Identifying flow transience in the hyporheic zone by Electric Resistivity Tomography

Joakim Riml[1], Liwen Wu[2], Robert Earon[1], Stefan Krause[3], Theresa Blume[4]

[1]KTH Royal Institute of Technology, Stockholm, Sweden.
[2]Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany
[3]University of Birmingham, Birmingham, UK
[4]GFZ German Research Centre for Geosciences, Potsdam, Germany

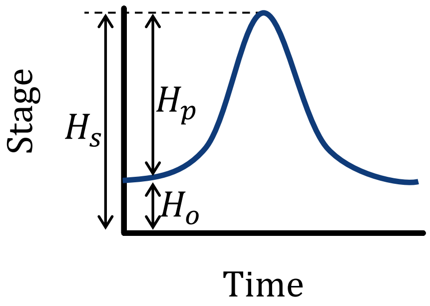
Motivations and aims

Plenty of research on the role of the hyporheic zone (HZ) has been performed, but mostly under steady state conditions or as transient numerical modeling studies.

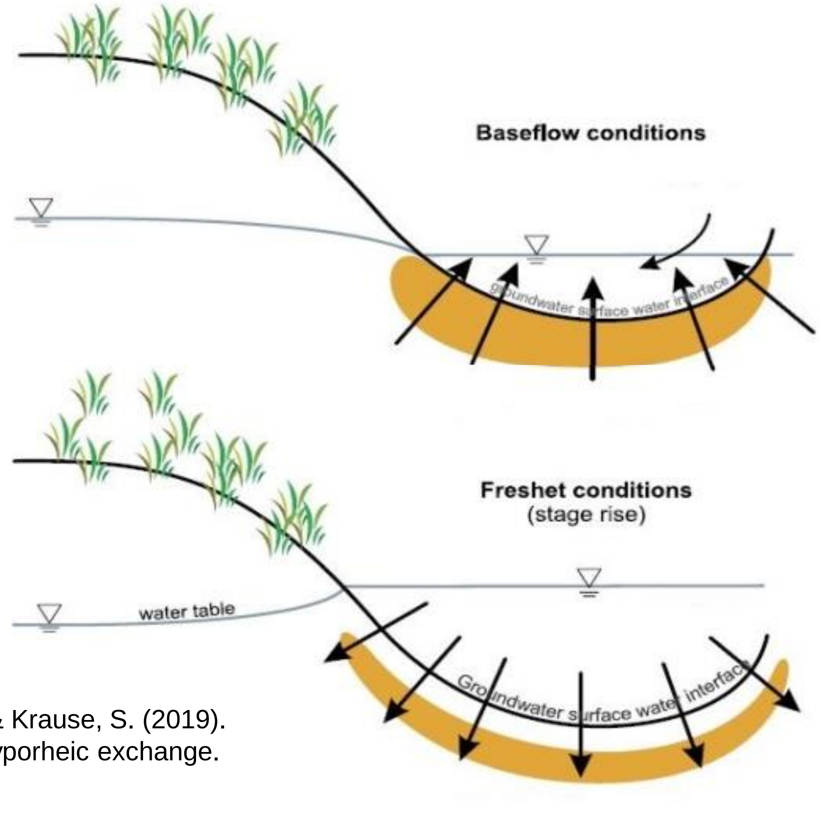
An artificial flood event was created in a small boreal stream to investigate the effects of a dynamic hydraulic forcing on the HZ extent

Can the effects of changing stream flow on the physical extent of the HZ be observed in situ?

Conceptual picture of a freshet



H_s - Total stage
H_p - Stage at peak
H_o - Reference stage



Modified from Singh, T., Wu, L., Gomez-Velez, J. D., Lewandowski, J., Hannah, D. M., & Krause, S. (2019). Dynamic hyporheic zones: Exploring the role of peak flow events on bedform-induced hyporheic exchange. *Water Resources Research*, 55, 218– 235. https://doi.org/10.1029/2018WR022993

