Salt-tracer experiments to measure hyporheic exchange in gravel-bed sediments

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Introduction

Many gravel-bed rivers in the central interior of British Columbia (BC), Canada, represent important salmon spawning habitats. The success of salmon spawning depends on the hyporheic flow conditions, which control the transfer of oxygen and heat between the surface water layer and the interstitial water in the gravel bed. To understand and quantify the depth distribution of hyporheic flow in gravel bed sediments, a series of tracer experiments were performed in large outdoor flumes at the Quesnel River Research Centre, Likely, BC, Canada (Fig. 1).

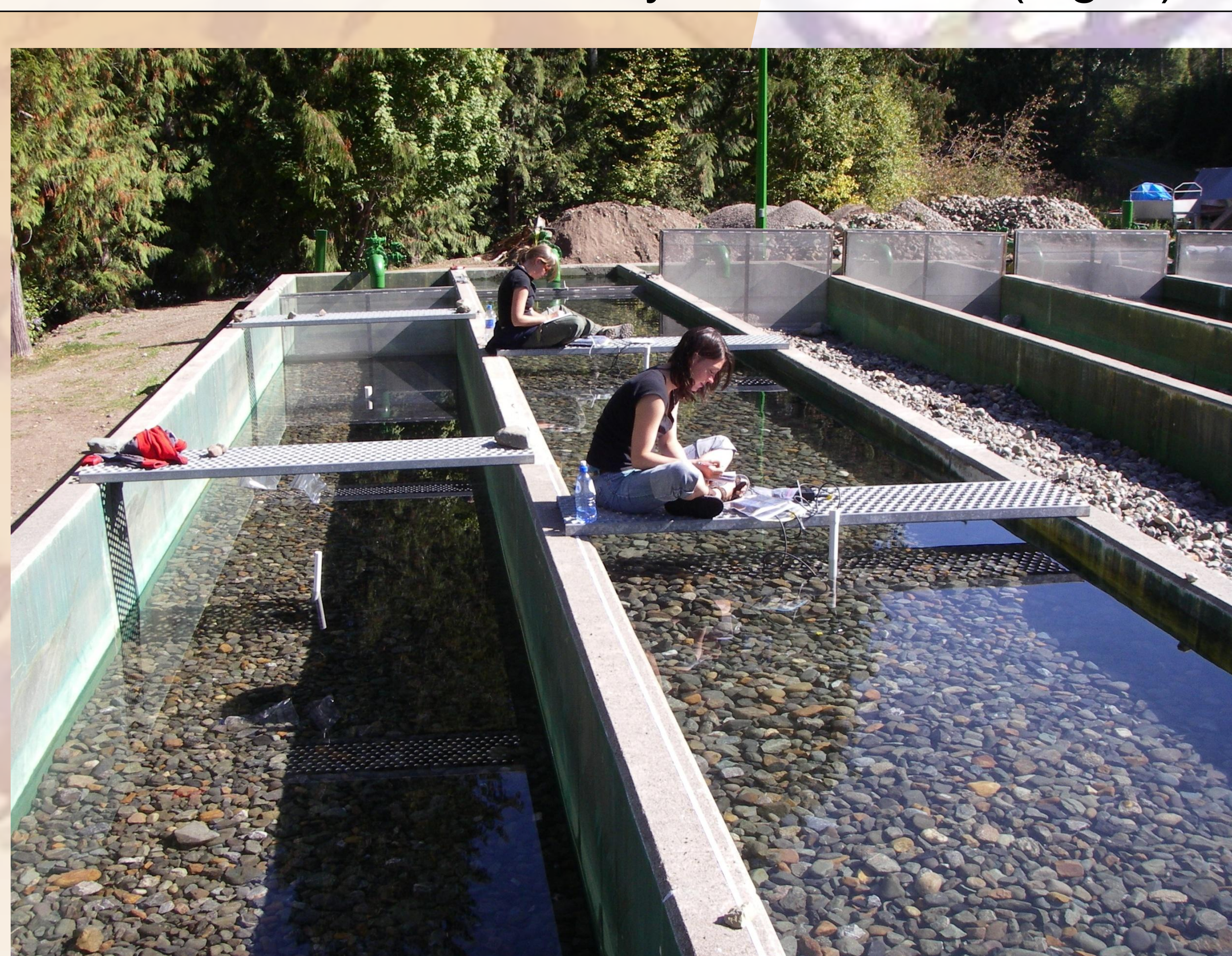

Figure 1 Outdoor flume at the Quesnel River Research Centre

Methods

The flume was filled with a 30 cm thick layer of well-sorted gravel (Fig. 2). The flumes were filled with aerated local groundwater. Subsequently, dissolved common salt was added to raise the electrical conductivity (EC). At the start of each experiment local groundwater was discharged at the upper end of the flume. At three locations downstream from the inlet, the decrease in EC was monitored in both the water layer and at a fixed depth of 0.05 m, 0.1 m, or 0.2 m in the gravel bed until the EC remained constant. Each experiment was replicated three times. Table 1 lists the main parameters of the experiments. The normalised breakthrough curves measured at different depths were used to calibrate a straightforward numerical model (Fig. 3).

