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Large-scale conceptual modelling of groundwater piezometric surfaces in low mountain range landscapes of Central Europe

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In order to meet the requirements of the EU Water Framework Directive (2000) the EU member states are obligated to assess the quantitative and qualitative status of groundwater bodies and to improve the groundwater resources to a good quality and quantity status by adequate measures. The time lag after which the groundwater protection measures will become effective depends on the flow paths and travel times of water in the unsaturated zone and the aquifer. In this regard conceptual hydrogeological models are considered as useful tools to assess the time horizon after which a good status of groundwater bodies may be attained.

The most important key parameter of such a conceptual model is the groundwater piezometric surface. This surface is usually generated for small investigation areas by gridding algorithms based on observed piezometric heads. However, these algorithms are not applicable for large and complex watersheds, in which the density of observed piezometric heads is in general very heterogeneous. This is especially the case in regions where solid rock aquifers occur and intensively investigated locations are separated by many square kilometres without any observation. Additionally, the piezometric surface of solid rock aquifers is to a large extent influenced by surface topography and groundwater recharge.

In this contribution a new gridding method for generating piezometric surfaces for large scale applications will be presented which provides piezometric heads depending on hydraulic characteristics of distinguishable hydrogeological units in the solid rock aquifers. It consists of five general steps:
1. The groundwater drainage level of aquifers is determined for individual hydrogeological units on the basis of the river network.
2. The flow direction of groundwater is derived from a DEM.
3. Individual flow pathways are modelled based on observed piezometric heads inside a distinct hydrogeological unit, the flow direction and the aquifers' drainage level.
4. Characteristic mean hydraulic gradients are estimated for each unit by a regression analysis of individual flow pathways and head differences (observed and modelled at the drainage level).
5. Finally, the estimated unit-characteristic hydraulic gradients, the flow direction and the modelled drainage levels are used to create a generalised area-wide piezometric surface.

The method for generating groundwater piezometric surfaces was applied to the German Federal State of Hesse (area approx. 21,200 km^2), which consists of approx. 80 % solid rock and 20 % unconsolidated aquifers. The results have shown that the new gridding method provides a generalized (but still hydraulically realistic) piezometric surface for the whole model area, i.e. also for large regions displaying low (heterogeneous) densities of observed piezometric heads.

The groundwater piezometric surface of Hesse has already been applied in the framework of a research project funded by the Hessian Agency for Environment and Geology for the assessment of groundwater residence times, i. e. for the practical groundwater management on the Federal State level.