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Decision Making under Climate Uncertainty for Water Utilities

Summary

Climate change will affect the natural fluctuations in climate, making it more unpredictable and variable. This increased uncertainty, particularly with respect to the level and extent of variability poses significant challenges to planners and designers, especially if current linear approaches continue to be employed. Actions taken to address variability provide a head start in managing risks from long-term climate changes. Predicting future climate based on global and regional models has its limitations and should not be relied upon as the sole starting point for local decision-making. As a design concept, reliability is going to be increasingly problematic as future conditions will alter today's calculation of reliability. A greater appreciation of the impact of uncertainty is needed. In order to cope with this, additional approaches and tools need to be used by decision-makers, planners, and designers.

Key Points

- Climate stationarity as a starting point of design is dead
- Anthropogenic changes will exacerbate climate change impacts leading to greater uncertainty for planners and designers
- Future design approaches should include methods that specifically address uncertainty
- Methods to address uncertainty include: no regret approaches, reversibility, safety margin strategies and soft (institutional and instrumental) solutions

Water Utilities are Used to Planning for a Single Future

Traditionally, water systems have been designed using an often-limited, historical hydrologic record. Statistical stationarity -- the notion that natural systems vary within a well-defined range -- has been fundamental to water resources engineering, management training and practice.[8]

However, climate change and variability challenge the presumption of stationarity. Natural fluctuations in climate can occur on longer time scales than once thought. There may be climate extremes (drought or floods) occurring more frequently than was once thought. Climate change may lead to gradual drying trends in some areas. Changes in land use, population, energy needs and other supply and demand variables also affect water availability. Some of these changes can be predicted with some certainty, but most cannot.

Water utilities plan for a range of time scales (from daily to decades and beyond). These plans can be sensitive to climate factors, so planning for a single future based on historical projections is not recommended. Even under present conditions, systems face risks due to climate fluctuations. Actions taken to address variability overlap with and provide a head-start to managing risks from longer-term climate change.

The primary methods developed for predicting climate are global and regional climate models (GCMs/RCMs). Although tempting to use in decision-making due to their deterministic output, GCM/RCM projections vary widely, have coarse spatial resolution, lack skill in reproducing variability and rely on emission scenarios that lack assigned probabilities.[1] While GCMs have appropriate uses, and their continued research and development is vital, using them as a starting point for local or regional decision processes can be even dangerous given these limitations.

Climate Change Uncertainties may be Problematic for Water Utilities

The significant increase of uncertainties associated with climate change and the dangers in assuming stationarity equate to the "end of reliability," where reliability can be defined as the probability that a water supply system will not fail.[1] A traditionally-planned system might be designed to be reliable 95% of the time. The marginal cost of protecting the additional 5% is considered too great for the benefits that would result from 100% reliability.[1]

There are four major problems with designing for 95% reliability. First, statistics from which design events are created become less useful when considering long-term climate changes. The "5% event" could become more (or less) common in a few decades, as uncertainties around projection of future risk limit confidence in defining a "5% event.[4]

Second, valuing costs and benefits when managing long time horizons and multiple spatial scales is problematic.[4] Thirdly, costs, impacts and risks are usually not distributed fairly across society, leading to questions of justice and ethics.

The fourth problem is that failure often results in immense human suffering (e.g. Hurricane Katrina) and political difficulties (e.g. Atlanta's 2007 drought). When the ability to better prepare for these 5% events is achievable, failure should be deemed unacceptable in water resources planning. Instead, there needs to be a vision of designing for all events.[1]

Addressing Uncertainties

Several approaches have been used to try to incorporate long-term climate information into decision analysis. One of these is scenario planning (see Figure 1), under which a limited set of scenarios are developed that span the range of future uncertainties. Through exploring the implications of these futures and considering how they could be managed, planners learn about vulnerabilities of their system and the options to address them.

Another approach is "stress testing" to identify vulnerabilities in a water system or long term plan[2,3]. This approach uses models of the system and statistics to identify vulnerabilities.

There are several general strategies to consider when making decisions under uncertainty.

- ***No-regret strategies*** -- those that will reap benefits even in the absence of climate change (e.g. fixing leaking pipes)[5].
- ***Reversible/flexible strategies,*** especially in cases of long-term infrastructure where one needs to plan for a range of climates (e.g. early warning systems).

Deep Uncertainty

Almost a century ago, economist Frank Knight made the distinction between *risk* and *uncertainty* as that which can and cannot be quantified about our unknown future. Some uncertainty comes from our human errors and insufficiencies in modeling that could be remedied. Other uncertainties are irreducible; that are unlikely to be improved by better models due to the complex nature of the climate system.[6]

As defined by *Hallegatte et al, 2012,* **deep uncertainty** requires one or more of these elements:
(1) Knightian uncertainty: multiple possible future worlds without known relative probabilities
(2) Multiple divergent but equally-valid world-views, including values used to define criteria of success
(3) Decisions which adapt over time and cannot be considered independently.

