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Capturing aquifer heterogeneity: Comparison of inverse modeling approaches through field studies in a highly heterogeneous glaciofluvial deposit

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The accurate delineation of subsurface heterogeneity in hydraulic conductivity (K) and specific storage (Ss) continues to be a topic of great importance. Over the last several decades, numerous approaches have been developed for characterizing and modeling heterogeneity. A recently developed approach for mapping K and Ss heterogeneity is hydraulic tomography (HT) which, to date, has not been compared to other methods for delineating heterogeneity in the field. In this study, we compare several well-utilized inverse modeling approaches for capturing heterogeneity using a set of field data collected at the North Campus Research Site (NCRS) located at the University of Waterloo campus, in Waterloo, Ontario, Canada. Site characterization included core sampling at five boreholes yielding 471 permeameter K measurements and detailed information on stratigraphy. In addition, nine pumping tests were conducted at discrete intervals with monitoring taking place using a 3D network of monitoring points. Of the nine pumping tests, four tests were chosen for model calibration and the other five tests were reserved for model validation. The four tests were then individually used to automatically calibrate: 1) an effective parameter model that considers anisotropy; 2) a heterogeneous field based on conditional simulation using the Transition Probability/Markov Chain Geostatistical method; 3) a geological model constructed using stratigraphic information from core samples; 4) heterogeneous fields using a stochastic inverse analysis of individual pumping tests; and 5) a heterogeneous field through the transient hydraulic tomography analysis of four pumping tests. Heterogeneous fields obtained via methods 4 and 5 are different from those published earlier by Berg and Illman [2011] in that the drawdown responses from only five boreholes are used to make a fair comparison with methods 1 – 3 and that the K and Ss distributions are conditioned to available permeameter data. The performance of each of these K and Ss distributions are assessed through forward simulations of nine pumping tests. Our results show that transient hydraulic tomography is best able to reproduce these tests in terms of the smallest discrepancy between simulated versus observed drawdowns. The robust performance of transient hydraulic tomography is due to the sequential inverse modeling of multiple pumping tests, which results in repeated model calibration and refinement of aquifer parameter fields.