

SESSION IV: Pop-Up Talks

- 1) Adam Whitmore, Adam Whitmore Consulting
 - 2) Bessma Maroud, Skoll Global Threats Fund
 - 3) Steve Moncaster, Anglian Water
 - 4) Mike Steel, Environment Agency
- Specialist: **David Groves**





Preparing for an Uncertain Future

Developing Robust Climate Adaptation Plans in the Water Sector

February 2016



David Groves, PhD
Water and Climate Resilience Center (www.rand.org/water)



Uncertainty underlies almost every aspect of climate adaptation planning

- How might the **climate** change?
- How might **other uncertain drivers** interact with climatic changes to impact society?
- How can we evaluate **many potential futures** objectively?
- How do we **balance across many objectives**?
- How do we **support public dialogue** over choices?

Traditional decision methods can backfire in deeply uncertain conditions

- Uncertainties are underestimated
- Competing analysis can contribute to gridlock
- Misplaced concreteness can blind decisionmakers to surprise

Planners now require *technical analyses* that
support deliberations

“Deliberations with Analysis”

Innovative
Methods



Data-Driven
Participatory
Planning



Informing Decisions in a Changing Climate (National Research Council, 2009)

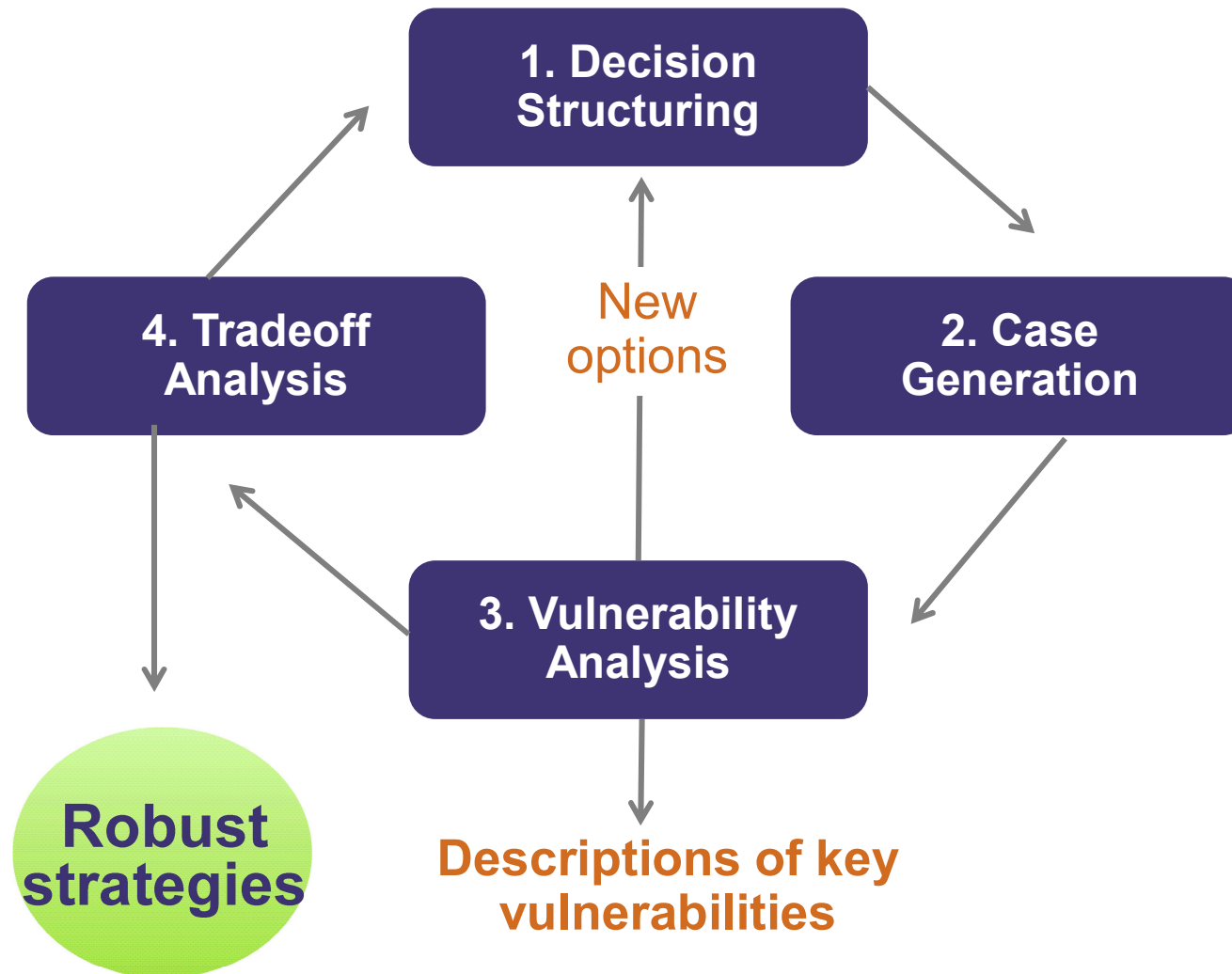
Methodologies go by different names and emphasize different aspects of the planning challenge

- Exploratory Analysis
- Robust Decision Making (RDM)
- Decision Scaling
- Multi-objective Robust Decision Making (MORDM)
- Dynamic Adaptation Pathways

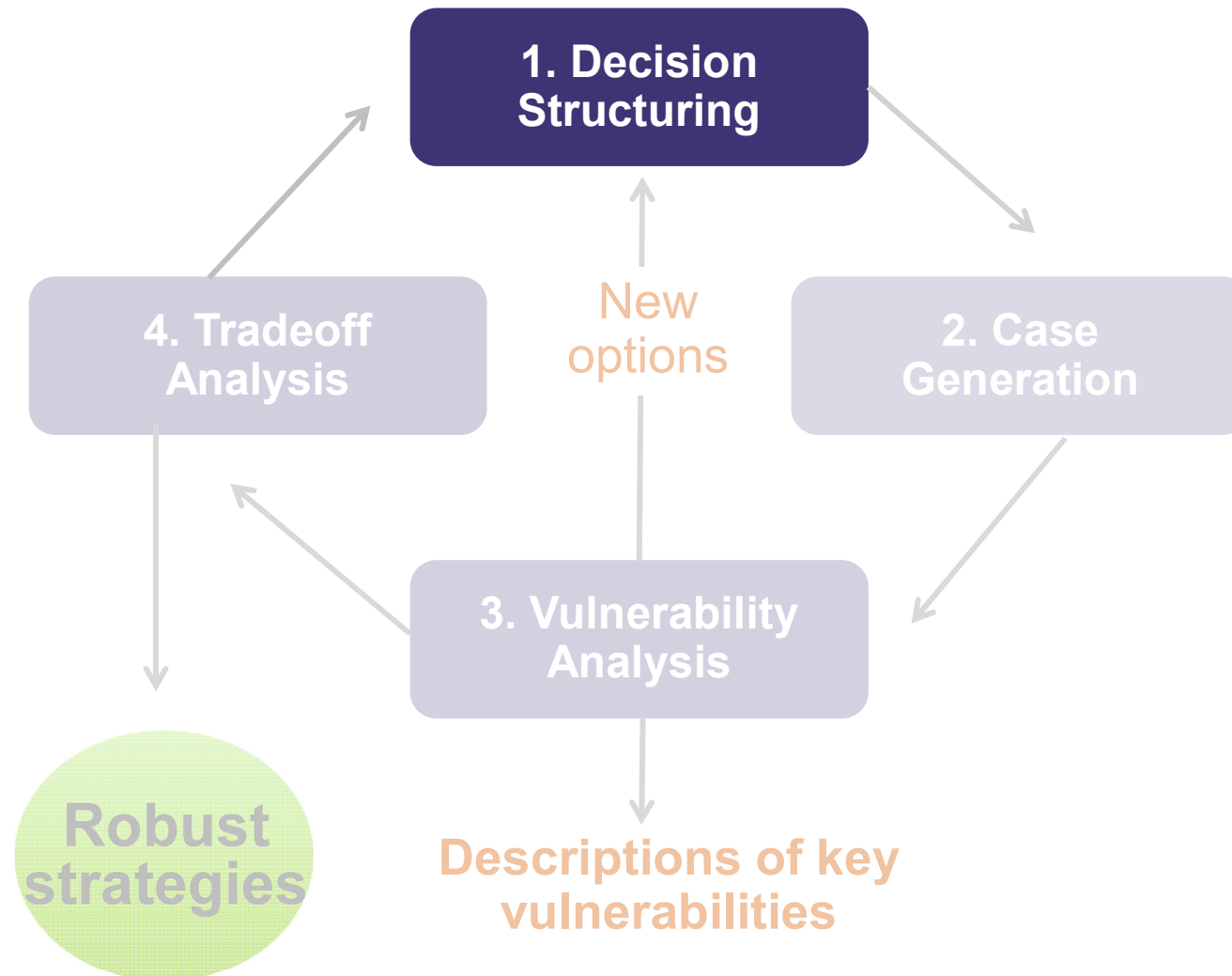
Key Concepts Underlying Decisionmaking Under Uncertainty Methods

1. Evaluate a multitude of futures
 - Reflecting what is plausible, not just most likely
 - Informed by best available science
2. Define candidate strategies
 - Interactive formulation
 - Pareto optimal solutions
3. Identify key vulnerabilities of candidate strategies
 - “Scenario discovery”
4. Develop robust strategies that adapt over time as the future unfolds
 - Thresholds and triggers
5. Highlight key tradeoffs and support deliberations
 - Distill analysis to irreducible tradeoffs
 - *Interactive visualization*

Robust Decision Making uses analytics to facilitate new conversations between decisionmakers



Decision structuring: decision stakeholders work to define objectives/parameters



Decision structuring produces information needed to organize simulation modeling in next RDM stage



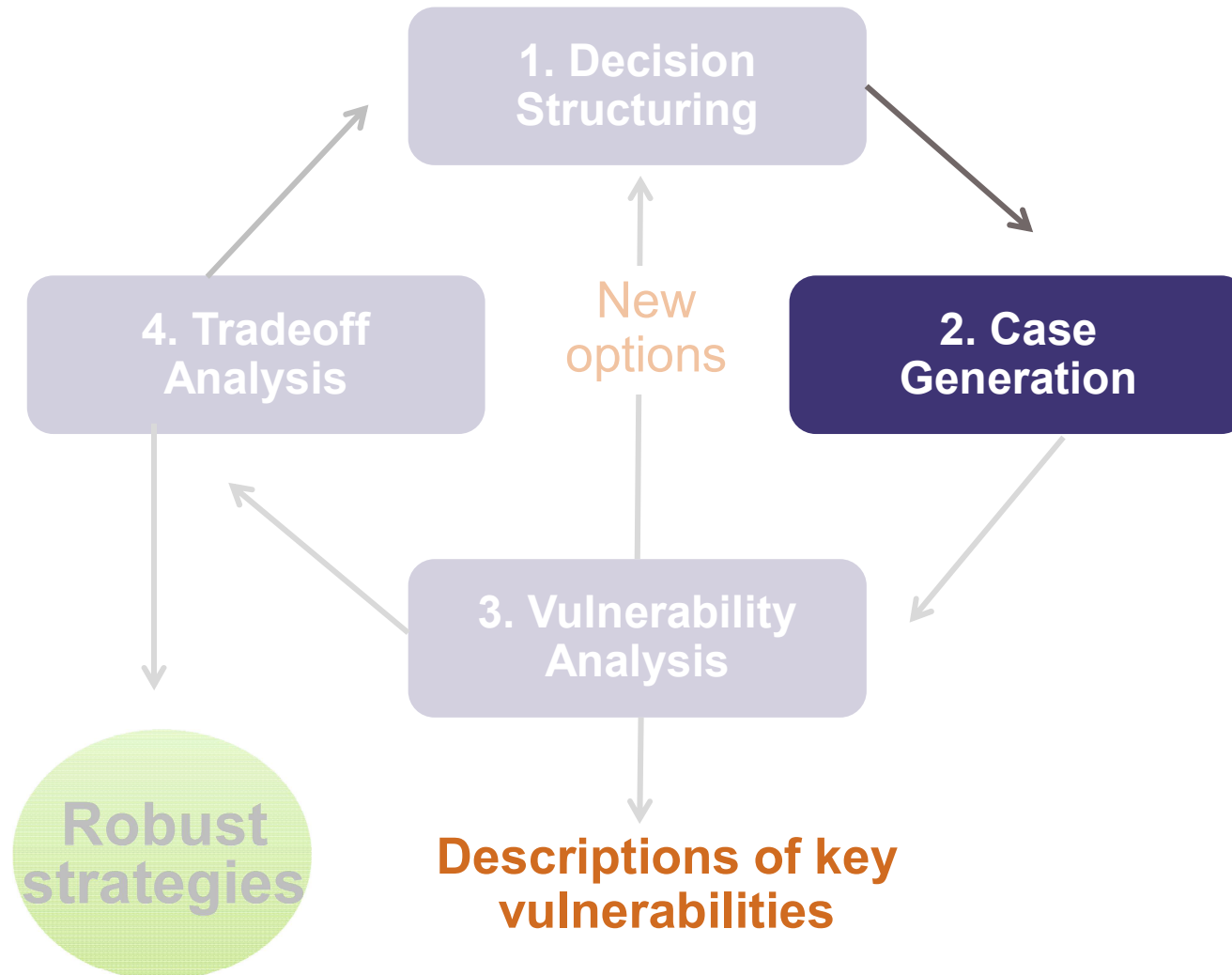
Information generated: XLRM

- **X**: Uncertain factors that may affect ability to reach goals
- **L**: Management strategies (levers) considered to pursue goals
- **R**: Relationships among metrics, levers, and uncertainties
- **M**: Metrics that reflect decision makers' goals

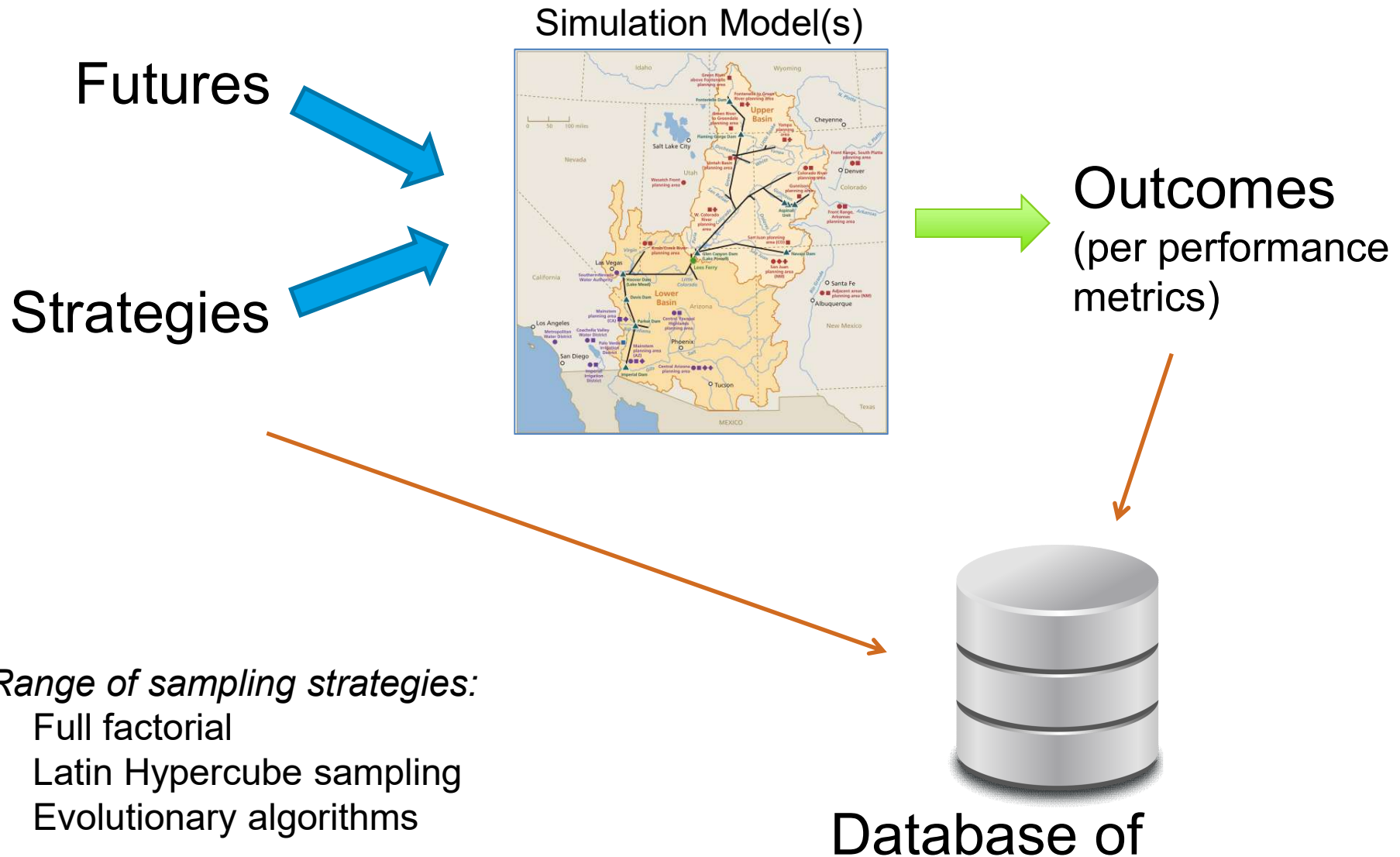
Different Approaches to Defining Candidate Strategies