Climate change thus carries "very deep" uncertainties, with "plenty of competing viewpoints and values, no clear probabilities within any of them, and highly interrelated decision series over time."[6]

- ***Safety margin strategies*** or a cautionary action (e.g. adding extra height to a sea wall).
- ***Soft strategies*** (e.g. insurance or institutionalizing long-term planning strategies into water management practices).
- ***Prioritize investment*** at time scales for which there is more certainty about climate.[5]

Decision makers, however, should consider conflicts and synergies between strategies and think across sectors.[5] For example, a coastal infrastructure project designed to protect against rising seas may be harmful to the tourism and ecosystem sectors.

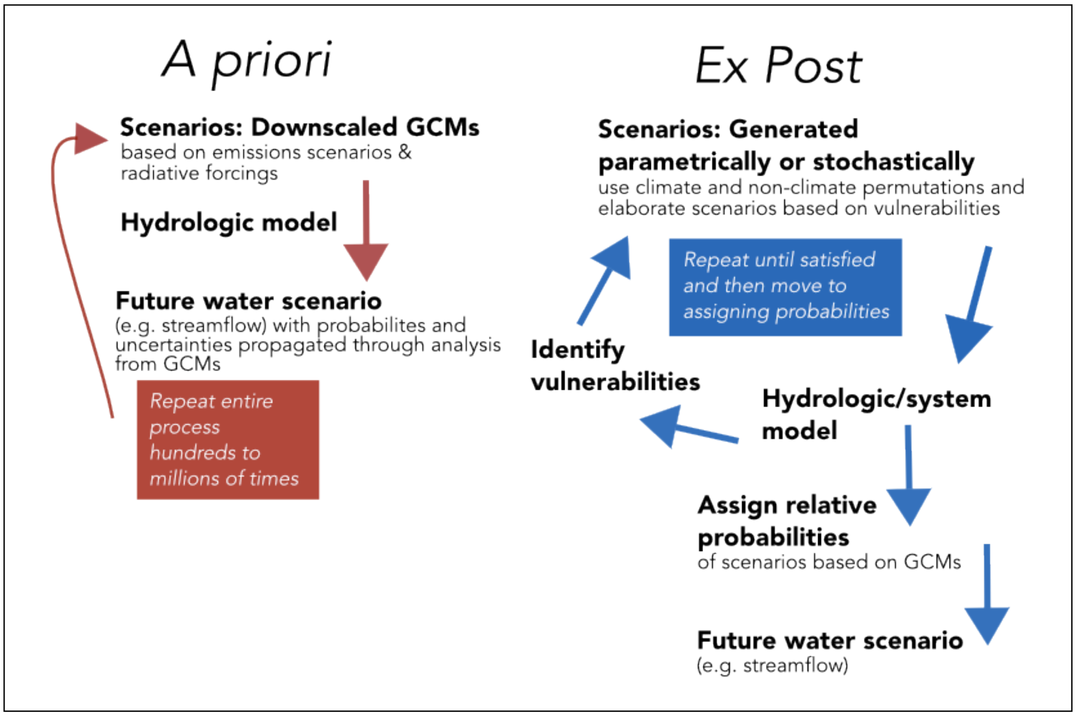

Figure 1: Common approaches (left column) to climate risk assessment depend on attempts to project the future, whether through historic record extension or climate projections. These are often called "predict then act." However, given the difficulty of predicting future evolution of climate, new approaches such as Decision Scaling (right column) emphasize identifying system or plan vulnerabilities and developing strategies to reduce them. These bottom-up approaches focus on specifics of a system rather than future climate prediction.

The table on the reverse page summarizes four specific methodologies for decision making under uncertainty. They are not mutually exclusive.

Conclusions

With climate change and climate variability the concept of designing for a given level of reliability becomes problematic as it is difficult to predict now how reliability will change in the future. The adoption of risk-based approaches that consider costs and benefits associated with providing greater reliability and resilience should become a fundamental part of future water services and water resources management planning. Scenario based planning, in conjunction with possible future climates provide a way to cope with uncertainties, whilst stress-testing of systems is another approach. In addition to these, complementary approaches include strategies such as; no regrets, reversibility/flexibility, safety margins, and soft strategies.

References

[1]Brown, C., (2010), The End of Reliability. J. Water Resour. Plann. Manage., 136(2), 143–145.

[2]Brown, C. and Wilby, R.L., (2012) An Alternate Approach to Assessing Climate Risks. EOS, 93(41), 401-403.

