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Water resources decision support under deep uncertainty: a classification of model-based frameworks and challenges for scenario discovery

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Abstract: Recent work in water systems planning has focused on exploratory “bottom-up” decision support frameworks, which aim to identify robust solutions capable of withstanding deviations from the conditions for which they were designed. Here we organize these frameworks according to their methods of (1) alternative generation, (2) sampling of states of the world, (3) quantification of robustness measures, and (4) machine learning and sensitivity analysis methods to identify influential uncertainties. We demonstrate these methods using an urban water portfolio planning problem in North Carolina, a region whose water supply faces both climate and population pressures. The task of scenario sampling poses particular challenges for water supply systems, because the frequency and severity of droughts must be modified while respecting historical streamflow statistics. To address this challenge, we introduce a modified synthetic streamflow generation technique and compare the generated drought scenarios to climate model projections. By exploring the implications for reliability and cost under increasingly severe scenarios, results indicate that methodological choices lead to the selection of substantially different planning alternatives. In light of these differences in decision support outcomes, this work highlights several recommendations: (1) alternatives should be generated via computational search rather than prespecified; (2) dominant uncertainties should be discovered via sensitivity analysis methods rather than assumed prior to the analysis; and (3) that an elicited multivariate satisficing measure of robustness provides an opportunity to achieve problem-specific performance requirements. This work emphasizes the importance of an informed problem formulation for systems facing challenging performance tradeoffs, and provides a common vocabulary to link the robustness frameworks widely used in the field of water systems planning.

Keywords: Water resources planning, deep uncertainty, climate adaptation