- Use the “Current Plan”
- Survey stakeholders and compile portfolios of options
- Find the optimal solution for one or a few futures
 - Linear programming
 - Multiobjective Evolutional Algorithms (MOEAs)

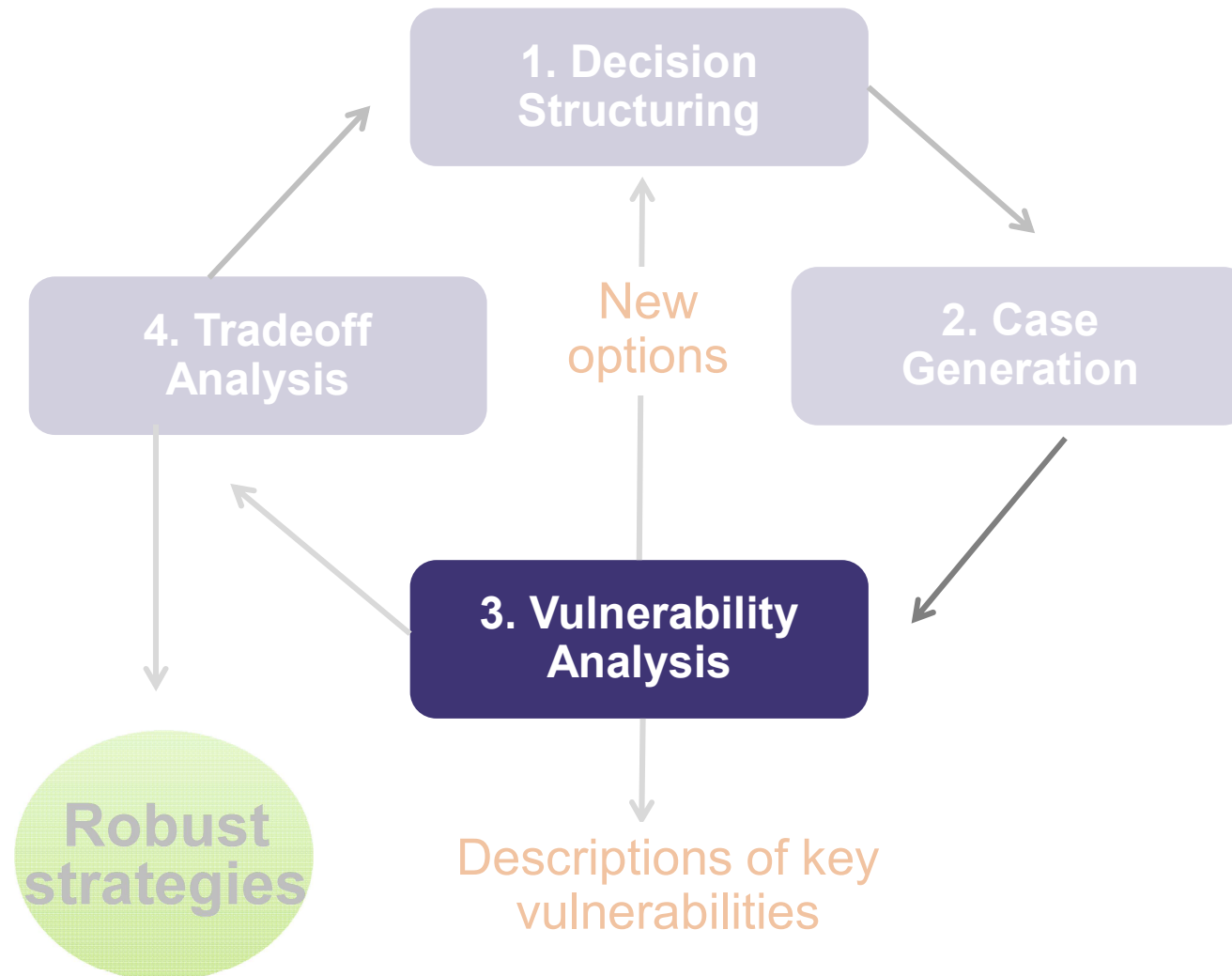
Case generation: evaluate strategy in each of many plausible futures



Models simulate outcomes across large sets of futures and strategies



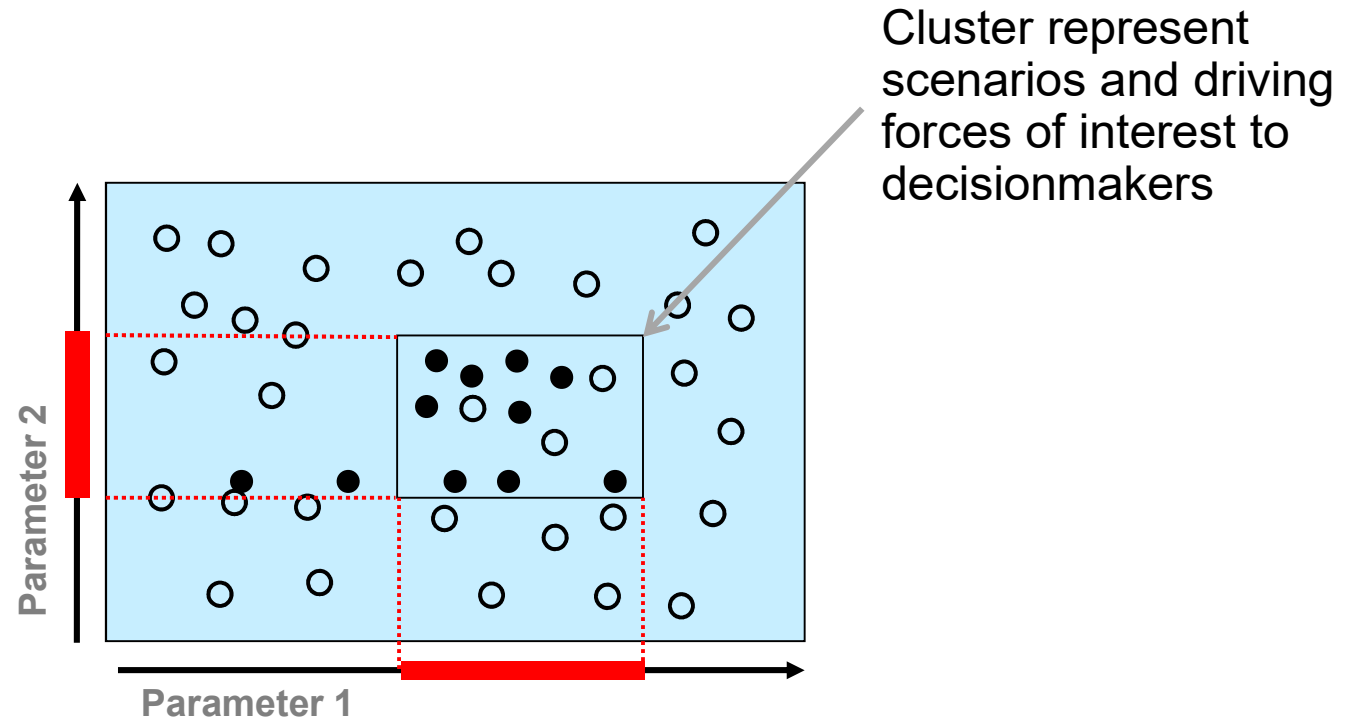
Vulnerability Analysis: Mine the database of cases to describe descriptions of key vulnerabilities



Vulnerability analysis defines future conditions that illuminate vulnerabilities of proposed strategy

1. Indicate relevant cases in database of simulation results

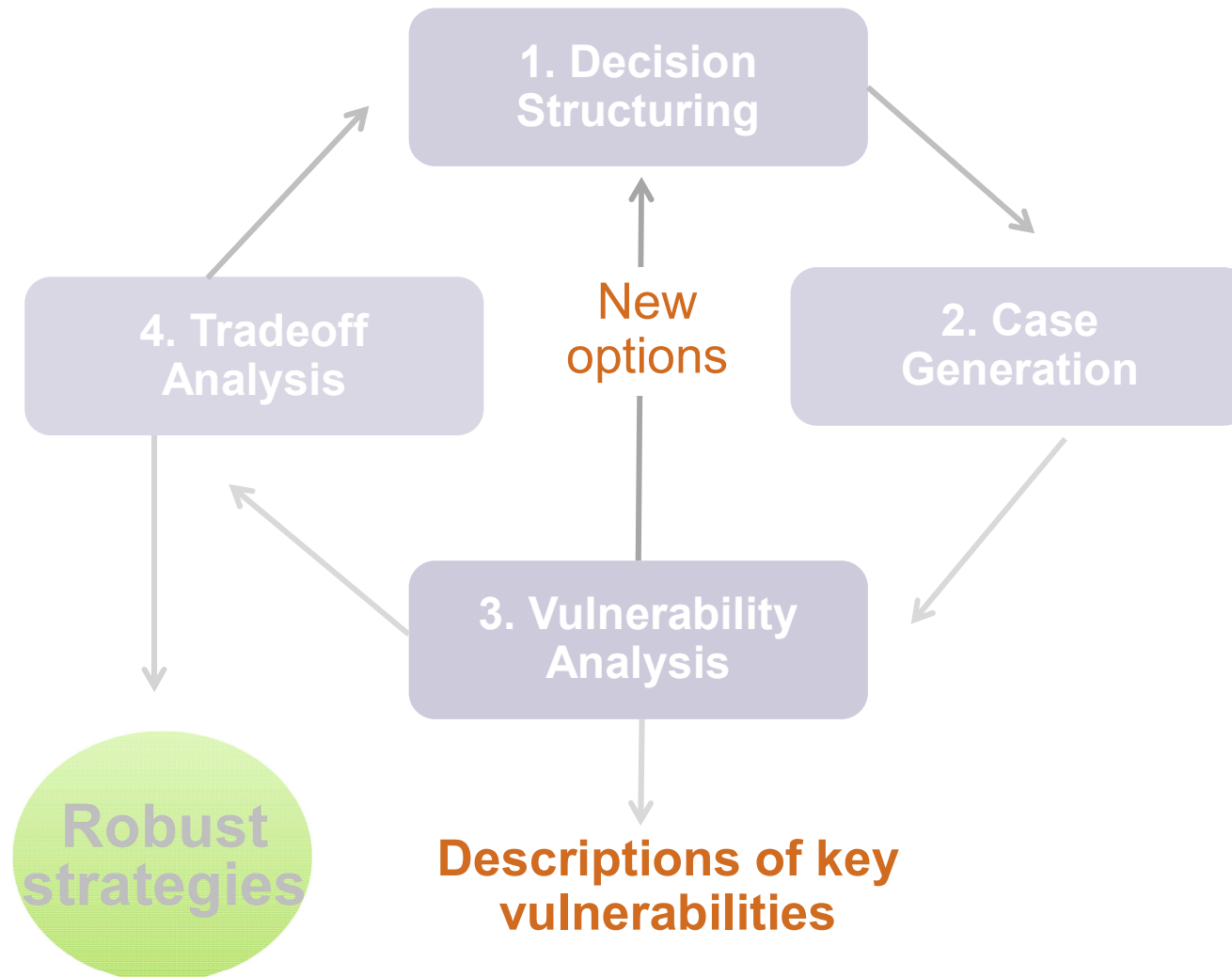
2. Statistical analysis finds low dimensional clusters with high density of these cases



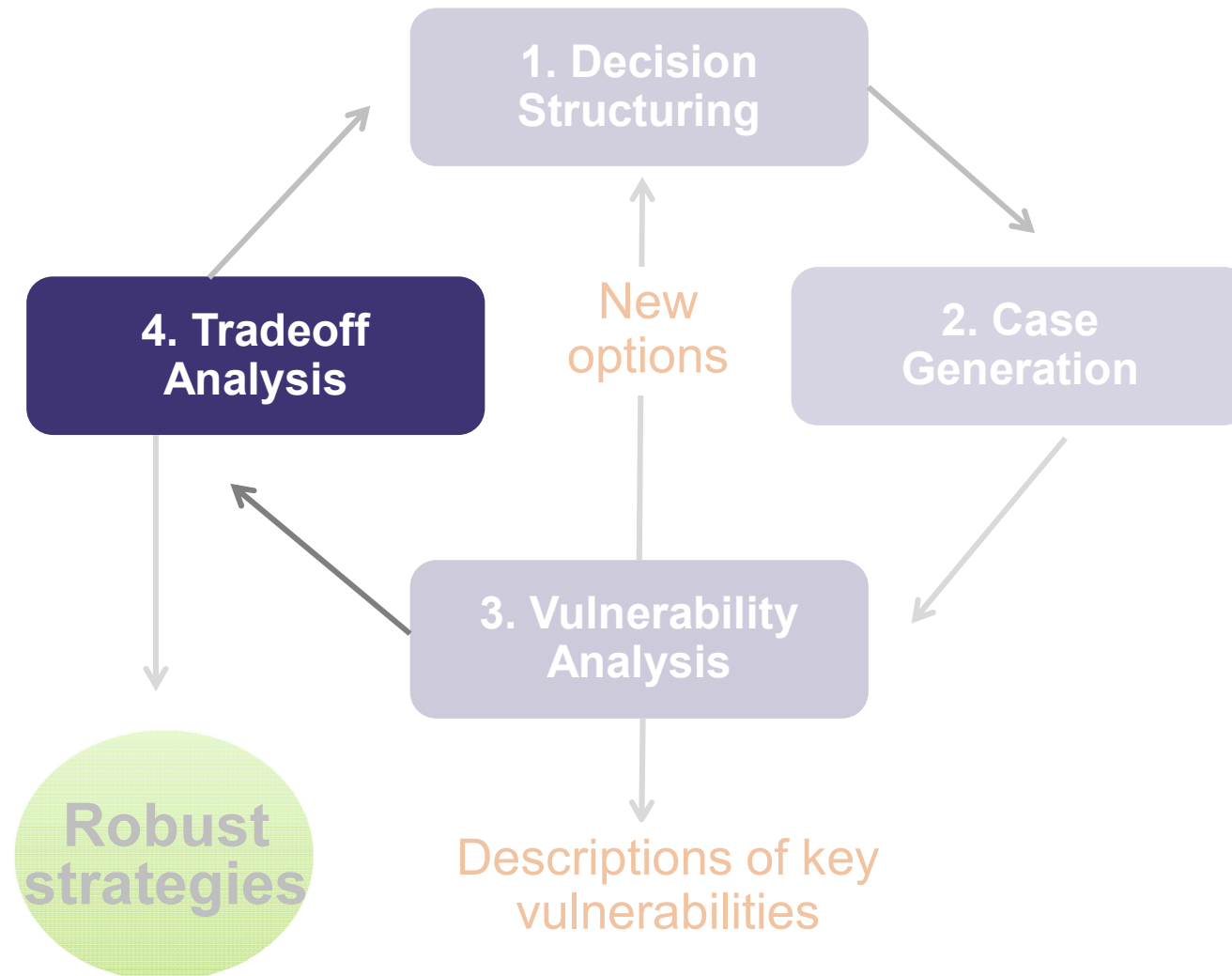
Scenario Discovery Methods:

- Patient Rule Induction Method (PRIM)
- Classification and Regression Tree (CAR)

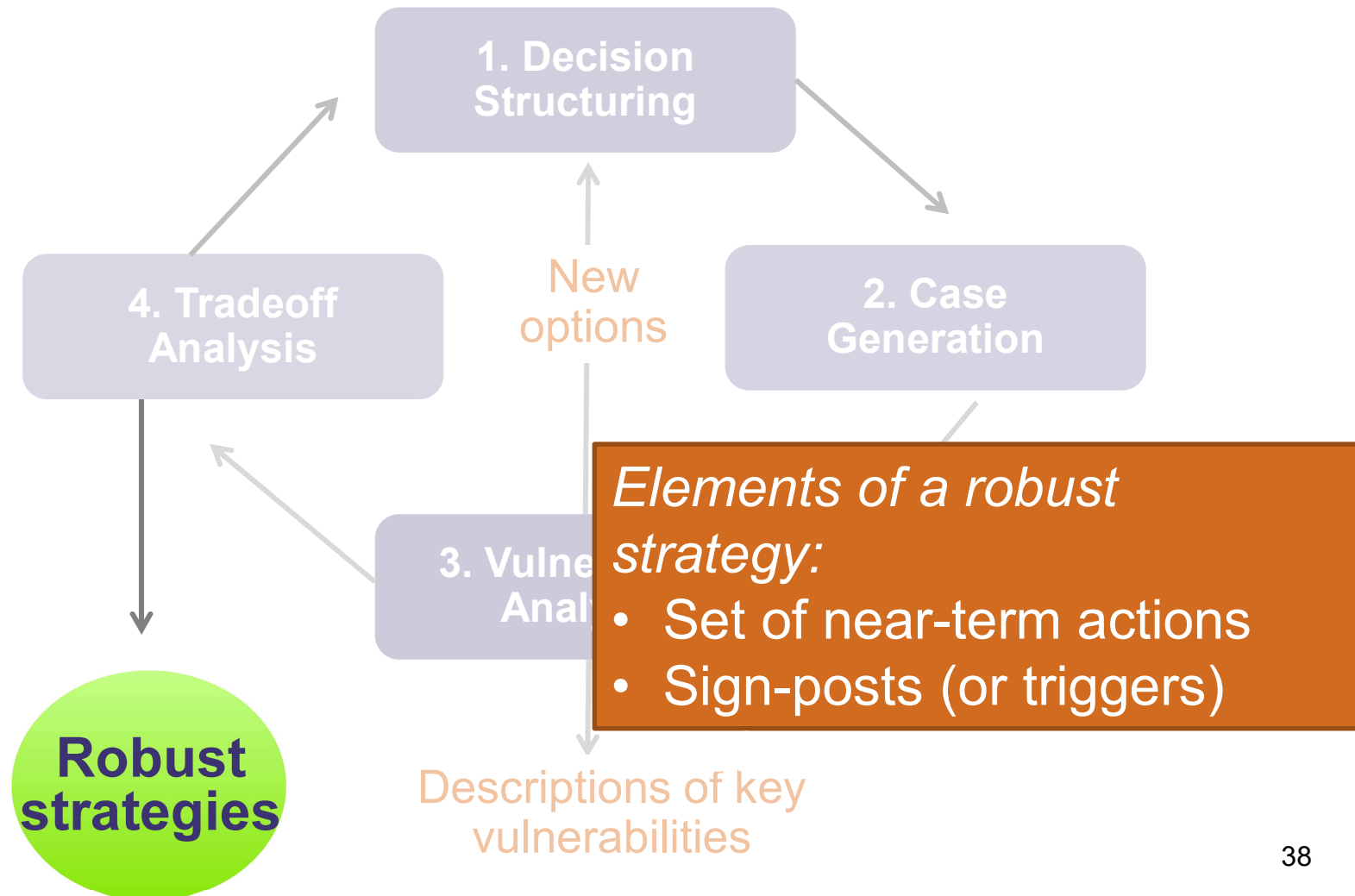
Vulnerability analysis provides information to design more robust strategies



Tradeoff Analysis: Allow decisionmakers to compare key tradeoffs among strategies...

