



Use of apparent flow dimension in transient pressure analysis to evaluate non-uniform flow in heterogeneous porous media

Kunwar Mrityunjai Sharma¹, Benoit Dessirier², Chin-Fu Tsang^{1,3}, and Auli Niemi¹

¹Uppsala University, Department of Earth Sciences, Sweden (mrityunjai.sharma@geo.uu.se)

²Stockholm University, Stockholm, Sweden

³Lawrence Berkeley National Laboratory, Berkeley, CA, USA

In well-test analysis, the generalized radial flow (GRF) model uses the non-integer flow dimension to describe the change in flow area with respect to radial distance from borehole due to non-uniform flow (Barker, 1988). But the flow dimension not only depends on the change in flow area but also on the permeability variance in the flow medium. Therefore, in our present study, the flow dimension, due to the combined effect of change in flow volume and permeability variance, is termed AFD, the apparent flow dimension. AFD can be determined as the second derivative of the drawdown-time plot from pressure transient testing and can have variable non-integer values as a function of time. This study presents a comprehensive set of analyses using rectangular channel networks representing multidimensional porous medium, starting from 1D (where the flow volume remains one-dimensional) and proceeding to 3D systems. We investigate the effect of conductance variance between the connected flow channels in a constant flow transient well test with the objective of formulating a relationship between conductance variance and AFD. Results in the one-dimensional case demonstrate that the AFD changes substantially as a function of channel conductance variation. Thus, the AFD increases abruptly when the propagating pressure reaches a high conductance channel, and it decreases when the pressure finds a channel with a lower conductance. The impact of conductance contrast on apparent flow dimension variation is summarized as a generalized plot of AFD upsurge/drop and conductance contrast between successive flow channels. In 2D and 3D systems, the channeling or preferential flow effect of the heterogeneous porous medium is also studied with the help of flow dimension analyses. The heterogeneity is introduced into the 2D network statistically through conductance distributions with varying variance values. The calculated flow dimensions, smaller than the corresponding dimension values, indicate the presence of flow channeling in the network (Verbovšek, 2009). Channelization in a 2D porous heterogeneous system is examined as a function of the conductance variance, and it is found that channeling tends to result from the larger variance of the conductance distribution. Following the investigation of the 1D and 2D porous media, similar ideas are applied to the 3D channel networks representing 3D systems in order to investigate both steady-state and transient flow problems. Results from this study provide new insight and the possibility of using transient pressure tests to supplement multiple single well tests, interference tests, and tracer transport tests for the characterization of the heterogeneous porous medium.

Barker, J. A. (1988). A generalized radial flow model for hydraulic tests in fractured rock. *Water Resources Research*, 24, 1796–1804.

Verbovšek, T. (2009). Influences of Aquifer Properties on Flow Dimensions in Dolomites. *Groundwater*, 47(5), 660–668. <https://doi.org/https://doi.org/10.1111/j.1745-6584.2009.00577.x>