the default ones, so it is necessary to define these values before starting to define the sections.

    b. Enter the channel length in meters
3. In the **sections** panel, the geometry of each section is defined
    a. Enter the coordinate table ($z, y$) of the points that define each section
4. In the **parameters** panel define the channel's Manning coefficient n as well as the minimum depth value. This value is normally the value associated with the $d_{50}$ value of the modelled material.
5. In the section **Initial Conditions** select "dry" as the initial condition of the system you are going to simulate.
6. In the section **Upstream condition** the hydrographic curve defined by points (t,Q(t)) must be specified in case of defining a flow input condition.
7. In the section **Downstream condition** select the type Q(h+Z). This type of output is very useful and is defined through a table (Q,h+Z) matching the characteristic curve of a hydraulic element, field measurements or specific conditions. In particular, it is possible to define a curve associated to the normal flow or uniform flow.
8. It is not necessary to enter gates, so the panels **Gates** and **Regulation** can be left unchanged.
9. In the **Simulation parameters** it is convenient to modify the values **Total simulation time**. Moreover, it is possible to specify the interval of longitudinal information generation specified in **Inter Data** as well as the frequency of information for the measurement probe (**Inter. Gauging)**. These values must be such that 100 or 200 time periods can be seen, so for the case in which the final time is 72000 seconds, here we must specify 360-720 s.
10. In the computational parameters, it is important to know that there is the possibility of modifying the number of cells used in the spatial discretization of geometry. In this case, we can select 50 cells ($\Delta x$=200m).

Once the geometry has been generated, and after pressing the simulate button, **it is advisable to rename the case from the ticket assigned by the system in order to avoid overwriting** the information of the previous ticket. After assigning a full name to the ticket, a window will appear informing you about the progress of the simulation.

