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# Large scale behavior of Flow in Heterogeneous Media

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Spatial heterogeneity of hydraulic conductivity can lead to anomalous behaviour in the pressure response to hydraulic stimulation. The classical interpretation framework of Theis, based on a homogeneous bi-dimensional equivalent medium is well known, but cannot describe the anomalous pressure behavior observed in nature. In order to explain anomalous behaviours with a physical meaningful model we considered a double permeability model. The model is constituted by two layers characterized by different hydraulic parameters, which constitute the mobile and immobile zone. Unlike the Barenblatt model (1960), which assumes quasi-steady pressure distribution in the mobile and immobile zone, we choose a non-equilibrium approach of kinetic pressure exchange between mobile and immobile zones. We obtain a temporally non-local governing equation for the hydraulic head that can model observed sub-diffusive drawdown behavior. We compare our model to the Theis model (1935) and the fractional flow models by Barker (1988) and Acuna and Yortsos (1995). We derive solutions for 1, 2 and 3 dimensions and apply them to the experimental data of pumping tests performed in a highly fractured aquifer (La Borgne, 2004). The Theis model clearly fails to explain the observed hydraulic variation, in particular the sub-diffusive trend of drawdown. The proposed double permeability model can explain the data of the drowdawn curves and the evolution of the characteristic drawdown time and the characteristic drawdown amplitude with the distance from the pumping well.