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On the Modeling of Brine Transport in Porous Media

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The problem of concentrated brine transport arises in the study of transport of pollutants released from a repository in a rock salt formation. An important characteristic of brine, as compared to other solutions normally encountered in groundwater problems, is that it contains a high concentration of solutes. This factor requires special attention in the development of mathematical models for brine transport problems. In this work we discuss certain important physical and mathematical differences between low- and high-concentration situations. In particular, we consider three primary aspects of a model: basic equations, boundary conditions, and numerical techniques. Recognizing the fact that in high-concentration situations, the fluid motion is not independent of the solutes movement, a new formulation of Darcy's and Fick's law are proposed. The basic equations comprise a set of two nonlinear coupled partial differential equations to be solved for the pressure p and the solute mass fraction ω. These equations have to be solved by means of iterative methods. Various possibilities involving finite difference methods have been studied. In one case, after discretizing the equations in a fully implicit way, the Newton-Raphson method has been employed to solve the system of nonlinear difference equations simultaneously. In another case, after removing part of the nonlinearity by a transformation of the dependent variable ω, a procedure of sequential solution of the two equations by successive substitution is employed. It turns out that the latter method is considerably faster than the former one as a result of the quasi-linearization. Finally, considering boundary conditions, it is shown that often they are also nonlinear and coupled. Appropriate conditions for a rock salt boundary and an outflow boundary are developed and their significance in high-concentration situations are discussed. In particular, a nonlinear time-dependent boundary condition at a rock salt boundary is developed which takes into account the process of salt dissolution and cap rock formation.