Modelling the coupled surface water and groundwater system of the Upper Rhine Graben

VULNAR project

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The Upper Rhine alluvial aquifer: geographical and geological context

SAFRAN annual precipitation (1970-2007)
The Upper Rhine alluvial aquifer: an important and vulnerable resource

- Groundwater resource: 45 billions m$^3$
- Absence of an impermeable cover
- Strong connection to the hydrographic network
- Water stock strongly linked to river water infiltration

Vulnerability to surface pollution and climate change

Source: MONIT
Functionning of the aquifer system

- Recharge processes: effective rainfall, river infiltration, lateral subsurface flow

- Several regional models built in the past (MONIT, LIFE project):
  - Limited to the plain part of the hydrosystem
  - Relative importances of the different processes are not well constrained
Three different modeling approaches

- **HPP-INV**: Finite elements method, inversion of hydrodynamic parameters
- **MODCOU**: Finite differences method, Spatial extension including the mountainous areas
- **SIM**: Identical to MODCOU for the aquifer part, Different approach of the soil water budget

Hydrogeological modelling – VULNAR project

- Infiltration rate
- Hydrodynamic parameters
- Direct evapotranspiration from the water table
A new regional model with water budget computations on mountainous catchments is built:

- Spatial extension to the mountain catchments
- Validation of the water budgets with river flow data
- Water losses from these catchments to the alluvial aquifer are assessed

Sensitivity tests of the model to different parameters:

- Transfer coefficients between the aquifer and the rivers
- Maximum infiltration rate from the rivers
- Transmissivity
- Rivers water levels
Coupled model MODCOU: principles

Forcing data: meteorology / PET - precipitation

Structure data:
- Physiographic parameters:
  - Elevation
  - Soil types
  - Land use

Hydrodynamic parameters:
- Transmissivities
- Drainage
- Specific storage

Surface module:
- Storage
- Infiltration

Groundwater module:
- Unsaturated zone

Surface runoff

Evaporation (AET)

Hydrographic network

Water table – rivers relations

Piezometric levels

Aquifer
Area discretisation

- Grid: square meshes 200 to 1600 m
- Alluvial aquifer: single layer
Surface water budgets area distribution

- Production functions: parameterization of the water budget for each surface mesh
Hydrodynamic parameters distribution

- Transmissivity values
  - From the HPP INV model (Majdalani et al., 2009)
  - See P. Ackerer, plenary lecture IX

- Sensivity tests conducted on several parameters
Coupled simulations


![Water exchange fluxes graph]

### Average exchange flow (m3/s)

-0.050 - 0.033
-0.032 - 0.010
-0.009 - 0.000
0.001 - 0.010
0.011 - 0.050
0.051 - 0.200
0.201 - 0.510

- Modeled area
- Alluvial aquifer
- Hydrographic network

![Map with water exchange flow distribution]
Sensitivity tests

- Temporally variable water levels in the Rhine river

![Graph showing water levels and flow models with bias and RMSE values]

- Bias = 0.6 m, RMSE = 0.16 m
- Bias = 0.21 m, RMSE = 0.39 m

Legend:
- Red: Variable water levels and flow model
- Green: Steady water levels and flow model
- Black: Observed

Map showing locations 127-065-1 and 03784X0022.
Parameters comparison criterion

- Aquifer stock variations comparison

- A mean to compare globally the different simulations

- No good criterion found with the biases and RMSE on piezometers

- Piezometric data analysis by Longuevergne et al. (WRR, 2007)
  - stock variation computed from data

- Comparison with stock variations obtained from simulations
Aquifer recharge processes

- Water budget for the recharge of the alluvial aquifer
Conclusion and perspectives

- The Upper Rhine hydrosystem is strongly influenced by interactions between the alluvial aquifer and the hydrographic network
- Simulations show the importance of a good estimation of river stages
- Interest of the mathematical analysis method of piezometric data for models’ results comparison

- On going comparison between different modeling approaches in the VULNAR project
- Understanding of the different recharge processes: enriched statistical analysis
- Vulnerability study with the use of climatic model outputs under different scenarii

- Project website:
  http://www.geosciences.mines-paristech.fr/equipes/systemes-hydrologiques-et-reservoirs/vulnar