SWITCH

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Natural Attenuation Potential of the Urban Hyporheic Zone: Foundational studies to the River Tame dipole field experiments

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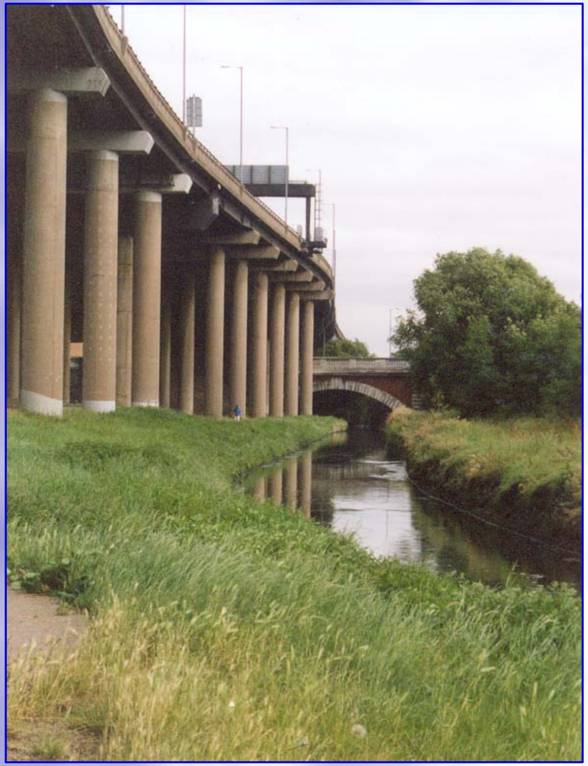
ENVIRONMENT AGENCY

Outline

- Research aims and concept
- Foundational studies on the River Tame
  - Field studies
  - Modelling studies
- Dipole field experiment site
  - Site location
  - Local field characterisation
  - Experiment design
- Future work

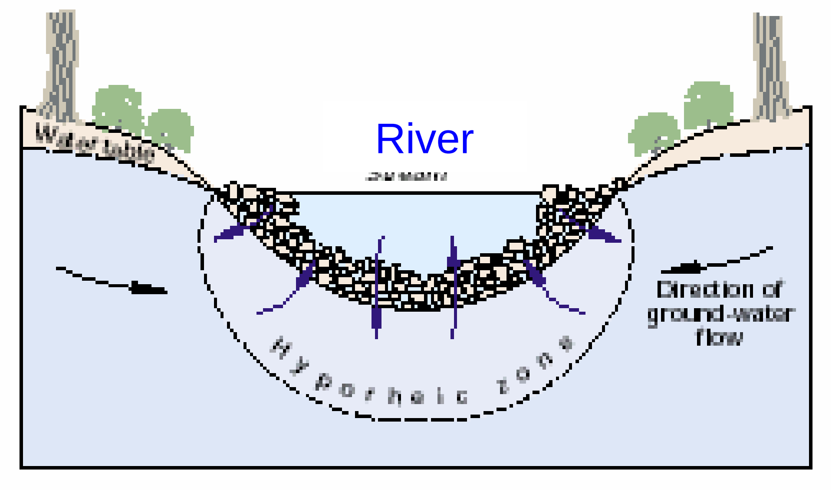


Research aims

Work Package 5.3 Natural Systems and the Urban Water Cycle

Task 4: Study of natural systems for water retention and self purification

Hyporheic Zone – Groundwater – surface water mixing



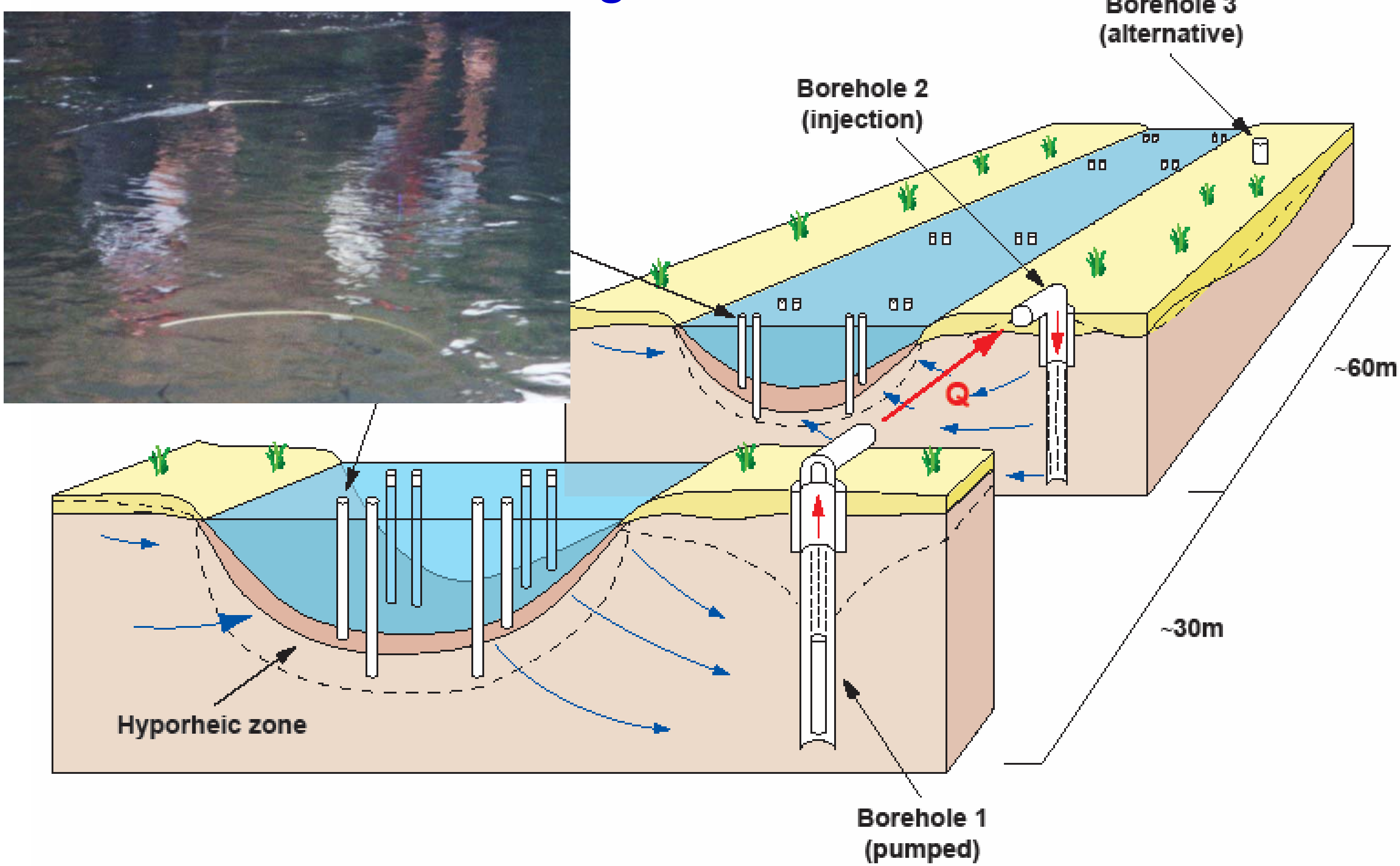
(USGS Circular 1139, 2001)

- Infiltration of oxygenated SW
- High organic carbon, nutrients
- High microbiological activity
- Steep redox gradients
- Dynamic flows

- To evaluate the potential of the urban hyporheic zone to naturally attenuate water contamination
- To predict potential for engineered enhancement of hyporheic zone attenuation

