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

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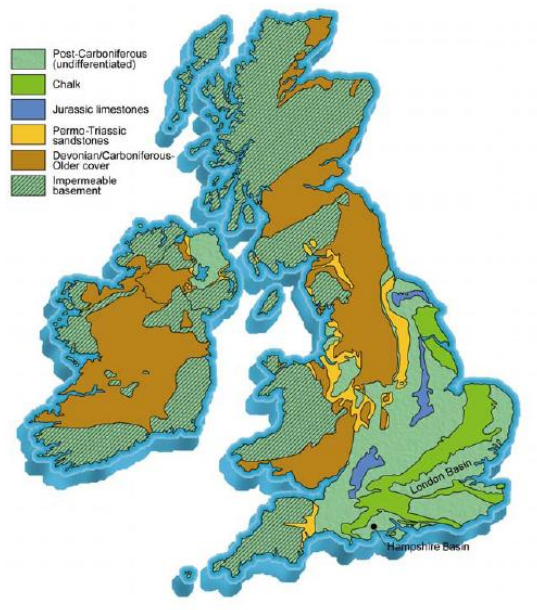
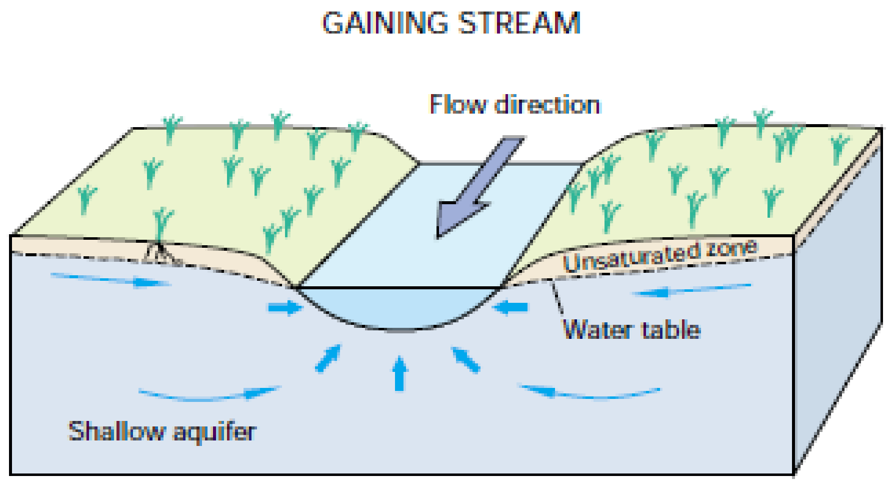
Ground water – surface water connectivity

Water Framework Directive and the requirement to understand flows and pollutant behaviour at the interface of groundwater and surface water.



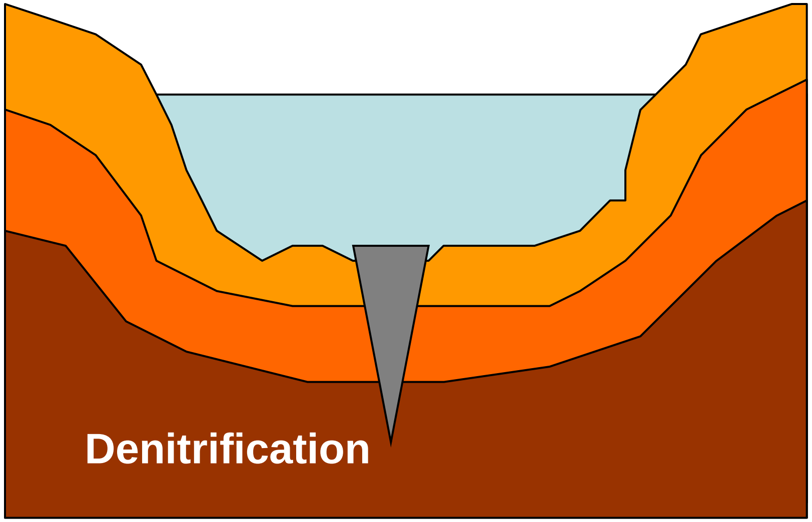


USGS (1998)

- Pressures on GW & SW resources: importance of understanding upwelling systems
- New urgency? possible effects of climate change on UK groundwater fed rivers

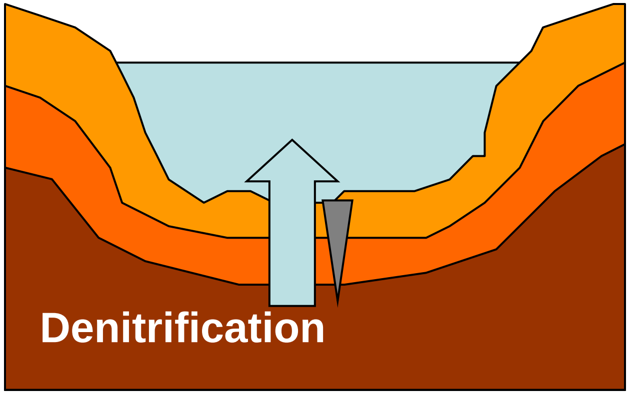
Signficance of nitrate removal by denitrification in the hyporheic zone of high nitrate environments?

In N-rich streams, hyporheic zone acts as a sink for nitrate.
(Jones & Holmes, (1996), Hill et al (1998), Pinay et al (1994))

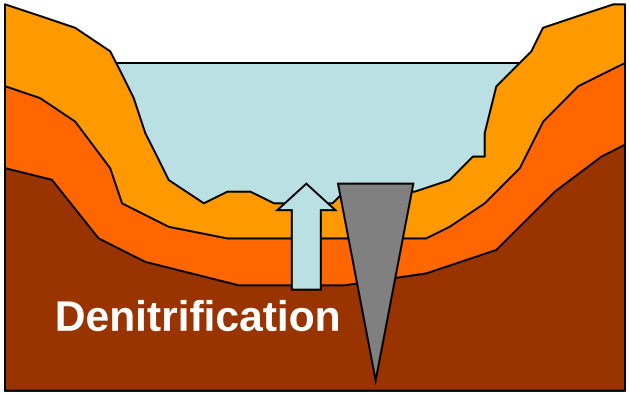


Factors controlling heterotrophic denitrification:
- Low oxygen conditions
- Supply of nitrate
- Availability of organic carbon

Decreasing potential for denitrification with depth?
(Holmes et al., 1996; Baker et al., 2000)



High fluxes, low residence time.
Low nitrate removal by denitrification?

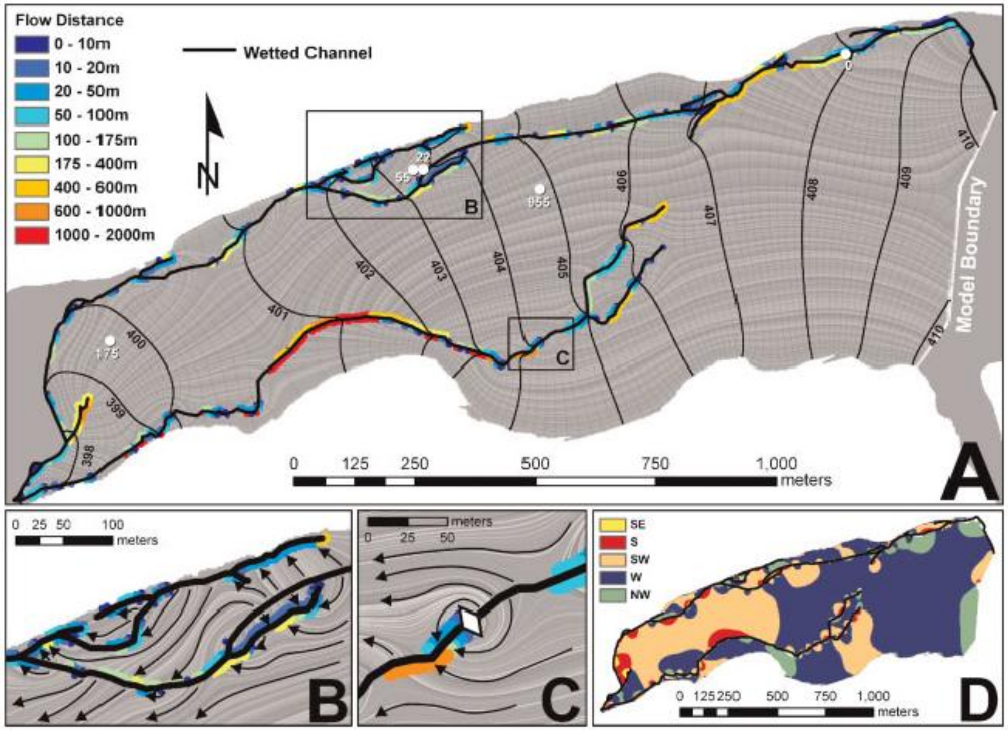


Low fluxes, high residence time.
High nitrate removal by denitrification?

