

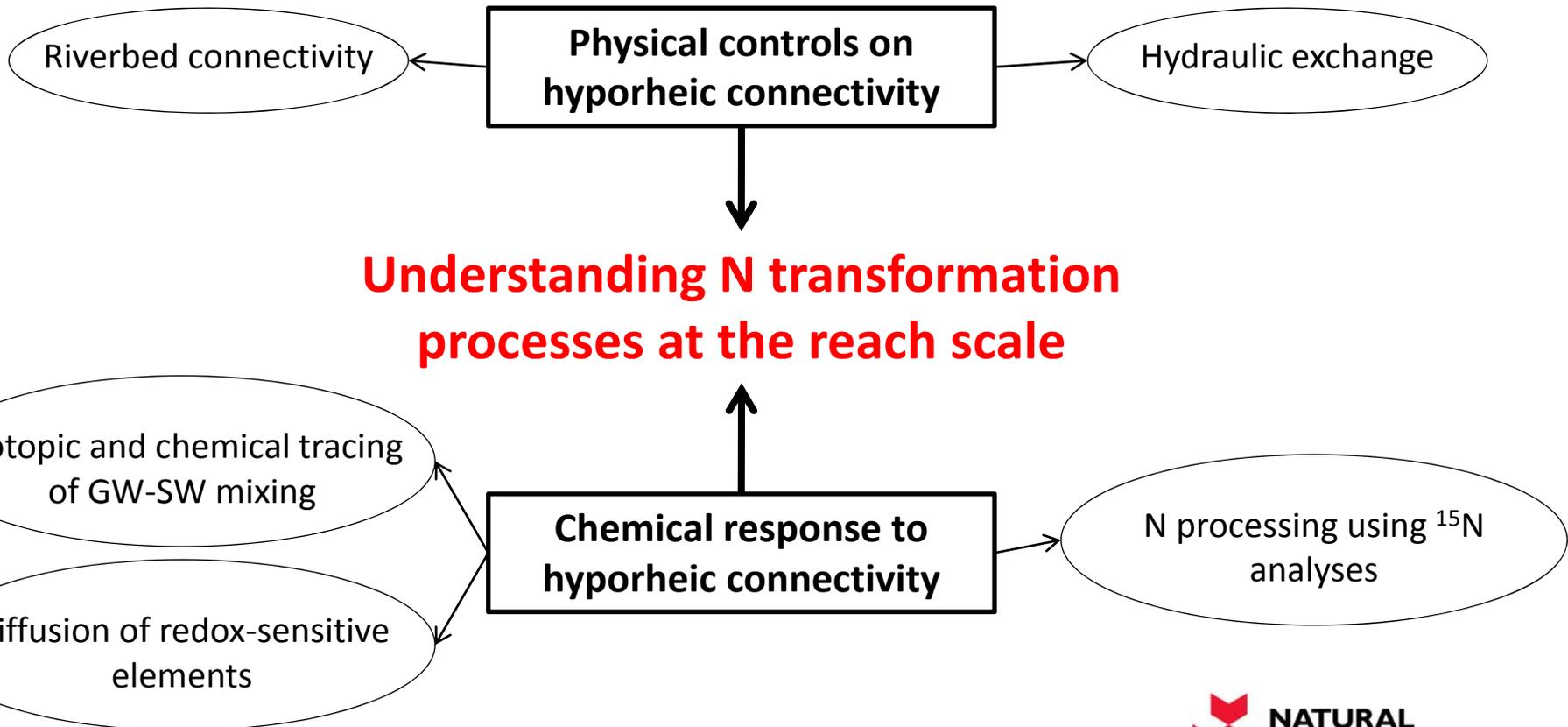
# Control of river stage on the reactive chemistry of the hyporheic zone

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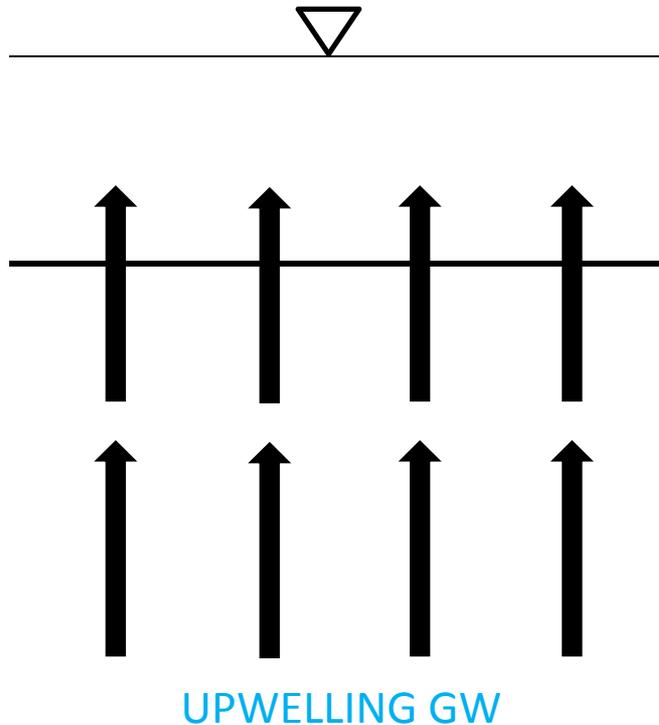
# Implications of groundwater-surface water connectivity for nitrogen transformations in the hyporheic zone

