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Reservoir Operation Rules with Uncertainties in Reservoir Inflow and Agricultural Demand Derived with Stochastic Dynamic Programming

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Abstract: A proposed stochastic dynamic programming (SDP) method with uncertainties in stream flow and water demand is developed to calculate optimal reservoir operation rules. The SDP method extends the classic SDP method that considers only one uncertainty in its operation rules. Time series of reservoir inflow and agricultural water demand for the Aydoghmoush Reservoir in eastern Azarbayejan, Iran, were obtained from meteorological data, available climate parameters, hydrologic data, and crop water demand. The application of the developed SDP with two uncertainties was evaluated with operation rules corresponding to four different scenarios, and optimal reservoir releases were determined for a drought year. Reservoir operation results were evaluated with different performance indices. This study's results demonstrate the advantage of considering uncertainties in reservoir inflow and water demand with the SDP method. The developed SDP method has general applicability under a range of climatic conditions, and the calculated operation rules cover the expected ranges of streamflow and water demand during the operating years. **DOI: 10.1061/(ASCE)IR.1943-4774.0001065.**

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Introduction

The simultaneous consideration of uncertainties in numerous aspects of water resources systems are commonly neglected, as exemplified by various studies, such as reservoir operation (Ahmadi et al. 2014; Bolouri-Yazdeli et al. 2014), groundwater resources (Bozorg-Haddad et al. 2013; Fallah-Mehdipour et al. 2013b), conjunctive use operation (Fallah-Mehdipour et al. 2013a), design operation of pumped-storage and hydropower systems (Bozorg-Haddad et al. 2014), flood management (Bozorg-Haddad et al. 2015b), water project management (Orouji et al. 2014), qualitative management of water resources systems, (Orouji et al. 2013; Bozorg-Haddad et al. 2015a; Shokri et al. 2014), water distribution systems (Seifollahi-Aghmiuni et al. 2013; Soltanjalili et al. 2013; Beygi et al. 2014), and algorithmic developments (Ashofteh et al. 2015b).

Reservoir operation involves variables that are affected by uncertainty. That uncertainty stems from multiple sources, such as future water demands and reservoir inflows. One must take uncertainty into account to calculate appropriate reservoir operation. Replacing uncertain variables with their expected values or their worst estimates can have severe influence on the performance assessment of water resource systems (Loucks et al. 1981). The stochastic dynamic programming (SDP) method derived from dynamic programming (DP) is suitable to tackle reservoir operation problems that take uncertainty into account (Yakowitz 1982; Stedinger et al. 1984). The SDP method has been applied in various works to calculate reservoir operation policies (Lubow 1994; Ben Alaya et al. 2003; Mousavi et al. 2004; Cervellera et al. 2006; Raje and Mujumdar 2010).

Stochastic models use statistical descriptions of reservoir streamflow and forecast processes instead of applying a specific streamflow sequence (as do deterministic models) to determine operating policies. Several authors applied sampling stochastic dynamic programming (SSDP) that generates operating policies capturing the temporal and spatial characteristics of reservoir inflows (Bras et al. 1983; Stedinger et al. 1985; Kelman et al. 1990). Shokri et al. (2013) pioneered the use of the SDP method considering the uncertainty in streamflow and sediment inflows to obtain optimal operating policies for water supply and sediment flushing.

A few authors have considered water demand uncertainty in modeling studies (Milliken and Taylor 1981). Maddock (1974) developed a quadratic programming model in which supply and demand resources were treated stochastically. Vasiliadis and Karamouz (1994) developed a demand-driven stochastic dynamic programming (DDSP) in which reservoir inflow's uncertainty was accounted for and monthly water demand varied within a year (that is, intraannually variable), but the water demand was set constant in each month interannually. The application of the model proved beneficial using monthly inflows of the Gunpowder River, located in the United States, for a 95-year long time series.

Agricultural water demands have noticeable intraannual variations, and these variations can influence the supply potential of municipal and industrial water use, and, thus, reservoir operation rules in general. Variations in climate, economic and social conditions, water and soils resources, and cropping patterns are important factors determining agricultural water demand. In fact, agricultural water demand exhibits remarkable monthly variations

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