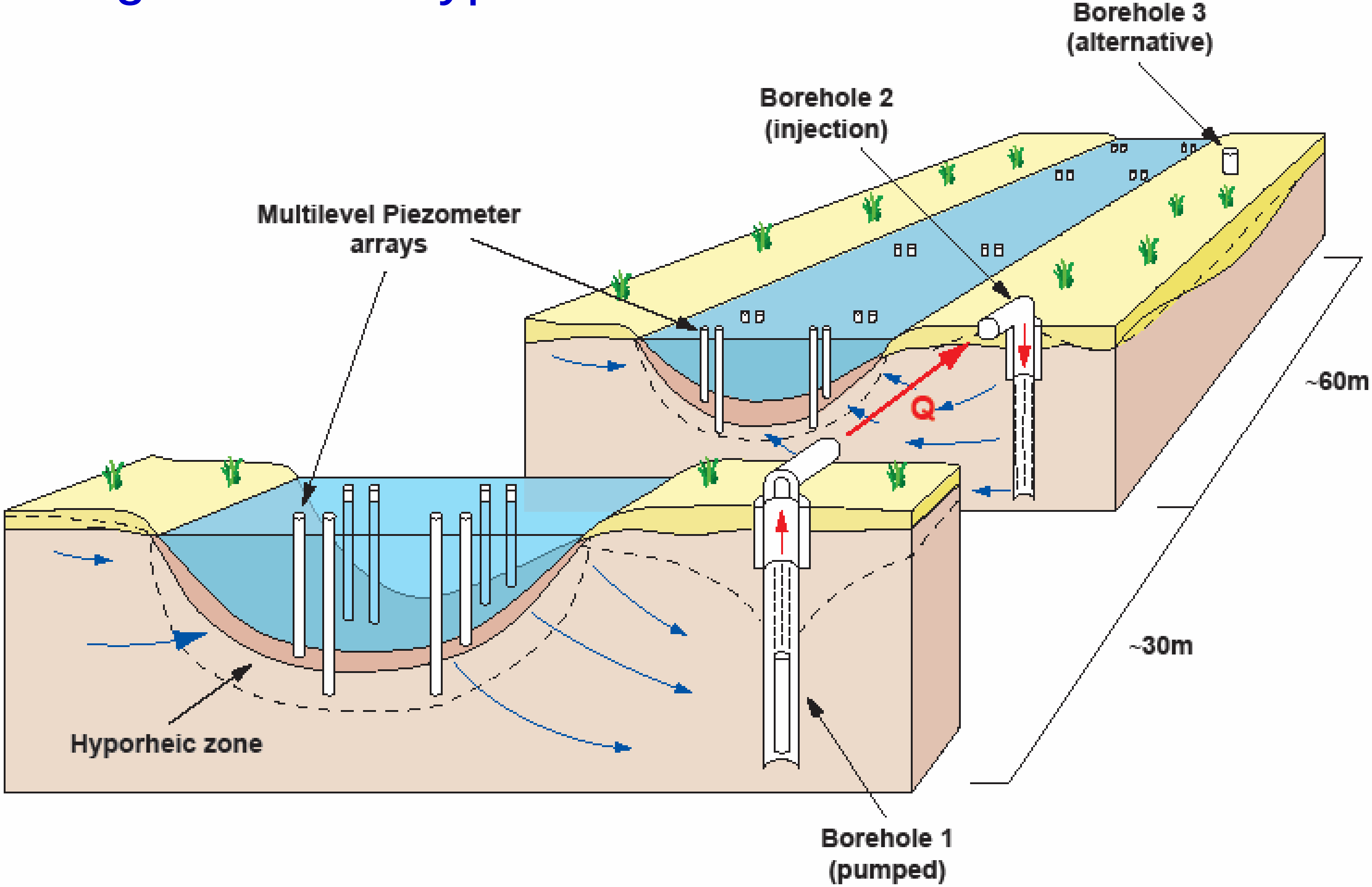
Research concept

- Dipole experiments involving extraction & injection well pairs adjacent to a river to perturb natural groundwater – surface-water exchanges in a controlled manner



Research concept

- Transport of solutes/contaminants naturally present and injected tracers will be monitored in experiments to investigate urban hyporheic zone natural attenuation.



Foundational studies (a selection):
River Tame – Birmingham Sandstone aquifer

Groundwater – Surface-water (Hyporheic zone)

- Ellis, P.A., 2003. The impact of urban groundwater upon surface water quality: Birmingham – River Tame study, UK. PhD thesis, School of Geography, Earth & Environmental Sciences, University of Birmingham, UK, 360 pp.
- Ellis, P.A., Mackay, R. and Rivett, M.O., *in press*. Quantitative modelling of urban groundwater river exchanges – A case study on the Tame river, Birmingham, UK. *J. Contam. Hydrol.*
- Ellis, P.A. and Rivett, M.O., *in press*. Assessing the impact of VOC-contaminated groundwater on surface-water quality at the conurbation scale. *J. Contam. Hydrol.*
- Ellis, P.A., Rivett, M.O., Henstock, J, Dowle., Mackay, R., Ward, R. and Harris, R., 2002. Impacts of contaminated groundwater on urban river quality – Birmingham, UK. In: *Groundwater quality: Natural and enhanced restoration of groundwater pollution*. IAHS publication No. **275**, 71-77.
- Ellis, P.A., Rivett, M.O. and Mackay, R. 2004. Estimation of groundwater-contaminant fluxes to urban rivers. In: *Hydrology: Science & Practice for the 21st Century*, British Hydrological Society (Publ.) 272-279.

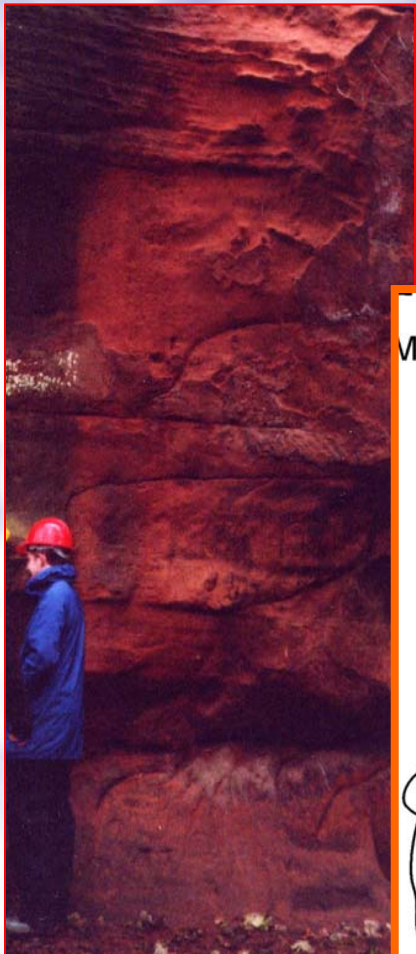
Groundwater

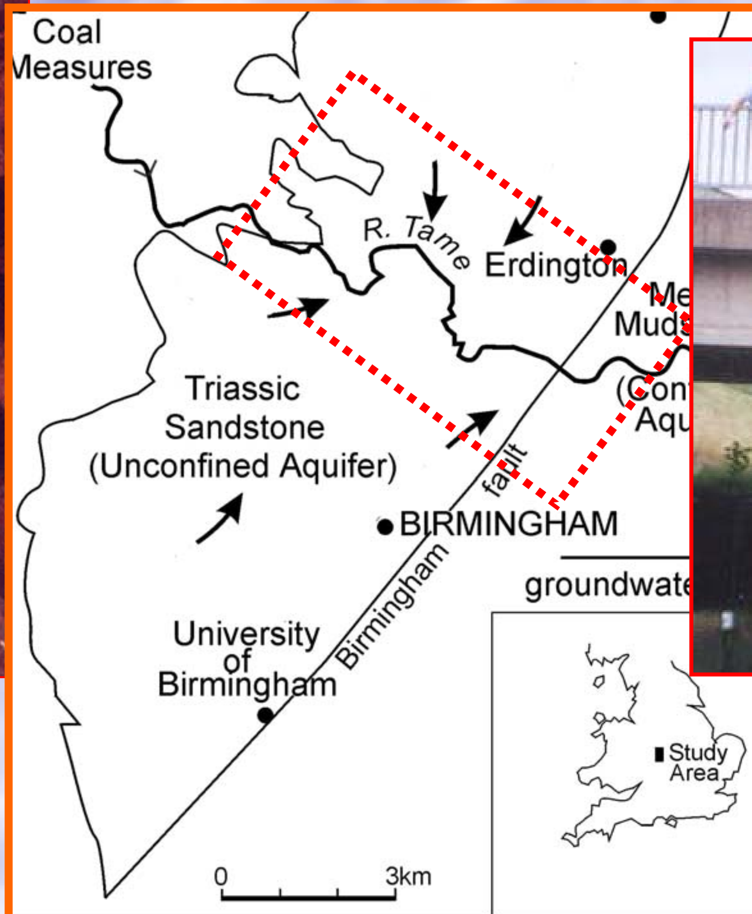
- Ford, M. and Tellam, J.H., 1994. Source type and extent of inorganic contamination within the Birmingham urban aquifer system, UK. *J. Hydrol.* **156**, 101-135.
- Jackson, D., Lloyd, J.W., 1983. Groundwater chemistry of the Birmingham Triassic Sandstone aquifer and its relation to structure. *Quart. J. Eng. Geol.* **16**, 135-142.
- Knipe, C.V., Lloyd, J.W., Lerner, D.N. and Gresswell, R., 1993. Rising groundwater levels in Birmingham and the engineering implications. *CIRIA (London). Spec. Publ*. **92**, 114pp.
- Rivett, M.O., Lerner, D.N., Lloyd, J.W. and Clark, L. 1990. Organic contamination of the Birmingham aquifer, U.K. *J. Hydrol.* **113**, 307-323.
- Rivett, M.O., Shepherd, K.A., Keeys, L., Brennan, A.E., 2005. Chlorinated Solvents in the Birmingham Aquifer, UK: 1986 – 2001. *Quart. J. Eng. Geol. & Hydrogeol.* **38**(4), 337-350.
- Shepherd, K.A., Ellis, P.A. and Rivett, M.O., 2006. Integrated understanding of urban land, groundwater, baseflow and surface-water quality – The City of Birmingham, UK. *Sci. Tot. Environ.* **360**, 180-195.
- Thomas, A., Tellam, J.H., 2006. Modelling of recharge and pollutant fluxes to urban groundwaters. *Sci. Tot. Environ.* **360**, 158-179.

