Building Resilience to a Changing Climate:

A Technical Training in Water Sector Utility Decision Support

WUCA
Water Utility Climate Alliance
10 YEARS · 2008-2018

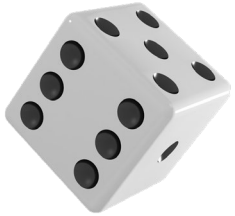
Methods for Decision Making Under Conditions of Deep Uncertainty (DMDU)

Robert Lempert, RAND

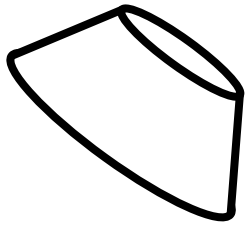
You've Received Much Advice So Far

- Past climate is no longer a reliable predictor of future, or even *current*, climate, but no one is sure exactly how climate has and will change
- Climate models are helpful when used appropriately, but far from perfect

  (But they are probably a lot better than economic models!)
- Don't wait for uncertainties to be resolved -- that won't happen anytime soon.
- Consider multiple objectives (reliability, cost effectiveness, equity, …)
- Many decisions will prove effective or provide benefits under multiple possible future conditions
  - Don't mistake
    - Well-characterized risk



    - For deep uncertainty



DMDU Methods and Tools Provide Water Managers Means to Take This Advice

Basic DMDU principles

1. Consider multiple futures, not one single future, in your planning. Choose these futures to stress test your organization's plans
2. Seek robust plans that perform well over many futures, not optimal plans designed for a single, best-estimate future
3. Make your plans flexible and adaptive, which often makes them more robust
4. Use your analytics to explore many futures and options, not tell you what to do

There are many ways, small and large,

to fold these principles into your organization.

Traditional Risk Management Works Well When Uncertainty is Limited

"Predict then Act"

What will future conditions be? → What is the best near-term decision? → How sensitive is the decision to the conditions?

Predict

Act

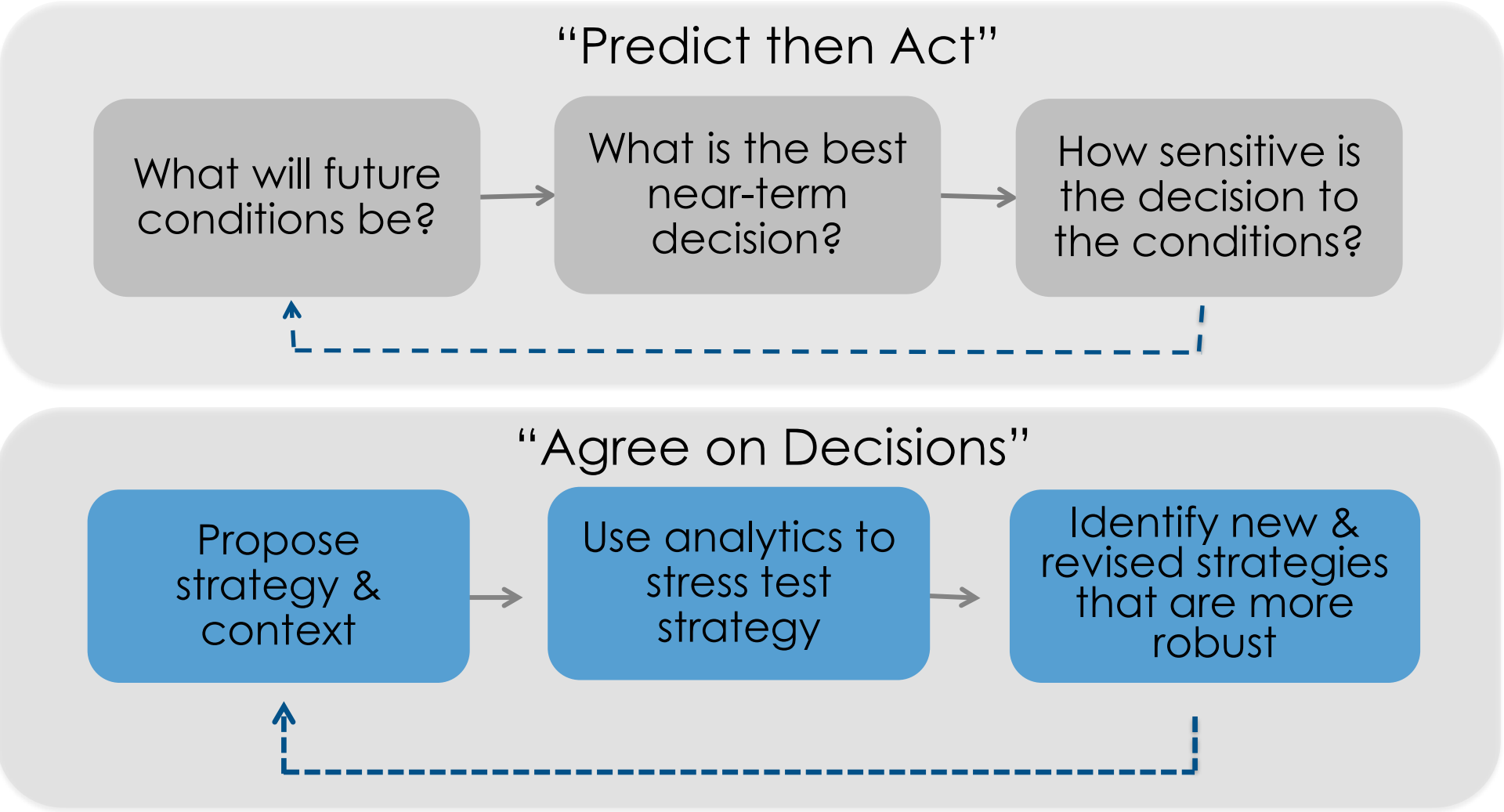
These are sometimes called "optimization methods"

