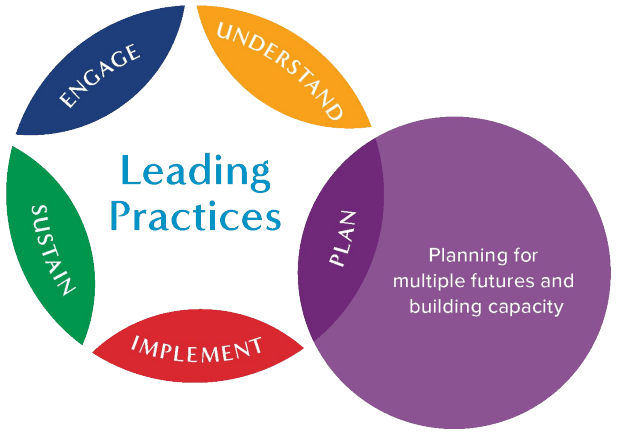
Building Resilience to a Changing Climate:
A Technical Workshop in Water Utility
Decision Support and Adaptation

WUCA
Water Utility Climate Alliance

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

Robert Lempert, RAND



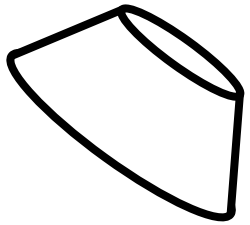
You've Received Much Advice So Far

- 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?

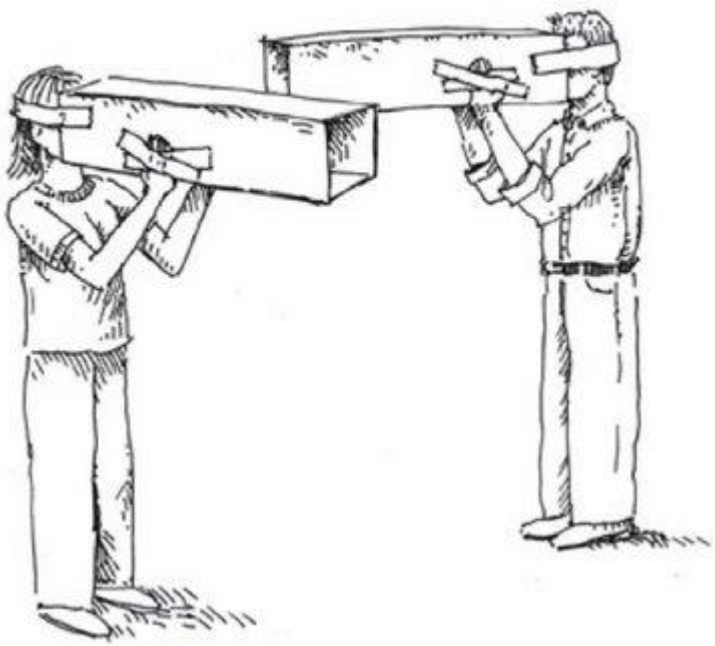
Predict

Act

These are sometimes called "optimization methods"