Foundational studies on the River Tame

– Field studies

Triassic Sandstone aquifer effluent to 7km reach of the River Tame

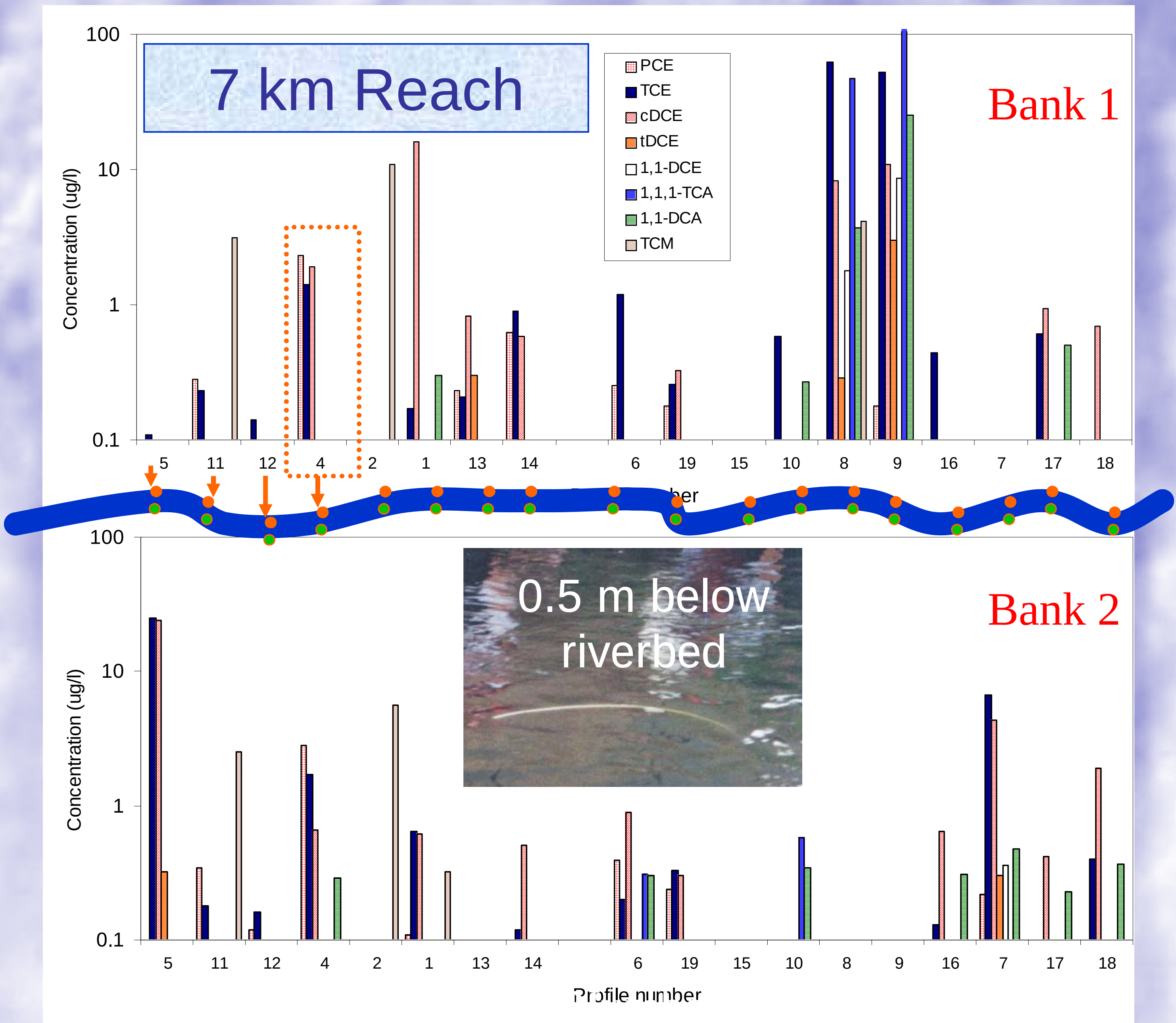




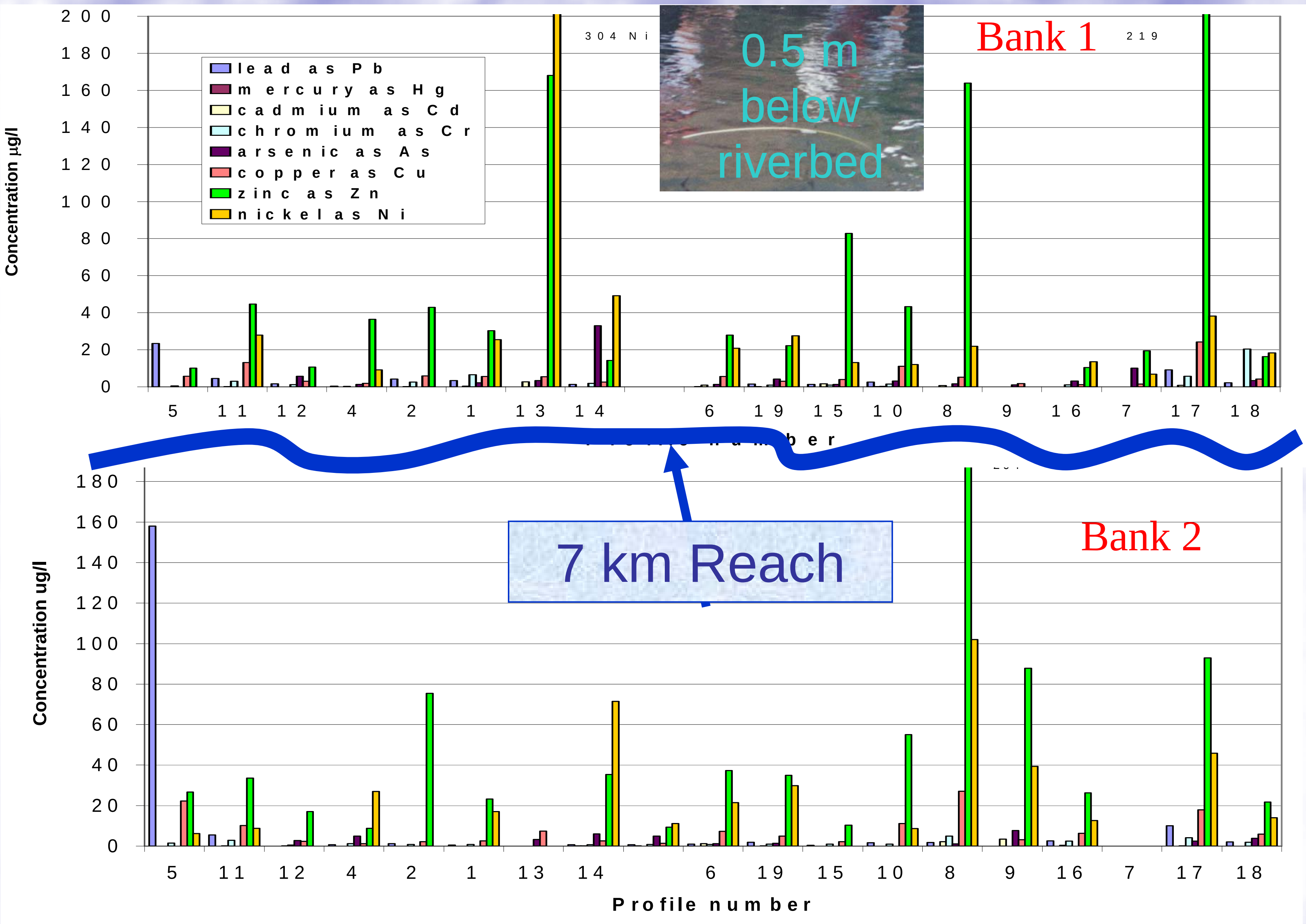
- K ~ 2 m/d
- n ~ 0.27
- S_y ~ 0.1
- Chlorinated solvents, metals

- Q_{min}~180 Ml/d
- Baseflow ~7% Q_{total}
- Quality Class E/F

VOCs in groundwater baseflow (7 km reach)

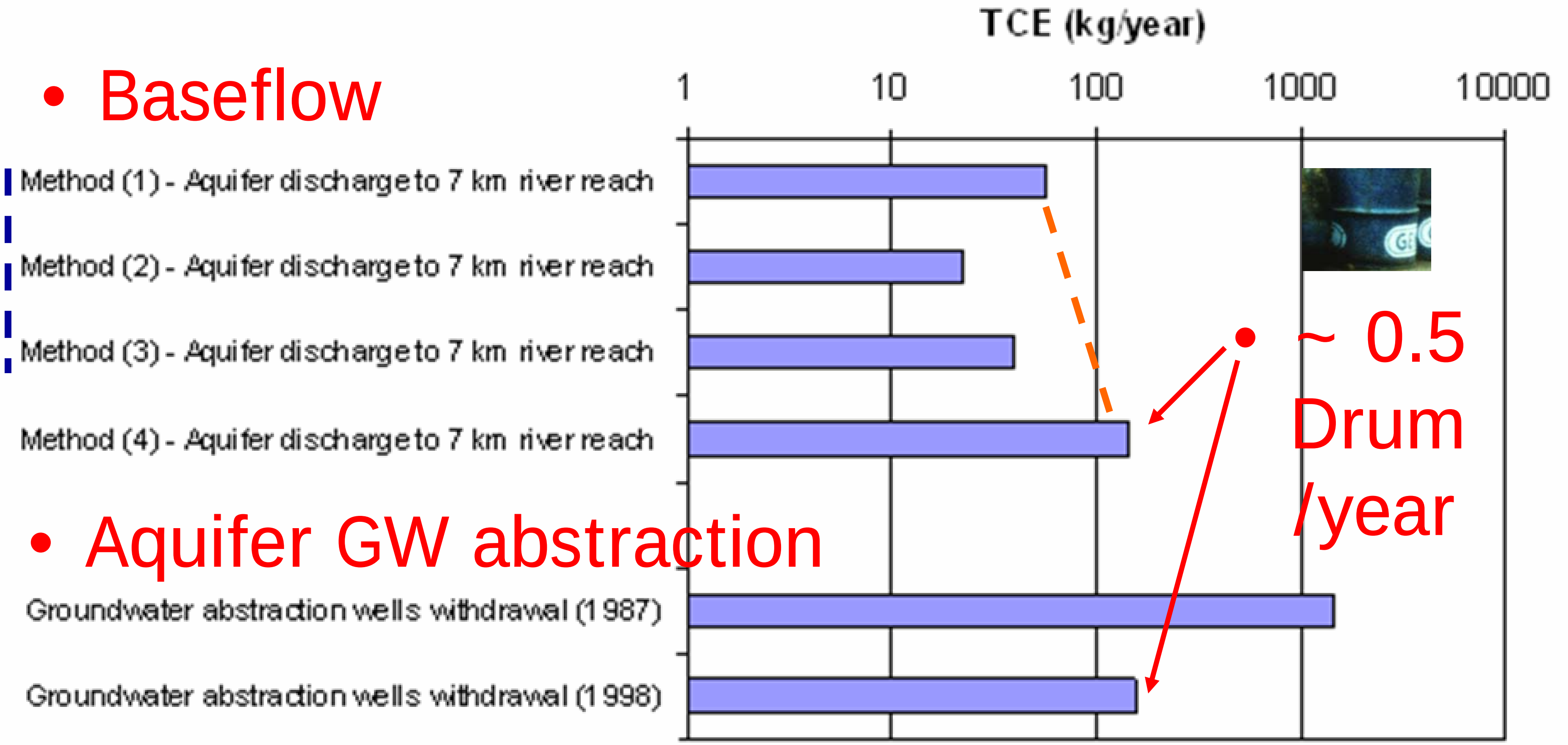


Metals in groundwater baseflow (7 km reach)