“Predict then Act” Can Break Down When Uncertainties are Deep

Under conditions of deep uncertainty:

- Uncertainties are often underestimated
- Competing analyses can contribute to gridlock
- Misplaced concreteness can blind decision makers to surprise

Under Deeply Uncertain Conditions, Often Useful to Run the Analysis " Backwards"



Kalra, N., S. Hallegatte, R. Lempert, C. Brown, A. Fozzard, S. Gill and A. Shah (2014). *Agreeing on Robust Decisions: A New Process for Decision Making Under Deep Uncertainty*. WPS-6906, World Bank.

DMDU Helps People Make Better Decisions, Not Better Predictions

Basic principles

1. Consider multiple futures, not one single future, in your planning. Choose these futures to stress test your organization's plans
2. Seek robust plans that perform well over many futures, not optimal plans designed for a single, best-estimate future
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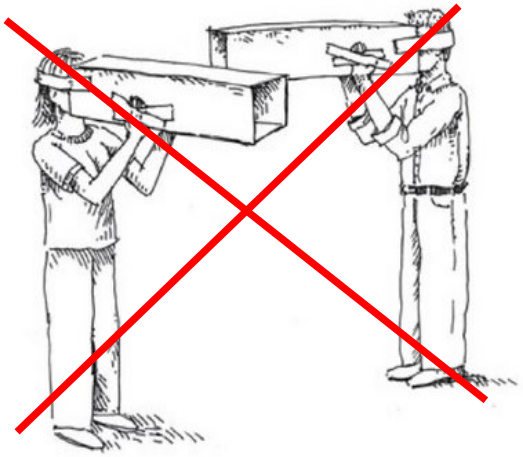
Plan over multiple futures



Deep uncertainty occurs when the parties to a decision do not know or do not agree on the likelihood of alternative futures or how actions are related to consequences

Outline

Introduction

DMDU Methods

Getting Started

Several Different DMDU Approaches are Available

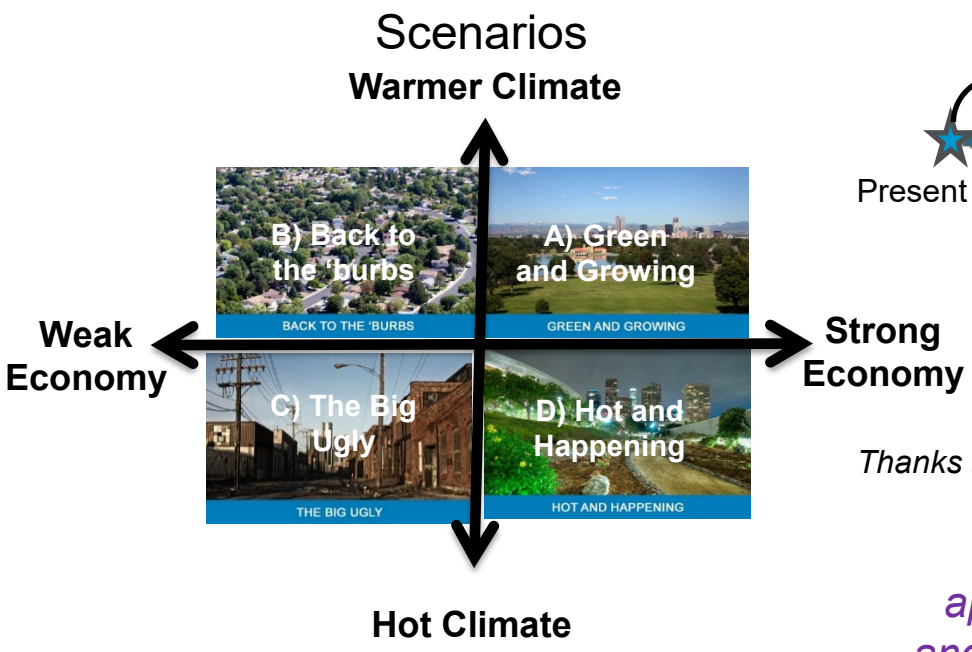
- Scenario planning
- Robust Decision Making (RDM)
- Adaptive pathways
- Decision scaling

