Applying DMDU to the Post-2026 Operations Exploration Web Tool

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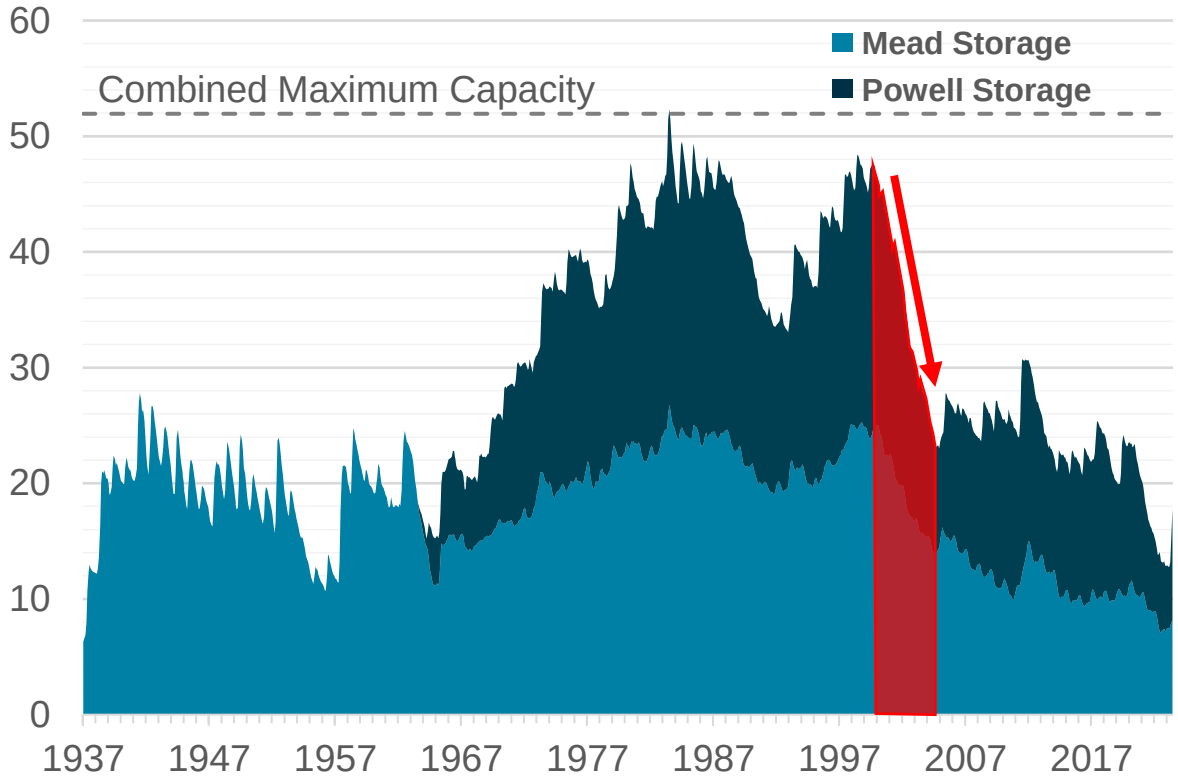
California Water and Environmental Modelling Forum
9.23.2023 Folsom CA

BUREAU OF RECLAMATION

Development of Operating Guidelines at Lake Mead and Lake Powell

- Driest 5-year period (2000-04) on record resulted in significant storage reduction
- 2007 Interim Guidelines introduced shortages, conservation, and coordination



Lake Powell		
Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf)[1]
3,700	**Equalization Tier** Equalize, avoid spills, or release 8.23 maf	24.3
3,636-3,666 (2008-2026)	**Upper Elevation Balancing Tier**[3] Release 8.23 maf; if Lake Mead < 1,075 feet, balance contents with a min/max release of 7.0 and 9.0 maf	15.5-19.3 (2008-2026)
3,575	**Mid-Elevation Release Tier** Release 7.48 maf; if Lake Mead < 1,025 feet, release 8.23 maf	9.5
3,525		5.9
3,490	**Lower Elevation Balancing Tier** Balance contents with a min/max release of 7.0 and 9.5 maf	4.0
3,370		0

Lake Mead		
Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf)[1]
1,220	**Flood Control Surplus or Quantified Surplus Condition** Deliver > 7.5 maf	25.9
1,200 (approx.)[2]	**Domestic Surplus or ICS Surplus Condition** Deliver > 7.5 maf	22.9 (approx.)[2]
1,145	**Normal or ICS Surplus Condition** Deliver ≥ 7.5 maf	15.9
1,075	**Shortage Condition** Deliver 7.167[4] maf	9.4
1,050	**Shortage Condition** Deliver 7.083[5] maf	7.5
1,025	**Shortage Condition** Deliver 7.0[6] maf Further measures may be undertaken[7]	5.8
1,000		4.3
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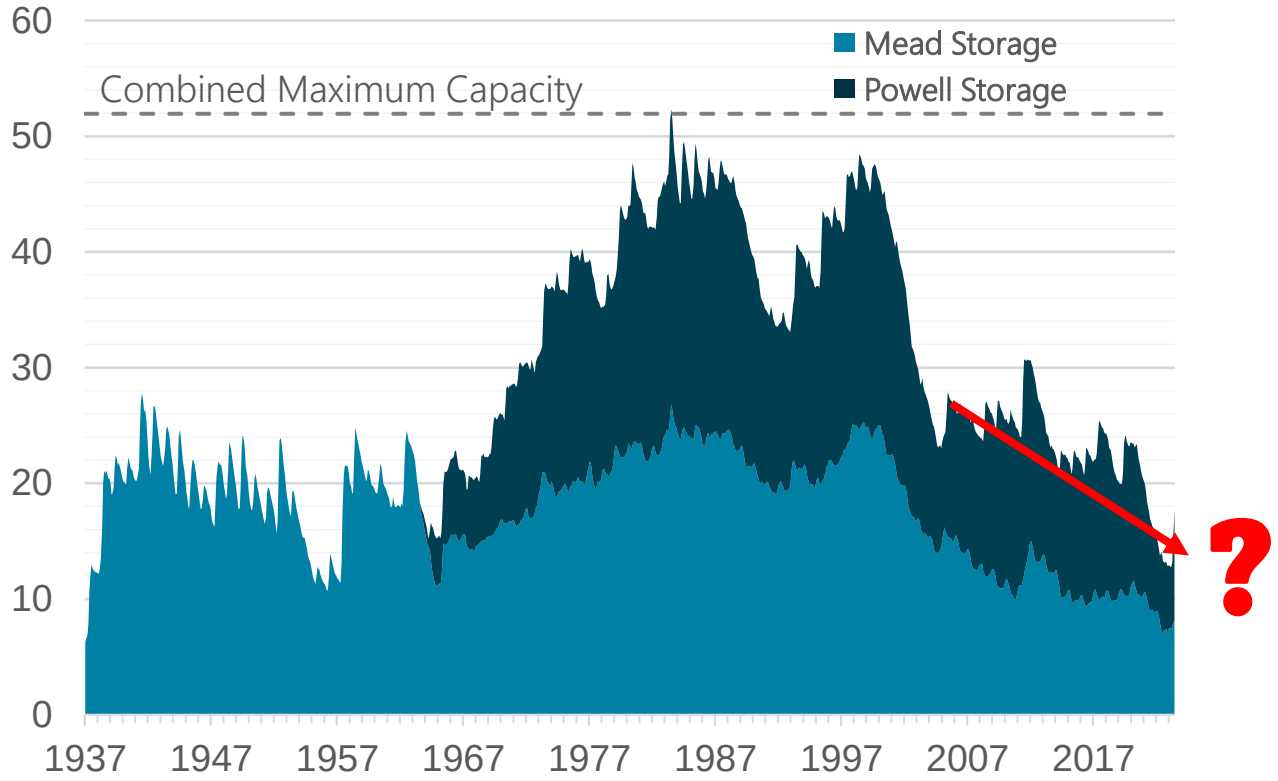
Post-2026 Process will Address Growing Challenges since the Development of 2007 Interim Guidelines

- Drought continued after '07 IGs - declining reservoirs despite more policy actions
- 2000-2022 was among driest 23-year periods observed in 1200-year paleo record



