Geoscience Meeting 2016

Use of Isotope data to quantify the interaction between the river Rhine and the groundwater at Oberriet, CH

Christian Gmünder[1], Simon Nusch[1], Stephanie Zimmermann[2]

[1]Simultec AG, Zürich
[2]BAFU, Abteilung Hydrologie, Sektion Hydrogeologische Grundlagen, Ittigen

Introduction

Alpenrhein flood protection project

The interaction between river and groundwater and the flow velocity towards drinking water wells must be known

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

NAQUA National Groundwater Monitoring

The BAFU performs oxygen isotope (^{18}O) measurements at the Balanggen well at Oberriet

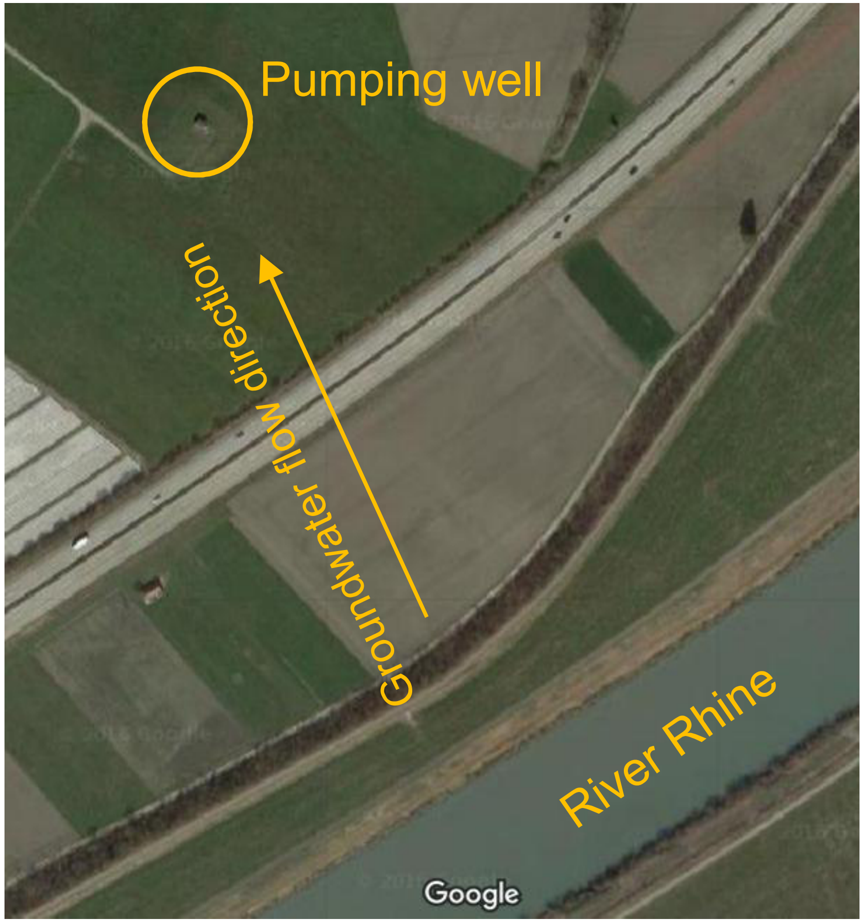
Simultec AG

Numerical groundwater model of the Alpenrhein valley and simulations of the electric conductivity (EC) values at the wells

Task

Can the ^{18}O measurements be used to improve the results.

Situation



Balanggen well

- 400 m from the River Rhine
- Groundwater flow is directed from the Rhine to the well
- A clear annual cycle of EC and ^{18}O can be measured at the well and the river.

But

- Infiltration is strongly dependent on river discharge
- An undercurrent of the riverbed is suspected