All are variations on similar themes

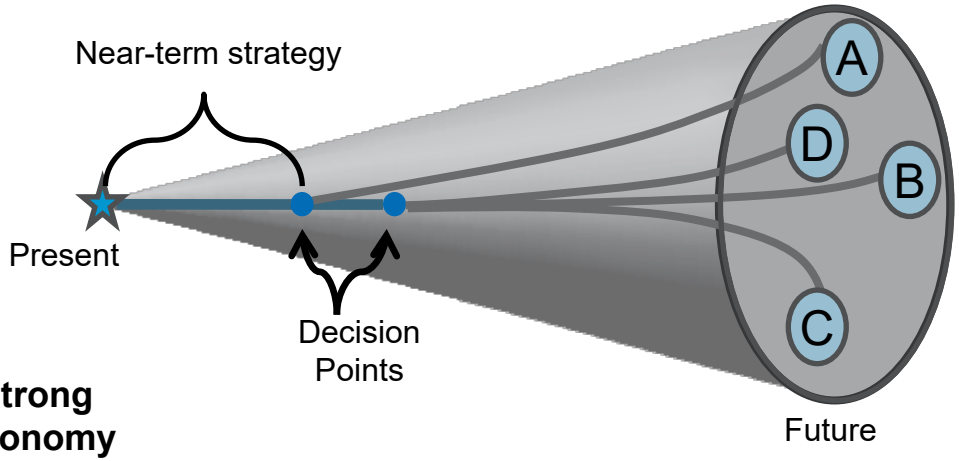
Scenario Planning Develops Robust Strategies From Scenarios People Create

Steps in scenario planning:

1. Identify decision challenge
2. Chose key driving forces, those most important and uncertain
3. Flesh out scenario narratives
4. Use scenarios to develop a robust adaptive plan



Robust, adaptive strategy



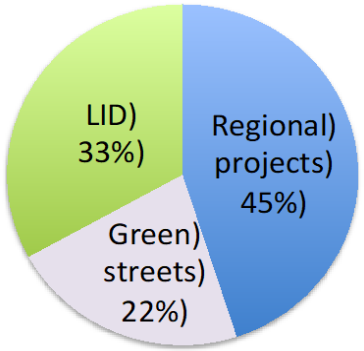
Thanks to Laurna Kaatz

Sometime called "story and simulation" approach because people chose the stories and then flesh them out with simulation models

Robust Decision Making (RDM) Provides a Quantitative Version of Scenario Analysis

Can Los Angeles meet its water quality goals in the face of climate change?

Plan aims to meet federal water quality standards by 2035



Optimal distribution of BMPs (best management practices) *assuming we know future climate!*

** Study focuses on Tujunga sub-watershed: 225 square miles (165 sq. miles Los Angeles National Forest + 60 sq. miles urbanized San Fernando Valley floor)*

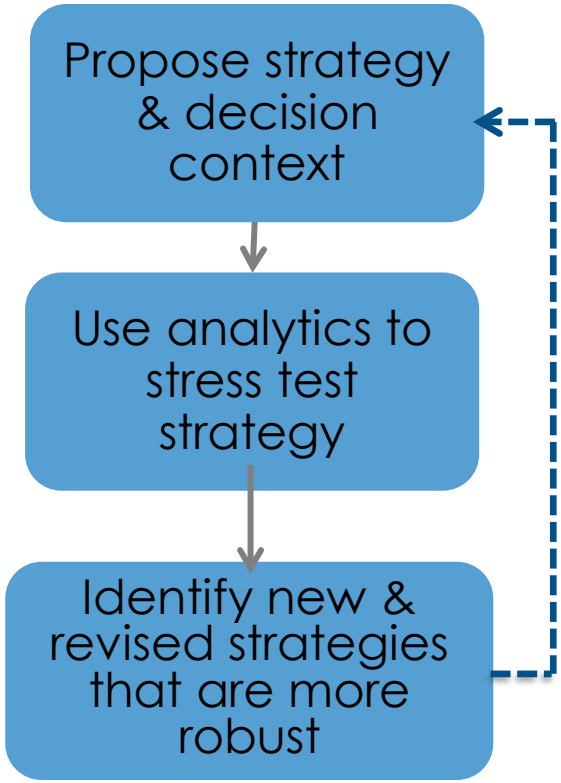
A. Tariq et. al., (2017) "A Climate Stress Test of Los Angeles' Water Quality Plans," Climatic Change

Let's Use RDM to Answer this Question

Checklist of steps in RDM process

- ☐ Frame the decision challenge, including:
  - What are we trying to achieve?
  - What actions might we take to achieve our goals?
  - What uncertainties affect our achieving our goals?
- ☐ Stress test proposed strategies over a wide range of futures
  - Identify most important factors affecting whether we meet or miss our goals
- ☐ Identify new or revised strategies that meet our goals over a wider range of relevant futures

Checklist Should Look Familiar



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Checklist of steps in RDM process

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RDM Begins with Decision Framing

Stakeholders' questions:

- *Will our expensive new water quality investments still meet water quality standards in a changing climate?*
- *If not, what can we do about it?*

Uncertain Factors (X)	Policy Levers (L)
Relationships (R)	**Performance Metrics (M)**

Frame → Stress Test → New Strategies

RDM Begins with Decision Framing

Stakeholders' questions:

- *Will our expensive new water quality investments still meet water quality standards in a changing climate?*
- *If not, what can we do about it?*

