Upscaling of bedrock fracture network models for use with porous media groundwater flow modelling tools

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SKB (Swedish Nuclear Fuel and Waste Management Company) is conducting site investigations and monitoring at the Forsmark site in mid-eastern Sweden. The investigations and monitoring form the basis for integrated site descriptive modelling (SKB 2008). As part of this modelling, regional-scale groundwater flow through fractured crystalline bedrock is simulated using ECPM (Equivalent Continuous Porous Media) models as representations of the fracture network in the bedrock. In SKB's work an ECPM is typically an upscaled representation of a DFN (Discrete Fracture Network) model realization. A DFN is a discrete, stochastic model of the geometric and hydraulic properties of a fracture network.

The hydraulic properties of an ECPM model and the ability of an associated porous media groundwater flow model to represent groundwater flow in fractured bedrock depend on many factors. For instance, such factors include the geometric-hydraulic properties of the fractured network, methodology and data availability for DFN modelling and for selection among DFN realizations for ECPM upscaling, upscaling methodology, and ECPM grid resolution.

This study is focused on the impacts of DFN-to-ECPM upscaling methodology and ECPM grid resolution on the results from porous media groundwater flow models. The impacts of these factors are investigated in a case study, comparing flow modelling results to field measurements from a selected pumping (interference) test in bedrock at the Forsmark site. Specifically, three DFN model realizations for a bedrock volume at Forsmark were upscaled using three different upscaling methodologies; two geometrical (Oda (1985) and GEHYCO (Ferry 2020)), and one hydraulic (here denoted Linear Darcy).

The DFN model realizations are produced using the FracMan software. In order to select DFN realizations to be used in the case study, pumping well inflow and groundwater level drawdown were first modelled using the PFLOTRAN software, simulating groundwater flow through each realization-specific network of discrete fractures. Subsequent to ECPM upscaling of the selected DFN realizations, the same interference test was modelled using the MIKE SHE software, using structured grids of different resolutions, and the DarcyTools software that can also handle unstructured grids. Relatively simple model domain geometries and boundary conditions were used in all flow model setups in order to facilitate inter model comparisons.

Compared to some other ECPM upscaling methodologies, such as hydraulic upscaling using a so-called guard zone (Jackson 2000), the upscaling methodologies of the current study can be expected to overestimate the connectivity of the underlying fracture network. For the scale of the model, flow regime and fracture network characteristics of the case study, the results show that the ECPM grid resolution is more important than the choice of upscaling methodology for the ability of an ECPM to reproduce the geometric-hydraulic properties of the underlying DFN model. This is a potentially important finding of relevance for the groundwater flow modelling community, specifically related to hydrogeological studies of e.g. construction and operation of facilities in fractured crystalline bedrock.

References

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