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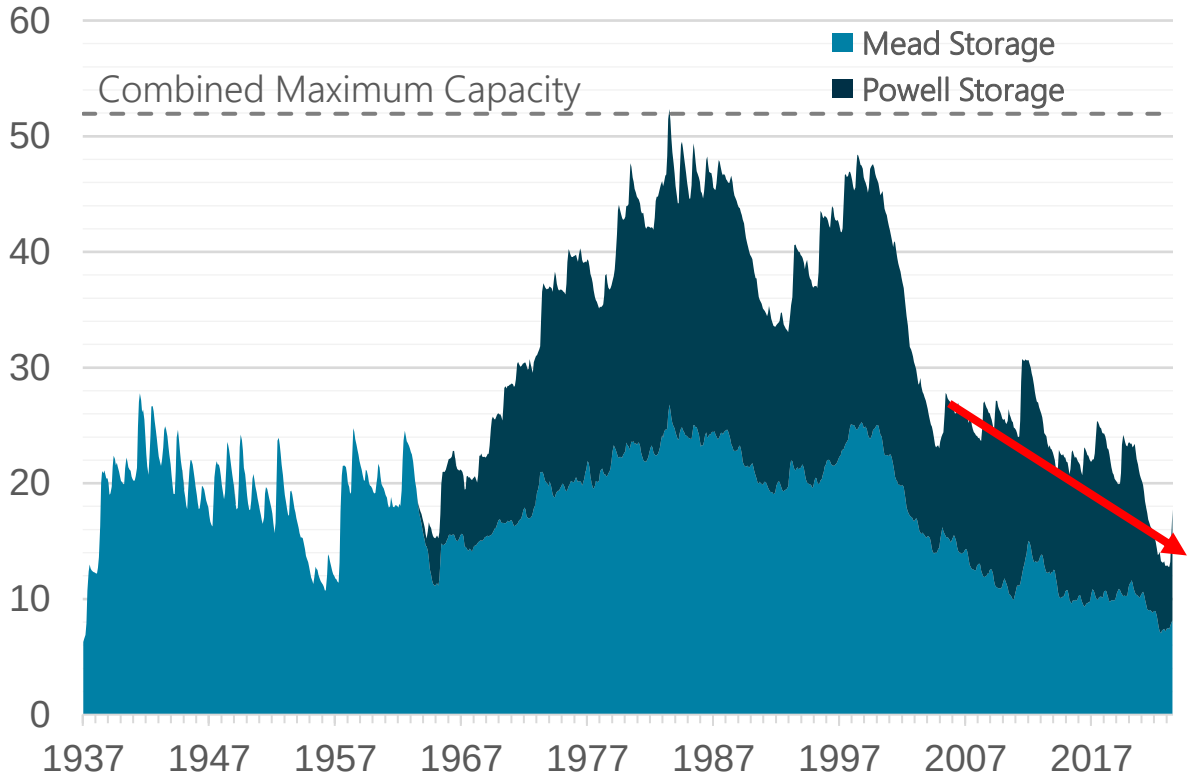
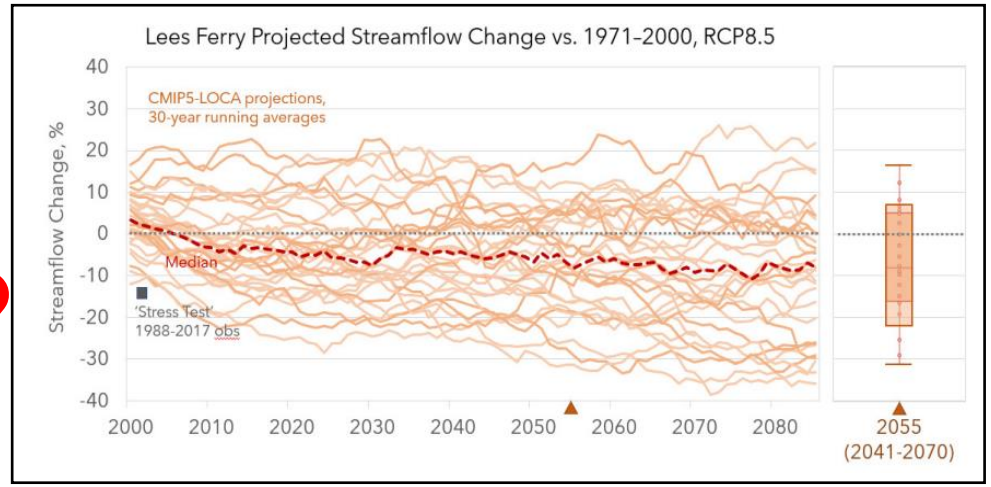
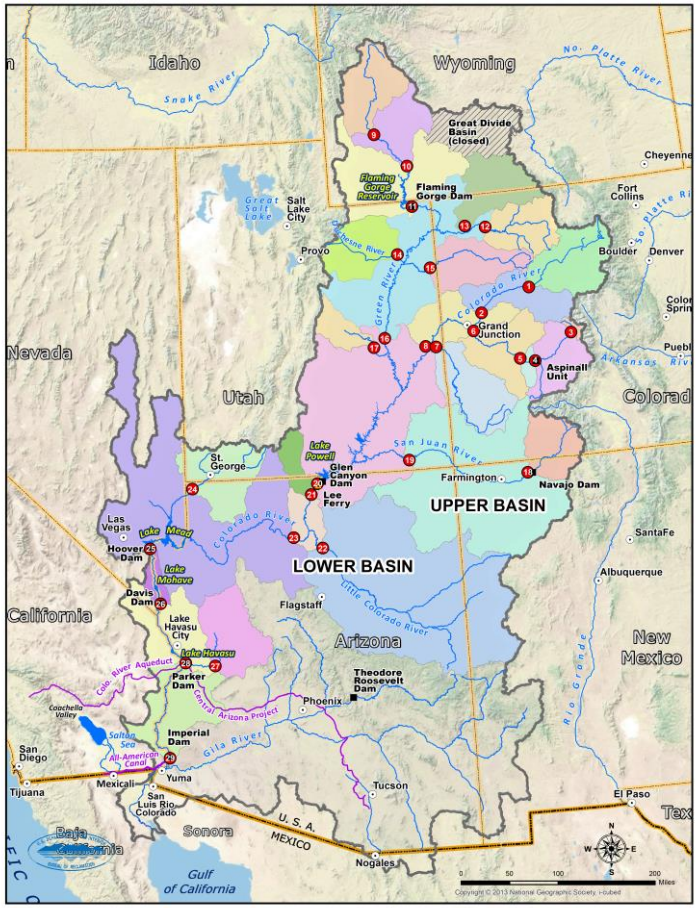


Any new policy must reflect growing uncertainty about future hydrologic conditions in the basin



What tools are available for planning under deep uncertainty in the Colorado River Basin?

1. CRSS: A Basin-Wide, Long-Term Planning & Policy Model



- Planning decisions are informed by the Colorado River Simulation System (CRSS), the primary tool for long-term analysis
- Developed in *RiverWare* software package with a user-friendly interface that makes it easy to share and collaborate with stakeholders
- Stakeholder modeling workgroup formed in 2010 includes states, tribes, municipalities, consultants, academics – this has ***created broad stakeholder acceptance for the modelling tools***
- Continual software development has made it possible to conduct and share ensemble-based probabilistic analysis for policy comparisons and uncertainty exploration

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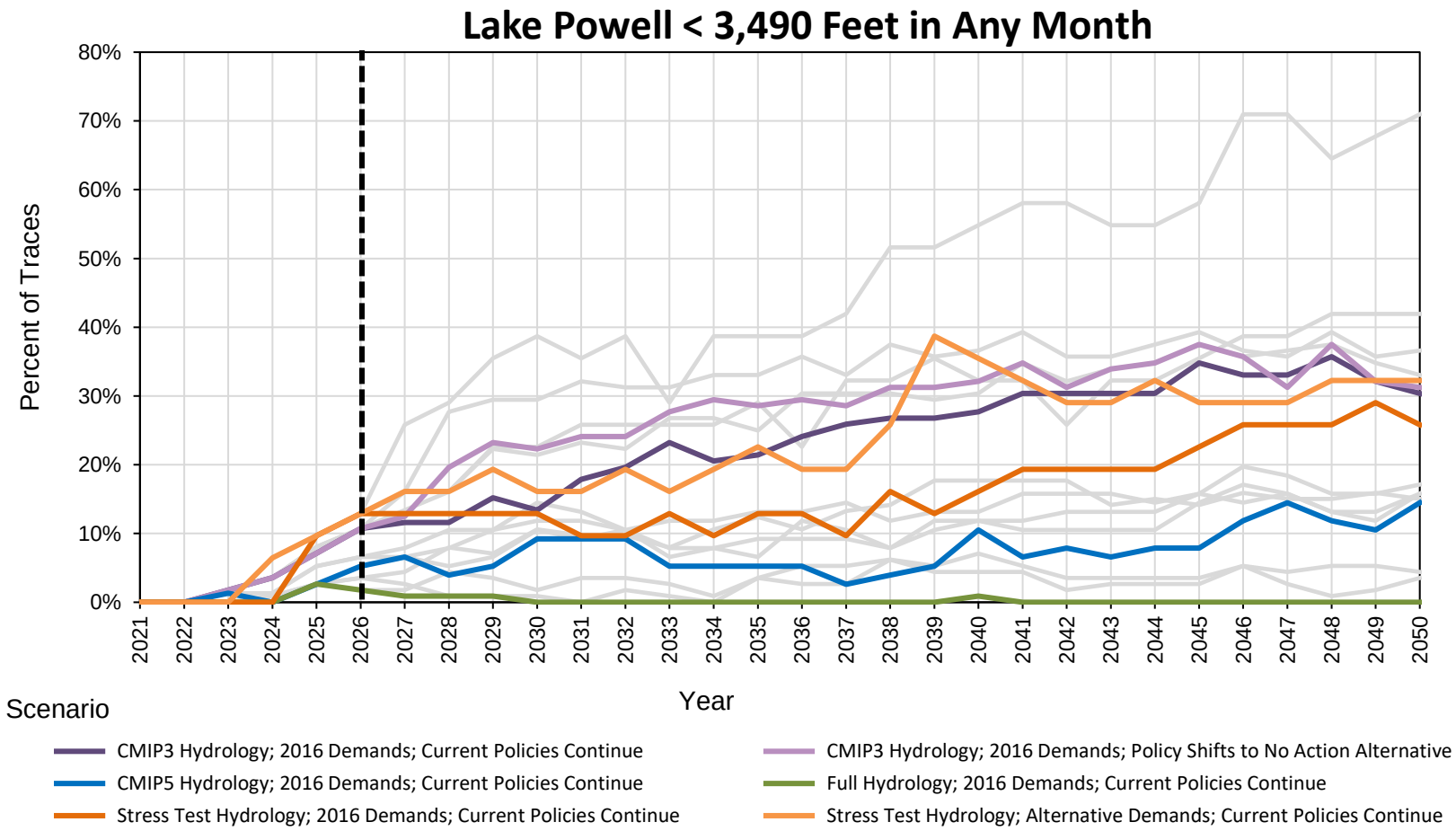
2. DMDU: Decision-Making Under Deep Uncertainty



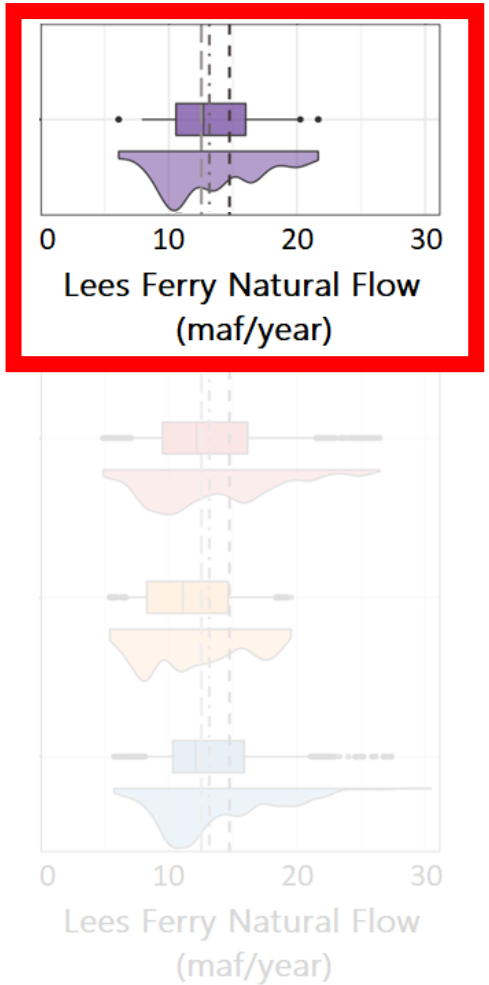
- Climate change is impacting hydrology and there is no scientific agreement on the best representation of supply
- Previous planning efforts have relied on achieving an acceptable level of 'risk' – dependent on the choice of ensemble and other assumptions about the future