→ Complex situation – can't be treated by a simple time series analysis

Task Analysis

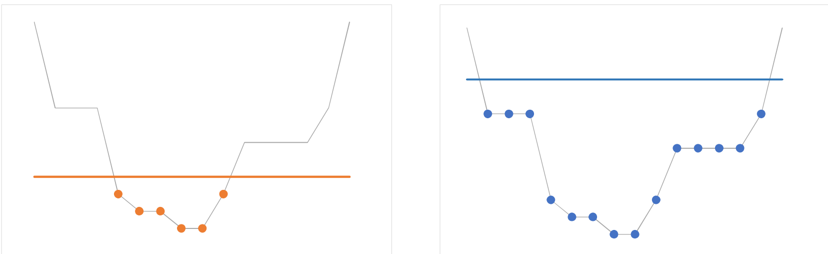
Needs

- Numerical model needed
- Model must be transient

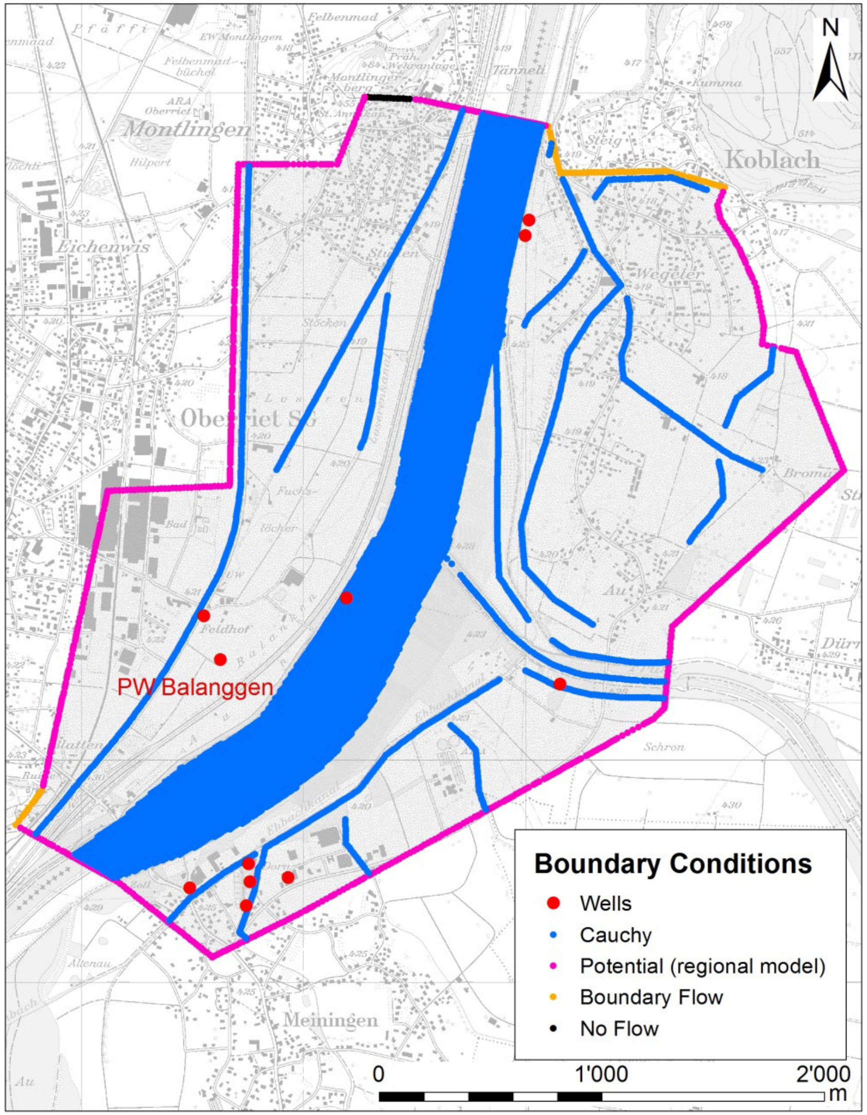
→ Local model embedded in the existing regional model

Unknown Parameters

- Leakage through the riverbed
- Aquifer permeability
- Effective porosity
- EC: mineralisation speed



