Salt-tracer experiments to measure hyporheic transit time distributions in gravel-bed sediments

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Introduction

We performed a series of tracer experiments in large outdoor flumes at the Quesnel River Research Centre, Likely, BC, Canada to quantify the hyporheic transit time distribution in gravel bed sediments.

Experimental set-up

For this purpose, a flume was filled with a 30 cm thick layer of well-sorted gravel (Figs. 1-2). The flumes were filled with aerated local groundwater, so that a standing water layer of 20 cm depth over the gravel bed was established. Subsequently, dissolved common salt was added to raise the Electrical Conductivity (EC). The flumes were equilibrated overnight to ensure a uniform distribution of the salt concentration across the flume. At the start of each experiment local groundwater was discharged at a rate of approximately 12 l/s at the upper end of the flume. At 10 m downstream from the inlet the EC was monitored in the water layer until the EC remained constant at a value close to the background value of about 150 µS/cm. The experiment was replicated three times. Table 1 lists the main characteristics of the flume experiments.

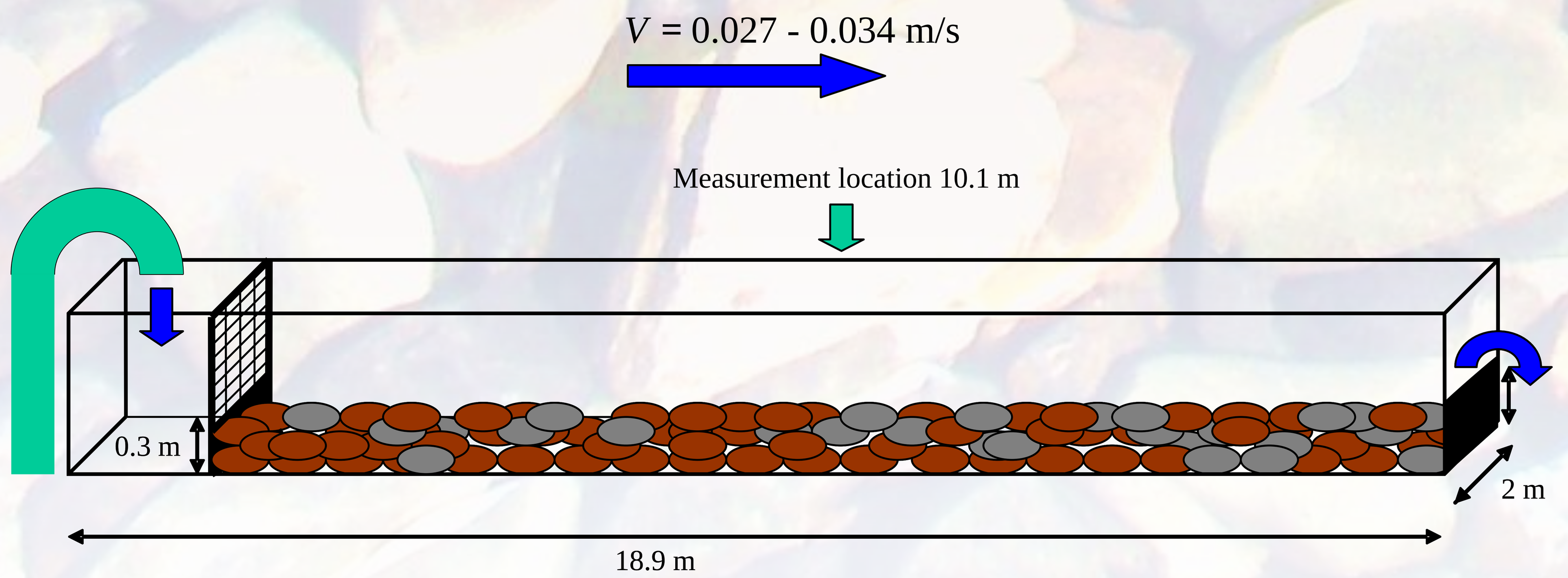

Figure 1 Experimental set-up

Table 1 Main parameters of the flume experiments

Flume dimensions	18.9 m × 2 m
Depth water layer	20 cm
Thickness gravel layer	30 cm
D50 gravel	39.1 mm
gravel porosity	0.4
Longitudinal gradient gravel bed	0.05%
Initial Electrical Conductivity in flume	400-800 µS/cm
Electrical Conductivity local groundwater	150 µS/cm

