Eberhard Karls Universität Tübingen

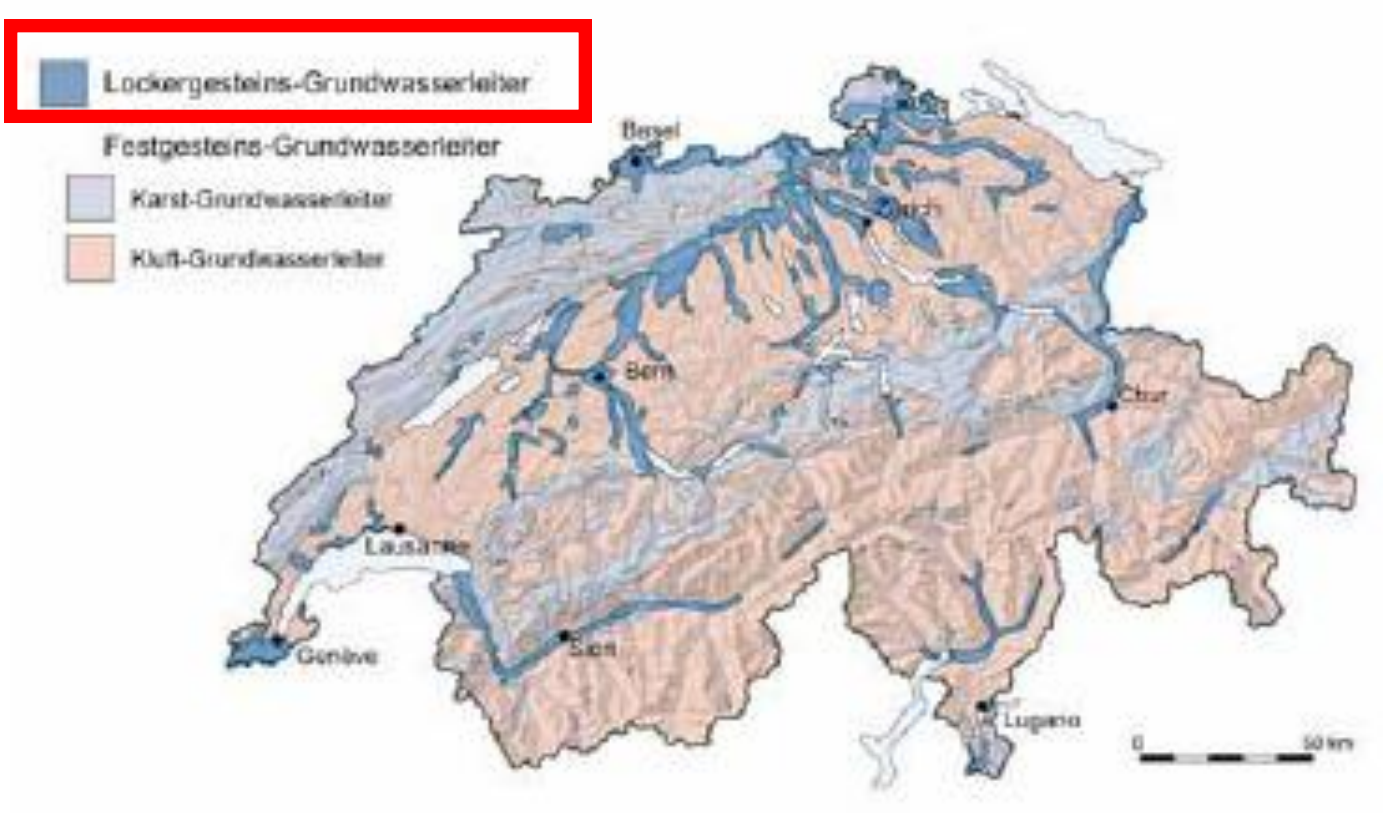
eawag aquatic research

Investigating Riparian Groundwater Dynamics by Means of Diurnal Oscillations of Natural Tracers at a Losing Swiss Peri-Alpine River

Tobias Vogt, Michael Döring, Masaki Hayashi, Mario Schirmer, Olaf A. Cirpka

Eawag: Swiss Federal Institute of Aquatic Research and Technology

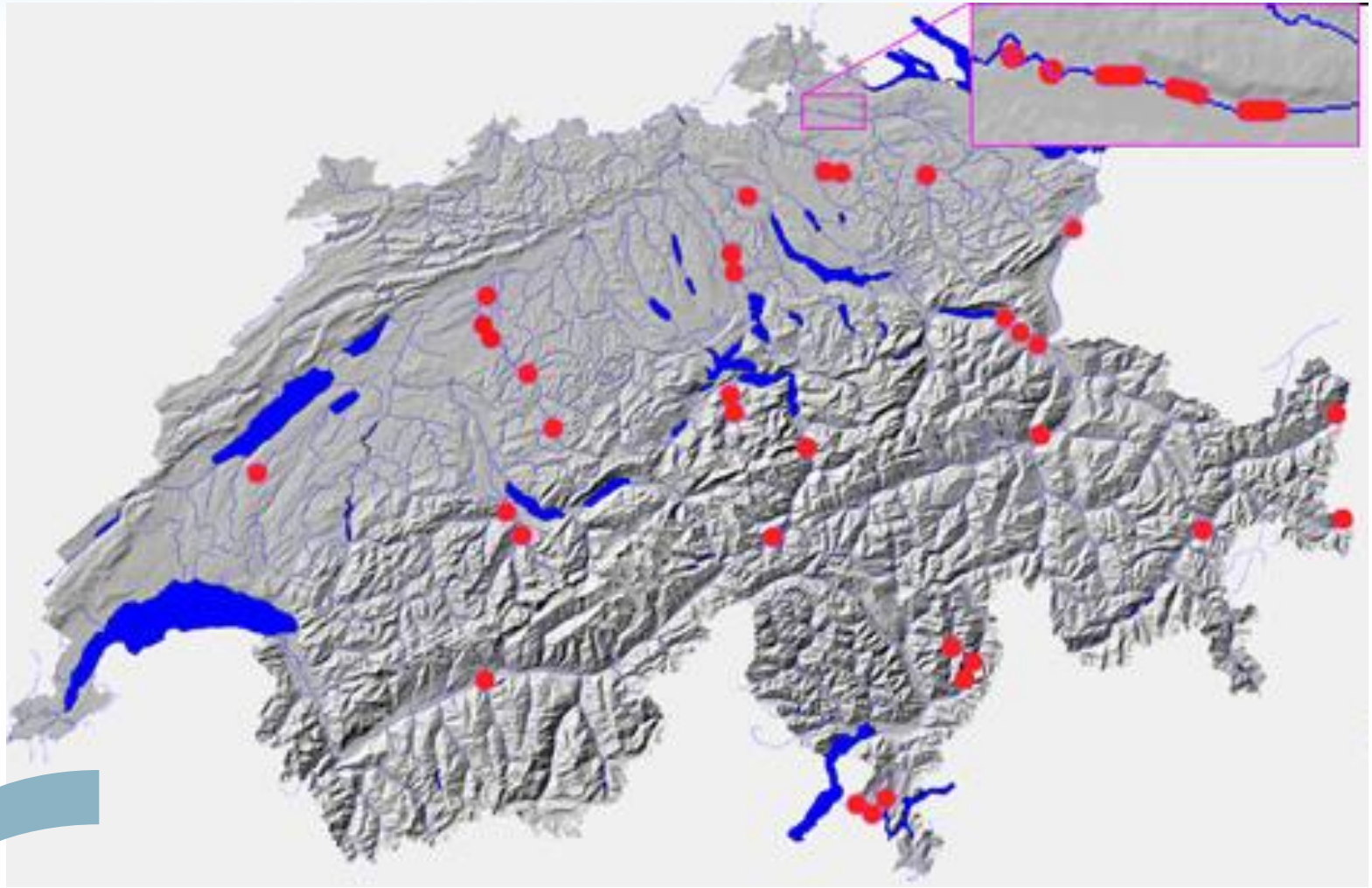
Groundwater Resources of Switzerland



Source: BUWAL 2004

Biggest groundwater resources of Switzerland are located in gravel aquifers of flood plains

River Restoration Projects in Switzerland



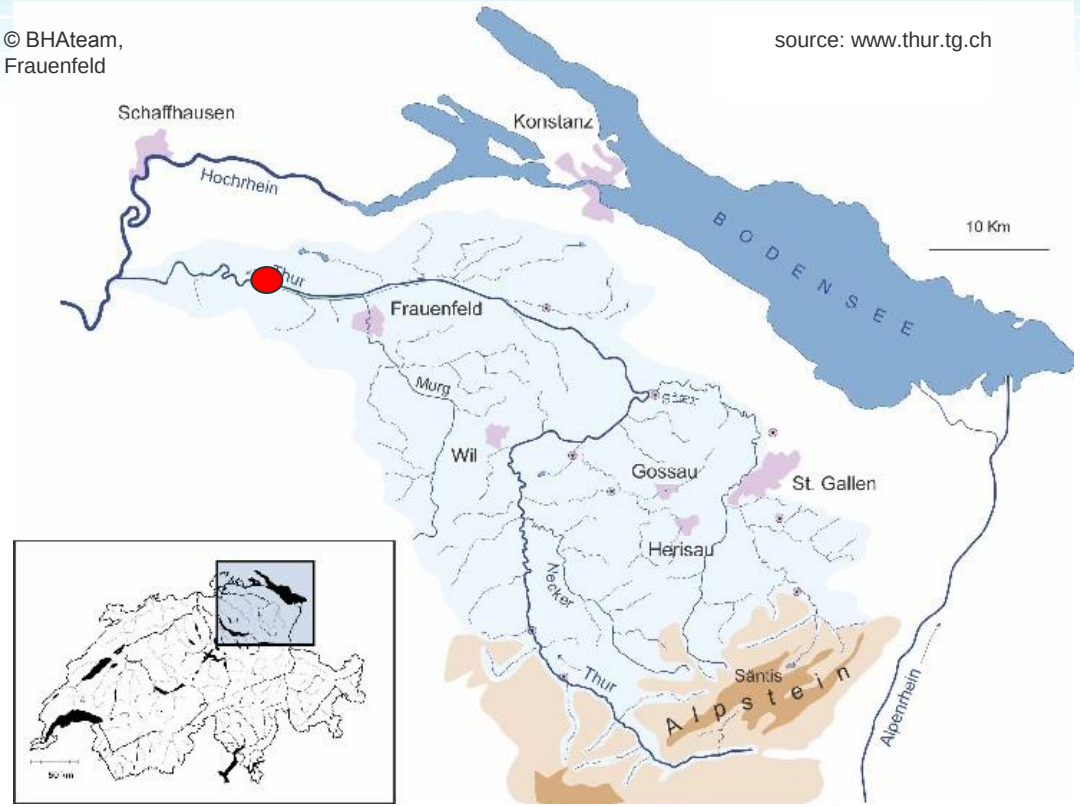
Source: http://www.wsl.ch/land/products/rhone-thur/aufweitungen

Most river restoration projects are located in alluvial flood plains

The Thur-Valley

© BHAteam, Frauenfeld

source: www.thur.tg.ch

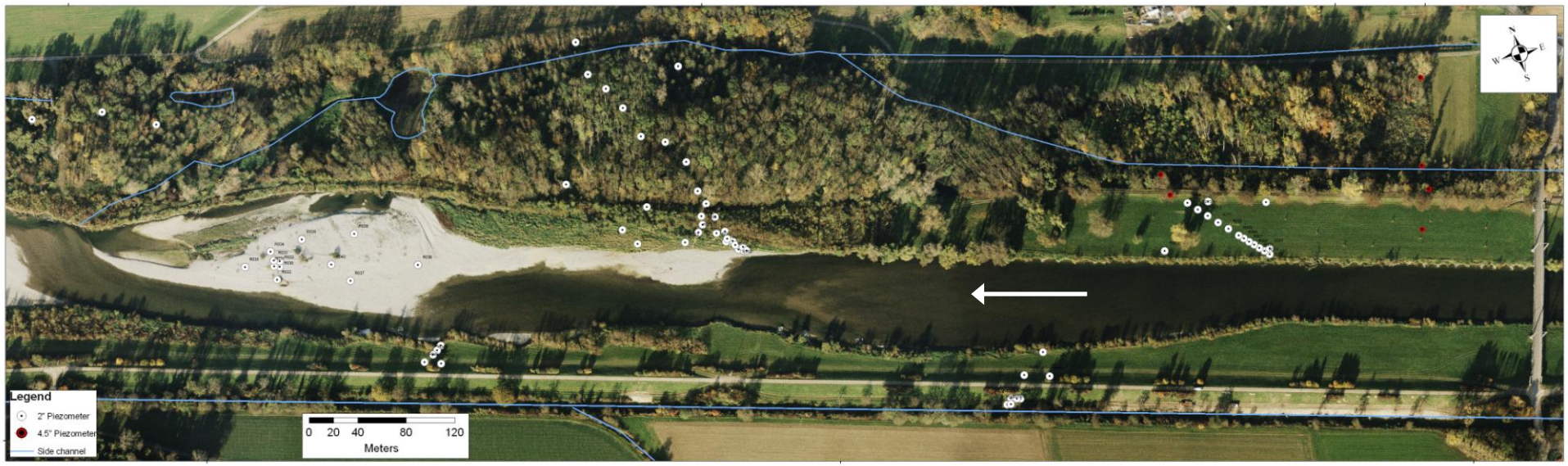


Assessment and Modeling of Coupled Ecological and Hydrological Dynamics in the Restored Corridor of a River

