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Multi-objective optimization of groundwater abstraction in Jinan springs field

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Jinan springs are an important historical heritage in China and have been well known around the world for many years. Recently, however, over abstraction of groundwater has seriously endangered the balance of the groundwater system of the Jinan springs field. Thus, how to maximize the groundwater abstraction while protecting springs has become an urgent research topic. In this study, given the complex hydrogeological condition of the karst springs field, the multi-objective optimization method is used to build a probabilistic multi-objective simulation-optimization model of groundwater abstraction in Jinan springs field considering the uncertainty of the hydraulic conductivity (K). The objectives of the newly developed model are to maximize the groundwater abstraction and ensuring the allowable lowest water level of the spewing of springs. Firstly, a probabilistic three-dimensional groundwater numerical simulation model of Jinan springs field is developed, and the DREAM algorithm that is based on the Markov Chain Monte Carlo method is used to quantitatively identify the uncertainty of the simulation model. Then, the probabilistic multi-objective simulation-optimization model of groundwater abstraction in Jinan springs field is developed based on the multi-objective optimization method. Finally, a new probabilistic multi-objective fast harmony search algorithm is developed to find the Pareto optimal solutions of the multi-objective optimization model. Also, Monte Carlo (MC) analysis is employed to evaluate the effectiveness of the proposed methodology. Comprehensive analysis indicates that the proposed methodology can find Pareto-optimal solutions with low variability and high reliability and will provide a new method for optimal design of groundwater abstraction in karst spring areas.