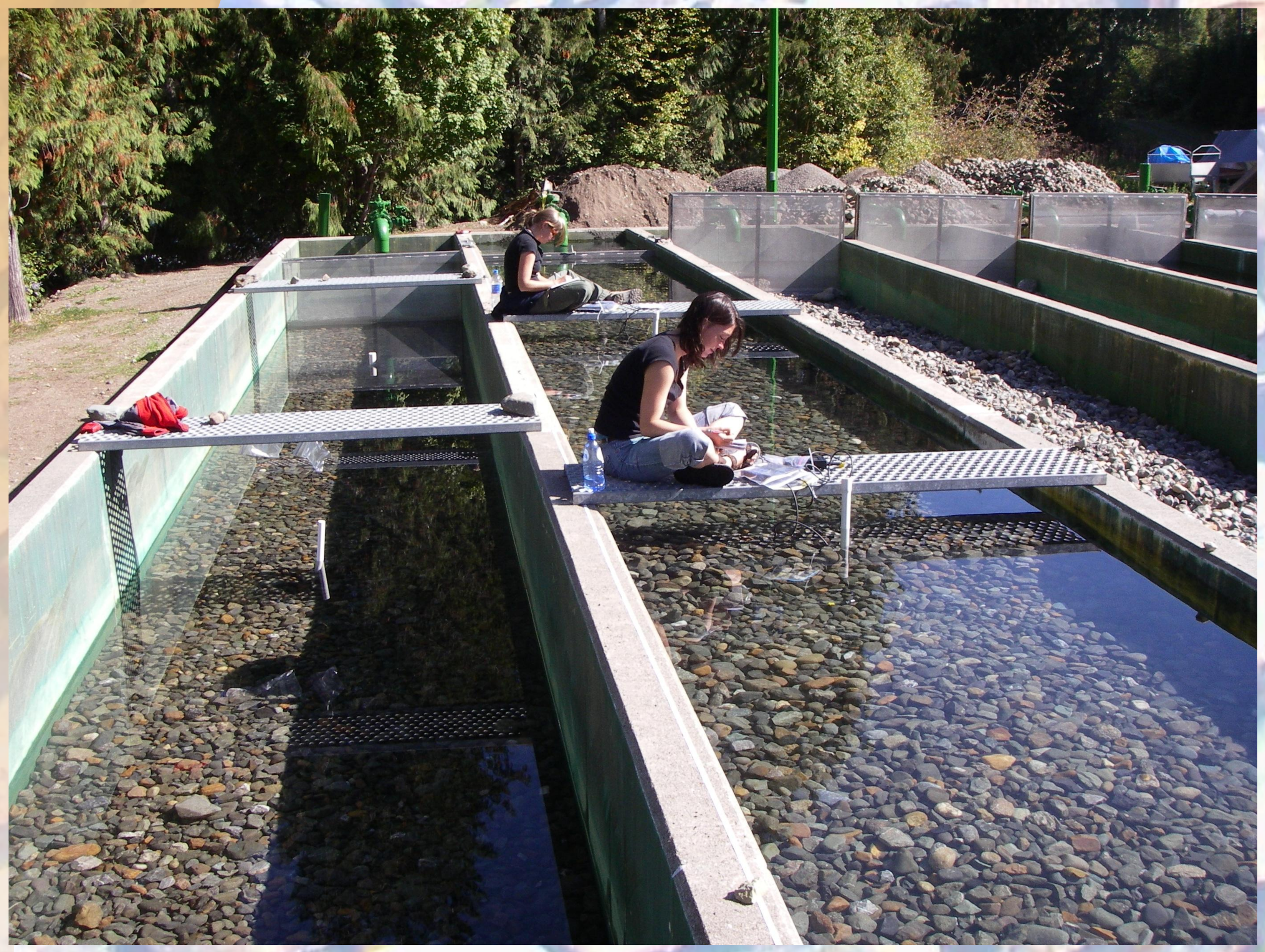

Figure 2 Outdoor flume at the Quesnel River Research Centre

Determination of transit time distribution

The measured breakthrough curves were normalised and used to calculate the overall transit time distributions of water in the 10 m stretch of the flume. The transit time distribution in the water layer was calculated using the longitudinal dispersion coefficient estimated using the empirical equation of Fischer et al. (1979). For the transit time distributions within the gravel layer we assumed a probability density function as proposed by Marion and Zaramella (2005):

$$r(t) = \frac{\frac{\pi}{T}}{\frac{\beta T}{t} + \left(\frac{t}{T} + 2\right)^2}$$

Where $r(t)$ = transit time distribution,
β = a constant,
T = distribution parameter representing a transit time scale

The hyporheic transit time distributions $r(t)$ were estimated using least-squares deconvolution of the overall transit time distributions.

Results

The fitted overall transit time distributions corresponded fairly well to the 'observed' distributions (Fig.3). The 10th percentile of the hyporheic transit time distributions in the 10 m stretch of the flume varied between 45 s and 65 s. The median transit time ranged between 200 s and 295 s and the 90th percentile between 790 s and 1435 s.

