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Calibration of a channel network model against Äspö field data and its application to long term prediction of tracer transport

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Final radioactive waste disposal in deep crystalline bedrock demands a thorough understanding of flow and transport mechanics in sparsely fractured rock formations. The structural complexity and heterogeneity of crystalline bedrock, and the scarcity of field data for the hydraulic characterization motivates the development of multiple alternative conceptual and numerical models, both to test our understanding and to evaluate prediction uncertainties. Discrete fracture network (DFN) models are widely used in radioactive safety assessment programs in hard crystalline rocks while channel network models offer another representation of flow networks and preferential pathways, in line with indications that flow and transport in deep fractured media are usually dominated by a relatively small number of long preferential pathways. This study applied the channel network modeling approach to understand the hydraulic behavior in a fractured granite system (approximately 450 m deep), at the Äspö Hard Rock Laboratory in Sweden. The channel network model is built from a hydro-structural model of the site including known fracture geometries, with the help of a python scripting library, pychan3d. The study focused particularly on an evaluation of the usefulness of different characterization data to build and calibrate such a channel network model, and to compare this to a calibrated DFN model of the same site. An evolutionary algorithm (CMAES_P implemented in the PEST code) was used to semi-automatically calibrate the channel conductances in the channel network model against the field characterization data (flow rates, drawdowns, and tracer recoveries) in multiple phases. It was observed during the calibration process that some proposed CNM connectivity maps lent themselves to conductance calibration, while others failed to do so. Channel tortuosity and width were then critical to describe transport appropriately in terms of peak arrival and dispersion. The CNM was shown to be more responsive to calibration and to general alterations than a DFN with uniform fracture planes. After calibration, the CNM could match the flow measurements closer than the reference DFN model for the tested characterization phases. The CNM and DFN with the calibrated conductances and fitted geometric parameters were then used to investigate a long-term tracer transport scenario. This comparative study highlights the potential differences and associated uncertainties in the behavior of the two distinct types of models used in the study of crystalline hard rock fractured system.