Uncertain Factors (X)	**Policy Levers (L)**
• Climate change • Land use	First iteration of analysis • City's proposed plan Second iteration adds: • Adaptive pathways
Relationships (R)	**Performance Metrics (M)**
• Hydrology and optimization models used in city's regulatory approval analysis	• Meet water quality requirements • Cost effective

Frame → Stress Test → New Strategies

Most Effort Went into the R's and X's

For X's, gathered:

- Ensemble of climate projects from previous study by LA County
- Land use projections from Southern California Association of Governments and from a local advocacy group (Tree People)

For R's, used LA County's Watershed Modeling and Management System (WMMS)

- Used two WMMS tools built by EPA:
  - Loading Simulation Program (LSPC)
  - System for Urban Stormwater Analysis and INtegration (SUSTAIN)
- Obtained help from County Flood Control District and from consultants to city of LA

Uncertainties (X)	Policy Levers (L)
• Climate change • Land use	• City's plan
Relationships (R)	**Metrics (M)**
• Hydrology and optimization models	• Water quality • Cost effective

Stress Test LA's Water Quality Plans

Checklist of steps in RDM process

- [x] Frame the decision challenge, including:
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- [x] Stress test proposed strategies over a wide range of futures
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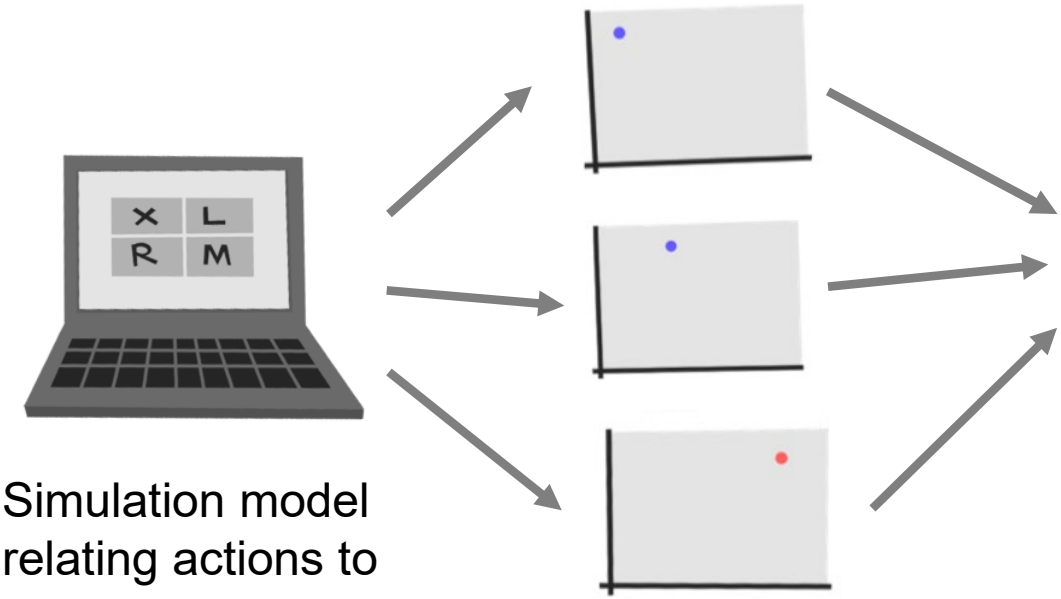
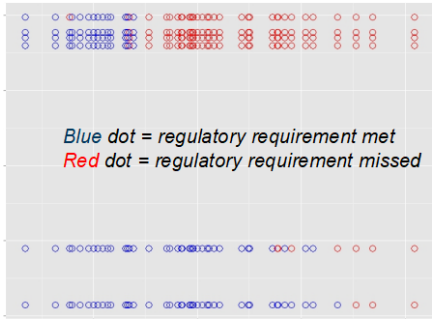
Generate Cases that Stress Test Strategy in Each of Many Plausible Futures

Run model for each off hundreds to millions of cases
Each case tests one strategy in one plausible future



Simulation model relating actions to consequences

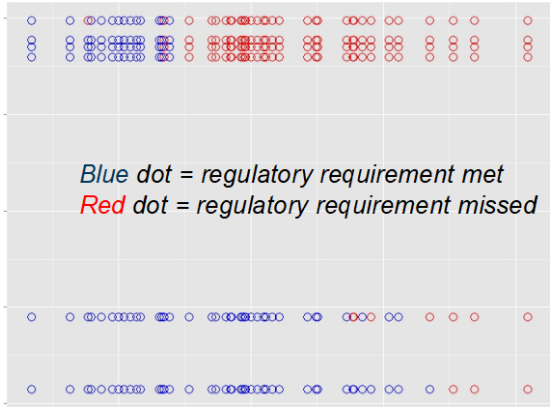
Gather all the cases in a large database



Strategy & Context → Stress Test → New & Revised Strategies

"Scenario Discovery" Summarizes Stress Test With Policy-Relevant Scenarios

1) Assemble database of model runs



- Study stress tested water quality implementation plan over 47 climate times 6 land use = 282 futures