TCE baseflow flux – 7 km reach

- Baseflow

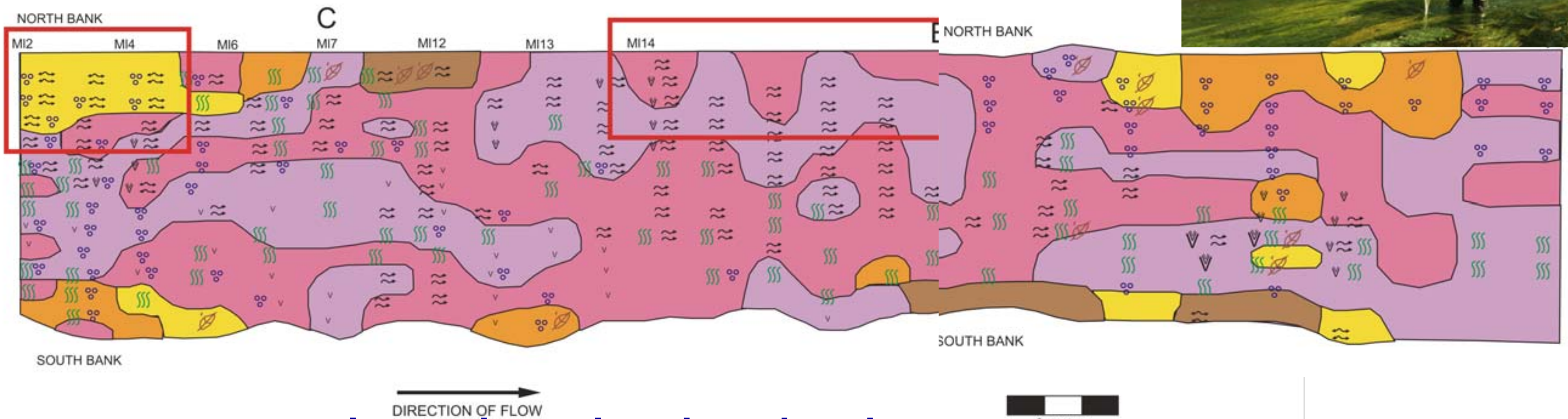


- Aquifer GW abstraction

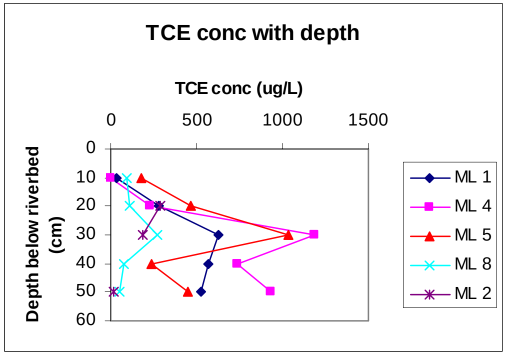
- ~ 0.5 Drum /year

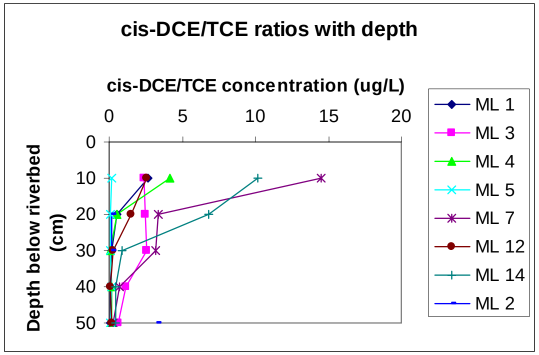
Local scale (< 100 m reach) natural attenuation studies

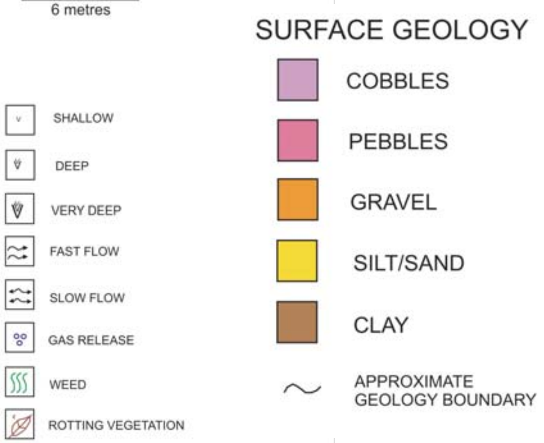
- Grain-size distribution of surface sediments



- ~ 120 sample points in riverbed







Foundational studies on the River Tame

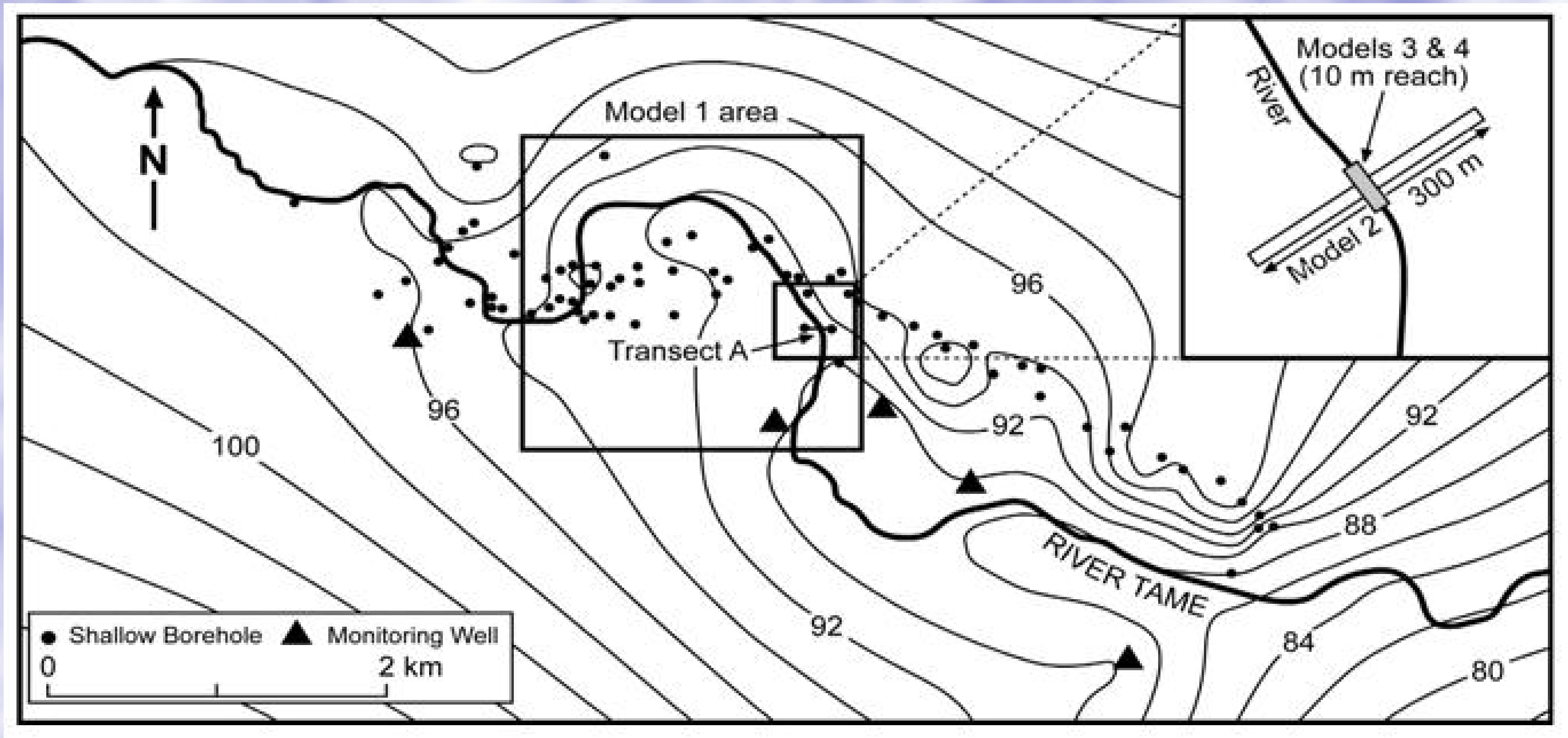
– Modelling studies

- Ellis, P.A., Mackay, R. and Rivett, M.O., *in press*. Quantitative modelling of urban groundwater river exchanges – A case study on the Tame river, Birmingham, UK. *Journal of Contaminant Hydrology.*

