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## Plume evolution, transport and mixing processes under highly transient boundary conditions: A laboratory-scale study

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Transient boundary conditions are important in the transport of dissolved solutes and contaminants in the subsurface, as they can generate complex groundwater flow fields that influence mixing and mixing-controlled reactions. An important example of highly transient boundaries are rivers in which the river stage changes fast and sharply due to the operation of hydropower plants. In order to better understand how these rivers influence the groundwater flow field, we performed a laboratory experimental study. A quasi two-dimensional flow-through chamber was filled with glass beads and sand and the surface of the saturated porous medium was connected to two water reservoirs representing two rivers in hydraulic contact with the aquifer. The river stage could be changed independently by a separate lifting system for each reservoir. This experimental set-up was inspired by shallow unconfined aquifers in hydraulic contact with rivers affected by hydropeaking. In order to observe the influence of the transient boundary conditions, we injected a color tracer and observed the evolution of the solute plume across the tank. We monitored the spatial distribution of the tracer and the impact of the dynamic river boundaries on the groundwater plume with a non-invasive image analysis technique, consisting in a background light foil and a CCD camera. Additionally, to analyze the breakthrough curves we also took samples at multiple outlet ports and measured the tracer concentration using a spectrophotometer. We characterized the plume behavior using different metrics, including the dilution index, the flux-related dilution index and the moments of the tracer distribution. We conducted experiments both under steady-state flow conditions (with and without rivers) and under different transient conditions, obtained by variations in the order and the intensity of the river fluctuations, and groundwater flow velocities.