Strategy & Context → Stress Test → New & Revised Strategies

"Scenario Discovery" Summarizes Stress Test With Policy-Relevant Scenarios

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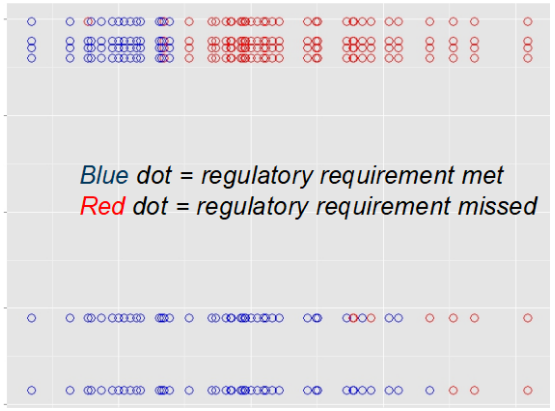
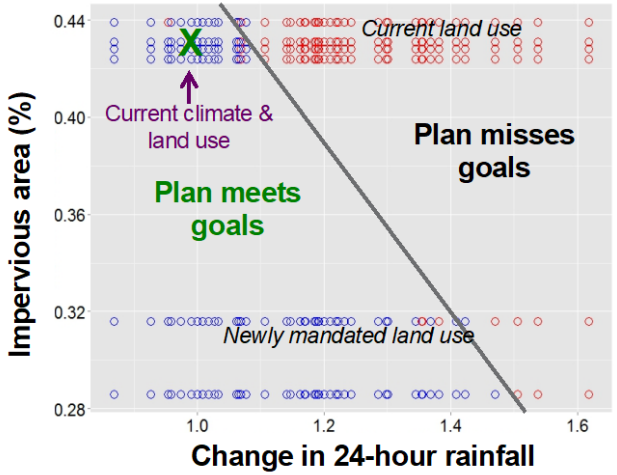


2) Conduct scenario discovery



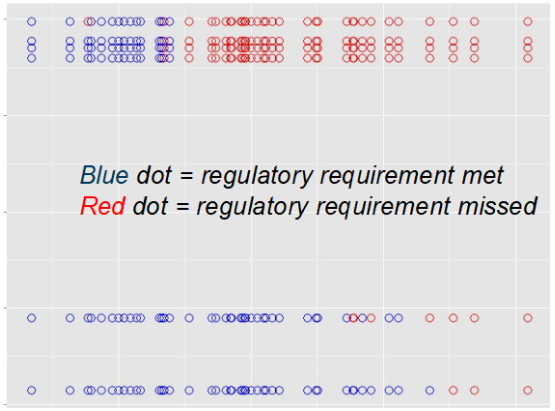
Scenario discovery algorithms separate model runs into two sets, futures in which Los Angeles: 1) meets and 2) misses its regulatory goal.

Algorithms also identify the combination of uncertainties *most important* in distinguishing these two sets of futures

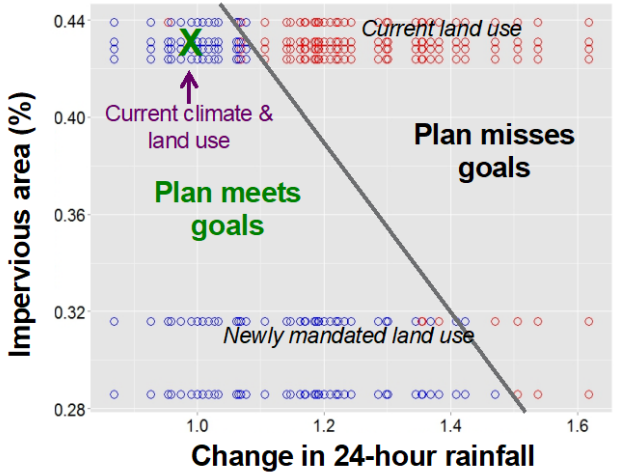
Strategy & Context → Stress Test → New & Revised Strategies