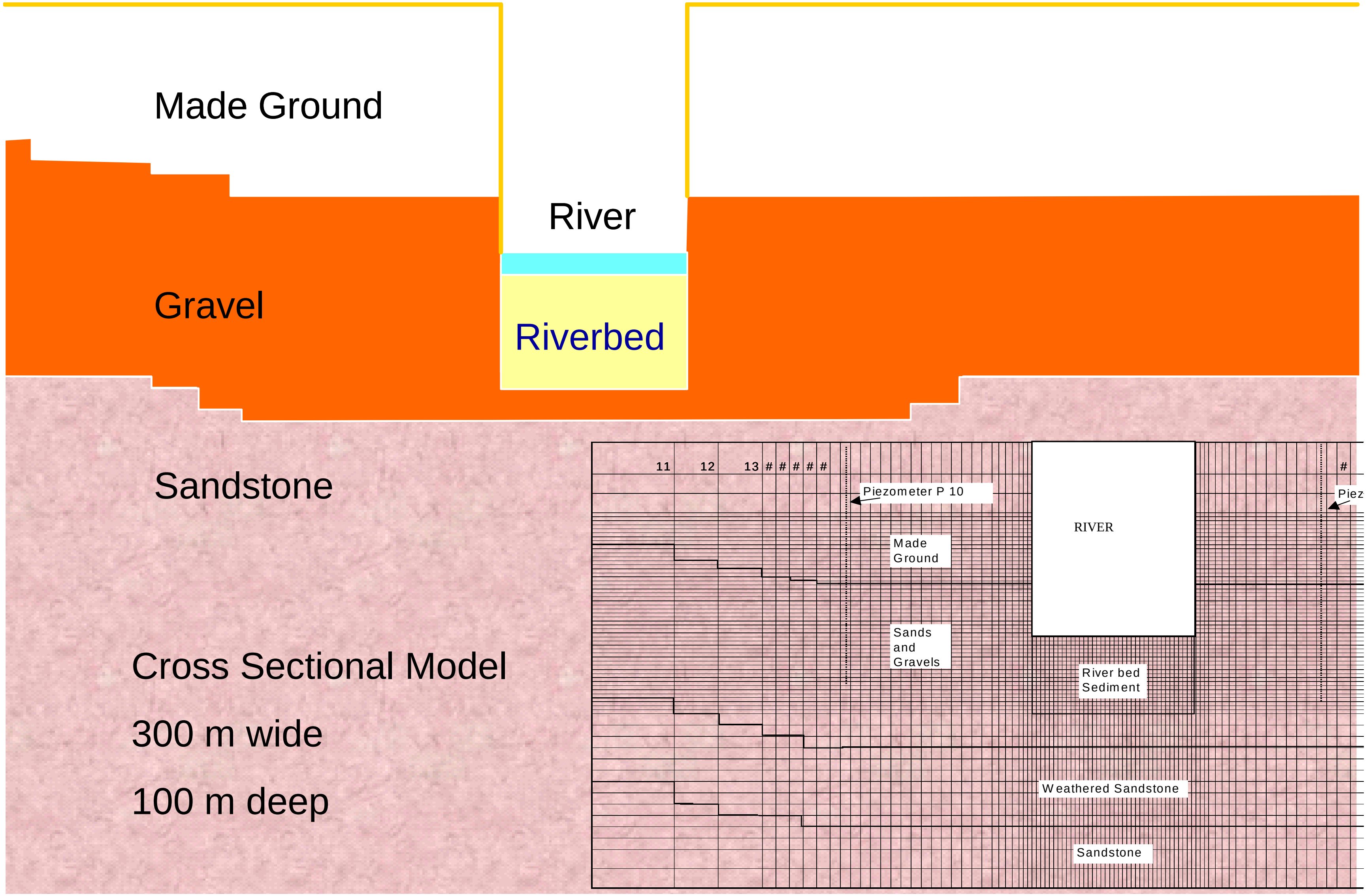
- *The SWITCH paper summarises the modelling findings*

Modelling

- Examine GW-SW interations / mixing zone
- 4 models at various scales



Model 2: 300 m transect

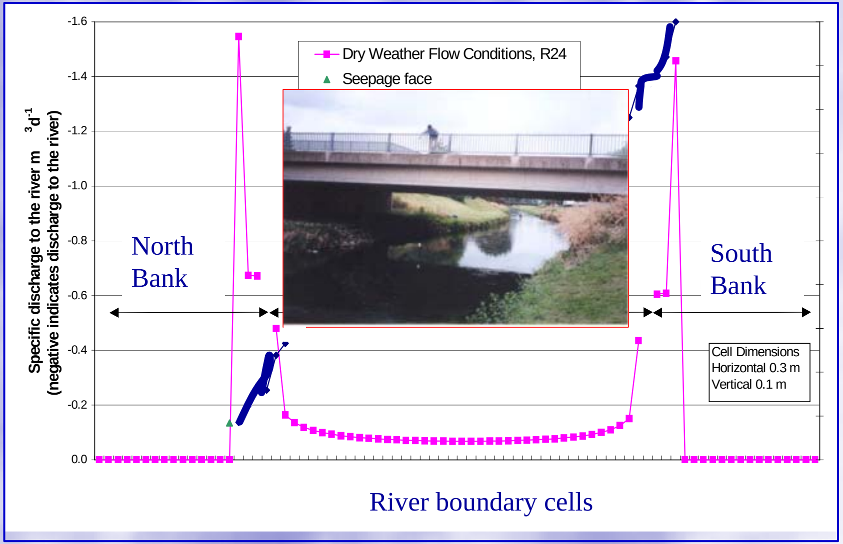


Cross Sectional Model

300 m wide

100 m deep

Example model findings:



- Dominance of lateral flows into the river through the river sides, e.g. central 50% of the river bed contributes only 25 % of total baseflow
- River water entering the river bed during the passage of the flood wave occurs only for very short times (<10 mins) and in negligible quantities - aquifer head changes derive mostly from damming of water entering the river rather than flow reversal
- After passage of the flood wave a persistent (rather than large short-term) release of groundwater occurs as the stored water progressively drains to the river
- Vertical pressure gradients through the bed of the river are higher at the river channel edge than near the centre
- Local scale geological heterogeneity (particularly clay lenses) substantially influences the flow geometry beneath the river.

