Extraction of Optimal Operation Rules in an Aquifer-Dam System: Genetic Programming Approach

E. Fallah-Mehdipour[1]; O. Bozorg Haddad[2]; and M. A. Mariño, Dist.M.ASCE[3]

Abstract: Surface water and groundwater are two important resources that can be used simultaneously to meet demand. To sustain these resources in a planning horizon, different conditions of supply and demand can be balanced by operational rules. Those rules can be extracted from prior experience while operating a conjunctive water system and then applied in future periods. Genetic algorithm (GA) is an evolutionary algorithm that has been extensively used to determine optimal operation rules. Commonly, the operation rule pattern is fixed by a linear equation, and GA calculates optimal coefficients in a defined pattern. In this paper, to compute a more effective operation rule that yields a better objective function value compared to GA for the same conditions, a fixed-length gene genetic programming (FLGGP) rule is developed and extracted based on genetic programming (GP). The FLGGP rules are employed in an aquifer-dam system with two subsystems, in which each subsystem can supply parts of the demand. Results show that the obtained objective function value using the FLGGP rules is 26 percent better compared to the common linear rule by GA. The developed operational rule uses more functions and mathematical operators than numerical variables. Thus, FLGGP is more flexible and effective in determining optimal rule curves for a conjunctive aquifer-dam system. **DOI:** **10.1061/(ASCE)IR.1943-4774.0000628.** © *2013 American Society of Civil Engineers.*

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Introduction

Limited amounts of fresh water, population growth, and different types of consumption are important issues to consider in the management and operation of existing fresh-water resources. Those issues are even more critical in arid and semi-arid regions because of frequent extended periods of deficiency in the water supply. To integrate the management of the water resource, suitable operational strategies should be devised to meet challenges inherent in the sustainable use and development of the resource. Those strategies traditionally are developed through intensive simulation techniques. Although the calculations are more precise using different simulation models, trial-and-error is used to calculate optimal/near-optimal management solutions. While it is possible to come up with optimal/near-optimal solutions by trial-and-error, the probability of success is directly related to the number of times one executes trial-and-error calculations, which can be time-consuming. Thus, use of an optimization method together with a simulation model is recommended to determine an optimal solution (Fallah-Mehdipour et al. 2011) to a conjunctive water-use problem.

Evolutionary algorithms (EAs) are among well-known optimization techniques that have shown high performance in addressing water-related management problems (Bozorg Haddad et al. 2008, 2009a, 2010a, b, 2011a, b; Soltanjalili et al. 2011; Bozorg Haddad and Mariño 2011; Ghajarnia et al. 2011; Karimi-Hosseini et al. 2011; Rasoulzadeh-Gharibdousti et al. 2011; Noory et al. 2012; Sabbaghpour et al. 2012).

Extraction of decision rules for many systems in the field of water management has been the focus of many recent investigations (Moradi-Jalal et al. 2007; Bozorg Haddad et al. 2009b; Afshar et al. 2010), which help operators to better manage hydrosystems in an accurate and faster way.

Many investigations have been reported in conjunctive water management that employ optimization techniques to operate a conjunctive system in the best manner possible. Rao et al. (2004) defined conjunctive use as the allocation of surface water and groundwater in terms of quantity and/or quality so as to achieve one or more objectives while satisfying certain constraints. They proposed a simulation-optimization method as a nonlinear, nonconvex combinatorial problem using a simulated annealing (SA) algorithm and an existing sharp interface model. The computational burden was managed within practical time frames. To simplify calculations, they replaced the flow simulator with an artificial neural network (ANN). Results showed that the combination of SA and ANN would not be useful in the solution of real-world, large-scale problems of medium size. Khare et al. (2006) used a linear programming (LP) model of conjunctive water use to maximize benefits of crop production in the Sapon irrigation command area of Indonesia. The proposed cropping pattern was more beneficial than the existing pattern. Pulido-Velazquez et al. (2008) used conjunctive water use models at basin-scale that simulated groundwater flow by using the response matrix method while

[1]Ph.D. Candidate, Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, Tehran, Iran. E-mail: Falah@ut.ac.ir

[2]Associate Professor, Dept. of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, Univ. of Tehran, Karaj, Tehran, Iran (corresponding author). E-mail: OBHaddad@ut.ac.ir

[3]Distinguished Professor Emeritus, Dept. of Land, Air and Water Resources, Dept. of Civil and Environmental Engineering, and Dept. of Biological and Agricultural Engineering, Univ. of California, 139 Veihmeyer Hall, Davis, CA 95616-8628. E-mail: MAMarino@ucdavis.edu

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