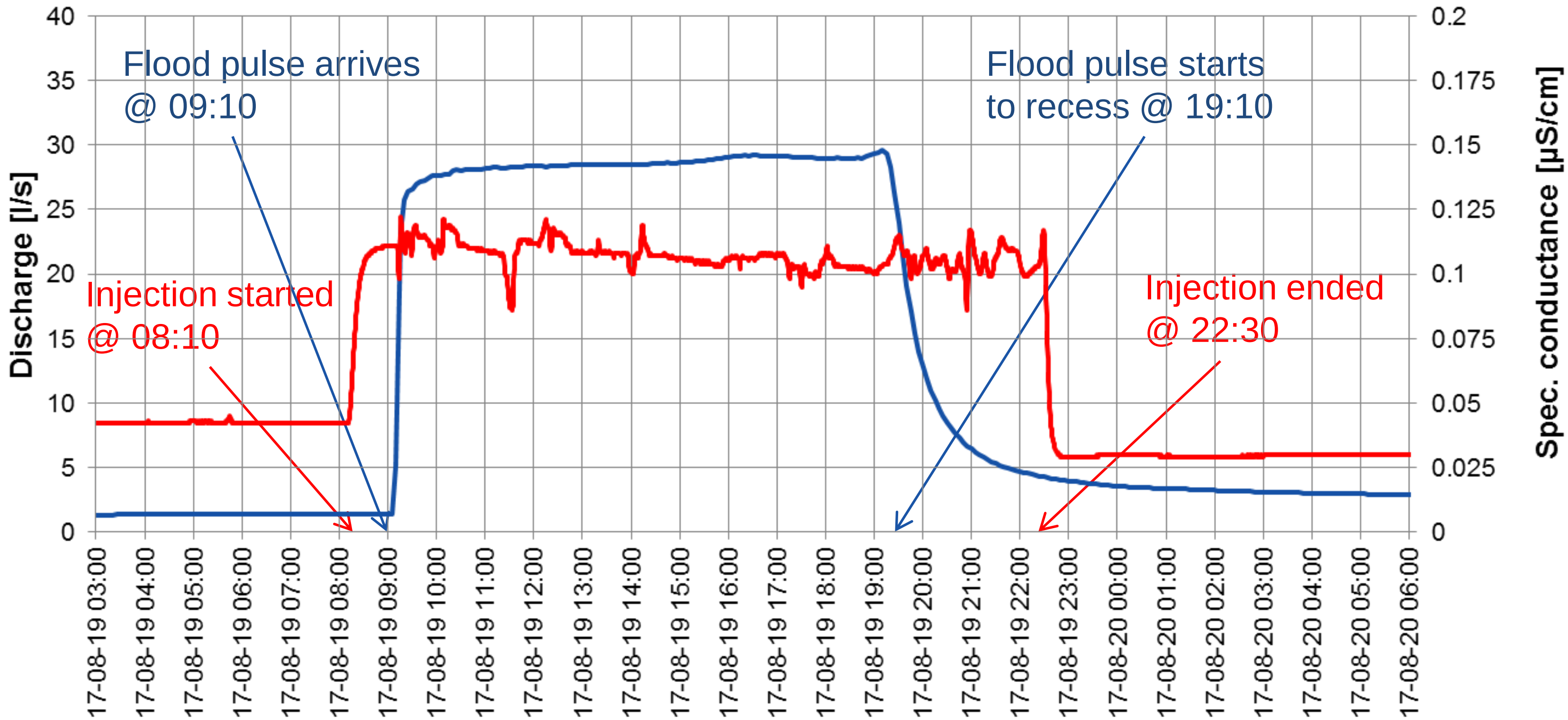
Methods: Flood event and tracer injection

Artificial flood event

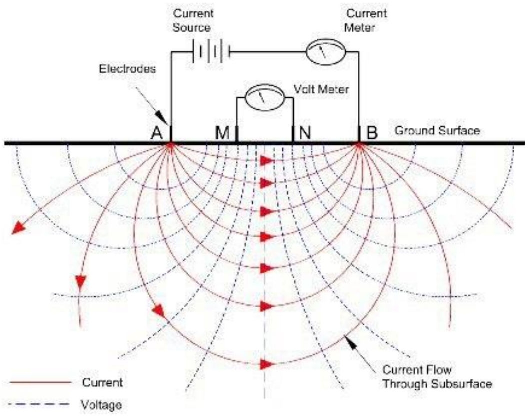
- Upstream damming resulted in $Q_{min} = 1.4$ l/s
- Release of water created a flood pulse, with $Q_{max} = 28.8$ l/s
- After a plateau in discharge during approx. 10 h, the stream flow recession started

Variable rate tracer test (Cl^-)