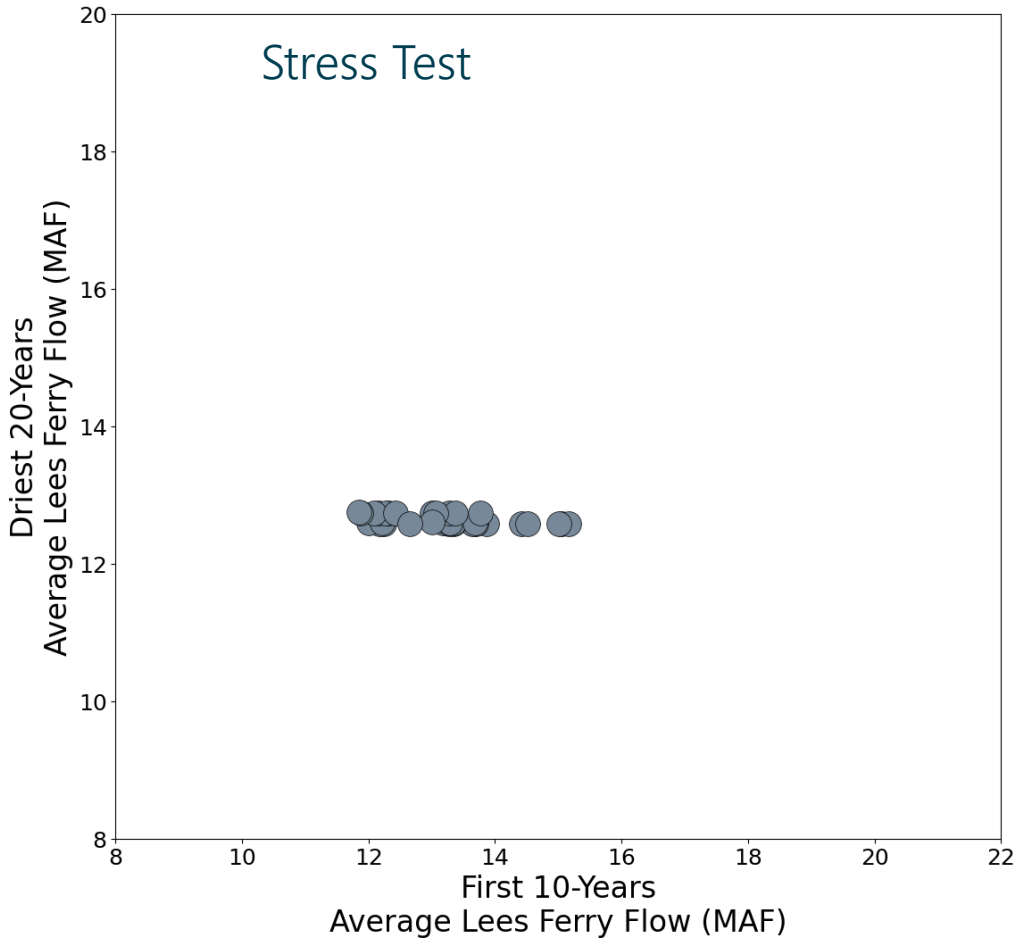
Thinking Outside the Ensemble

Decision Making under Deep Uncertainty (DMDU) methods incorporate concepts and tools that can help address the Basin's unprecedented planning challenges

Stress Test :

- Recent historical *observations*
- Drier than full historical record
- Limited sequence diversity





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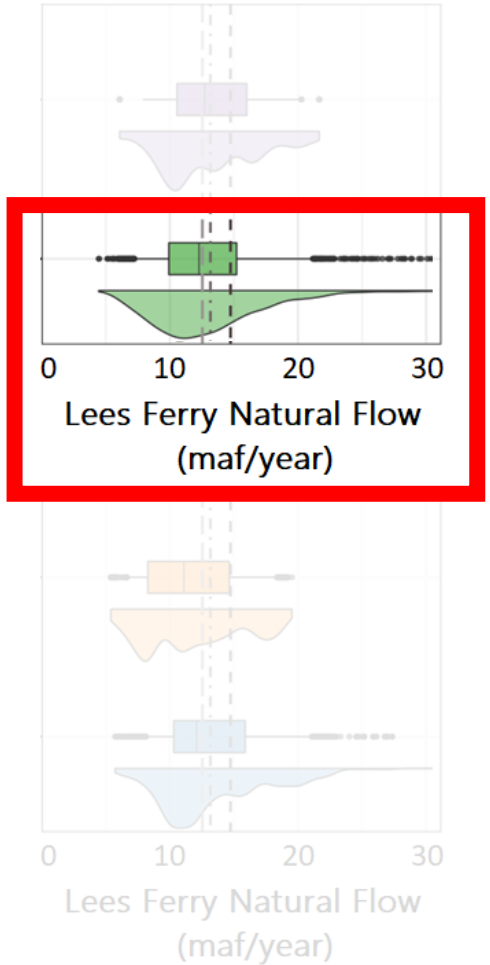
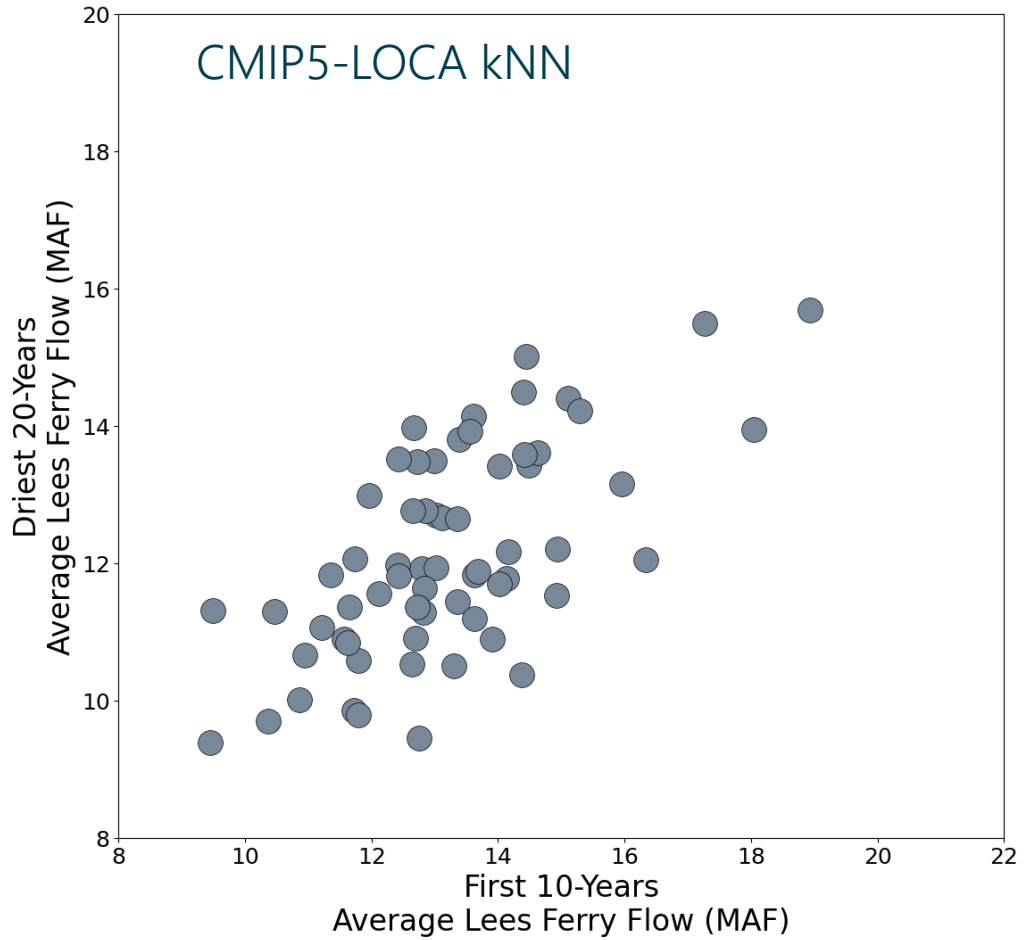
CMIP5-LOCA (kNN):

- Physically-based *representation of climate change* processes
- Require downscaling
- Large uncertainties in predicting climate change impacts





