Dissipation in aquifers

Olivier Devauchelle[1], Eric Lajeunesse[1] & Graham P. Benham[2]

[1] Institut de Physique du Globe de Paris, Université Paris Cité, 1 rue Jussieu, 75238 Paris, France
[2] School of Mathematics and Statistics & Earth Institute, University College Dublin, Belfield, Dublin 4, Ireland
devauchelle@ipgp.fr

The porous ground over which we walk collects rainwater, stores it, and directs it towards a stream, which will eventually return it to the sea. The Darcy flow of water through the ground is made non-linear by the presence of a free surface—the water table (figure 1). In steady state, and when the flow is perpendicular to the river, complex analysis provides a closed-form solution to this problem [1]. The amount of groundwater available to the river then scales like $R \ln R$, where R is the ratio of the rainfall rate to the hydraulic conductivity of the ground.

Surprisingly, one can obtain this peculiar scaling through a simple energy balance. Indeed, rain delivers not only water, but also potential energy, which needs to be dissipated by viscous friction before groundwater joins the river. Because a river is much narrower than the catchment it drains, the groundwater flow forms a logarithmic singularity in its neighborhood, and this singularity is where most of the energy dissipation takes place. This assumption straightforwardly leads to the above scaling.

Could this energy balance be extended to non-stationary flows, such as the recession associated to a drought or, conversely, the surge of the river's discharge during a storm? We address this question with numerical simulations and laboratory experiments. If this approach works, we can hope to represent the groundwater flow with a low-dimensional dynamical system [2], which should allow us to predict the discharge of rivers based on the rainfall input.

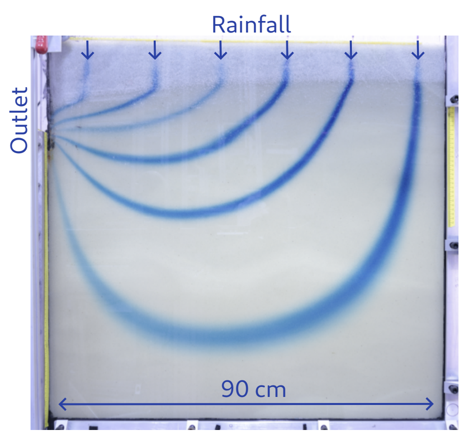

Figure 1. Flow through an experimental aquifer [1]. Glass beads make up the porous matrix (3 mm). Rainfall is kept constant, and blue dye shows streamlines. Kinks in streamlines reveal the water table.

References

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