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

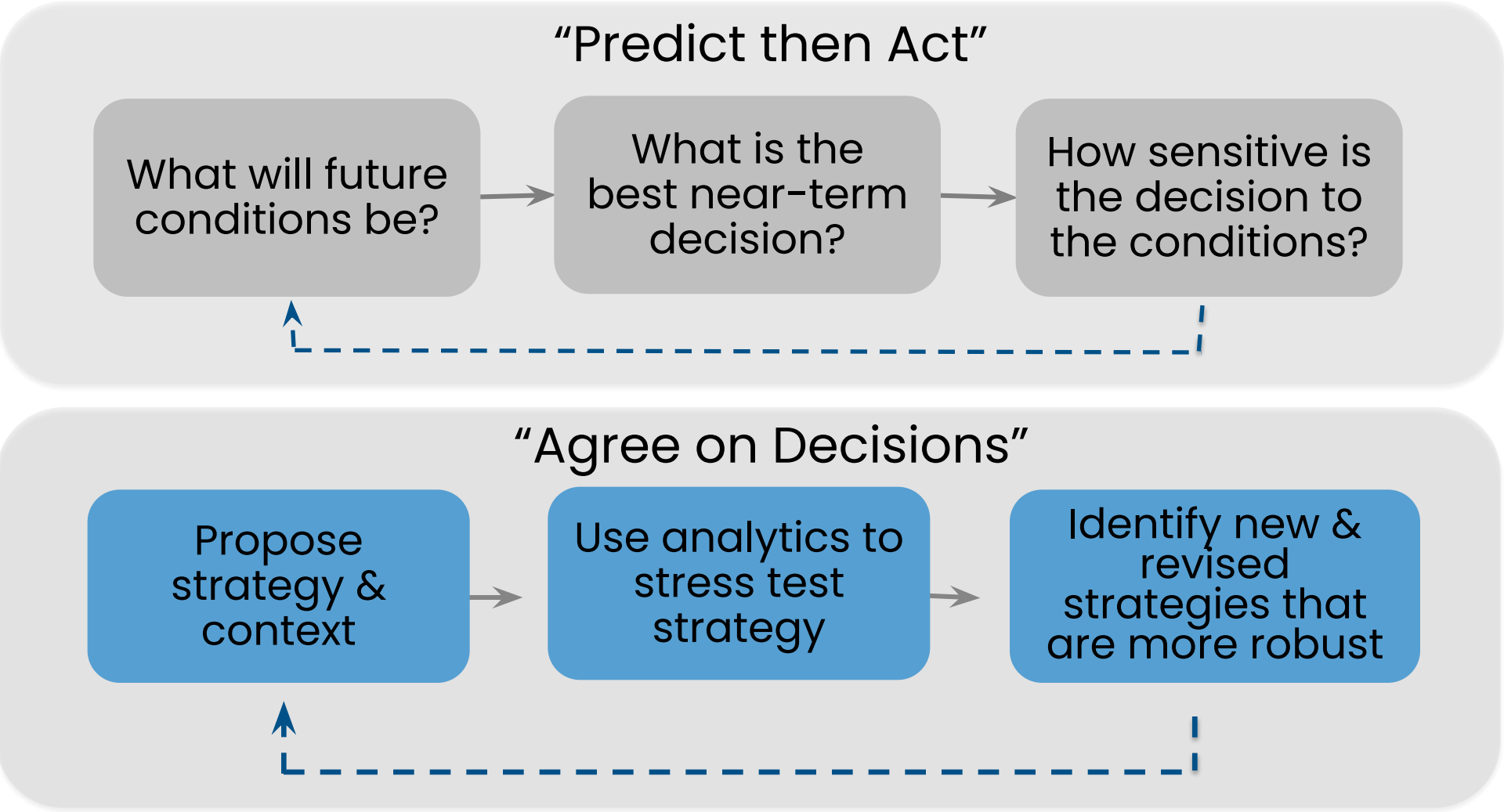
“Predict then Act” Can Break Down When Uncertainties are Deep



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

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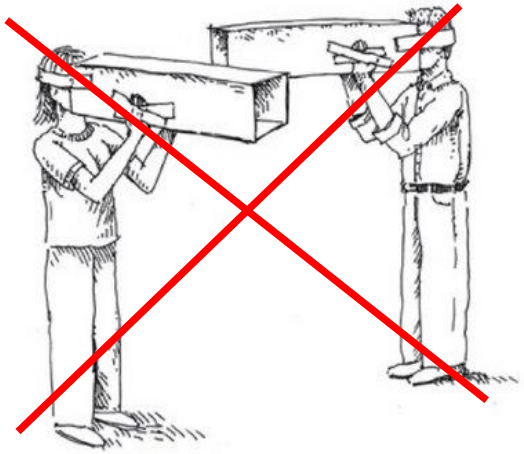
Plan over multiple



