The SWITCH Hyporheic Zone Test Site, Birmingham:
Overview of Baseline and Extraction Test 1 data

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The hyporheic zone (HZ), the zone of groundwater – surface-water mixing beneath a river, represents an important natural system for water self purification. Research is in progress to better understand and exploit the urban HZ system as part of *SWITCH* WP 5.3. The research is set within the *SWITCH Demonstration City* of Birmingham and also forms part of the Environment Agency (for England & Wales) (EA) hyporheic zone research programme. The aim is to learn enough about the dynamic behaviour of the urban hyporheic zone to confirm the continuous spatial and temporal attenuation capacity of the zone and to develop appropriate concepts that can be employed as part of any river restoration project for the purposes of minimising future potential risks from contaminated groundwater discharges to the river. Key objectives are to investigate groundwater – surface-water mixing processes and their importance within the HZ; provide insights into the dynamic behaviour of the HZ including its temporal persistence; investigate chemical attenuation potential of the HZ and spatial relationships between attenuation capacity and flow patterns; and, based on these, establish, descriptions of the HZ through modelling that can contribute to river restoration design. The research is based at our urban hyporheic zone test site (*HZ Site*) on the river Tame, Birmingham (UK) developed under *SWITCH*. It builds upon our research on the Birmingahm aquifer – river Tame system (Rivett et al., 1990, 2005; Ellis et al., 2004, 2007; Ellis & Rivett, 2007; Shepherd et al., 2006). Other on-going relevant research includes the study of HZ volatile organic compound (VOC) attenuation at a site 3 km upstream (Roche et al., in press) and a city-wide study of VOCs and water table rebound in the Birmingham aquifer (Botha, 2006; Murcott, 2008). The latter indicates groundwater levels are now close to estimated pre-industrialisation levels. Natural groundwater baseflow discharge to the Tame is hence probably greater now than at any time in the past century.

Principal infrastructure installed at the *HZ Site* include a groundwater extraction borehole 5 m from the river Tame and a network of riverbed monitoring points over the adjacent 200 m reach to measure groundwater – surface-water flow and chemical exchange processes in the HZ. Operation of the extraction borehole allows the hydraulic gradients across the HZ to be modified leading to perturbed groundwater – surface-water interactions and chemical solute/contaminant attenuation behaviour. Establishment of the *HZ Site* required liaison with land owners and the Environment Agency to obtain regulatory permissions including land access agreements, borehole drilling and extraction consents and a discharge consent to dispose of extracted water to the downstream river. Final permissions were acquired in May 2008 allowing the extraction tests to proceed. Prior to this time, the site infrastructure had been developed and 'baseline data' collect under non-extraction natural flow conditions. Nine transects of cross riverbed monitoring have been installed that each comprise >3 multilevel samplers to measure in-riverbed chemical quality profiles, piezometers to record hydraulic head and pressure transducers to obtain continuous temporal records of river stage and head.

Baseline head and chemical water quality data were obtained in Autumn 2007 and Summer 2008 immediately prior to 'Extraction Test 1' (ET-1) that commenced on 4 July 2008 with the borehole pumping at 78 l/min. This continues to date (Nov. 2008). The extraction was expected to reduce riverbed gradients and increase HZ residence time, or even cause gradient reversals locally prompting increased surface-water mixing into the riverbed. Although data analysis is on-going, gradients do not appear to have significantly reduced at the monitored riverbed transects. Groundwater heads generally remain at or close to river level despite significant drawdown (6 m) in the extraction borehole. The preliminary conclusion is that the borehole influence is being obscured by the natural variability in river flows and, or discrete flow regimes exist in the heterogeneous geology that are not being captured by the monitoring. Mean daily river flows have varied by up to an order of magnitude above baseflows of ~1.5 m^3/s. Prolonged periods of steady baseflow conditions that are best for assessing the extraction borehole influence have been relatively rare since extraction began. Gradient reversals or reductions appear to mainly relate to natural flow variability, the most noticeable occur close to peaks in river stage during rainfall events and may only last a few hours. River water quality then is noted to be highly variably sometimes containing high EC (electrical conductivity) first flush run-off up to 1500 µS/cm that becomes rapidly diluted where upon river ECs may approach 500 µS/cm to be followed by a gradual rebound to more normal 800-1000 µS/cm as lower flows return.

Three baseline and three ET-1 period water-quality sampling campaigns have been conducted on the riverbed monitoring network to date. Although the intent was to sample under sustained low flow conditions, this has not always been possible due to the rainfall frequency. The natural variability in river flow conditions appears to be influencing chemical profiles. Some profiles appear relatively stable with time, others more dynamic and responsive to the natural hydrological variability. Although distinction of discharging groundwater baseflow and influent surface water into the riverbed is not always easy, it is possible at some localities with trends in hydrochemical profiles apparent. Determinants that show most variability across the riverbed with some distinction between typical groundwater and surface-water end-members are chloride (a conservative solute), nitrate (potentially reactive due to denitrification), phosphate (potentially reactive due to sorption) and TOC (potentially reactive as an electron donor). These are all generally more elevated in the surface water than groundwater with the exception of nitrate that usefully shows reverse profiles. Other determinants that may also serve the science objectives potentially include some of the trace metals monitored (some data still awaited) and sulphate. Although there is some similarity in cross channel transects, not surprisingly there is significant spatial variability in behaviour that is reasonably attributed to riverbed sediment physical and geochemical heterogeneity. Similar to water flows, it is presently difficult to unequivocally discern the extraction borehole influence against natural variability. Data obtained suggest there may be an influence in specific locations, however, further data and analysis are required and on-going.

It is proposed to step the borehole extraction rate up to 150 l/min (ET-2 phase) shortly to allow a greater flow perturbation. ET-2 will last until February 2009 when extraction will cease and natural flow conditions allowed to return. Field data will continue to be collected with a preliminary field data interpretation report to be prepared in March 2009. The project will thence predominantly involve modelling works, both for further data interpretation and development of river restoration design aspects of the project.