- Target stream water EC: 100 µS/cm
- Manually regulated injection rate of Cl^- (w. pump)
- In-situ observations of stream water EC
- Up-stream/down-stream continuous EC loggers
- ”Continuous” ER observations



Methods: Resistivity measurements



Resistivity surveying investigates variations in electrical resistance and depends on properties of the geologic material and the chemical composition of the pore water

- By performing a tracer experiment where the in-stream EC is elevated, the physical extent of the HZ can be investigated

Longitudinal set-up

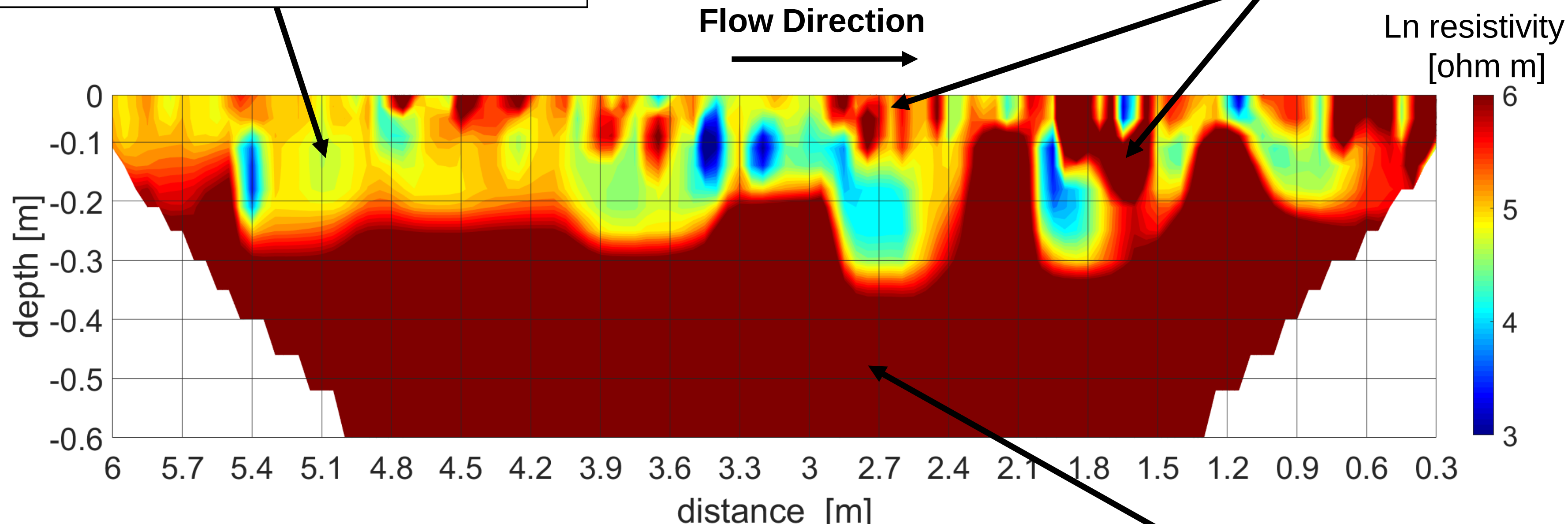
- Total length: 6.3 m
- Electrodes: custom made insulated (at top) and buried in the sediments
- Spacing: 0.1m
- Total number of ER measurements: 12
- Measurement time: roughly 25 minutes, including more than 1300 individual measurements

Methods: Inverse modelling

The observed values of apparent resistivity were used as input values to an inverse model (RES2DINV) and the resistivity in the entire subsurface domain could be estimated

Low resistivity at shallow depths contains tracer-laden surface water

High resistivity most likely stones



High resistivity at greater depths

- **with different geological properties**
- **contains small amounts of surface water**

