Institut Pprime
Recherche en physique et ingénierie

Experimental and numerical analysis of sediment remobilization modes under unsteady flows

Context

Hydroelectric dams are the primary source of renewable energy in France, but they can have a significant impact on the proper functioning of aquatic ecosystems by altering the ecological continuity of waterways. These structures can disrupt sediment transport and thus reduce sediment availability in downstream sections, causing major disturbances to the morphology, ecology, and human uses of the environment. To mitigate this deficit, sediment can be replenished through sediment recharge operations. Predicting sediment transport, particularly the remobilization of these sediments, is of paramount importance in accurately assessing the effectiveness and sustainability of replenishment, especially during flood events, which involve significant variations in flow and for which conventional models can reach their limits. Numerous physical parameters related to flow conditions (flow gradient, minimum and maximum values, duration, water depth, turbulence, etc.) and the composition of the sedimentary bed (grain size, bed structure, sediment inputs, history, etc.) come into play in these interactions.

While the mechanisms of erosion and sediment transport under steady-state conditions are now relatively well established, numerous recent studies have shown that the temporal dynamics of flows modify the thresholds for initiating movement and modes of transport, calling into question approaches based solely on instantaneous values of bottom stress. Several experimental and numerical studies have shown that, under unsteady flow conditions, the initiation of sediment movement depends not only on the amplitude of the flow, but also on its temporal evolution, via acceleration, hysteresis, and memory effects. It suggests the existence of specific mechanisms, in which the response of the sediment is out of phase with the hydrodynamic forcing, leading to behaviors not observed in quasi-steady-state conditions.

Thesis work:

This thesis builds on the work of Florent Grattepanche, who showed that the instationarity of hydrographs can induce distinct remobilization modes directly linked to the temporal shape of the hydrographs. These results highlight the need to analyze the parameters describing non-stationarity, beyond maximum flow alone, in order to better understand the mechanisms governing the stability of localized sediment inputs. The main objective of this thesis is to conduct a fundamental analysis of the modes of sediment remobilization subjected to idealized and controlled hydrographs, based on clearly identified temporal parameters.

Simplified hydrographs will be considered in order to separate the effects of maximum flow, characteristic rise and fall times, and associated accelerations. This choice is consistent with a modeling approach aimed at identifying the dominant mechanisms, as is typically sought in fundamental studies of unsteady hydraulics. The analysis may be extended to multi-peak hydrographs, allowing the effect of successive stresses on remobilization dynamics to be studied and phenomena already observed in unsteady transport contexts to be explored. The influence of the initial geometry of the sediment supply will also be studied. The shape of the deposit (height, characteristic length, upstream and downstream slopes, symmetry) determines the spatial distribution of hydrodynamic stresses and forces exerted on the sediments, and plays a decisive role in destabilization mechanisms.

The methodological approach will be based on a close combination of laboratory experiments and numerical simulations. The experiments will be conducted in a hydraulic channel, with sediment inputs of controlled geometry subjected to precisely defined unsteady hydrographs. The velocity fields and their temporal evolution will be characterized using non-intrusive measurement techniques, such as particle image velocimetry (PIV), to assess acceleration effects and stress variations in the vicinity of the deposit. In parallel, numerical simulations of unsteady flows coupled with sediment transport will be developed to complement the experimental analysis.

This work aims to identify the parameters of unsteadiness governing the remobilization of sediment inputs and to determine critical thresholds that depend jointly on the temporal dynamics of the flow and the geometry of the deposit. The expected results will contribute to a better fundamental understanding of the processes of erosion and sediment transport under unsteady flows, and to the improvement of existing models.

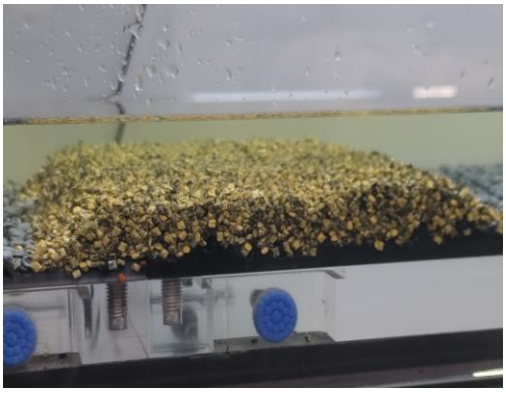
(a)  (b) 

Figure 1 : : a) Hydro-sedimentary channel of the pHE at the Pprime Institute b) Visualization of a modeled sediment input in the laboratory channel

Required profile/areas of competence:

Master's degree in Fluid Mechanics, Environment, or Engineering Sciences. Writing skills in English would be appreciated.

Duration: 36 months (from October 1, 2026, to October 1, 2029)

Location:

Institut Pprime, Département Fluides, Thermique et Combustion, Université de Poitiers, UPR 3346,
11 Boulevard Marie et Pierre Curie, TSA 51124
86073 Poitiers Cédex 9, France

Supervisors:

Guillaume Gomit
guillaume.gomit@univ-potiers.fr

Damien Calluaud
damien.calluaud@univ-potiers.fr