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Discussion

Experimental study of velocity fields in rectangular shallow reservoirs

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Introduction

The authors present the results of a new experimental study to improve the flow classification in rectangular shallow reservoirs. Although previous papers have paved the way for the classification (Dewals *et al.* 2008, Dufresne *et al.* 2010), the authors are complemented for the detailed flow-field measurements conducted for a high number of reservoir geometries, complementing the previous observations based on Large Scale Particle Image Velocimetry (Dewals *et al.* 2008).

The studied rectangular reservoirs have a length L and a width B, and the width of the inlet and outlet channels is b. The authors refer to a non-dimensional shape parameter $T = L/(B-b)^{0.6}/b^{0.4}$, which is actually a multiple of the shape parameter $L/[(B-b)/2]^{0.6}/b^{0.4} = 2^{0.6}T \approx 1.516\,T$ as defined by Dufresne *et al.* (2010). For the tested hydraulic conditions, the authors report that for $T < 4.09$, the flow remains symmetric, while for $T > 4.48$, the flow is asymmetric, with a transition zone between the two limits, corresponding to "unstable" flow pattern. Repeated tests under similar conditions lead alternately to a symmetric or an asymmetric flow field. It is intended below to shed light on this transition zone using 2D numerical simulations. The authors state that the flow in the transition zone is sensitive to so-called "external perturbations", whereas we argue that the flow is particularly influenced by the initial test conditions. Using a particular post-processing of the computed flow fields, a hysteresis effect is detected.

Numerical simulations

The simulations are based on the numerical model of Dewals *et al.* (2008), which was validated for the same test set-up as in the discussed paper. The model solves the shallow-water equations based on a finite volume scheme (Erpicum *et al.* 2010). Dewals *et al.* (2008) present experimental and numerical results for only eight different geometric configurations, varying either the length or width of a reference reservoir (6 m × 4 m). In contrast, the authors performed flow measurements for 41 different geometric configurations. Therefore, the numerical results corresponding to these new configurations are discussed below, specifically focusing on the transition zone.

To investigate the effect of the flow history on the final steady flow field in the transition zone, all numerical simulations have been performed twice, starting from two different initial conditions: either water at rest (symmetric) or an initially

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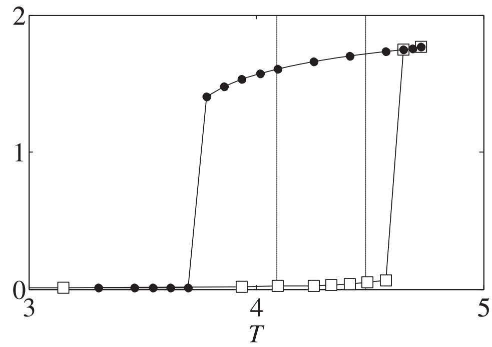

Figure 1 Global moment M versus. shape parameter $T = L/[(B-b)^{0.6}b^{0.4}]$. (□) and (●) refer, respectively, to simulations conducted with water at rest and an asymmetric flow field as initial condition. Dashed vertical lines indicate the experimental thresholds $T = 4.09$ and $T = 4.48$

asymmetric flow field. Over thirty 2D simulations were performed for different geometric configurations.

Results

To compare the symmetric and non-symmetric flow fields, an indicator of the "intensity" of flow-field asymmetry was introduced by Dewals *et al.* (2008). It is defined as moment m of the u-velocity field with respect to the reservoir centreline, which may be expressed in non-dimensional form as

$$m = \frac{2}{UB^2}\int_{-B/2}^{B/2} uy\,\mathrm{d}y \tag{D1}$$

with u being the velocity component in the longitudinal direction, y as the transverse coordinate and $U = Q/(Bh)$ as the reference velocity corresponding to a plug flow in the whole reservoir, with h as the water depth and Q as the total discharge.

The moment is $m = 0$ for a symmetric velocity profile, while it quantifies the deviation of the actual velocity profile from a symmetric for non-symmetric flow fields. The global moment M is defined as the norm of m, averaged along the reservoir length as

$$M = \frac{1}{L}\int_0^L m\,\mathrm{d}x \tag{D2}$$

The global moment is used below as the scalar indicator of flow-field asymmetry. Figure 1 shows the global moment M versus the shape parameter T for each performed simulation, confirming that for low values of T the flow pattern is symmetric, whereas it becomes asymmetric for high values of T. In the ranges $T < 3.75$ and $T > 4.6$, the computed flow pattern does not depend on the flow history.

The computational results also reveal a range of geometric parameters in which both symmetric and asymmetric steady flow patterns may exist depending on the initial conditions. The transitions between flow patterns do not occur for the same value of T as the geometry is varied. If the basin length is gradually increased thereby increasing T, the transition occurs for a higher value of T than under the reversed transition if the basin length is gradually reduced. These results are consistent with the non-linear nature of the governing equations, enabling the system to converge towards different steady states depending on the initial conditions. Similarly, multiple steady-state solutions were observed for transitions at low Reynolds numbers (Mizushima and Shiotani 2001).

Although the computed transition zone ($3.75 < T < 4.6$) is wider than the experimental, the numerical results qualitatively agree with the experimental observations of the unstable flow field. Since laboratory tests obviously do not enable to perfectly control experimental conditions such as the initial state of the water, the experimental flow fields appear to be randomly either symmetric or asymmetric, whereas they are shown here to be particularly sensitive to the flow history. Making modellers aware of this behaviour is of engineering relevance: If retention basins or desilting structures are designed based on numerical simulations, the stability of the computed flow fields needs to be carefully checked by conducting sensitivity analyses, not only with respect to the modelling parameters but also with respect to the initial conditions. A quantitative agreement between the numerical and experimental results for the transition zone is expected to result by calibrating the turbulence model or by using a more complex model.

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Reply by the Authors

The authors are grateful to the Discussers for their precious contribution, which raises the problem of the effect of initial conditions on the developing flow pattern. As also pointed out by the Discussers, it has not been possible to appreciate this effect in the experiments performed up to now, but the work presented by the Discussers is considered as an interesting base for continuing research on this topic.

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