Discharge dependent Cauchy boundary



Model boundaries and boundary conditions

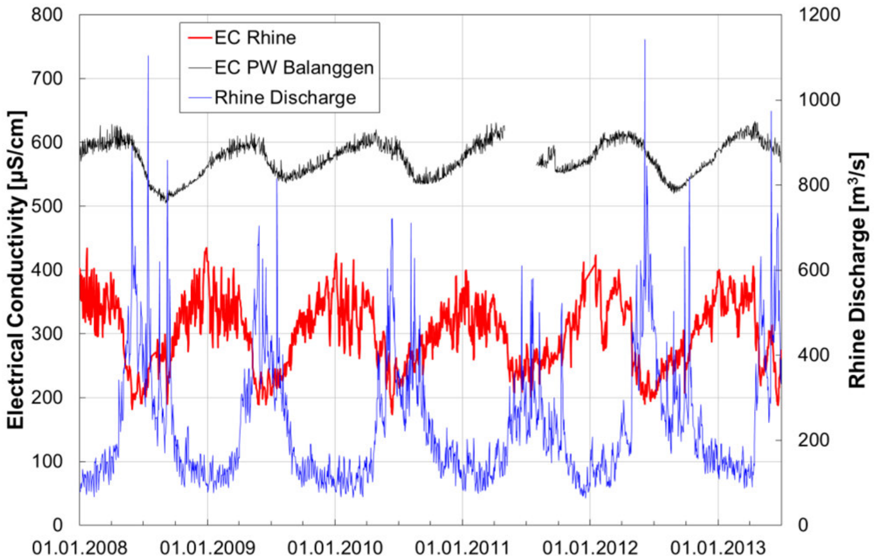
Candidate observations

EC

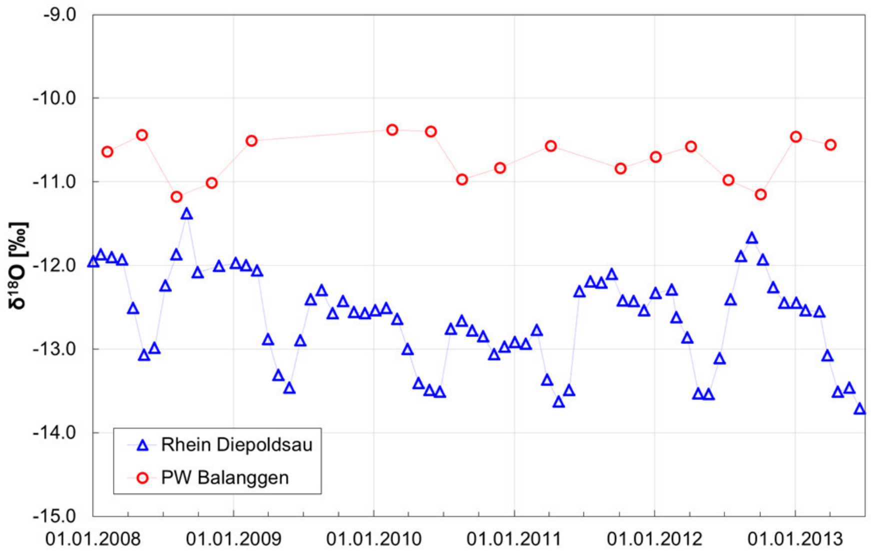
- Cheap measurements
- river and background GW concentration differ
- Adapts to background value
- Background values 600 μS/cm

^{18}O

- Expensive measurements
- river and background GW concentration differ
- No change during gravel passage
- Background values -10.3 ‰ [4]



Electrical conductivity measurements



Oxygen isotope measurements

Methods

Boundary conditions

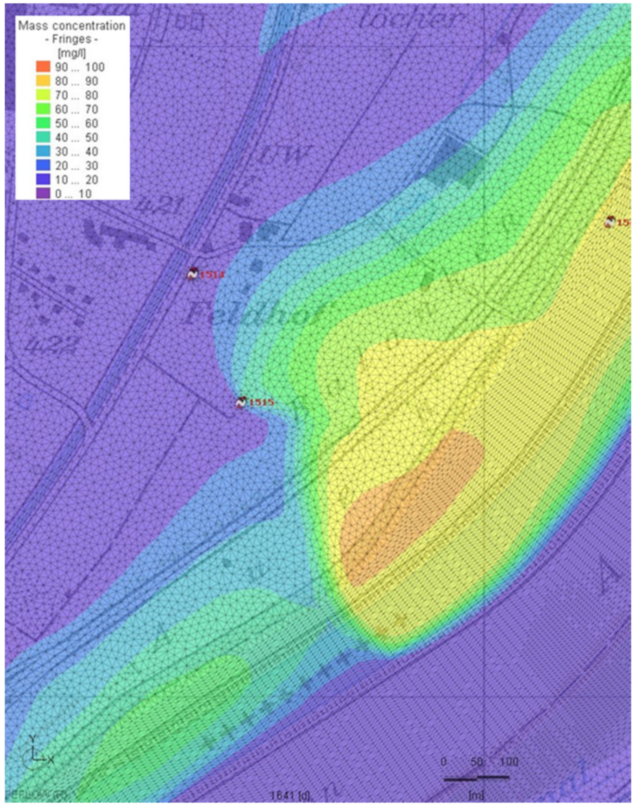
- All inflows to the model get a zero concentration
- Inflows from the river Rhine get a concentration calculated as the difference between background and measured concentration
- Mineralization of EC is considered by an exponential degradation of concentration