Current challenges in hyporheic zone research:

1. Exploring the complex three dimensional flow pathways of surface water – groundwater exchange in the hyporheic

Using MODFLOW to simulate patterns of groundwater movement and flow path length.

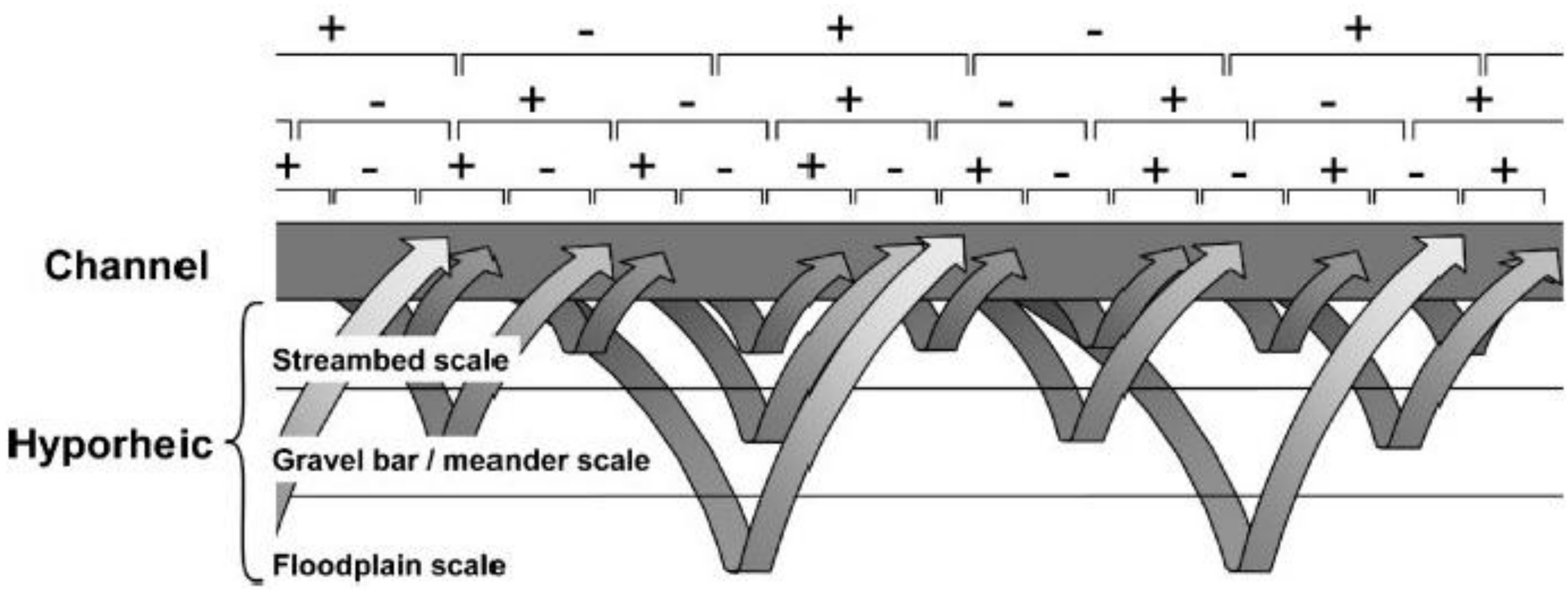


Poole et al (2008) River. Res. Applic. 24: 1018-1031.

Current challenges in hyporheic zone research:

2. Establishing the various scales of surface water – groundwater exchange and their associated dynamics

is path length a simple surrogate for residence time?



Schematic to show nested hyporheic flow paths at multiple scales.

Poole et al (2008) River. Res. Applic. 24: 1018-1031.

Current challenges in hyporheic zone research:

3. Understanding the effect of surface water – groundwater exchange and residence time of water in the hyporheic on fate and transport of nitrogen species

relationship between path length / residence time and nitrate removal in the hyporheic.

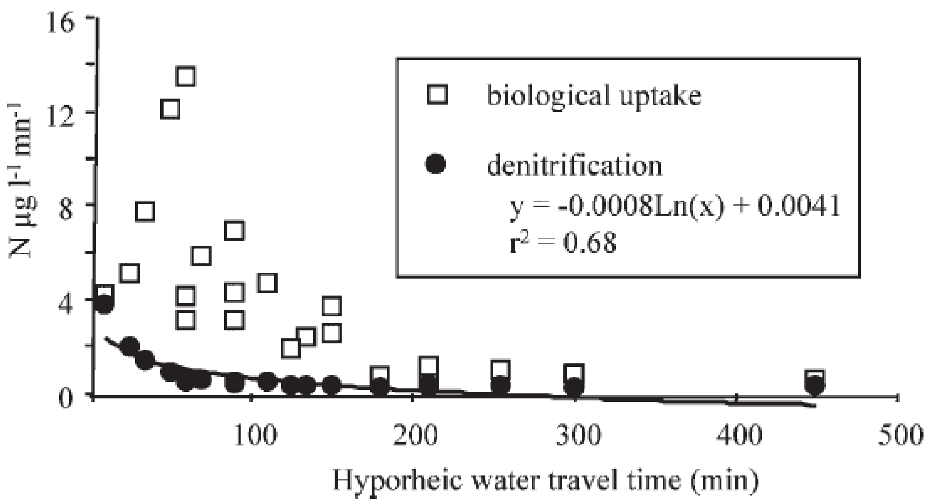


Figure 5. Relationship between the hyporheic water travel time after nitrate injection and the resulting biological uptake (white squares) and denitrification (filled circles) during the same period. The equation corresponds to the best fit of the denitrification data

Pinay *et al* (2009) River. Res. Applic. 25: 367-375.

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

Purpose of presentation: *To demonstrate our approaches to the current scientific challenges facing hyporheic research.*

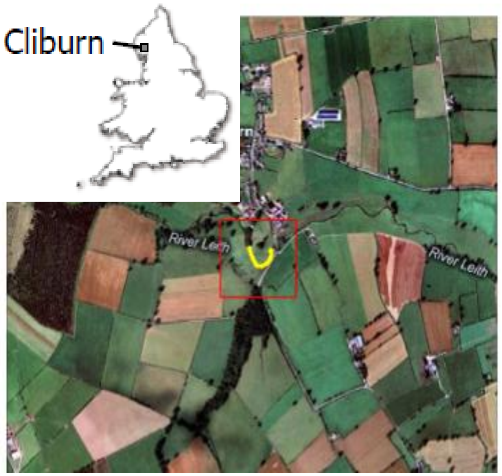
- Nested instrument approach to establishing flow pathways in the hyporheic

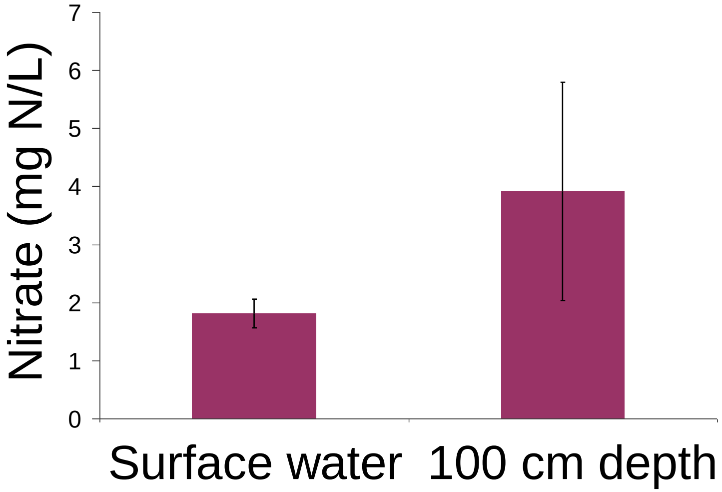
- Investigating spatial controls on the magnitude of SW-GW mixing to one metre depth using chemical and isotopic tracers and temperature

- Measurements of rates and magnitudes of nitrogen cycling over a variety of scales in the hyporheic zone using sediment potential assays, push-pull and diffusive equilibrium in thin film techniques