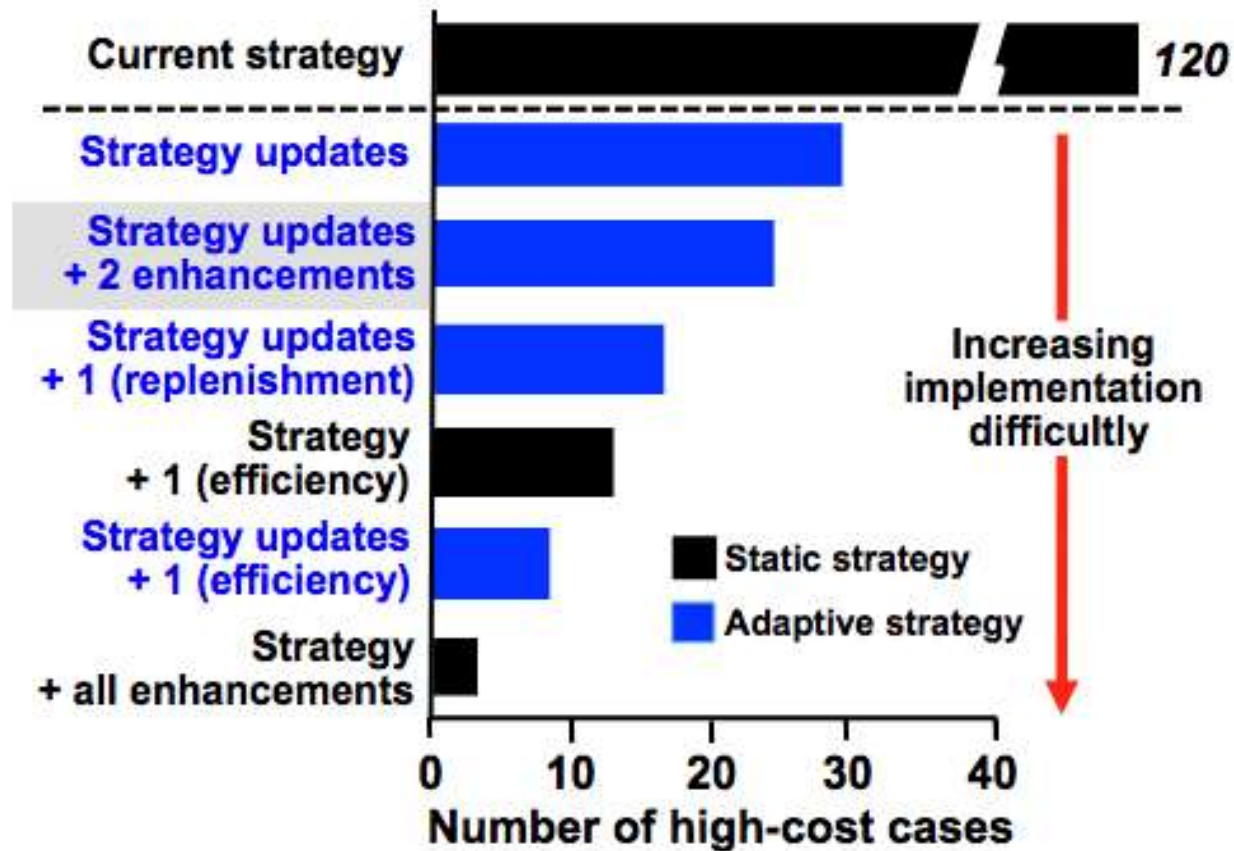


...and define robust strategies



Key Tradeoff Visualizations

Focus Decisionmaking on What Matters



This approach has been applied across the globe...

RAND applications



...and in many different settings

Water Resources
Planning



Community
Resilience



Coastal
Resilience



Flood Risk
Management





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Ensuring Robust Water Management Strategies in Lima-Callao, Peru

Nidhi Kalra | Director, RAND Center for Decision Making Under Uncertainty

David Groves | Director, RAND Water and Climate Resilience Center

Laura Bonzanigo | Policy Analyst, World Bank

Edmundo Molina Perez | RAND

Cayo Ramos | Professor, Catholic University of Peru

Ivan Rodriguez Cabanillas | Planner, SEDAPAL

Carter Brandon | Global Lead Economist, World Bank





Lima faces major water-related challenges

- 8.6M people
- Rapidly growing population
- Many industries

Lima faces major water-related challenges

- 6mm rainfall annually
- Depends on water from three river basins
 - Andean glaciers nearly gone
 - Andean rainfall is vulnerable to climate change

ZONA DE
MIRADOR

Lima faces major water-related challenges

- Persistent water shortages
- 1M underserved poor
- Competition among users





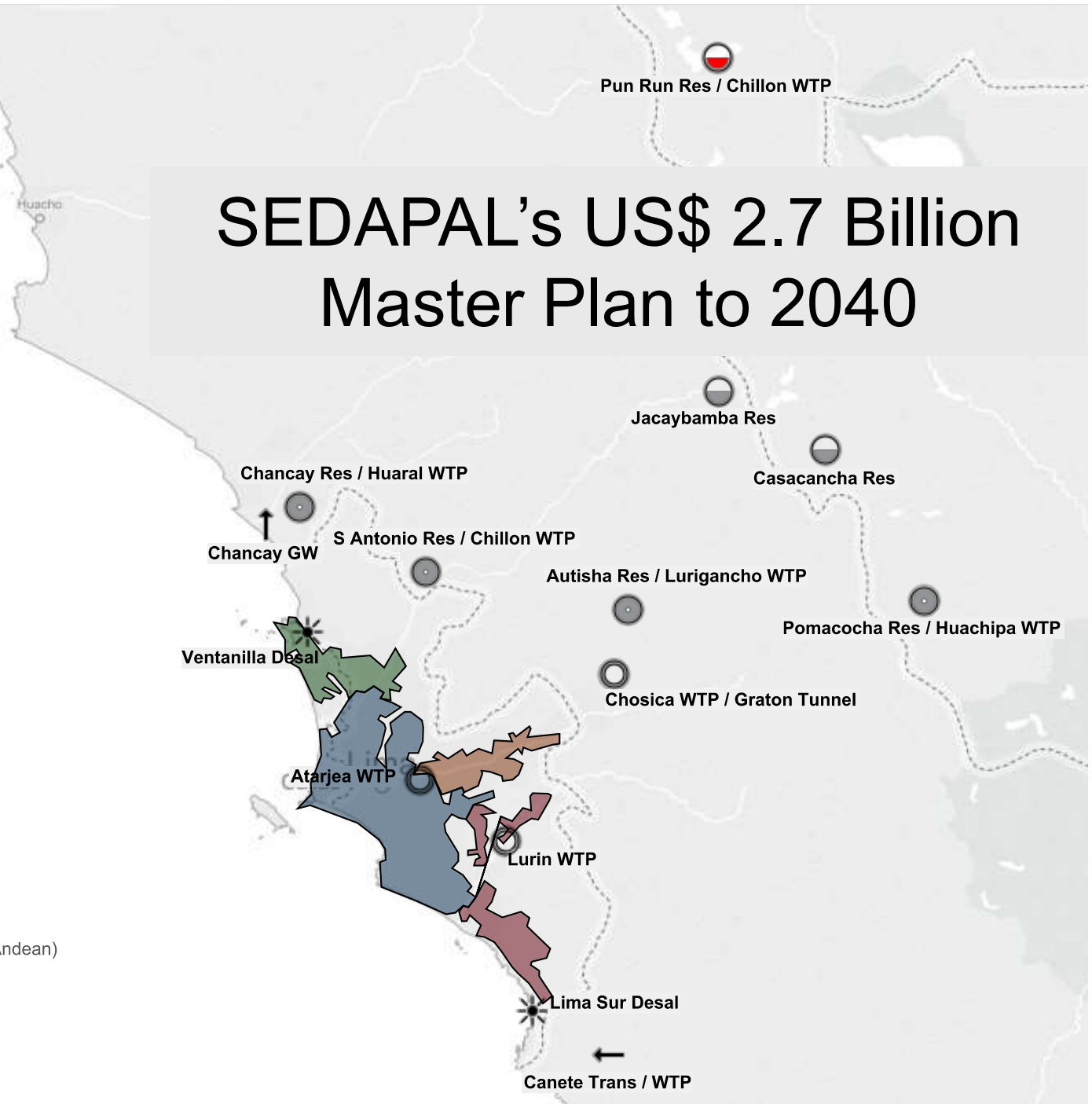
SEDAPAL's US\$ 2.7 Billion Master Plan to 2040

Demand Regions

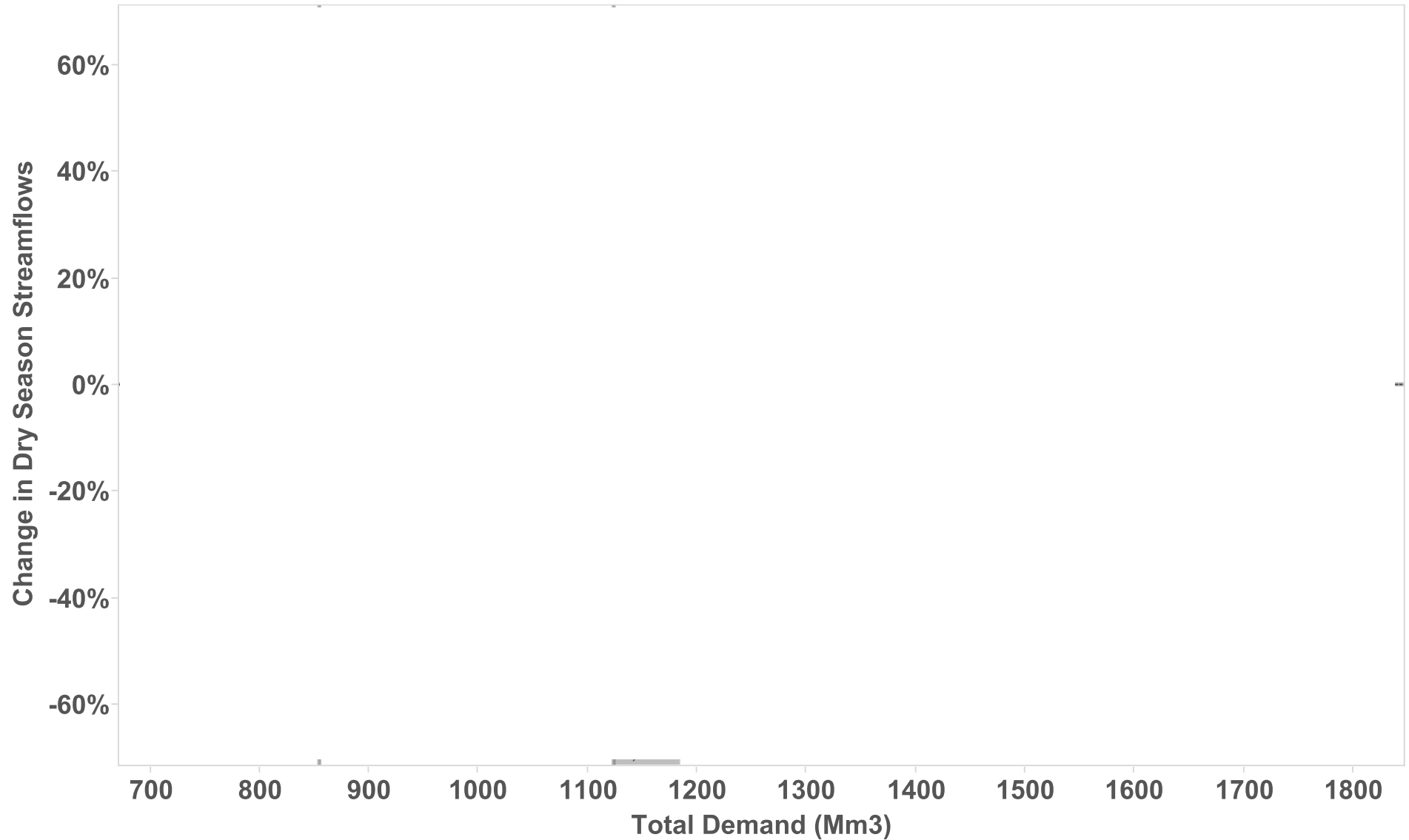
- Central Lima
- Eastern Lima
- Northern Lima and Callao
- Southern Lima

Project Type

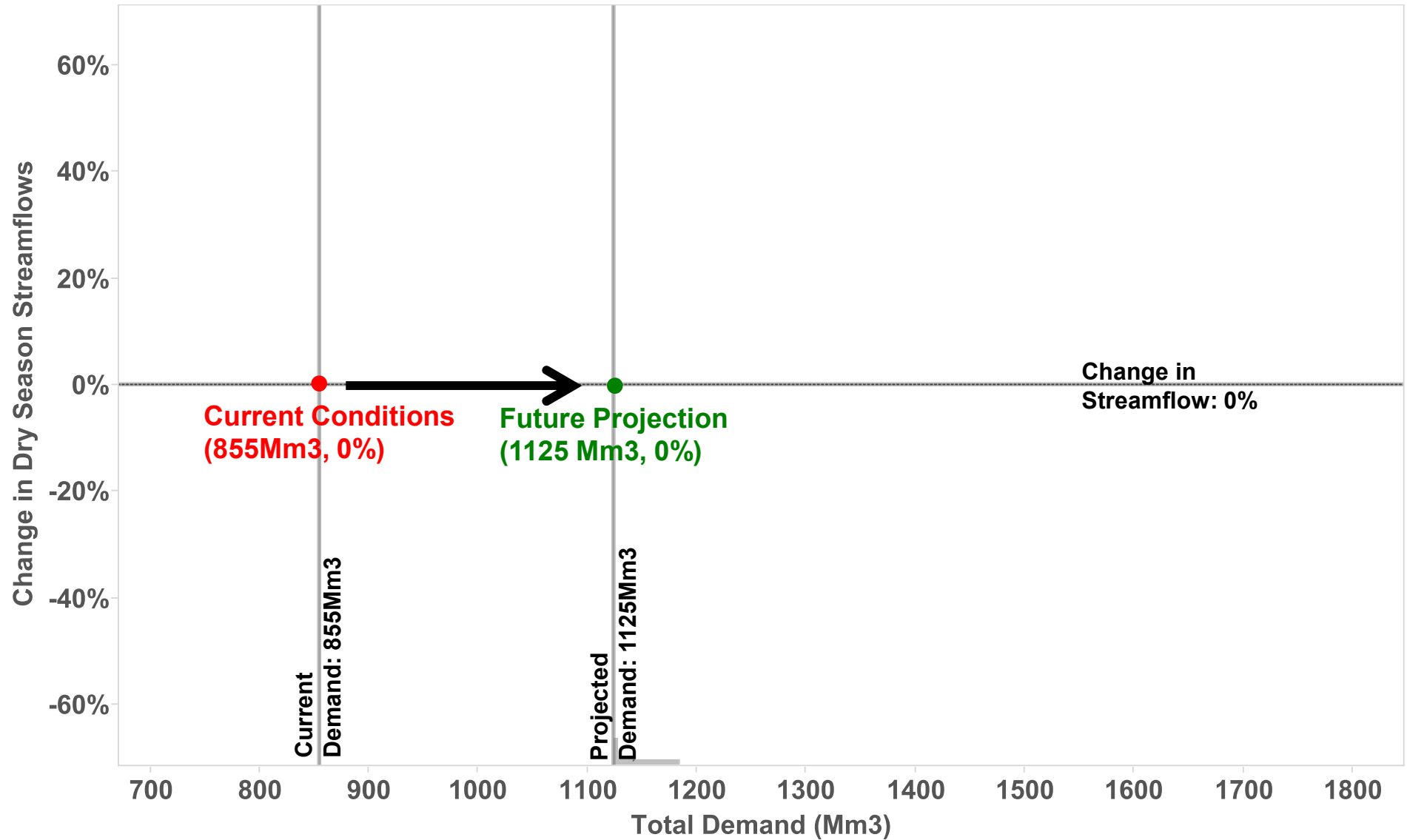
- Desalination Plant
- Groundwater
- Reservoir
- Reservoir and Water Treatment Plant
- Reservoir and Water Treatment Plant (trans Andean)
- Transmission and Water Treatment Plant
- Water Treatment Plant