Dipole field experiment site

- Site location

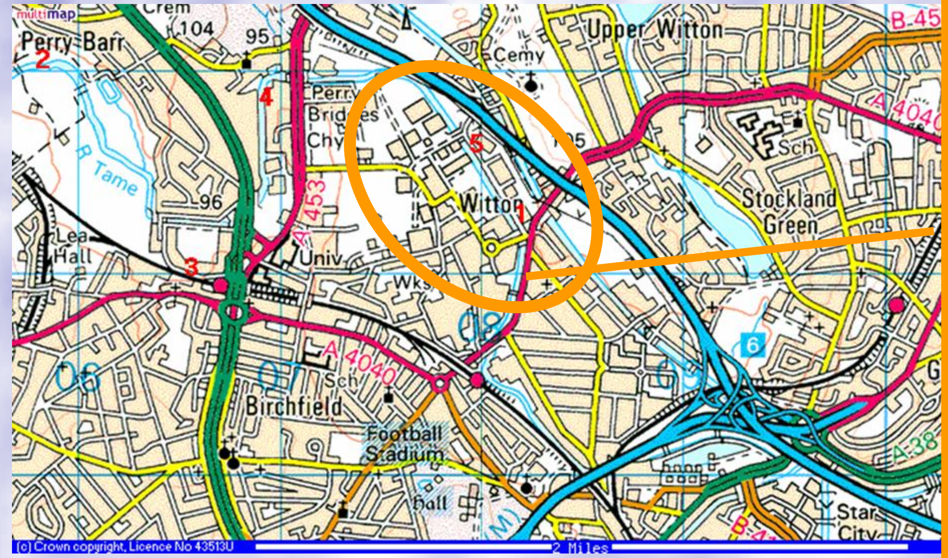
River Tame, Birmingham





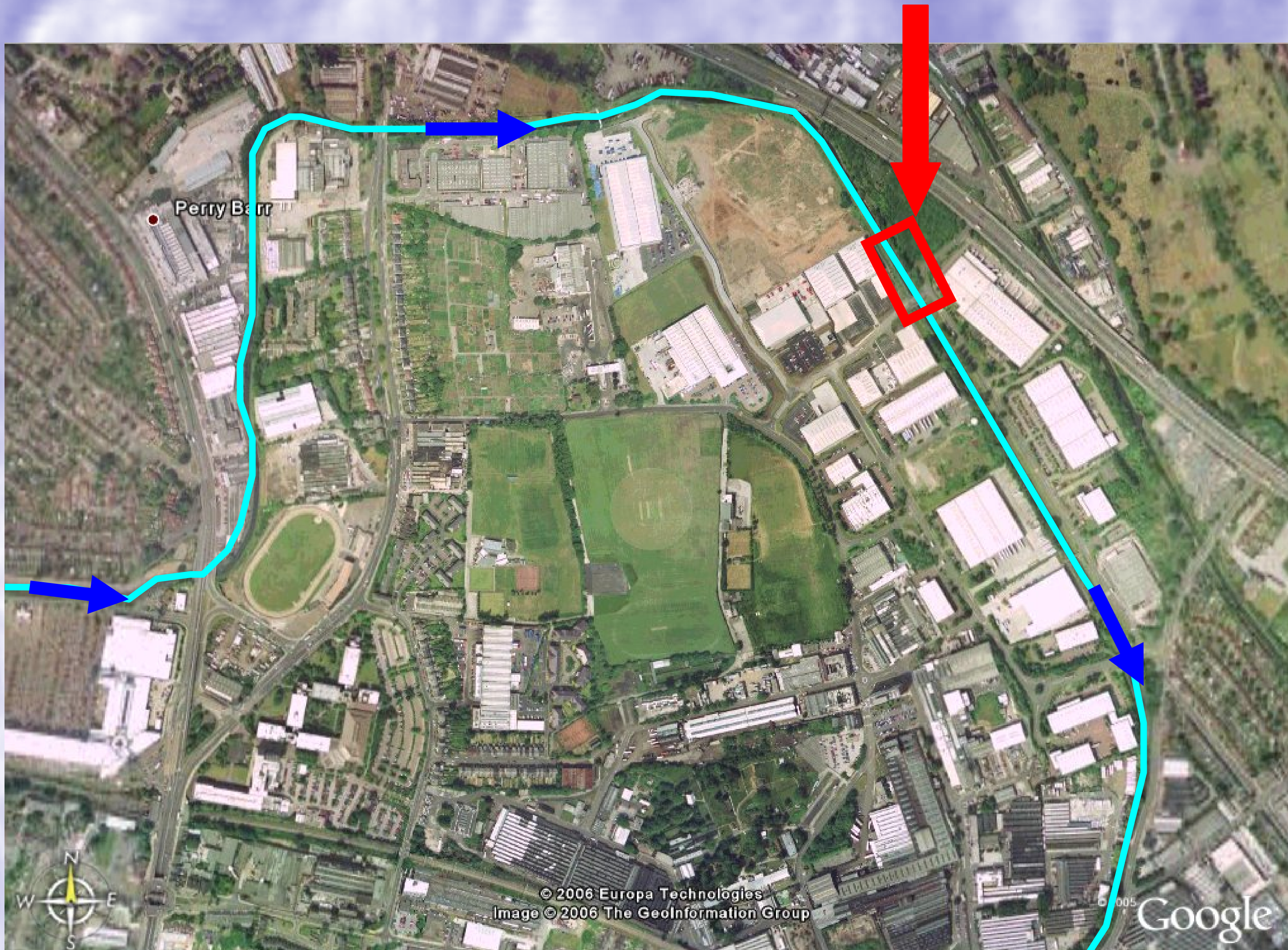



The search for a site....

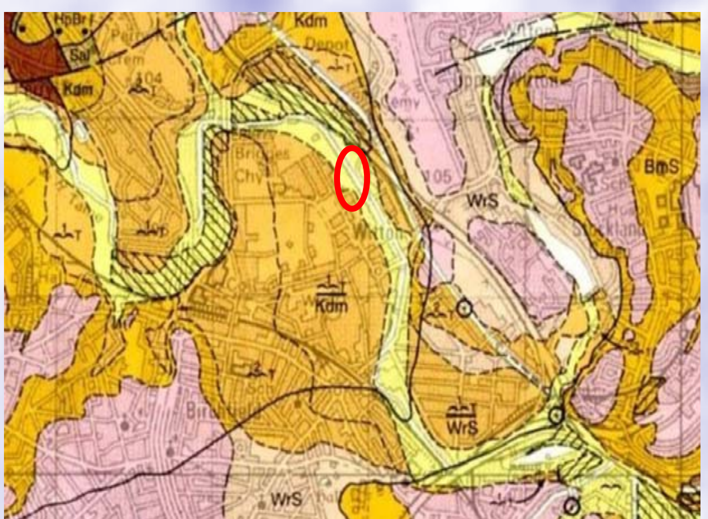


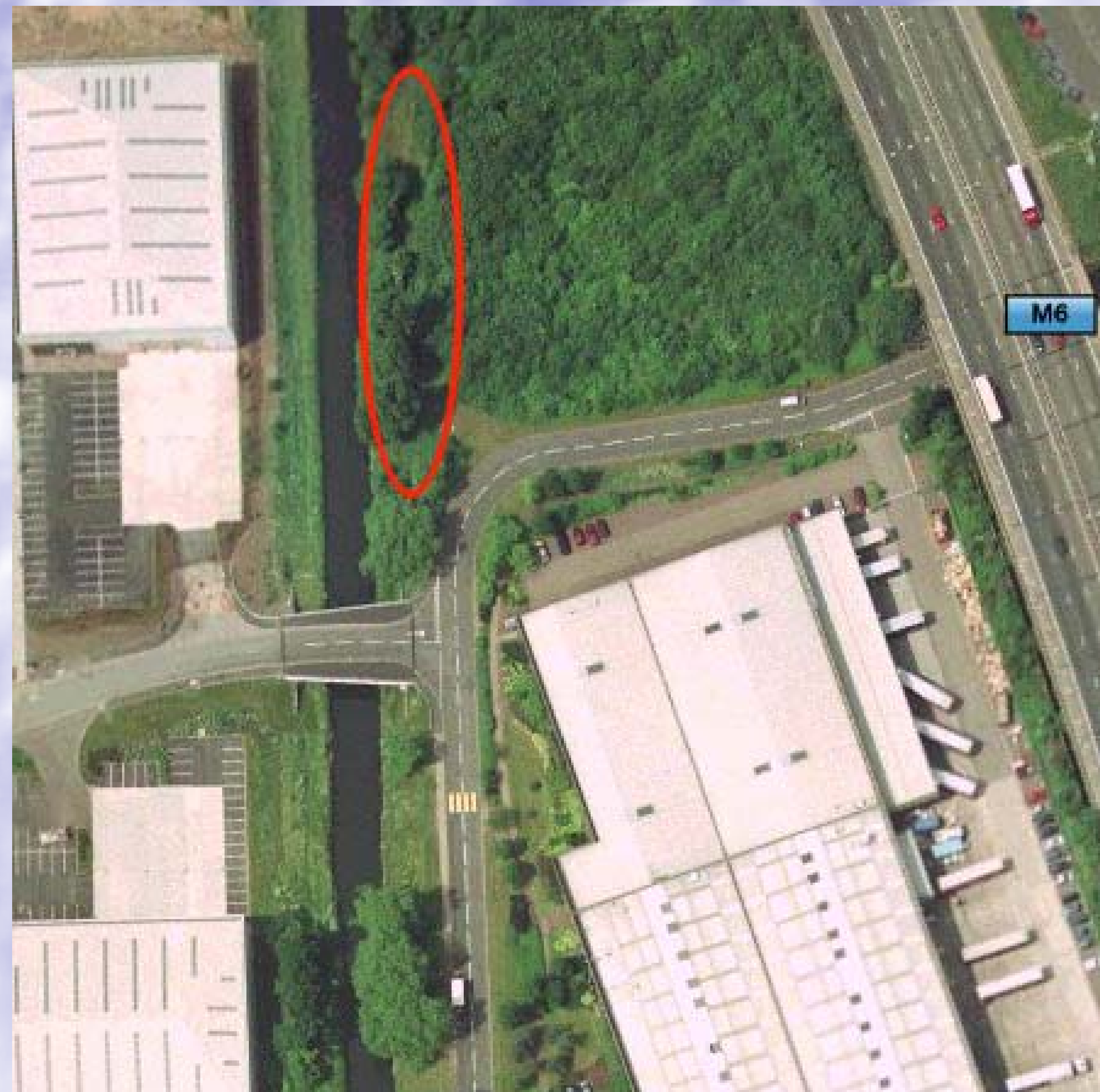
- Access for drilling
- Electricity
- Cooperative landowner
- Scientifically interesting