(NERC grant: NE/F006063/1)

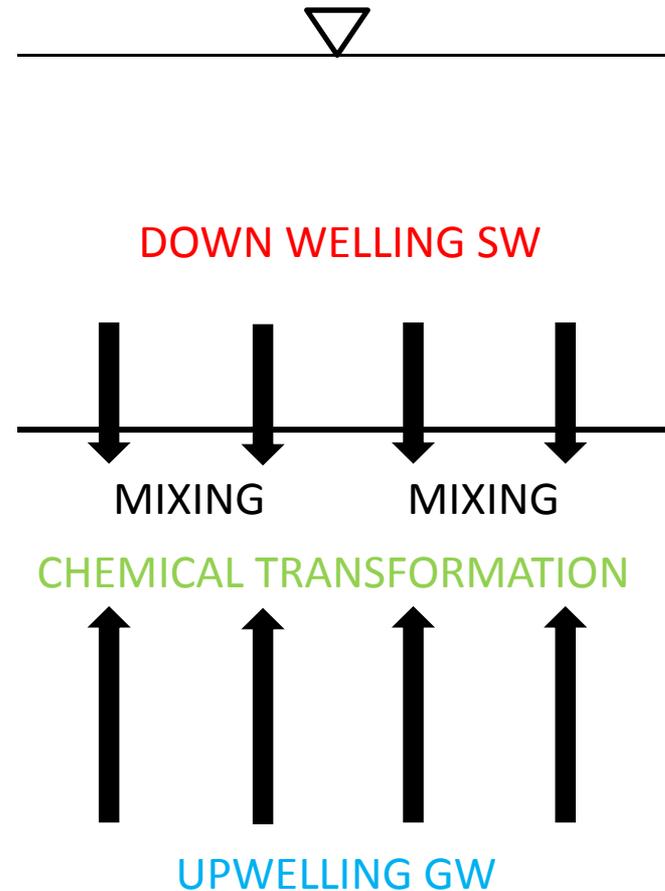


# How does river stage fluctuation affect connectivity and reactive chemistry in the HZ?

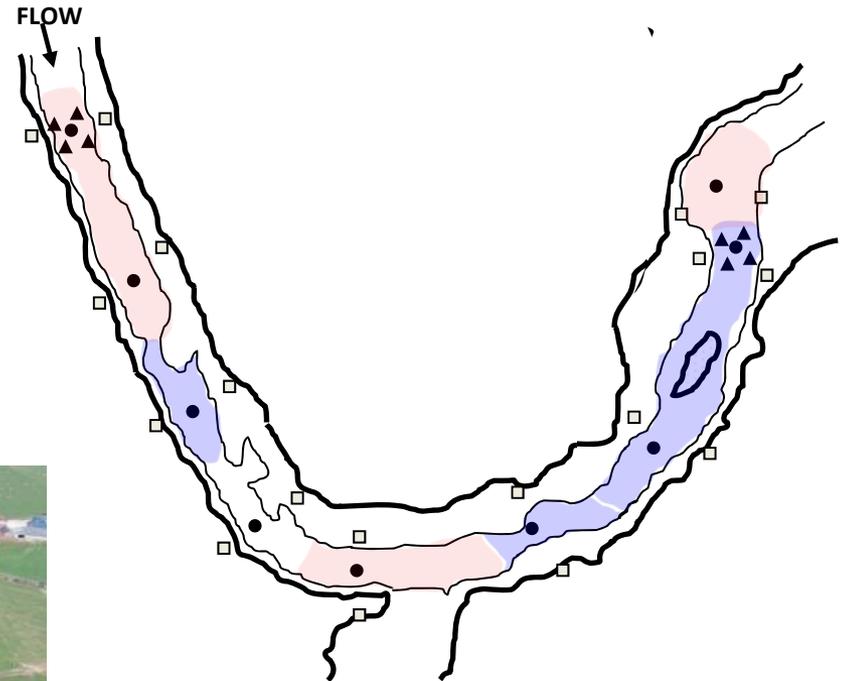
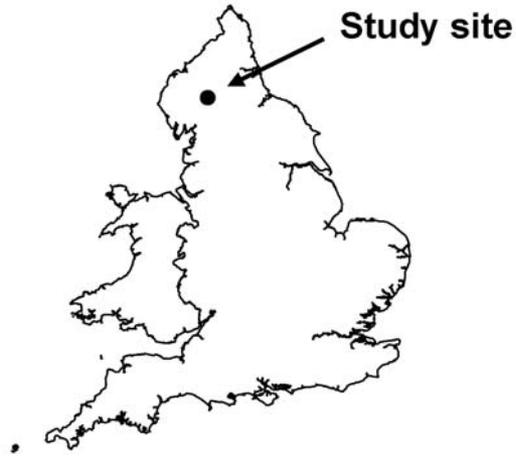
(A) LOW STAGE