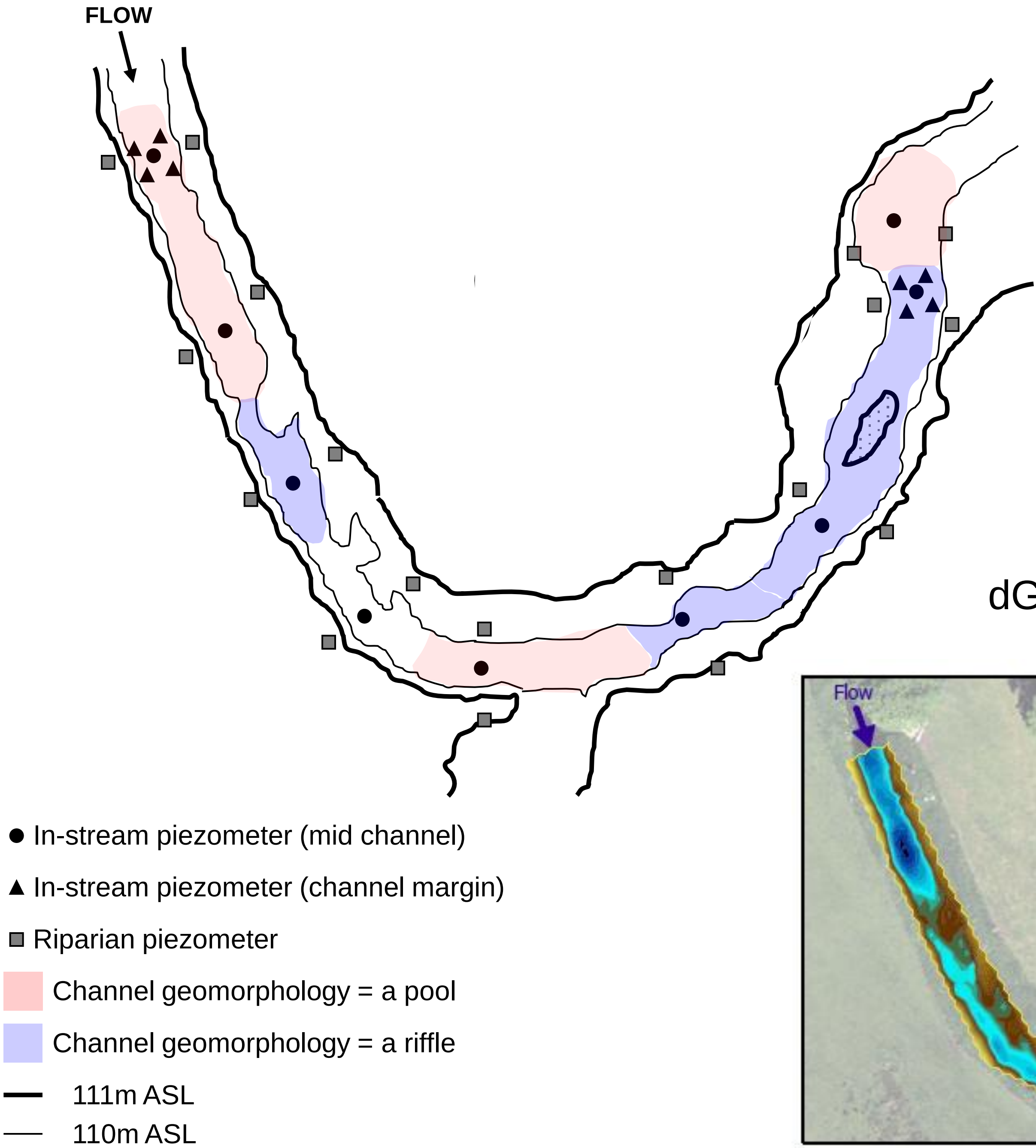
Fieldsite: River Leith, Cumbria, UK

250 m gaining reach; permo-triassic sandstone
Agricultural pastoral and arable landscape

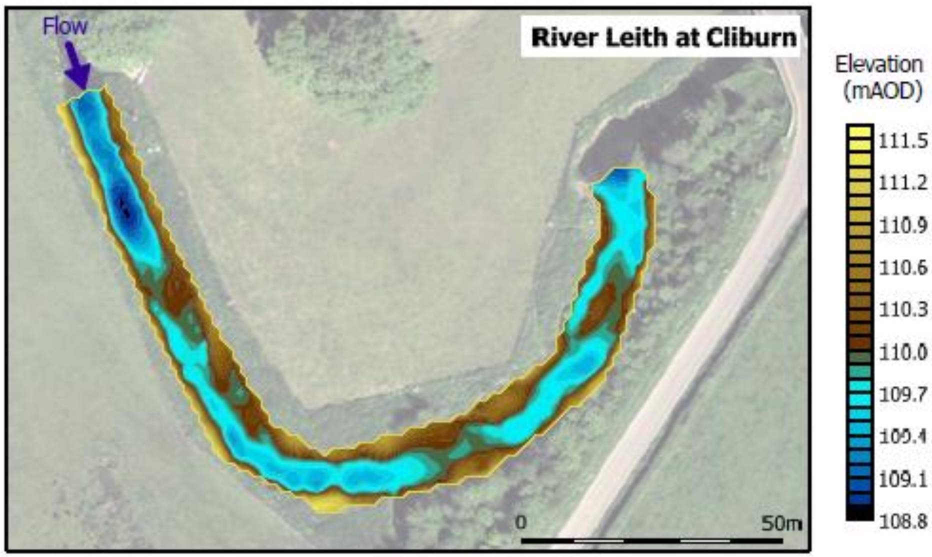




Geomorphic features at the site

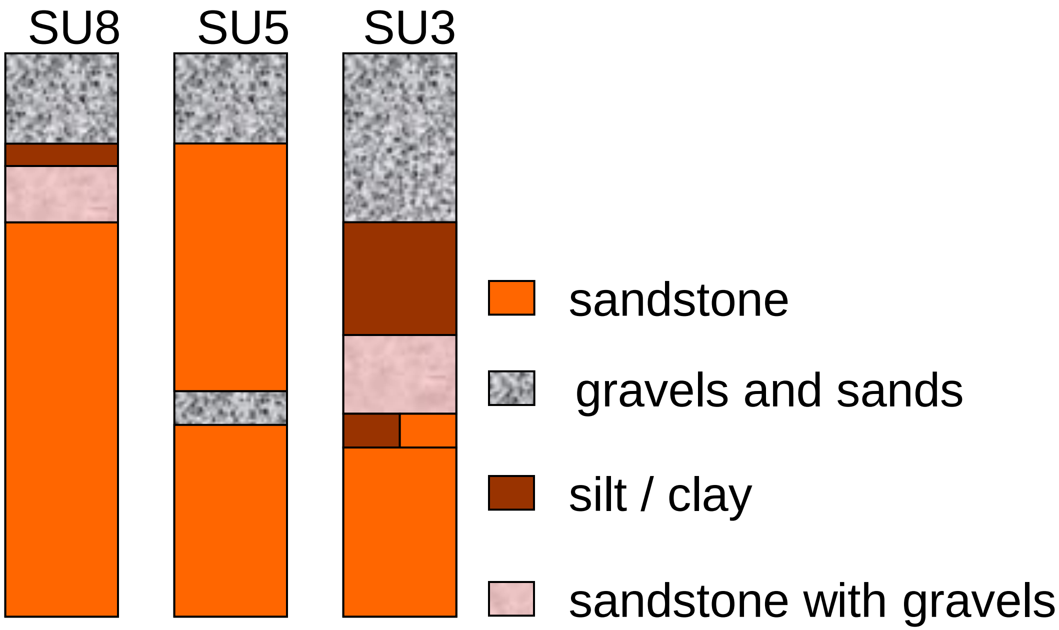


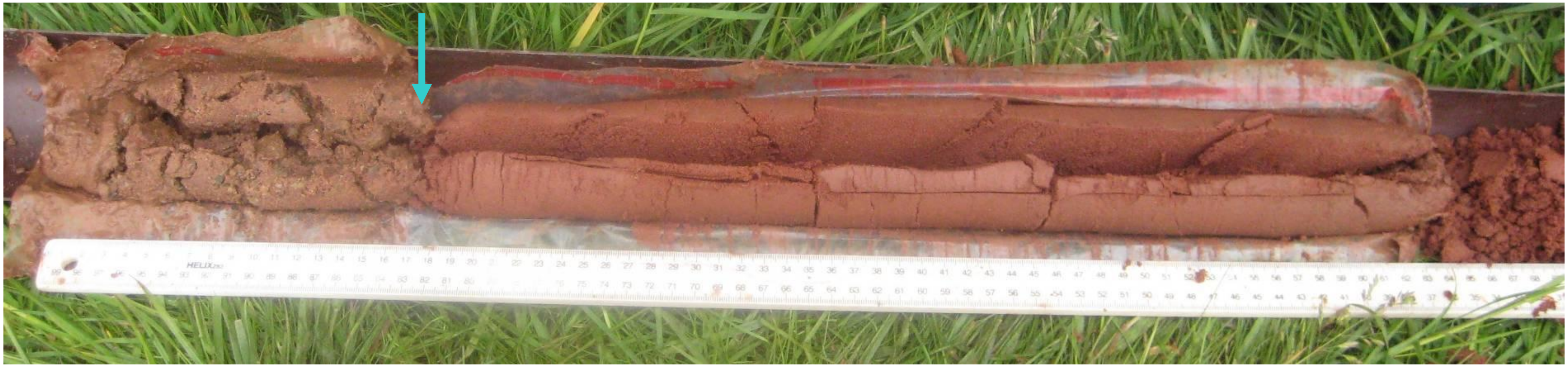
dGPS survey of R. Leith fieldsite (2010)



