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Trade-offs in hydropower reservoir operation under the chain of uncertainty

Georgia Konstantina Sakki[1], Andrea Castelletti[2], Christos Makropoulos[3], and Andreas Efstratiadis[4]
[1]Dept. of Water Resources and Environmental Engineering, National Technical University of Athens, Athens, Greece (sakkigk@mail.ntua.gr)
[2]Dept. of Electronics, Information, and Bioengineering Politecnico di Milano, Milan, Italy (andrea.castelletti@polimi.it)
[3]Dept. of Water Resources and Environmental Engineering, National Technical University of Athens, Athens, Greece (cmakro@mail.ntua.gr)
[4]Dept. of Water Resources and Environmental Engineering, National Technical University of Athens, Athens, Greece (andreas@itita.ntua.gr)

The Water-Energy-Food-Ecosystem nexus is characterized by synergies, complementarities and conflicts, and thus its management is a demanding task. This becomes more challenging when socioeconomic influences are embedded. Key components of this nexus are multipurpose water reservoirs that provide drinking water, electricity, agricultural water for food production, and ecosystem services. These systems are driven by inherently uncertain processes, both hydroclimatic and human-induced (e.g., legal regulations, strategic management policies, real-time controls, and market rules), and thus their management should account for them. In this vein, this research proposes an uncertainty-aware methodology for assessing the long-term performance of hydropower reservoirs. Specifically, we investigate and describe in stochastic terms the main uncertain drivers i.e., rainfall, water demands, and energy scheduling, and eventually explore the cascade effects of the uncertainty chain. The modeling framework is stress-tested on a hydropower reservoir in Greece, Plastiras, which has been subject to challenging socioeconomic conflicts during its entire 65-year history. To estimate the water targets, we employ a statistical analysis of historical abstractions, concluding that the irrigation demand is strongly correlated with the reservoir level while it is negatively correlated with antecedent rainfall. For the estimation of the power plant's energy target, we adopt a copula-based approach, in which the desirable releases for energy production are dependent on day-ahead electricity prices. In particular, we adopt three policies, i.e., conservative, median, and energy-centric, that refer to 95%, 50%, and 5% quantiles of the copula. Finally, to account for the hydroclimatic and market process uncertainties, we are taking advantage of stochastic models for the generation of synthetic rainfall and electricity price data, respectively. Our findings indicate that the cascade effects of the joint uncertainties are crucial for all operation policies. Specifically, in terms of profitability the energy-centric and the median are similar, while from a water supply and irrigation reliability perspective, the uncertainty range of this policy is wider, thus making it unacceptable for some scenarios. Consequently, the conventional approach of ignoring uncertainty in policy selection may result in misleading

perceptions for the operator, eventually guiding to sub-optimal reservoir management.