SWITCH Tame HZ Site



Proposed Dipole Expt Location





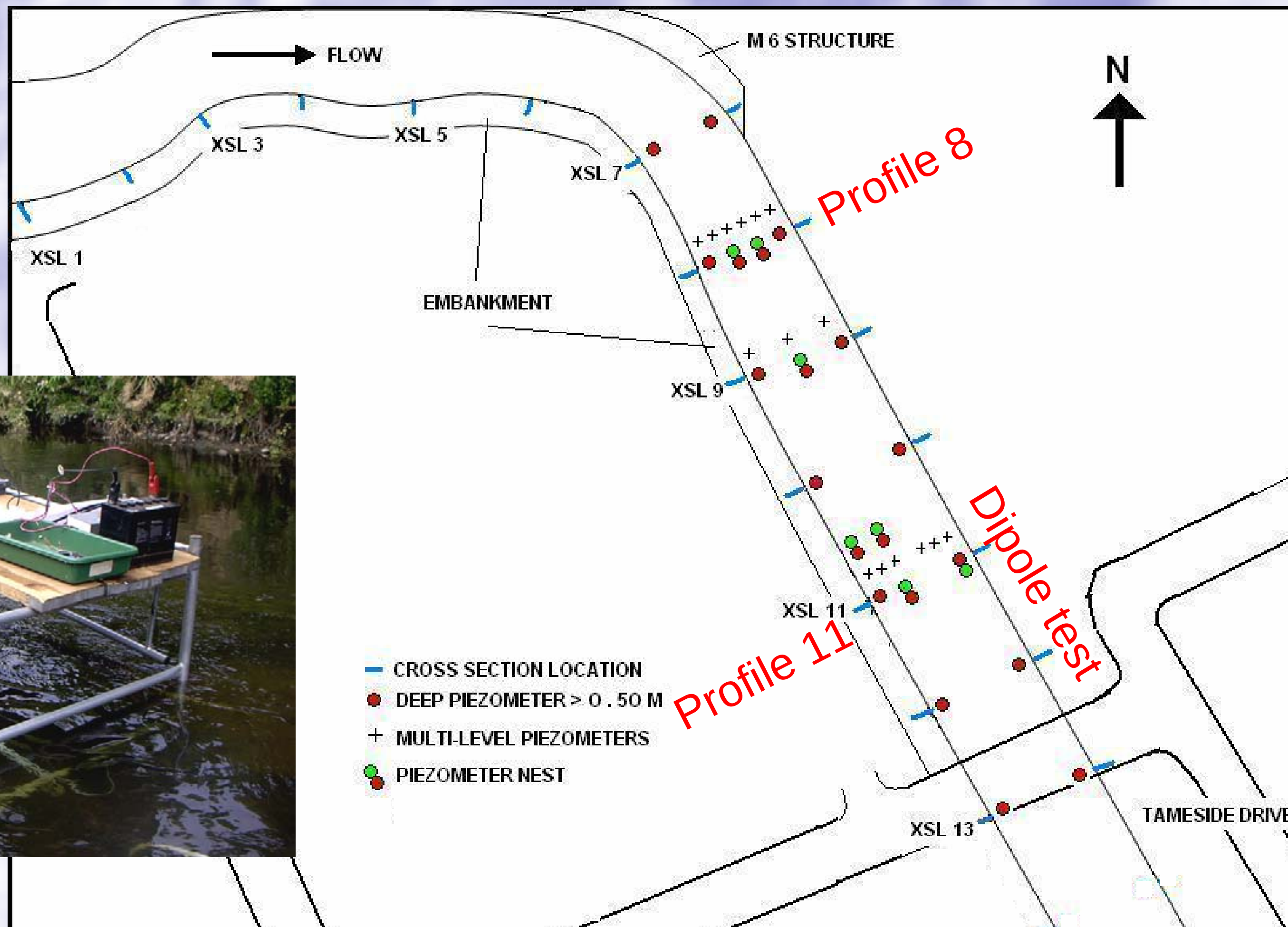
Dipole field experiment site

- Local field characterisation

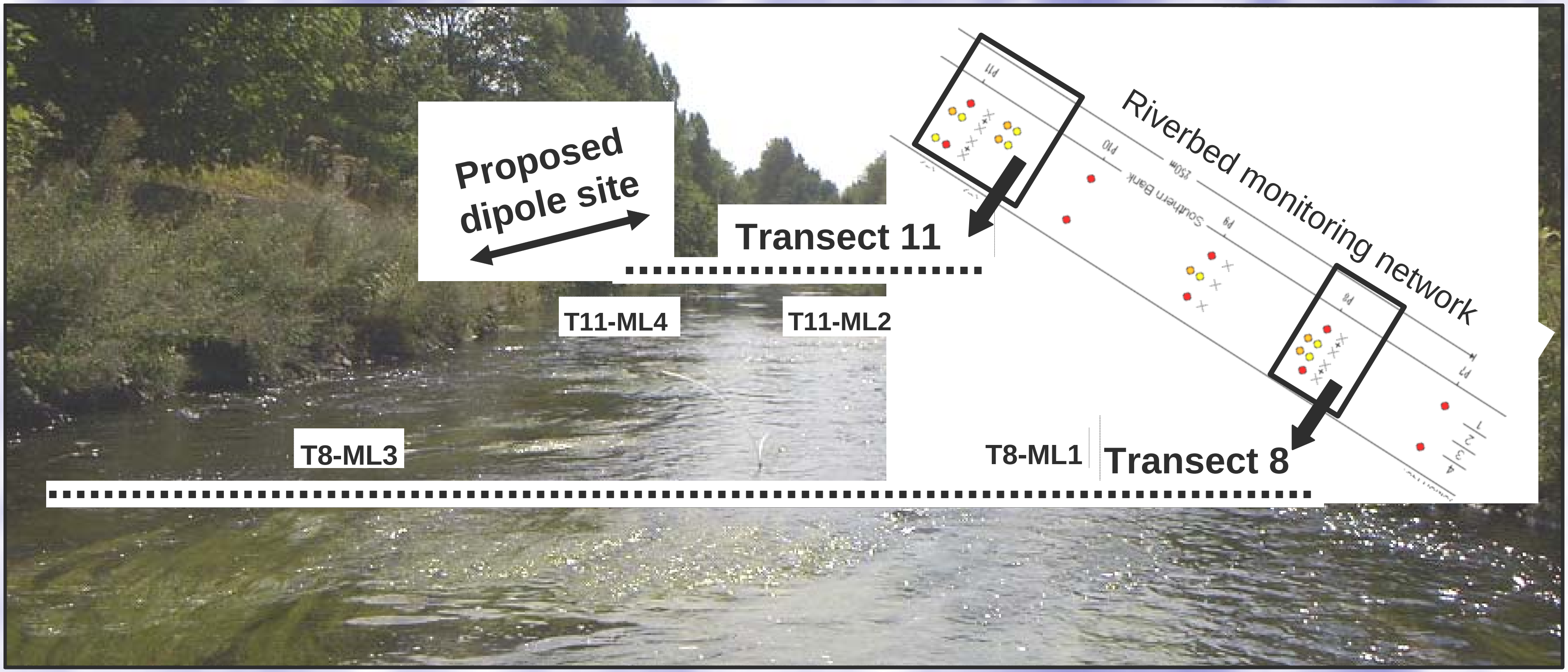
MSc studies 2006 **(~600 m reach)**

Derek Conran: GW-SW mixing zone

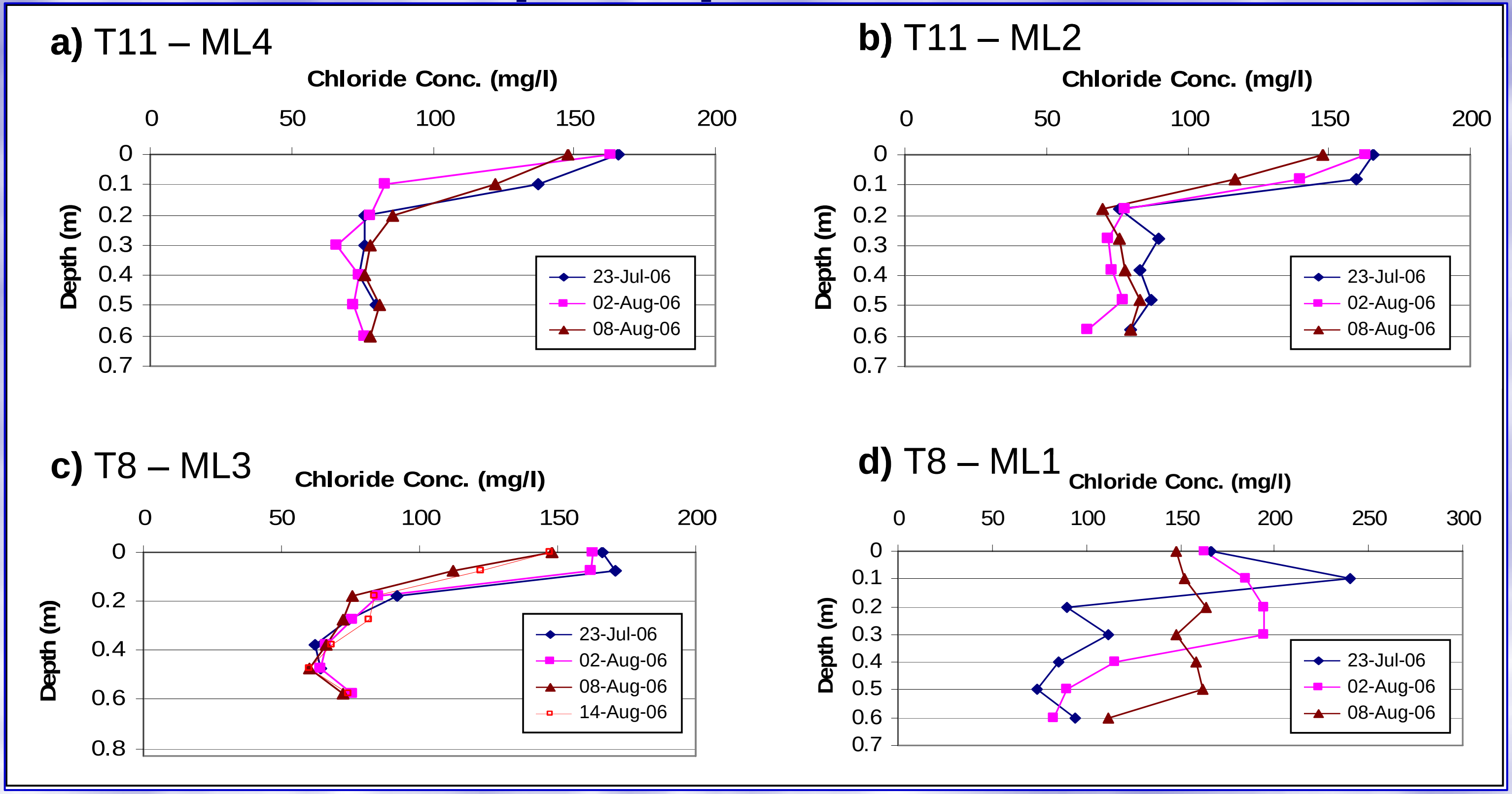
Conor Lydon: Data for test design



Multilevel sampler transects



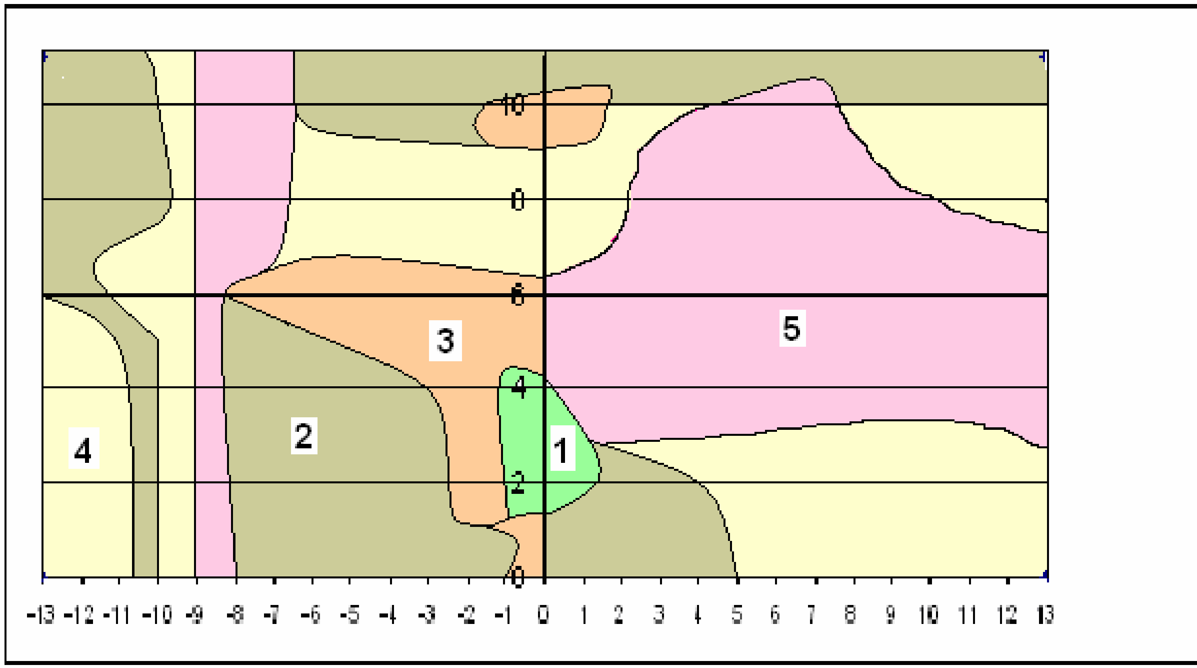
Chloride depth profiles in riverbed



- GW-SW mixing zone often stable ~ 10-20 cm (with some exceptions)
- Such thin zones were predicting by our modelling
- Thicker zones are possible and were also predicted by modelling if other processes invoked, e.g. heterogeneity, momentum exchange (see SWITCH paper for details)

Profile 11

- Plan view: Geology ± 13 m up/down stream



= Sand and gravel overlying red and yellow fine grained sand

= Very soft consolidated sticky sand overlain by a sandy gravel

= Predominantly red sand with some gravels intermingled

= Consolidated coarse red sand which is not malleable. Low gravel content.

= Red malleable sand with small silt content, overlain by cobbles.

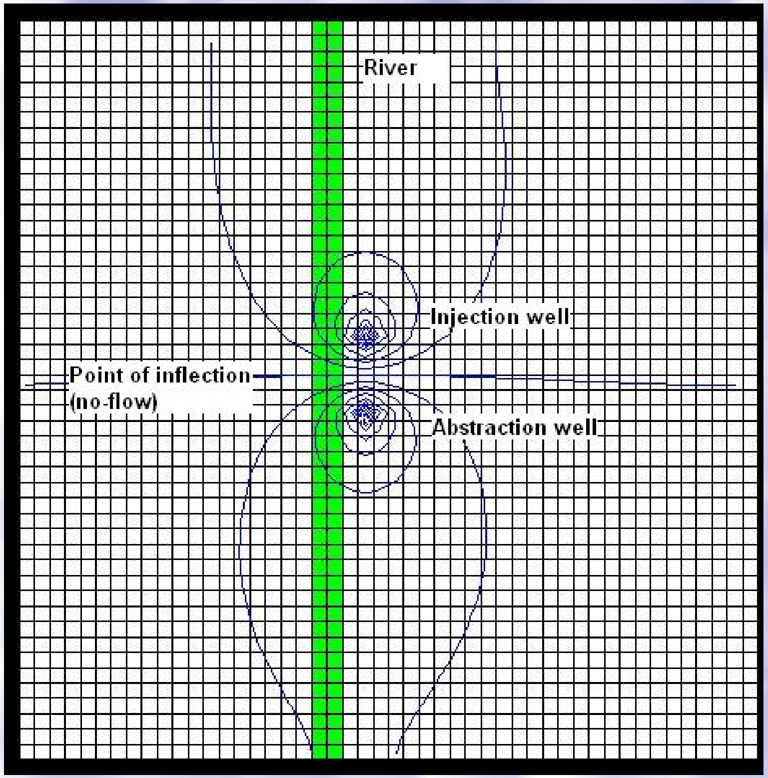
Numbers 1-5 represent sediment types from which samples were retrieved for sieve analysis

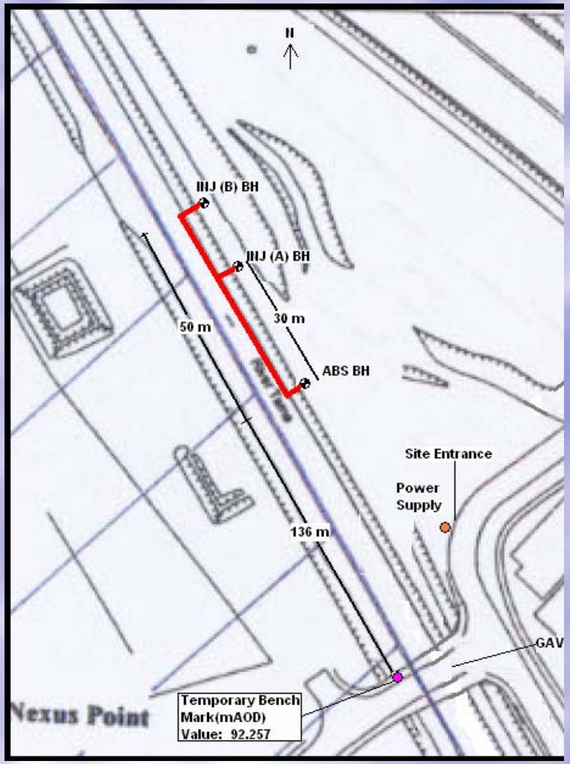
Dipole field experiment site

