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Simulation of the hydrological cycle of the karst system Gallusquelle / Swabian Alb with MIKE SHE

Joanna Doummar, Tobias Geyer, and Martin Sauter

Georg-August University, Goldschmidtstraße 3, 37077, Göttingen, (jdoumma@gwdg.de)

The aim of this work is the process-based simulation of water flow through a karst system for the assessment of vulnerability of karst water resources. In karst systems, water flow occurs in highly permeable conduits, as well as in the low permeability fissured matrix, resulting in highly complex flow and recharge processes. Challenges in modeling such systems arise mainly as a result of the dual flow behavior in the saturated and unsaturated zone.

Important parameters for vulnerability were investigated by an extensive sensitivity analysis of physical parameters in different karst system compartments. For this purpose, the entire water cycle in the catchment area of a karst spring is modeled using the integrated hydrological modeling system MIKE SHE (DHI, 2007). The approach accounts for meteorological input data, land use, infiltration of water into soils, percolation of water through the unsaturated zone, and flow in the saturated zone.

Over a period of five years, daily discharge of the Gallusquelle spring (Southwest Germany) was simulated. The karst spring drains a groundwater catchment of ca. 45 km2. The annual average discharge is 0.5 m3/s. The catchment is geologically and hydrogeologically well investigated. Numerous tracer tests and intensive borehole investigations were undertaken to characterize hydraulic parameters of the system (Sauter, 1992).

The unsaturated zone (soil, epikarst, fissured matrix) in the Gallusquelle catchment is about 100-150 meter thick and was discretized vertically into two layers. Unsaturated flow is modeled using the Gravity model. Both layers were attributed different moisture retention curves and hydraulic conductivity curves. The bypass component provided by MIKE SHE is used to simulate rapid recharge. Simulation in the saturated zone (SZ) is based on the Finite Differences method. The SZ was divided into two main layers, namely the Jurassic Aquifer consisting of a matrix/fissured matrix, and a lens portraying the highly conductive preferential flow zone, assigned tentatively along dry valleys. Hydraulic parameters were assigned respectively to both the aquifer and the lens. The parameters were regarded as physical fixed parameters, defined from previously undertaken borehole tests. Simulated flow velocities in the lens are in the range of observed flow velocities from artificial tracer tests in the Gallusquelle catchment.

The simulated spring discharge was validated in comparison with the observed discharge rates using RMSE (Root Mean Square Error). Sensitivity analyses show that some parameters varied within physical ranges play an important role in reshaping the recessions and peaks of the recharge functions and consequently the spring discharge. In the unsaturated zone, the type and thickness of the soil (water retention and hydraulic retention curves) have an effect on the infiltration/ evapotranspiration and recharge functions. At the level of the saturated zone the hydraulic conductivity of the matrix and highly conductive lens are the major parameters playing a role in the spring response. Other less significant parameters appears to influence the shape of the spring response yet to a smaller extent, as for instance specific storage of the matrix and the parameters α in the Van Genuchten relation for soil moisture content curves.

References

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