(B) HIGH STAGE



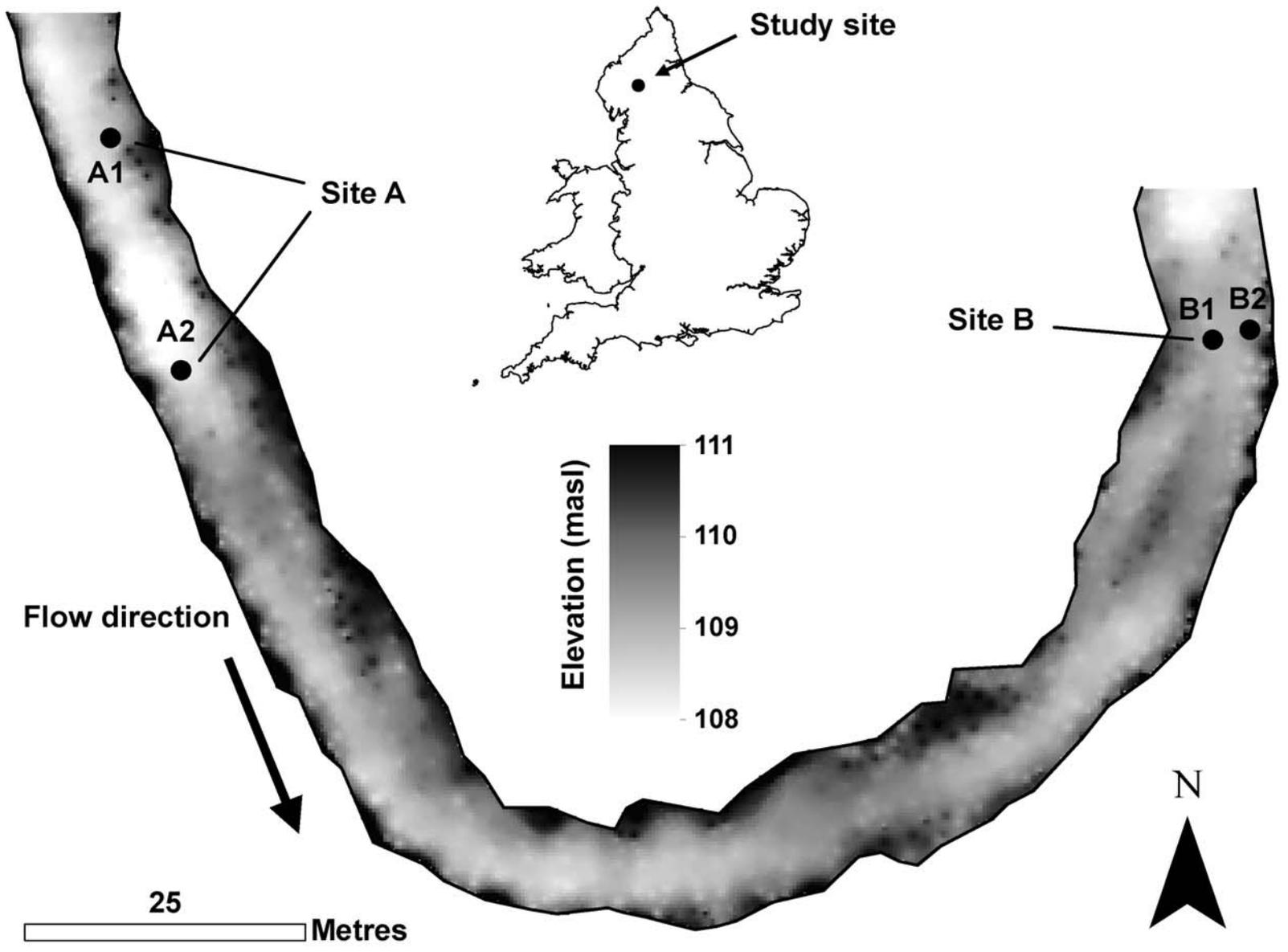
# Experimental site: R. Leith, Cumbria, UK



Simon Ledingham

<http://www.visitcumbria.com/simon.htm>

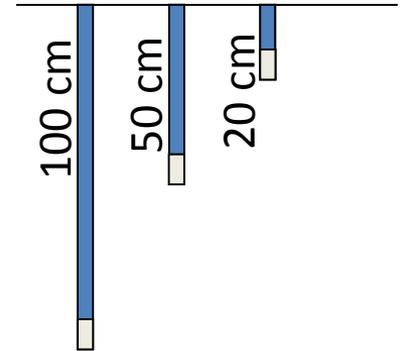
- In-stream piezometer (mid channel)
- ▲ In-stream piezometer (channel margin)
- Riparian piezometer
- Channel geomorphology = a pool
- Channel geomorphology = a riffle
- 111m ASL
- 110m ASL