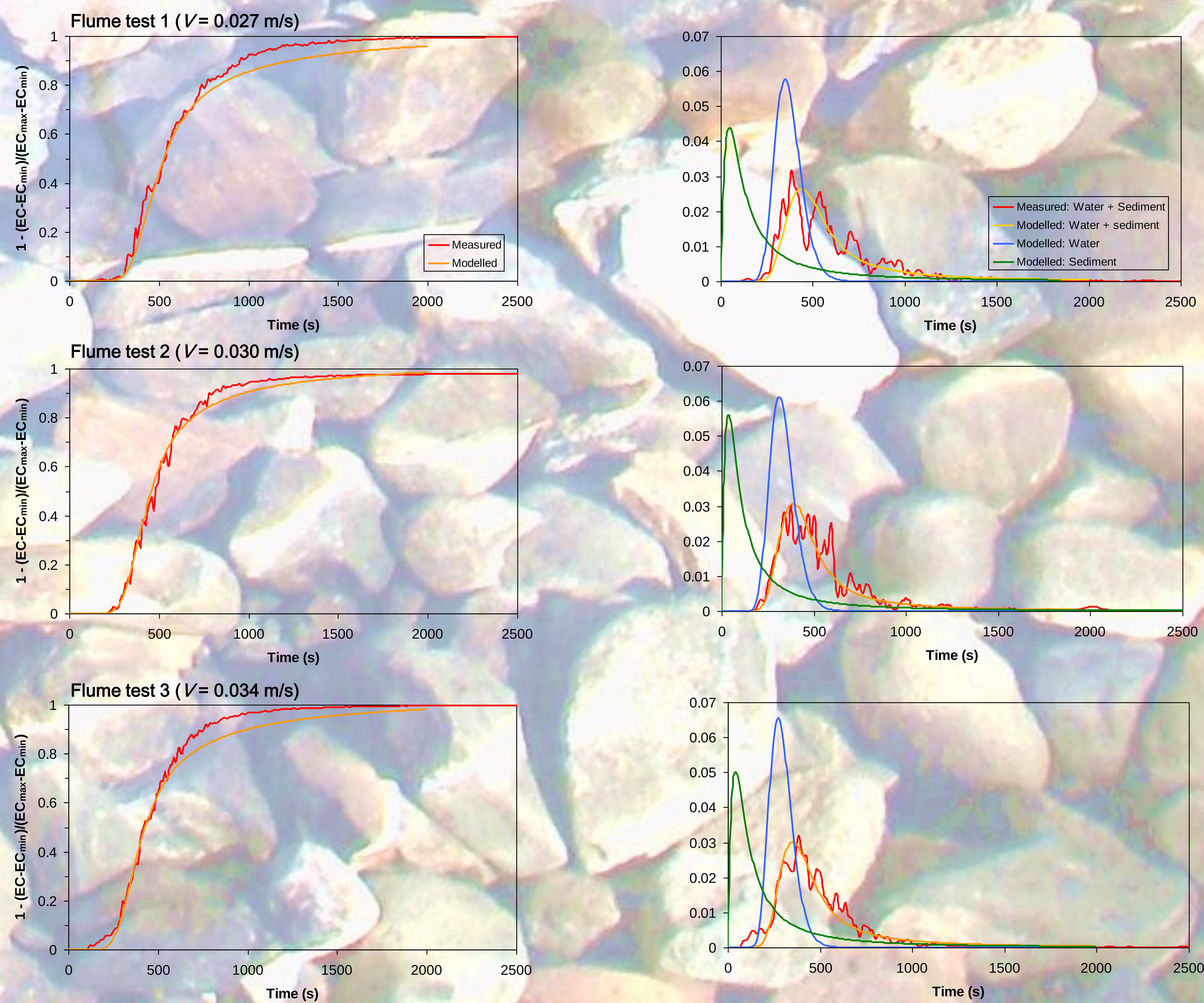

Figure 3 Measured and modelled EC breakthrough curves and transit time distributions for the three flume experiments

Conclusions and perspectives

The salt-tracer experiments provide a good starting point for measuring hyporheic transit time distributions. Future work will include on the effect of bedforms and sediment characteristics on the transit time distribution.

References

Fischer, H.B., E.J. List, R.C.Y. Koh, J. Imberger, and N.H. Brooks 1979. *Mixing in Inland and Coastal Waters*. New York: Academic Press.

Marion, A., and M. Zaramella 2005. A residence time model for stream-subsurface exchange of contaminants. *Acta Geophysica Polonica* **53**: 525-538.