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

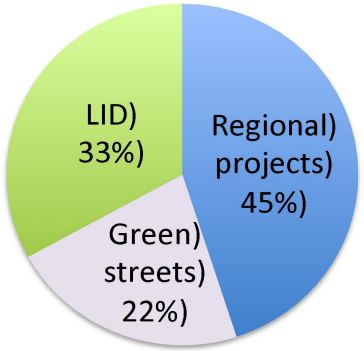
DMDU Example

Alternative DMDU Approaches

Robust Decision Making (RDM) Is One Important DMDU Approach

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)*

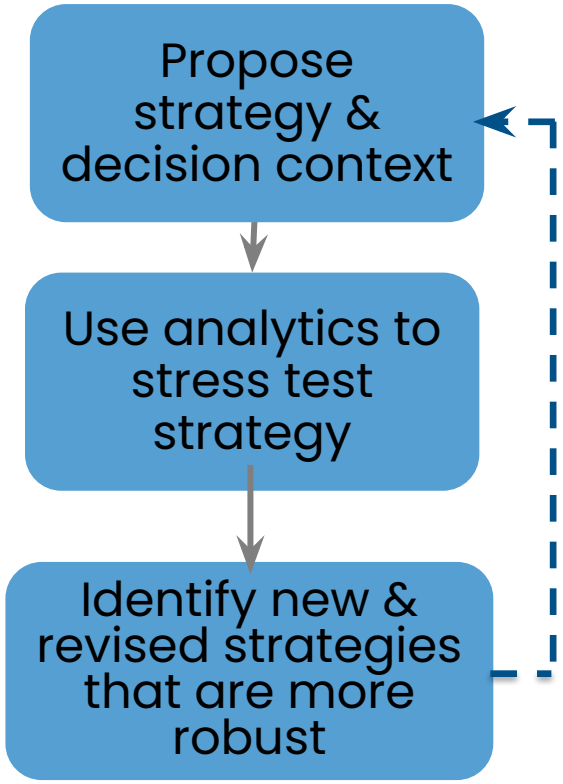
A. Tariq et. al., (2017) "A Climate Stress Test of Los Angeles' Water Quality Plans," Climatic Change

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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Let's Use RDM to Answer this Question

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 R's and X's

Stress Test LA's Water Quality Plans

Checklist of steps in RDM process

- [x] 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?
- [x] Stress test proposed strategies over a wide range of futures
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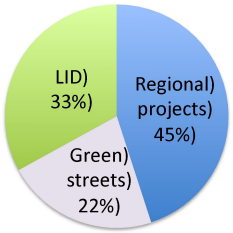
Stress Test Proposed Plan Over a Wide Range of Futures

How Can Los Angeles Meet Water Quality Goals In the Face of Climate Change?

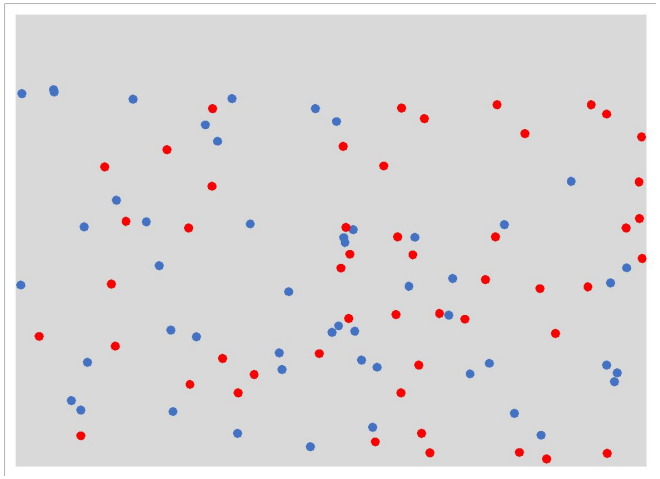
- Stress test plan over a wide range of plausible futures

The Plan



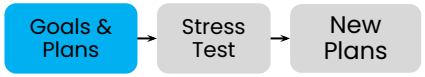
Uncertainties

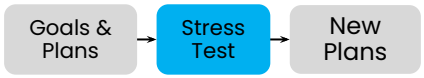
- Land use
- Climate change



Blue: plan meets goals

Red: plan misses goals





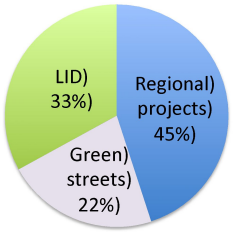
A. Tariq et. al., A Climate Stress Test of Los Angeles' Water Quality Plans, Climatic Change (2017)

Stress Test Proposed Plan Over a Wide Range of Futures

How Can Los Angeles Meet Water Quality Goals In the Face of Climate Change?