SEDAPAL designed this plan by projecting historical trends forward

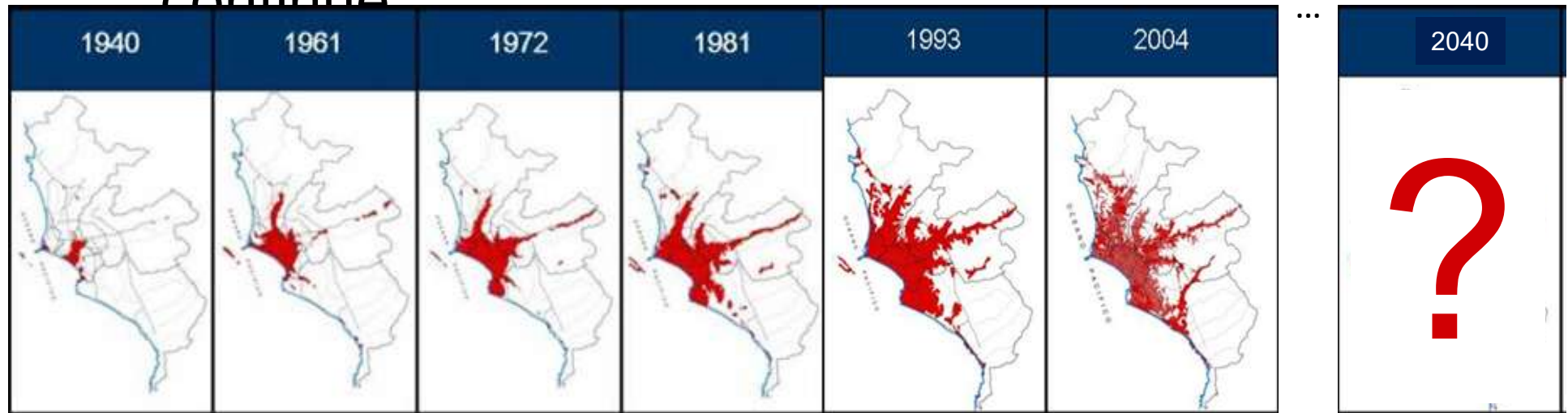


SEDAPAL designed this plan by projecting historical trends forward



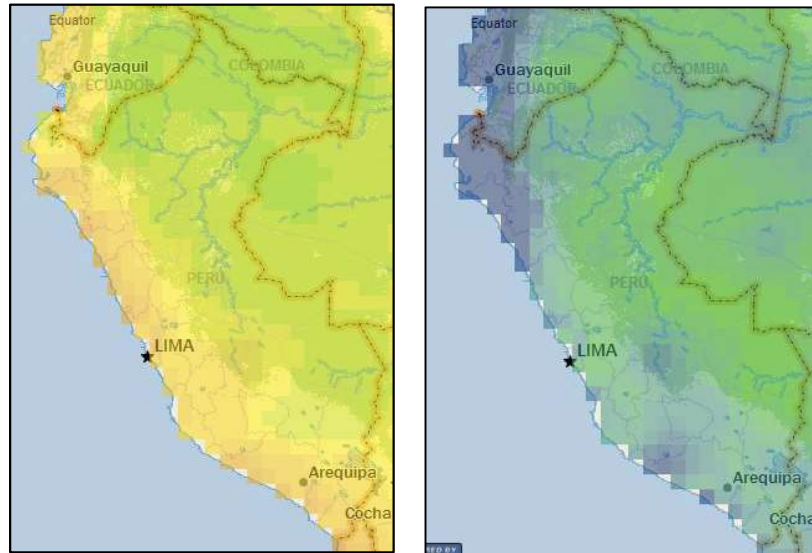
But future demand is deeply uncertain

- Rapid population growth may or may not continue



- Per-capita water use may change
 - Affluence → more water consumption
 - Better technologies → less water consumption

And future climate is deeply uncertain



*Much less
precipitation*

*Much more
precipitation*

-15%

+23%



- Climate projections disagree
- Droughts may become more common



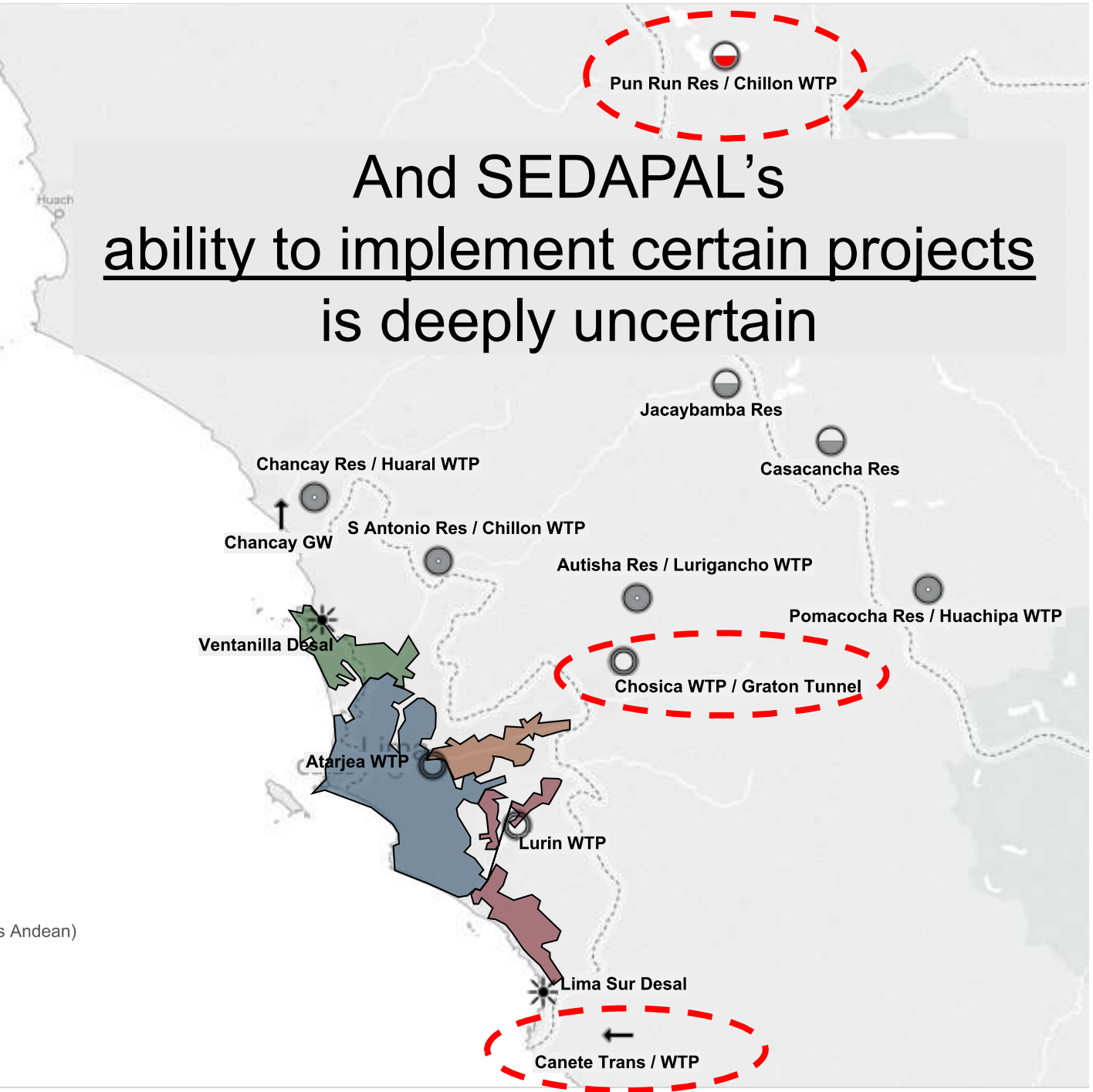
And SEDAPAL's ability to implement certain projects is deeply uncertain

Demand Regions

- Central Lima
- Eastern Lima
- Northern Lima and Callao
- Southern Lima

Project Type

- Desalination Plant
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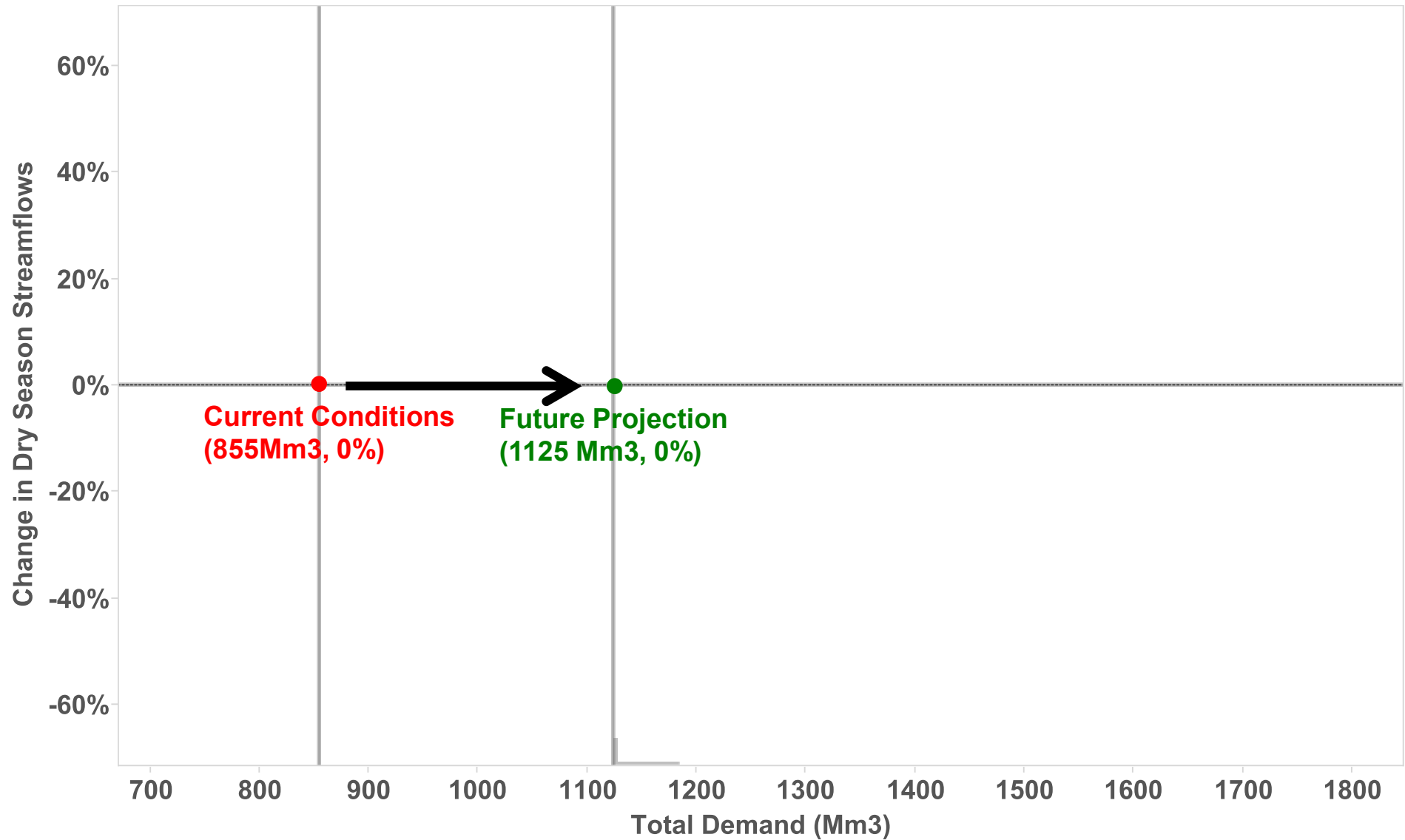
The \$2.7 Billion Question:

How can SEDAPAL prioritize these projects so that their plan is robust?

- Ensuring water reliability in widest range of cases
- Economically efficient

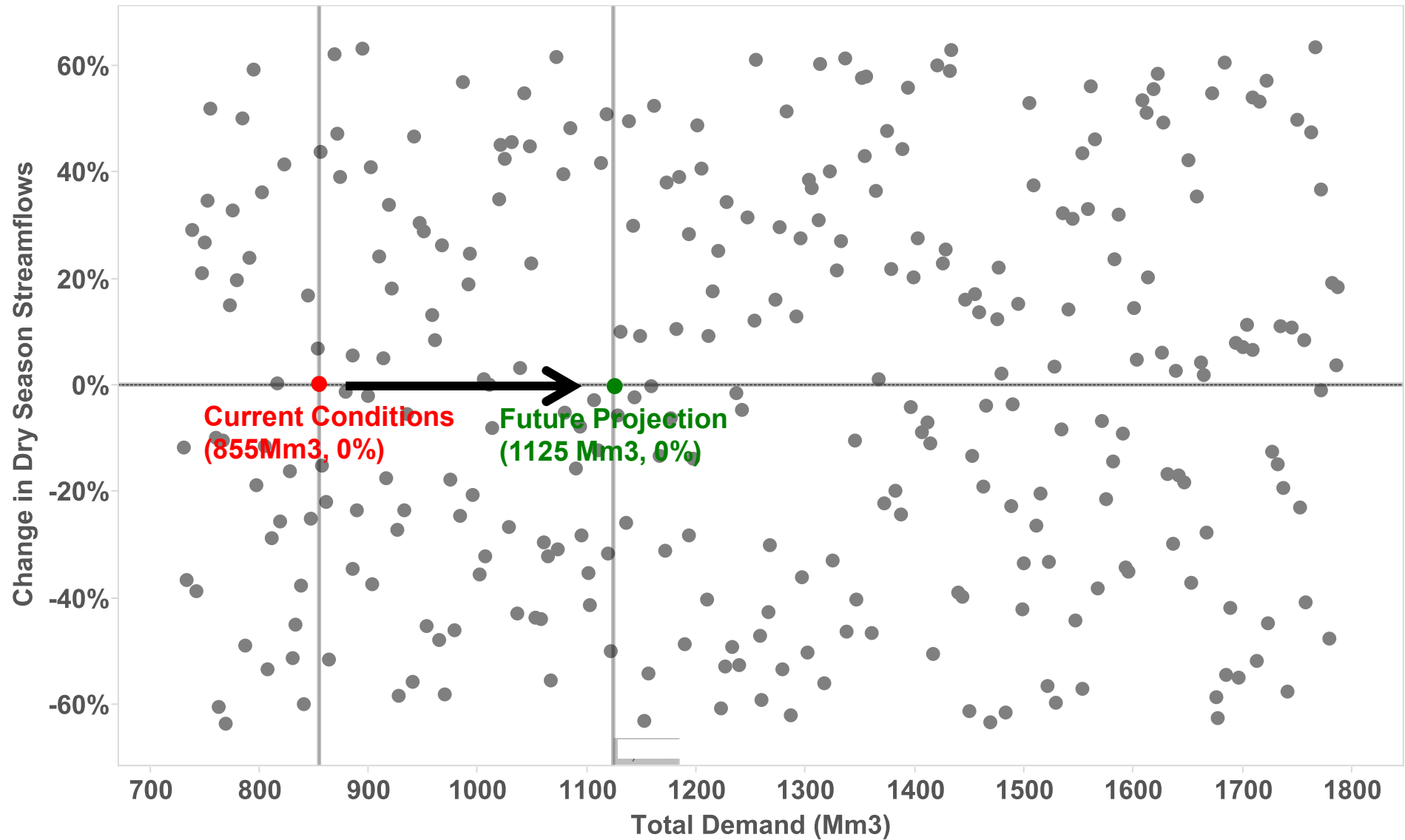
We developed 600 plausible futures

(300 demand/streamflow conditions x 2 project feasibility conditions)



