# Automatic cross-section estimation from 2D model results

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## Introduction

Both in river science and consulting practice, numerical models aid in a variety of tasks including system analysis, operational predictions and model-based design. The specific task determines which model structure is preferable. In many cases, this structure will be a detailed 2D or 3D numerical model. However, there are many applications for which 2D or 3D models are impractical, such as operational forecasting and long term analyses that are a burden on the computational budget. In such cases one-dimensional models leverage their computational speed but arguably compromise on accuracy.

Although 1D models are faster, they require more assumptions and abstractions. For example, model results are known to be very sensitive to the choice of cross-section location. However, two-dimensional models contain valuable information, such as hydraulic connectivity, that can be used to improve onedimensional models.

In this abstract we describe a method that constructs a 1D model from a 2D model using minimal human intervention. We aim to drastically reduce the building cost and increase the accuracy of 1D models. Once generated, the 1D model could be used as a surrogate for the preferred 2D model in computationally constrained tasks.

## Methodology

We assume that the following information is available:

- Hydraulic results of a 2D model from a computation with slowly, monotonically rising waterlevels.
- A list of locations $l_k = (x_k, y_k)$ and distances $L_k$ between cross-sections.

Fig. 1 gives a graphical overview of the problem. For a given control volume, our aim is to match the rating curves between the 1D and 2D models:

$$h_{1d}(Q)=h_{2d}(Q) \quad (1)$$

We aim to achieve this by two-step matching of geometry and hydraulic resistance. In this abstract, we only discuss geometry matching. The control volumes are automatically assigned to cross-sections on basis of the k-NN (nearest neighbour) classification algorithm.

### Geometry matching

The 2D geometry within a control volume is not necessarily homogeneous – straightforward mapping to a 1D cross-section is therefore not always possible. We do not aim to construct a symmetrical cross-section that (vaguely) resembles reality, but one that replicates the lumped 2D characteristics by matching the wet volume at any given time. However, 1D cross-sections cannot reproduce the 2D water balance in the control volume if the water levels are inhomogeneous. Such conditions may occur if the floodplain is partitioned by, for example, summer-dikes. To account for such twodimensional behaviour we introduce a subgrid correction term. We model this term as a three-parameter logistic function. This function releases extra volume if a certain threshold is exceeded. The final equation for matching the geometry is:

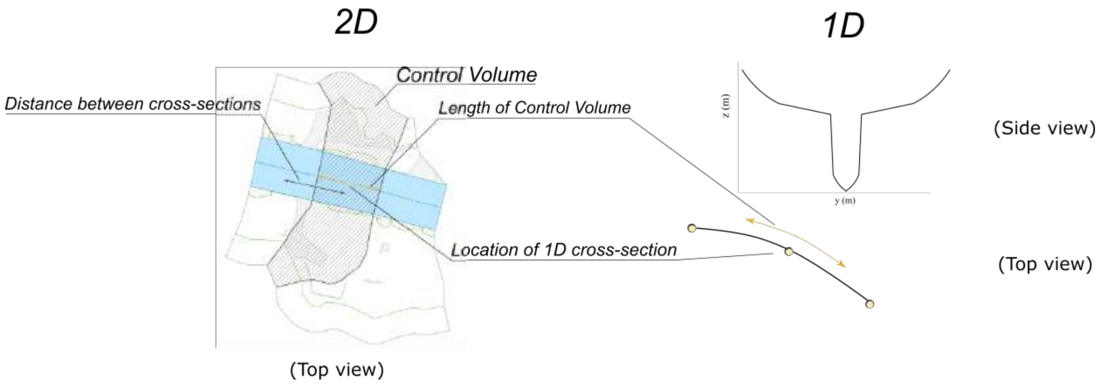


*Figure 1. Schematic overview of the problem. Modified from Berends (2015).*

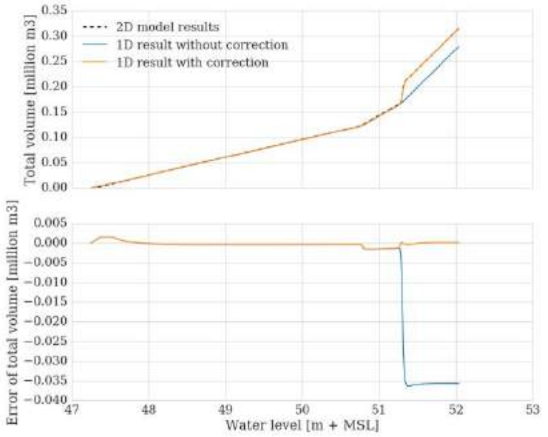


*Figure 2. Comparison of 2D and 1D graphs showing water volume in the control volume against the water level in at the cross-section location.*

$$A_k(\breve{h}) = L_k{}^{-1}\left[\sum_{i=1}^{n} h_i(\breve{h})A_i + \sum_{j=1}^{m} C_j(\breve{h})\right] \qquad (2)$$

with

$$A_i \in A_w$$

and correction term $C$ [$m^3$]:

$$C(\breve{h}) = \Xi\left(1 + e^{\log(\delta)\tau^{-1}\left(\breve{h}-\left(\gamma+\frac{\tau}{2}\right)\right)}\right)^{-1}$$

where $A_k$ is the cross-sectional area [$m^2$], $A_w$ the collection of wetted 2D cells in the control volume, $h$ the water level in a 2D cell, $\breve{\boldsymbol{h}}$ the water level at the location $\boldsymbol{l_k}$ [m], $n$ the number 2D cells in the control volume, $m$ the number of correction terms, $h$ the waterdepth in a computational cell [m], $A$ the planview area [$m^2$] of a cell, $\boldsymbol{\Xi}$ the required volume correction [$m^3$], $\boldsymbol{\tau}$ the transition height over which the volume become available to the 1D model [m], $\boldsymbol{\delta}$ an accuracy parameter [-] and $\boldsymbol{\gamma}$ the water level at which the extra volume becomes available [m]. The parameters $\boldsymbol{\tau}$, $\boldsymbol{\Xi}$ and $\boldsymbol{\gamma}$ are determined through minimisation of the error between the 2D and 1D volumes. To our knowledge, the only currently available software package that is able to incorporate a term like $\boldsymbol{C}(\breve{\boldsymbol{h}})$ is SOBEK, albeit with a limit of $m=1$. Finally, we simplify the generate cross-section by line generalisation using the method proposed by Visvalingam and Whyatt (1993).

## Application to a simple case

### Case description

We apply this method to a simple case of a straight, linear river channel. We modelled this river in Delft3D Flexible Mesh. The cross-section has a simple two-stage rectangular profile geometry. Part of the floodplain is partitioned by an embankment or summer dike with a crest level at approximately 51.3 m. As a result, a significant part of the floodplain will be flooded if the water level on the main channel has well exceeded the floodplain base level.

### Results

Fig. 2 shows the comparison between the 1D and 2D volumetric graphs. The linear segment from 47.3 to 50.8 m. is consistent with a rectangular profile. The sudden change in slope at 50.8 m results from a sudden increase in available area which, in this case, signifies the wetting of the floodplain. At 51.3 m. we observe an increase in volume at nearly nonvariant water levels. This is typical for the flooding of a floodplain compartment behind an embankment. Onedimensional cross-sections will, by definition, be unable to reproduce this behaviour unless specifically accounted for. We see that the subgrid correction term introduced above adequately reduces volume error. The step from Fig. 2 to 1D cross-sections is straightforward.

## Conclusion and future work

In this abstract we introduced a method to automatically construct onedimensional profiles from 2D models. We demonstrated that we can use information from the 2D model to accurately generalise the cross-sectional flow area. We quantified the error of the 1D approximation and minimised it using a novel subgrid correction term. Future work will focus on validation of the method against 2D results for various cases ranging from riverine to estuarine applications and study of the applicability of 1D surrogate models in a multifidelity framework.

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