Transport model

- Dispersion considered
- Needs a fine element discretisation to avoid numerical dispersion

Mass balance along flow paths

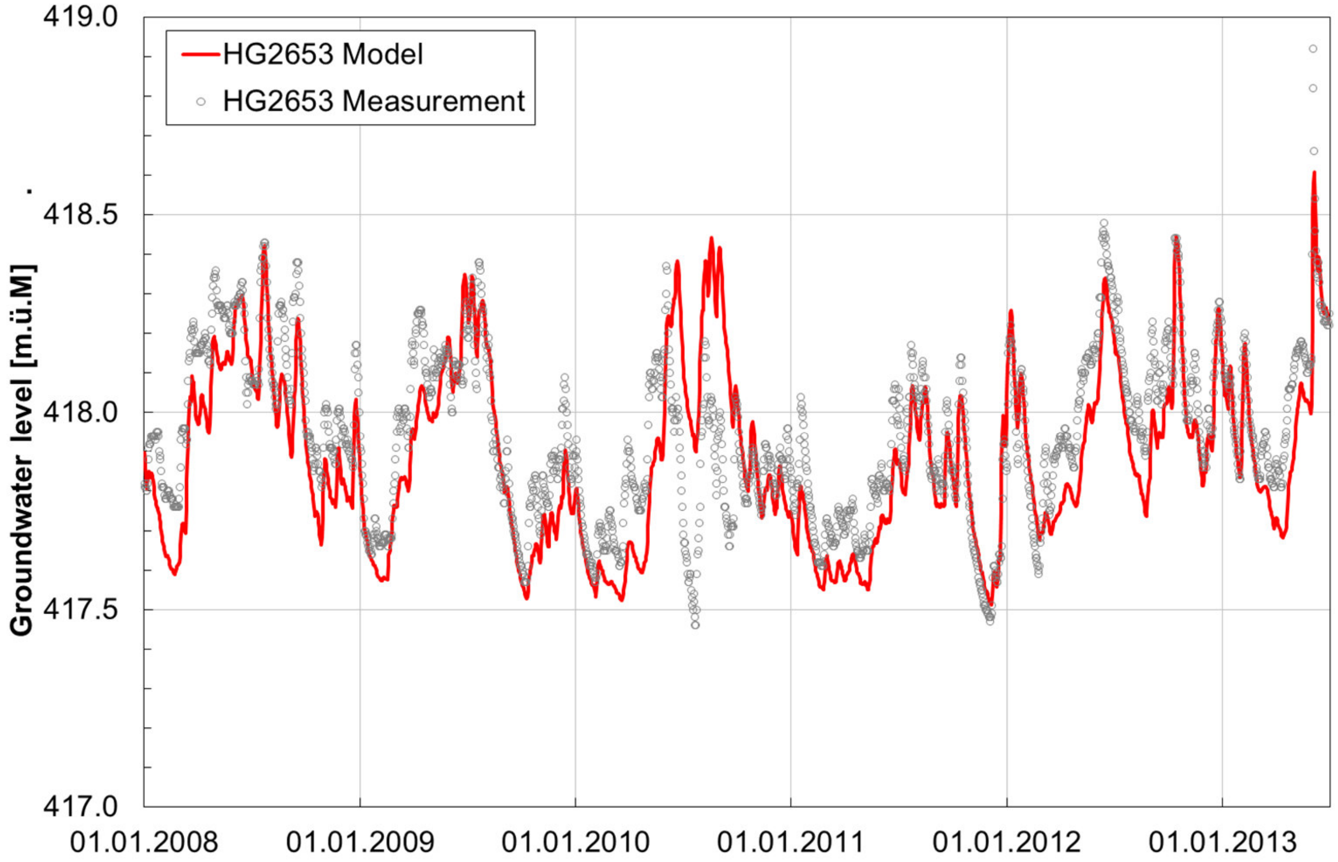
- Flow paths in continuous velocity field [1,3]
- Faster and more stable
- Statements about flow times possible



