RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT

Robust Decisionmaking For Climate-Related Decisions: Application to Water Resources

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RAND Infrastructure, Safety, and Environment

Climate Change Science and Hydropower Management:
Is Existing Science Useful Yet?

January 28, 2010

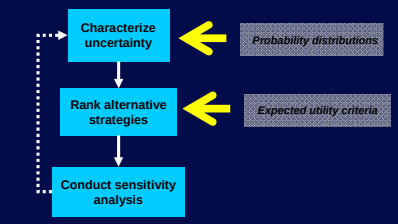
Outline

- Robust decisionmaking (RDM) approach to climate-related decision support
- Example water management application
- Evaluating the impacts on decisionmaking

Traditional Decision Analysis Ranks Strategies Based on Probabilistic Characterization of Uncertainties

Optimal Expected Utility

- Rank strategies contingent on characterization of uncertainties



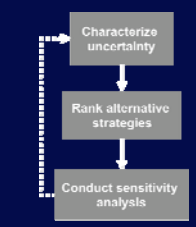
Traditional Decision Analysis Ranks Strategies Based on Probabilistic Characterization of Uncertainties

- But climate change confronts decisionmakers with deep uncertainty
  - Do not know and/or do not agree on system model or prior probabilities
- Decisions can go awry if decisionmakers assume risks are well-characterized when they are not
  - Uncertainties are underestimated
  - Competing analyses can contribute to gridlock
  - Misplaced concreteness can blind decision-makers to surprise

Robust Decisionmaking (RDM) Characterizes Deep Uncertainties Contingent on Proposed Strategy

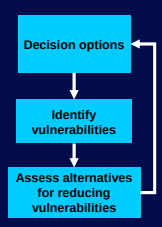
Optimal Expected Utility

- Rank strategies contingent on characterization of uncertainties



Robust Decisionmaking

- Characterize uncertain vulnerabilities contingent on proposed strategy



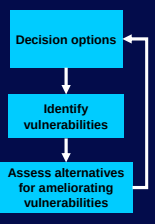
Robust Decisionmaking (RDM) Characterizes Deep Uncertainties Contingent on Proposed Decision

Robust Decisionmaking

- Characterize uncertain vulnerabilities contingent on proposed strategy

Key attributes:

- Characterize uncertainty with multiple views of the future
- Use robustness, not optimality, criteria to compare strategies
- Conduct iterative vulnerability and response option analysis to identify better decision options



RDM provides a method for decision support focused on designing better choices, not predicting what will happen

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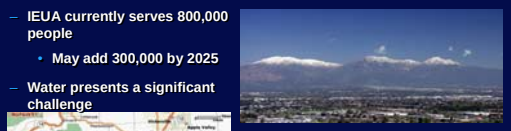
RAND Helped Inland Empire Utilities Agency (IEUA) Include Climate Change in Their Long-Range Plans

- IEUA currently serves 800,000 people
  - May add 300,000 by 2025
- Water presents a significant challenge



- Current water sources include:
  - Groundwater 56%
  - Imports 32%
  - Recycled 1%
  - Surface 8%
  - Desalted 2%

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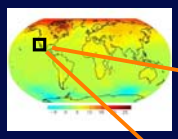
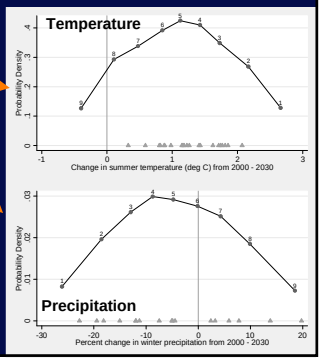
Focus of IEUA's 25 year plan

Used State-of-the-art Regional Probabilistic Climate Projections for Southern California





- Derived from forecasts from 21 general circulation models with A1B emissions scenario
- Each forecast weighted by ability to reproduce past climate and level of agreement with other forecasts

(Tebaldi et al.)