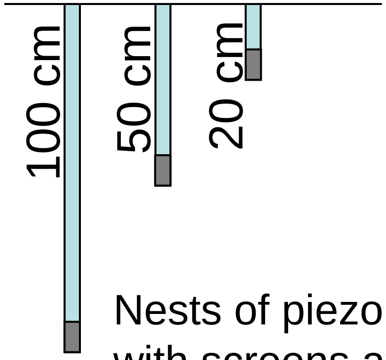
River Leith: Baseflow conditions

Sediment stratigraphy





Determining vertical, lateral and longitudinal flow pathways in the hyporheic

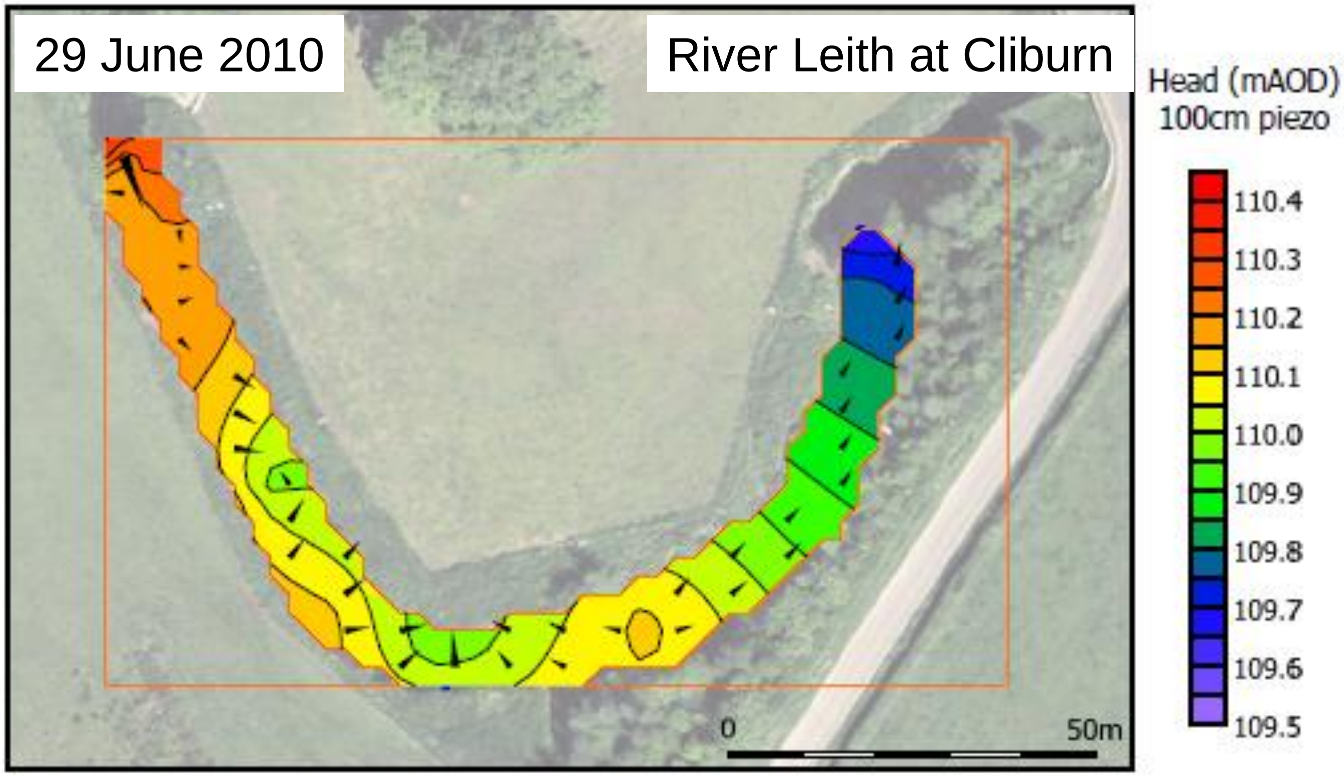


Nests of piezometers with screens at 20,50 and 100 cm

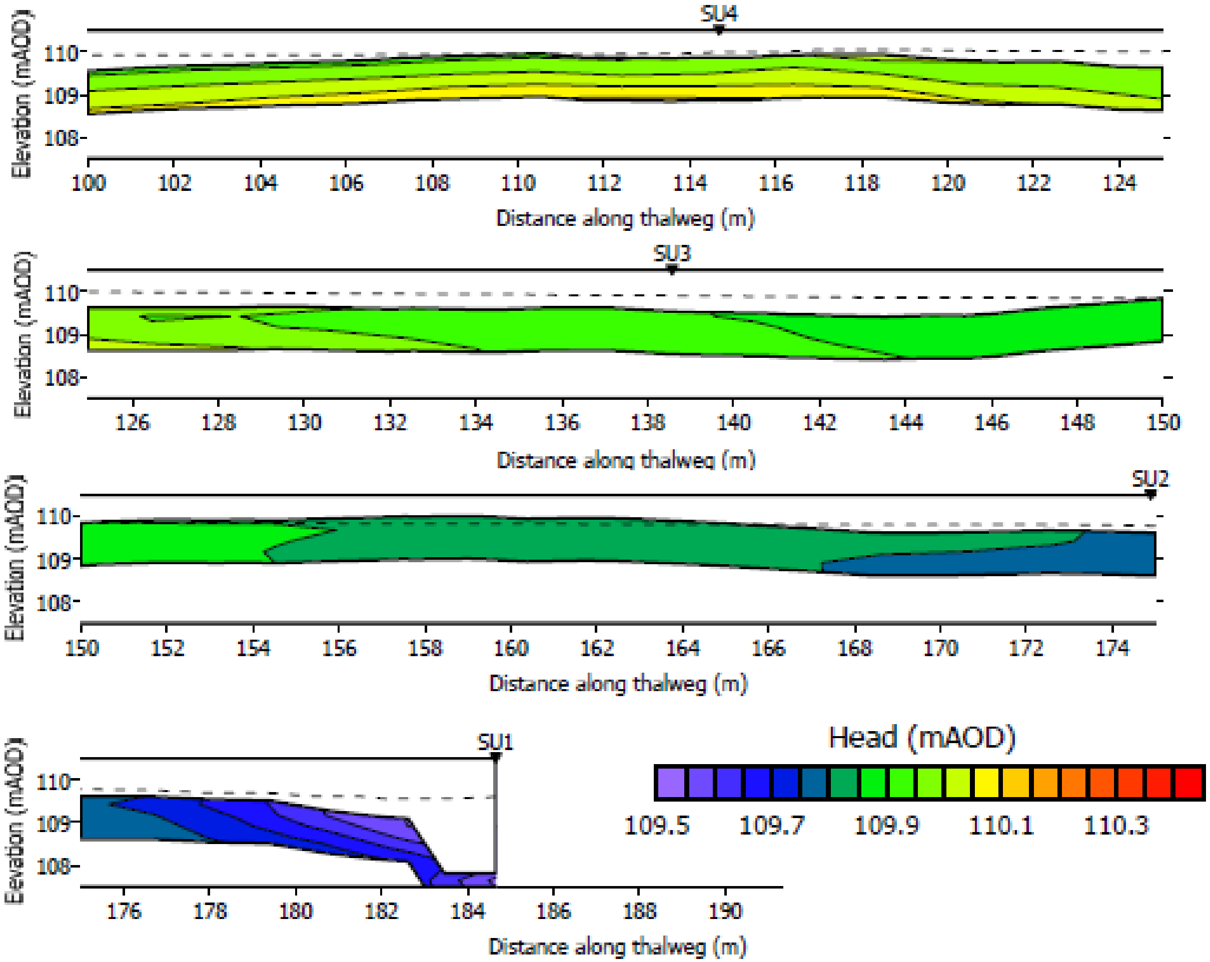
- Monitoring wells used to measure vertical head gradients on a fortnightly basis (some continuously recording with dataloggers)