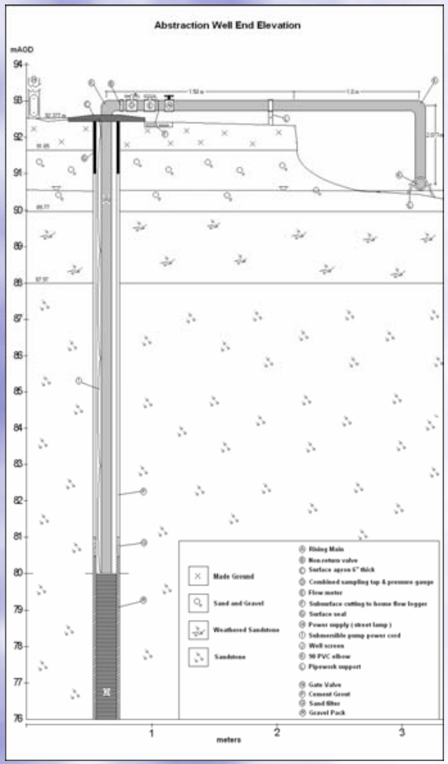
- Dipole experiment design

Dipole test design

MSc Thesis: Conor Lydon 2006

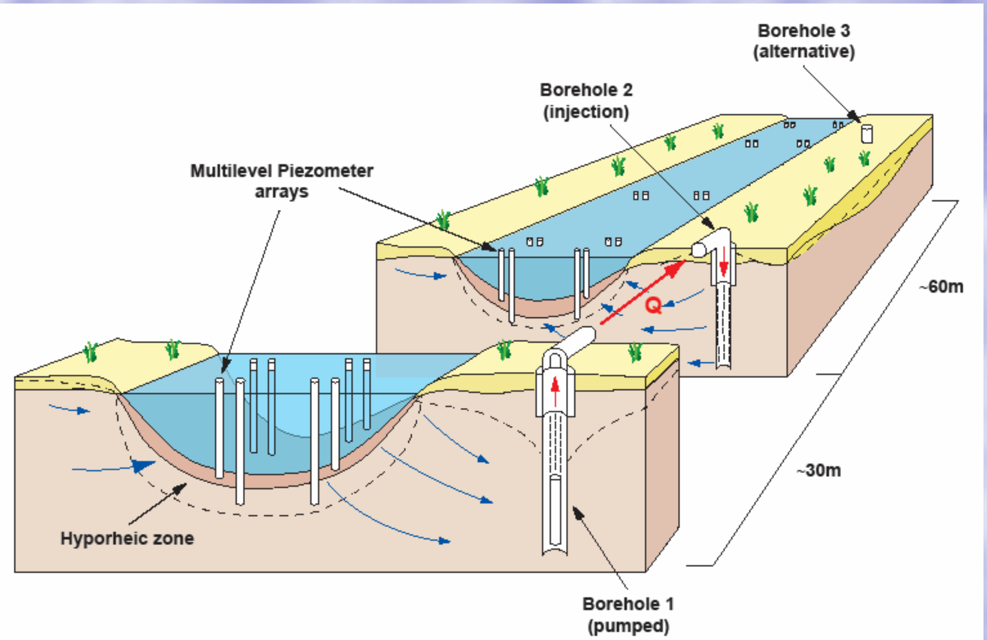






- In short,... We have an initial test design
- Based on field data, numerical modelling)

Process-based research:



- Confirmation of relationships between river and groundwater gradients
- Evaluation of mixing depth extents and dynamic controls
- Assessment of redox dynamics / electron acceptor transport (key to biodegradation)
- Elucidation of controls on contaminant attenuation capacity
- Such process-based understanding underpins engineering of bed forms to remediate contamination present.

Future work

- Finalise access permissions for the dipole site
- Finalise field site design (incl. modelling)
- Appoint contractors, phased installation of site infrastucture (wells, extraction system, riverbed monitoring) and test
- Conduct background monitoring to further establish the natural temporal/ spatial variability
- Finalise design of dipole tests and science objectives
- Conduct extraction-injection tests
  - For adequate time to adjust and stabilise the mixing depths, each test is likely to exceed 120 days.
  - A period of 18 months will allow four full scale tests to be completed and analysed.


Questions
please !
Thank you.