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A computational tool for a first-cut engineering analysis in coastal aquifers management

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When dealing with exploitation, restoration and management of coastal aquifers the common problem that we are confronted with, is the saltwater intrusion. Climate changes such as sea level rise or extended drought periods affect the extent of seawater intrusion and, furthermore, overexploitation of groundwater, especially during summer months, results to the extra penetration of the seawater into the aquifer's system which decreases aquifers efficiency beyond sustainability levels.

Therefore, the sustainable management of coastal aquifers is a challenging task for planners. Modeling of salt and fresh water flow in coastal aquifers is an essential part for assessing the extent of saltwater intrusion and for planning the rational exploitation of water resources. If those models are combined with heuristic and stochastic optimization techniques, integrated operational management tools can be synthesized.

In this paper we will present a generic computational model describing the evolution in the 3D space and time of the fresh and salt water movement and the intrusion of salt water in coastal aquifers. The model is based on the assumption of 2D Horizontal stratified flow of the two immiscible layers of the salt and fresh water. The formulation of two-layer mathematical model is based on the equilibrium equation and the mass balance, subject to two simplifying assumptions: first the assumption of a sharp interface between fresh and salt water layers which is used for coastal stratified flows and for porous flows and second the "Dupuit" assumption, referring to the hydrostatic pressure distribution in the two layers (assumption of nearly horizontal flow). The numerical solution is done by an explicit Finite Differences 2nd order centered scheme, giving to the user the ability to follow the time-space evolution of the free surface and of the salt-fresh water interface.

The model in its 1DH and 2DH form is applied under several management scenarios, comprising production wells as well as various technical means offering protection to the aquifer from salt water intrusion and ensuring the safe operation of the production wells. Three techniques for controlling the length of seawater wedge will be demonstrated; the use of underground diaphragms, of scavenger wells and of recharge canals. These techniques can be associated with the operation of production wells in a flow field which poses an interesting optimization problem.

The presented model is simple and effective and can be coupled with heuristic and stochastic optimization methods, based on the method of genetic algorithms or the method of "simulated annealing" for an ultimate synthesis of an operational tool for the integrated management of coastal aquifers under the contemporary demand pressures and the forecasted climatic changes.