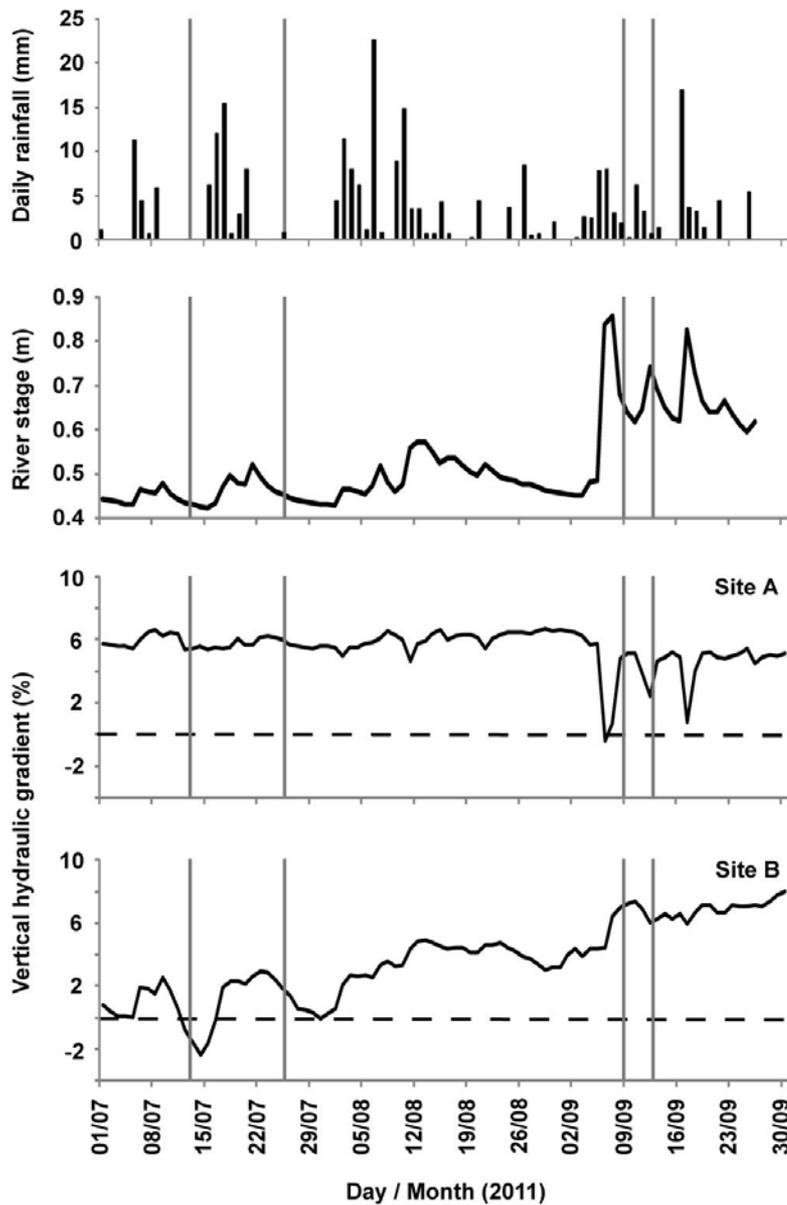


**Figure 1.** River Leith study reach showing riverbed elevation and the location of experimental sample sites.

# Field Data

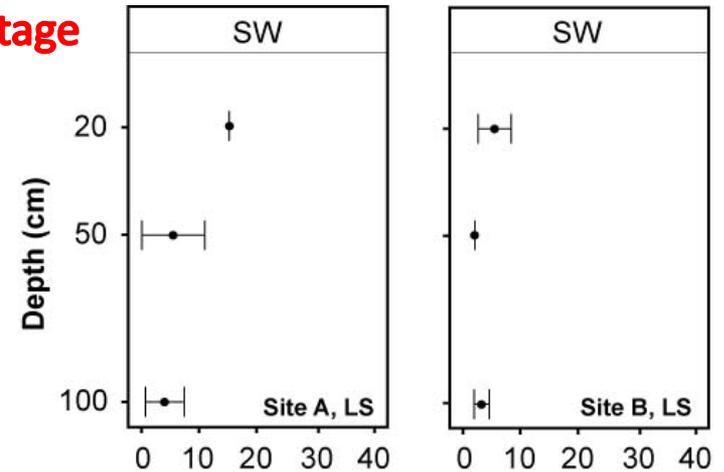
- Vertical flux ( $K * dh/dl$ )
  - Channel piezometers screened at 20, 50 and 100cm
- Pore water chemistry ( $NO_3^-$ ,  $SO_4^{2-}$ ,  $Cl^-$ ,  $NH_4^+$ , DOC, Mn)
  - 100 cm piezometer equipped with multi-level pore water sampler (10, 20, 50, 100 cm)
- River stage and subsurface head
  - Continuous recording with data loggers at 100cm



