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Transition between symmetric and asymmetric flow in rectangular shallow reservoirs – a case of maximum dissipation?

Martijn Westhoff (1), Sebastien Erpicum (2), Pierre Archambeau (2), Michel Pirotton (2), and Benjamin Dewals (2)

(1) Earth and Climate cluster, VU Amsterdam, Amsterdam, Netherlands (m.c.westhoff@vu.nl), (2) Department ArGEnCo, University of Liege, Liege, Belgium

Shallow reservoirs are often used in hydraulic engineering as sediment traps or storage basins. Sedimentation within these reservoirs depends on the flow pattern, which in turn depends on the shape of the reservoir. For short rectangular reservoirs, the main jet flows straight from the inlet to the outlet with on both sides identical recirculation zones. In longer reservoirs, however, the main jet reattaches to the side of the reservoir leading to a small and a large recirculation zone.

Previous studies have found an empirical geometric relation describing the switch between these two different flow patterns. In this study, we demonstrate that this switch in flow pattern coincides with a maximization of energy dissipation in the shear layer between the main jet and the recirculation zones. To show this we described the power received from the jet by the recirculation zone as the product of a fluid-fluid friction coefficient and the square of the velocity difference times the shear velocity of the recirculation zone. This power is balanced by the bottom friction of the recirculation zone. Energy dissipation in the shear layer is then determined as the difference between the power performed by the jet and the power received by the recirculation zone.

In this setup, energy dissipation is maximized by optimizing the friction coefficient. We show that for short reservoir lengths, energy dissipation is higher in the case of a symmetric flow pattern, while for longer reservoir the energy dissipation is higher for asymmetric flow patterns. The simulated switch between the two flow patterns appears to be very close to the empirical relation. This suggests that the flow pattern adapts in order to maximize energy dissipation between the jet and recirculation zones.

The strength of this approach lies in the fact that no detailed knowledge of small scale processes is needed, while large scale structure formation can still be predicted.