You can also use the previously generated ticket ***channelw2***

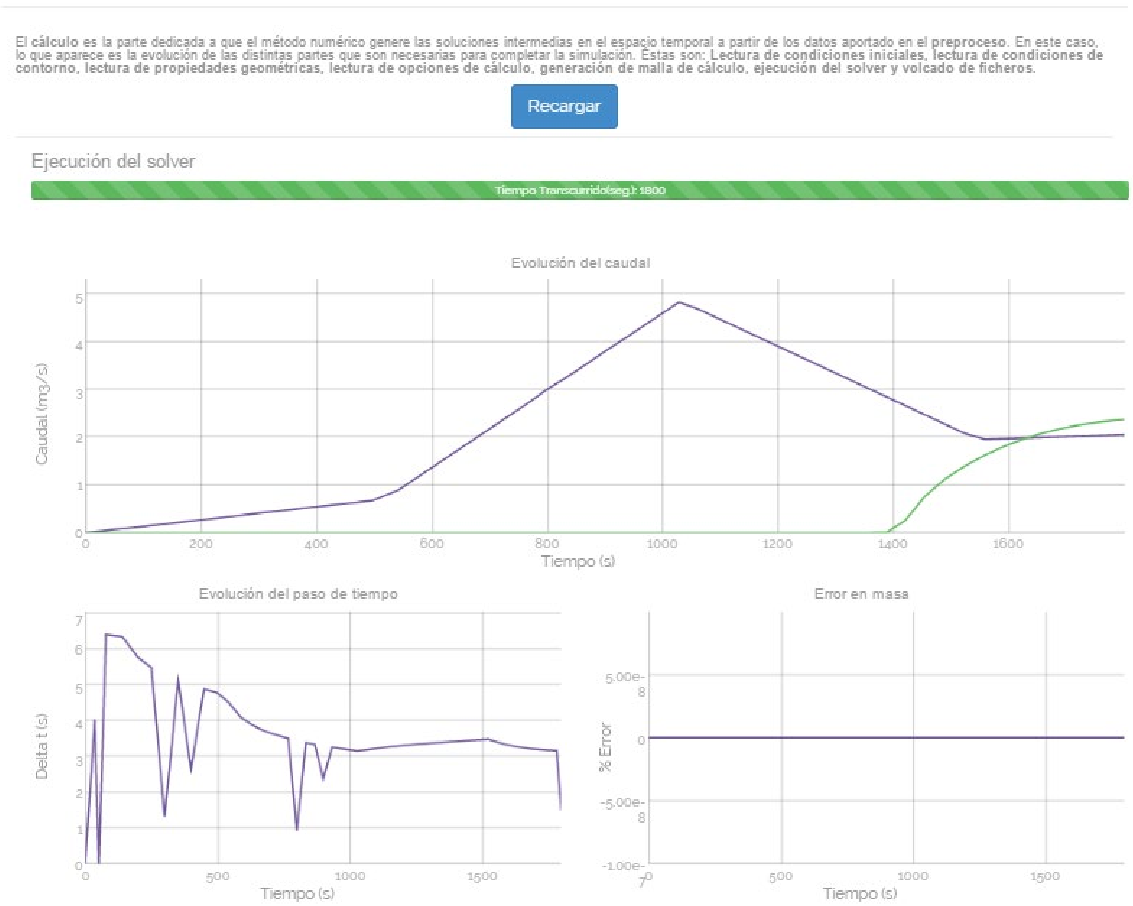


*Figure 2 Simulation evolution table*

Once the simulation has finished, the button that allows access to the post-processing of the information will be activated and is labelled as **Step III- Postprocessing**. In this window, level and flow information will be shown along the domain. For the selected points of time it is possible to simulate the desired conditions.

It is also possible to download the information using the button **Download results**. Both the **sonda.out** and the **evolucionq.out** file will be relevant for this practice. The first one provides information about time, depth, velocity and flow rate at the measurement point and the second one provides information about input and output flows.

### 1.1.1 Exercises

Considering the scenarios in table 2:

1. Apply the Uniform Flow downstream boundary condition (for the channel slope), obtain a uniform profile and note the **Normal Depth** for each of the 6 configurations in table 2.
2. Analytically calculate the **Critical Depth** for each of the 6 configurations in table 2.

3. Modify the downstream boundary conditions to generate a non-uniform stationary flow in case 1 and 3. Display the longitudinal profile of the wetted area in the steady state for each configuration.

**Notes:**

- Note that the model will perform a transient analysis so you should let enough time pass to ensure stationary conditions. Raise the flow rate from 0 to the requested smoothly (in 500 seconds for example) to help the model converge.
- Choose an end time long enough for your convergence (72000 seconds).

| Configuration | $S_o$ | n | Inlet flow rate ($m^3/s$) | Critical depth (m) | Entrance velocity (m/s) | Normal depth (m) | Fr |
|---|---|---|---|---|---|---|---|
| ***C1*** | 0.0001 | 0.012 | 1 | | | | |
| ***C2*** | 0.0001 | 0.022 | 1 | | | | |
| ***C3*** | 0.001 | 0.012 | 1 | | | | |
| ***C4*** | 0.001 | 0.022 | 1 | | | | |
| ***C5*** | 0.0001 | 0.012 | 0.5 | | | | |
| ***C6*** | 0.0001 | 0.022 | 0.5 | | | | |

*Table 2 Simulation characteristics for each of the configurations*

Display the longitudinal profile of the wet area in the steady state for each configuration.

## 1.2 CHANNEL WITH OBSTACLES UNDERNEATH

Define a new case using the geometry shown in Figure 3.

