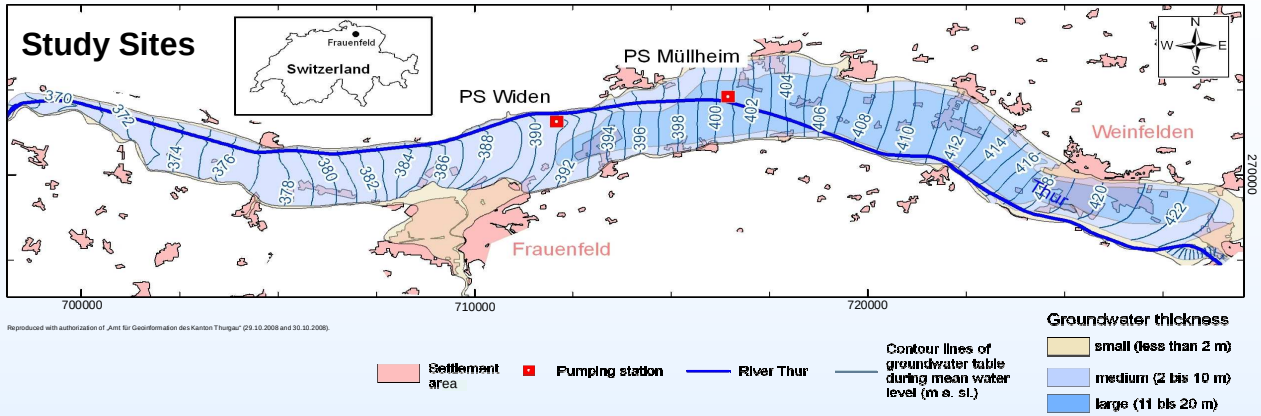
Investigation of Bank Filtration in Gravel and Sand Aquifers using Time-Series Analysis

T. Vogt[1], E. Hoehn[1], P. Schneider[1], O. A. Cirpka[2]

[1] Department of water resources and drinking water, Swiss Federal Institute of Aquatic Science and Technology (EAWAG), Switzerland, contact: *tobias.vogt@eawag.ch*
[2] Center for Applied Geoscience, Eberhard Karls Universität Tübingen, Germany

RECORD Restored Corridor Dynamics — eawag aquatic research



Motivation

- Pumping stations close to rivers
- Swiss legislation requires a 10 days residence time.
- Artificial tracer tests are expensive and represent only specific hydrological situation.

Methods

Data collection

Sensors with data loggers → Time-series of water level, temperature and EC in the river and in observation wells.

Cross correlation

- Correlation coefficient of the river and groundwater signals after shifting and smoothing the input data.
- Optimal time shift → characteristic time of transfer.
- Optimal degree of smoothing (moving average) → indicator of diffusive processes
- Linear regression of smoothed and shifted data
  ⇨ slope: recovery rate
  ⇨ intercept: bias in mean

Non-parametric deconvolution after Cirpka et al. (2007)

- Constructs breakthrough curve of a tracer test without injection of an artificial tracer → travel time distribution.
- Transfer function (Green function) is free to adjust to the data set → Features like multiple peaks are determined.
- Use of geostatistical smoothness criterion and Lagrange multipliers to enforce nonnegativity.

Objectives

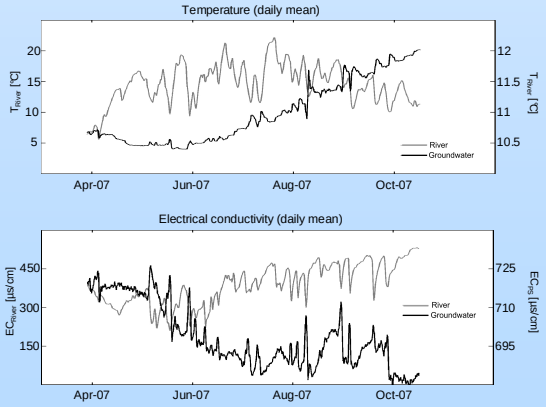
Determine travel times of infiltrated river water by time-series analysis of naturally varying tracers (temperature, EC).

Results

Pumping station Müllheim

Anti-correlated signals of EC and temperature.

→ No river water infiltration → No further analysis.



References

BUWAL. Wegleitung Grundwasserschutz. Bundesamt für Umwelt, Wald und Landschaft, Bern (2004)

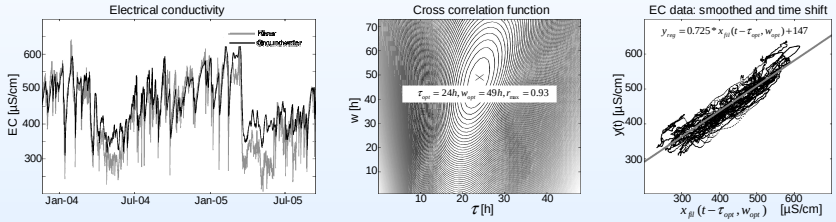
Cirpka, O.A., Fienen, M.N., Hofer, M., Hoehn, E., Tessarini, A., Kipfer, R., Kitanidis, P.K.: Analyzing bank filtration by deconvoluting time series of electric conductivity. Ground Water 45, 318-328 (2007)

Pumping station Widen III

Continuous river water infiltration with very well connection to the aquifer.

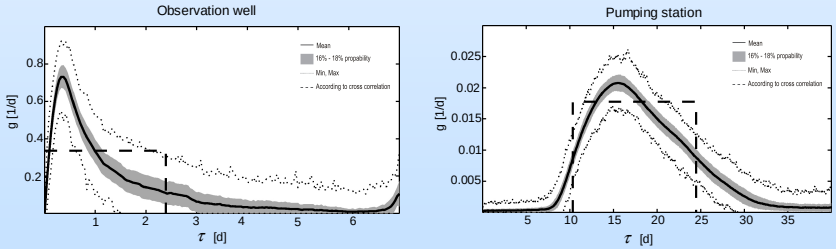
Cross correlation

- Example well: maximum correlation for 24 h time shift and 49 h smoothing width.
- Mineralization and mixing with older alluvial groundwater.



Travel time distribution after non-parametric deconvolution

- Example well: mean travel time = 35h; instantaneous breakthrough.
- Pumping station: significant breakthrough starts after 10 days
- Produced drinking water consists to ≈ 25% of freshly infiltrated river water.



Conclusions

Non-parametric deconvolution yields full distribution of travel times rather than a single optimal time-shift value.

Such distributions may be used:

- **to predict the breakthrough of contaminants in case of an accidential spill into the river**
- **to quantify the risk that a degrading river-borne compound reaches a production well.**

Acknowledgements

This work was funded by Competence Center Environment and Sustainability of the ETH Domain (CCES).

We are indebted to Romeo Favero, Andreas Scholtis, and Marco Baumann of Amt für Umwelt, Canton Thurgau for installing, equipping and maintaining the observation wells.