"Scenario Discovery" Summarizes Stress Test With Policy-Relevant Scenarios

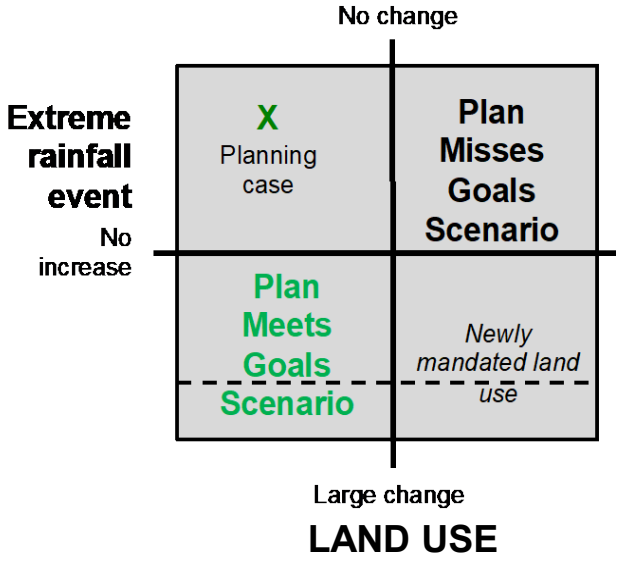
1) Assemble database of model runs



2) Conduct scenario discovery analysis



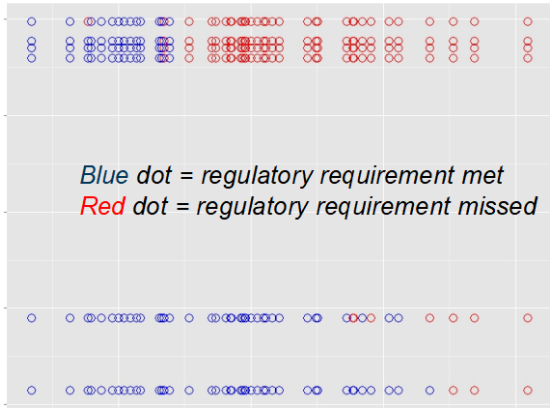
3) Interpret as policy relevant scenarios



These two scenarios suggest that climate change puts LA at risk of missing water quality goals, but successfully implementing storm water master plan eliminates climate risk

Should Decision Makers Worry?

1) Assemble database of model runs



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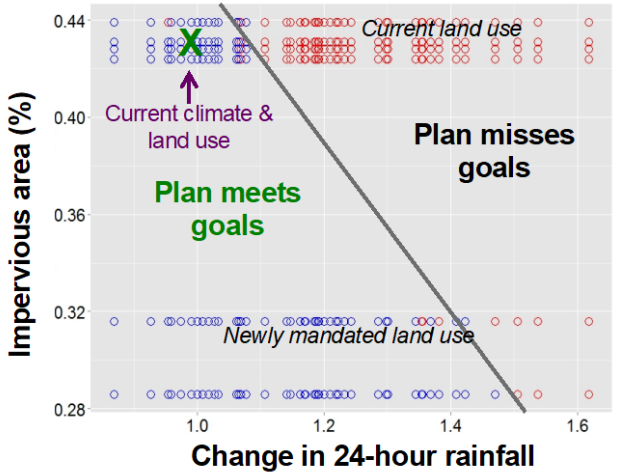

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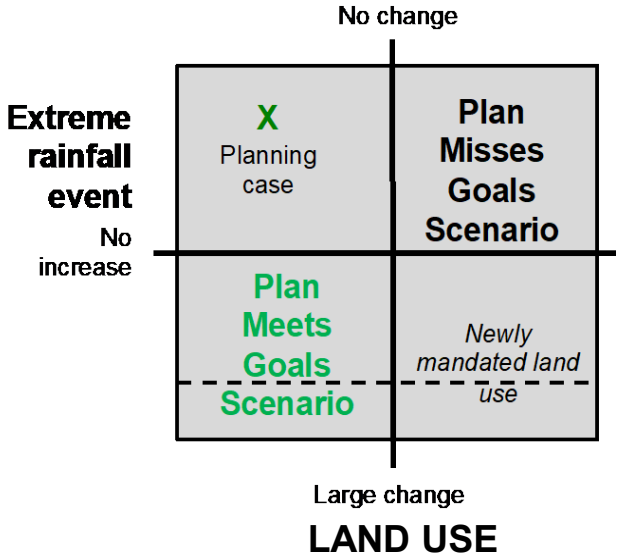
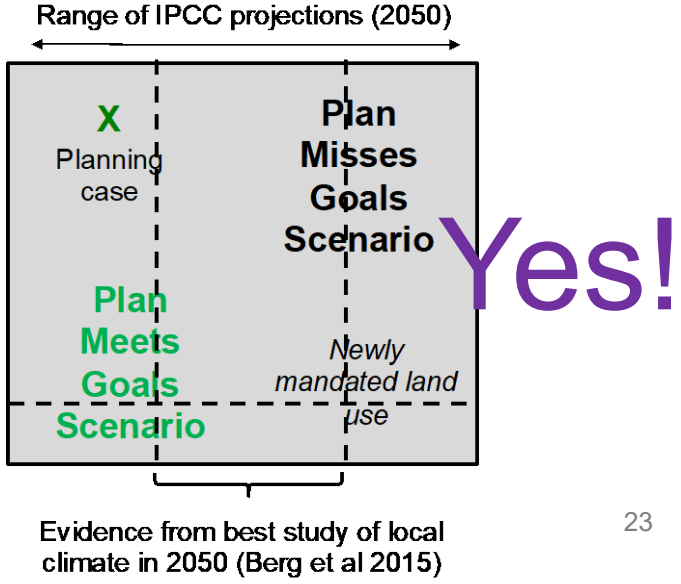