-Falling and rising head slug tests to derive hydraulic conductivity (repeated annually to account for variations in river bed stratigraphy)

Interpolation of piezometer head data (100 cm) to indicate dominant hydrologic flow paths

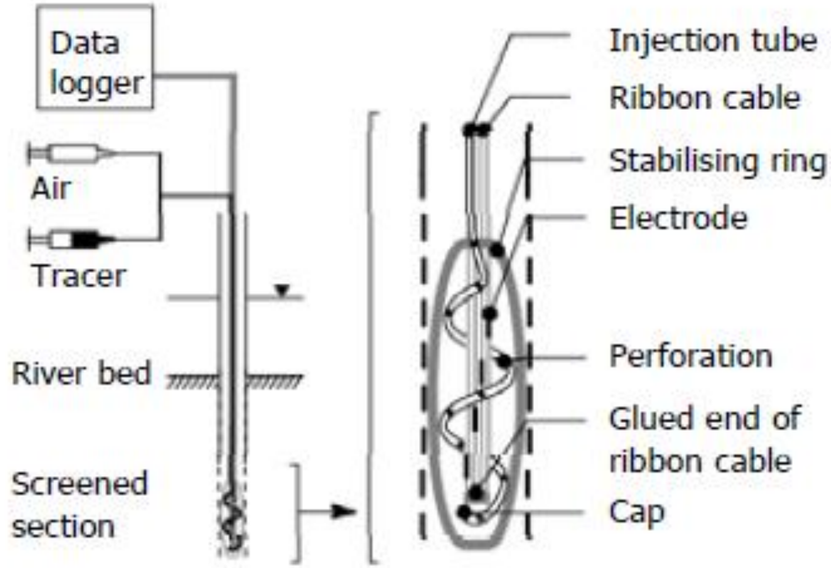


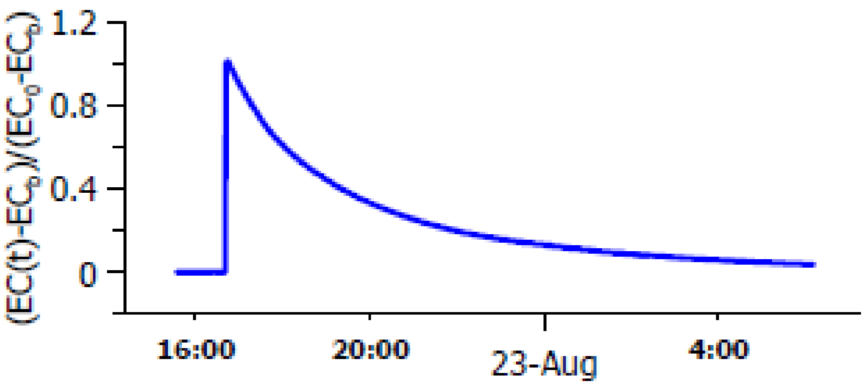
Head profile: vertical section along thalweg 09 Sept 2011



Note: Vertical:horizontal scale is 1:1

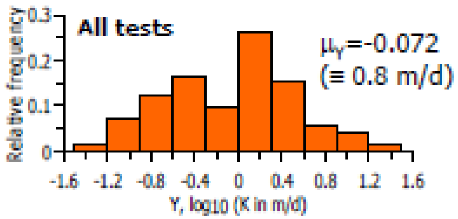
Quantifying lateral & longitudinal fluxes using single well dilution tests

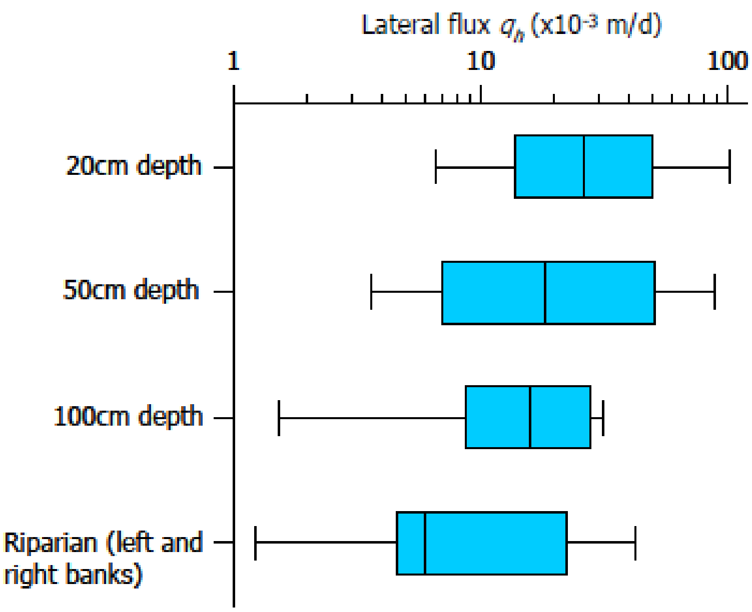




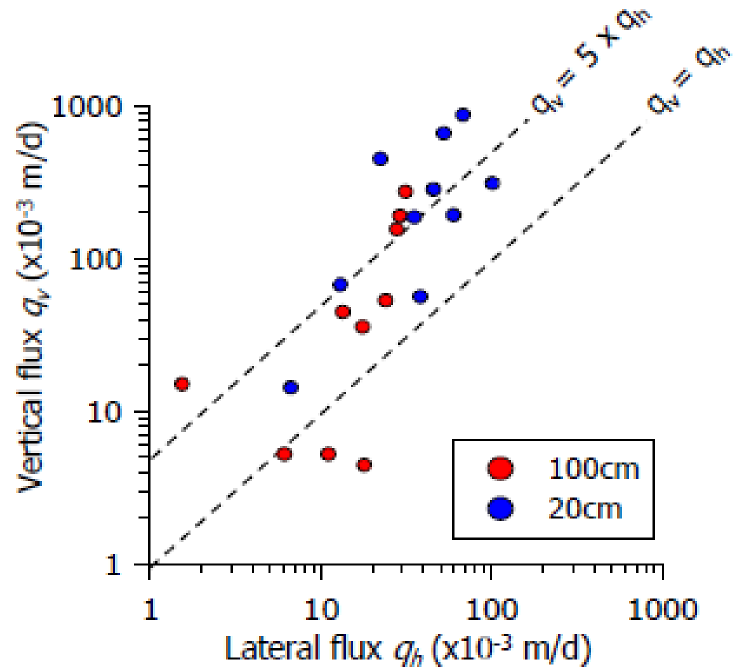
Binley *et al.* AGU poster (2010)

Inter-quartile ranges in hydraulic conductivities and lateral fluxes at given depths across the site





Lateral fluxes

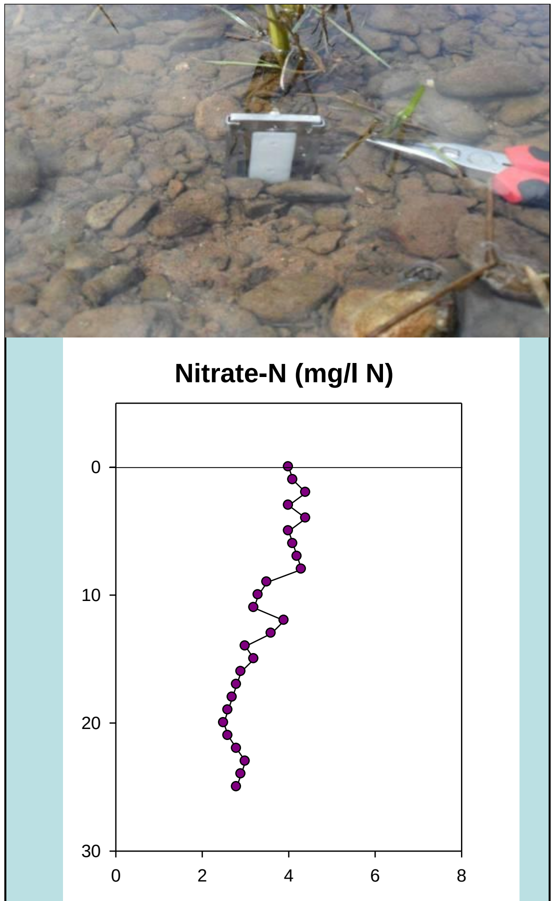


Comparison of lateral & vertical fluxes

Binley *et al*. AGU poster (2010)

