# What controls nitrogen cycling in the bed of a groundwater-fed river?

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## 1. Introduction

Denitrification in the hyporheic zone is an effective means of nitrogen attenuation in a fluvial network; however, under certain conditions production of nitrate can occur within the river bed. Also, the extent to which mixing processes alter river bed nitrate concentrations is often overlooked.

Here, we investigate controls on nitrogen cycling in the bed of a groundwater-fed river under base flow conditions by:

i) Consideration of mixing processes using an end member mixing model

ii) Measurement of biogeochemical parameters (e.g. $NO_3^-$, dissolved $O_2$, microbial activity, organic carbon)

iii) Characterising the hydrology of the reach

## 2. Field site

This research was performed in a gaining reach of the groundwater-fed River Leith, Cumbria, UK. Piezometers (n = 88, maximum depth = 1m), some equipped with multi-level water samplers, were installed in the sands, gravels and Permo-Triassic sandstone throughout the 250m reach (Fig. 1).

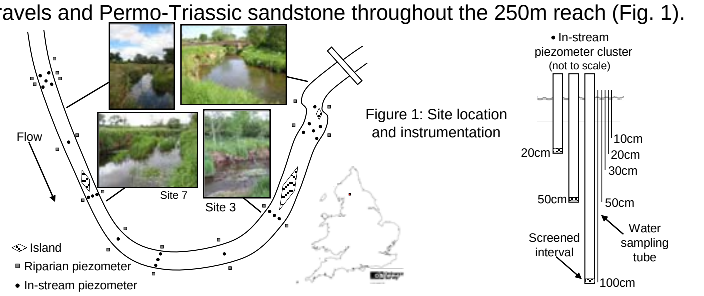



Figure 1: Site location and instrumentation

## 3. Results and Discussion

A) Water within the river bed was not solely a mixture of downwelling surface water (SW) and upwelling groundwater (GW, =100cm sample, Fig. 2a and b). A third end member (EM) was required in the mixing model.

B) Mixing alone cannot explain the changes in pore water nitrate concentrations observed (Fig. 2c).

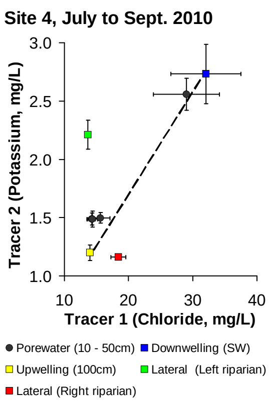



Figure 2a: EM plots of conservative tracers

Variability in EMs was assessed. Tracer pairs where EMs were i) not resolved or ii) could not constrain pore water data were discarded.

Also note, if pore water was simply a mixture of SW and GW, pore water (black circles) would fall on the dashed line.

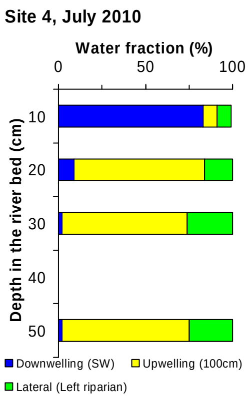



Figure 2b: Sources of water to the river bed

All EM combinations were entered into a 3-EM mixing model. If multiple mixing scenarios were obtained, the 'correct' model was chosen by:

i) Assessing potential for SW downwelling using sediment chlorophyll

ii) Assessing potential for GW upwelling using vertical head gradients

iii) Assessing potential for lateral flows (from the riparian zone) using a flow network of the reach.

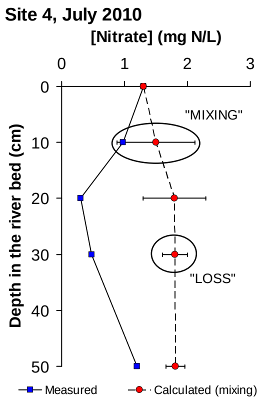



Figure 2c: Pore water nitrate, mixing versus measured

Nitrate concentrations that would result from mixing of the identified water sources (= model output) were calculated, along with uncertainties.

Pore water nitrate concentrations resulting from mixing were compared to those measured in samples collected from the piezometer network ($\Delta NO_3^-$, *see* Fig. 3) and were classified as "mixing", "gain" or "loss".

C) Areas of biogeochemical nitrate gain and removal were identified **below** the zone of SW and GW mixing.

D) A combination of physical, biological and chemical mechanisms control nitrogen cycling in the bed of the river.

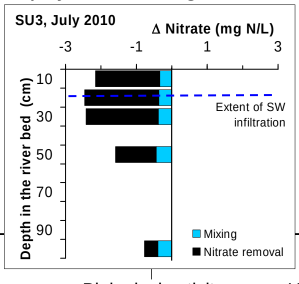
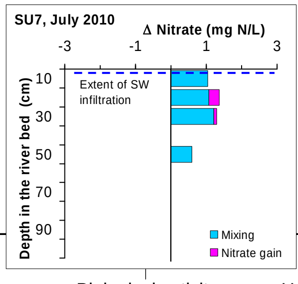
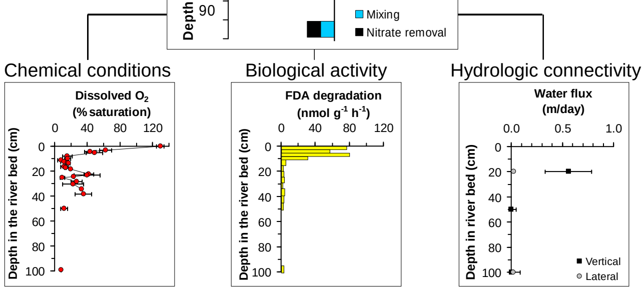
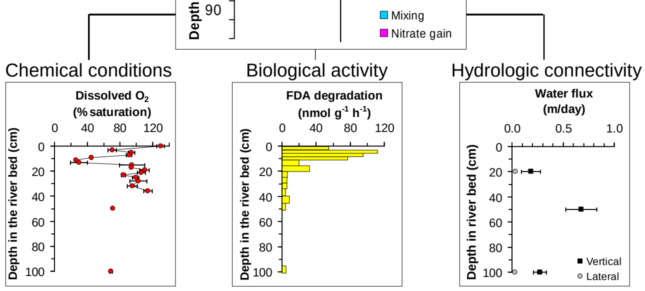



Figure. 3: Two sites of contrasting nitrate biogeochemistry within the reach. On the left (Site 3), biogeochemical removal of nitrate is occurring. On the right (Site 7) pore water nitrate concentrations are mainly the result of mixing of SW, GW and lateral inputs. Also shown are chemical, biological and hydrologic factors that influence these nitrogen transformations.




## 4. Conclusion

- Quantification of GW-SW mixing in this groundwater-fed river was not straight forward. A third end member, lateral inputs from the riparian zone or upstream areas, was required to satisfy the model.
- Nitrate concentrations in the river bed were altered by mixing processes. Biological and chemical factors however, also influenced pore water nitrogen chemistry.
- The conceptual model of nitrogen cycling presented on this poster will be further refined by:
  - using sediment characteristics in addition to other explanatory variables
  - measurement of natural abundance $\delta^{15}N$- and $\delta^{18}O$-$NO_3^-$
  - targeted *in situ* measurements of nitrogen transformations using $^{15}N$

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