4) Compare to available science



Identify More Robust Strategies

Checklist of steps in RDM process

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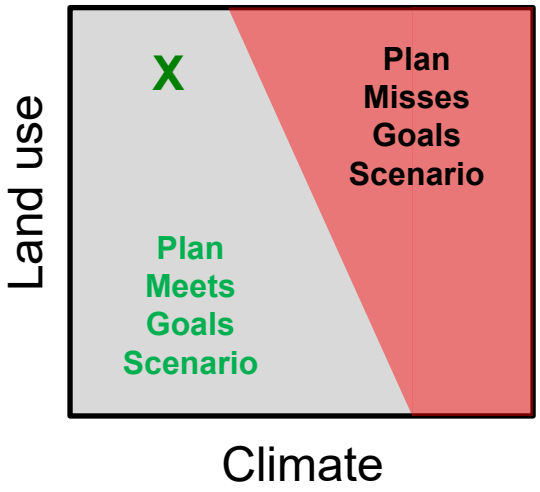
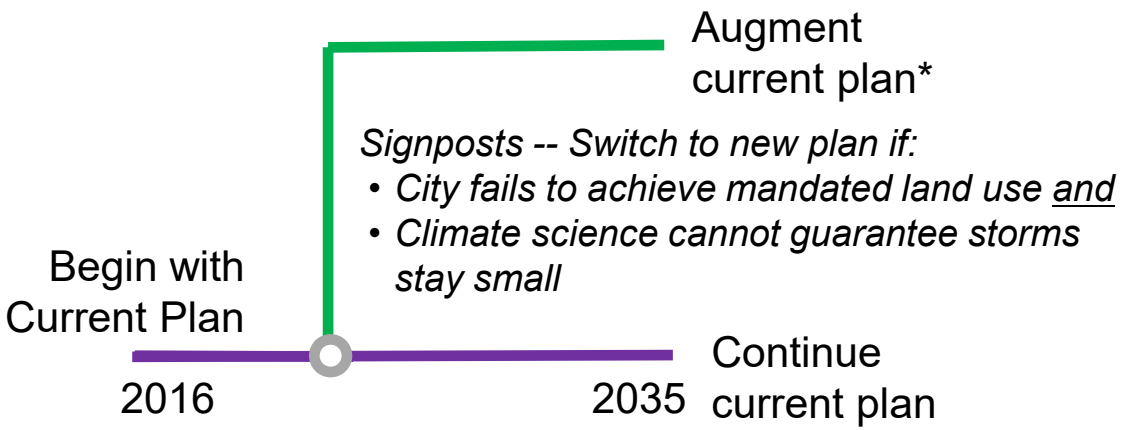
Stress Test Results Suggest Using a Robust, Adaptive Water Quality Implementation Plan

Consider an adaptive plan consisting of

- Near-term actions,
- Signposts to monitor, and
- Contingent actions if signposts are observed

Vulnerability analysis informs signposts



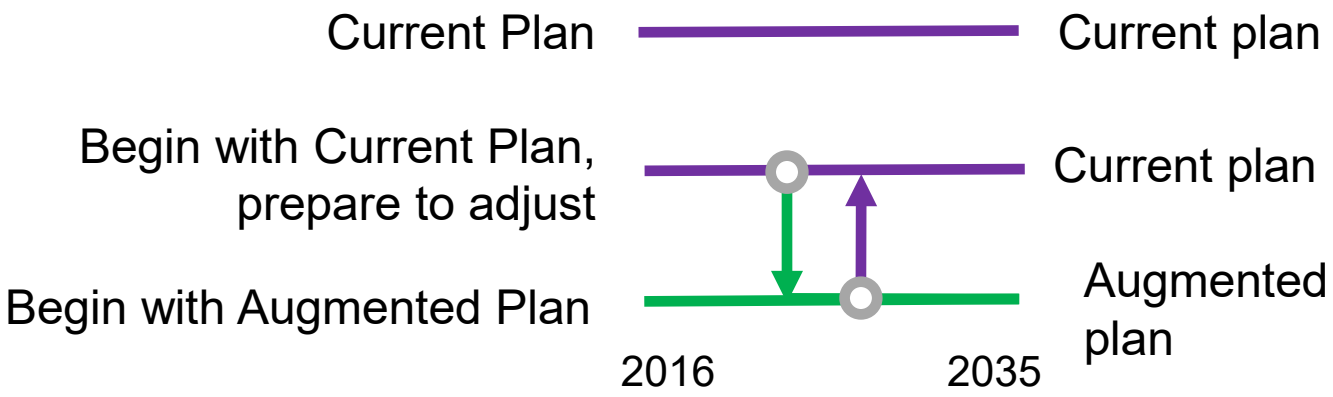


* Used optimization to identify augmented plan

Strategy & Context → Stress Test → New & Revised Strategies

Should Decision Makers Adopt This Adaptive Plan?

Consider three alternative plans



Note: RDM is designed to illuminate tradeoffs for people to evaluate, rather than dictate optimal solutions

Compare Tradeoffs Over Multiple Objectives and Multiple Scenarios

Start with multi-objective tradeoff analysis for one scenario

Begin with Augmented Plan

Begin with Current Plan, prepare to adjust

Current Plan

Plan Meets Goals Scenario	
Water quality	Cost
Yes	Highest
Yes	Slightly higher
Yes	Lowest

Strategy & Context → Stress Test → New & Revised Strategies

Help Decisionmakers to Compare Tradeoffs Among Alternative Strategies

The strategies perform very differently across the two scenarios

	Plan Meets Goals Scenario		Plan Misses Goals Scenario	
	Water quality	Cost	Water quality	Cost
Begin with Augmented Plan	Yes	Highest	Yes	Lowest
Begin with Current Plan, prepare to adjust	Yes	Slightly higher	Yes	Slightly higher
Current Plan	Yes	Lowest	No	Highest