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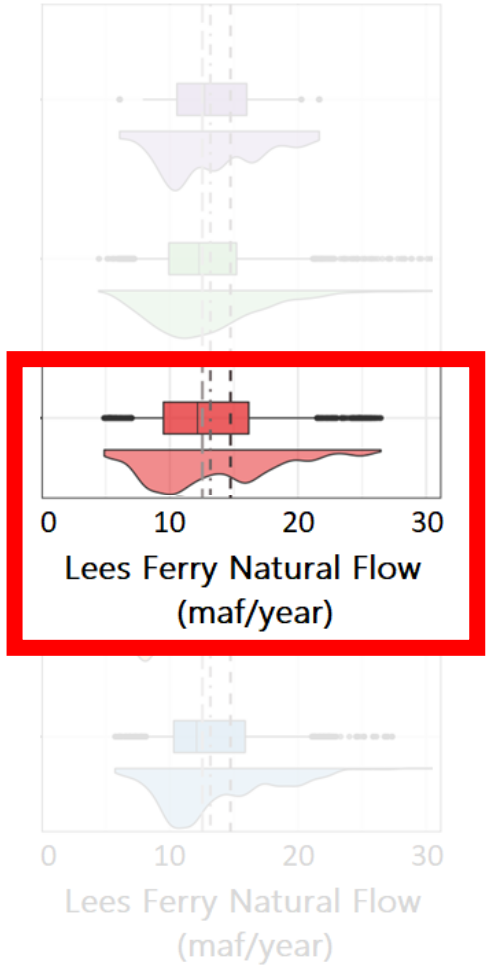
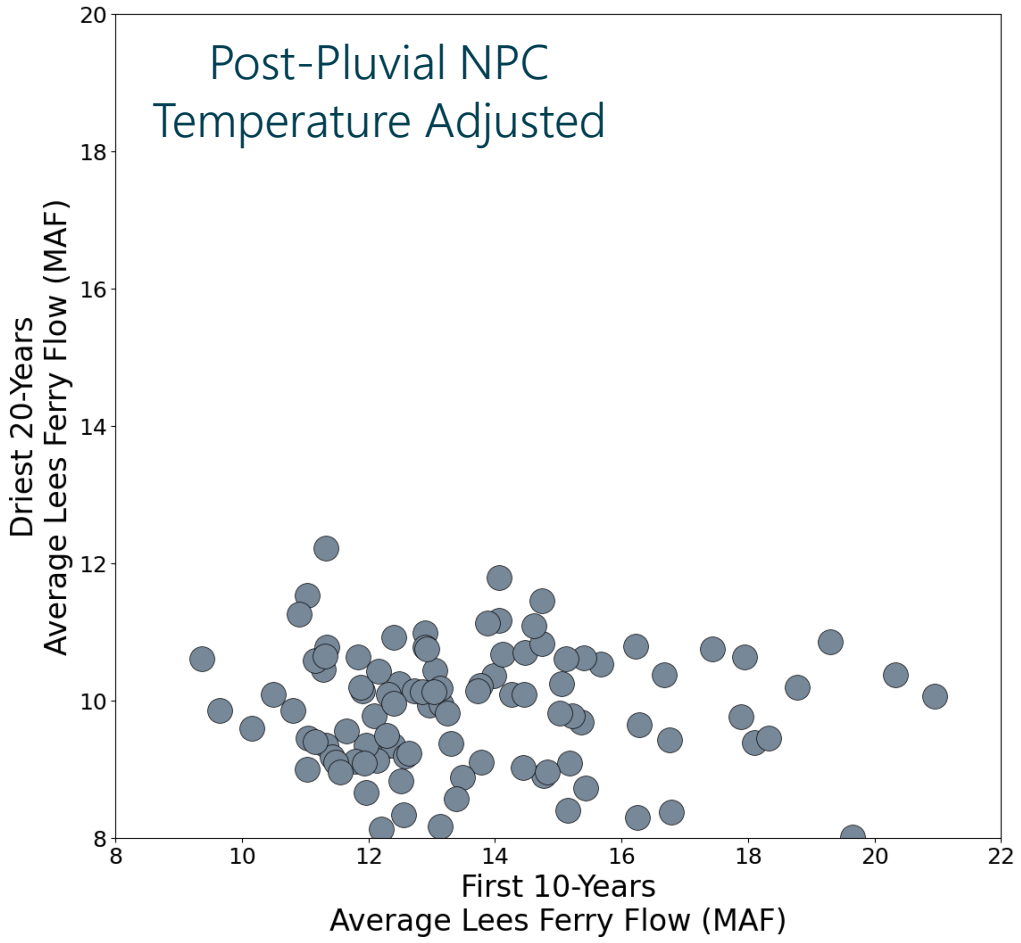
Post–Pluvial NPC Temperature Adjusted

- Uses *paleo record patterns* to sample sequences from the historical record (1931-2020)
- Temperature adjustment adds a downward trend to the sampling method





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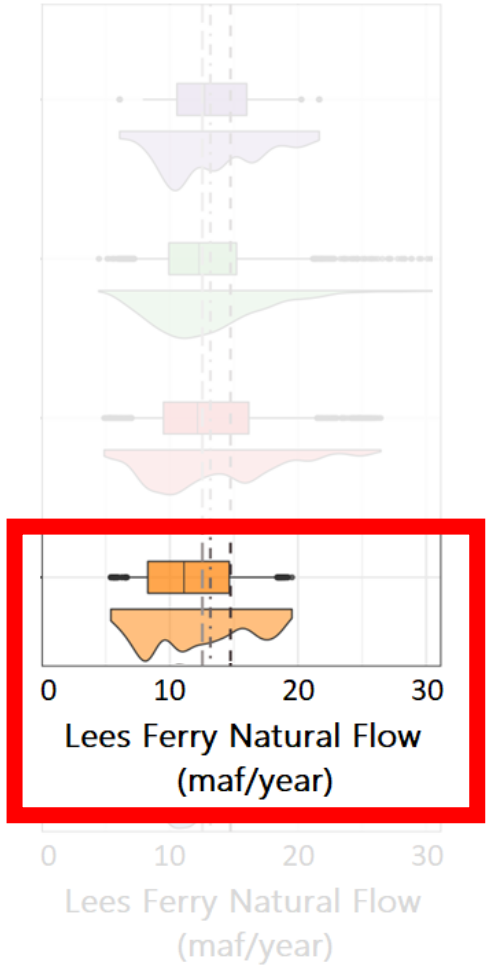
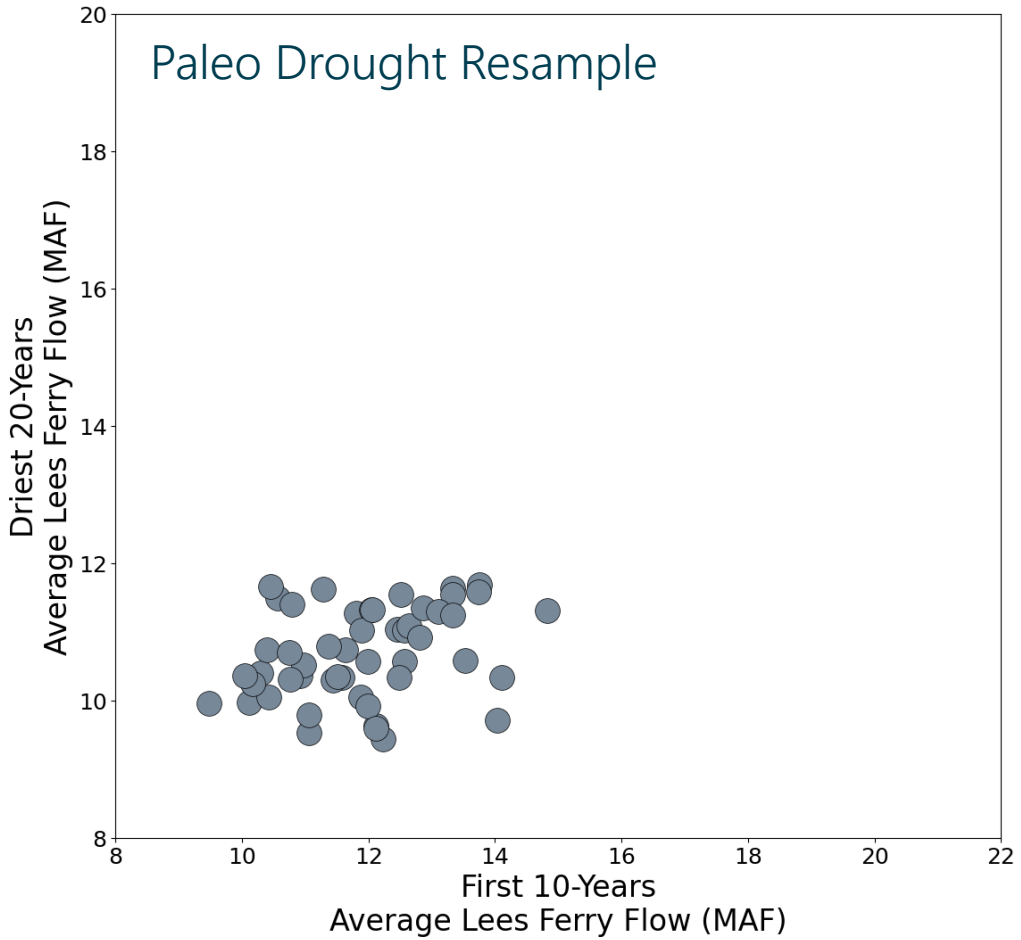
Paleo Drought Resampling:

- Samples only from *most extreme drought* in paleo record (1576-1600)
- Small sample set (25 yrs) limits diversity of conditions across ensemble





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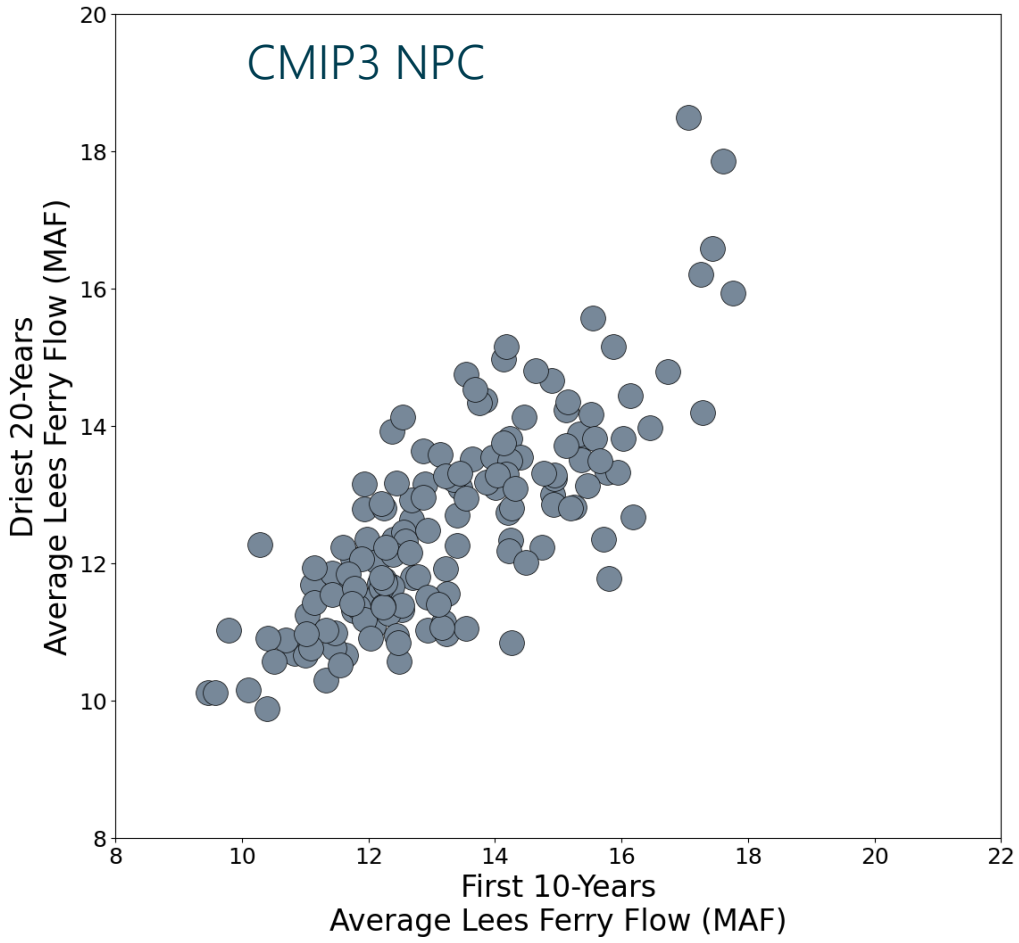
CMIP3 NPC