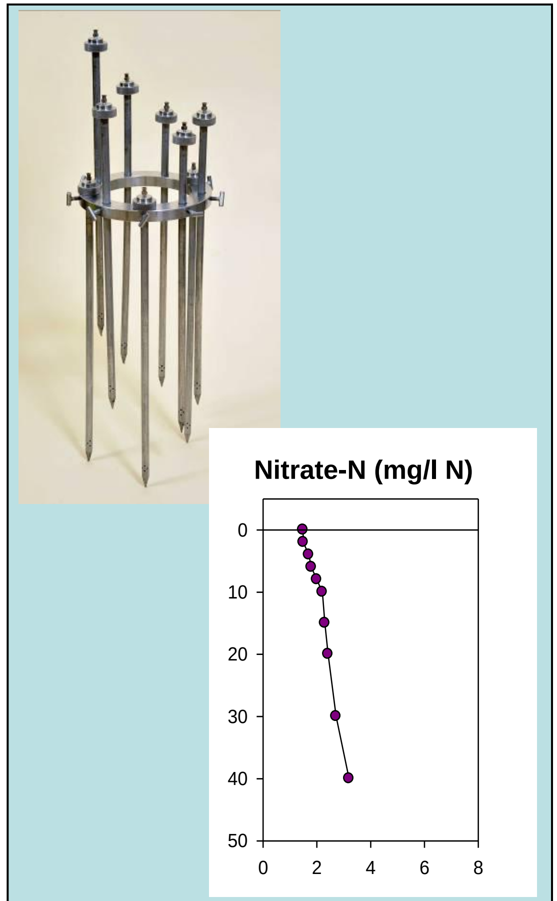
Scales of N species profile measurements

mm - cm



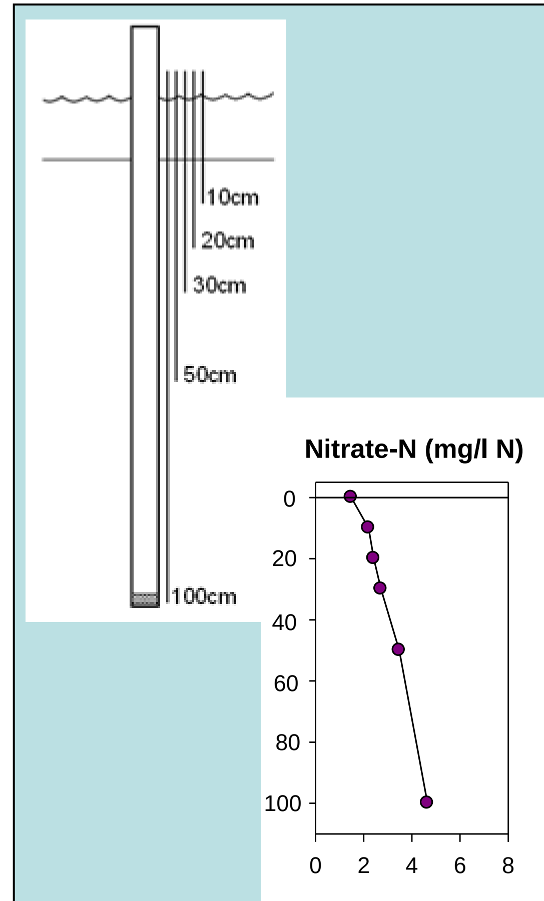
DET

cm - dm



Pore water probes

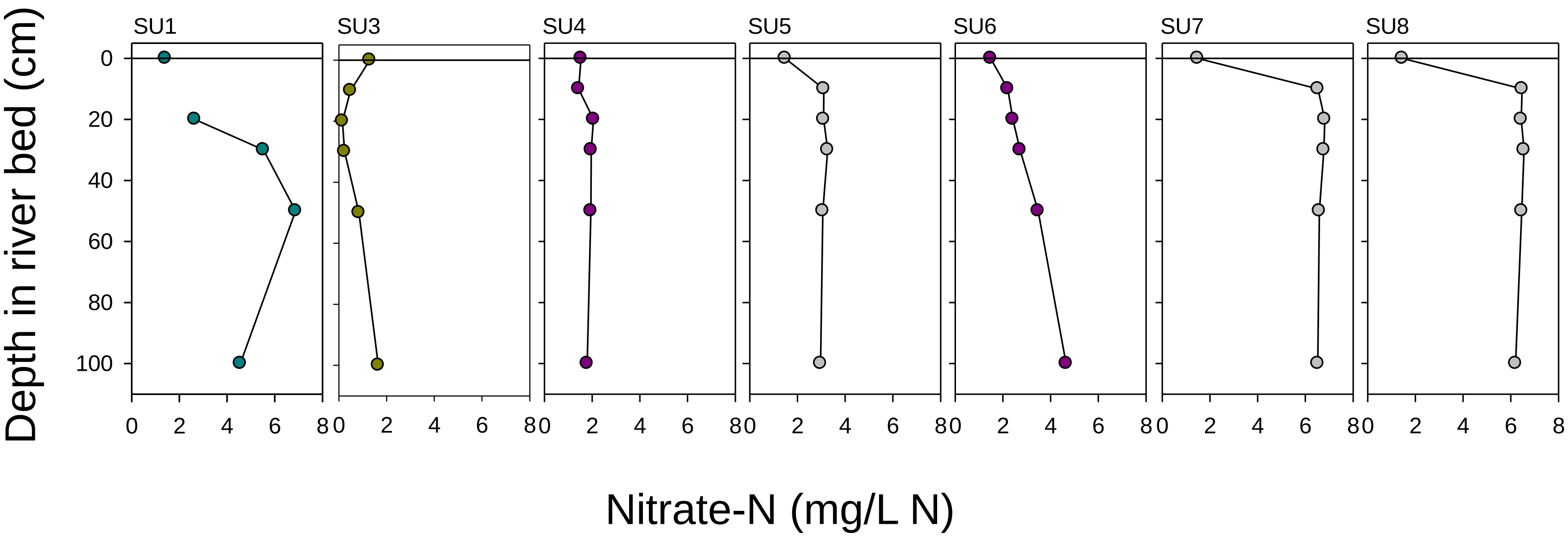
dm - m



Pore water tubes

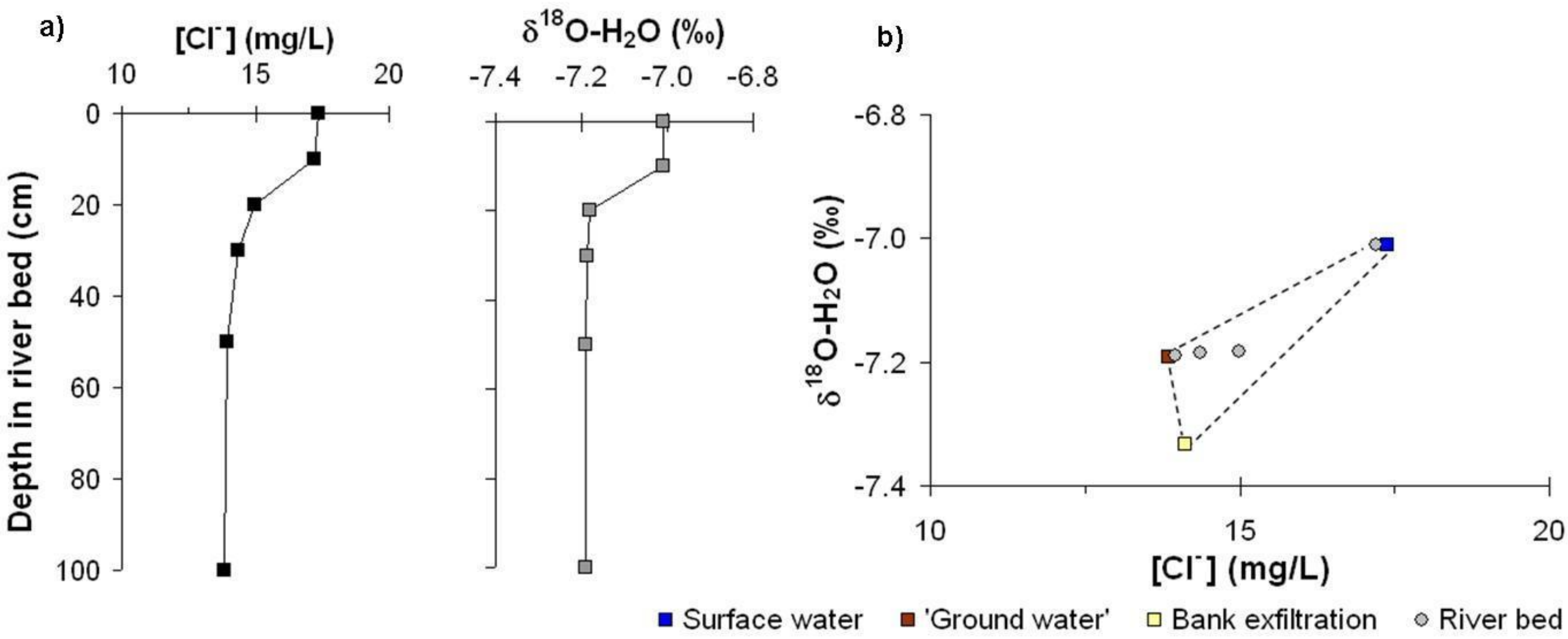
Variation in nitrate concentration profiles