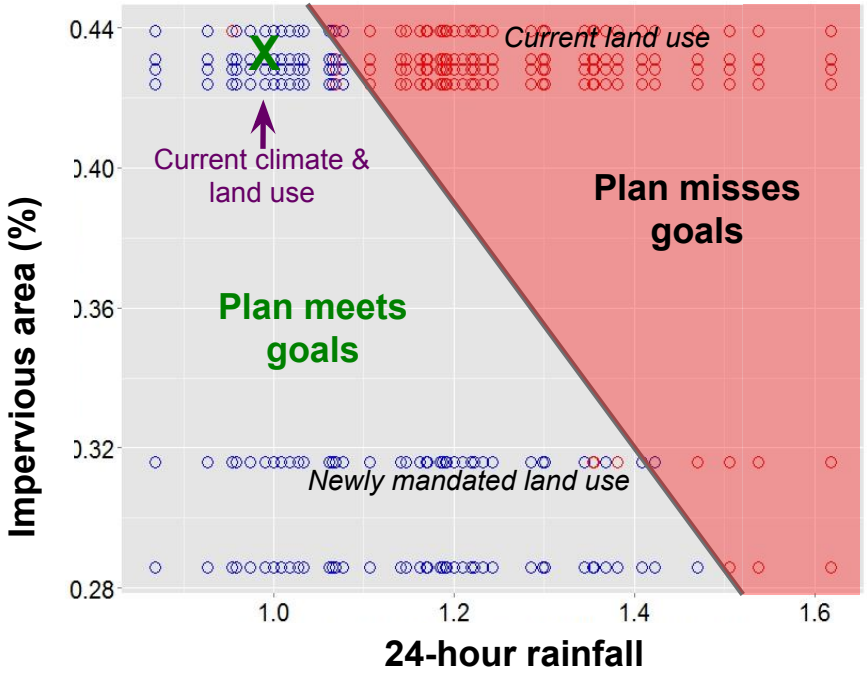
- Stress test plan over a wide range of plausible futures
- Use this data to identify scenarios that illuminate the plan's vulnerabilities

The Plan



Uncertainties

- Land use
- Climate change

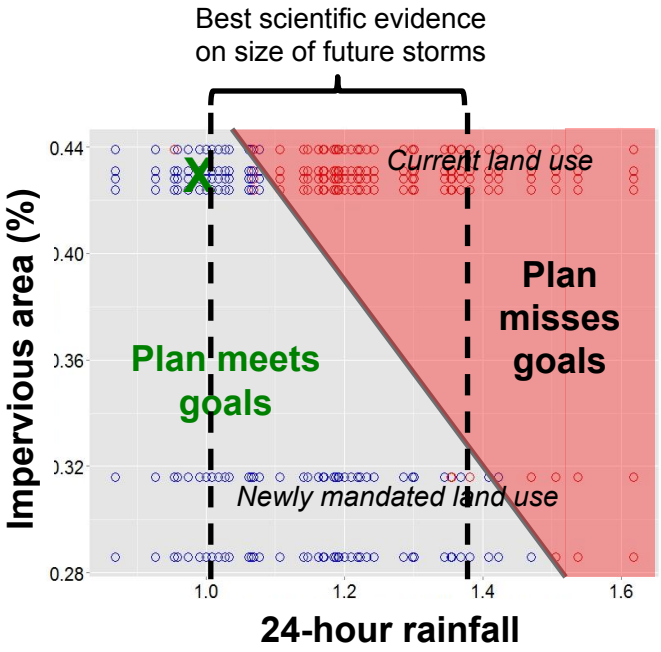


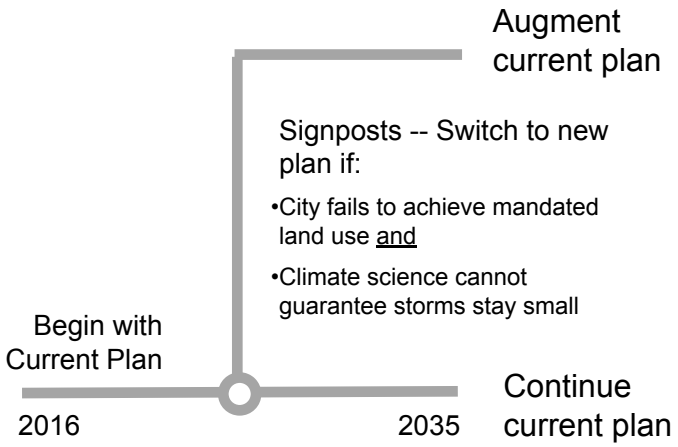
Goals & Plans → Stress Test → New Plans

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

Resulting Scenarios Inform the Design of Robust Adaptive Strategies

Robust plan consists of current plan, signposts to monitor, and contingent actions if signposts are observed