- Uses paleo record patterns to sample from one of 112 CMIP3 model projections
- Sub-sampled for *maximum diversity* compared to the other selected traces



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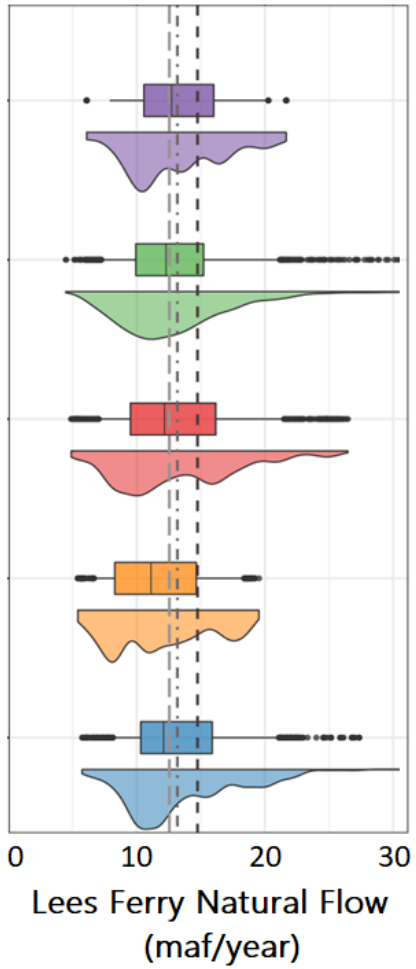
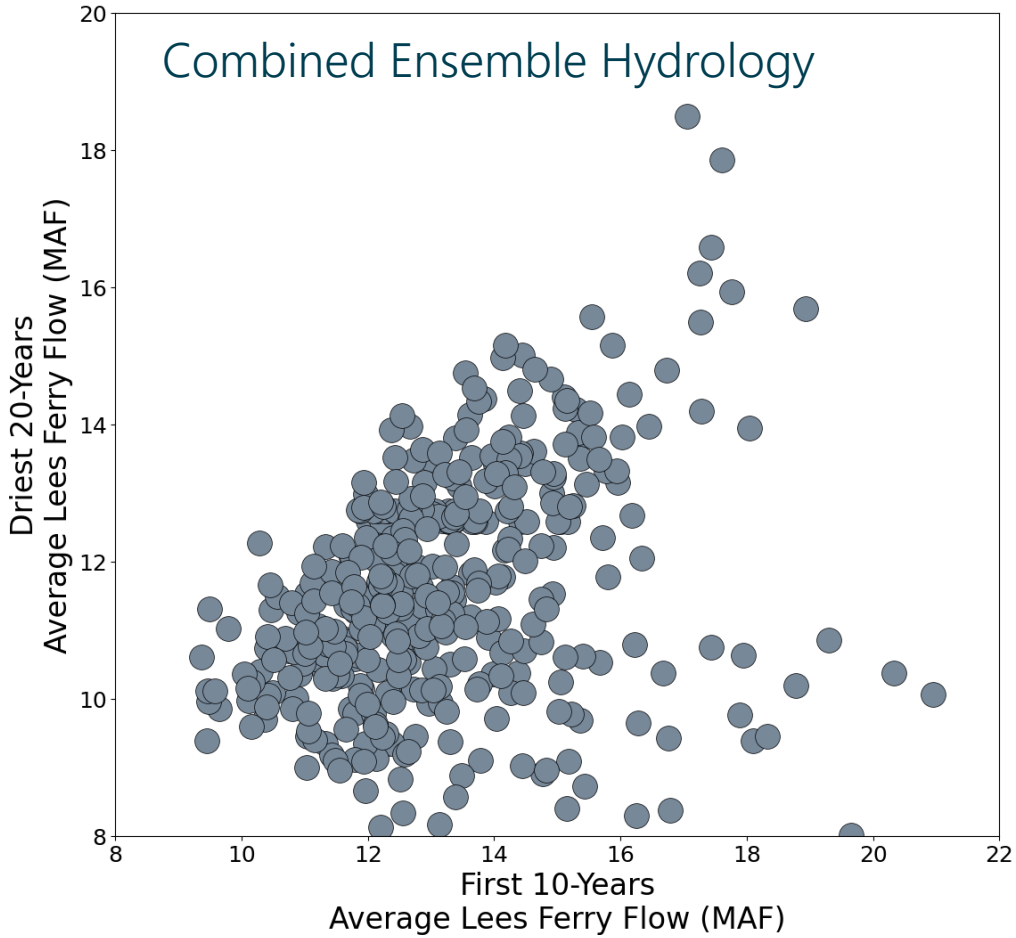
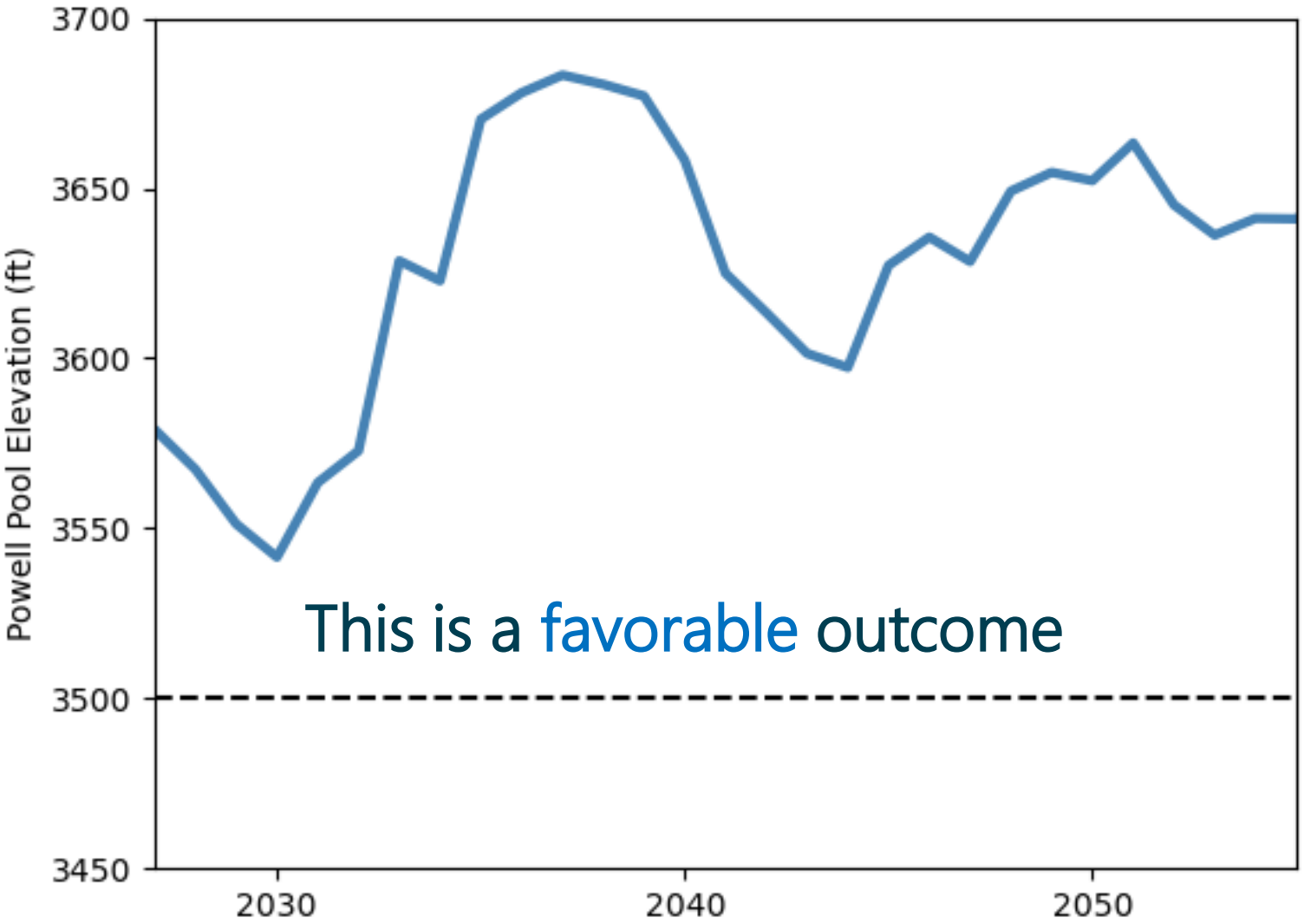
Sampling to enable analysis across *a wide range* of future conditions without assigning likelihood beforehand





What does it mean for an alternative to be robust?



- Robustness measure a binary outcome – is an outcome favorable or not in an individual future?
- Example – does **Powell** Pool Elevation fall below **3500ft** in any year during a 30 – year CRSS simulation?

