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Modeling of flow and solute transport to solve environmental problems in, Kerbala City, Iraq

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An investigation was carried out to evaluate the hydrogeological conditions of the Center of Kerbala City (CKC) aquifer which encompasses the holy shrines of Al-Hussein and Al-Abbas. A three-dimensional finite-difference groundwater flow model was implemented to conceptualize flow conditions and establish the hydrogeological budget of the aquifer. The shallow and contaminated part of this aquifer comprises serious environmental problems that accelerated during the golf war. The city, as well as the shrines, has suffered from these problems for thirty years.

The groundwater system consists of an upper phreatic, middle semi-pervious, and a lower semi-confined (leaky) aquifer, respectively of about 5, 2, and 30 meters average thickness. Chemical characteristics and fluctuations of groundwater levels, as well as the numerical simulation of the aquifer, indicate that the upper layer is recharged by leakage of drinking water pipe network, sewers, and septic tanks. Also, more than 80 % of the recharge of the upper layer is transmitted to the lower aquifer via the middle layer, while the rest discharges into the drains surrounding the study area.

Three principal mathematical models were constructed and several add-on packages were implemented. MODFLOW program was applied to simulate the flow and hydraulic condition of the system. Then, The efficiency of various dewatering schemes such as pumping wells, Horizontal drains, and cut-off walls (diaphragms) were evaluated by flow model around the holy shrines. Based on the simulation results, a general 50% reduction of the Annual leakages will result to a desired water table drawdown of 1m. The drains, if constructed, would lower the water table just a few meters away from the drain axis, and therefore, does not meet the needs. Simulation by MODFLOW indicates that lowering the water table below the shrines can be carried out by pumping wells in the lower layer rather than the drains in the superficial layer

and cut-off walls. Therefore, pumping the lower aquifer around each shrine is suggested to reach the desired drawdown and maintain the lowered water table. The GWM (Ground-Water Management) Package and the Modular Groundwater Optimizer (MGO) Code were used to optimize location and number of pumping wells and, time and rate of pumping. The first package is a gradient base optimization method while the second package uses the Genetic Algorithm. The results of the MGO code were more reliable than that of GWM Package. The Subsidence and Aquifer-System Compaction (SUB) Package was used for estimating the subsidence due to water table decline.

The calibrated flow model and the MT3DMS code were jointly used for simulating contaminant transport based on the advection and dispersion in groundwater system. Mass transport simulation by MT3DMS indicates that, if chloride input to the aquifer ceased, after 20 years a reduction of 82% of the chloride concentration in the aquifer will occur. Contaminant migration from some alternative point sources was also simulated.