Goals & Plans → Stress Test → New Plans

Help Decisionmakers to Compare Tradeoffs Among Alternative Strategies

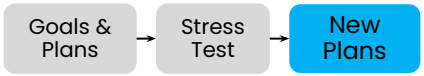
The strategies perform very differently across the two scenarios

	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



What Did We Miss? (Confronting Surprise)

- After conducting the analysis, we asked “what is missing from the model that might change our views on the robust strategy?”
- Our best answer:
  - We assumed zinc was the limiting pollutant
  - In Los Angeles, zinc runoff mostly comes from automobile brakes
  - If most cars become EV’s with regenerative braking, zinc may no longer be the limiting pollutant

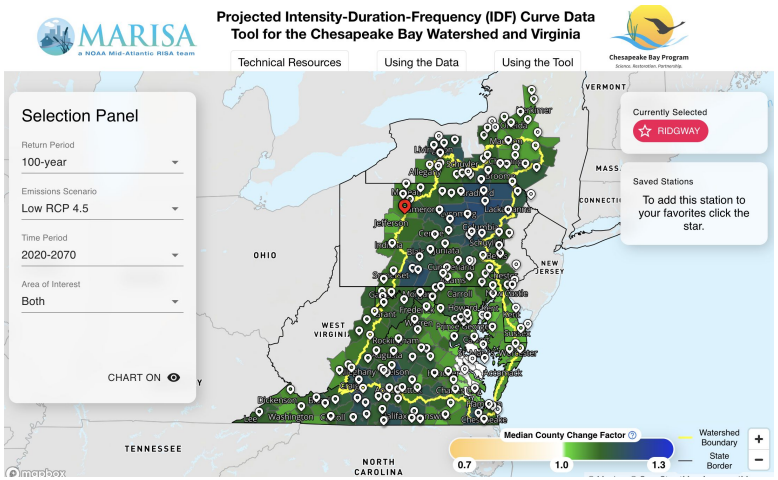
Goals & Plans → Stress Test → New Plans

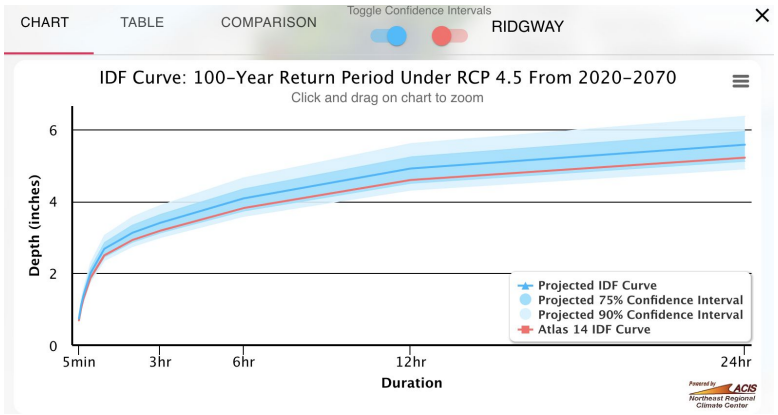
Key Attributes of What You Just Saw

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

Data Increasingly Available to Support Such Analyses

Mid-Atlantic RISA (MARISA) developed projected IDF curves for stress testing plans





https://midatlantic-idf.rcc-acis.org/

- Tool provides climate change-adjusted IDF curves for the Chesapeake Bay watershed and Virginia for stormwater managers
- Tool includes data from multiple downscaled climate model datasets, GCMs and RCPs
- Users can examine the full range of IDF curve values, select a value, or stress test their system against the future changes
  - Can be used as inputs to hydrologic and hydraulic models to look at uncertainty in floodplains from climate change
- Tool was co-developed with the Chesapeake Bay Program Urban Stormwater Workgroup and the State of Virginia

Outline

Introduction

DMDU Example

Alternative DMDU Approaches

Several Different DMDU Approaches are Available

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

All are variations on similar themes

Several Different DMDU Approaches are 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

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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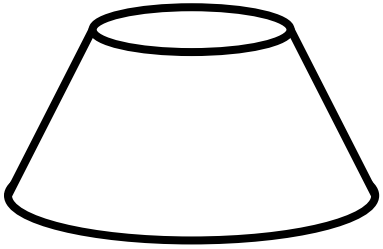

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