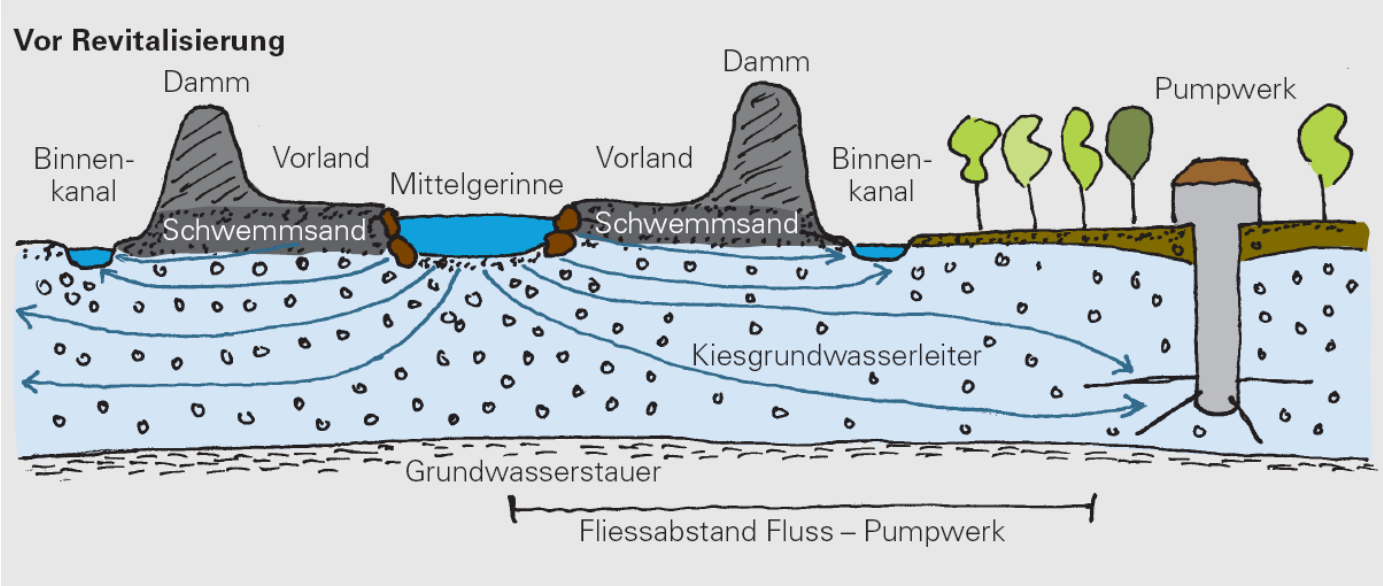
RECORD

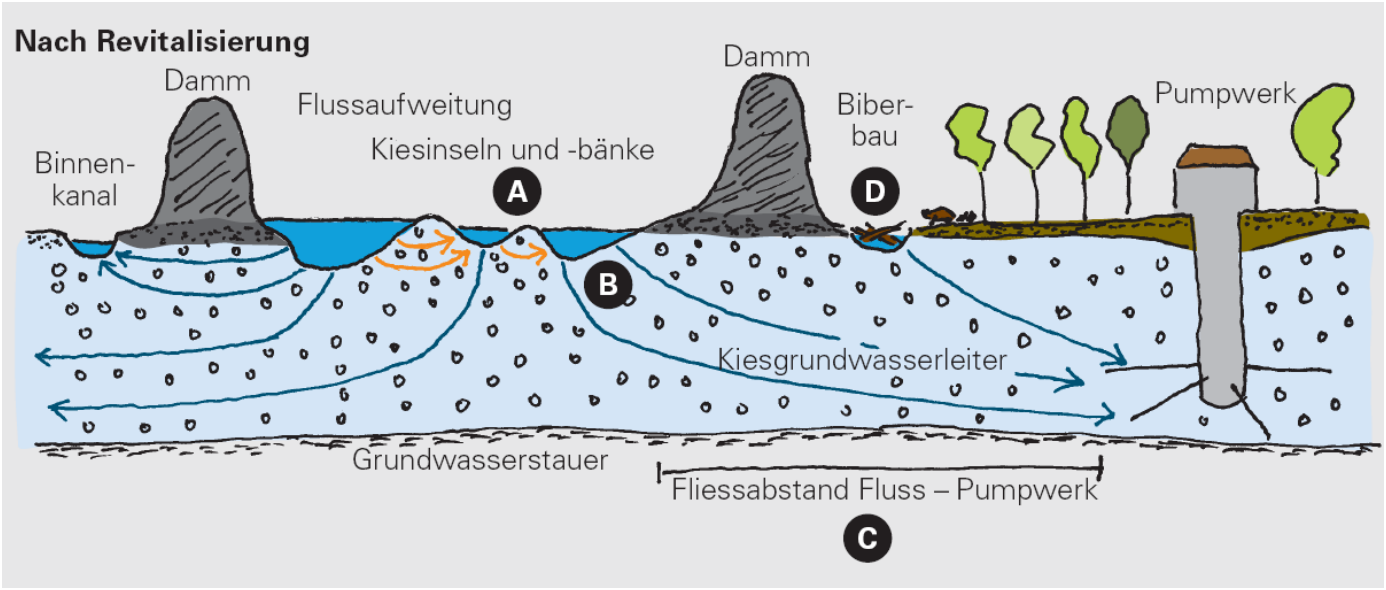
Restored Corridor Dynamics

Study Site


Legend
2" Piezometer
4.5" Piezometer
Side channel
0 20 40 80 120
Meters
N
E
W
S

The Thur valley





Tracer Tests for Determination of Travel Times between Losing Rivers and Wells

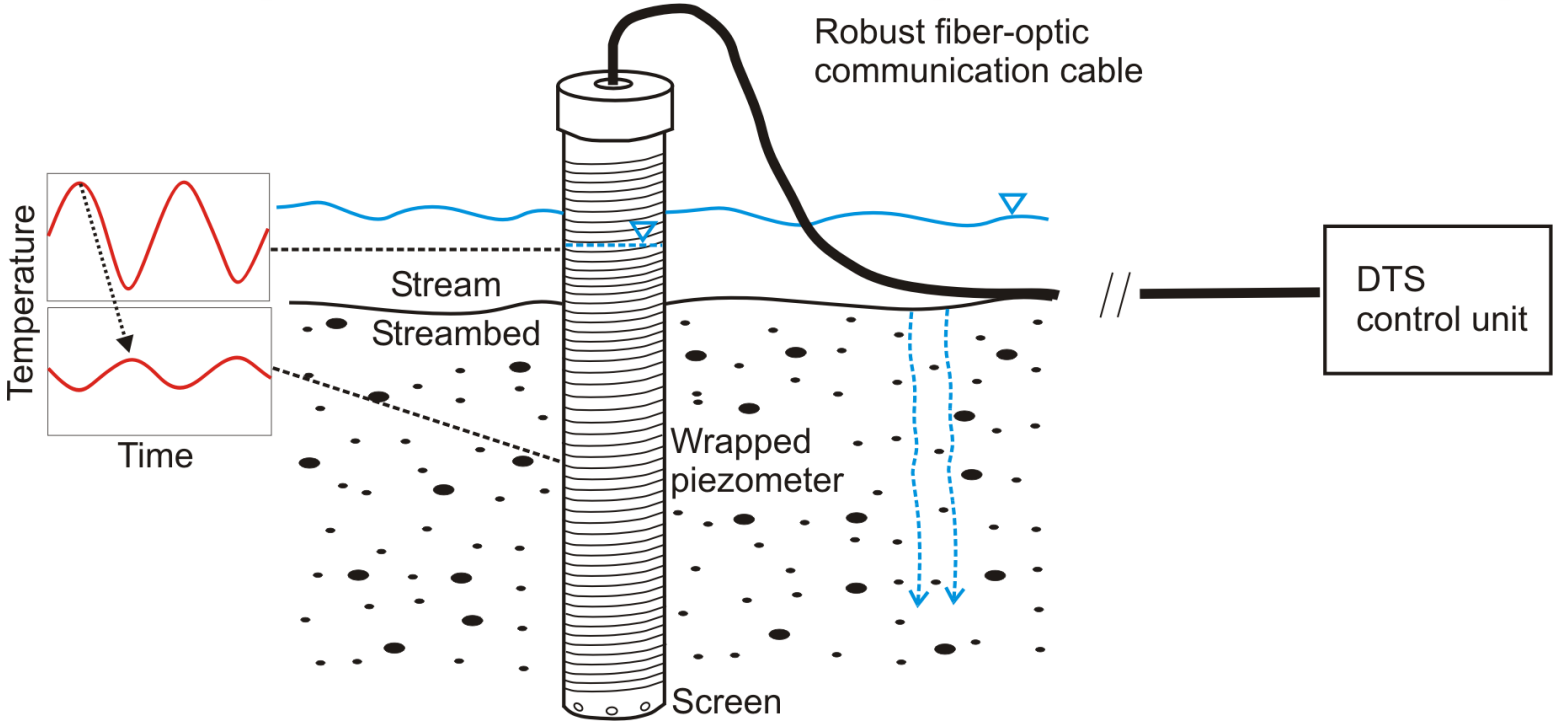

Source: www.geologie-franken.de


Source: www.protectingourwater.org/watersheds


Source: USGS

Results are valid only for the specific hydrologic conditions during the test.
For large rivers a big tracer mass is necessary.

Fiber-Optic High-Resolution Vertical Temperature Profiler



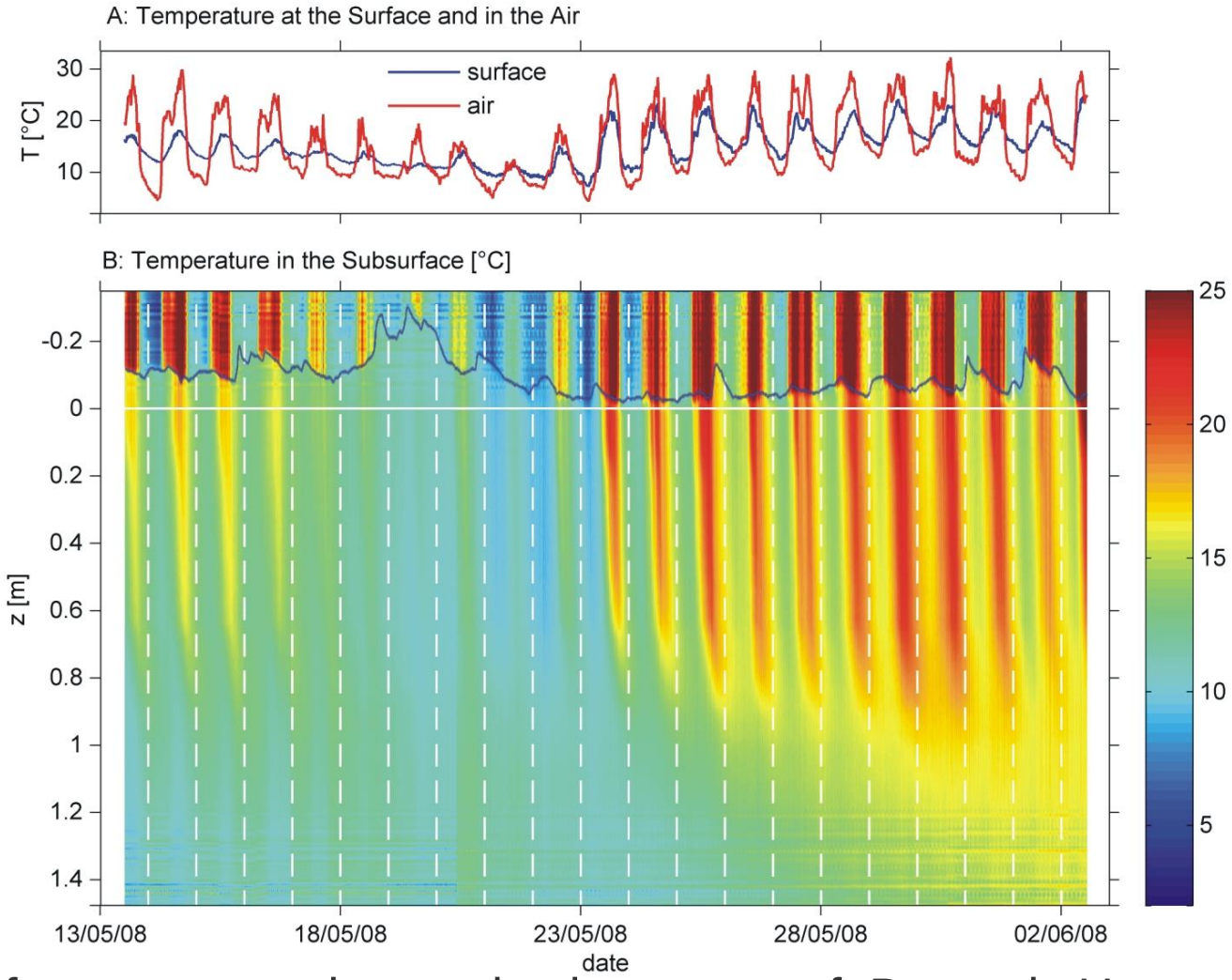
Wrapping around a 2” piezometer-tube (PVC):

1 m cable length results in 0.005 m depth intervals

→ high vertical resolution

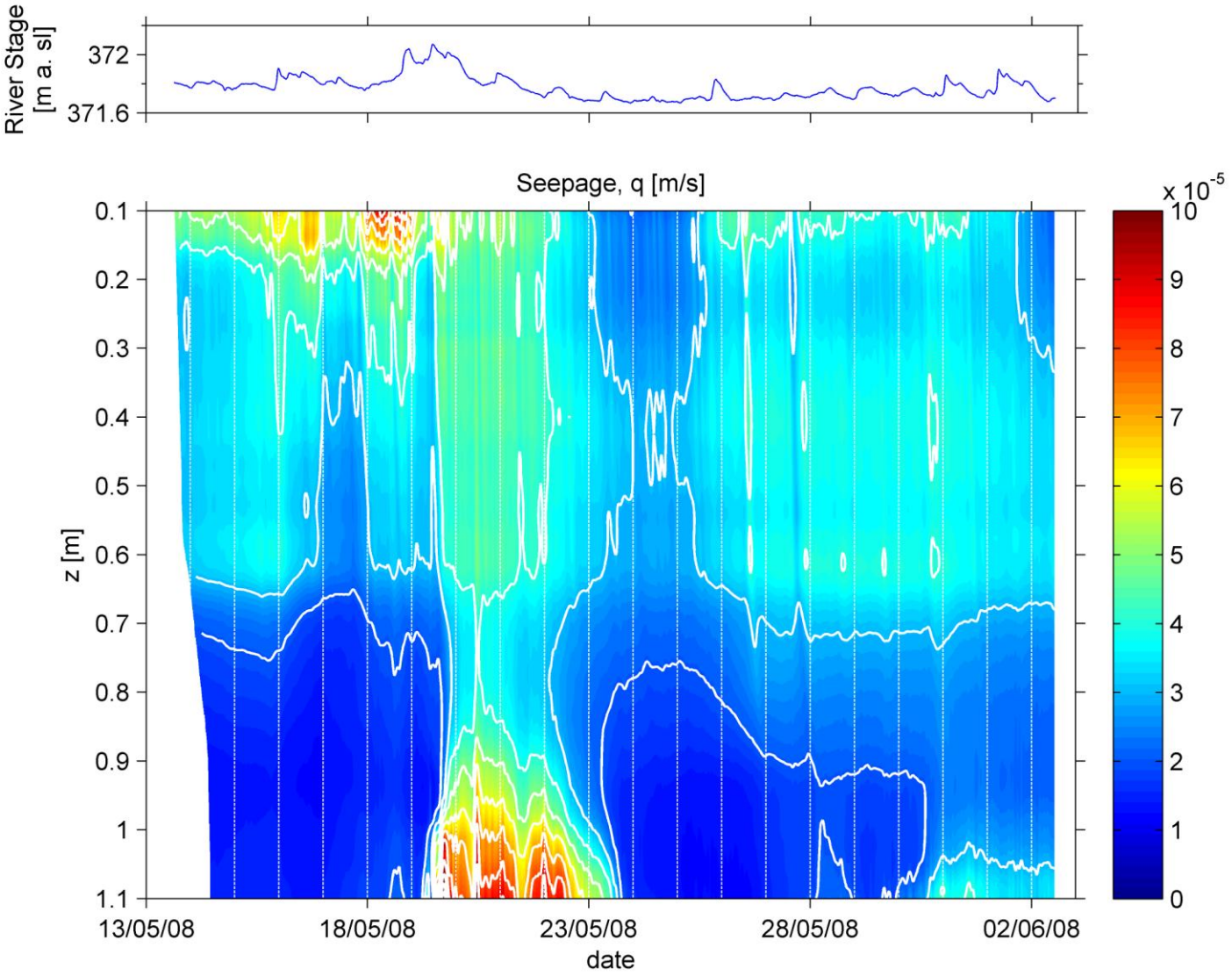
Vogt et al.: Estimation of Seepages Rates in a Losing Stream by Fiber-Optic High-Resolution Vertical Temperature Profiling. J. Hydrology (2010).

Temperature Distribution along the Fiber-Optic High-Resolution Vertical Temperature Profiler



Analysis of temperature time series by means of Dynamic Harmonic Regression (Young et al. 1999).

