Uncertainty inclusion in optimization of multi-quality water distribution systems

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A water distribution system (WDS) is an interconnected collection of sources, pipes, and hydraulic control elements (e.g. pumps, valves, regulators, tanks) delivering consumers prescribed water quantities at desired pressures and qualities. Such systems are often described as a graph, with the links representing the pipes, and the nodes defining connections between pipes, hydraulic control elements, consumers, and sources. The behavior of a water distribution system is governed by: (1) the physical laws which describe the flow relationships in the pipes and the hydraulic control elements, (2) the consumer demands, and (3) the system's layout. Management problems associated with WDSs can be classified into (1) layout (system connectivity/topology), (2) design (system sizing given a layout), and (3) operation (system operation given a design). On top of those, problems related to aggregation, leakage, reliability, unsteady flow and security can be identified for gravity, and/or pumping, and/or storage branched/looped WDSs and water quality/water age can be considered for one or multiple loading conditions, taking into consideration of inputs/outputs as deterministic or stochastic variables. Problems associated with water distribution systems management are often formulated deterministically to understand its various processes and behaviors. However, in reality, most of these processes inherently contain uncertainty, either in parameter measurement, future estimations or due to assumptions on model simplicity. The combined result of these uncertainties and mathematical constraints lead to erroneous estimates reducing its reliability. Researchers in WDSs management employed various methods to handle this uncertainty like probabilistic approach, fuzzy approach, etc. The input uncertain parameters are assumed to vary in a probabilistic or as a fuzzy variable. The effect of these variations in output parameter are obtained from large, sampled simulations to obtain a probabilistic or fuzzy output variable. Then according to probability theory and fuzzy theory, the output parameter is estimated based on the reliability needed. The sampling of data for simulations is commonly done by MCS (Monte-Carlo simulations) or Latin Hypercube Sampling (LHS). Uncertainty in WDSs management can be partitioned into uncertainty in hydraulics, and uncertainty in water quality. The behavior of water distribution systems with uncertain water quality parameters have been studied but have never been incorporated in water distribution systems optimization. This talk objective is to describe the challenges in filling that research gap, to include water quality uncertainty along with hydraulic uncertainty to solve design/operation water distribution systems problems for receiving robust design and robust management solutions.