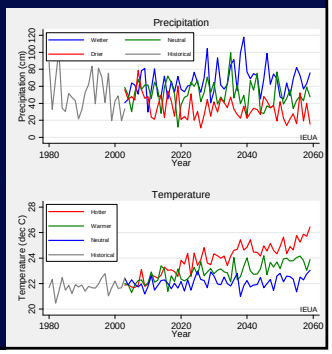
Generated Future Weather Sequences by Resampling Historic Local Climate Records

KNN* method produces hundreds of local weather sequences

- Daily and monthly variability that matches historic Chino climate
- Temperature and precipitation trends that match climate model forecasts

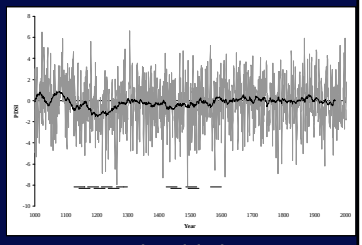
(Yates et al.)

* k-nearest neighbor algorithm



Developed New Future Weather Sequences Consistent with Paleo-Record

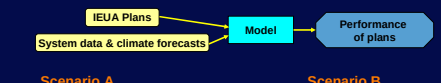
- Evaluated Palmer Drought Severity Index (PDSI) hind-casts for Southern California
- Developed monthly temperature and precipitation sequences consistent with PDSI record



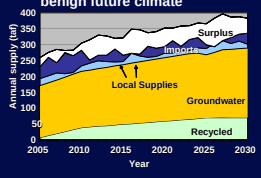
Temperature and precipitation sequences developed for dry periods indicated above.

Abbie H. Tingstad, David G. Groves, Robert J. Lempert "Tree-ring based climate scenarios to inform decision making in water resource management, in preparation

Simulation Model Assesses Performance of IEUA Plans in Many Different Scenarios

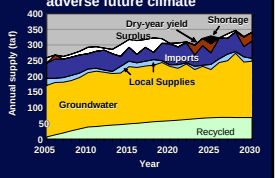


Scenario A
Plan generates surpluses in benign future climate



Temp: +0.7ºC Precip: +3%

Scenario B
Plan suffers shortages in adverse future climate



Temp: +1.6ºC Precip: -10%

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Groves et. al. (2007)

Many Uncertain Factors Could Impact the Performance of Current IEUA Plan

Natural Processes	• Future temperatures • Future precipitation • Changes in groundwater processes
Performance of Management Strategies	• Development of aggressive waste-water recycling program • Implementation of groundwater replenishment
Costs of Future Supplies and Management Activities	• Imported supplies • Water use efficiency

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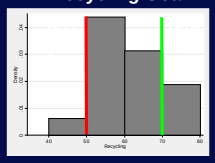
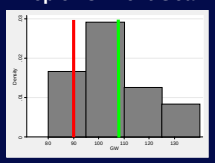
Effective Planning Requires Information About a Full Range of Uncertainties

Conducted elicitations with IEAU stakeholders to estimate likelihood of achieving planning goals

Recycling Goal



Replenishment Goal



Meet Goals
Miss Goals

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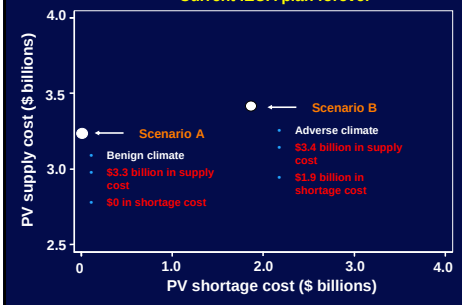
"Scenario Maps" Help Decisionmakers Visualize a Plan's Vulnerabilities

Current IEUA plan forever



Consider options → Identify vulnerabilities → Assess alternative responses

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Source: David G. Groves, Robert J. Lempert, Debra Knopman, Sandra H. Berry, 2008: Preparing for an Uncertain Future Climate in the Inland Empire: Identifying Robust Water-Management Strategies, DB-550-NSF, RAND

"Scenario Maps" Help Decisionmakers Visualize a Plan's Vulnerabilities

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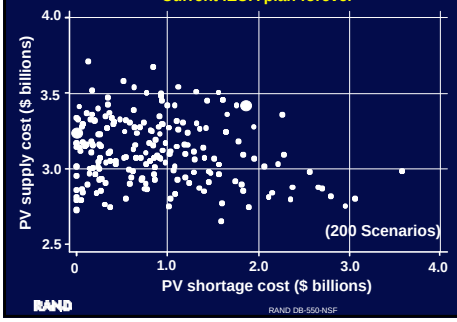