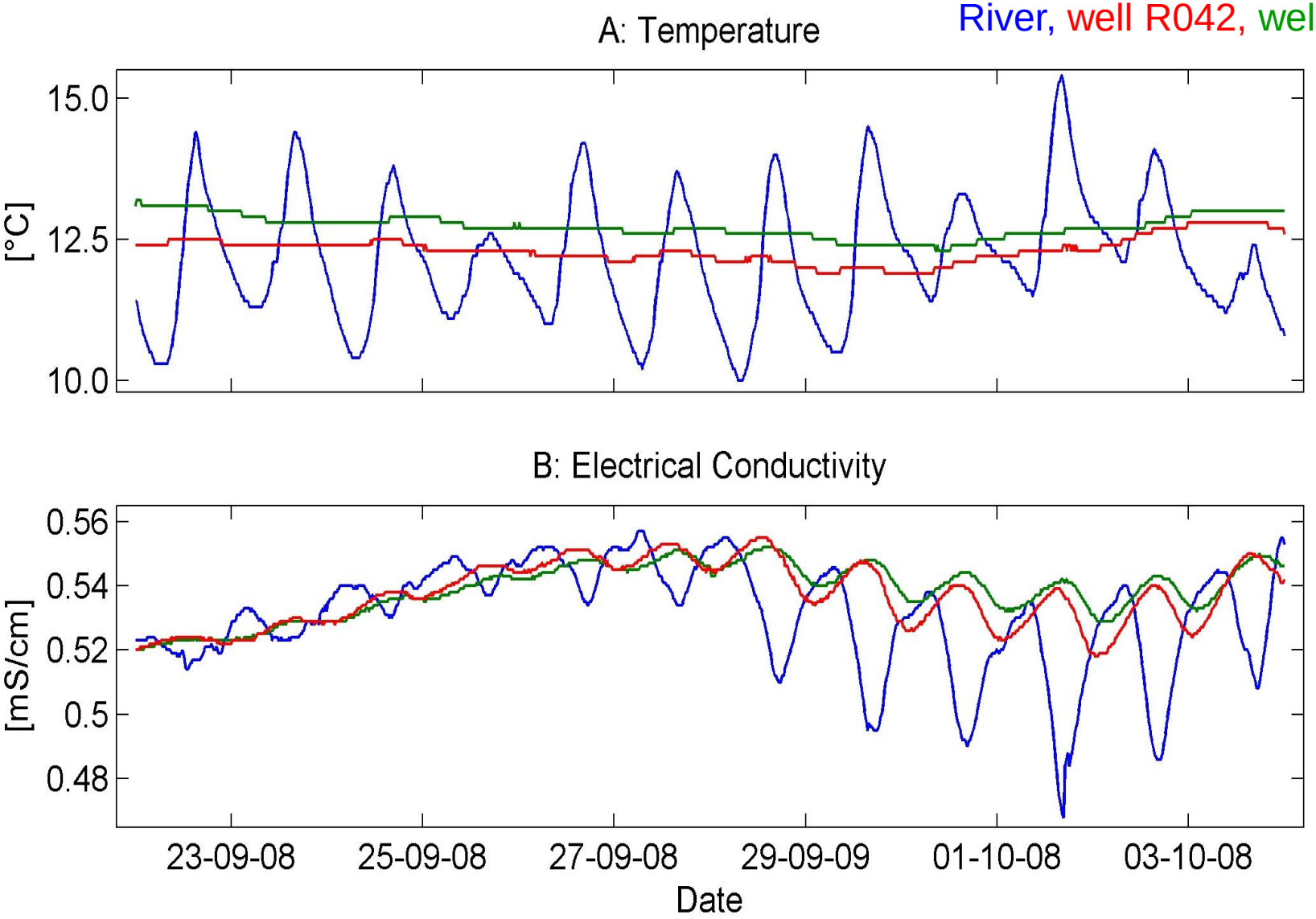
Apparent seepage variability over depth and time



Vogt et al. 2010
J.Hydrol.

Diurnal Oscillations in Young Groundwater

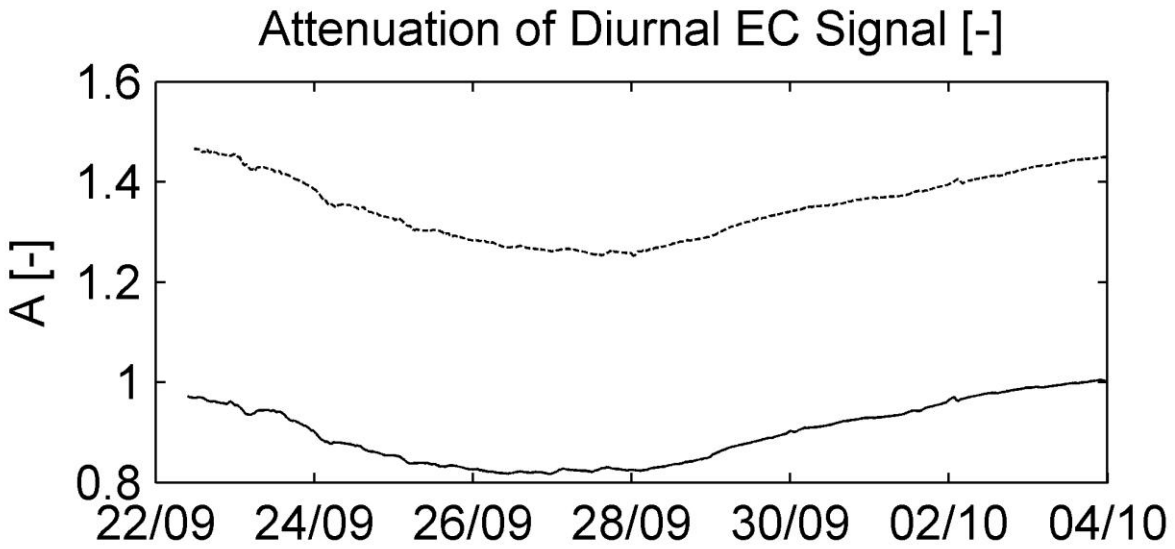
River, well R042, well R043



Vogt et al. (2010), Adv.Wat.Res.

Advective Travel Time of Diurnal EC Oscillations

Dynamic Harmonic Regression (Young 1999) is used to extract amplitudes and phase angles of sine-cosine functions with the frequency 1/day.

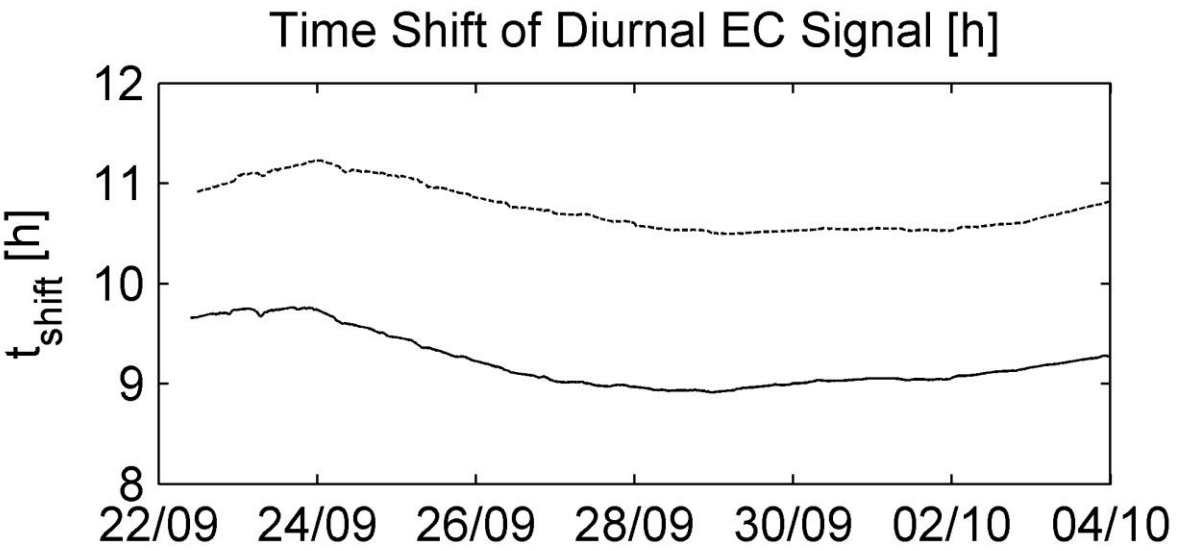


Fitting of simple analytical expression for 1D solute transport

Advective velocity = 10^{-4} m/s
Dispersion coefficient = 10^{-6} m^2/s

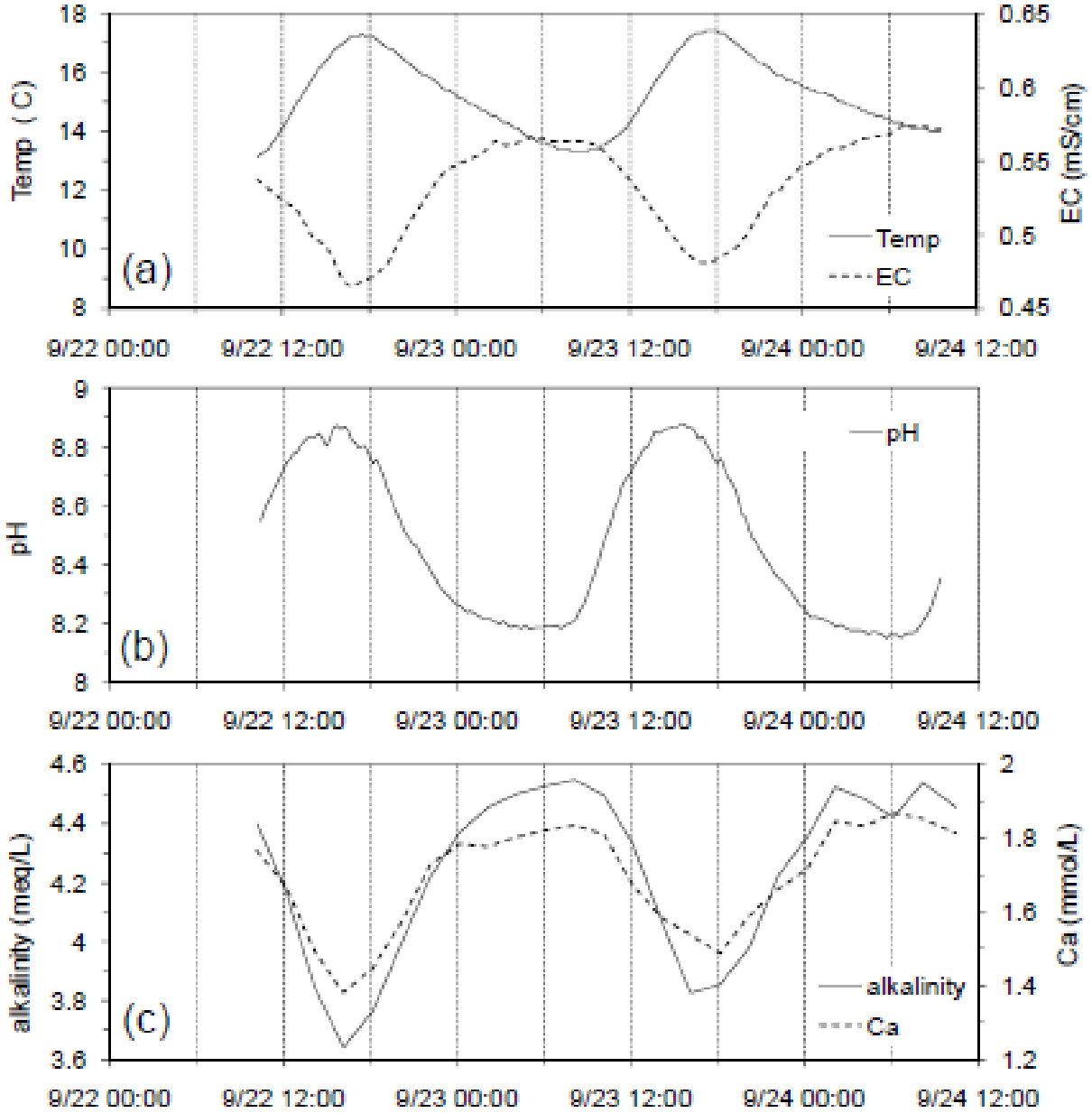
Peclet number > 100

Advection dominates

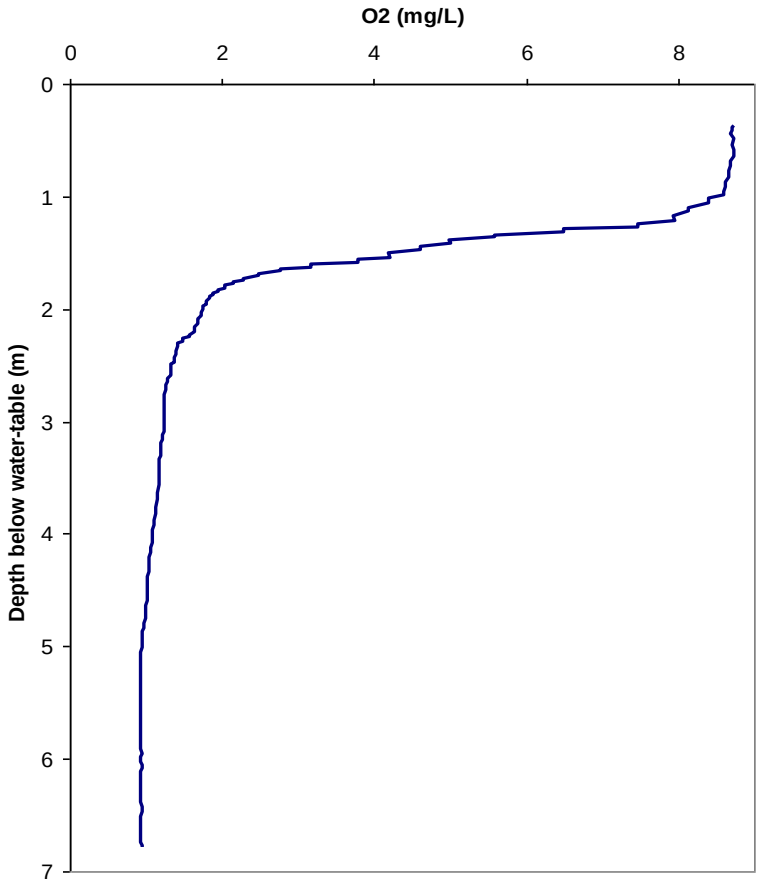


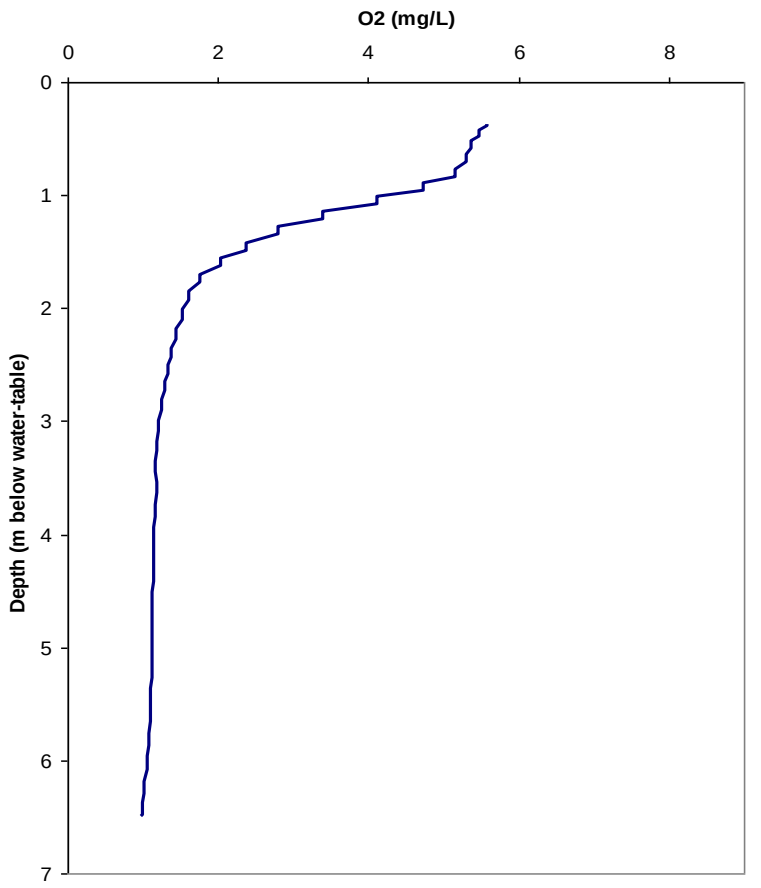
Vogt et al. (2010), Adv.Wat.Res.