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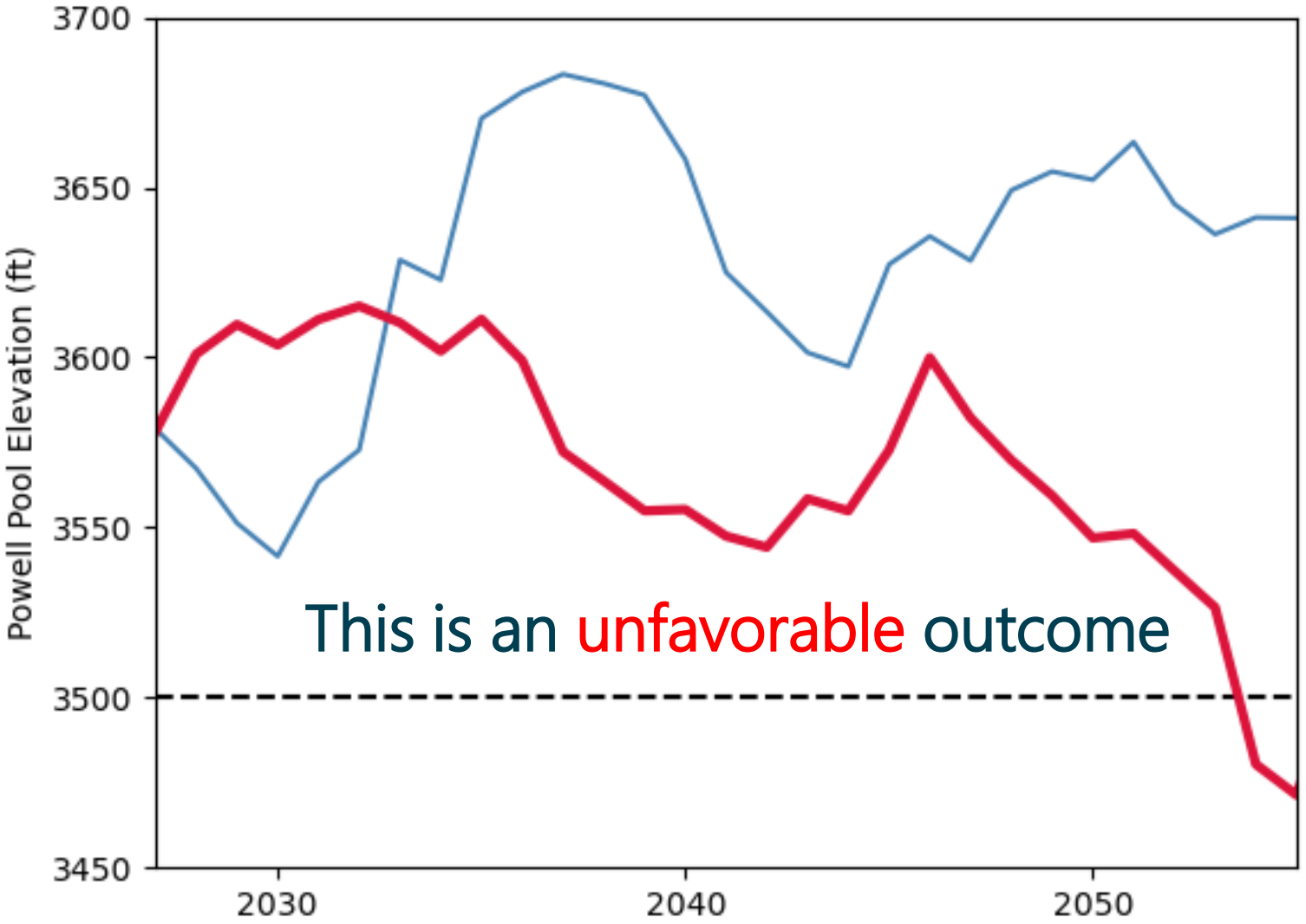

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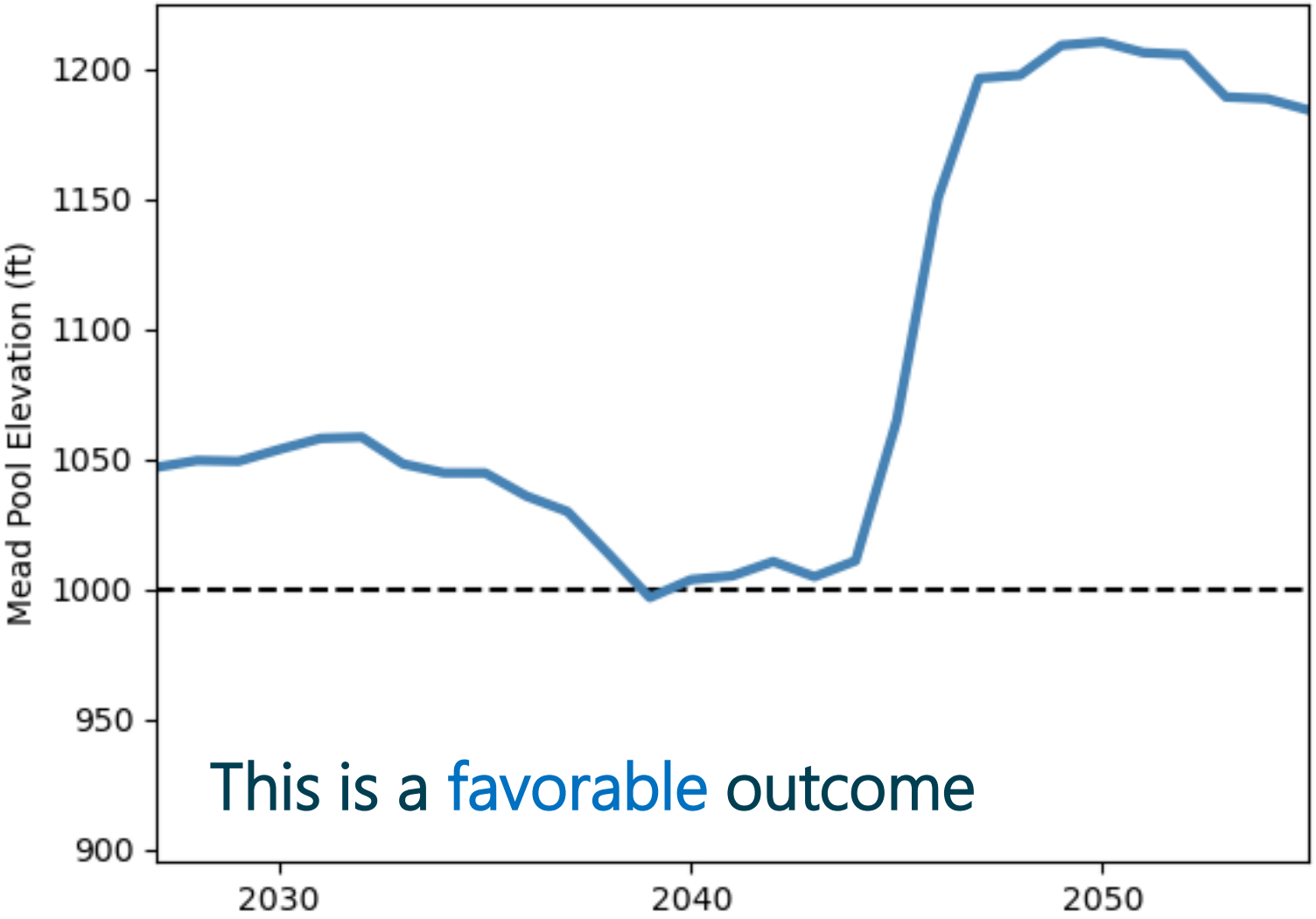
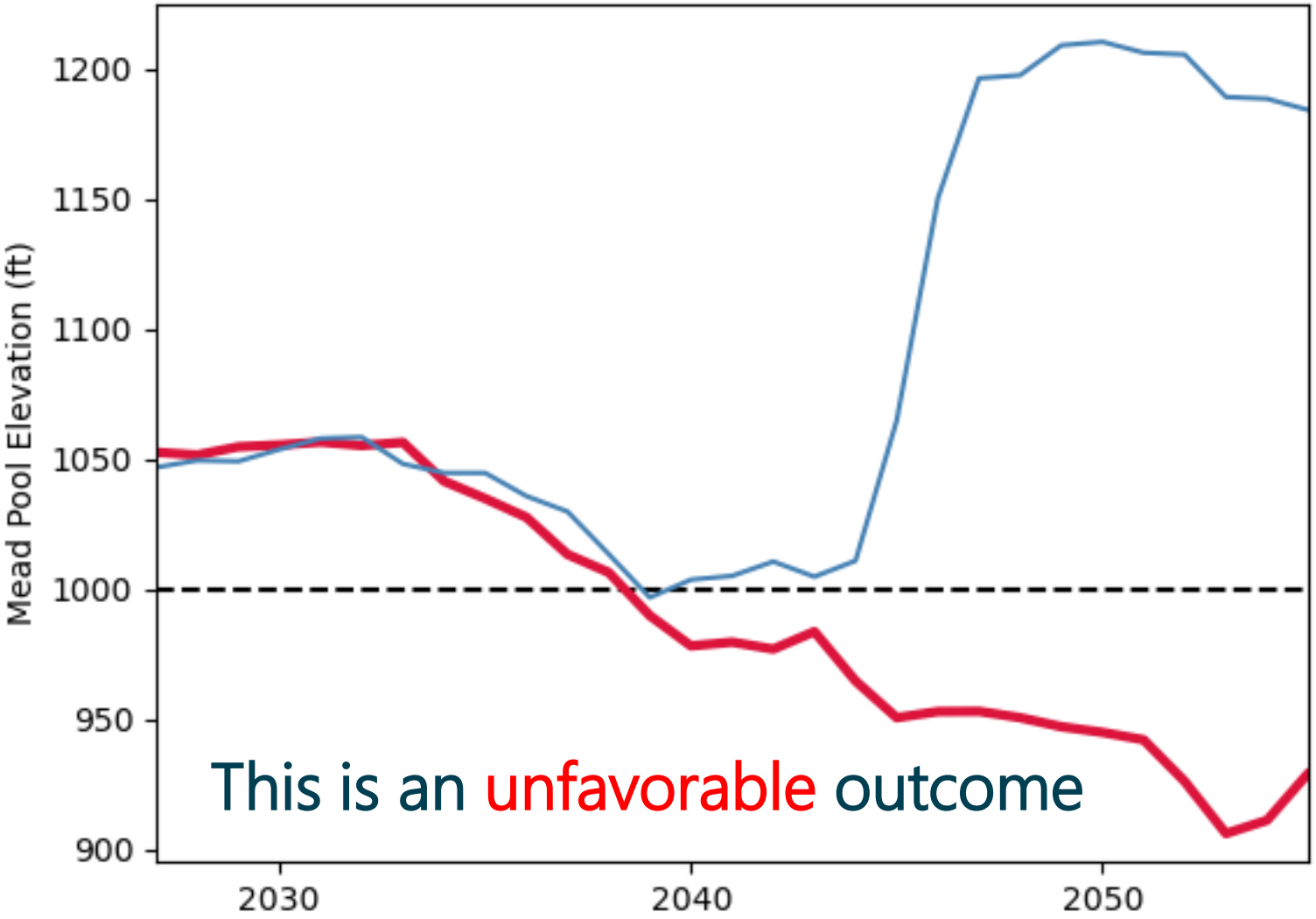
Are your thresholds ‘hard’ or ‘soft’?