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RAND DB-550-NSF

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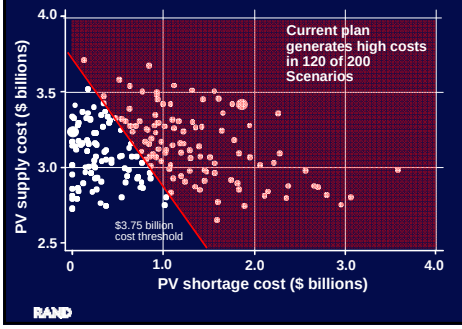

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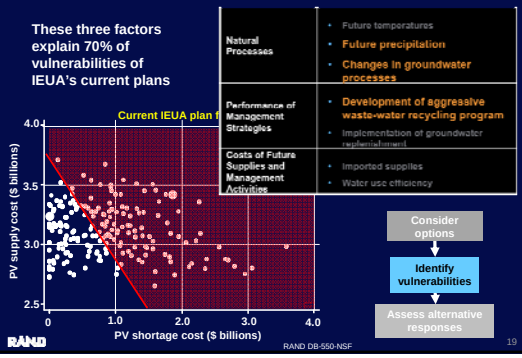
Statistical "Scenario Discovery" Analysis Identifies Scenario Where Existing Plan Fails

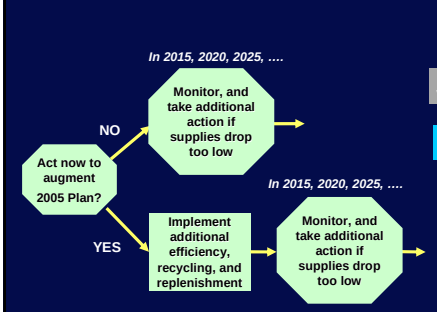
These three factors explain 70% of vulnerabilities of IEUA's current plans



Consider options → Identify vulnerabilities → Assess alternative responses

RAND DB-550-NSF

IEUA Considered Response Options That Evolve Over Time With New Information



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RAND Conducted Formal Evaluation of Effect of Analysis on Policymakers' Views

- Four IEUA workshops presented modeling results to participants including:
  - Agency professional managers and technical staff
  - Local elected officials
  - Community stakeholders
- Compared RDM, probabilistic, and traditional scenario approaches
- "Real-time" surveys measured participants'
  - Understanding of concepts
  - Willingness to adjust policy choices based on information presented
  - Views on RDM and alternative approaches

Evaluation Suggests Analyses Changed Views

Participants reported:

- Tradeoffs between the simplicity and usefulness of alternative approaches
- Preferences for scatter plots over histogram scenario maps

After the workshops:

- 35% said consequences of bad climate change now appeared "more serious" than before
- 40% thought the likelihood of of bad climate change outcomes for the IEUA was "greater" than before
- 75% though the ability of IEUA planner to plan for and manage effects was "greater" than before

Overall, RDM analysis increased:

- Perceived likelihood of serious climate impacts
- Confidence that IEUA could take effective actions to reduce its vulnerability to climate change
- Support for near-term efficiency enhancements to current IEUA plan

Currently Applying This RDM Approach With Many Resource Management Agencies

Key Features of Robust Decisionmaking Approach

- **Characterize uncertainty with multiple views of the future**
- **Use robustness, not optimality criteria, to compare strategies**
- **Conduct iterative vulnerability and response option analysis to identify better decision options**

RDM encourages policymakers to change the question from

"What will the future bring?"

to

"What steps can we take today to most assuredly shape the future to our liking?"

Implications for FERC Licensing

- **Licensing facilities for multiple decades requires that key uncertainties be considered systematically**
- **Ignoring uncertainties will not reduce their impact on long-term outcomes**
- **Use of a few scenarios may not fix the problem**
- **Uncertainties presented by climate change and other factors can be incorporated into analysis**
- **Robustness, not optimality, is the more desirable design criterion**

More Information

Bryant, B. P., and Lempert, R. J., "Thinking inside the box: A participatory, computer-assisted approach to scenario discovery." *Technological Forecasting and Social Change*, 77(1), 34-49, 2010.

