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Validation of Sharp-Interface Optimization Model for the Control of Seawater Intrusion in Laboratory Experiment

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Between intruding seawater and ambient fresh groundwater there exists a transition zone of finite thickness in which solute concentration varies continuously. The thickness varies depending on a number of factors; the dispersivity and the pore-water velocity are the most significant. The most rigorous modeling approach for the seawater intrusion phenomena is the density-dependent flow and transport technique. However, the flow and solute transport approach requires a high-resolution spatial discretization so that the number of unknowns can reach millions easily. Additionally, iterations needed to solve the nonlinear governing equations make computational demand prohibitive even for a single forward simulation. Use of the flow and transport model in embedded simulation-optimization, that requires numerous solutions of the simulation model, for most practical problems is not feasible even with advanced computers. The sharp-interface assumption neglects the transition zone. However, it allows much faster simulation results, therefore, it may be the only practical technique amenable to simulation-optimization approach. In this study the applicability of a sharp-interface optimization model for controlling seawater intrusion to protect freshwater pumping wells are investigated using observation results from two laboratory sand tanks. Freshwater injection and saltwater pumping have been used to reduce seawater intrusion and to protect freshwater pumping wells. Two aspects of the numerical results will be compared with experimental results. First, the shape of the saltwater-freshwater interface before and after control measures will be compared. The interface is visualized using dyed saltwater. Photographs of the views through the side glass of the sand tanks are analyzed to identify the transition zone that will be compared with the sharp interface. Image analyses using commonly available software allow high-resolution delineation of the transition zone. Secondly, composition of pumped water will be compared. Although the sharp interface model cannot simulate water quality directly, mixing ratios of saltwater and freshwater at pumping wells can be computed with a simple algorithm. Applicability of the sharp-interface optimization model will be demonstrated along with efficiencies of freshwater injection and saltwater pumping.