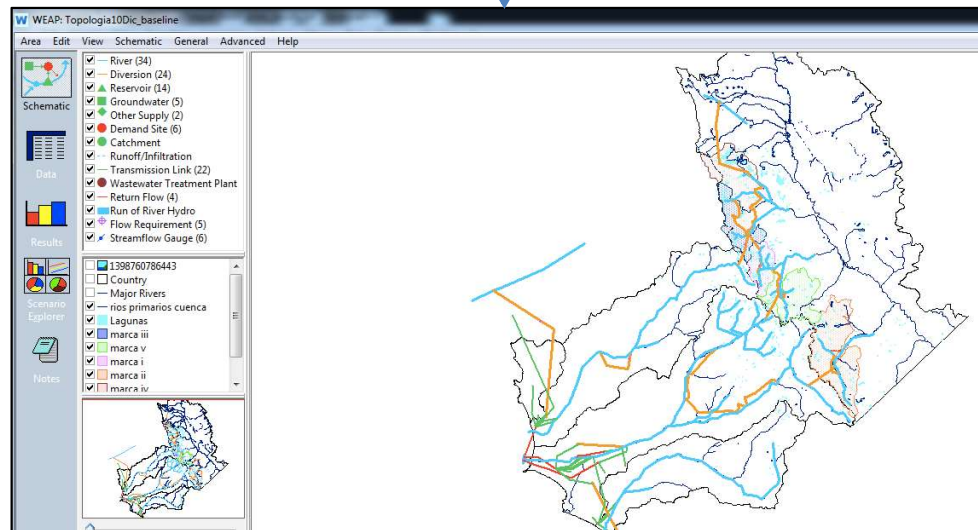
We developed 600 plausible futures

(300 demand/streamflow conditions x 2 project feasibility conditions)



We simulated Lima's water system and assessed water reliability for each future

- Monthly time series of demand and streamflow
- Which of 14 projects to implement



WEAP model of existing system and proposed projects

90th percentile of monthly met demand

We Developed a Decision Support Tool to Support Project Development and Showcase Results



A Robust Strategy for Implementing Lima's Long-Term Water Resources Master Plan

May, 2015



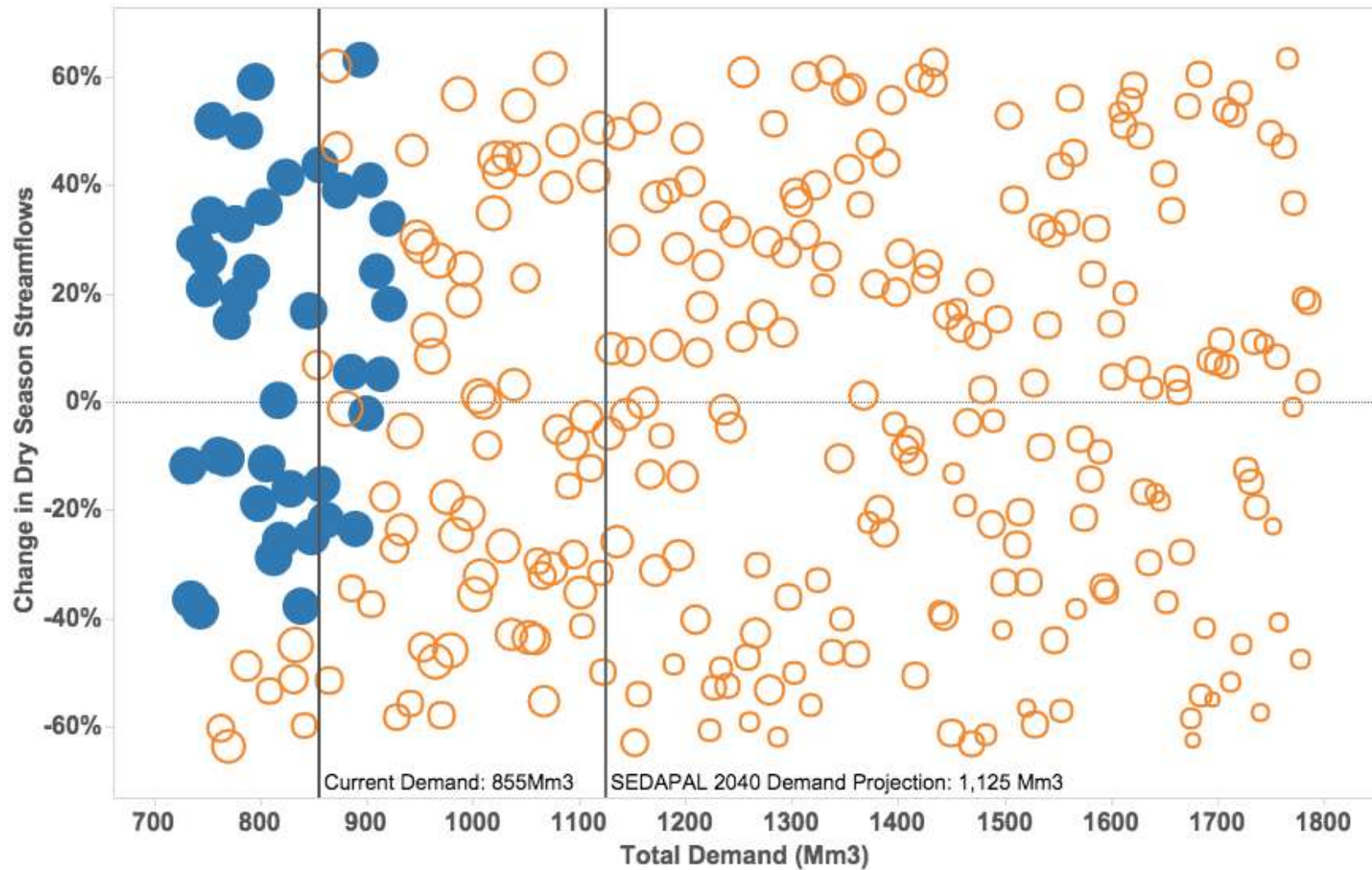
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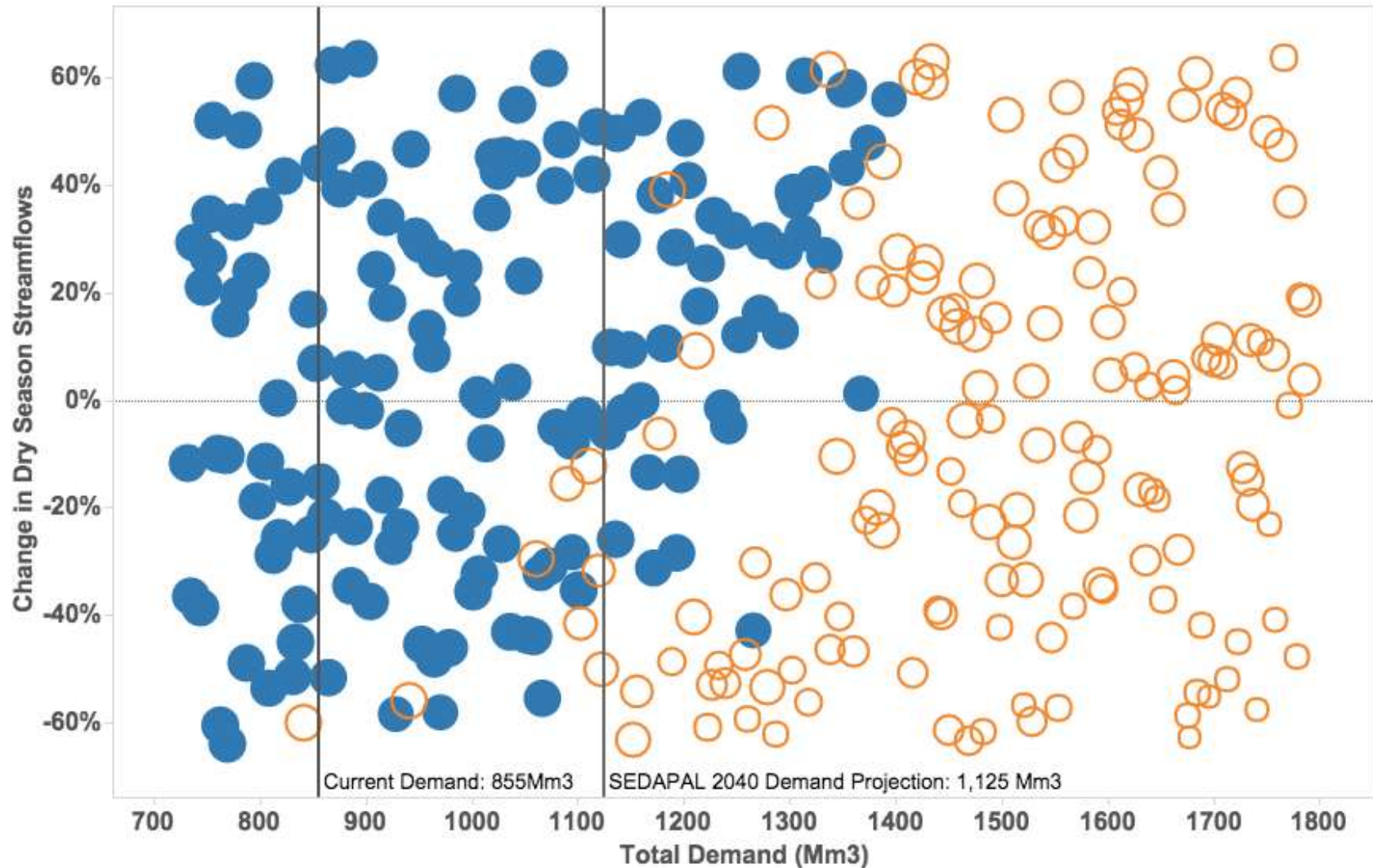
evolving logic
Robust Adaptive Planning™

Developed using Tableau – deployed via the web

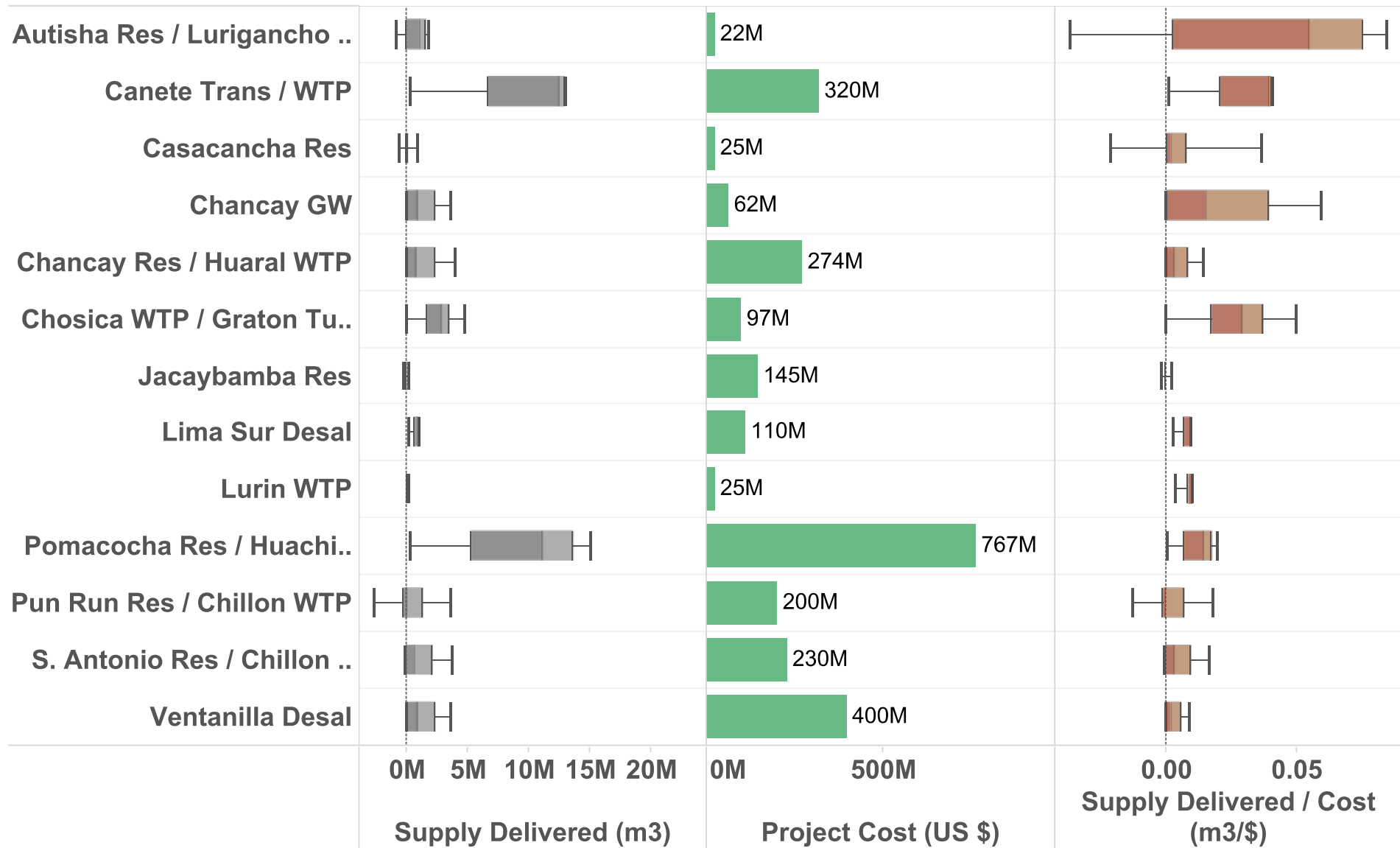
Current system is vulnerable to most futures



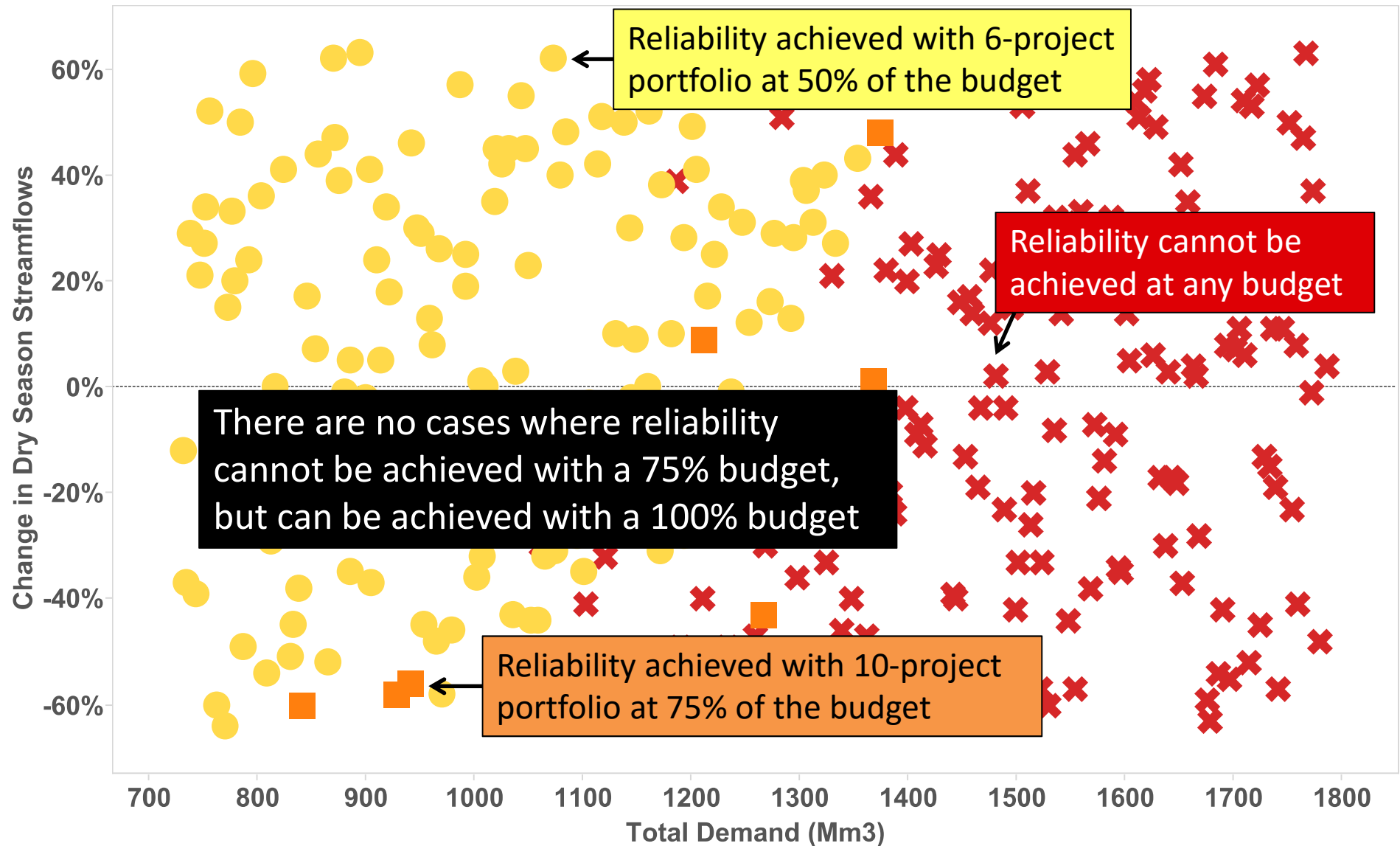
Complete implementation of \$2.7B Master Plan improves performance