August 2010



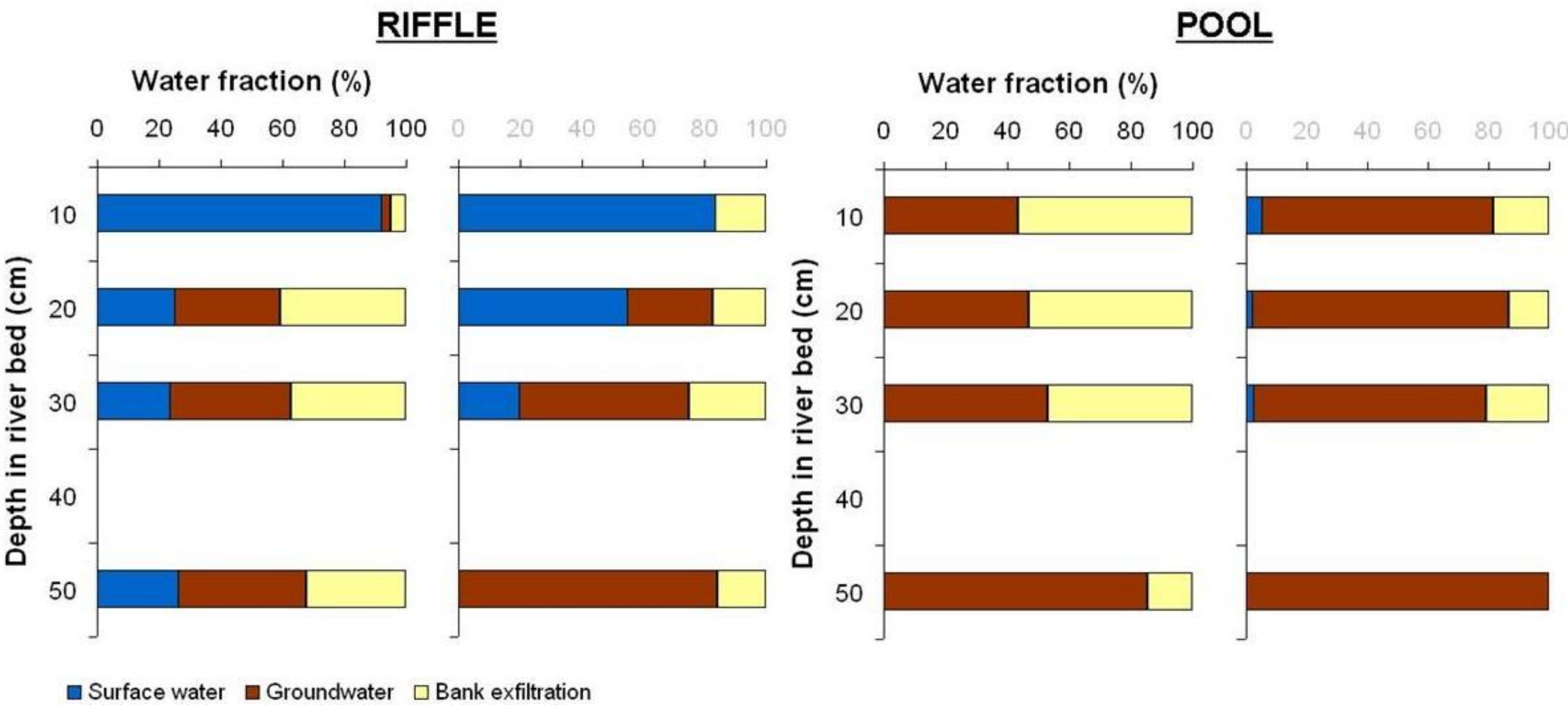
What is the relative contribution of mixing and nitrogen cycling?

Mixing or N cycling? Using chemical tracing of GW-SW mixing in the hyporheic zone



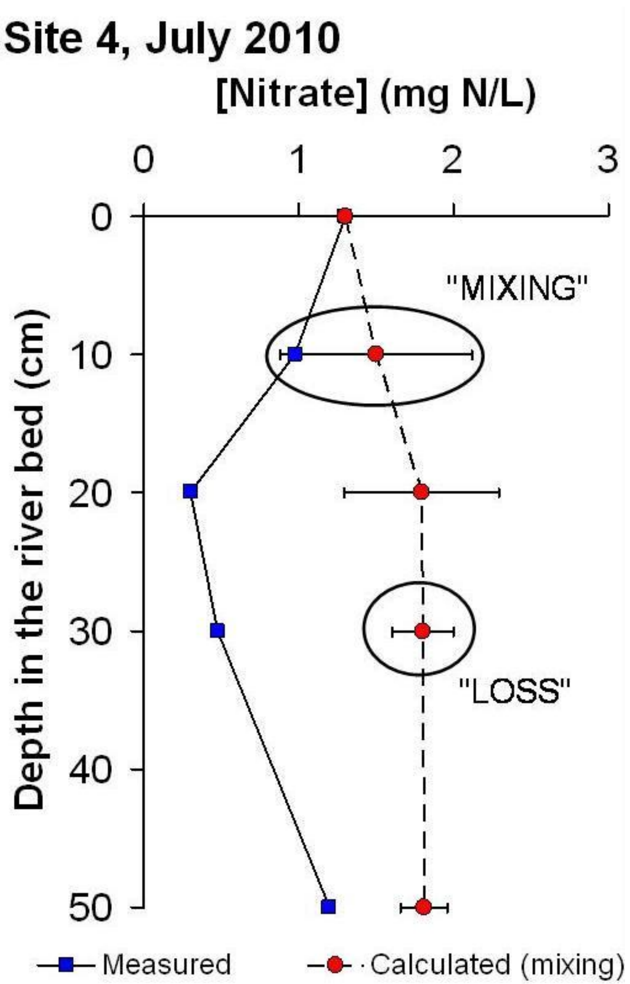
End member mixing analysis (EMMA) to quantify ‘source’ fractions indicates more than two end members

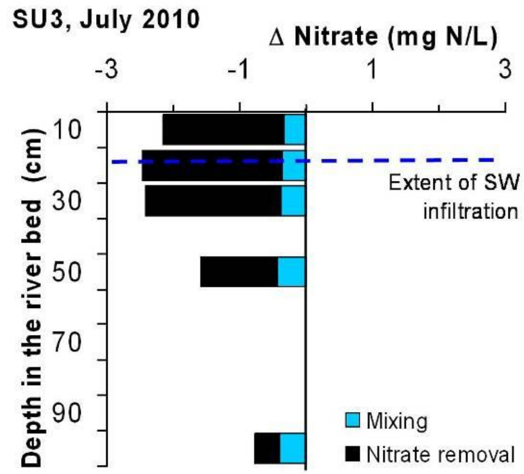
Identifying magnitudes of water source fractions at different sites

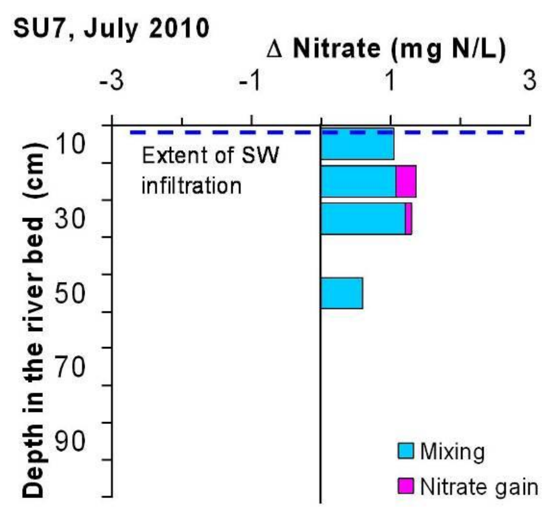


Riffles are locations of localised surface water – groundwater exchange to tens of centimetres in the river bed.