Photosynthesis Controls Diurnal EC and CaCO3 Oscillations



O_2-Profiles of Riparian Observation Wells

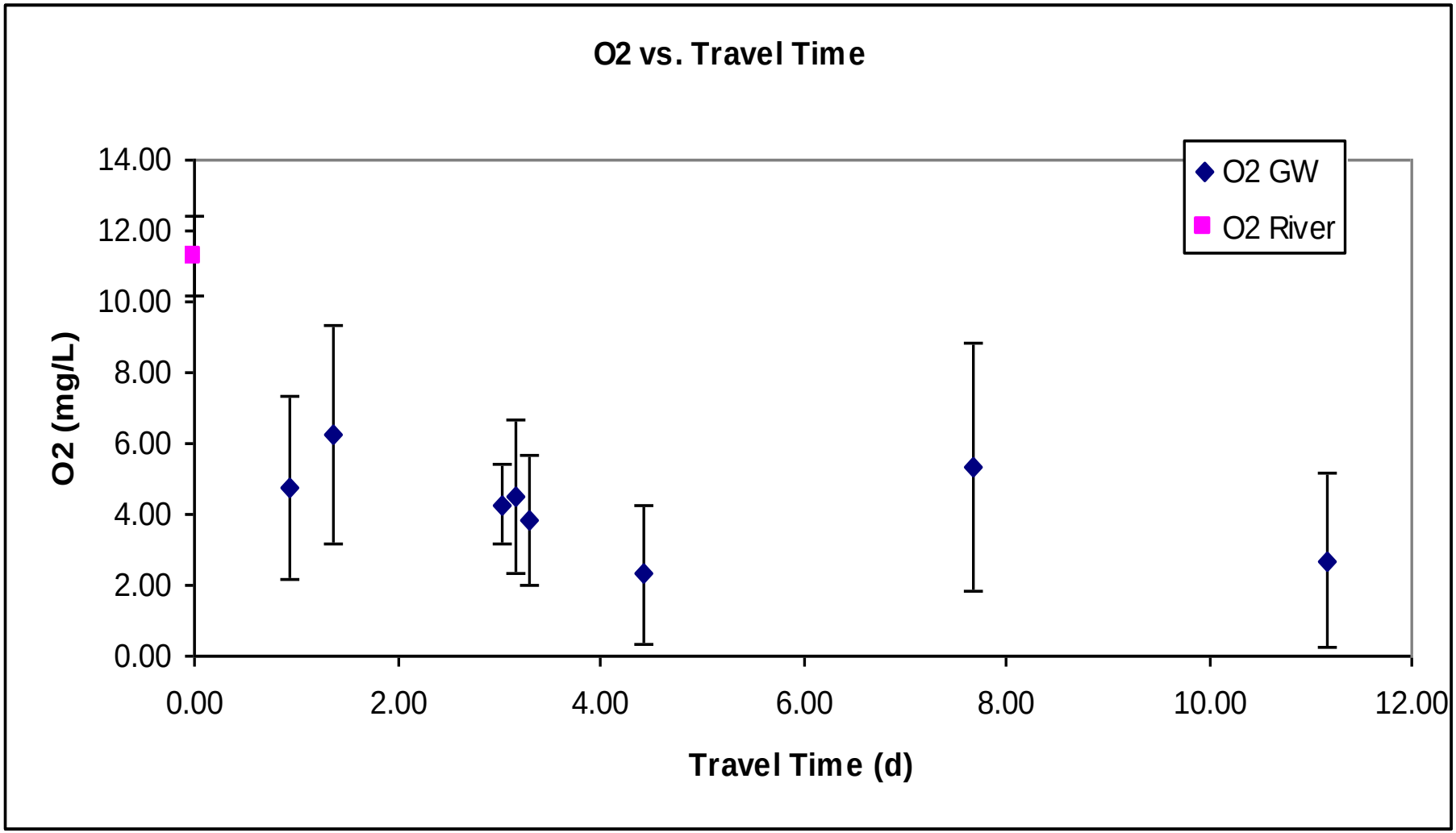




Increasing distance from the river

Fresh river water infiltrate on top, older groundwater below.

Travel Times vs. Biogeochemistry

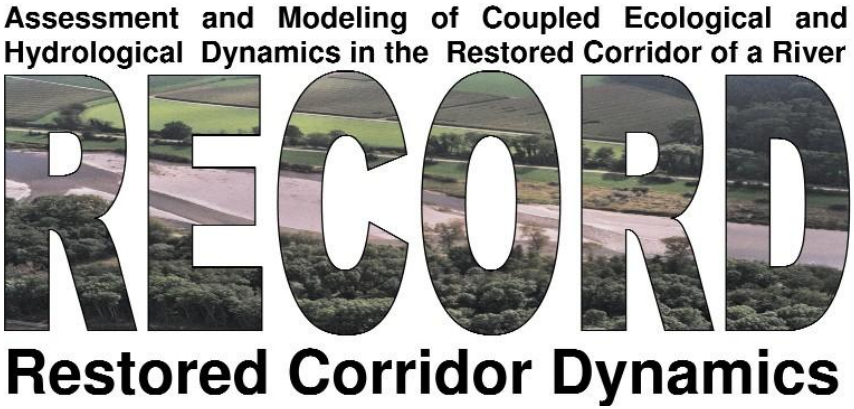


Concluding remarks

- Diurnal oscillations of natural tracers offer useful signals to quantify river – groundwater interaction at losing river sections.
- EC fluctuations give a more comprehensive indication of bank filtration than temperature and water-table fluctuations.
- Temporal variability can be quantified.

  ⇨ Shortest travel times during times of higher river stage.
- Photosynthesis induces diurnal variations of water chemistry (even in a big river like river Thur)
- Vertical and temporal variability of oxygen conc. in riparian groundwater.
- Methods can be used to evaluated effects of river restoration on groundwater. A particular benefit originates from such studies, if data before and after the restoration exist.

Acknowledgements



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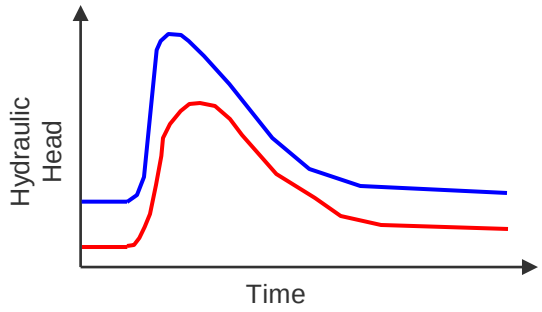
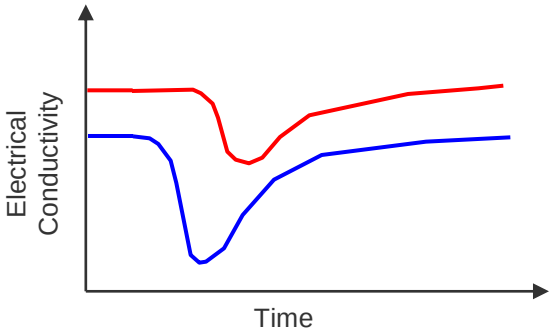
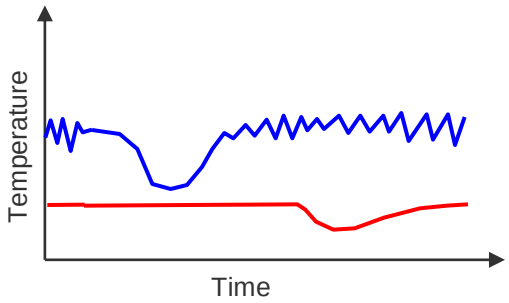
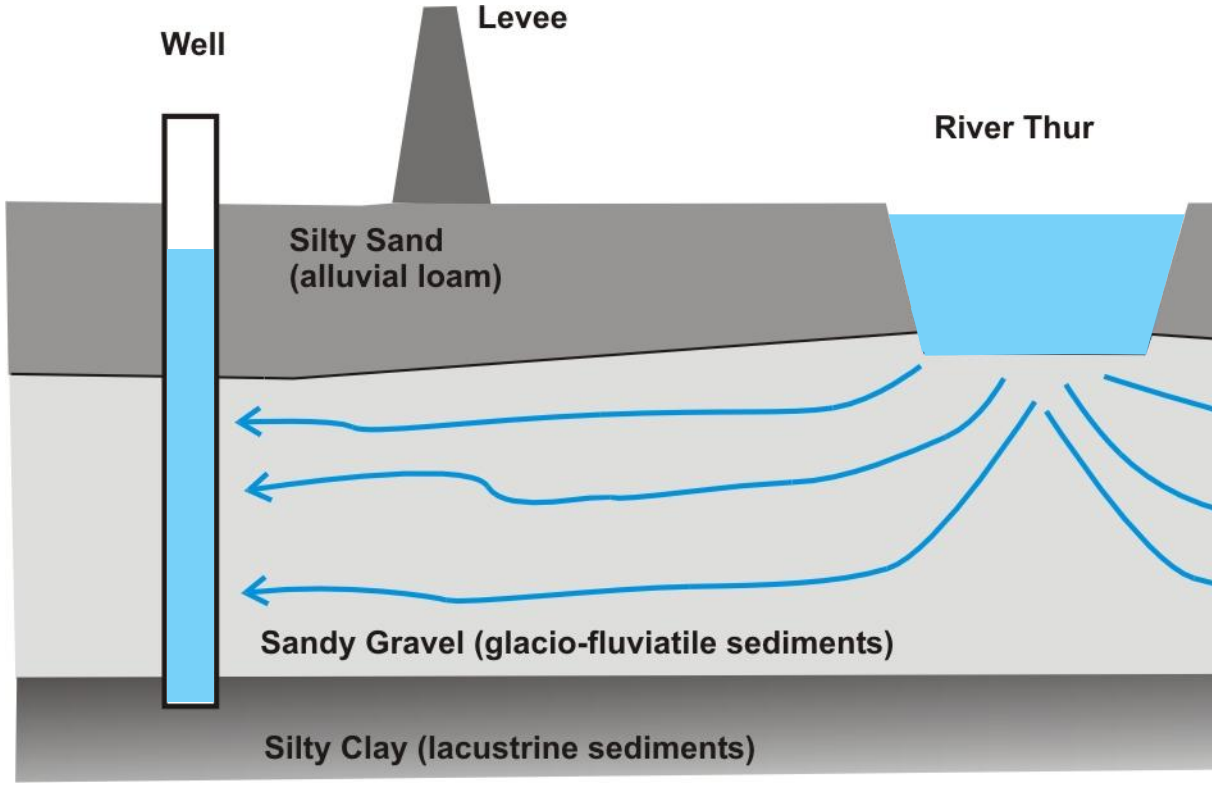
Propagation of Natural Tracers in the Aquifer