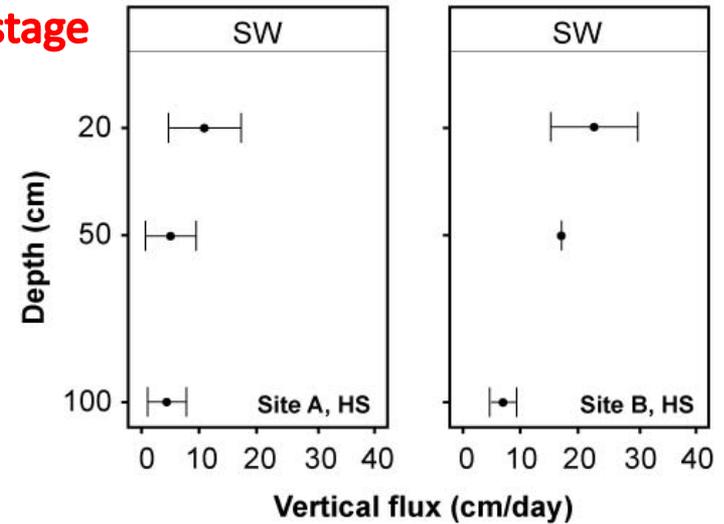


# VHG and vertical flux

Low stage



High stage

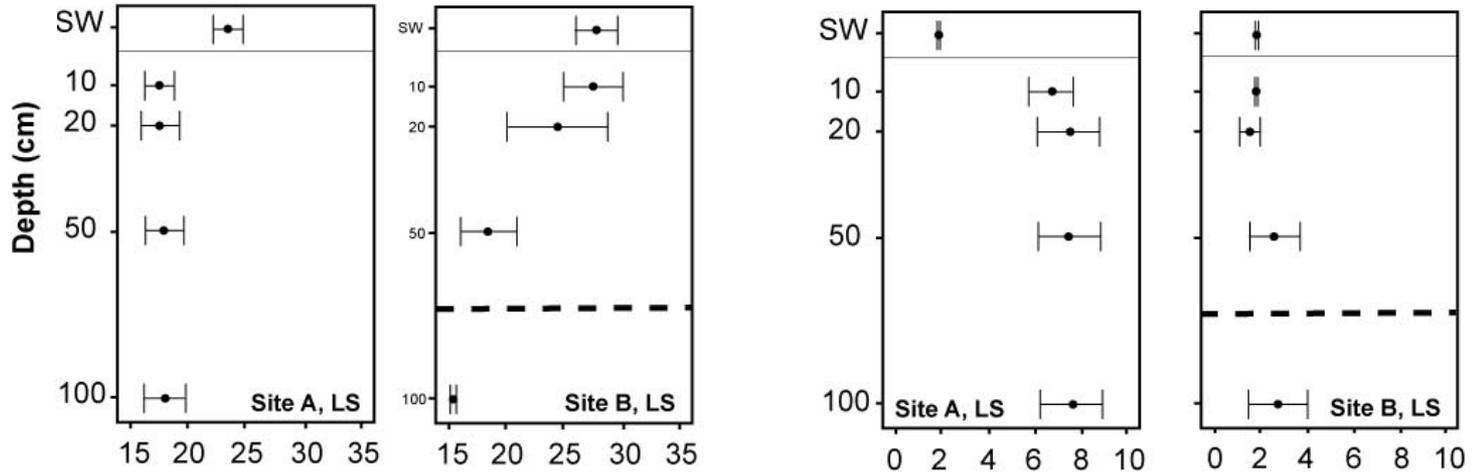


**Figure 2.** Daily rainfall, mean daily river stage and vertical hydraulic gradient (%) from logging pressure transducers at site A and site B for the study period. Sampling dates are indicated by the grey vertical lines. Horizontal dashed lines indicate zero gradient.

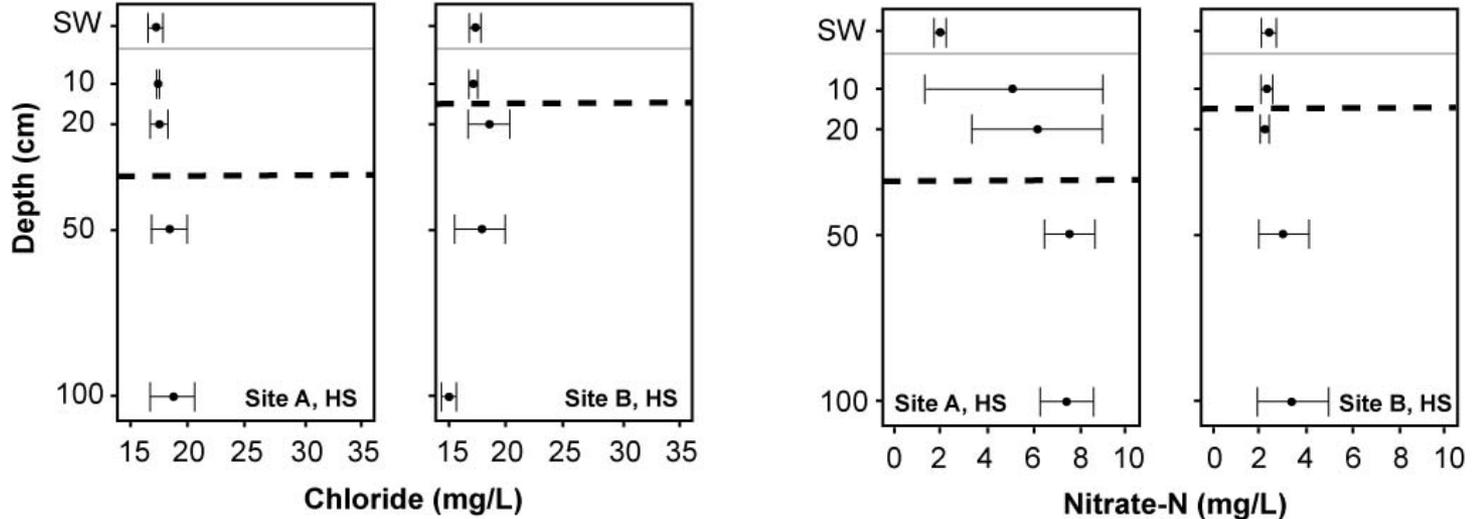
**Figure 3.** Summary of riverbed vertical flux measurements (mean [ $n = 4$ ] and standard deviation) at site A and site B at low stage (LS) and high stage (HS).

