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Stochastic Modeling of Diffusivity and Constant-Rate Pumping Tests in Heterogeneous Aquifers in a Tomographic Setup and Its Application to Field Measurements

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Characterization of spatially variable aquifer properties is a necessary first step towards modeling flow and transport. An emerging technique in hydraulic tomography, known as diffusivity tests, consist of injecting (or pumping) a volume of water through short segments of a well for a short time and measuring the travel time of the peak of the head signal at different points in the surrounding aquifer volume. In our stochastic model, the specific storage is assumed to be constant, while the hydraulic conductivity of the heterogeneous aquifer is modeled as a random lognormal field. The axi-symmetric anisotropic structure is characterized by a few parameters (logconductivity mean and variance and horizontal and vertical integral scales). The mean and variance of the peak travel time are then determined as a function of distance from an instantaneous source by solving the flow equation using a first-order approximation in the logconductivity variance. The mean travel time is recast in terms of the equivalent conductivity, which decreases from the harmonic mean near the source to the effective conductivity in uniform flow for a sufficiently large distance. Similarly, the variance drops from its maximum near the source to a small value.

A different type of tomographic test is the constant-rate pumping one. We propose to apply the first order stochastic approach to the data from the Boise Hydrogeophysical Research site (BHRS) to characterize the aquifer properties by estimating heterogeneity statistical parameters. Equivalent properties are first calculated by matching a homogeneous aquifer solution to the pointwise data to obtain a spatially varying hydraulic conductivity (K_{eq}) and storativity ($S_{s,eq}$). Then the statistical properties of K and S_s are to be computed by a best fit between the theoretically derived statistical moments of the equivalent random properties (K_{eq}, $S_{s,eq}$) and those from field measurements. Our preliminary results indicate that the proposed stochastic methodology is robust and reliable as well as computationally more efficient than the conventional hydraulic tomography techniques.