River Well

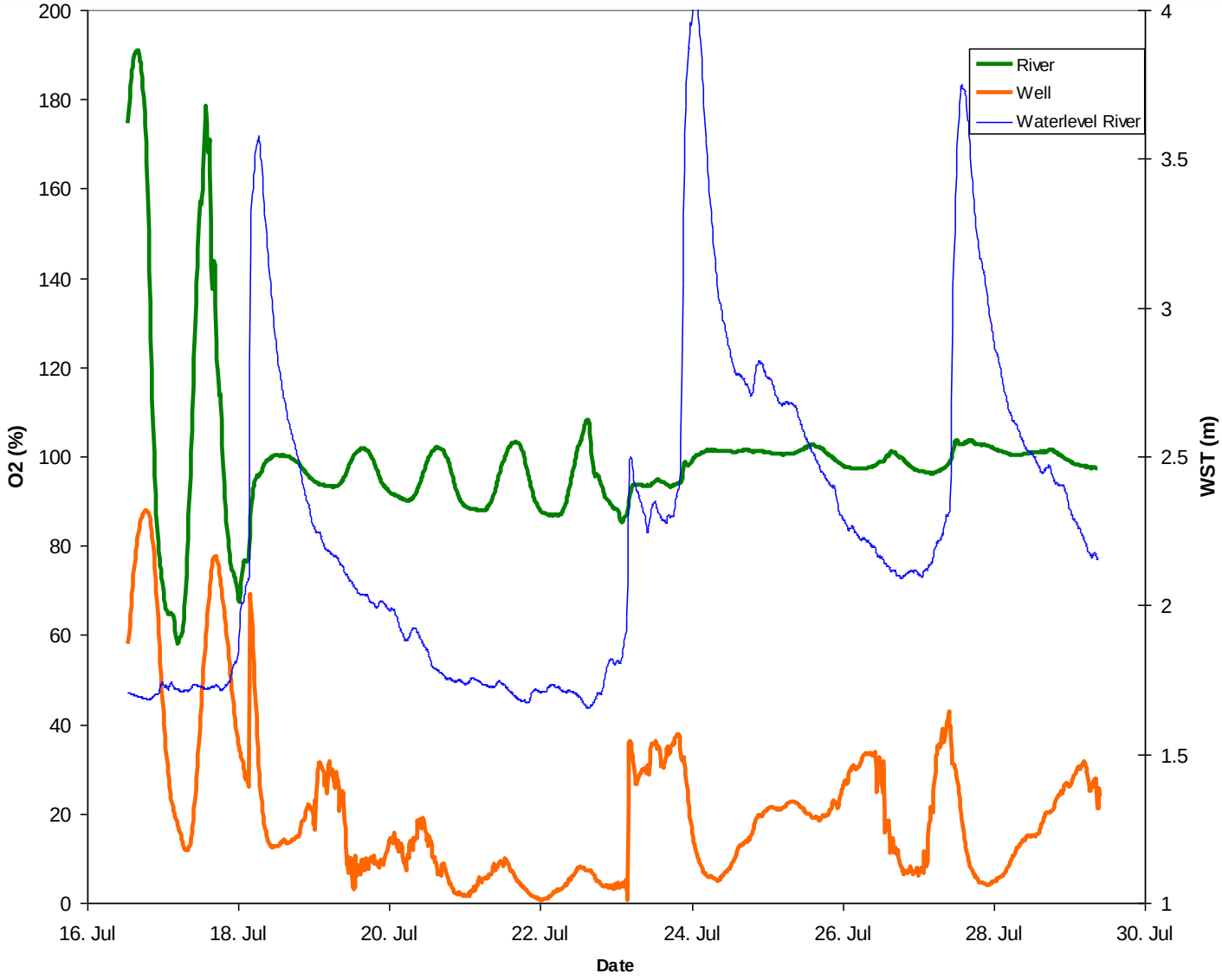




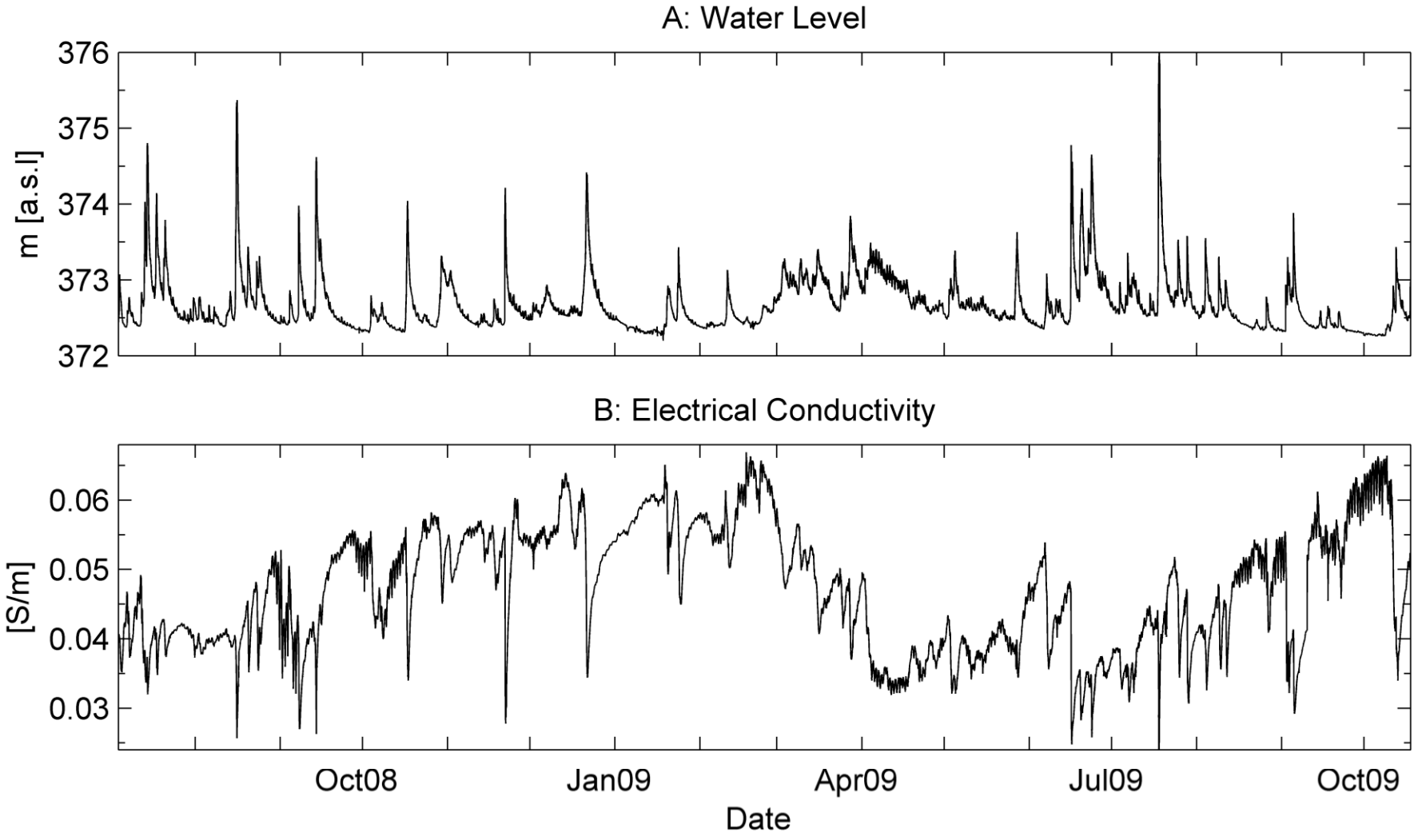




Oxygen Time Series

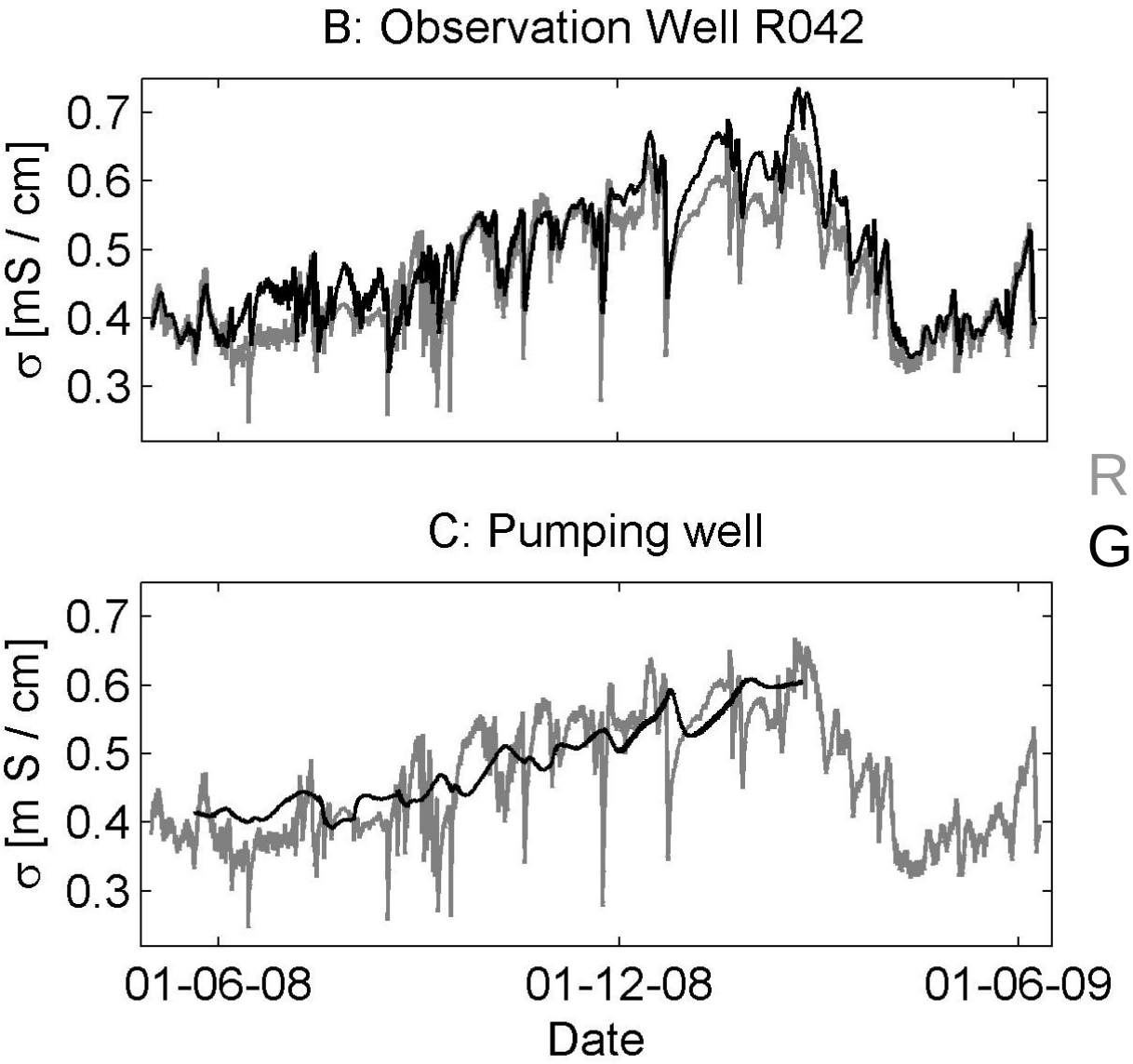


Time Series of River Thur



Vogt et al. (2010), Adv.Wat.Res.

Dampening of Electrical Conductivity Signal



River

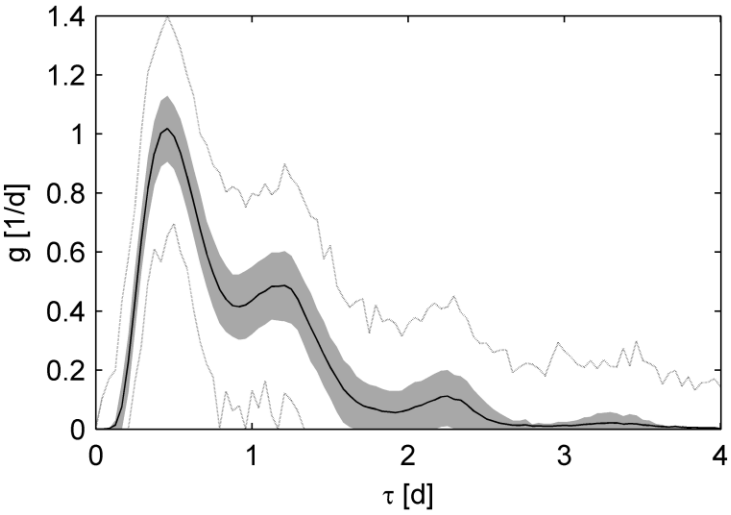
Groundwater

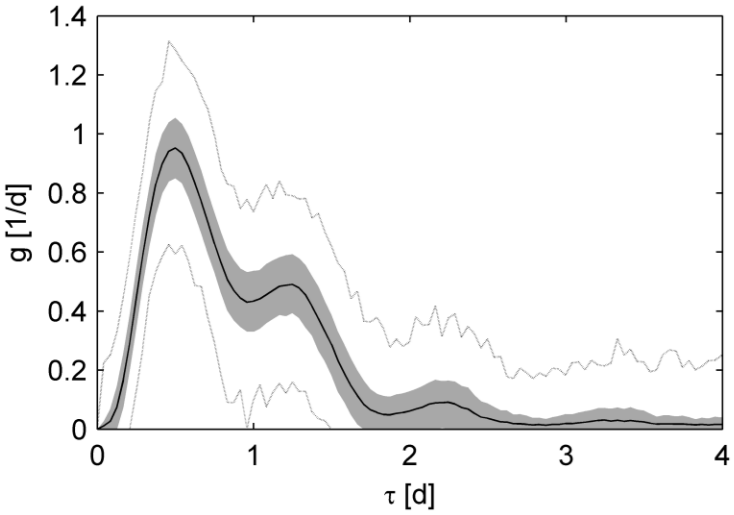
Nonparametric Deconvolution

R042 (shallow sensor)

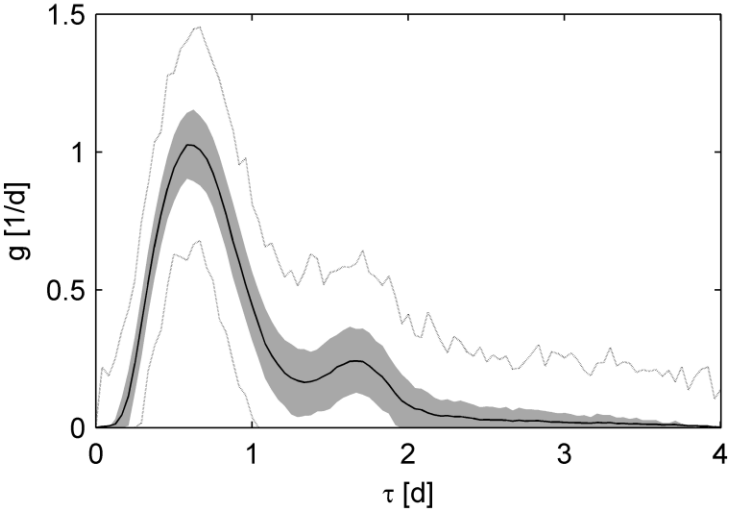
R042 (deep sensor)

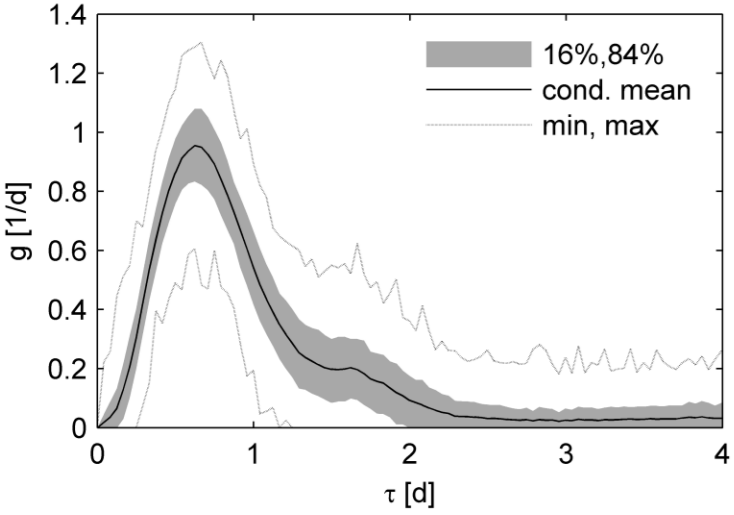
Including diurnal oscillations





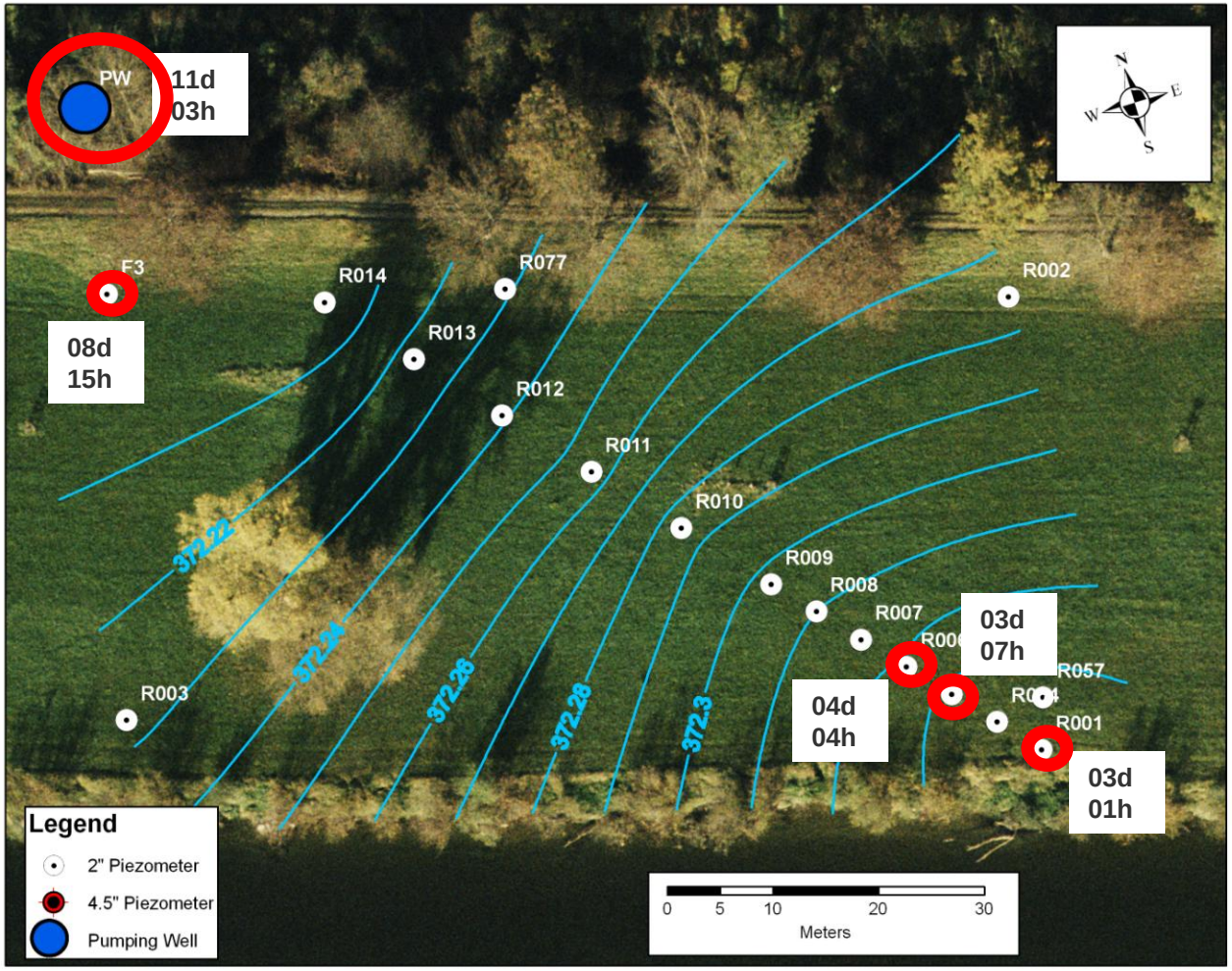
Removed diurnal oscillations





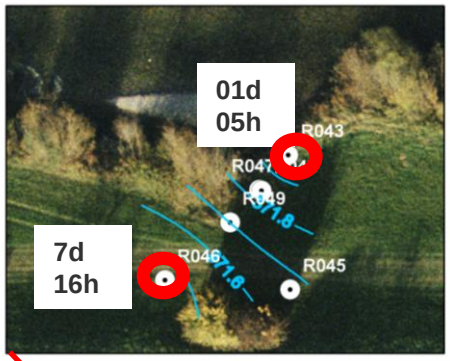
Vogt et al. (2010), Adv.Wat.Res.