# Surface and pore water Cl<sup>-</sup> and NO<sub>3</sub><sup>-</sup> concentrations

Low stage



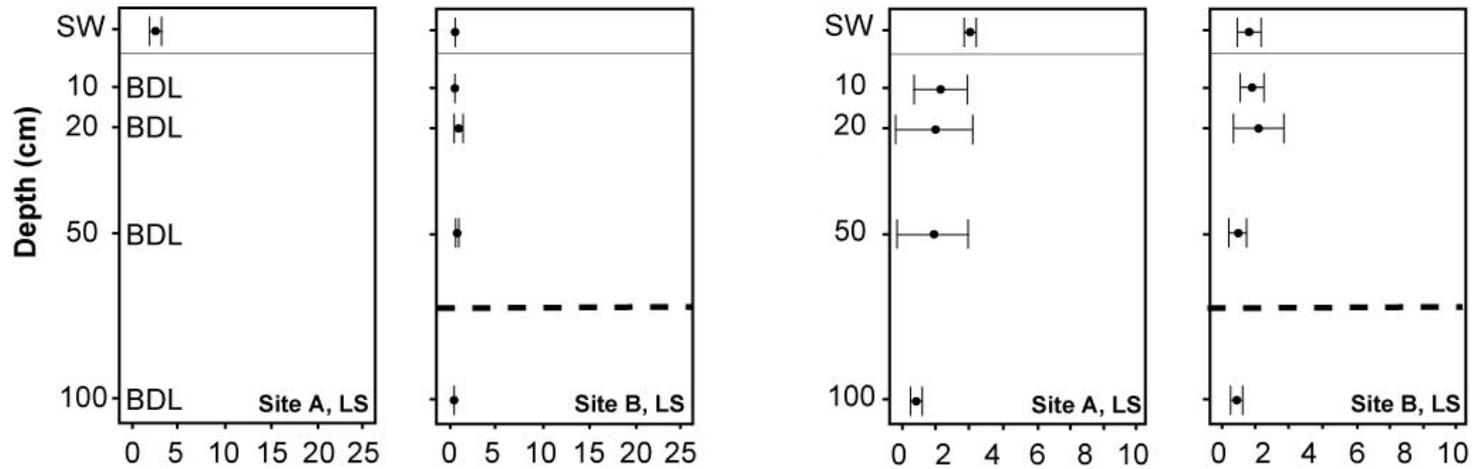
High stage



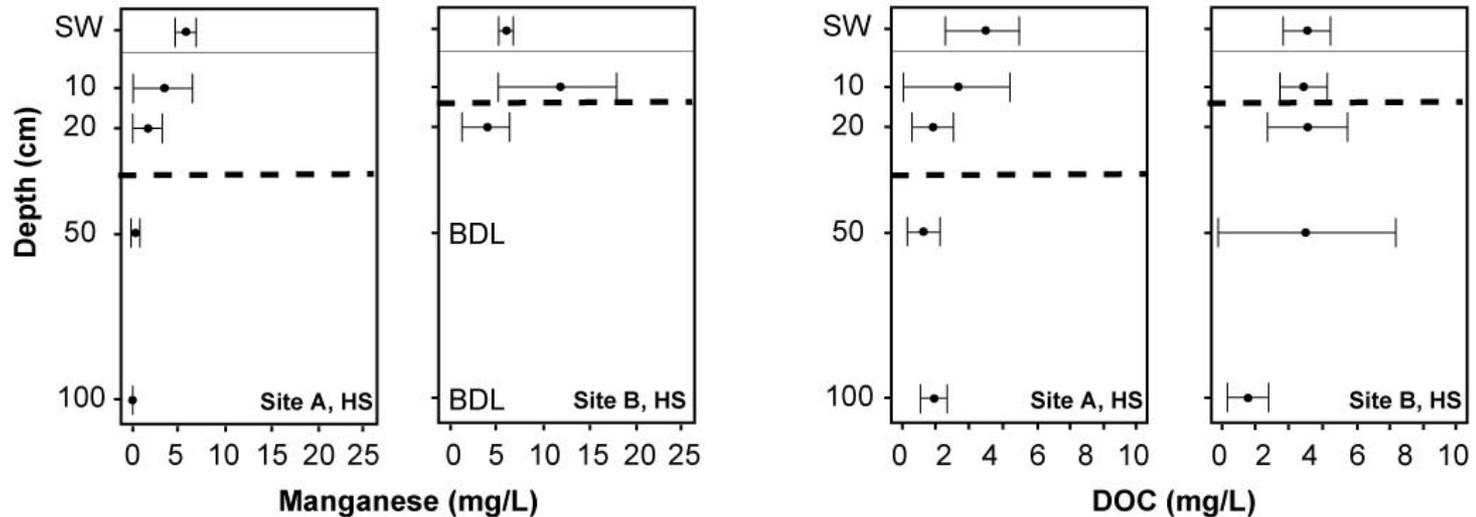
**Figure 4.** Summary of (a) chloride and (b) nitrate (mean [n = 4] and standard deviation) surface and pore water concentrations at site A and site B at low stage (LS) and high stage (HS). SW = surface water sample. The horizontal dashed line indicates the proposed vertical extent of groundwater-surface water mixing.

# Surface and pore water Mn and DOC concentrations

Low stage



High stage



**Figure 5.** Summary of (a) manganese and (b) DOC (mean [ $n = 4$ ] and standard deviation) surface and pore water concentrations at site A and site B at low stage (LS) and high stage (HS). The horizontal dashed line indicates the proposed vertical extent of groundwater-surface water mixing. SW = surface water sample. BDL = below instrument detection limits.