Results: Electric Resistivity

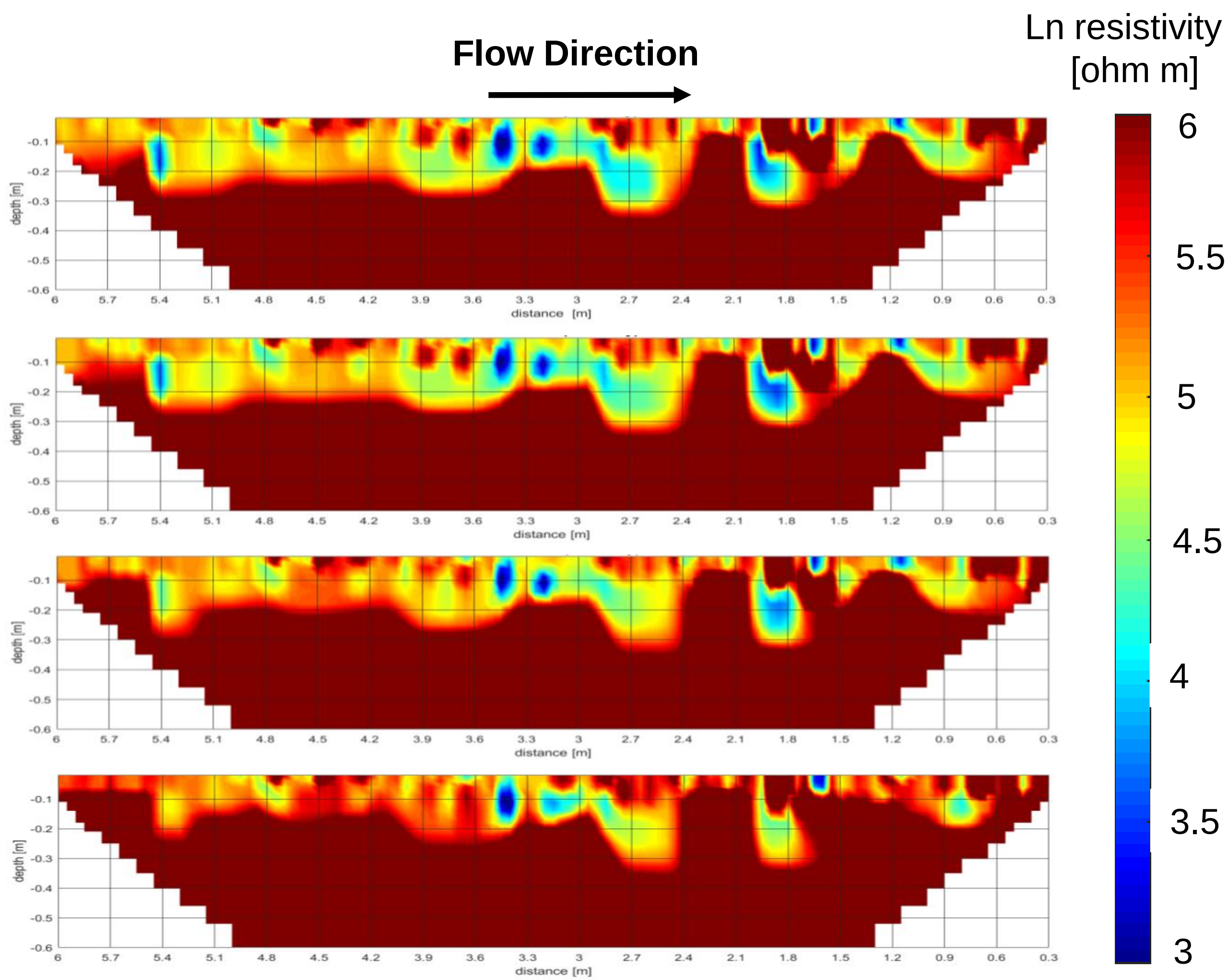
The results indicate that the resistivity in the streambed is connected to the hydraulic forcing. Changes in resistivity can be attributed to changes in the pore water composition i.e. the amount of tracer-laden surface water present at a given streambed position.

Time: 15:24
Q_{max} = 28.8 l/s
EC_{stream} = 0.10 mS/cm

Time 19:30
Q = 22.2 l/s
EC_{stream} = 0.11 mS/cm

Time 20:43
Q = 5.5 l/s
EC_{stream} = 0.11 mS/cm

Time 08:26
Q = 1.4 l/s
EC_{stream} = 0.11 mS/cm



Results: Time lapse modelling

Time lapse displaying the increase in resistivity (decrease in conductivity) during the recession of discharge. Each graph compares the resistivities at the time of maximum discharge to resistivities at times of lower discharge.