[3]Brown, C., Y. Ghile, M. Laverty, K. Li, (2012) "Decision Scaling: Linking bottom-up vulnerability analysis with climate projections in the water sector" Water Resources Research 48, W09537, doi:10.1029/2011WR011212.

[4]Hall et al., (2012), Proportionate Adaptation. Nature Climate Change, 2, 833-834.

[5]Hallegatte, S., (2009), Strategies to adapt to an uncertain climate change. Global Environmental Change, 19, 240-247.

[6]Hallegatte et al., (2012), Investment Decision Making Under Deep Uncertainty: Application to Climate Change. The World Bank Office of the Chief Economist.

[7]Knight, F.H., (1921). Risk, Uncertainty, and Profit. Boston, MA: Hart, Schaffner & Marx; Houghton Mifflin Company.

[8]Milly, P. C. D., et al. (2008), "Stationarity is dead: Whither water management?" Science, 319(5863), 573–574.

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Table 1: Methods for decision making under uncertainty, from *Hallegatte et al, 2012* unless noted. See *Hallegatte et al* for more information and case studies.

Method	Summary	Applicability	Benefits	Drawbacks
Cost Benefit Analysis (CBA)/CBA Under Uncertainty	Typical steps: - Identify alternatives - Identify sources of uncertainty - Evaluate costs and benefits for each alternative - Calculate the net present value of alternatives - Evaluate results' robustness For uncertainty, can attribute "subjective probabilities" and evaluate expected probability-weighted benefits.	- Where there is deep uncertainty, CBA should be used as a complement and a tool to facilitate consultations and discussions; it should not replace them. - To ensure robustness, it should encompass the all possible assumptions	- Useful for gathering information and stakeholder opinion on the consequences of a project - When uncertainty is small, can identify best investment opportunities	- In cases with large uncertainties of the inputs, can reach very different results given differing but reasonable input values - Can rarely be used to make a purely objective decision - Extremely sensitive to tails of distribution function
Real Options	- Going a step beyond CBA, RO values the options created and destroyed by a project, in addition to its expected net present value. ENPV = Expected Net Present Value + (Value of Options created – Value of Options Destroyed)	Can improve accuracy of economic evaluation and add robustness when: - Uncertainty is dynamic and not necessarily deep and will be resolved in time - There are significant irreversible investments or the project creates/destroys significant capabilities	- Easily incorporated into a social cost-benefit framework - Allows for explicit valuation of created and destroyed options; often not included in CBA. - For climate change, "may be particularly useful to evaluate adaptation options, such as the options to cope, to rebound, to abandon, to retreat and to flexibly adjust along one or several dimensions."	- More information and higher ENPV after waiting assumes some uncertainty will eventually be resolved - More complexity, sometimes leading to problems impossible to solve.
Climate Informed Decision Analysis (also known as Decision Scaling) (Figure 1b)	- Organized around the decision at hand and the stakeholders involved in making the decision, as well as those affected by the decision - Combines top-down and bottom-up approaches - Begins with vulnerability analysis that provides information on how a system would respond to changes in climate, and then uses GCMs and other climate information to assess likelihood of those changes - Does *not* try to reduce uncertainties - Determines which decision options are robust to a variety of plausible futures	- Decisions regarding long-term investments that may be climate-sensitive - Can handle poorly-characterized climate change uncertainties to make good use of available climate information - In project planning, can be used as a framework for climate risk analysis or to compare multiple project options	- Estimates usefulness of downscaling GCM for decision at hand (can avoid unnecessary investment and ensures only relevant information produced) - Separate vulnerability analysis and climate information ensures easy updating of analysis when new information available - Late application of GCM data reduces impact of uncertainties - Allows incorporation of alternative future scenarios - Results tie decision options to specific climate futures, facilitating adaptive management that reacts to changes in climate indicators - Explicitly addresses limits of anticipating a project's future	- Lack of confidence in plausibility of various climate scenarios leads to subjective judgment of scenario probability - Relevance and efficacy of decision is dependent on initial stakeholder process - Requires quantitative modeling
Robust Decision Making	- First, thoroughly explores a project's vulnerabilities and sensitivities - Uses analysis and stakeholder involvement - Identifies potential changes to plan that could reduce vulnerabilities.	- Projects with multiple, deep uncertainties - Stakeholders with a variety of world-views, priorities and definitions of success - A variety of decision options that allow for project plans robust over many different future scenarios - Long-term commitments that make it hard to change near-term decisions	- Proposed projects are given complete vulnerability analysis - "Transparent, reproducible, and exhaustive scenario discovery reduces overconfidence bias" - Stakeholder process strengthens consensus on project action even given wide range of priorities - Explicitly addresses limits of anticipating a project's future - Plans easily evolve	- Resource and time intensive - Relevance and efficacy of analysis is dependent on initial stakeholder process - Requires extensive quantitative modeling