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Discussions

Interactive comment on "Coevolution of water security in a developing city" *by* V. Srinivasan

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This paper uses Sivapalan et al.'s (2012) framework of socio-hydrology to demonstrate water system dynamics in a large city (Chennai) in Southern India. The author models interconnections among climate conditions, reservoir storage, market forces, human behavior, and management decisions. Feedbacks occur as people respond to drought by digging wells which cause groundwater levels to drop, which in turn, increases shortage conditions, causing more people to rely on expensive tanker-trucked water for supply. Although the model is more focused on replicating historical patterns rather than on exploring alternative futures, it includes several counterfactual experiments that investigate what past trajectories would be if different management decisions had been made, including decisions about infrastructure size and water pricing . The author acknowledges the need to move beyond reproducing historical conditions (what she calls

backward looking, descriptive, and explanatory) to develop capacity for futures analysis and scenario planning (what is called forward looking, prescriptive, and management oriented). The use of the counterfactual in this context represents a sort of middle ground in the sense that it: (1) acknowledges the possibility of alternative starting conditions and storylines (2) includes an aspect of decision support and policy analysis. Bankes (1993) makes a useful distinction between consolidative modeling which uses known facts to replicate an actual system and exploratory modeling in which models are used to investigate the consequences of varying assumptions and hypotheses about the system and its future dynamics. The former is useful in optimization and prediction, while the latter acknowledges that not all relevant and important information is available. Exploratory modeling is appropriate for situations in which there is a high level of system complexityâĂŤwhere nonlinear behaviors and feedbacks can result in unintended consequences and potentially catastrophic events. This paper uses a consolidative model for exploratory purposes.

While it is important to use the best available information (including knowledge about historical system dynamics), this information may or may not be useful for problems of deep uncertainty. Deep uncertainty characterizes situations in which analysts do not know or cannot agree upon the key drivers that will shape the future, probability functions that represent uncertainty, and how to value who gains and who loses from key outcomes (Lempert et al. 2003). The essence of this uncertainty is that we do not know the boundary conditions that will structure future water systems from either a physical (i.e. climate change) or social and economic (i.e. markets, policy, income distribution/social equity) perspective. Thus, it is useful to be able to imagine a wide range of future conditions and look for strategies or policies that perform well across them. The essence of decision making under uncertainty is to find robust solutions that perform reasonably well compared to the alternatives across a wide range of plausible future scenarios and avoid worst-case regrets.

A second aspect of exploratory modeling is that researchers cannot remain in their traditional scientific role as external observers of water systems because they decide what to model, which variables to include and exclude, and what decision-relevant trade-offs to report in an immensely complicated system. In suggesting solutions to the current problem of too little scientific information being used for societal decision making, Dilling and Lemos (2011) have emphasized the importance of two-way, iterative engagement between producers and users of scientific information to build trust and better understand the needs of policy. Cash et al. (2003) found that credibility (whether the information meets rigorous scientific standards), salience (whether it is usable for decision making), and legitimacy (whether it is developed and disseminated in a fair and transparent way) are strong determinants of whether information is used by policy makers. Clark and Clarke (2011) highlighted the importance of active negotiation processes to support the creation of usable scientific knowledge as well as social networks between researchers and decision makers. Crona and Parker (2011) found that policy makers who have greater social interactions with researchers were more likely to utilize scientific information to govern water resources. If socio-hydrology is to move from what Srinivasan calls backward-looking to forward-looking models, its members will need to shed their unease with the policy process and play a more active, enduring, collaborative, and transparent role in the decision support and decision making process. Indeed, the great strength of exploratory modeling is that it uses stakeholder feedback to identify socially relevant trade-offs, builds trust in the modeling process, and integrates the qualitative knowledge of stakeholders with the more quantitative knowledge of model developers.

In sum, this paper is a valuable addition to the new field of socio-hydrology. It highlights the importance of time scales in system dynamics, the power of the counterfactual to demonstrate the sensitivity of system dynamics to policy and operational decisions, and the way weak management is revealed in long-term negative trajectories. Equally significant is that it raises important questions about where the field is headed, including how much it emphasizes the past relative to the future, how critical empirical validation and legitimacy is in a future that is defined by deep uncertainty, the role there

is for scientists in evidence-based decision making, and how stakeholders and decision makers should engage in the model-building process.

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