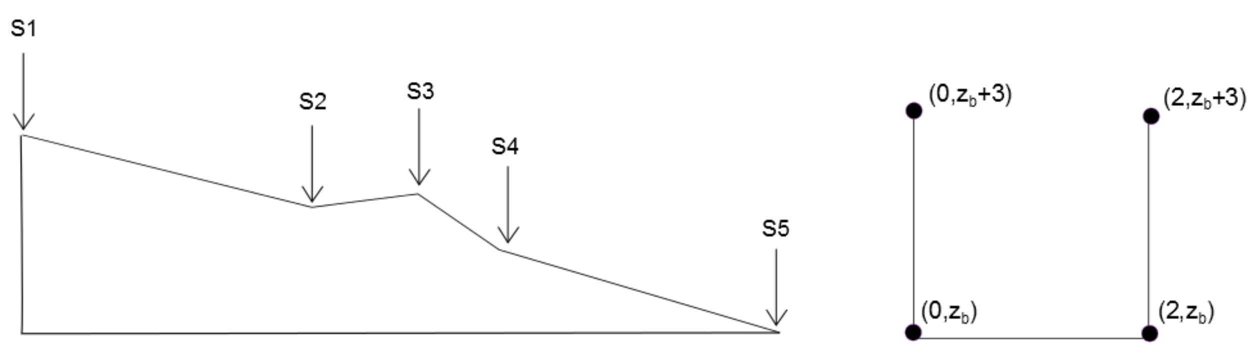


*Figure 3 Sketch of the longitudinal case profile with obstacles underneath*

Note that the dimensions of each of the sections are defined by the points shown in figure 3 using table 3. **Important**: Remember to define the section with 5 sections and 4 points per section.

| Configuration | Section position | $Z_b$ |
|---|---|---|
| **S1** | 0 | 10 |
| **S2** | 4950 | 5.05 |
| **S3** | 5000 | 6.05 |
| **S4** | 5050 | 4.95 |
| **S5** | 10000 | 0 |

### 1.2.1 Exercises

Using a sufficiently long simulation time (1 hour) and starting from an initial dry state, two simulations are requested to be carried out using:

1. Manning's n of 0.012 (minimum draught 1 mm) and flow rate 0.5 m$^3$
2. Manning's n of 0.012 (minimum draught 1 mm) and flow rate 1m$^3$.

Graphically display the longitudinal profile h+Z and Z (use the last file hZ.out that you will find in the level folder of the file that can be downloaded once the simulation has finished).

## 1.3 CHANNEL WITH SECTION CHANGE

2 Define a new case that allows you to define the following geometry:

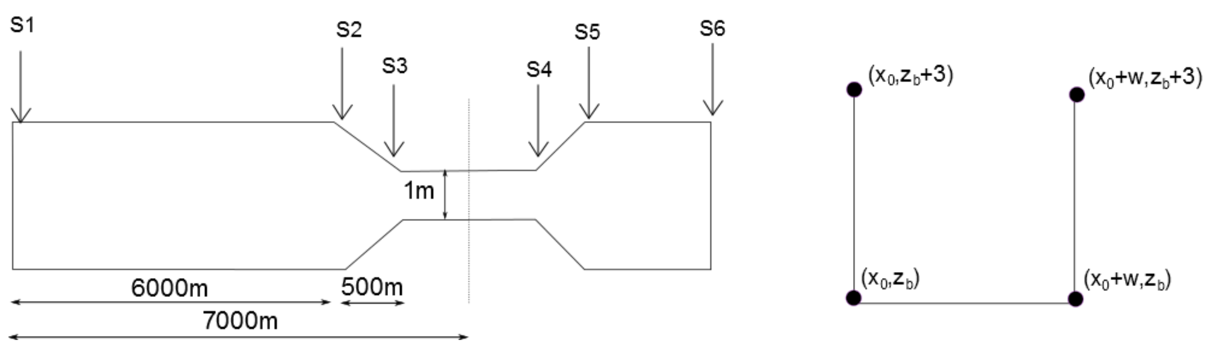


*Figure 4 Scheme of the longitudinal case profile with change of section*

The following data is needed to define the case:

- The total length of the section to be simulated is 10000m with a constant 0% slope. Furthermore,
- The width of the sections S1, S2, S5 and S6 is 2 m
- The width of the sections S3 and S4 is 1 m.
- All sections are aligned with the longitudinal axis (axial symmetry).

**Important**: Remember to define the section with 5 sections and 4 points per section.

### 2.1.1 Exercises

Using a sufficiently long simulation time (1 hour) and starting from an initial dry state, two simulations are requested with a Manning' s n of 0.012 (minimum depth 1 mm) and flow rates of 0.5 m$^3$ and 1m$^3$. Graphically display the longitudinal profile of h+Z and Z.