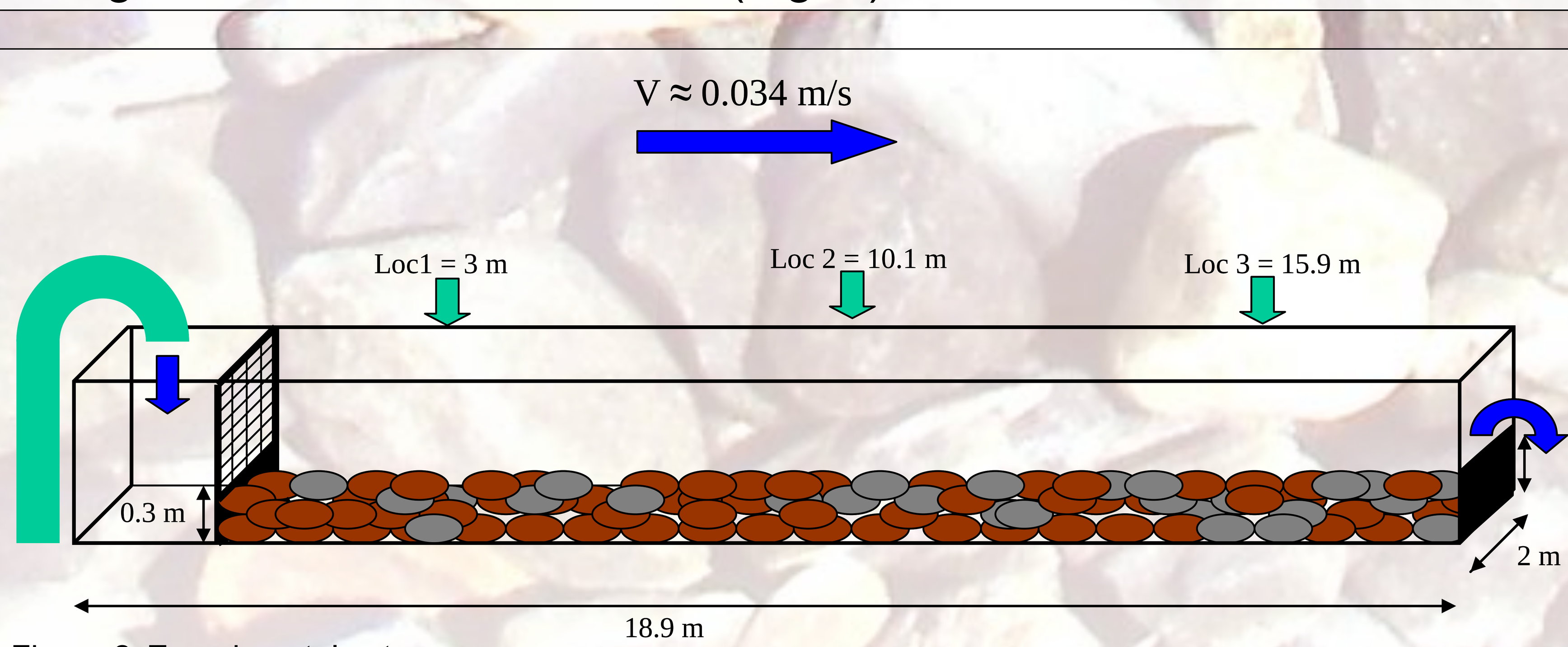

Figure 2 Experimental set-up

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

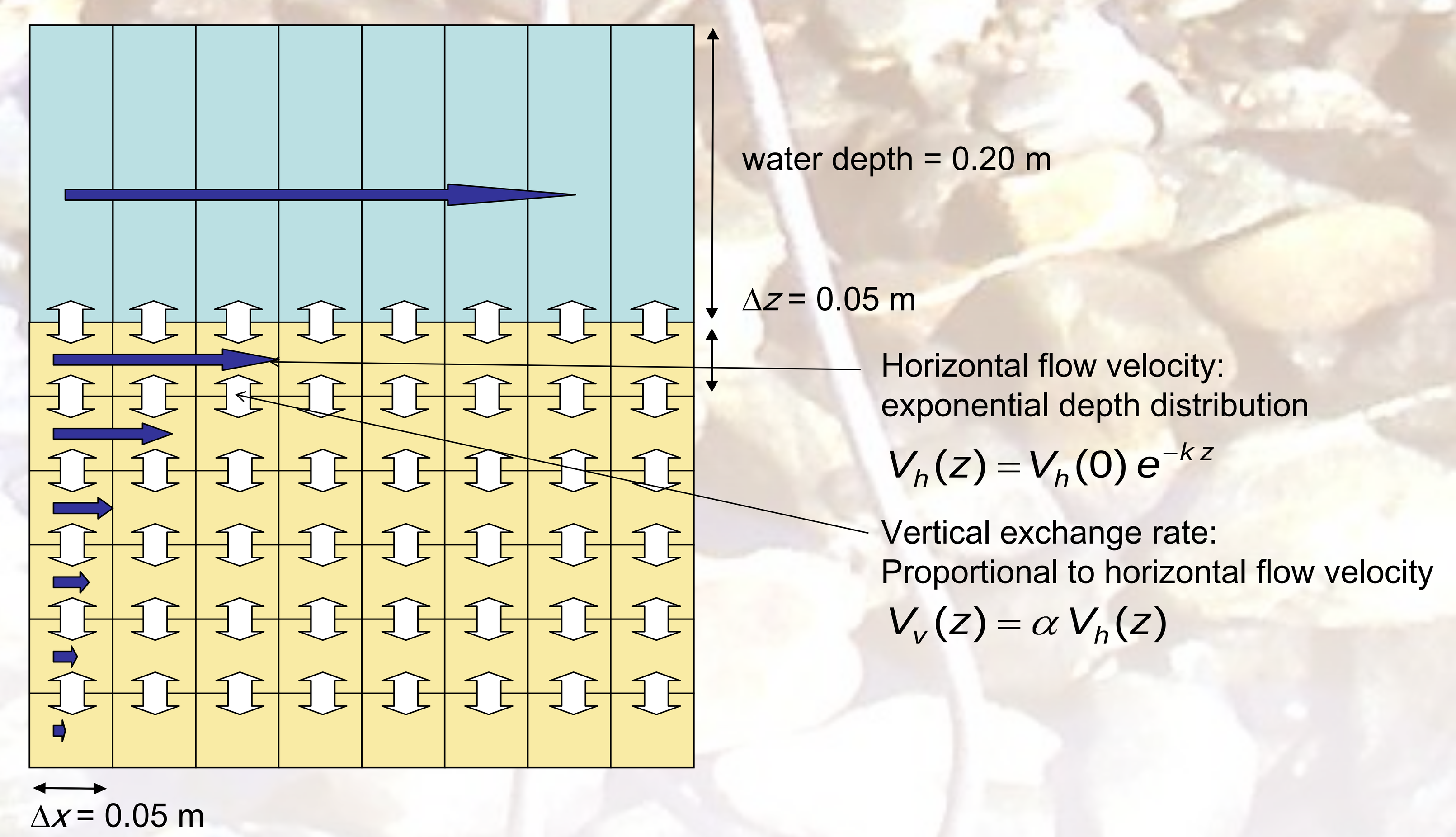

Figure 3 Schematic overview of the numerical model

Results and perspectives

Table 2 Fixed model parameters

Parameter	Value
Water flow velocity	0.034 m/s
Longitudinal dispersion coefficient	0.008 m^2/s
Interstitial water flow velocity at z = 0	Gravel porosity × Water flow velocity

Table 3 Calibrated model parameters

Parameter	Value
exponent k	
best fit	41 m^{-1}
minimum	37 m^{-1}
maximum	42 m^{-1}
α	
best fit	0.99
minimum	0.60
maximum	1.00

