The Flow Dimension of Groundwater Resources in Northeastern Illinois

Basic Information

Title:	The Flow Dimension of Groundwater Resources in Northeastern Illinois
Project Number:	2005IL62B
Start Date:	3/1/2006
End Date:	3/1/2007
Funding Source:	104B
Congressional District:	15
Research Category:	Ground−water Flow and Transport
Focus Category:	Groundwater, Water Supply, Methods
Descriptors:	
Principal Investigators:	Douglas D. Walker, Albert Joseph Valocchi

Publication

1. Walker, D. D., P. A. Cello, R. M. Roberts, and A. J. Valocchi, 2007. Screening Models of Aquifer Heterogeneity Using the Flow Dimension, AGU Fall Meeting, San Francisco, Dec, 2007.
2. Cello, P. A., D. D. Walker, A. J. Valocchi, and B. Loftis, 2007. Flow Dimension and Anomalous Diffusion Coefficient as Potential Indicators of the Connectivity of a Fractured Aquifer, AGU Fall Meeting, San Francisco, Dec, 2007.
3. Walker, D. D., and R. M. Roberts, 2007. Reply to Comment by Chia−Shyun Chen and I. Y. Liu on “Flow dimensions corresponding to hydrogeologic conditions”, Water Resources Research, vol. 43, no. 2, W02602, doi:10.1029/2006WR005781.

Illinois Water Resources Center
Final Report 2007

Problem and Research Objectives:
Characterizing groundwater flow and contaminant transport in fractured rock aquifers is complicated by their highly heterogeneous nature, translating into uncertainties in managing groundwater resources. An alternative approach to interpreting aquifer tests is the Generalized Radial Flow (GRF) approach, which infers the geometry of groundwater flow via an additional parameter, the flow dimension, which describes the effective flow area and how it changes with the radius of investigation. This research will elucidate the relationship between aquifer heterogeneity and the flow dimension, with the specific focus on the characteristics of fractured dolomite aquifers that are part of the groundwater resources in northeastern Illinois.

Methodology:
The principle tasks of this research are:
<u>1. Reinterpret existing aquifer test data from ISWS archives</u> to infer the range of flow dimensions observed for fractured dolomite aquifers in northeastern Illinois. This task will use nSIGHTS, an advanced software package created by Sandia National Laboratories for the analysis of hydraulic tests.
<u>2. Enhance the Monte Carlo simulation</u> to include additional statistical analyses and thus help define the relationships between the flow dimension and aquifer parameters. Determining the flow dimensions for complex models of aquifer heterogeneity requires a Monte Carlo analysis of numerical models. In collaboration with and funded in part by NCSA, the ISWS has adapted public domain programs for geostatistical simulation (GSLIB) and transient groundwater flow (MODFLOW2000) to estimate the expected value and variability of the flow dimension for an aquifer test in candidate models of heterogeneity. The computational burden of this analysis is managed through the use of the NCSA TeraGrid set of distributed computing resources.
<u>3. Manually calibrate the parameters of candidate models</u> until the results of the Monte Carlo simulation reproduce the observed flow dimensions.

Note: A six-month, no-cost extension of this project was approved on February 15, 2007. This changes the completion date to August 31, 2007.

Principle Findings and Significance:
During the second year of this two-year project, we have used nSIGHTS to determine the flow dimensions for 10 aquifer tests from the ISWS archives (Task 1). We have continued using the Monte Carlo simulator to determine the flow dimensions of candidate models of aquifer heterogeneity (Task 2). The results this year indicate the following:

1. Aquifer tests in fractured dolomites have apparent flow dimensions ranging from 1.44 to 2.05 with an average of 1.7.
2. Several commonly used models of aquifer heterogeneity do not produce the flow dimensions observed in aquifer tests of fractured dolomite aquifers, even over a wide range of parameters for those models.

3. Site percolation networks can produce the flow dimensions of fractured dolomites, at least temporarily.
4. Fracture networks (Boolean models) also appear to be able to produce the flow dimensions of fractured dolomites. Ongoing work is helping to establish how the parameters of this model are related to the flow dimension.

The finding that the flow dimension appears to be associated with network models is significant because these networks have fractal characteristics, and as such, would have dramatically different contaminant transport than is found in the more traditional models of aquifer heterogeneity.