The adaptive "Begin with current plan, but prepare to adjust" plan represents a "low regret" strategy

In general, a robust strategy is one that:

- Performs well over a wide range of plausible futures,
- Keeps options open, or
- Trades some optimal performance for less sensitivity to broken assumptions

Key Attributes of What You Just Saw

- Multi-scenario, multi-objective analysis which builds on agency's single scenario analysis
- Many model runs clustered into two policy-relevant scenarios
- Probability ranges used to interpret implications of scenarios, not as an input to the analysis
- Adaptive strategy used achieve robust strategy

Outline

Introduction

DMDU Methods

- Scenario planning
- Adaptive pathways
- RDM and variants

Getting Started

Alternative DMDU Approaches Available

- **Scenario planning** develops robust strategies from scenarios that people create
- **Adaptive pathways** provides a framework for developing strategies that adjust over time
  - Works especially well when the ”tipping points” are simple
- **RDM** proves useful for more complicated vulnerabilities,
  - Scenarios emerge from analysis and often depend on combinations of climate and socio-economic factors
  - Need to start with a proposed strategy
- **Decision scaling** focuses on vulnerability analysis, in particular vulnerabilities associated with climate change
  - Reduces reliance on climate models

Outline

Introduction

DMDU Methods

Getting Started

DMDU Is Part of "Mainstreaming" Climate Adaptation into Your Organization

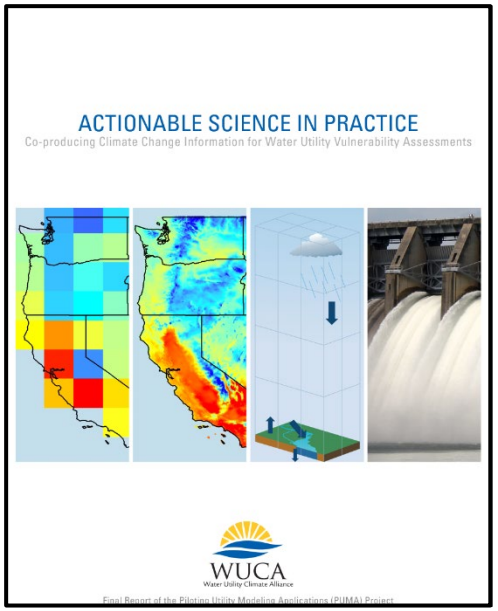
Most important step is to get started

- Conduct a climate vulnerability analysis
- Use scenario planning
- Recruit a scientific climate advisory panel

You can adopt DMDU incrementally, augmenting each planning cycle

One Potential Sequence for "Mainstreaming" DMDU into Your Organization

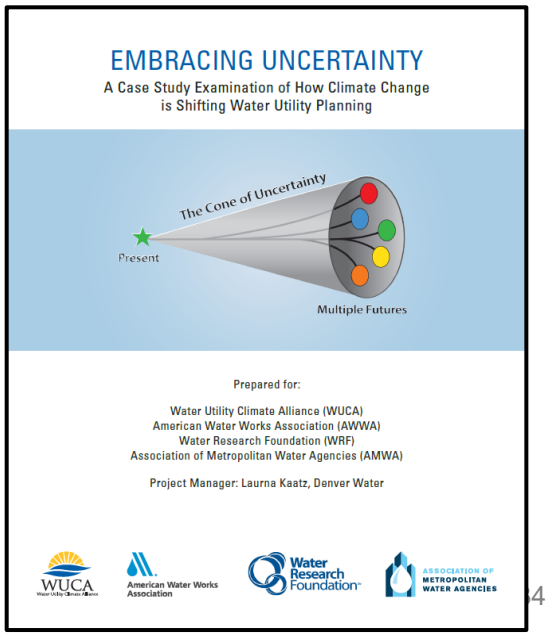
1. Embrace concepts of multiple futures, robust and flexible strategies
2. Employ qualitative methods and/or separate, piecework analyses
3. Then begin running your system models over multiple futures to i) stress test plans and ii) identify and evaluate robust and flexible plans



These WUCA documents can help

Actionable Science in Practice

Embracing Uncertainty



Resources Becoming More Available to Help Implement DMDU Methods

There now exists:

- Open source software for implementing most DMDU methods
- Increasing numbers of case studies
- Many groups able to help

THE SOCIETY FOR Decision Making under Deep Uncertainty

www.deepuncertainty.org

Some examples of RDM & other DMDU analyses

DMDU Methods and Tools Can Help Water Managers Address Today's Uncertain Conditions

Our current and future climate is not the same as past climate, and no one is sure exactly how it has and will change

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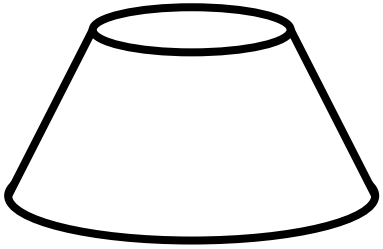

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Poll #6

How are you feeling now about scientific uncertainty in the context of climate change adaptation decision making?