



Multi-Objective Optimization Framework for Managed Aquifer Recharge: A case study in Akrotiri, Cyprus

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The implementation of managed aquifer recharge (MAR) systems, which have the potential to store surface water underground for future use or environmental advantages, has become increasingly popular due to the world's growing water scarcity. It has been demonstrated that MAR is a successful strategy for mitigating the effects of climate change on the world's water supplies as well as on issues related to spatiotemporal water shortages. However, conflicting goals, such as maximizing recharge efficiency while reducing total operational costs, must be balanced while designing MAR systems. This study aims to create a novel framework for a multi-objective optimization of MAR systems to handle such kind of trade-offs and also support decision-making.

This work introduces the first design steps and the general structure of a framework that integrates the capabilities of the existing web-based groundwater modelling platform INOWAS (www.inowas.com) with a hybrid evolutionary algorithm. The framework effectively explores optimal solutions in complex solution spaces by combining groundwater models implemented on the INOWAS platform with tools from the MODFLOW family (MODFLOW-2005, MT3DMS, SEAWAT) with global search capabilities (e.g., Genetic algorithm) and local refining methods (e.g., Simplex algorithm). The evaluation of the first design steps of the proposed framework was conducted with python, and not through direct implementation on the INOWAS platform.

The proposed framework is applied to the Akrotiri River Basin, a coastal region in the southern part of the Republic of Cyprus, facing complex and competing water management challenges. The region faces a number of key challenges related to water-scarcity, such as seawater intrusion into the coastal aquifer, overexploitation of the groundwater resources, deterioration of hydrochemical water quality, lack of sufficient monitoring infrastructure and low trust from local farmers in current water management strategies. Soil aquifer treatment (SAT) has been implemented at the site since 2016 through the infiltration of tertiary-treated wastewater using seventeen recharge ponds. The proposed framework integrates groundwater flow and transport modeling with a multi-objective optimization algorithm to simultaneously enhance groundwater quantity and quality, mitigate saltwater intrusion, protect drinking wells from any negative impact of injectant flow, hence supporting the reliability of water supply. Several meaningful trade-offs between these competing objectives are explicitly explored. Solutions are expressed as pareto fronts, which

represent sets of optimal trade-off solutions that are non-dominated with respect to one another and superior to all other solutions in the search space.