- For some metrics of interest, thresholds may be less clear-cut
- Infrequent/short/small periods beyond threshold may still result in a favorable outcome – such as this example of Lake Mead Pool Elevation falling below 1000ft

Are your thresholds ‘hard’ or ‘soft’?



- For some metrics of interest, thresholds may be less clear-cut
- Some frequency or magnitude of violation may still result in a favorable outcome
- More significant violations are required for unfavorable outcomes

Thinking Outside the Ensemble

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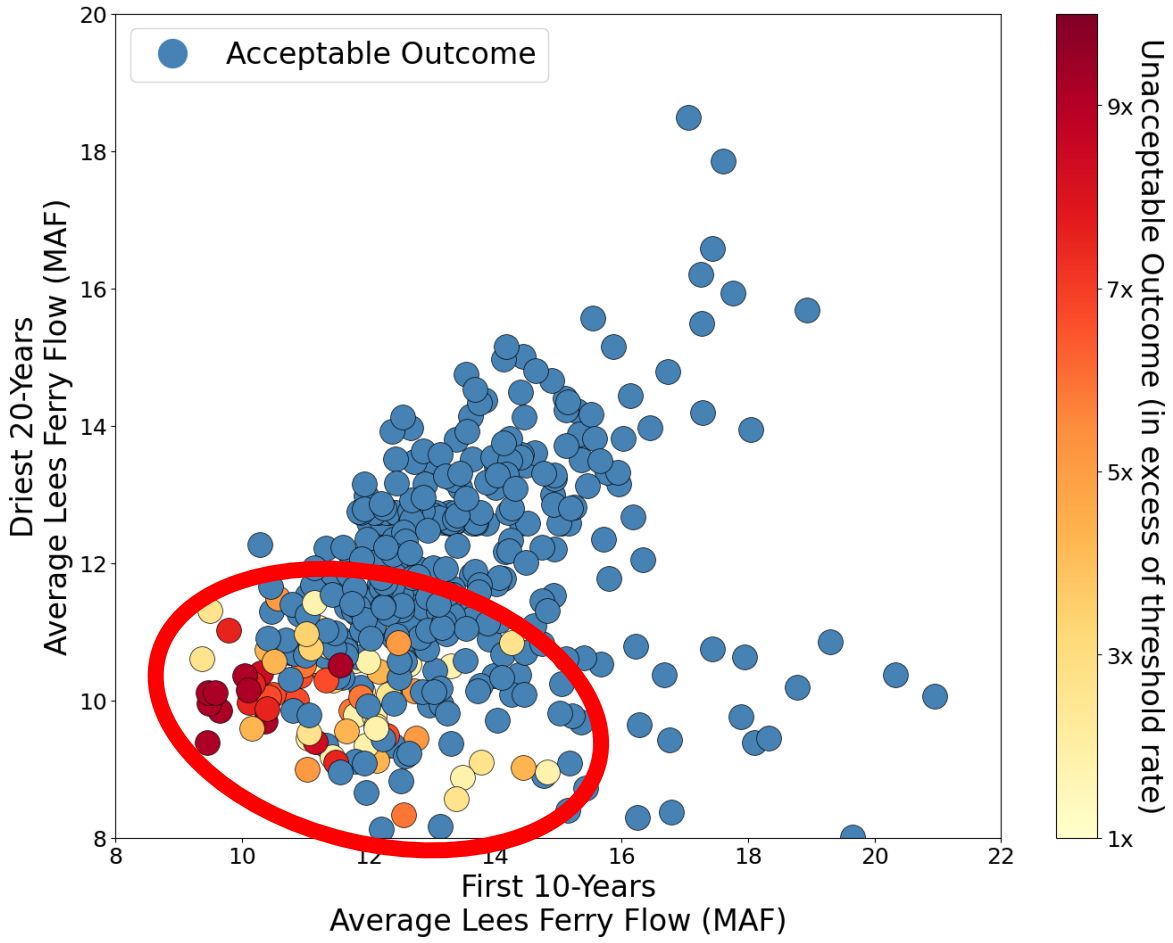
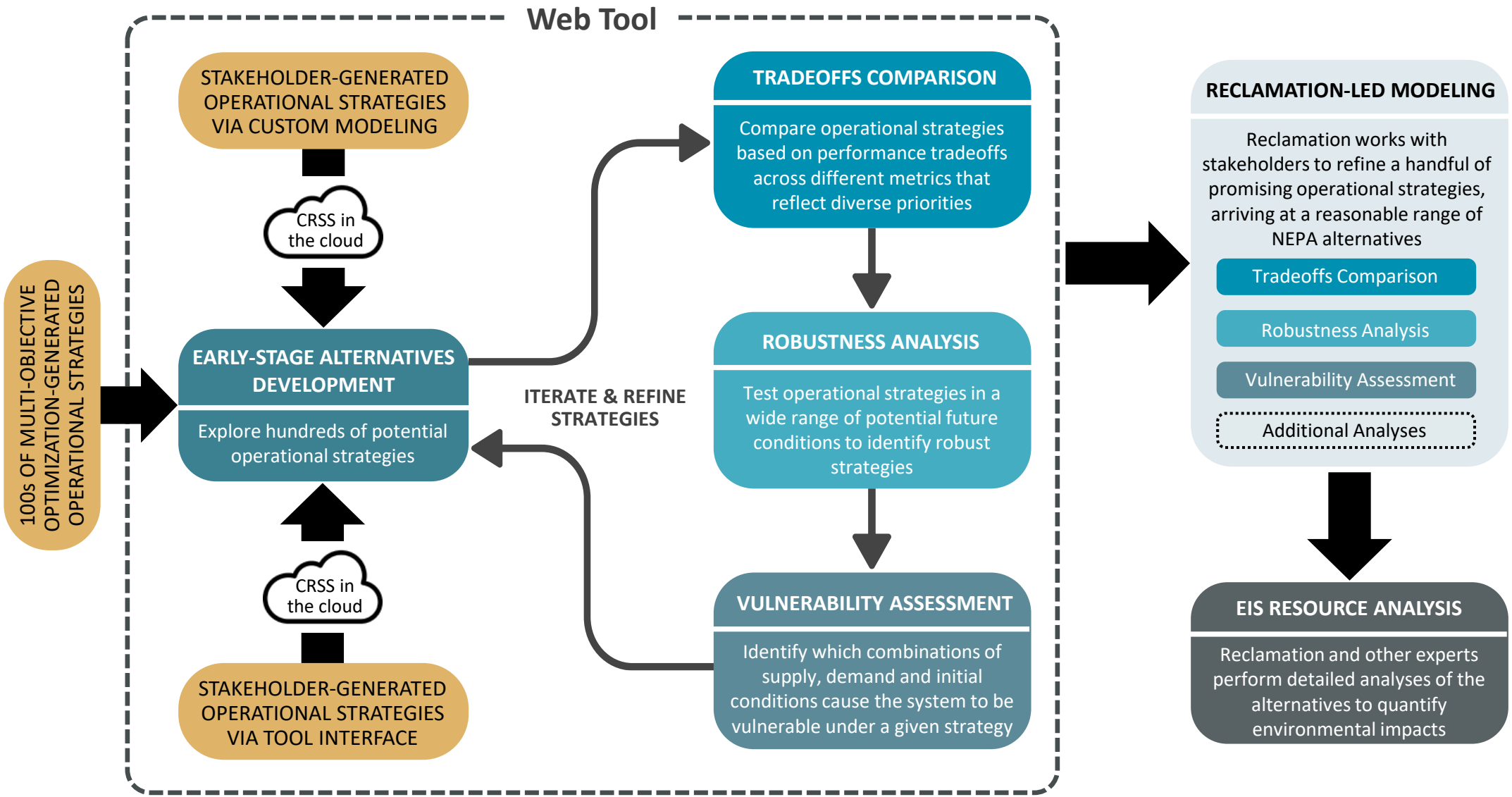
Key Elements

- Prioritize ***robustness***, or the ability of a policy to perform acceptably well in a wide range of conditions
- Assess the ***vulnerability*** of a policy: what uncertain future conditions might cause it to perform poorly?
- This sets the stage for a discussion: how likely are different vulnerabilities and how should we ***tradeoff*** different objectives in the case of extreme conditions?