Transport model screenshot

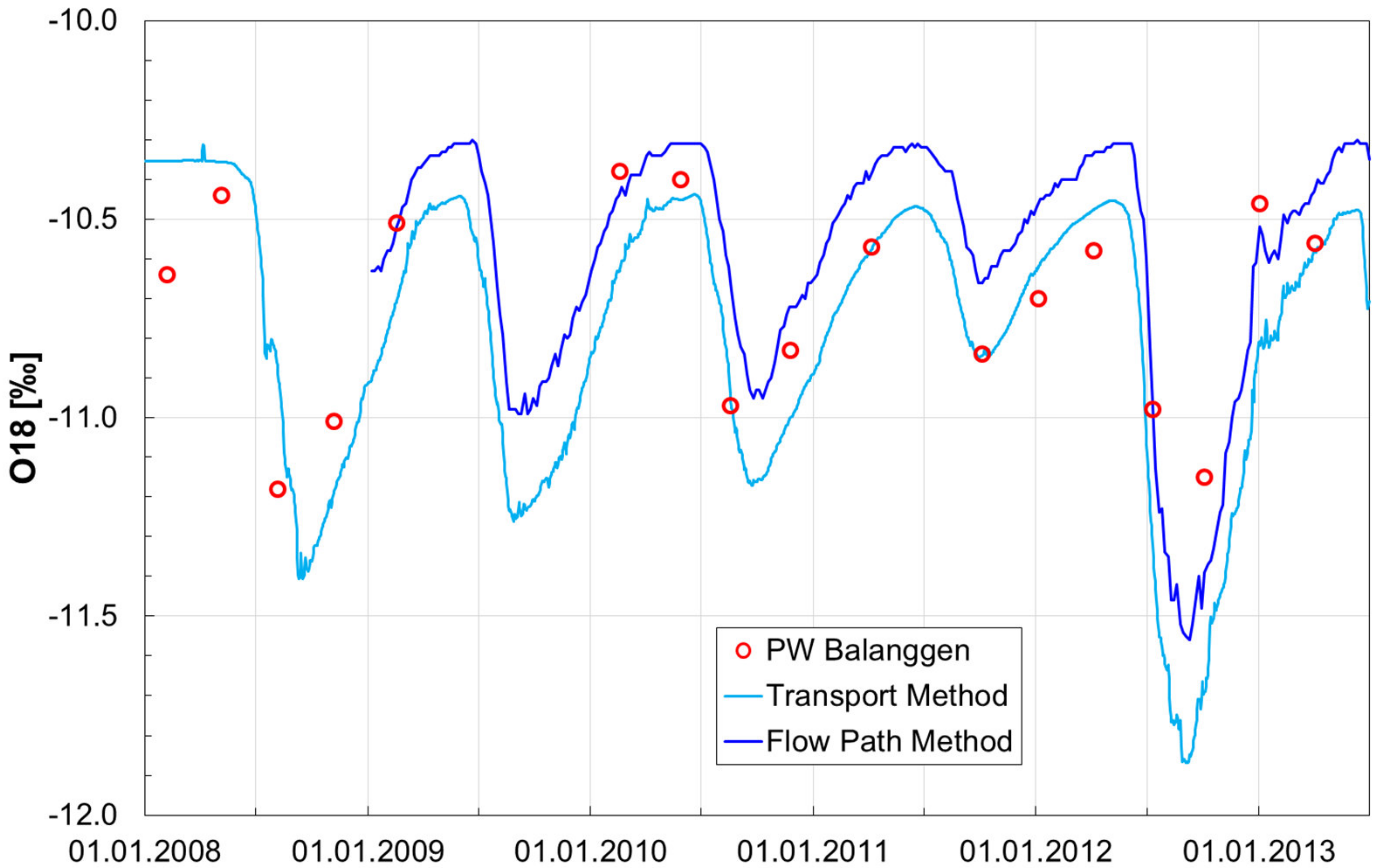
Calibration by groundwater level measurements

- Aquifer permeability can be calibrated
- Level fluctuations are not sensitive to leakage values at project site
- Effective porosity can't be calibrated (not fillable/drainable porosity)