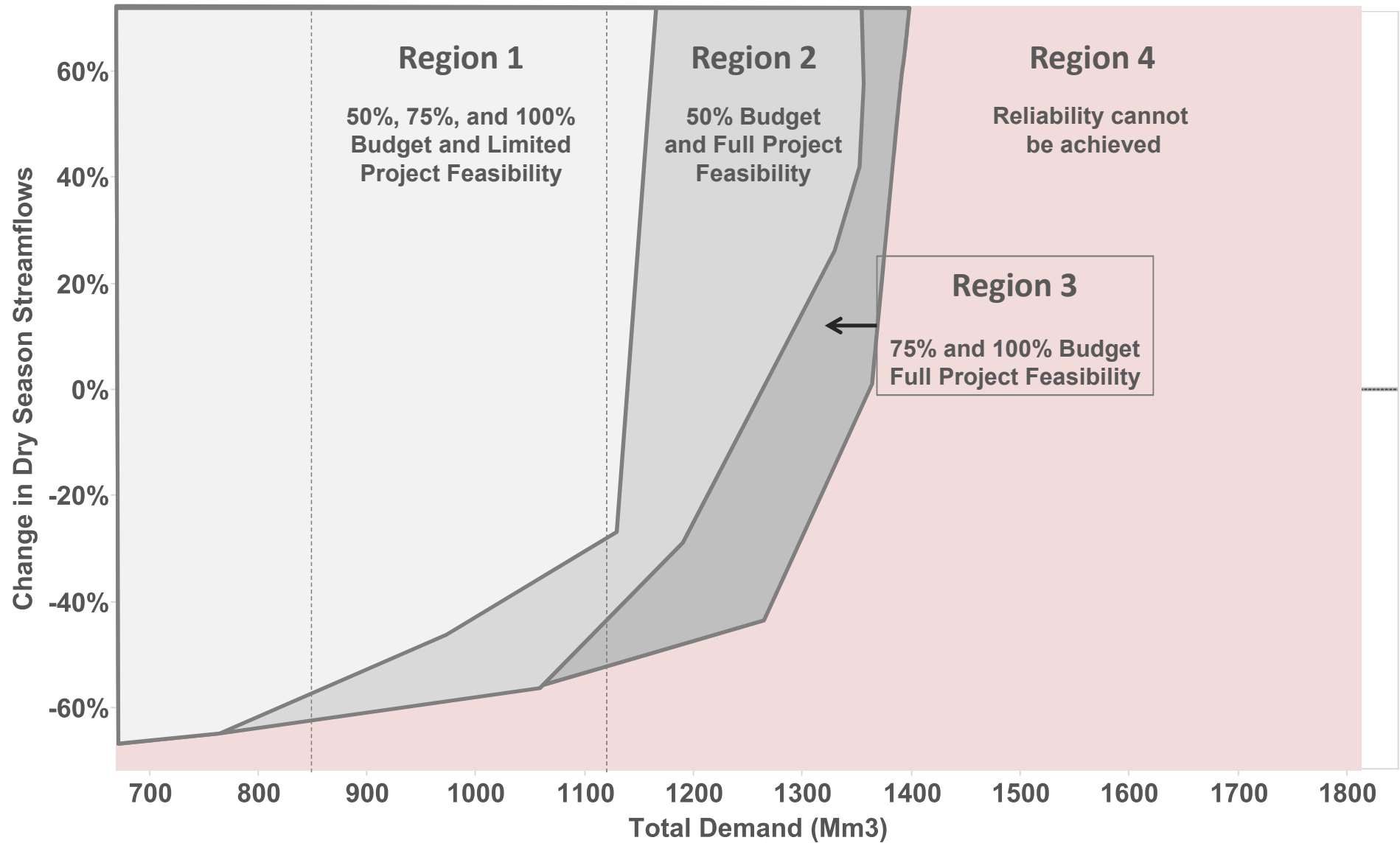
We used an optimizer to build the optimal portfolio for each budget, based on cost effectiveness



We found the optimal portfolio in each future



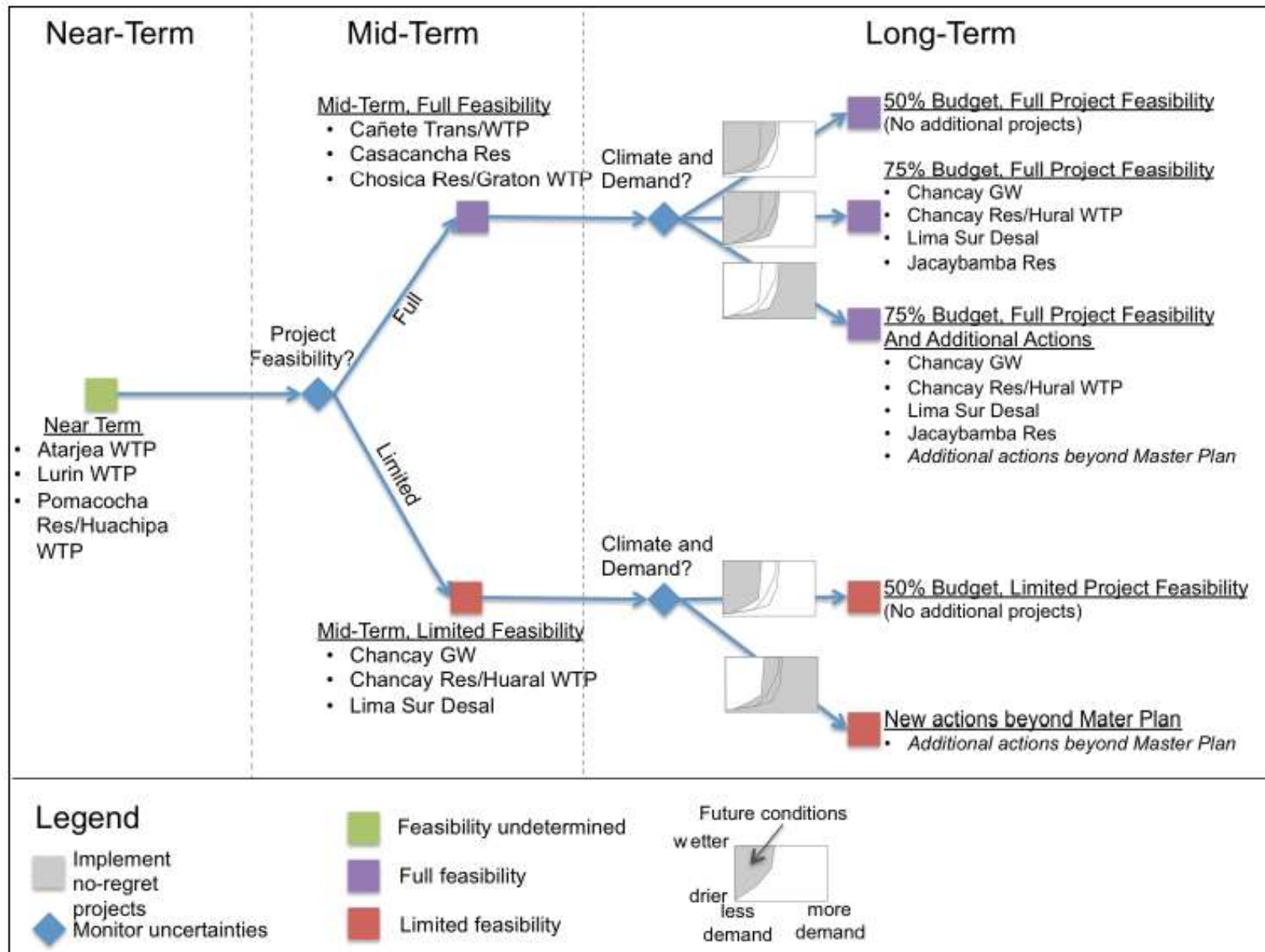
If SEDAPAL knew the future, it could choose the most robust portfolio



Without knowing the future, can SEDAPAL can still make some smart choices?

| | | Atarjea WTP | Autisha Res / Lurigancho WTP | Canete Trans / WTP | Casacancha Res | Chancay GW | Chancay Res / Huaral WTP | Chosica WTP / Graton Tunnel | Jacaybamba Res | Lima Sur Desal | Lurin WTP | Pomacocha Res / Huachipa WTP | Pun Run Res / Chillon WTP | S. Antonio Res / Chillon WTP | Ventanilla Desal |
|-----------------------------|--|-------------------------------------|------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Full Project Feasibility | 100% Budget, Full Project Feasibility | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| | 75% Budget, Full Project Feasibility | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| | 50% Budget, Full Project Feasibility | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Limited Project Feasibility | 100% Budget, Limited Project Feasibility | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| | 75% Budget, Limited Project Feasibility | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> |
| Limited Project Feasibility | 50% Budget, Limited Project Feasibility | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

A decision tree helps SEDAPAL navigate the uncertainty in the near-term, mid-term, and long-term



This project helped SEDAPAL...

- Understand its Master Plan more fully
 - Assess climate change threats without first needing to predict the future climate.
 - Identify projects that particularly important for achieving water reliability.
 - Reveals the strengths and vulnerabilities of its Master Plan specifically and concisely

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- Implement its Master Plan robustly
 - Identify near-term, no-regret projects it can embark upon now
 - Pursue additional actions adaptively as future conditions evolve

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....plan for the future without first predicting it

Check out the Decision Support Tool and Project Report

A Robust Strategy for Implementing Lima's Long-Term Water Resources Master Plan

Navigation: Welcome | About This Tool | Project Timeline | Map of Projects and Demand Areas | 300 Demand and Streamflow Futures | Baseline Vulnerability in 300 Futures | Individual Project Effects, Costs, and Cost Effectiveness

A Robust Strategy for Implementing Lima's Long-Term Water Resources Master Plan

May, 2015



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evolving logic
Robust Adaptive Planning™

<http://goo.gl/BRojPW>

Report No: AUS3381

Republic of Peru


Robust Decision-Making in the Water Sector

A Strategy for Implementing Lima's Long-Term Water Resources Master Plan

June 30, 2015

Authors:
Nidhi Kalra¹, David G. Groves¹, Laura Bonzanigo², Edmundo Molina Perez¹, Cayo Ramos³, Carter Brandon², and Ivan Rodriguez Cabanillas⁴

GWADR
LATIN AMERICA AND CARIBBEAN



1. Evolving Logic, Inc.
2. The World Bank
3. Universidad La Molina, Lima, Peru
4. SEDAPAL

<http://goo.gl/e1Ch7t>



David Groves (groves@rand.org)

www.rand.org/water

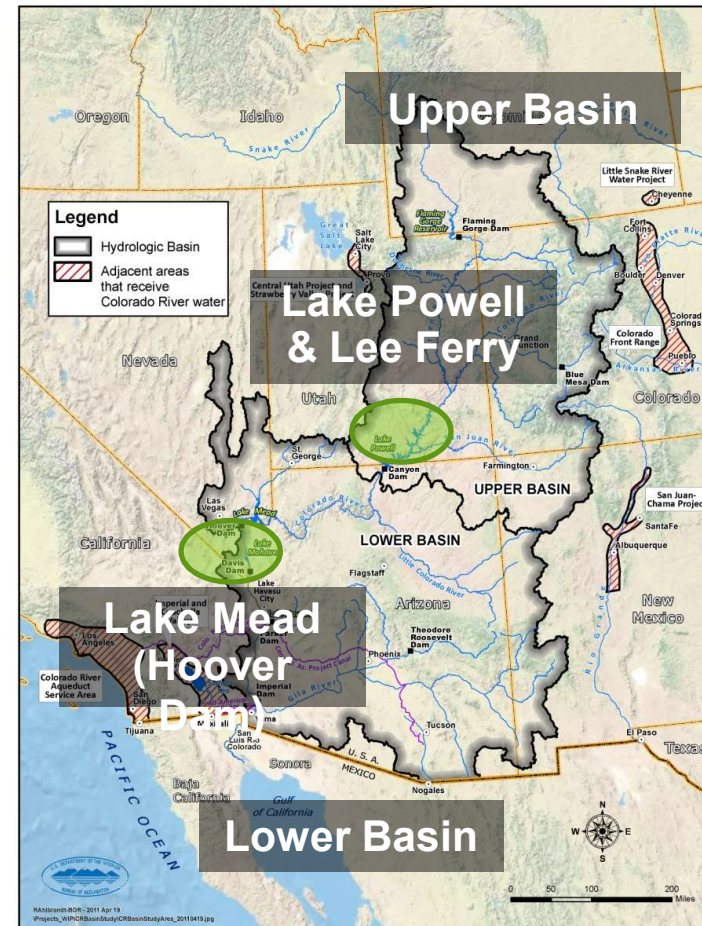
www.rand.org/methods/rdmlab.html

Supporting the Colorado River Basin Study With Robust Decision Making

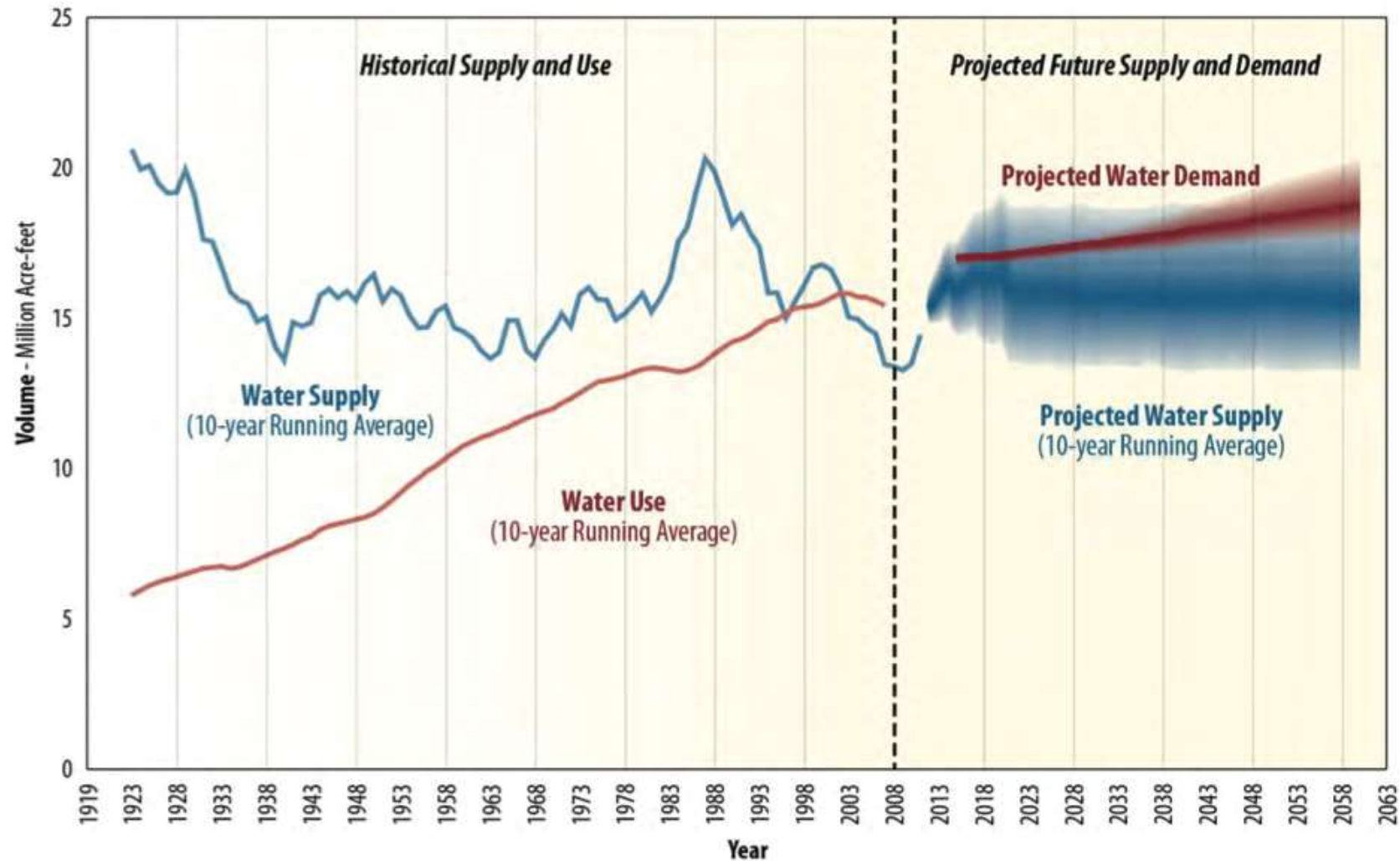


The Colorado River Basin is a vital natural resource

- Provides water and power for 40 million people in 7 states and 22 tribes
- Supports billions of dollars in economic activity annually
- Irrigates 15% of U.S. crops
- Lifeline for 24 national parks, wildlife refuges, and recreation areas