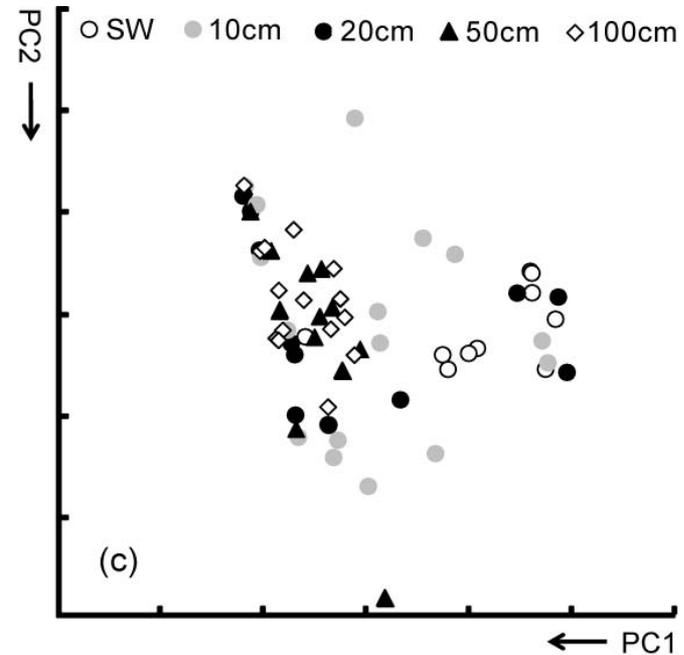
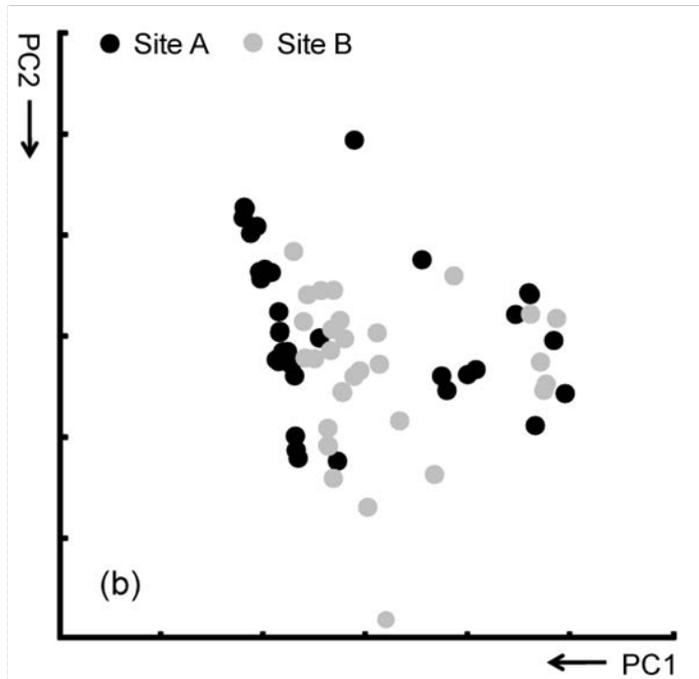
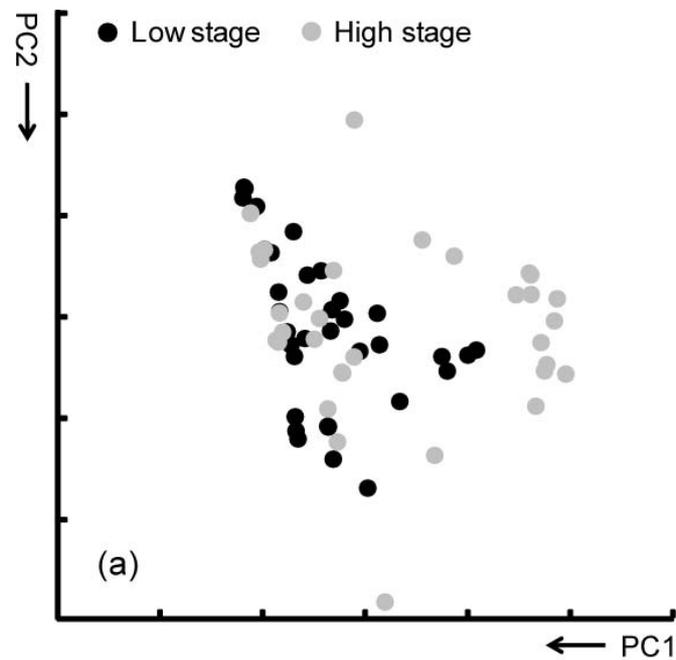
# Principal components analysis of R. Leith biogeochemistry

**Table 1.** Principal component loadings and explained variance for the PCA. Correlations reported are the correlations between the principal components and the individual variables in the original dataset.

	<b>PC1 loadings</b>	<b><i>r</i></b>	<b>PC2 loadings</b>	<b><i>r</i></b>
DOC	0.488	0.652**	-0.831	-0.702**
Nitrate-N	-0.793	-0.624**	0.311	0.480**
Ammonium-N	-0.594	0.168	0.033	0.150
Chloride	-0.481	0.045	-0.178	-0.166
Sulphate-S	-0.621	-0.413**	0.091	0.094
Manganese	0.934	0.841**	0.356	-0.079
% variance explained	59.9		20.2	
% cumulative variance	59.9		80.1	

