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Variability of hyporheic exchange in an experimental gravel bed

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A series of tracer experiments in a large outdoor flume were conducted to examine the variability of hyporheic exchange in gravel bed sediments. An 18 m long section of a 2 m wide flume was filled with a 30 cm thick gravel layer with a porosity of 0.39. The gravel of the 17 cm top layer was well-sorted and had a $d_{50}$of 37 mm, whereas the deeper layer consisted of finer gravel with a d_{50} of 11 mm. The flumes were filled with water, so that a standing water layer of 20 cm depth over the gravel bed was established. The experiments included flush-out experiments and instantaneous injection experiments using a salt tracer at various water discharge rates. During the experiments, the breakthrough curves of local groundwater was monitored in the water layer and at three gravel depths (-5 cm, -10 cm, and -20 cm) at four locations downstream of the flume inlet. In addition, dye tracer experiments were performed to investigate the patterns of exfiltration relative to the point of infiltration by injecting uranine dye tracer in a pore at the sediment-water interface. The results of the salt tracer experiments demonstrate that the time to breakthrough in the water layer and the top 10 cm layer of the gravel bed is consistent and increases with distance from the flume inlet and with depth below the sediment-water interface. However, in the deeper layers of the gravel bed (-10 cm and -20 cm), the time to breakthrough exhibits considerable variability at short distances with differences up to 30%. This suggests that, despite that the gravel was relatively homogeneous, the hyporheic exchange rate and waiting time distribution vary considerably locally depending on local pore space configurations and accompanying hyporheic flow patterns. The results of the dye tracer experiments show that the locations of exfiltration were temporally stable and occurred mostly within 1 m downstream from the point of infiltration. On a few rare occasions the water exfiltrated within 10 cm upstream from the point of infiltration.