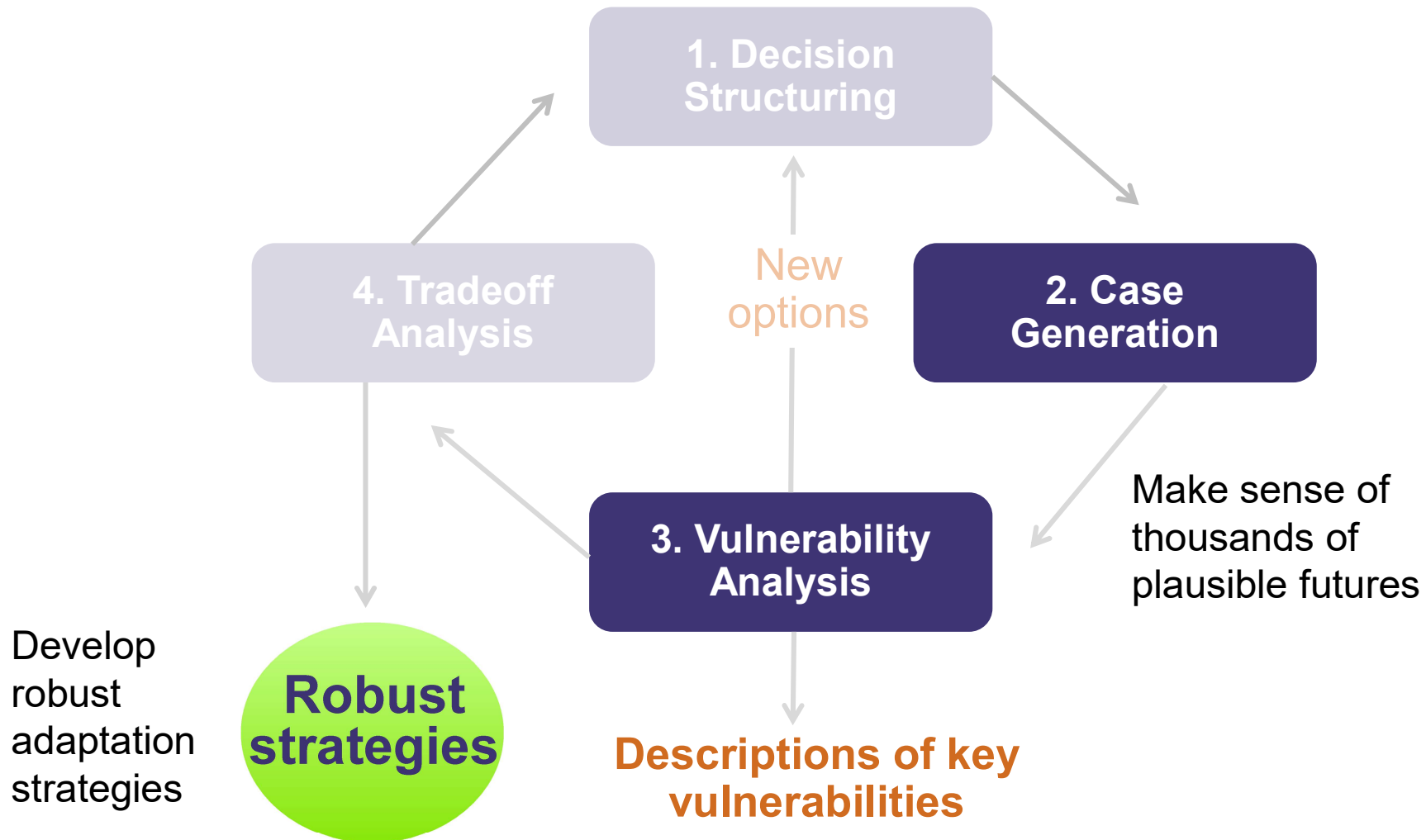
Climate change and other trends threaten its successful management



Source: US Bureau of Reclamation,
2012

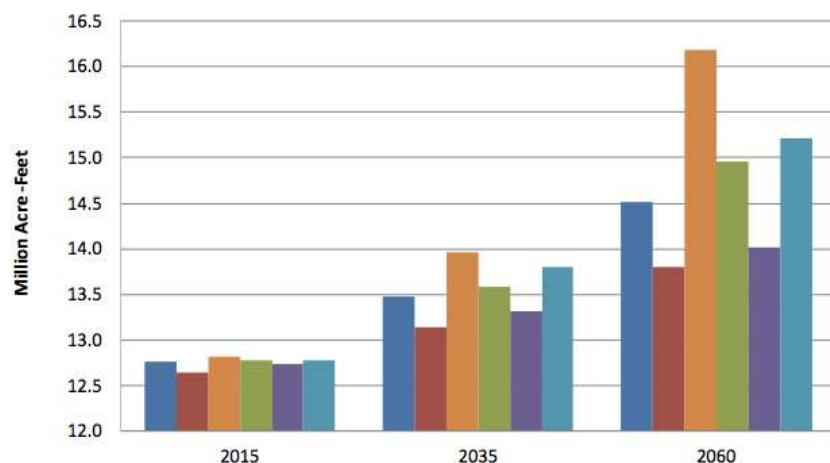
[Interactive Supply and Demand](#)

Why did we use RDM?



Basin States developed thousands of futures

6 Demand scenarios



X

1,959 Supply traces

- Resampled observed
- Paleo resampled
- Paleo conditioned
- Downscaled GCM projections

X 2 Operational regimes

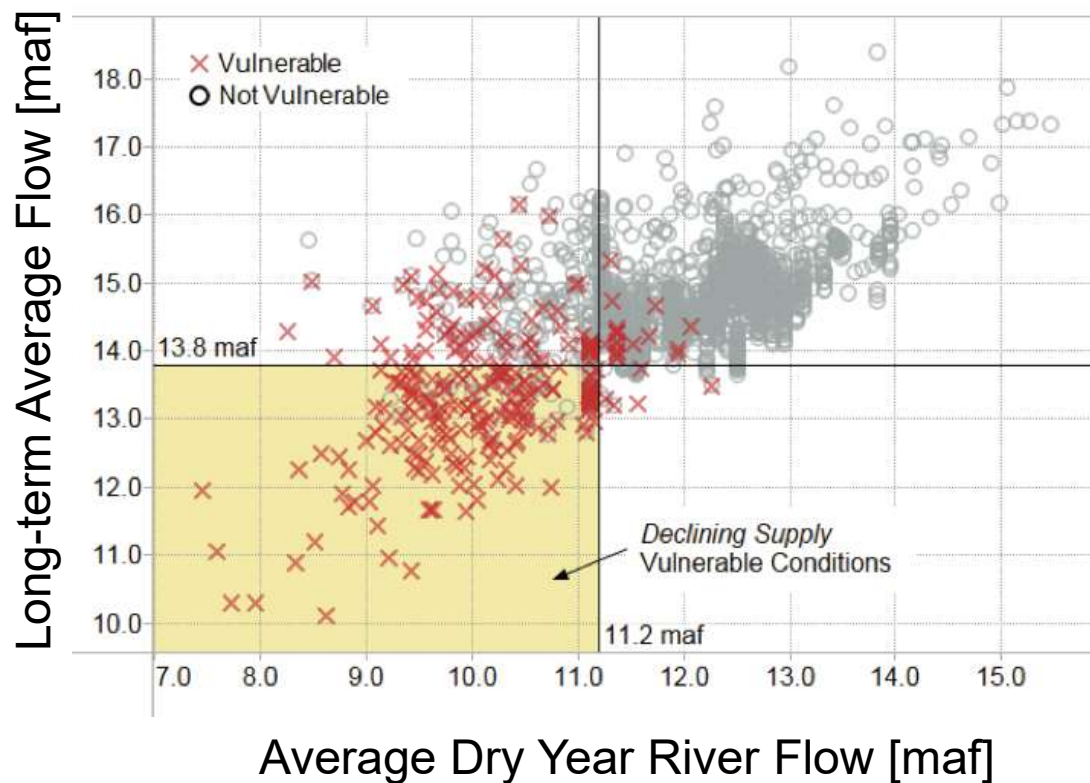
= 23,508 futures

Configured Colorado River Simulation System (CRSS) evaluated system performance

- Reclamation's official model of Colorado River system
 - RiverWare™ (CADSWES)
- Driven by monthly streamflow traces at 29 locations
- Demand projections for over 400 entities
- Simulates operations of twelve reservoirs and required minimum flows



We analyzed simulation results to identify Upper Basin vulnerabilities

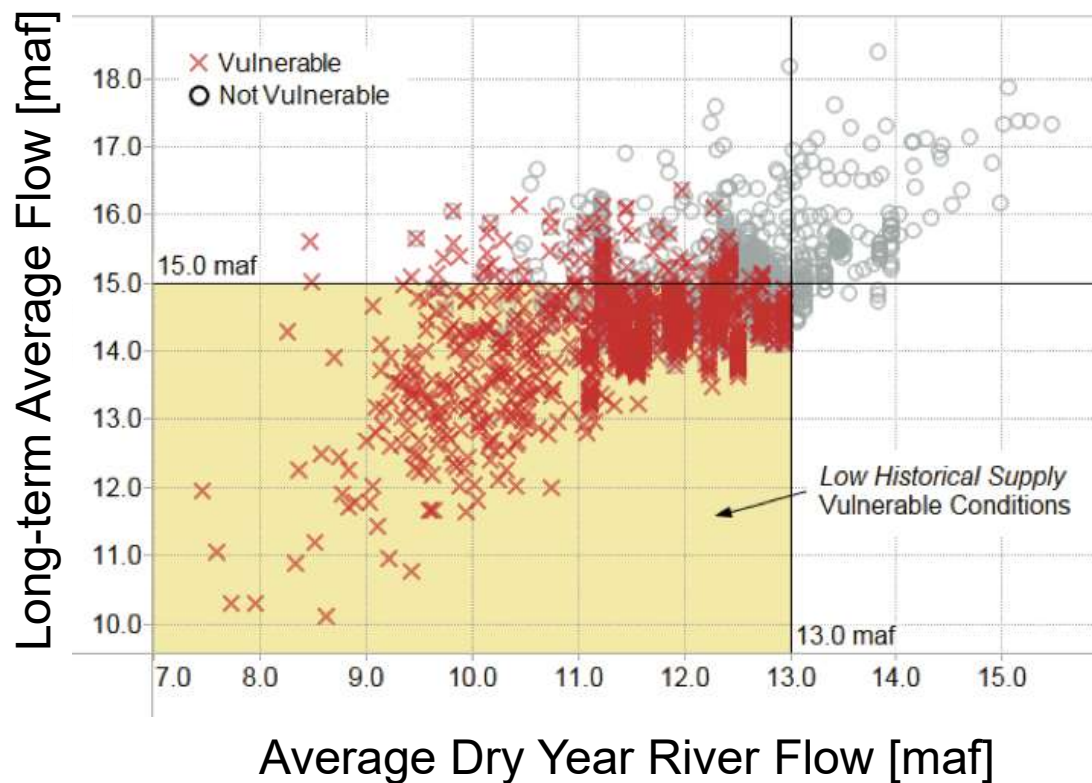


- Describes 85% of vulnerable traces, (coverage)
- 87% of traces in conditions are vulnerable (density)

Declining Supply Vulnerable Conditions

- Long Term Average streamflow < 13.8 MAF
- 8-year dry spell with average streamflow < 11.2

We analyzed simulation results to identify Lower Basin vulnerabilities

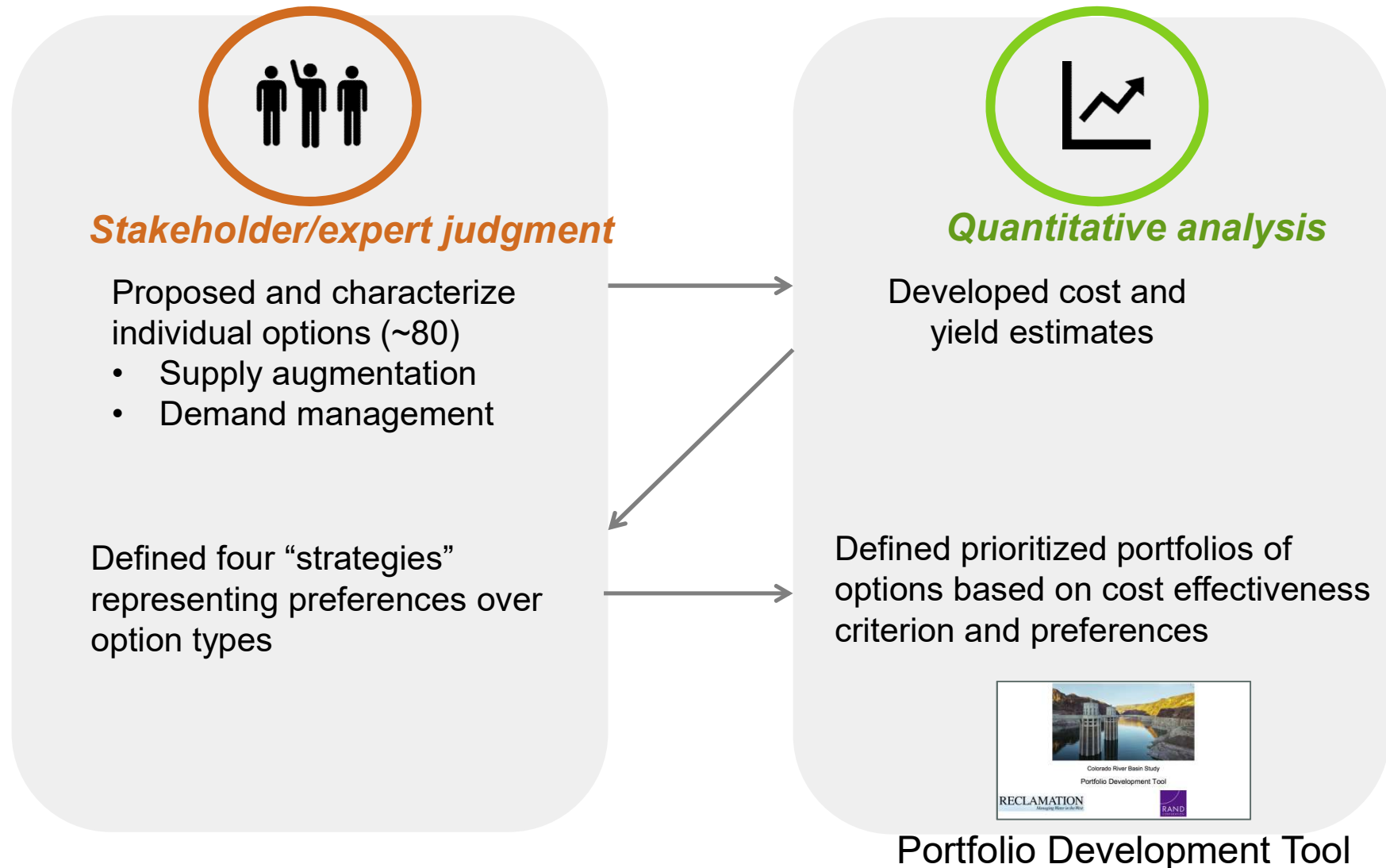


- Describes 86% of vulnerable traces (coverage)
- 72% of traces in conditions are vulnerable (density)

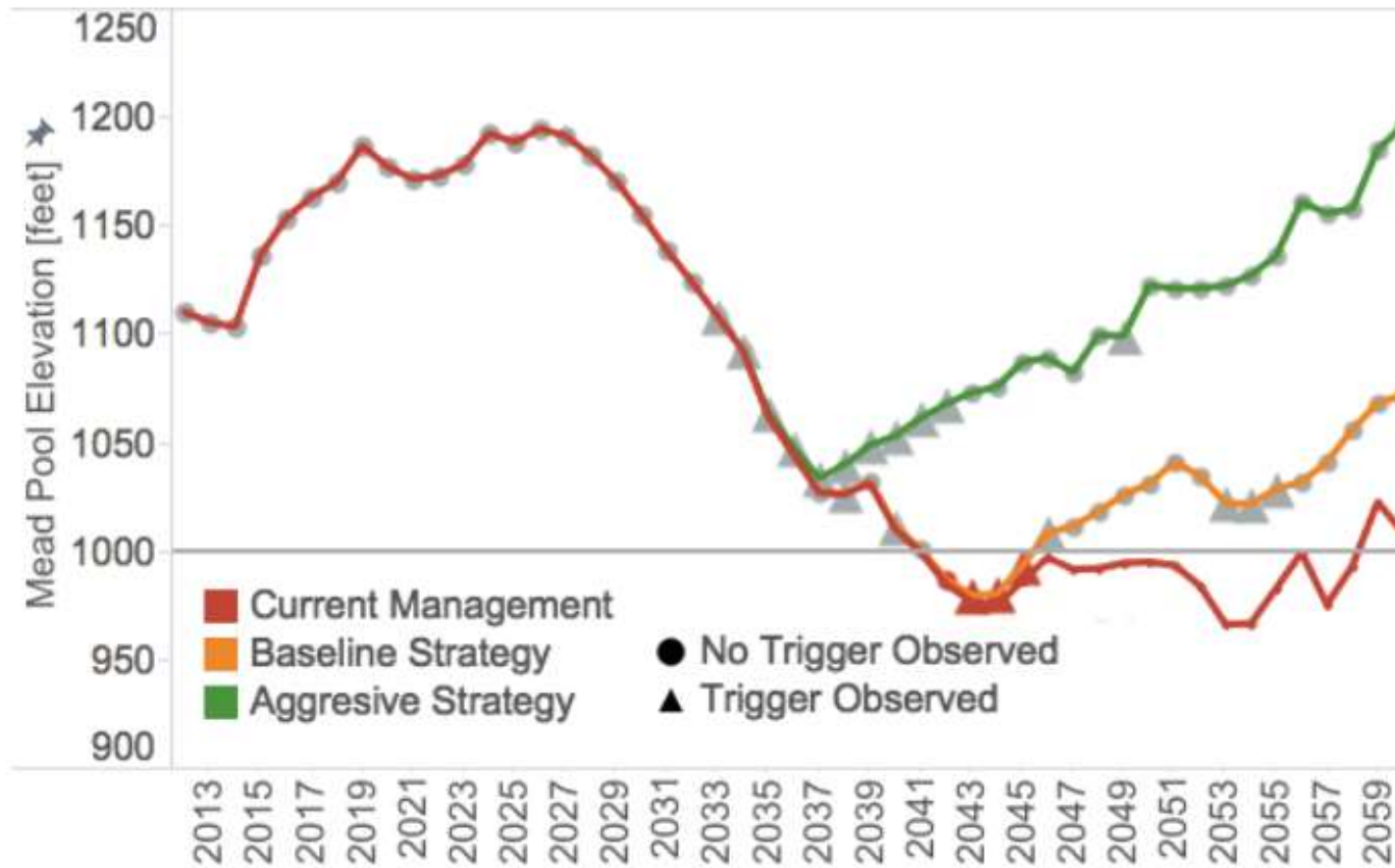
Low Historical Supply Vulnerable Conditions