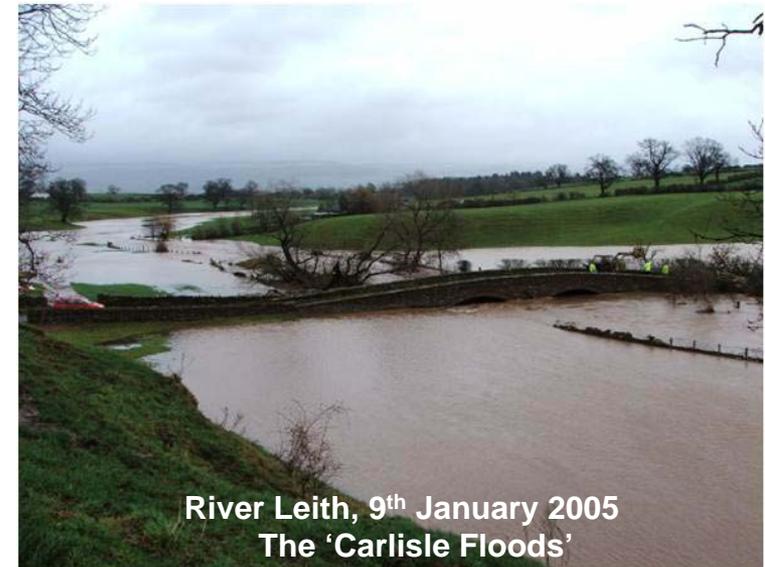
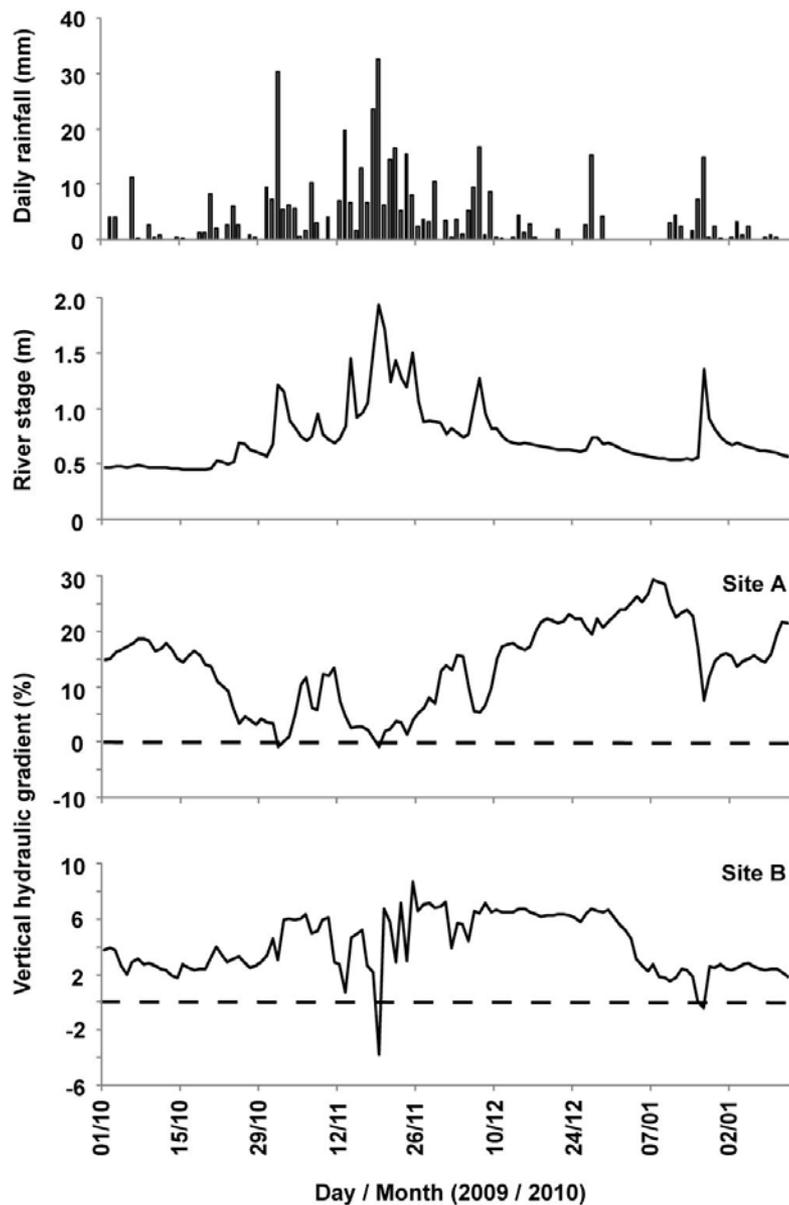
\*\* significant at 0.01 level.

# PCA biplots



**Figure 6.** Principal component analysis biplots showing the distribution of surface and pore water biogeochemical samples along the first two ordination axes. Samples are grouped according to (a) stage level, (b) sample location and (c) sample depth. Arrows on the ordination axes indicate the direction of decreasing principal component scores.

# What about much higher stage increases?



**Figure 7.** Daily rainfall, mean daily river stage and vertical hydraulic gradient (%) from logging pressure transducers at site A and site B for the period October 2009 to April 2010. Horizontal dashed lines indicate zero gradient.

# Conclusions

- River stage fluctuations significantly affect biogeochemical patterns in the hyporheic zone
- Delivery of DOC to hyporheic sediments during high river stage may fuel biological reduction processes
- Future studies may aim to quantify:
  - the extent to which the supply of DOC to hyporheic sediments varies throughout the year
  - potential for  $\text{NO}_3\text{-N}$  removal under low and high stage conditions
  - catchment-scale studies