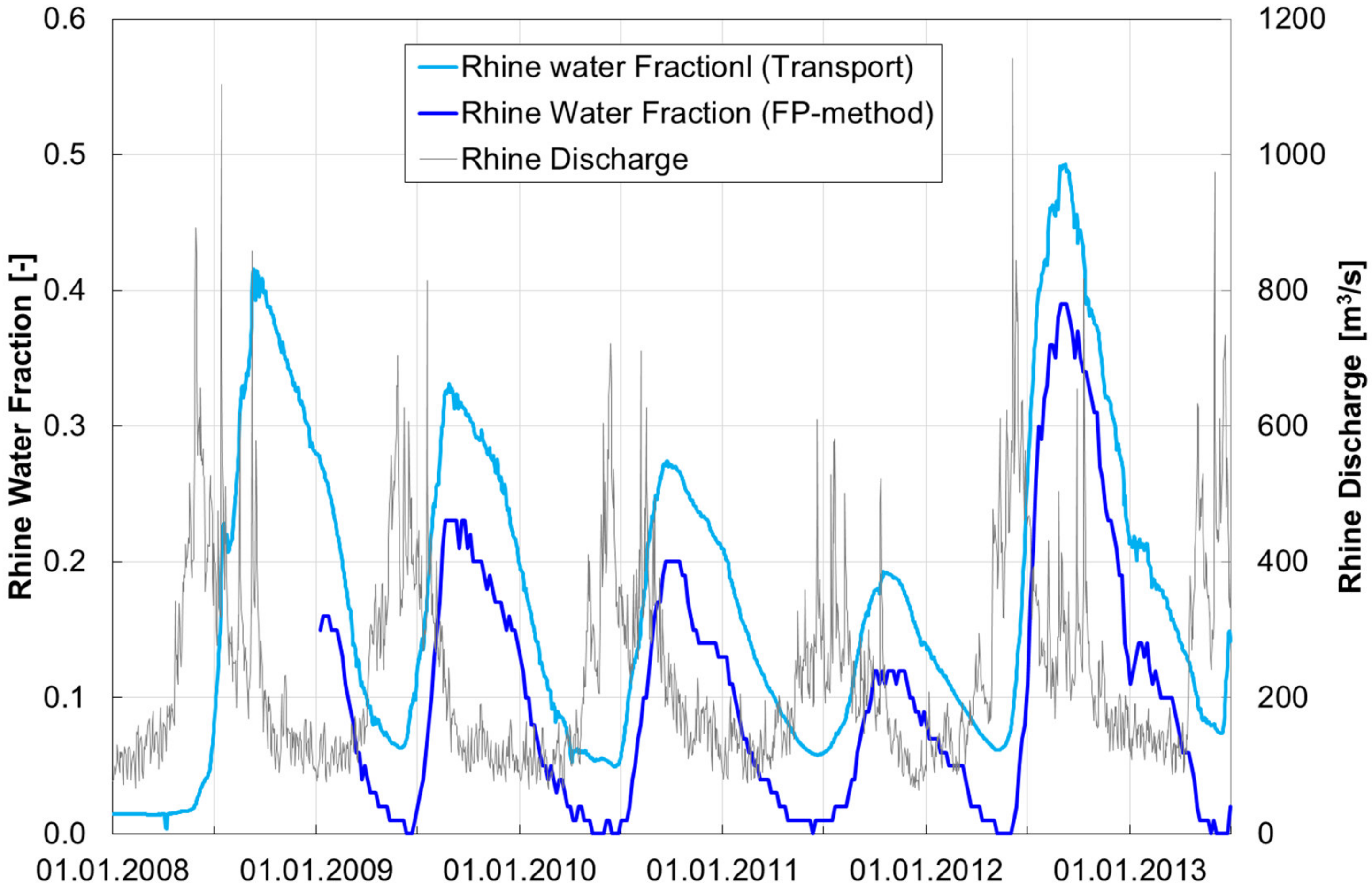
Calibration by ^{18}O signal

- Effective porosity can be calibrated by modelling the time lag between signal in the river and signal in the well
- Leakage value can be calibrated by simulating the absolute values