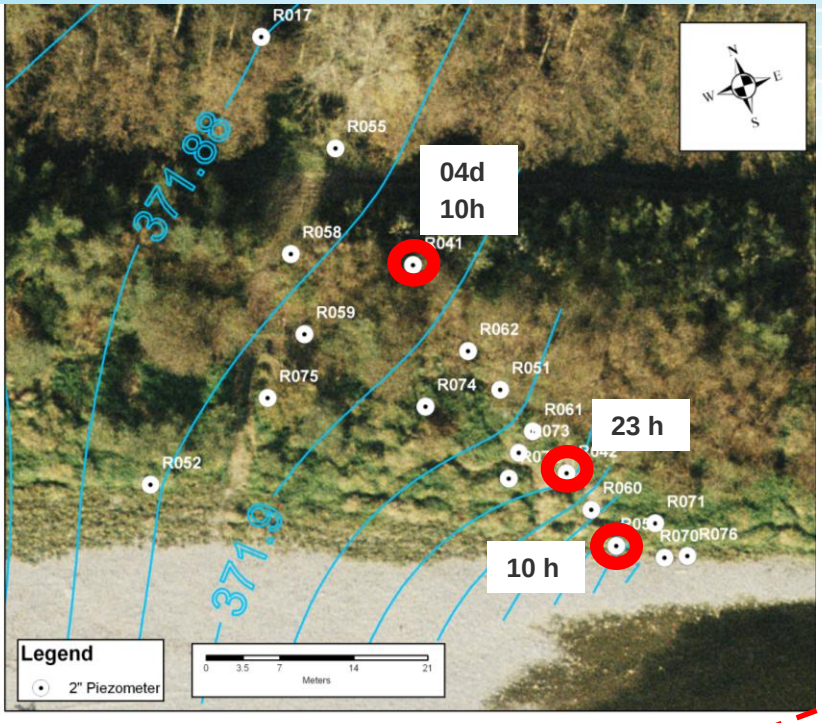
Travel Times “Channelized River Corridor“



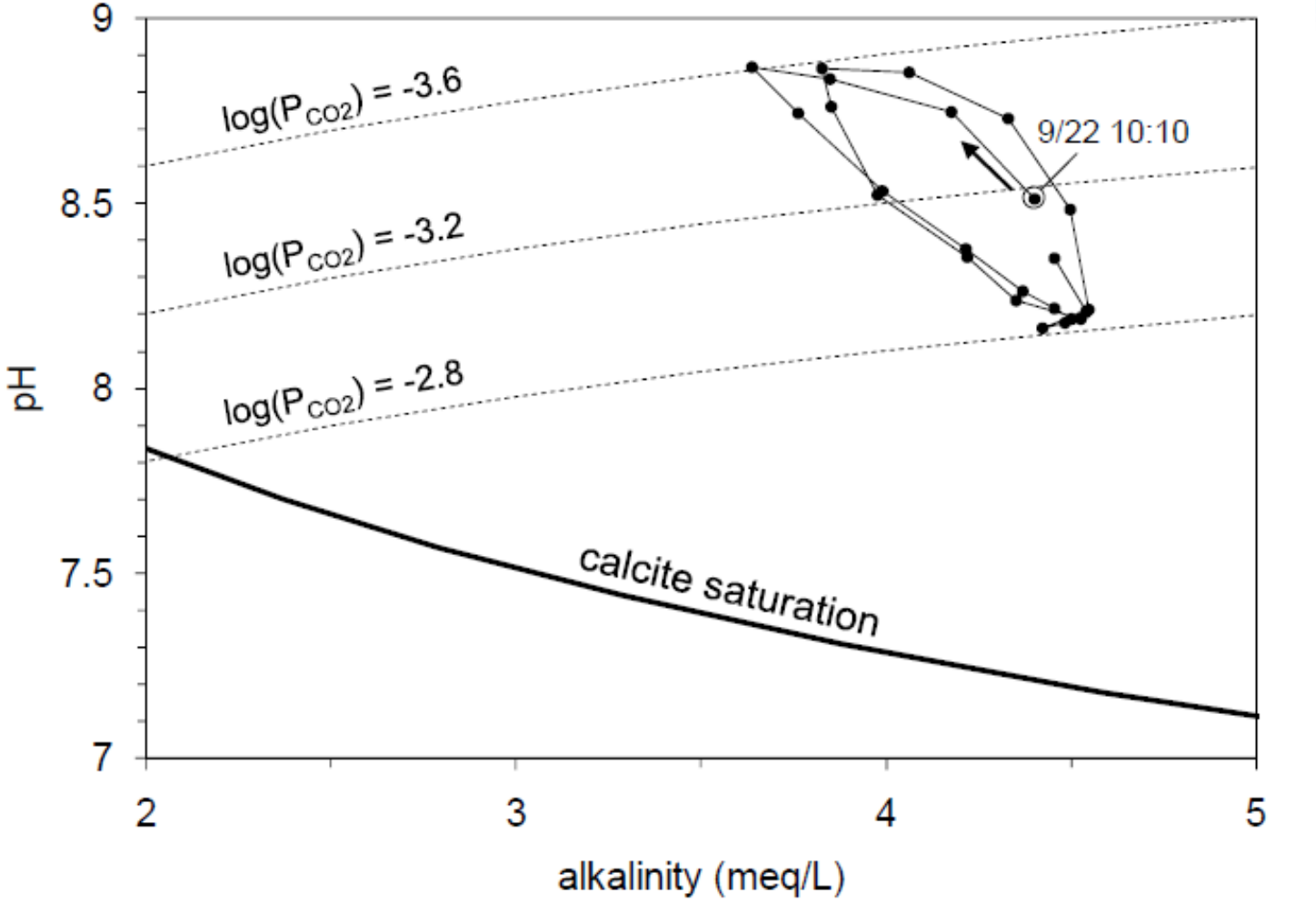
Travel Times

“Restored River Corridor”

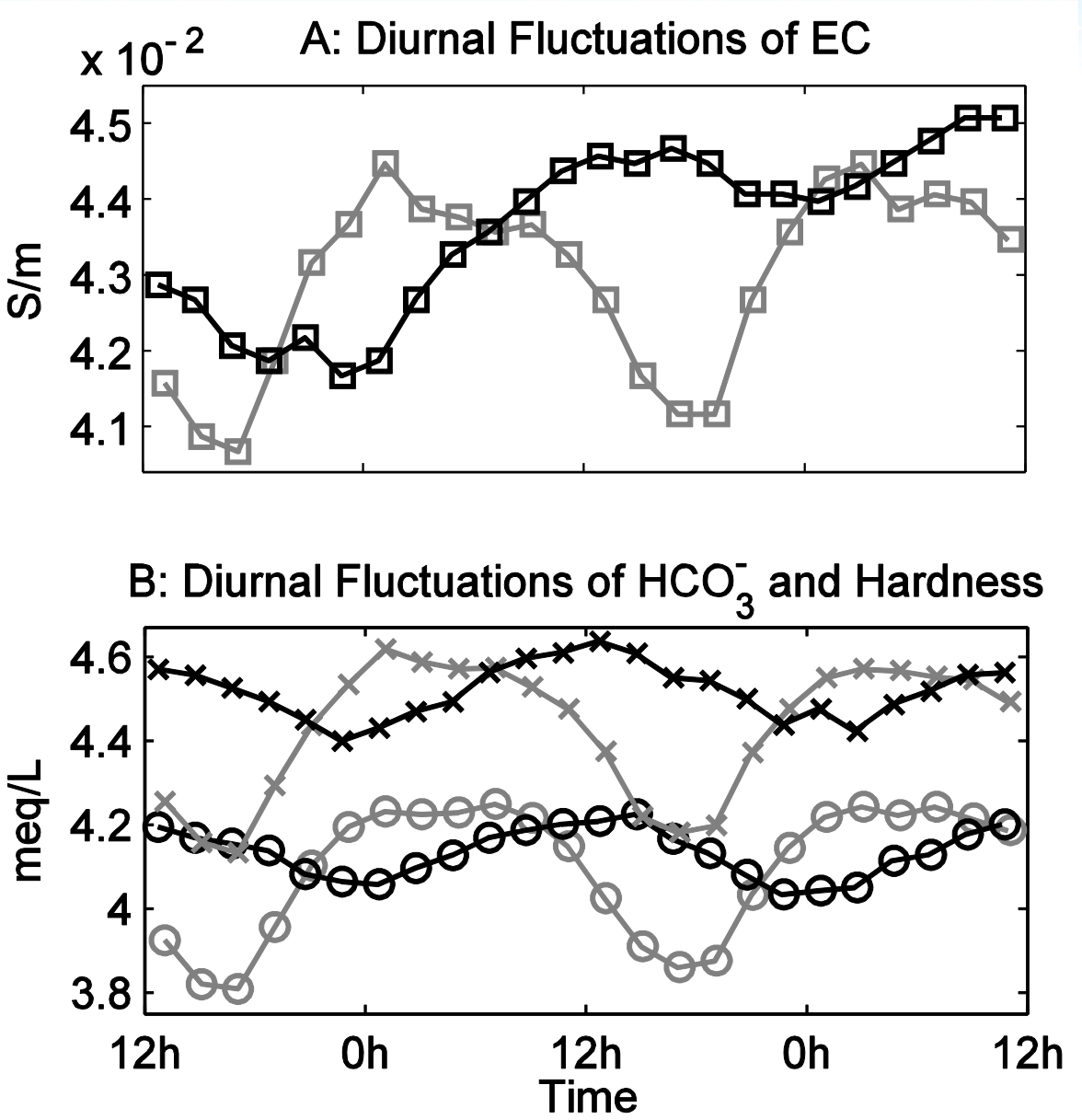




Diurnal EC Oscillations

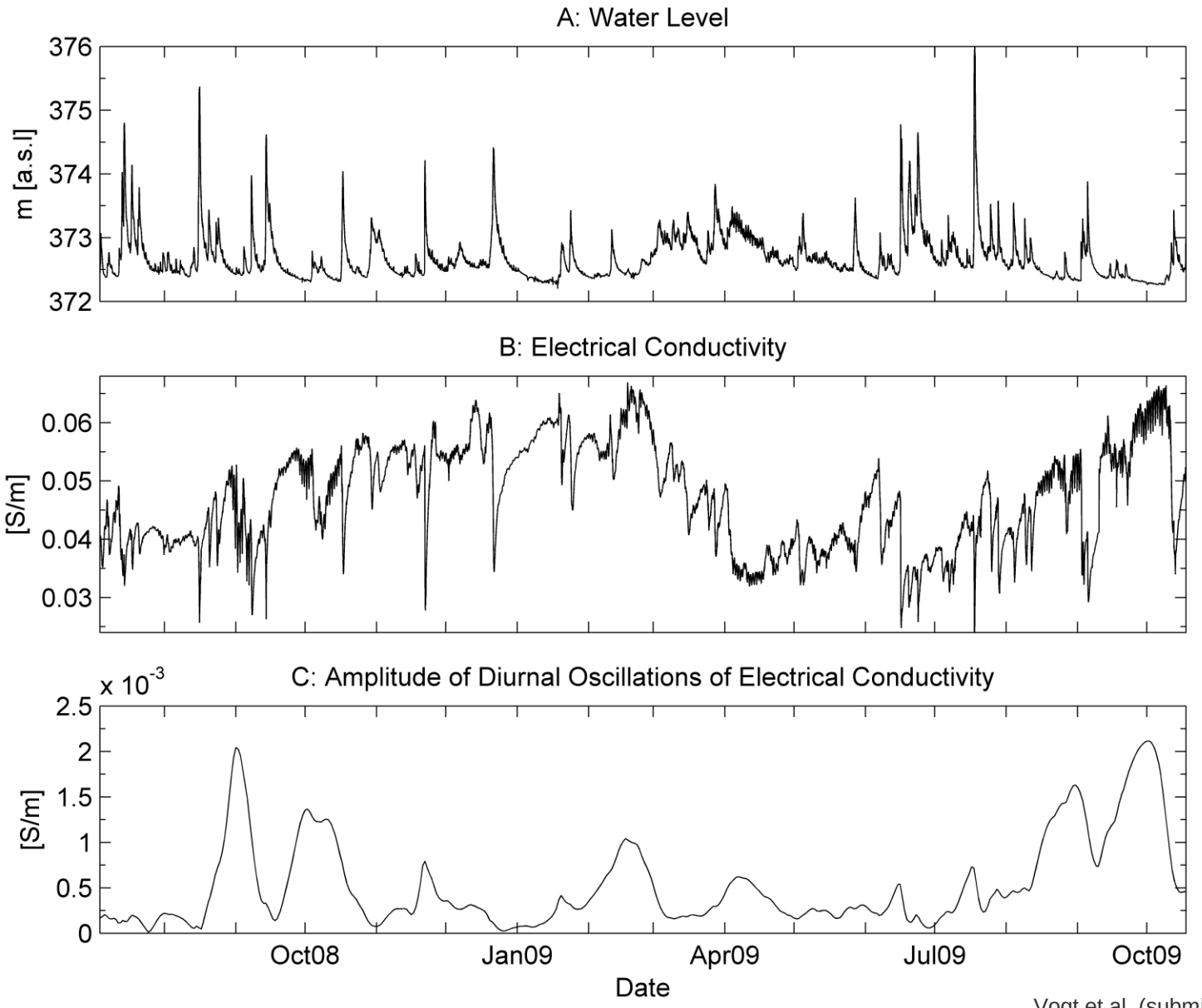


Diurnal EC Oscillations



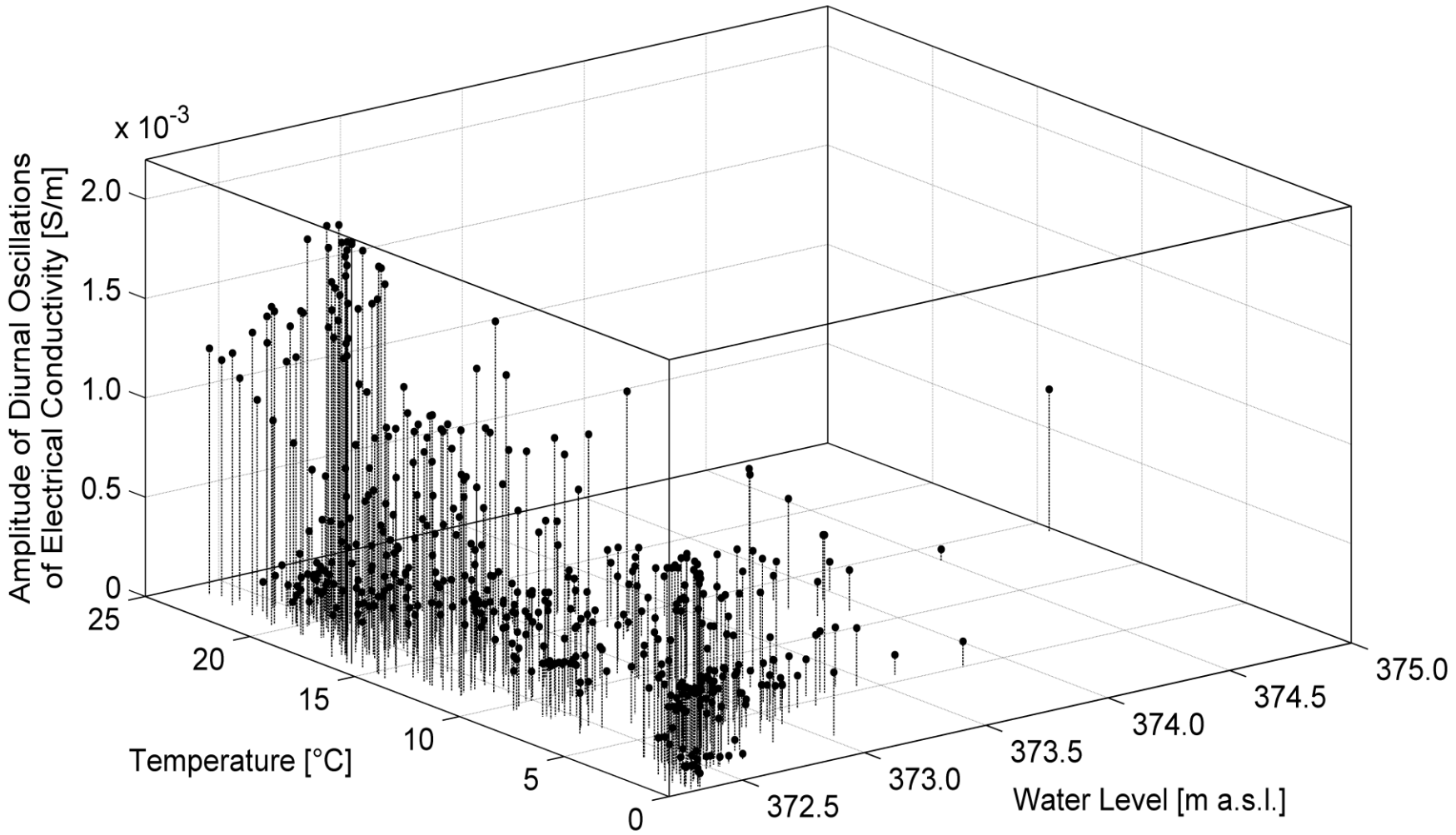
Vogt et al. (2010), Adv.Wat.Res.