David G. Groves, Robert J. Lempert, Debra Knopman, Sandra H. Berry: Preparing for an Uncertain Climate Future: Identifying Robust Water Management Strategies, RAND DB-550-NSF, 2008.

David G. Groves, Debra Knopman, Robert J. Lempert, Sandra H. Berry, and Lynne Wainfan, Presenting Uncertainty About Climate Change to Water Resource Managers, RAND TR-505-NSF, 2007.

David G Groves, David Yates, Claudia Tebaldi, "Developing and Applying Uncertain Global Climate Change Projections for Regional Water Management Planning," 44(W12413) , 2008.

Lempert, R., and Collins, M. (2007). "Managing the Risk of Uncertain Threshold Responses: Comparison of Robust, Optimum, and Precautionary Approaches." *Risk Analysis*, 27(4), 2007.

Steven W. Popper, Robert J. Lempert, and Steven C. Bankes: "Shaping the Future," Scientific American, vol 292, no. 4 pp. 66-71, April 2005

www.rand.org/ise/projects/improvingdecisions/

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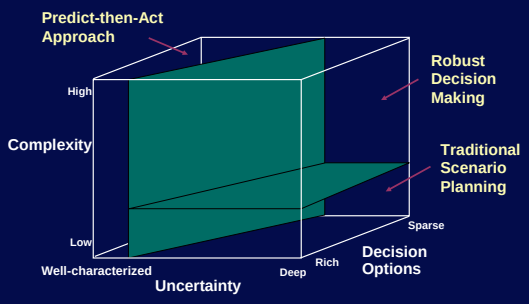
Back-up Slides

Relaxing Stationarity Assumptions Poses Both Analytic and Organizational Challenges

- **Planning with statistics of future climate based on projections, rather than just replicating recent history, requires**
  - **Usefully summarizing incomplete information from new, fast-moving, and potentially irreducibly uncertain science**
  - **Justifying analytic choices to diverse constituencies, many of whom may object to implications of some particular choices**

- **Solution requires rethinking *how we use* uncertain climate information in our planning**
- **Recent CCSP report suggests:**
  - **There are limits to the applicability and usefulness of classic decision analysis to climate-related problems**
  - **Seeking robust strategies may prove a preferable approach**

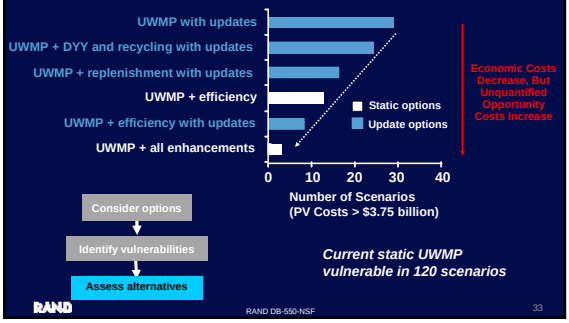
RDM Most Appropriate When Uncertainty Is Deep and Decision Makers Have a Rich Set of Options



Robust Decision Making Appears to Facilitate Decisions Under Deep Uncertainty

- Vulnerability and response option analysis framing can help decision makers
  - Reach consensus on key uncertainties and tradeoffs even when they disagree on policy and on expectations about the future
  - Reduce overconfidence and the deleterious impacts of surprise
  - Include imprecise probabilistic information systematically in their consideration of policy options

Compare Alternative Plans With Different Mixes of "Act Now" vs. "Act Later"



Consider options → Identify vulnerabilities → Assess alternatives

Current static UWMP vulnerable in 120 scenarios

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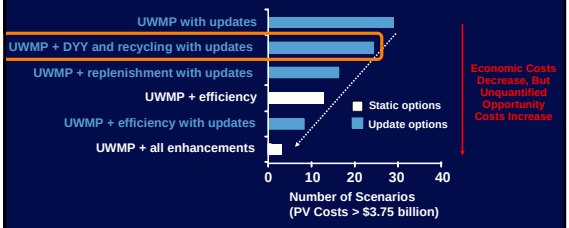

IEUA chose to accelerate their dry-year yield and recycling programs, and adapt as needed down the road

Robust Strategies May Trade Small Costs for Less Vulnerability to Broken Assumptions