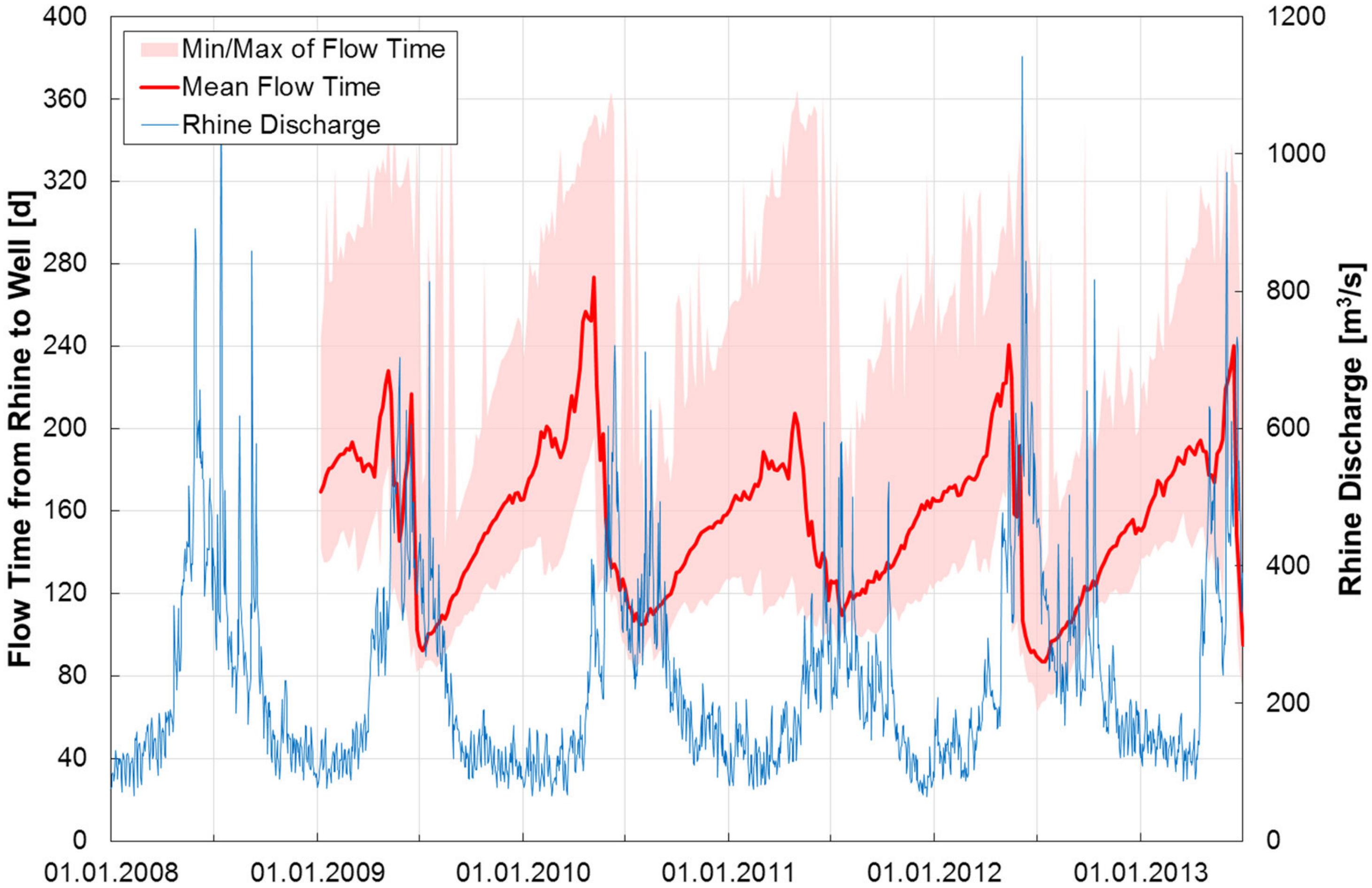
Results: Rhine Water Fraction

- Rhine River fraction depends strongly on Rhine discharge
- Fraction values between 0% and 50%