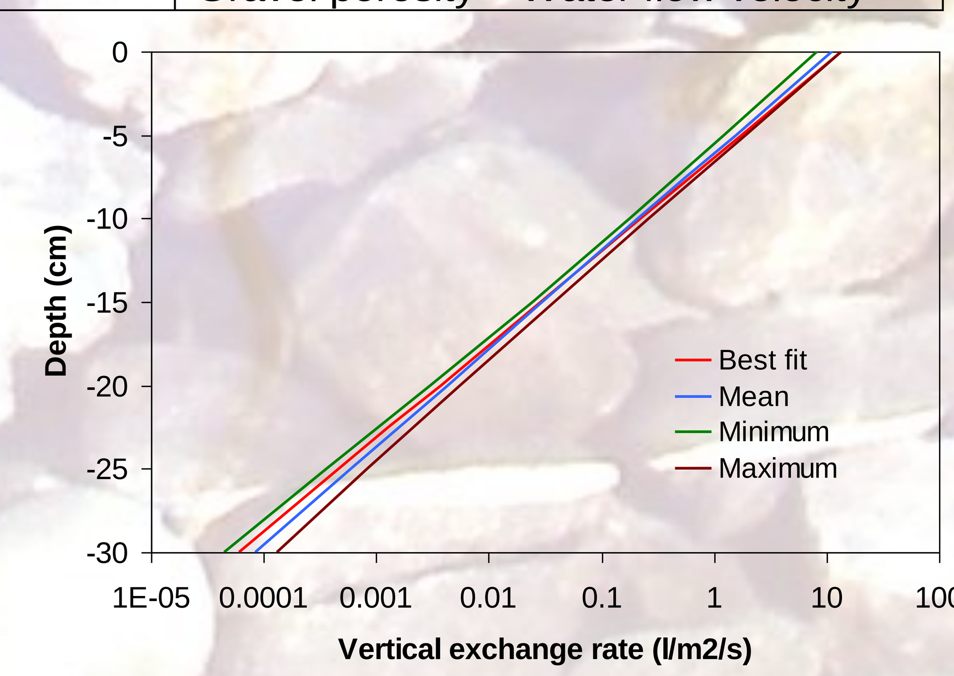

Figure 4 Calibrated vertical exchange rate as function of depth

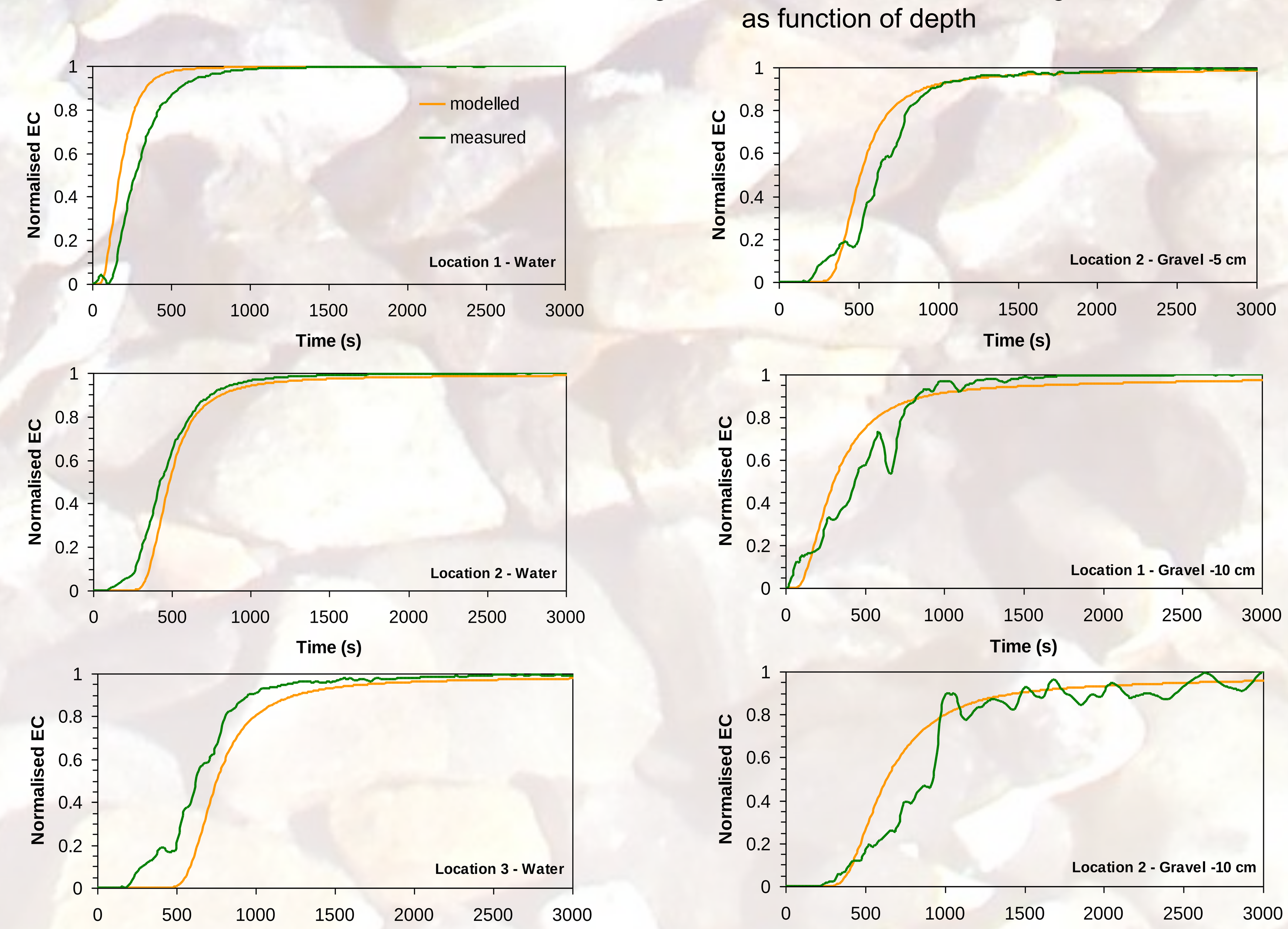

Figure 5 Measured and modelled breakthrough curves

The calibration results of the (Tables 2-3; Figs. 4-5) reveal that the exchange rate at the sediment-water interface is as high as 13.5 l/m2/s, but rapidly decreases to 0.2 l/m2/s at 10 cm depth. The results of these experiments provide good perspectives to further study the penetration and deposition of fine sediments in gravel beds.