- Long Term Average streamflow < 15 MAF
- 8-year dry spell with average streamflow < 13

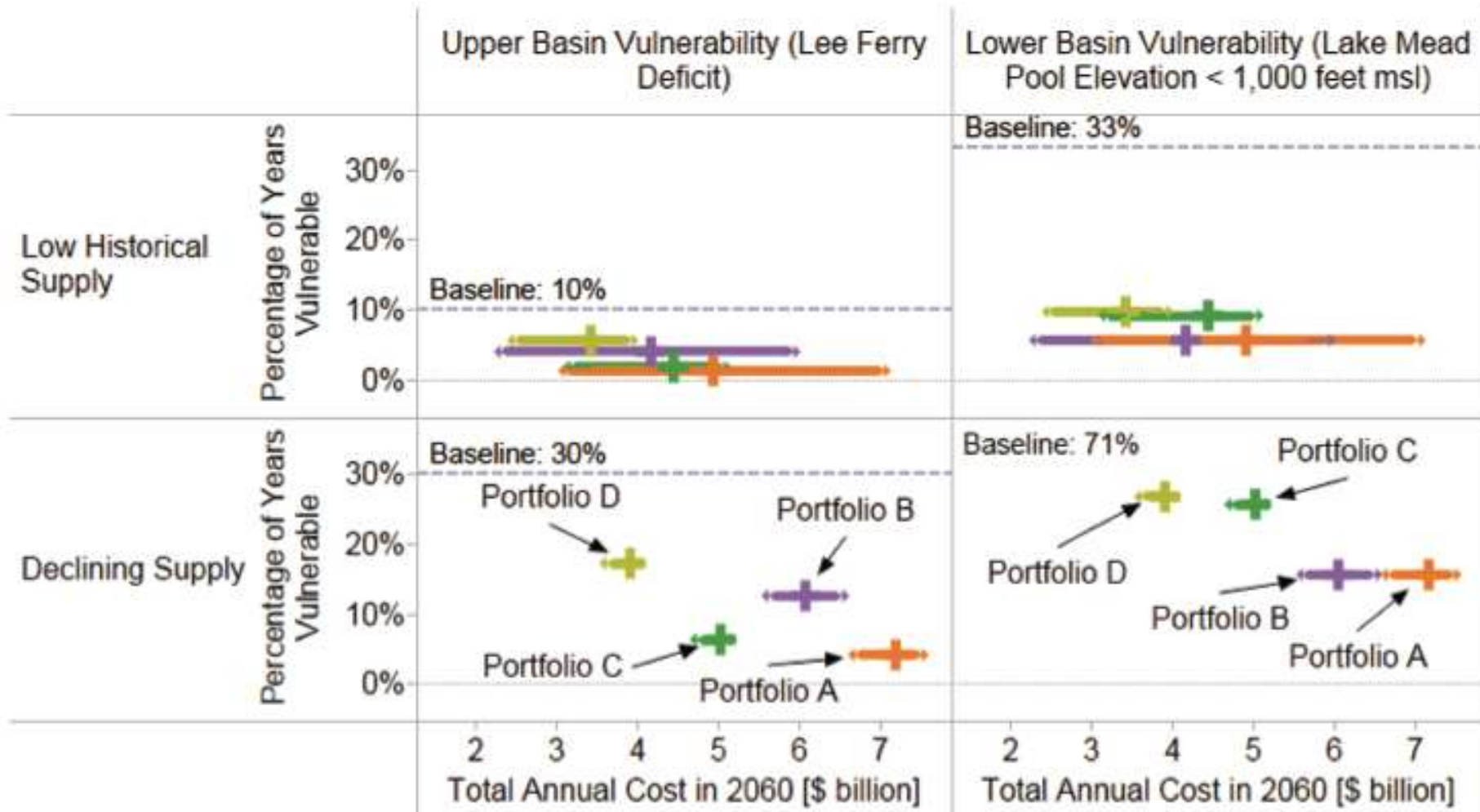
Adaptation strategies were developed combining stakeholder judgment with quantitative analysis



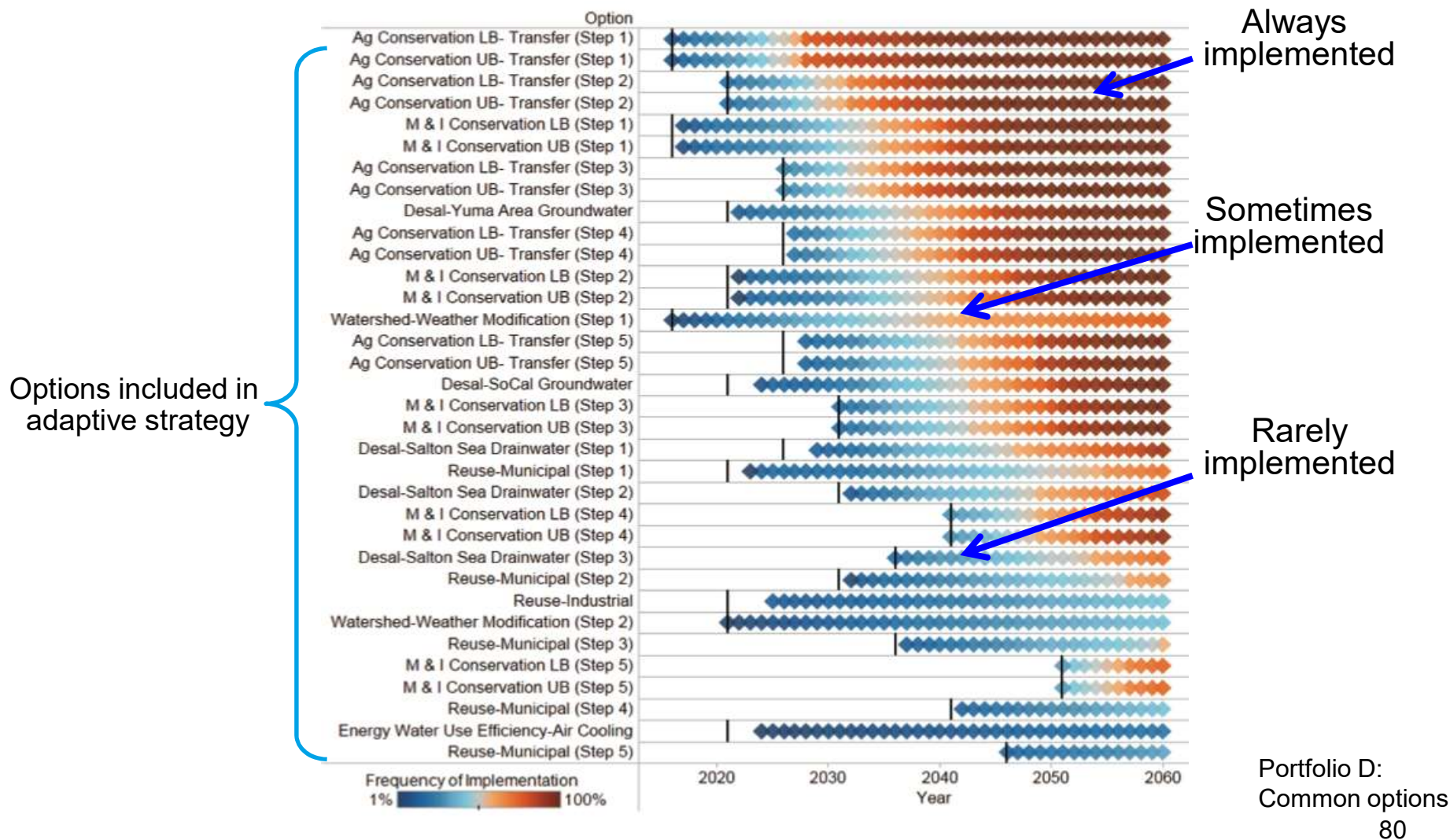
Modeled adaptive implementation of portfolios using triggers tied to vulnerabilities



Analysis highlighted key tradeoffs across strategies: vulnerability reduction vs. cost

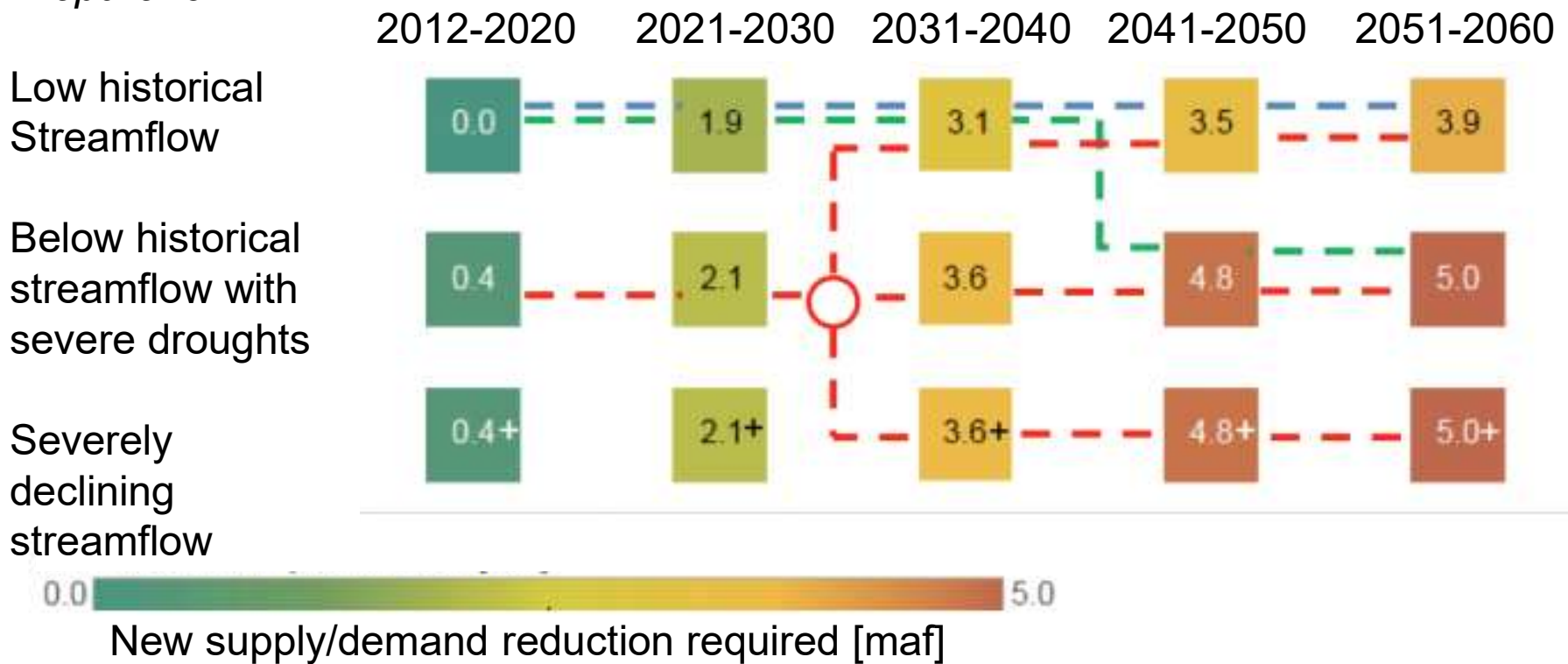


Simulations of adaptive strategies identified frequency and timing of option implementation

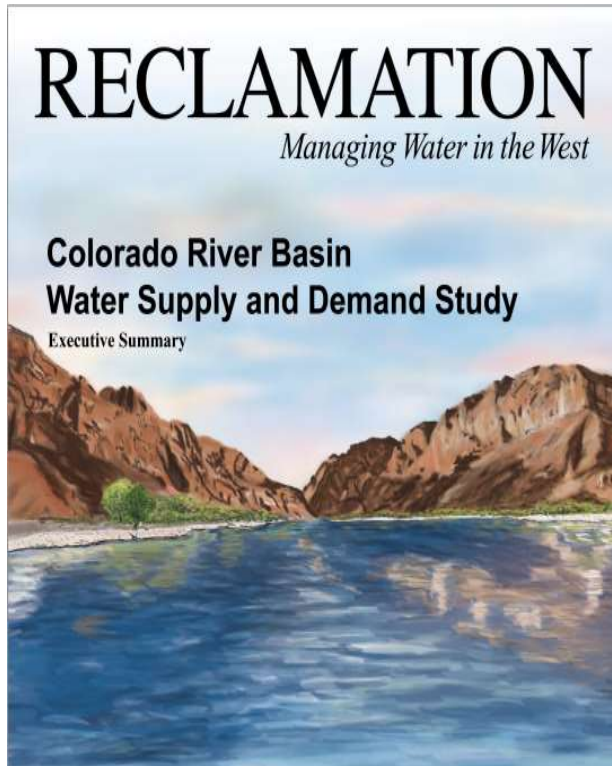


Subsequent analysis suggests pathways for implementing a robust, adaptive strategy for Basin

Prepare for:



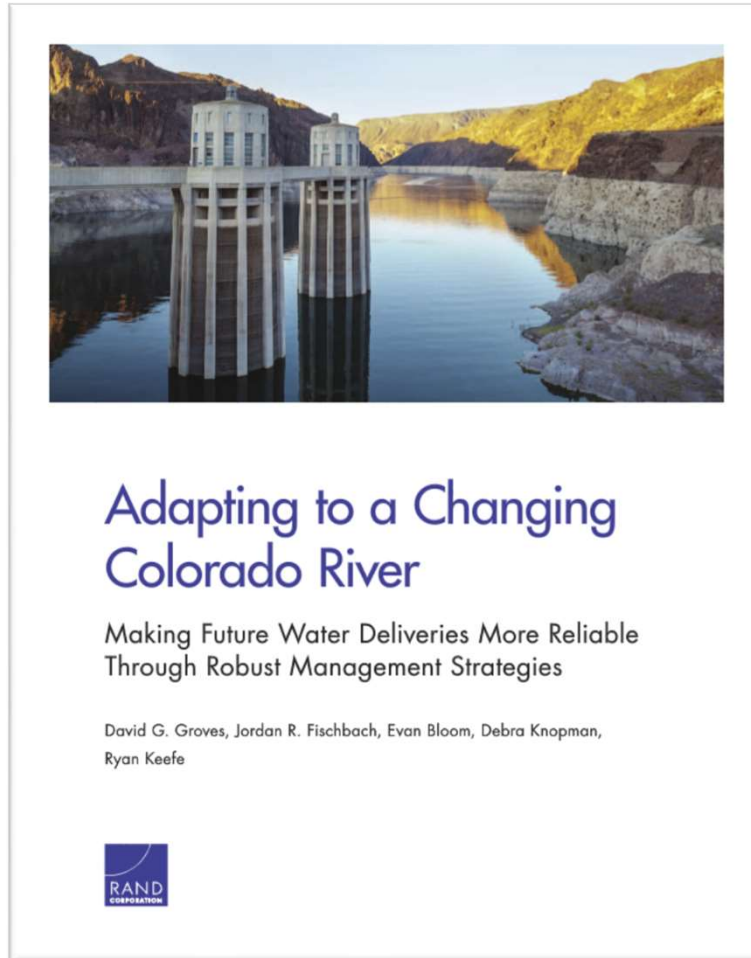
How did RDM inform the Colorado River Basin Study?



- Organized stakeholder input about uncertainties, metrics, options
- Identified key vulnerabilities to future uncertainty
- Structured design of alternative adaptive strategies
- Highlighted key tradeoffs among adaptive strategies
- Defined near-term actions for implementation

[www.usbr.gov/lc/region/
programs/crbstudy/finalreport/](http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/)

Additional publications and briefs online



RAND Research Report
(www.rand.org/pubs/research_reports/RR242.html)

Adapting to a Changing Colorado River



RAND Interactive Research Brief
(www.rand.org/jie/projects/colorado-river-basin/interactive-brief.html)