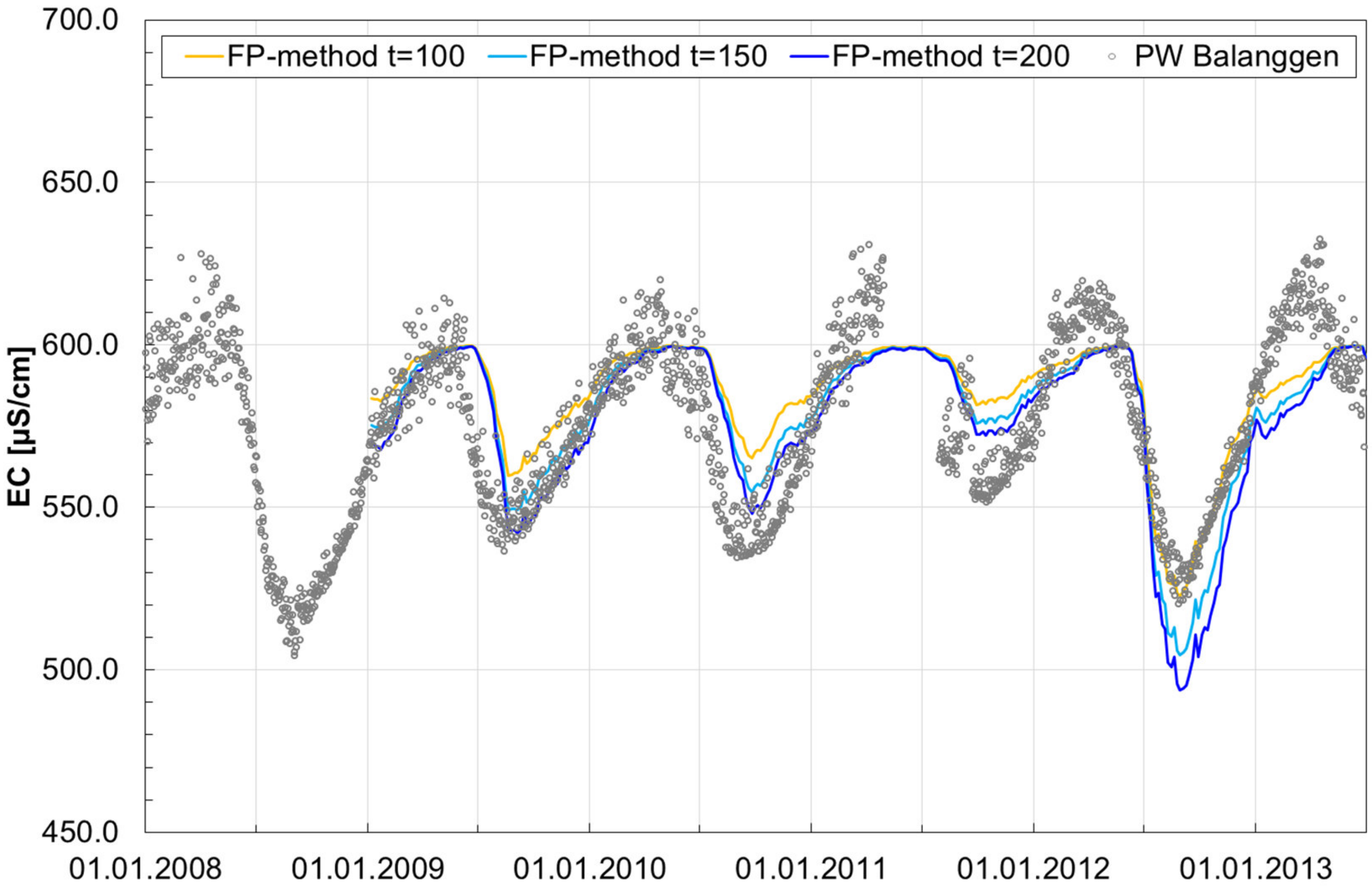
Results: Flow Times from Rhine to Well

- Flow times from Rhine to well depend on Rhine discharge
- Values along different flow paths vary between 70 and 360 days



Added value: EC mineralization speed

- Mineralization speed can be estimated by a sensitivity analysis
- Half time values are in the range of 100 to 200 days



Conclusions

- Knowledge on the interaction between river Rhine and groundwater was gained by building up a transient groundwater model
- The use of oxygen isotopes helped us to calibrate the leakage value of the river
- ^{18}O Measuring frequency should be higher than four times per year
- As a byproduct, we were able to estimate the EC mineralization speed

Questions?

1. Cordes C. & Kinzelbach W. (1992): Continuous Groundwater Velocity Fields and Path Lines in Linear, Bilinear, and Trilinear Finite Elements - Water Resources Research, Vol. 28, No 11.
2. EAWAG (2011). Untersuchung der Flusswasserinfiltration mittels Zeitreihenanalyse der NAQUA Daten Oberriet, Kappelen und Brugg, interner Abschlussbericht BAFU.
3. Gmünder C. (2008): Modellgestützte Ermittlung der Einzugsbereiche von Grundwasserfassungen, Mitteilungen der Thurgauischen Naturforschenden Gesellschaft, Band 63.
4. Kralik et al. (2011): Grundwasseralter ausgewählter Grundwasserkörper 2009/2010. Grazer Feld, Jauntal, Leibnitzer Feld, Rheintal, Unteres Salzachtal, Wulkatal. Publikation des Umweltbundesamtes, Perspektiven für Umwelt & Gesellschaft.