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Optimal pumping scenarios for the estimation of the saltwater intrusion front in the coastal aquifer of Tympaki, Crete – Greece

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This study examines the saltwater intrusion problem, a naturally occurring phenomenon that is often augmented by human activity through the over-exploitation of the groundwater reserves. Saltwater intrusion occurs in most coastal aquifers due to the constant contact with the saltwater and the imbalance of the freshwater / saltwater that occurs under intense pumping conditions. The present study focuses on the Municipality of Tympaki aquifer in Heraklion, Crete, where the phenomenon is particularly intense. The main source of income in the region is agriculture, an activity that demands large amounts of water, especially during the summer. In the Tympaki basin there are 27 pumping wells with the majority of them located at the centre of the basin.

The purpose of this study is to investigate the current extent of saltwater intrusion as well as to find the optimal pumping scheme, for which the saltwater intrusion will retreat, while meeting the irrigation needs of the region. A mathematical model that simulates the groundwater flow is used, in order to study the size, extent and rate of the phenomenon. MODFLOW was chosen for this purpose, which is a three-dimensional finite-difference groundwater flow model. Initial conditions, boundary conditions, hydraulic conductivity values and precipitation data for the basin were used in order to perform the model calibration and simulation.

The optimization of the pumping sheme was performed using the GWM (Ground-Water Management) model, which utilizes the simplex method. The optimization problem at hand is slightly nonlinear because of the nonlinear relation of the free surface groundwater system to the pumping stress. GWM solves the nonlinear problem using a sequential linearization approach. At each step, the aquifer is considered confined and the response matrix of the system is calculated for an initial set of pumping rates. The Simplex method is then used in order to solve this linear problem and compute the optimal pumping rates for the 27 pumping wells. The calculated pumping rates are used as initials for the next step of the algorithm and new response coefficients are calculated. The process is terminated when the difference between two successive solutions is less than a user-specified convergence value.

The Ghyben-Herzberg equation was used to identify the position of the saltwater intrusion front for the aquifer. Considering the aquifer depth at sea level to be 100 m the seawater intrusion front was estimated to be extended in coastal regions with hydraulic heads between 100 and 102.5 m. Initially, the optimal pumping rates that meet the water demand in the region while preventing further intrusion were calculated. Three additional scenarios were then considered in order to investigate the possibility of retraction of the saltwater intrusion front towards the shoreline. These scenarios seek to maximize pumping activity while allowing the saltwater intrusion front to retreat towards the shoreline in pre-specified locations that fall between the worst case scenario (current conditions) and best case scenario (zero pumping activity).