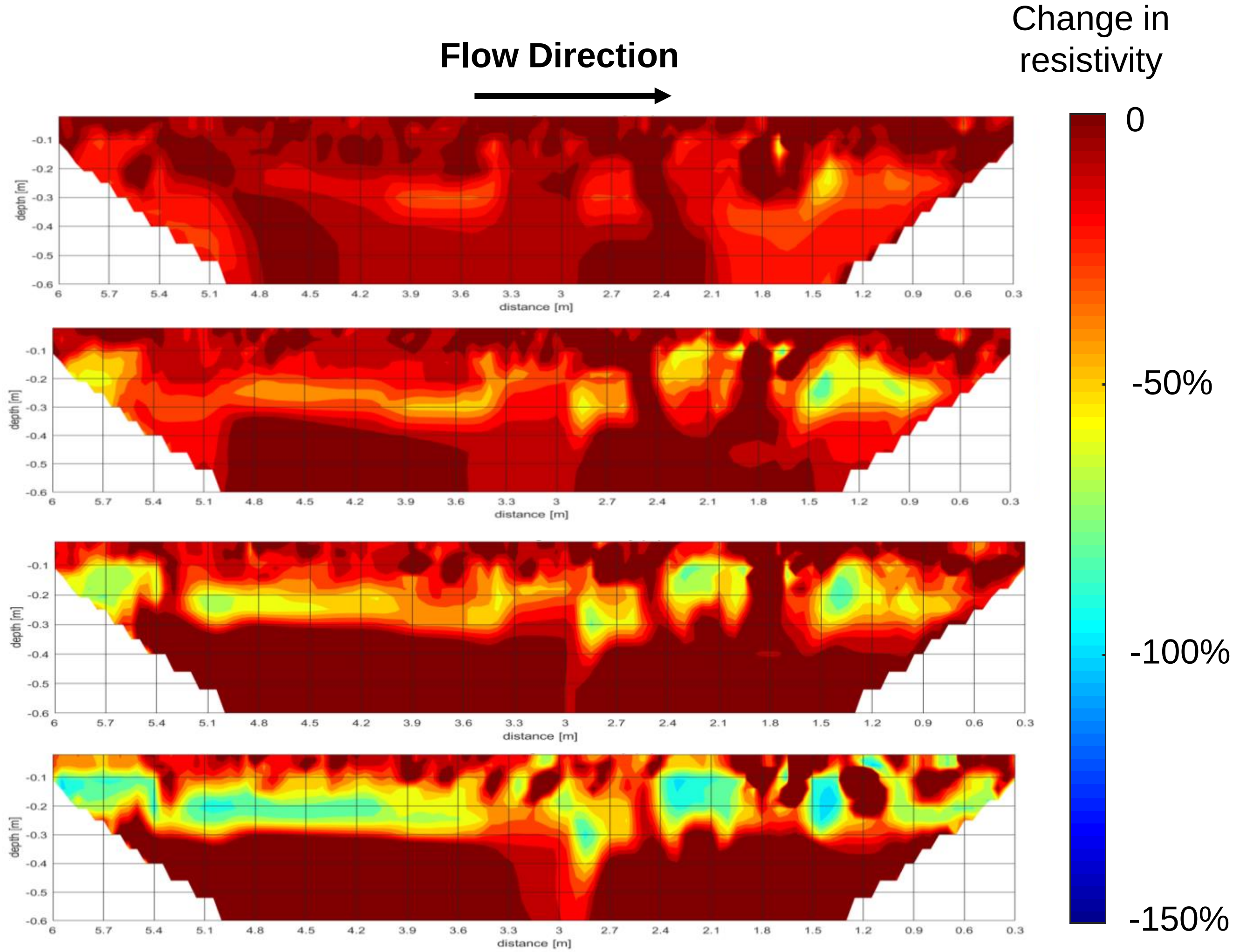
<u>Comparative state:</u>

Time: 19:30
Q_{max}/Q = 1.3

Time 19:55
Q_{max}/Q = 2.3

Time 20:43
Q_{max}/Q = 5.2

Time 08:26
Q_{max}/Q = 20.6



Conclusions

- The results showed a strong spatial variability in the HZ extent in both longitudinal and vertical direction over the 6.3 m longitudinal stream transect
- The results indicate a quick response of the hyporheic zone to changing pressure distribution on the streambed
  - During the recession of discharge, the highly conductive tracer disappeared from the deeper part of the HZ and gradually increased the streambed resistivity
  - The increase in conductivity at high discharges was especially visible at streambed depths around 15-25 cm
  - The decrease in resistivity also displayed a spatial variability indicating an alteration of flow paths implying changes in the residence time distribution as the discharge varies

For further information, please contact:

Joakim Riml, riml@kth.se