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Extended Abstracts

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title: **Three dimensional modelling of a long term bank-side borehole pumping experiment for better understanding of river-aquifer interactions**

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MOTIVATION

The biogeochemical processes in the hyporheic zone may naturally attenuate the concentration of some pollutants. Nevertheless, the different factors controlling these processes, especially the influence of hydrodynamic conditions on biodegradation, are not fully understood, and therefore cannot be artificially controlled. An experiment has been implemented to better understand the hydrodynamic conditions that can affect the biogeochemical processes in the hyporheic zone and, potentially, provide the basis for new tools to improve the natural potential of attenuation by artificial means. This paper examines the performance of this test and the lessons that can be drawn from its implementation.

AN INNOVATIVE EXPERIMENTAL DESIGN

The experiment used long-term extraction from a bank-side well installed adjacent to the River Tame, Birmingham, UK, to modify the hydrodynamic conditions locally within the hyporheic zone of a well geologically and topographically characterised reach. Both short-term and long-term extraction induce a decrease in the vertical components of flows from groundwater to surface water (Figure 1) increasing their residence time within this interface as well as, potentially, increasing the river / groundwater mixing depths. The resulting temporal evolution of hydrodynamic and chemical conditions was monitored using a network of riverbed minipiezometers and multilevel samplers (Figure 1). The key objective was to observe the impact of the changing hydraulic conditions on the processes involved in surface water/groundwater mixing and the conditions causing changes in biodegradation.

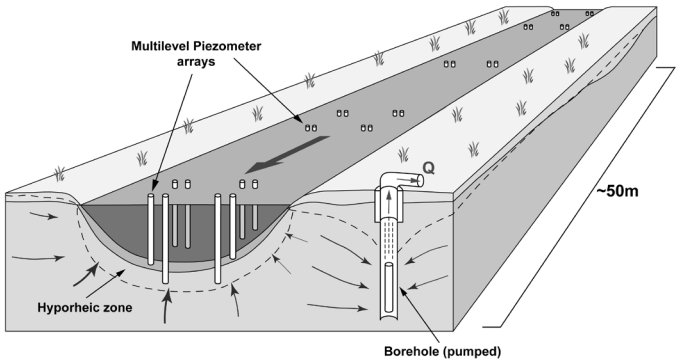

Figure 1. Schematic view of the experimental design.

RESULTS AND INTERPRETATION THROUGH A 3D HYDROGEOLOGICAL MODEL

A 3D hydrogeological model was built to run with the MODFLOW code. This allowed to test the sensitivity of some key parameters.

Calibration of general parameters

Step pumping tests in January 2008 allowed the general calibration of the hydrodynamic parameters. The hydraulic conductivity (K) of the Permo-Triassic sandstone was found around 2.3×10^{-5} m/s, and the storage coefficient (S) around 2×10^{-5}. However, the cells corresponding to the borehole had to be set with higher values for these parameters ($K=10^{-2}$m/s, $S=3\times10^{-3}$), due

to the gravel pack. The Figure 2 shows the best fit (reference model) found with a pumping rate of 103 l/mn, and two sensivity tests decreasing respectively K in the sandstone and S in the borehole by a factor 2/3. The first test leads to a final head value in the borehole 2.5 m below the observed one. The second test leads to a faster decrease of heads in the borehole at the beginning of the pumping.

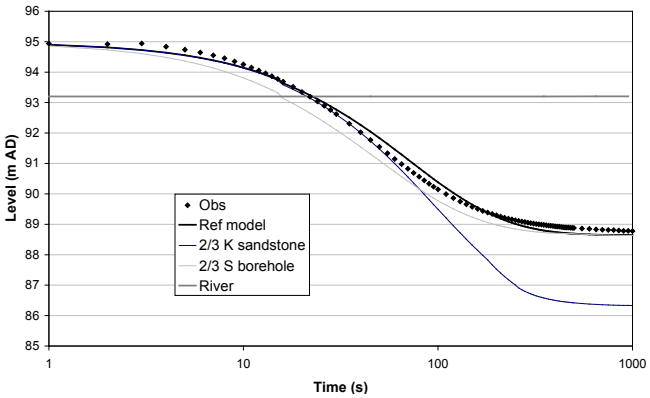

Figure 2. Heads in the borehole during a short pumping test of 103 l/mn (January 2008); observations compared to three simulation results: a reference model and two others, decreasing respectively the value of the sandstone hydraulic conductivity and the storage coefficient in the borehole cells.

Impact of pumping in the hyporheic zone

A two hour pumping test in June 2008 allowed to quantify the impact of the pumping on the hyporheic zone heads. A head decrease between 2 and 3 cm within the hyporheic zone could be related to the impact of the pumping (Figure 3). This is relatively low compared to the natural variations of the river, in the same range of values at this low flow period, but potentially increasing of one to two meters during flood events.

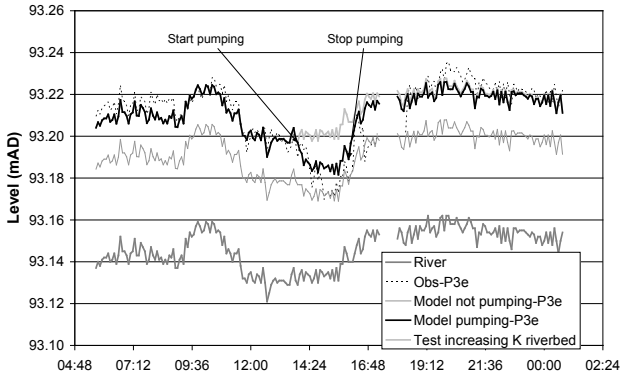

Figure 3. Impact of a 2h pumping test within the hyporheic zone (June 2008). Observation heads compared to one model without pumping and one under pumping conditions. Sensitivity of a K increase in the riverbed by a factor 10.

On Figure 3, one can also note that an increase of the hydraulic conductivity in the riverbed by a factor 10 leads to lower heads within the hyporheic zone: reduction of 2 cm all across the modelled period.

CONCLUSION

Both the field measurements and the 3D hydrogeological model results show a coupled influence of the river levels and of the extraction test on the hydraulic heads within the hyporheic zone. A pumping rate around 80 l/mn induces a decrease in the average vertical flow discharging from the hyporheic zone to the river of about 15% across the monitored section. A novel aspect of the results is that the intensity of the on-site monitoring installations has enabled the spatial and temporal patterns of change in hydraulic gradients, both across and along the river reach, to be directly measured. The results show that this pattern is highly heterogeneous spatially, depending on the hydraulic conductivity distribution, on the riverbed morphology, and on the relative position to the pumping. During the pumping experiment, the hydrochemical data collected indicate that the dynamics of the river flows provide significant temporal variability to the exchange flows in the river bed on timescales from hours to months. Full account of these had to be included in the model in order to explain the observations. The results also show that anthropogenic modification of this stretch of urbanised river (e.g. riverbed, made ground, bridge/sewer crossings) is significant in altering both the spatial and temporal pattern of discharge to the river by affecting the permeability and storage properties of the river bed and banks. This has important implications for river restoration approaches within the urban environment.

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