ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT ET PHYSIQUE DE L'UNIVERS, PARIS

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Subject title: Response of an alluvial river to an external forcing

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Host lab/ Team : *please fill in and leave out meaningless information*
IPGP- Team Geological FLuid Dynamics – UMR7154

Financing: Doctoral contract with or without teaching assignment

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Presentation of the subject: (Maximum 2 pages)

Alluvial rivers build their channel in a bed of mobile sediment, such as sand or gravel. The feedback between the flow of water and the mechanics of sediment transport thus selects the shape and size of rivers, in a way that is not fully understood yet. Field observations show that rivers adjust their shape so that the sediment that makes up their bed is close to the threshold of entrainment (Phillips *et al.*, 2022). Below this threshold, a river deposits all the sediment it carries, and its bed builds up until it eventually reaches the threshold. Conversely, above the threshold, erosion of the bed quickly brings the river back to the threshold. Based on this simplistic reasoning, early theories assumed that rivers construct their own bed so that sediments are exactly at the threshold of motion. This so-called ``threshold theory'' accounts for the observation that the width of rivers increases as the square root of their discharge, an empirical relation known as Lacey's law (Métivier *et al.*, 2017). Yet, the shape of alluvial rivers is highly sensitive to sediment transport : even a small departure from threshold induces a significant change in the channel's shape.

Since sediment transport is difficult to measure in the field, we chose to investigate its influence in small laboratory rivers, in which a laminar flow erodes a layer of plastic grains (Fig.1). Based on these experiments, we showed in a series of recent publications how the diffusion of the momentum carried by the flow combines with gravity and the diffusion of traveling grains to determine the shape of a river (Abramian *et al.*, 2020; Popović *et al.*, 2021). Our model reliably reproduces the experiments without any tuning, and explains why rivers adjust their form to stay close to the threshold of sediment motion.

Despite this progress, many questions are still open. Our theory only predicts the shape of a steady state river. It does account for the transient, following a perturbation of the flow or sediment discharge. The objective of this Ph.D. project is to design and perform a series of laboratory experiments allowing us to document how a river responds to a change of sediment and flow discharge.

The first year of the thesis will be devoted to a systematic exploration of the effect of control parameters on the response of the river. The first year of the thesis will be devoted

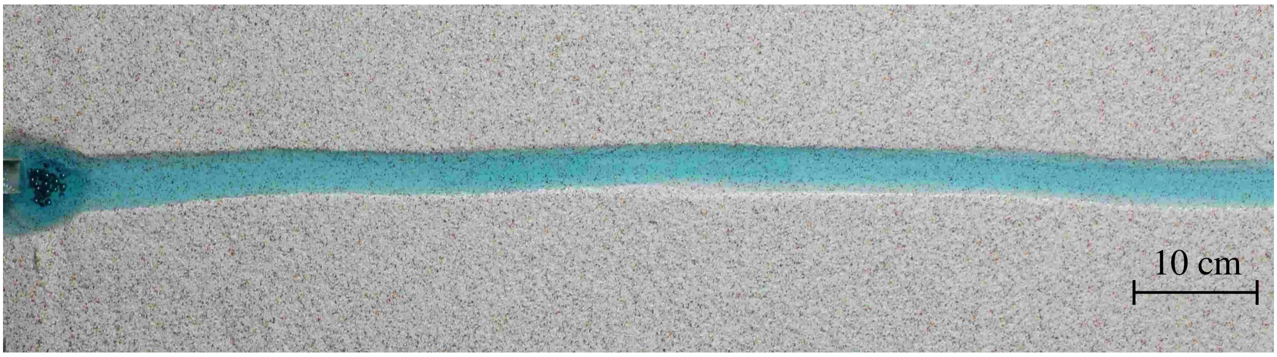

Fig.1 : Top view of a laboratory river. the discharge is Qw = 1.0 L/min and the sediment flux is Qs = 0.42 g/min.

to a systematic exploration of the effect of the control parameters on the response of the river, with particular emphasis on the measurement of the time necessary for the river to relax towards equilibrium. Based on his/her experimental observations, the candidate will devote the second year of his/her thesisPh.D. to the development of a theoretical model. The third year will be devoted to the application of this theory to the field data avaliable in the literature.

We are looking for a candidate with a strong background in physics, fluid mechanics, and granular physics, as well as a strong expertise in — and a taste for — the resolution of partial differential equations. Autonomy and ability to work in a team will also be considered in the evaluation process.

References

- Abramian, A., Devauchelle, O., & Lajeunesse, E. (2020). Laboratory rivers adjust their shape to sediment transport. *Physical Review E*, *102*(5), 053101.
- Métivier, F., Lajeunesse, E., & Devauchelle, O. (2017). Laboratory rivers: Lacey's law, threshold theory, and channel stability. *Earth Surface Dynamics*, *5*(1), 187-198.
- Phillips, C. B., Masteller, C. C., Slater, L. J., Dunne, K. B., Francalanci, S., Lanzoni, S., ... & Jerolmack, D. J. (2022). Threshold constraints on the size, shape and stability of alluvial rivers. *Nature Reviews Earth & Environment*, *3*(6), 406-419.
- Popović, P., Devauchelle, O., Abramian, A., & Lajeunesse, E. (2021). Sediment load determines the shape of rivers. *Proceedings of the National Academy of Sciences*, *118*(49), e2111215118.