Time Series of River Thur



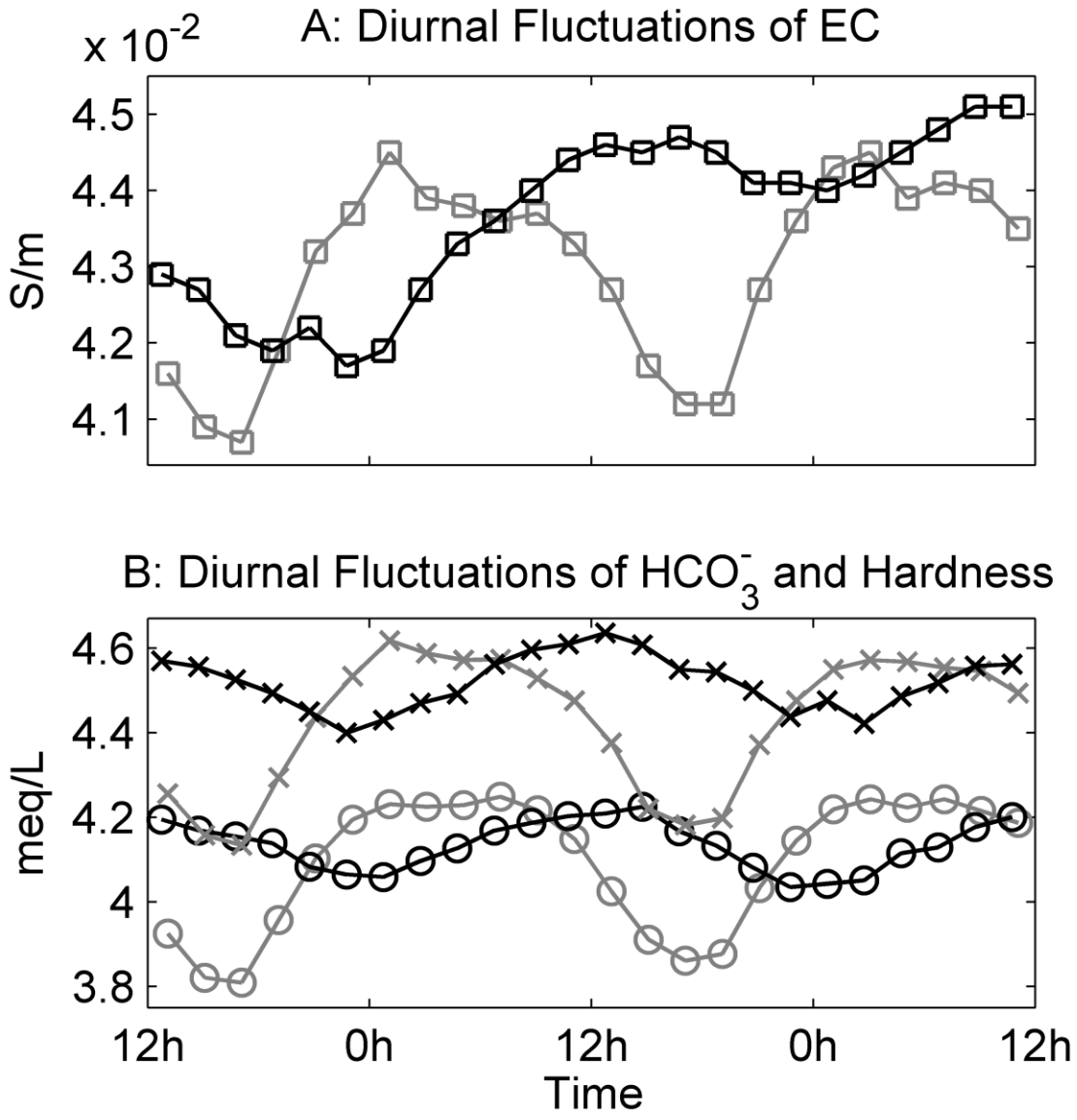
Vogt et al. (submitted), Adv.Wat.Res.

Amplitude of Diurnal EC Oscillations



Vogt et al. (submitted), Adv.Wat.Res.

Diurnal Variation of Hydrochemical Parameters

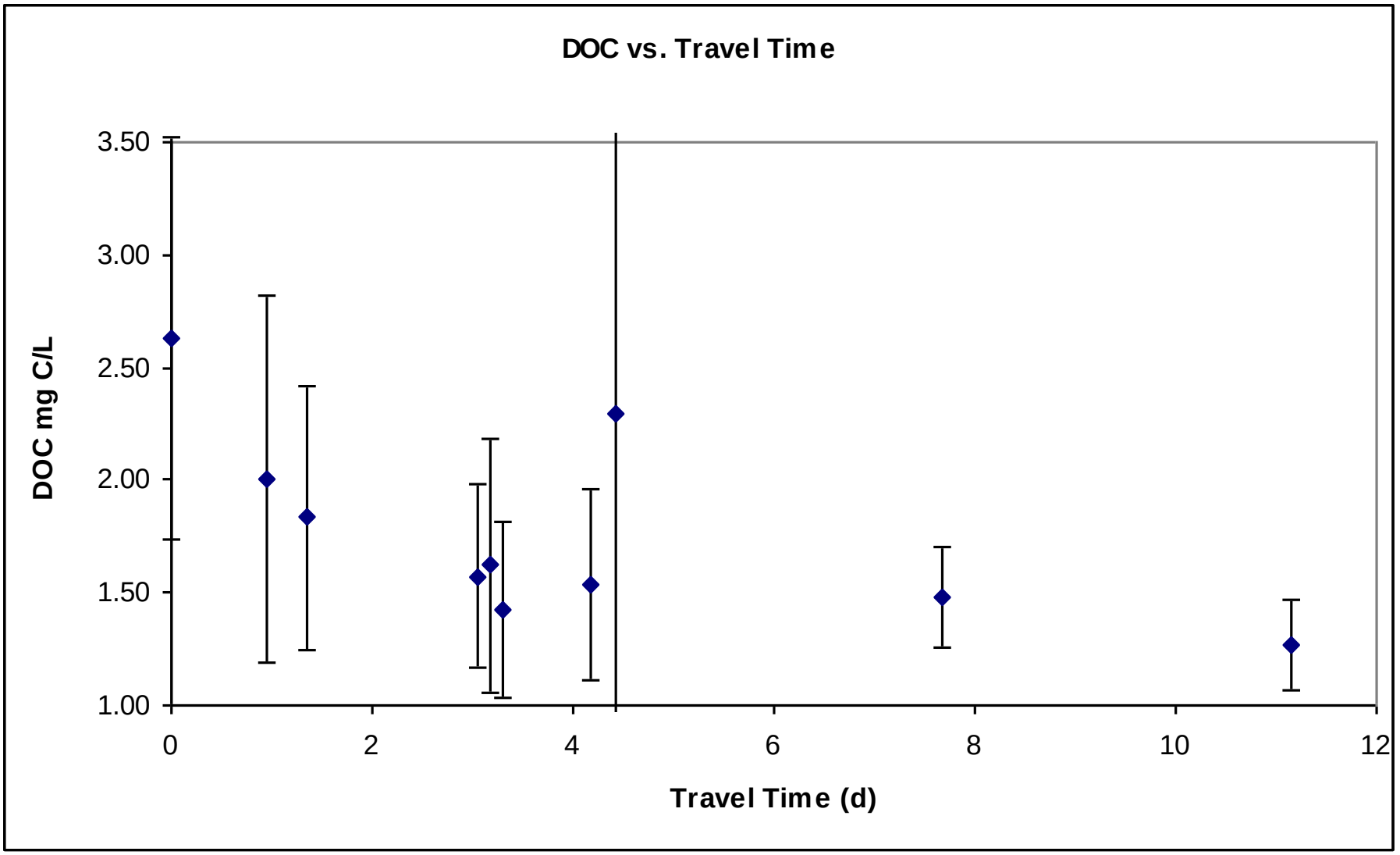


River
GW

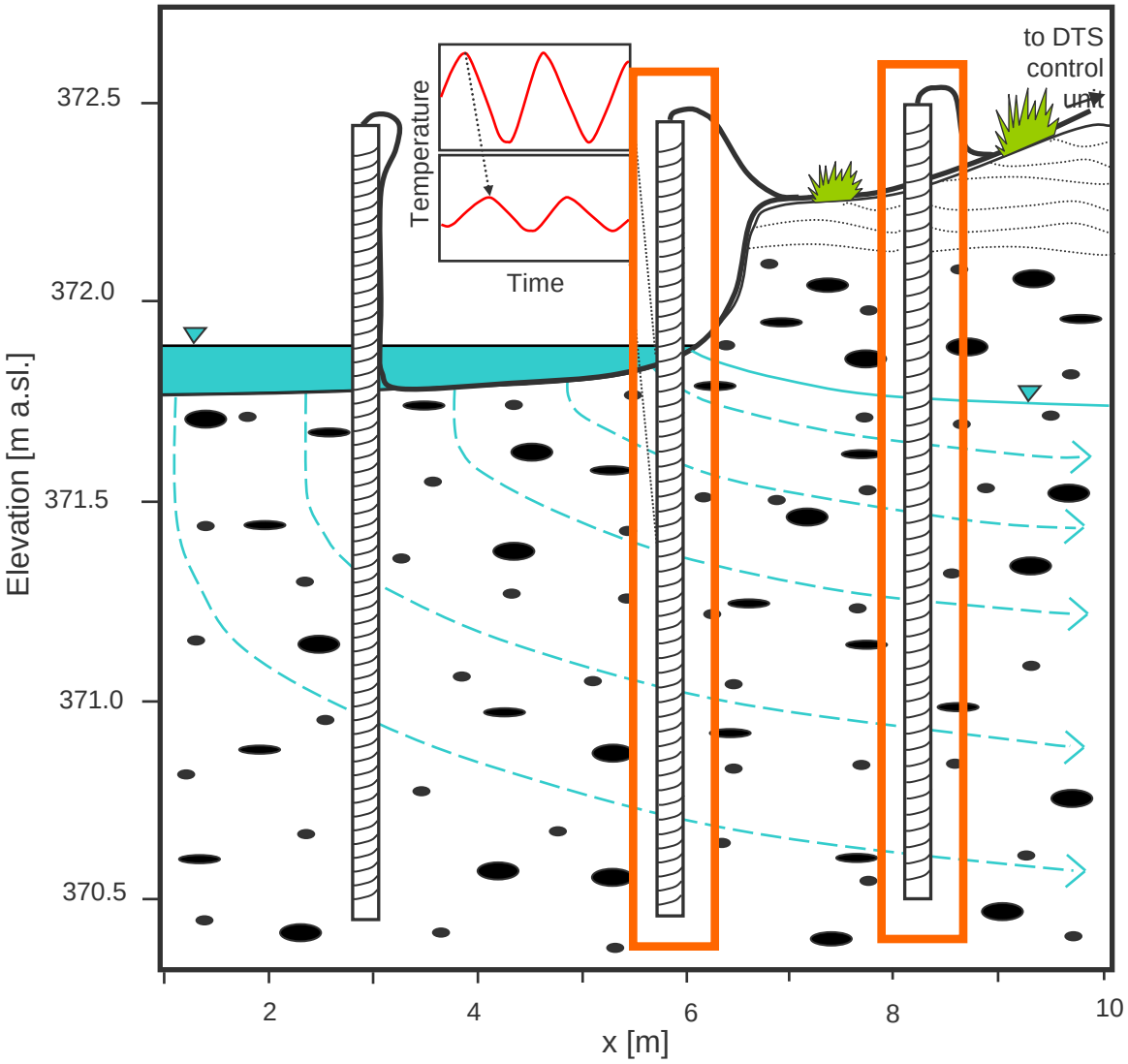
X = hardness
O = HCO3-

Vogt et al. (submitted), Adv.Wat.Res.

