Title: **Preliminary Comparison of a Discrete Fracture Model with a Continuum Model for Groundwater Movement in Fractured Dolomite**

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Background/Need: Fractured-rock aquifers underlie nearly one-half the surface area of Wisconsin. Major fractured-rock aquifers in the state include the Silurian dolomite, the Sinnipee and Prairie du Chien groups (dolomite and limestone), and Precambrian crystalline rocks. Thousands of private and public water-supply wells in the state derive water from these fractured aquifers.

Practically all previous investigations and monitoring studies of fractured rock aquifers in Wisconsin have relied on porous-media models, but rigorous testing of these models in the field is usually difficult and expensive, and the errors produced by using such models in fractured-rock environments are usually unknown. There is a great need to understand the applicability and limits of porous-media-based models for simulating groundwater flow in fractured rocks both in Wisconsin and elsewhere in the United States. This project begins to address the following question: When and at what scale does a porous-media-based model provide an adequate simulation of groundwater movement through fractured rocks?

Objectives: To begin to determine guidelines for the appropriate application of the porous-media approximation to groundwater flow in fractured-rock environments.

Methods: An existing computer code for simulating groundwater flow in discrete fracture networks was modified and enhanced for use on 386- and 486- class microcomputers. Using fracture statistics and other hydrologic data collected from field sites in Door County, Wisconsin, the model was used to simulate the effects of model domain size, anisotropy, and fracture density on the shape of capture zones for pumping wells. Model results were compared to results from a porous-media model of the same area.

Results: Dolomite of Silurian age in Door County, Wisconsin contains two statistically significant fracture sets. Significantly, the scale and method of fracture measurement have little or no effect on the statistical results. The directional permeability distribution of a stochastic model based on the vertical fracture networks visible in Door County begins to approximate an ellipse for simulation areas greater than about 500 m on a side. As the model domain increases in size, the directional permeability distribution becomes more isotropic, approaching an anisotropy ratio of 1:1 at domain sizes above 750 m on a side. Global hydraulic conductivity of the fracture network increases as mean fracture aperture increases. Effective porosity of the fracture networks simulated by the SDF model is about 0.05%.

A groundwater flow model based on stochastic simulation of discrete fractures (the SDF model of Rouleau, 1988) will run efficiently on microcomputers and can be a useful tool in simulating and understanding groundwater movement in simple fractured-rock systems. Additions of the ability to simulate pumping and withdrawal wells and particle-tracking capabilities, along with post-processing routines, have significantly enhanced the usefulness of the SDF code.

Implications/ Recommendations: Even in densely fractured aquifers, and with relatively simple boundary conditions, the zone of contribution determined by a fracture-flow model is significantly larger than the capture zone determined by porous-medium-based models. Therefore, a circular or smoothly elliptical permeability plot alone is not sufficient to justify the use of a porous medium model for capture-zone analysis in fractured systems. In general, most porous media models will probably underestimate the size of the capture zone for wells developed in fractured aquifers because of significant spreading of the capture zone in the direction of predominant fracture sets. This problem is particularly acute in anisotropic situations. Although discrete flow models may have limited practical use in wellhead protection, our results suggest that a large safety factor is necessary when delineating wellhead protection areas in fractured rocks using other approaches.

Related Publications: Bradbury, K.R., and M. A. Muldoon. 1992. Practical approaches to wellhead protection in fractured rocks. Abstracts, 29th International Geologic Congress, Kyoto, Vol III, p.906.

Bradbury, K.R. 1992 Application of a discrete fracture model to simulate groundwater movement in fractured carbonate terrain. Abstracts with Programs, Geological Society of America, 1992 Annual Meeting, v.24. no.7, p A252.

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Final Report: A final report containing more detailed information on this project is available for loan from Wisconsin's Water Library, University of Wisconsin - Madison, 1975 Willow Drive, Madison, Wisconsin 53706 (608) 262-3069.