River Restoration with Complex Hydrological and Ecological Interactions

Restored Corridor Dynamics

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Engineered Rivers Needed, e.g. for

- Flood protection
- Hydropower Production
- Irrigation
- Shipping Traffic
Motivation

• River Restoration to Achieve “Good Ecological and Chemical Status”
  – Floodplains are Threatened Ecosystems, Particularly in Areas with Intensive Agriculture and Urbanization (Swiss Plateau)

• River Courses have Multiple Functions
  – Among others, they can Mitigate Floods and Feed Alluvial Aquifers (Contributing 40% of Swiss Drinking Water)

• Complex Interactions along River Corridors
Assessment and Modeling of Coupled Ecological and Hydrological Dynamics in the Restored Corridor of a River

RECORD

Restored Corridor Dynamics

The Thur-Valley

© BHATeam, Frauenfeld
The Thur river dynamics
There are many, often conflicting interests

Drinking water production  
Nature protection  
Landscape esthetics  
Flood mitigation  
Economy  
Recreation  
Forestry  
Housing  
Agriculture  
Biodiversity  
Water infiltration  
River restoration
Goals of the Research Project

• Determination of Impact of River Restoration on the Functioning of the System River – River Corridor – Aquifer

• Mechanistic Understanding of Processes
  – Hydro(geo)logy
  – Biogeochemistry
  – Ecology
  – Water Quality
  with Focus on Interfaces
    ▪ Hyporheic Exchange
    ▪ Alluvial Soils / Groundwater

Without Process Understanding, Predictions on Revitalization Remain Speculations
General Approaches in the Project

1. Comprehensive Field Measurements
   • Distribution of Materials
   • Hydrological Observations
   • Biogeochemical Observations
   • Ecological Surveys

2. Targeted Laboratory and Field Experiments

3. Process-Based Modeling
Common Assignments

- **A** observation towers
- **B** piezometers/wells
- **C** groundwater measurements
- **D** meteorological measurements
- **E** ecological monitoring + soil measurements

Shared database
Travel Times Calculations

- We do not know flow direction in aquifer.
- We do not know flow velocity.
Tracer Tests for Determination of Travel Times

Results are valid only for the specific hydrologic conditions during the test. For large rivers a big tracer mass is necessary.
Propagation of Natural Tracers in the Aquifer

River    Well

Hydraulic Head

Time

Temperature

Time

Electrical Conductivity

Time

Silty Sand (alluvial loam)

Sandy Gravel (glacio-fluvialite sediments)

Silty Clay (lacustrine sediments)

Well

Levee

River Thur

EC

Temp
Diurnal oscillations in river and young groundwater

River Thur, well R042, well R043

A: Temperature

B: Electrical Conductivity

Dampening of EC Signal

B: Observation Well R042

C: Pumping well

σ [m S/cm]

River
Groundwater

01-06-08 01-12-08 01-06-09
Date
Travel time distribution after deconvolution

Pumping station

Travel Times “Channelized River Corridor”
Travel Times

“Restored River Corridor with Natural Riparian Zone”
Traveltime Inversion: velocity model

Porosity model
Quantification of flow field and velocities: 3D groundwater flow modelling

Diem et al. (subm.), JofH
Biogeochemical Investigations and Monitoring
Benzotriazole (corrosion inhibitor)

**Graph:**
- **Concentration (ng/L)** vs. **Discharge (m³/s)**
- Lines and markers indicate concentration and discharge data over time, labeled as Thur 12h, Thur 1h, Thur 2h, Thur 12h, R001 shallow (3d), R042 shallow (1d), discharge.

**Additional Information:**
- Benzotriazole is a corrosion inhibitor.
- LogD (pH7) = 1.3
- Huntscha et al. (in prep.)
Benzotriazole – depth & time resolved

Pumping Station Transect

Thur 12h
Thur 1h
Thur 2h
Thur 12h
discharge

Concentration (ng/L)
Discharge (m³/s)

Huntscha et al. (in prep.)
High discharge event - MCPA (herbicide)

Forest Transect:

Thur  R050  R042 (1d)  R051  R041

Discharge (m³/s)
Concentration (ng/L)

Retention 0-14 h
$\rightarrow t_{1/2 \text{ est}} < 4 \text{ h}$

Strong degradation

$< \text{BDL}$
Control factor: subsurface hydrology

- Strong interaction between hydro(geo)logy and biogeochemistry
- Feedback subsurface processes and ecological development
Impact of restoration on terrestrial communities

Spatial patterns
Temporal processes

Biodiversity, Community structure

Ecosystem function

Vegetation

Soil morphology, vegetation structure
Successions, Floods, water table changes

Vegetation invertebrates
Surface invertebrates

Earthworms

Amoebae

Bacteria

C & N Transformations
Litter decomposition

Soil respiration
Enzymatic activity
Sampling sites

- GC: Colonised Gravel
- PH: Tall Grasses (Phalaris)
- SB: Salix Bush
- F: Mixed Forest
- FF: Ash Forest (Fraxinus)
- SF: Old willow forest
- P: Pasture
In general higher species richness in the restored sites than in the channelised site.

- What factors affect species richness?
- How do patterns of community structure relate to ecosystem function and habitat characteristics?
Conclusions

• A multidisciplinary approach and process understanding are key in complex systems
• Biogeochemical and ecological data can only be interpreted with hydro(geo)logical information
• Our newly developed travel time evaluation method is reliable and very cost-effective
• Restoration increased biodiversity across all taxonomic and functional groups
• Let’s test our newly developed hypotheses and methods in other river corridors!
RECORD Catchment: Coupled Ecological, Hydrological and Social Dynamics in Restored and Channelized Corridors of a River at the Catchment Scale

- Catchment area 1700 km²
- No retention basin
  - Very dynamic discharge regime
  - 3 - 1100 m³/s
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  – WSL Ecosystem Boundaries (Edward Mitchell)
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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

Adective velocity = $10^{-4}$ m/s
Dispersion coefficient = $10^{-6}$ m$^2$/s
Peclet number > 100
Advection dominates

well R042, well R043
Time Series of River Thur

A: Water Level

B: Electrical Conductivity

Behavior of Organic Micropollutants During Riverbank Filtration

Control factor: subsurface hydrology
Link to CCES Platform **Swiss** Experiment

- Platform on Environmental Sensing and Data Management
  - Innovative & Cost Efficient Sensors
  - Wireless Communication
  - Data Acquisition, Handling and Analysis Tools

- Several Highly Instrumented Sites Throughout Switzerland…
  … Including RECORD Sites
RECORD Data model and Wiki

- Successful application of a data model combined with a communication and data access platform (Wiki) for
  - manual sampling data,
  - manual sensor data,
  - automatic sensor data
  - all meta data,
  - automated data upload into the data base.

This results in more 600 accessible wiki pages providing views and access to the data by location, time and type.