COMPARISON OF SINGLE AND DUAL CONTINUUM REPRESENTATIONS OF FAULTS AND FRACTURES FOR SIMULATING GROUNDWATER FLOW AND SOLUTE TRANSPORT IN THE MEUSE/HAUTE-MARNE AQUIFER SYSTEM

R. McLaren[1], R. Therrien[2], E. Sudicky[1] & H. Benabderrahmane[3]

1. **Department of Earth and Environmental Sciences University of Waterloo 200 University Avenue West Waterloo, Ontario, Canada N2L 3G1 (mclaren@uwaterloo.ca)**
2. **Département de géologie et de génie géologique 1065 Avenue de la Médecine, Pavillon Pouliot Université Laval, Québec, G1V 0A6 Canada (rene.therrien@ggl.ulaval.ca)**
3. **ANDRA, 1/7 rue Jean Monnet, 92298 Châtenay-Malabry Cedex, France (hakim.benabderrahmane@andra.fr)**

The Paris Basin system covers approximately 200 000 km^2 and consists of 27 aquiferous and semi-permeable (aquitard) hydrogeological units of Trias to Quaternary age (IFP *2004*) that are intersected by 80 regional faults (BRGM *2009a, 2009b*). The Meuse/Haute-Marne site is located in the eastern part of the Paris Basin and covers approximately 250 km^2. Within the sector, the Callovo-Oxfordian clay formation is a potential host for the French high and intermediate level and long lived radioactive waste. It is located at a mean depth of 500 m and has a minimum thickness of 130 m and very low hydraulic conductivity, on the order of 10^{-14} m/s. The Callovo-Oxfordian is confined between the overlying Oxfordian aquifer and the underlying Dogger aquifer. Both the Oxfordian and Dogger are limestone aquifers characterized locally by macro-pores, regional faults that oriented along the N40°E direction (the Gondrecourt and Joinville faults) and the N150°E direction (the Marne and Poissons faults), as well as diffuse fracture zones located south west of the Meuse/Haute-Marne Repository site. To support site investigation of the Meuse/Haute-Marne underground repository, a single continuum multi-scale hydrogeological model of the Paris Basin and the Meuse/Haute-Marne sector has been developed (Andra *2009*). The model represents 27 hydrogeological units at the scale of the Paris Basin, and it is refined at the scale of the sector to represent 27 different layers that range in age from the Trias to the Portlandien. The model has been calibrated to observed hydraulic heads by varying the hydraulic conductivity of the individual layers, using a single continuum approach.

To investigate the impact of treating the two confining layers for the clay formation, the Oxfordian and Dogger aquifers, as single continua with equivalent hydraulic properties for the combined fracture and matrix system, additional simulations have been conducted with either a dual continuum or discrete fracture approach. These simulations aim to estimate the uncertainty or discrepancy associated with the single continuum approximation. Simulations have been conducted with the HydroGeoSphere model (Therrien and Sudicky *1996*, Therrien *et al. 2008*), which simulates three-dimensional fluid flow and solute transport in heterogeneous porous media. The model uses the control volume finite element method to solve the governing flow and transport equations, and rectangular block and prism elements are used to discretize the three-dimensional simulation domain. A subgridding algorithm has also been implemented for multi-scale simulations, where transition elements allow efficient mesh refinement in areas where finer discretization is needed. To represent fluid flow and solute transport in fractured porous media, the model uses a series of different conceptual models that range from the equivalent porous medium approach (single continuum), the dual continuum approach and the discrete fracture approach. The dual continuum approach assumes that, at a given location, the fractured porous medium can be represented by two separate continua, the porous rock matrix and the fractures, with flow and transport properties defined for each continuum and fluid pressure and solute concentration computed separately in each continuum. Fluid and solute exchange between the continua are described by a Darcy-type relationship and by an advectivedispersive mass transfer term, respectively, and individual fracture location and geometry need not be specified in the model. For the discrete fracture approach, on the other hand, the exact location and geometry of individual fractures is specified and flow and transport in fractures is coupled to flow and transport in the rock matrix by assuming either instantaneous equilibrium at a fracture-matrix intersection, or by using first-order fluid and mass transfer terms.

For the simulations presented here, the dual continuum approach is used to represent flow and transport in the Oxfordian and Dogger aquifers, accounting for minor and diffuse fracturation, and a discrete fracture approach is used to represent the major fracture zones. The hydraulic properties of the fracture continuum are obtained by assuming that the calibrated hydraulic conductivities of the single continuum model represent the bulk fracture-matrix properties. Using the measured hydraulic conductivity of the rock matrix, and the observed fracture spacing and aperture, the resulting hydraulic conductivity of the fracture system is obtained from the bulk hydraulic conductivity. The major fracture zones that are aligned along the regional principal stress direction (NW-SE) are treated as permeable discrete fractures, while those major zones perpendicular to that direction are assumed to have a lower permeability.

Because the bulk hydraulic conductivity remains similar for the single continuum and dual continuum models, similar hydraulic heads are obtained. A sensitivity analysis of dual continuum transport properties, for several transport scenarios representing solute migration from a potential repository, is then conducted to investigate the difference between single continuum and dual continuum representations of the confining aquifers. The discrepancy or the uncertainty associated to the single continuum is measured regarding the performance of the repository. The trajectories length and transit time distributions from repository emplacements within the Meuse/Haute-Marne site to potential and/or real outlets of the aquifer system are analysed.

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