Identifying areas of nitrate gain and loss in the river bed

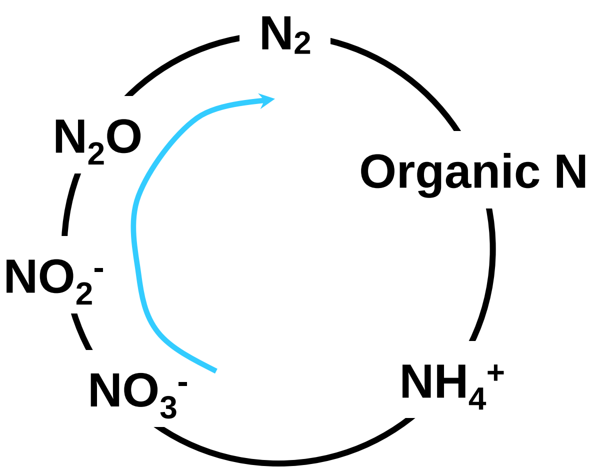




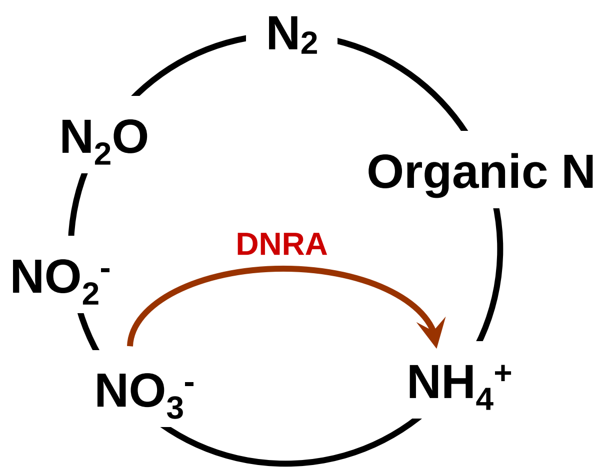


Areas of nitrate gain and loss are identified beneath the zone of SW-GW exchange.

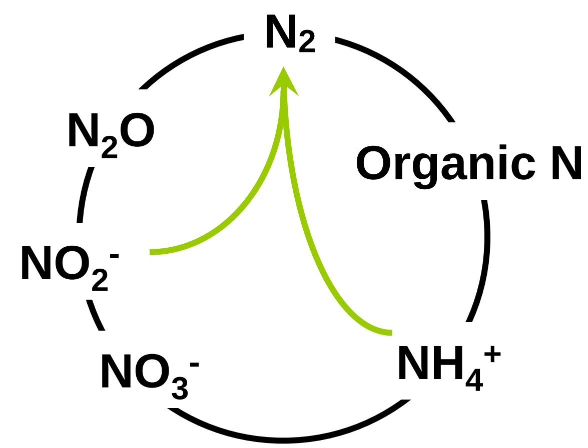
What processes could nitrate losses be due to?



Denitrification



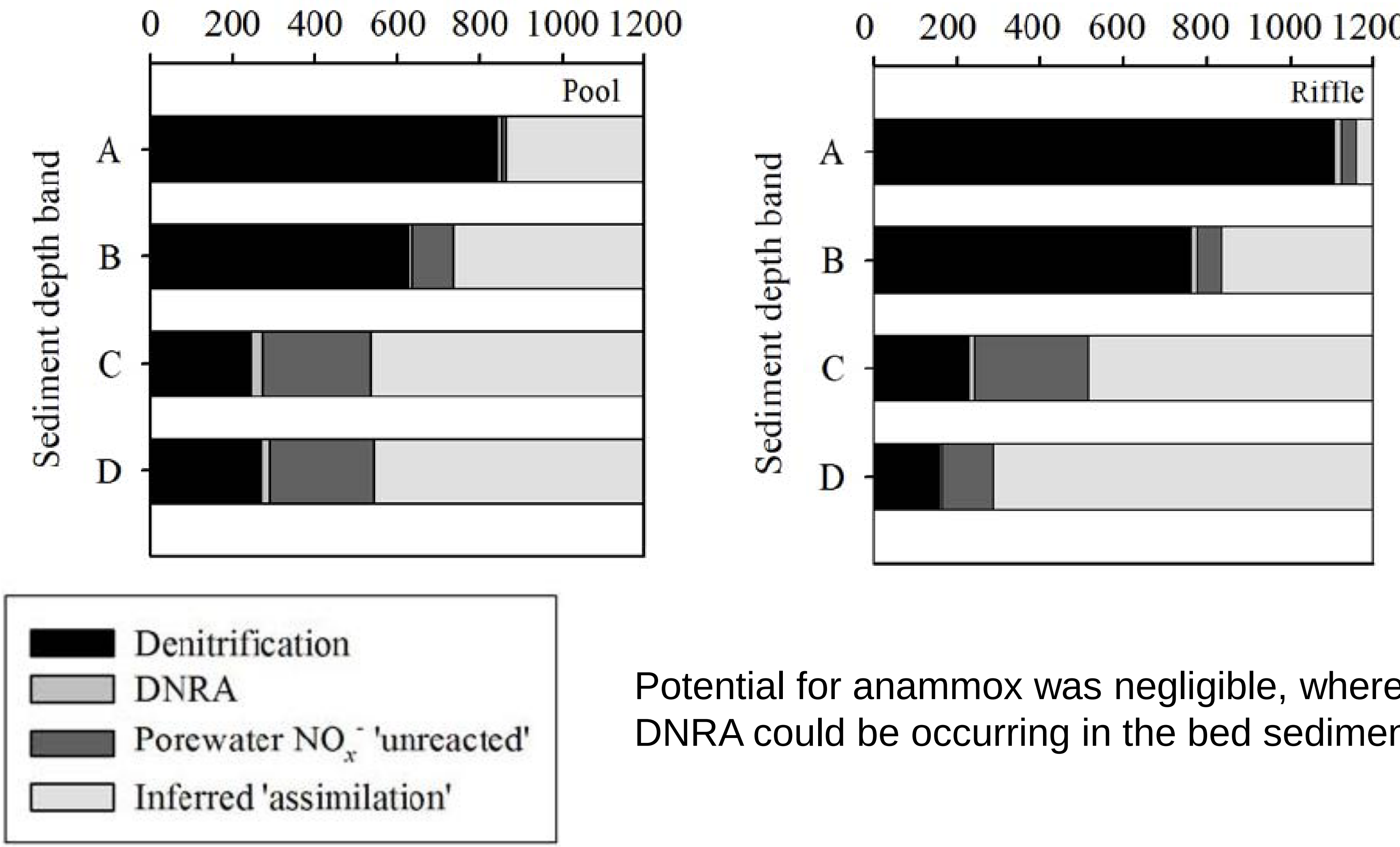
Dissimilatory
Nitrate Reduction
to Ammonium



Anammox

Potential measurements to determine N cycling processes in hyporheic

15-nitrate budgets as N equivalents (nmol at end of incubation)



Potential for anammox was negligible, whereas DNRA could be occurring in the bed sediments

Conclusions

Hydrological analyses has indicated that there are complex three-dimensional vertical and lateral fluxes of water in the sediment of the R. Leith. These interactions are occurring in a predominantly upwelling reach & under baseflow conditions.

End member mixing analysis has indicated that:

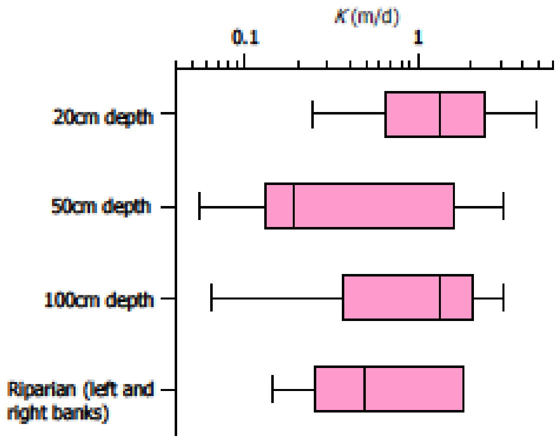
- riffles can be areas of SW-GW exchange to tens of centimetres depth

- there may be areas of nitrate gain and loss occurring at greater depth than the pathways of SW-GW exchange

Sediment potential assays have shown that:

- there is the potential for denitrification, DNRA and microbial assimilation to occur in these bed sediments.

- see next presentation for sediment potential and in-situ details



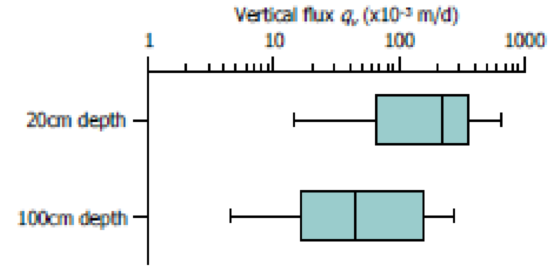


Figure 6: Comparison of vertical fluxes computed at 20cm and 100cm depths.