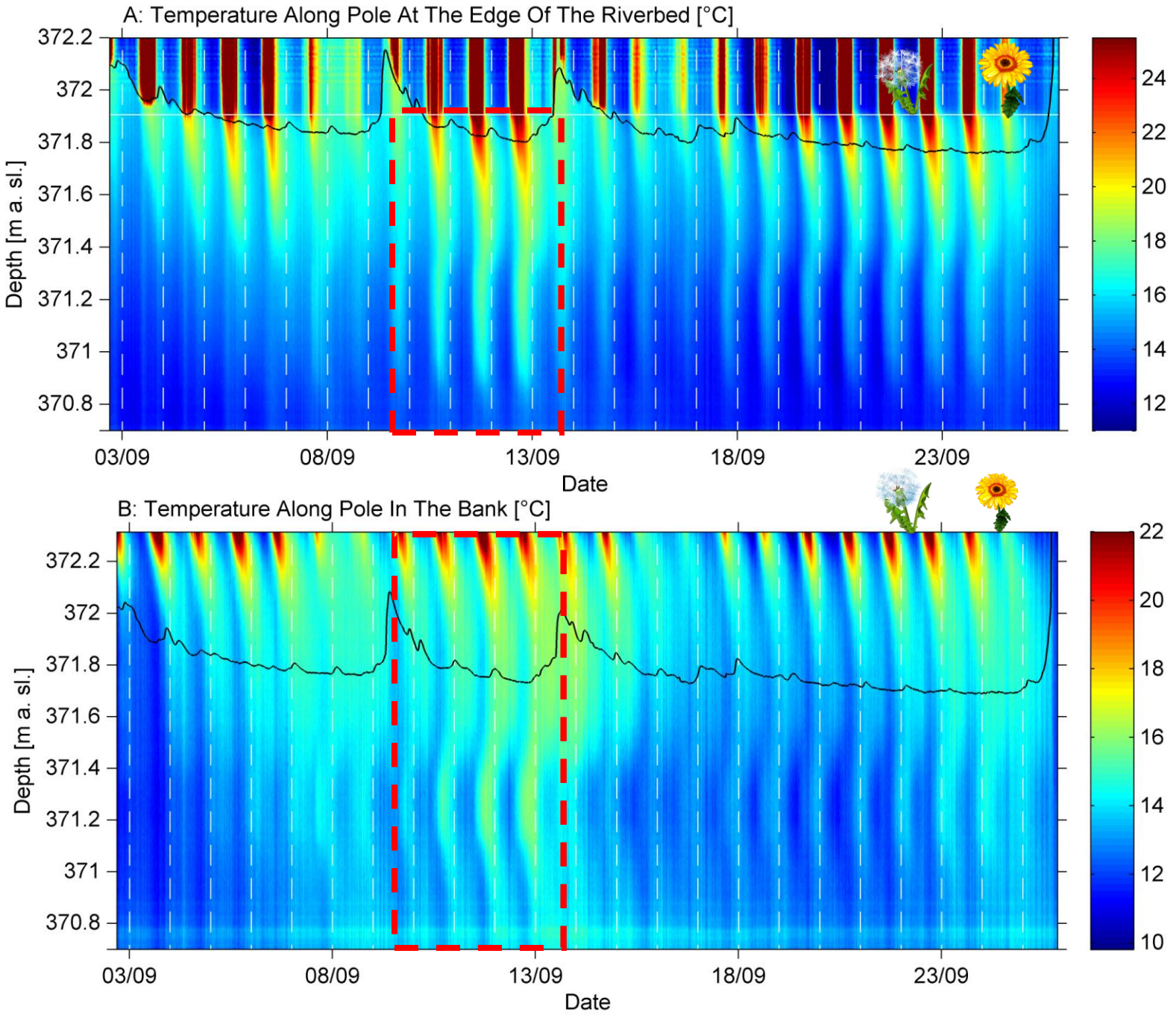
Travel Times vs. Biogeochemistry



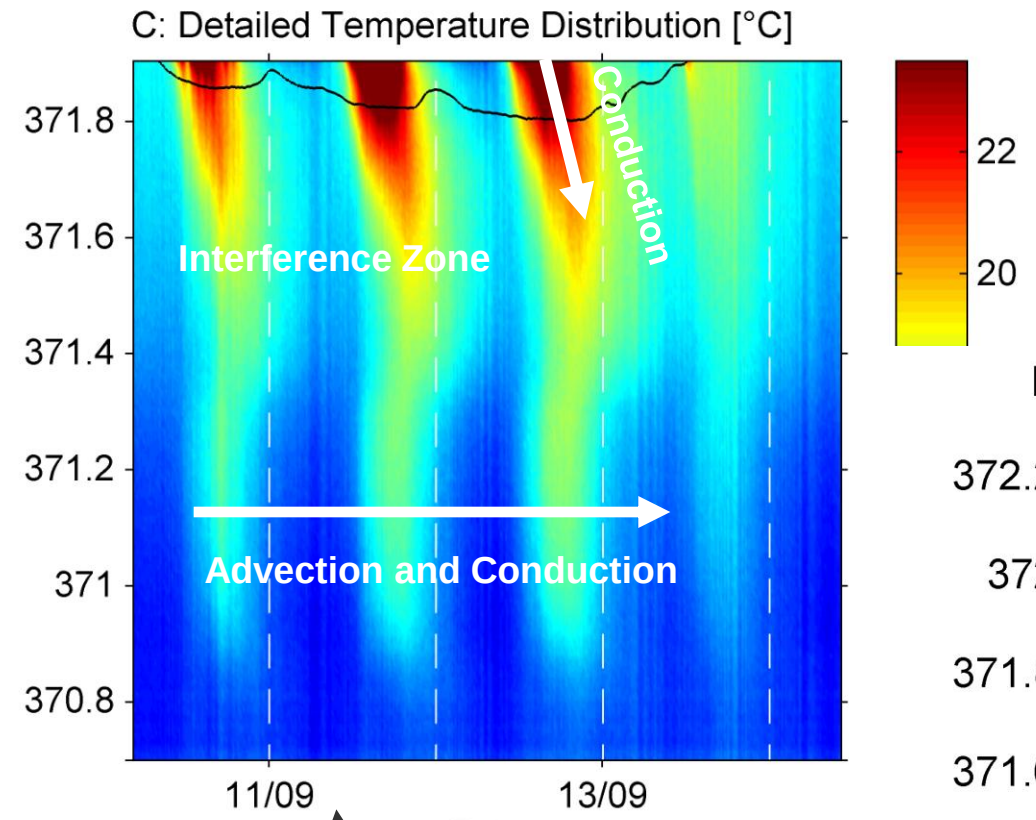
Experimental Set-Up DTS

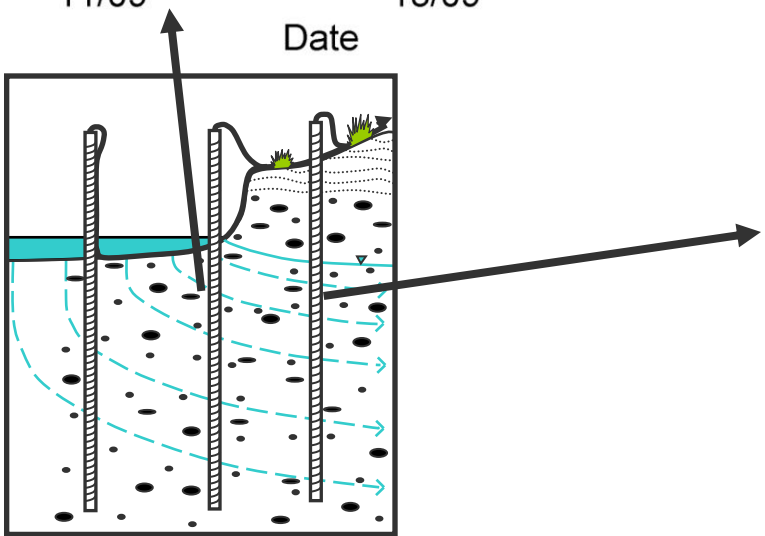


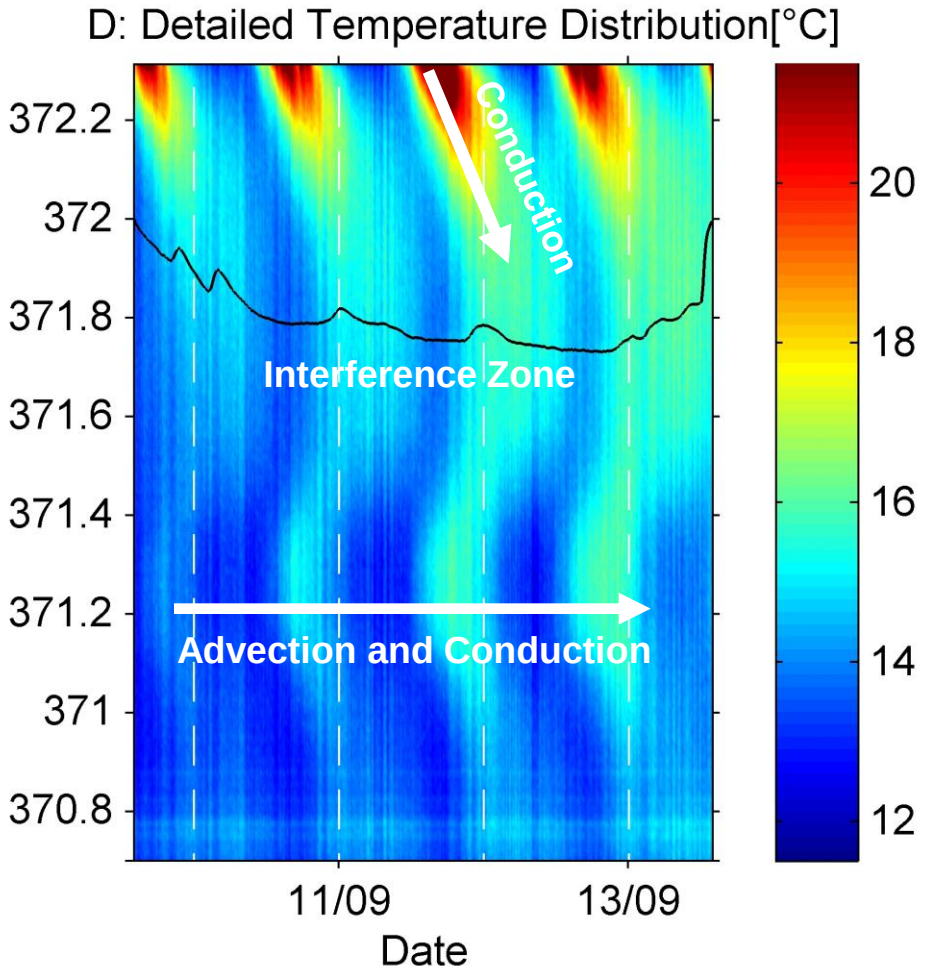
Temperature Distribution in the Bank



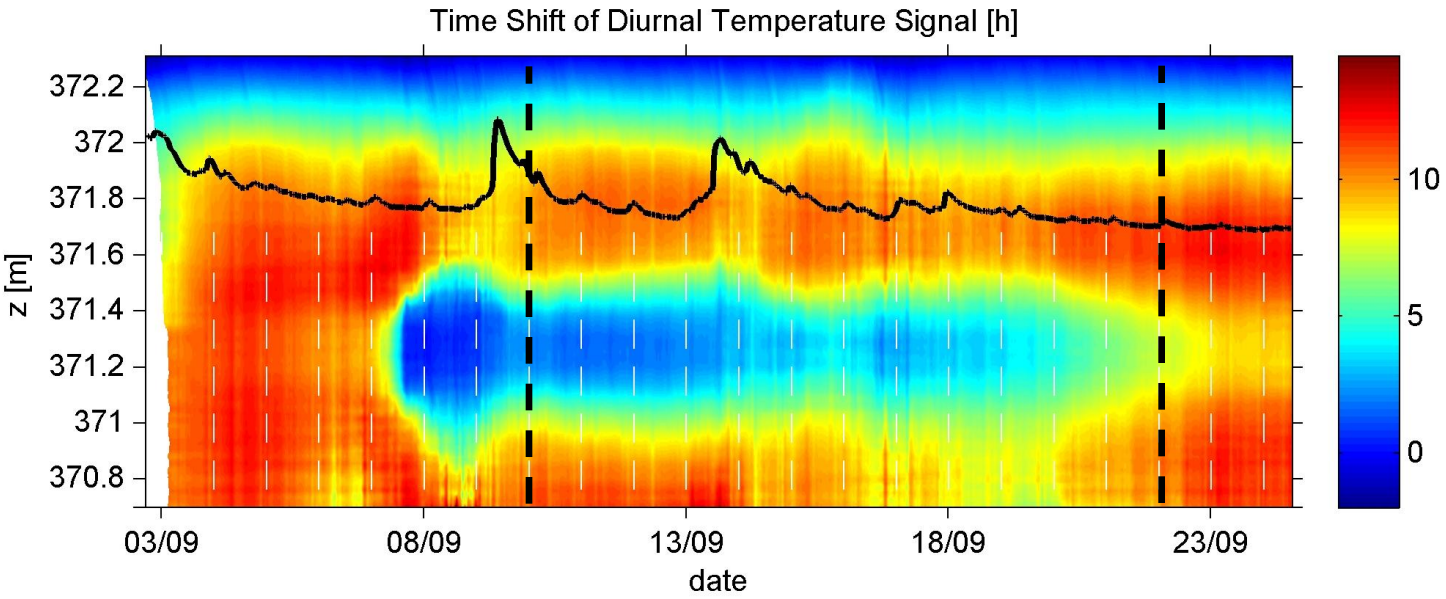
Temperature Distribution in the Bank

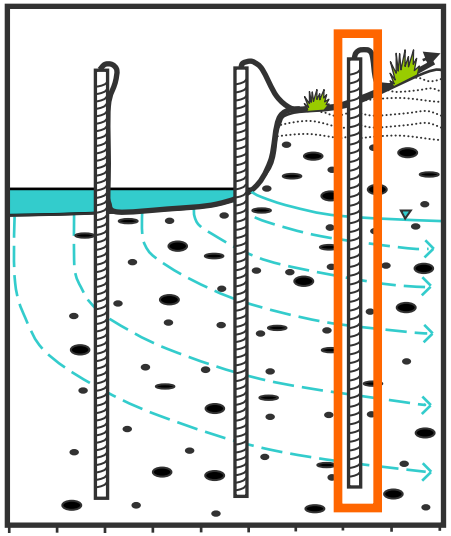


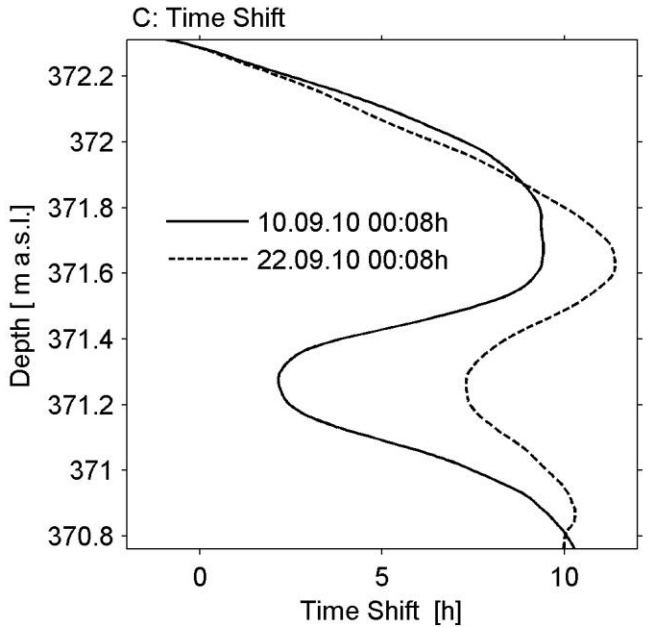


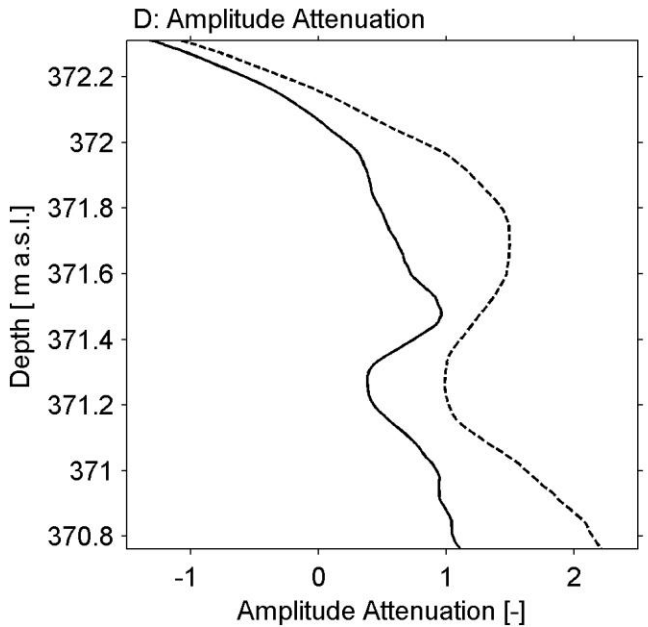


Time Shift of Diurnal River Temperature Signal

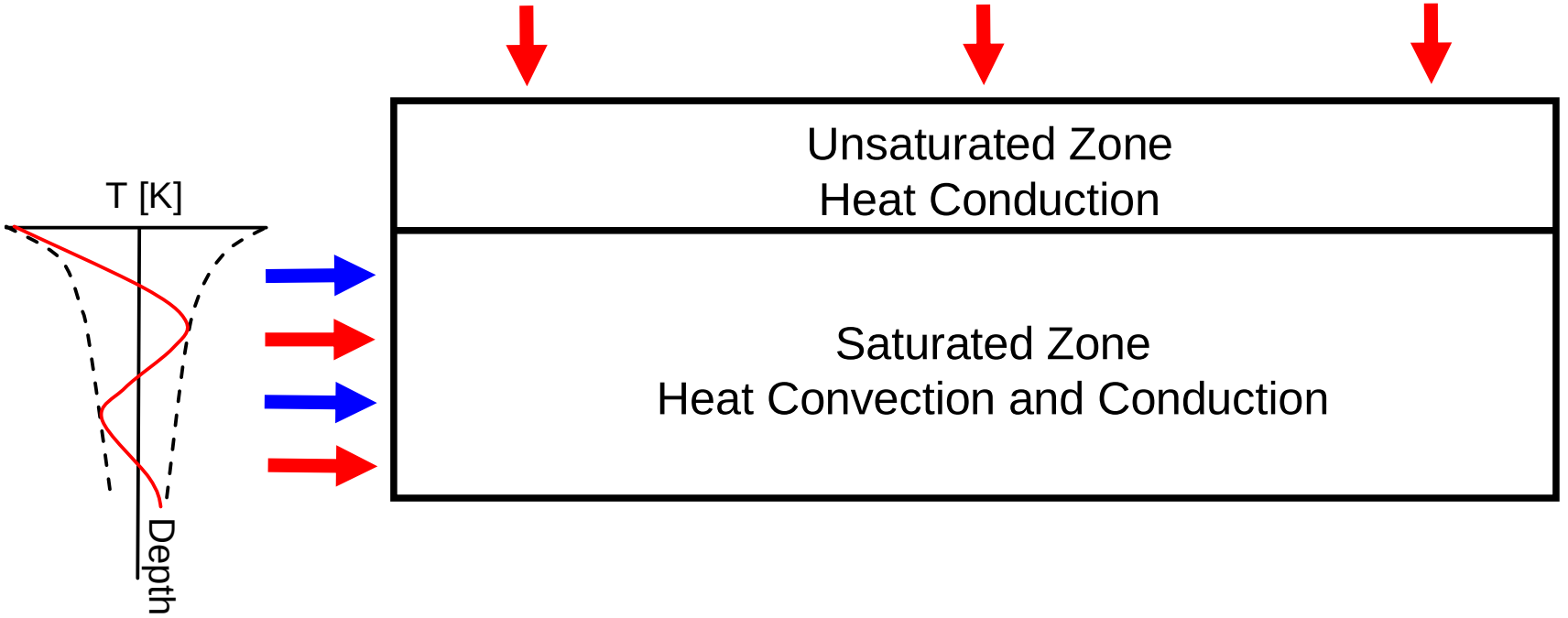








Modeling of Heat Transport upon River-Water Infiltration



Modeling of Heat Transport upon River-Water Infiltration