Post-2026 Operations Exploration Web Tool



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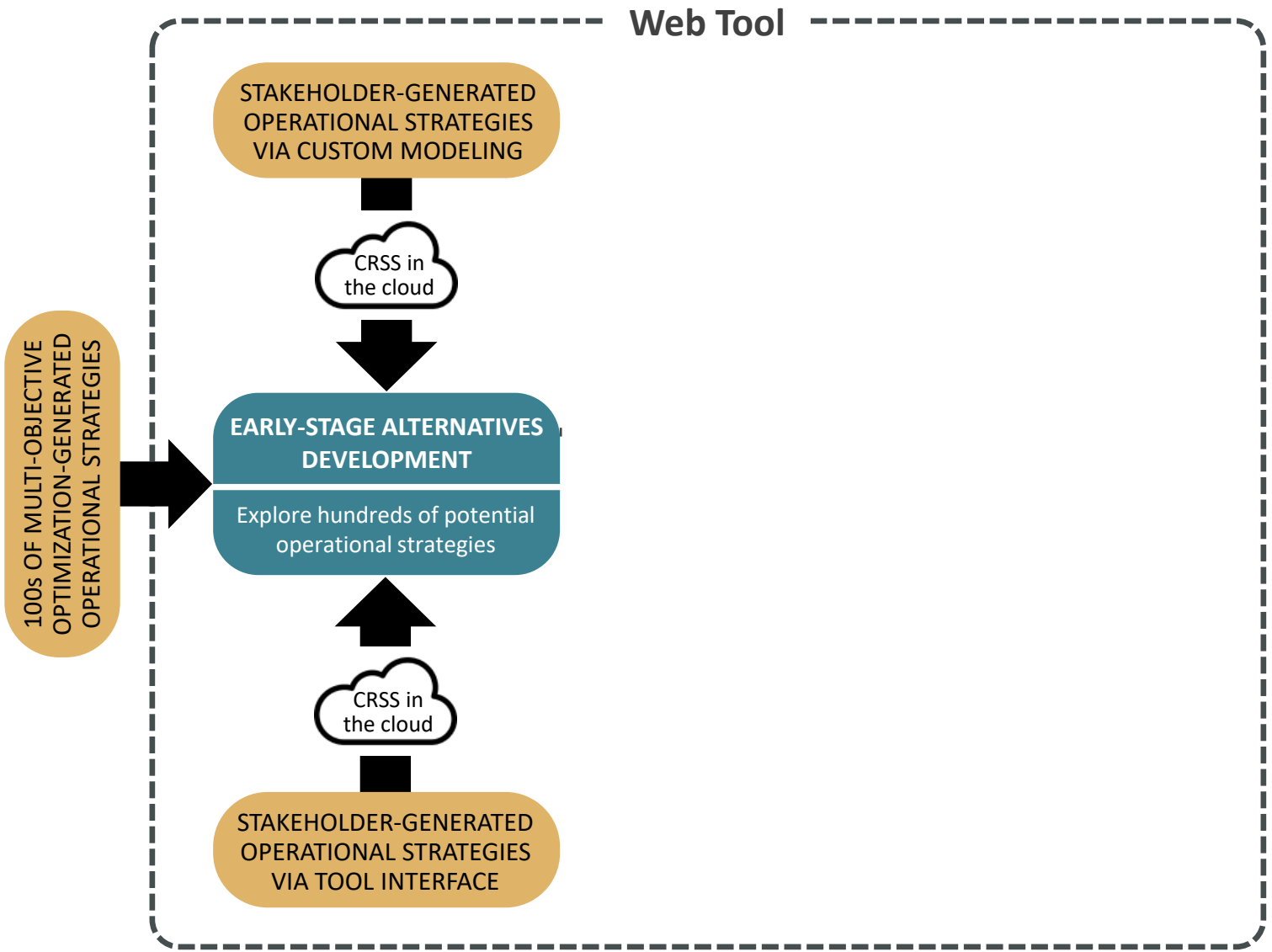

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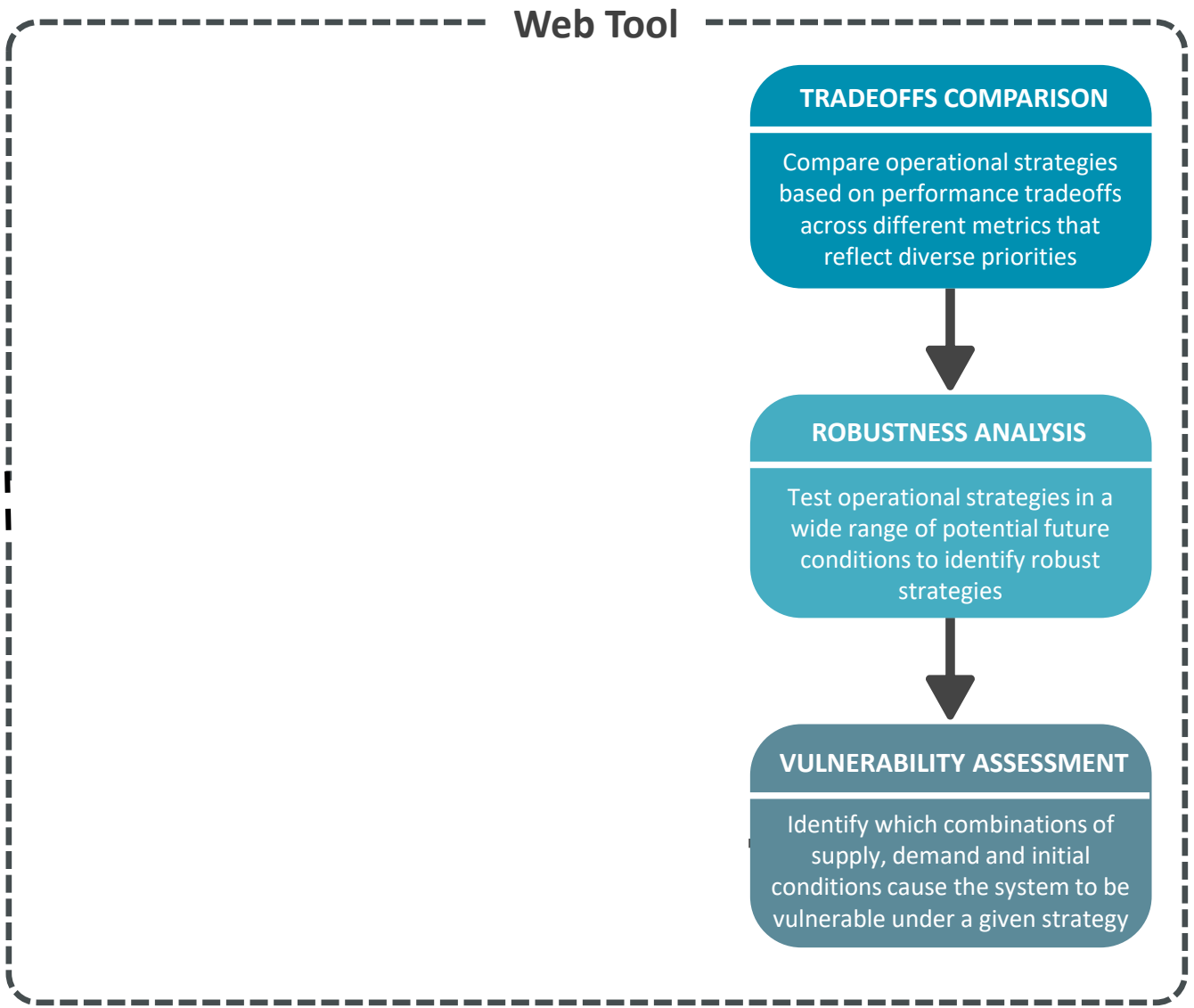

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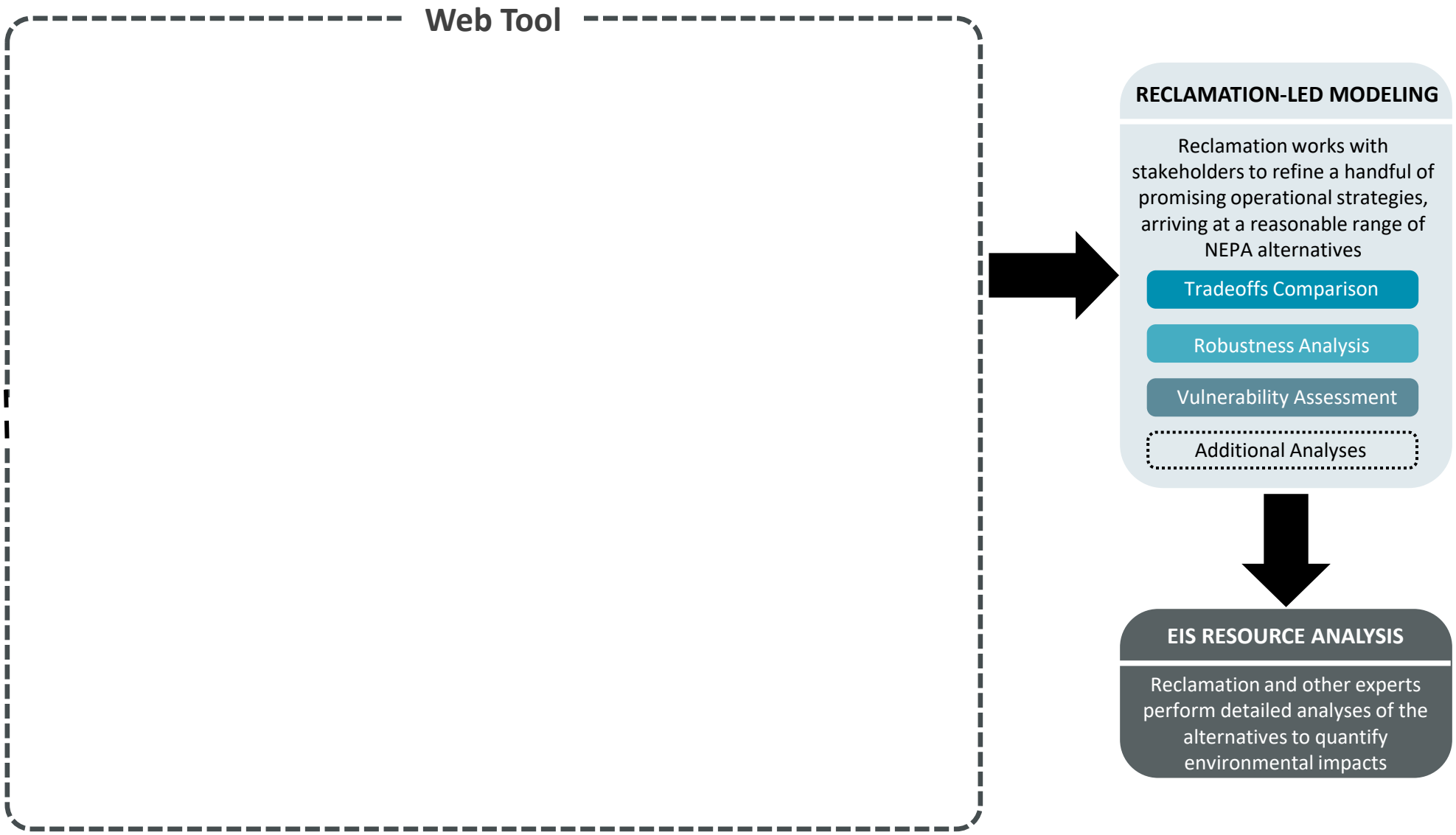
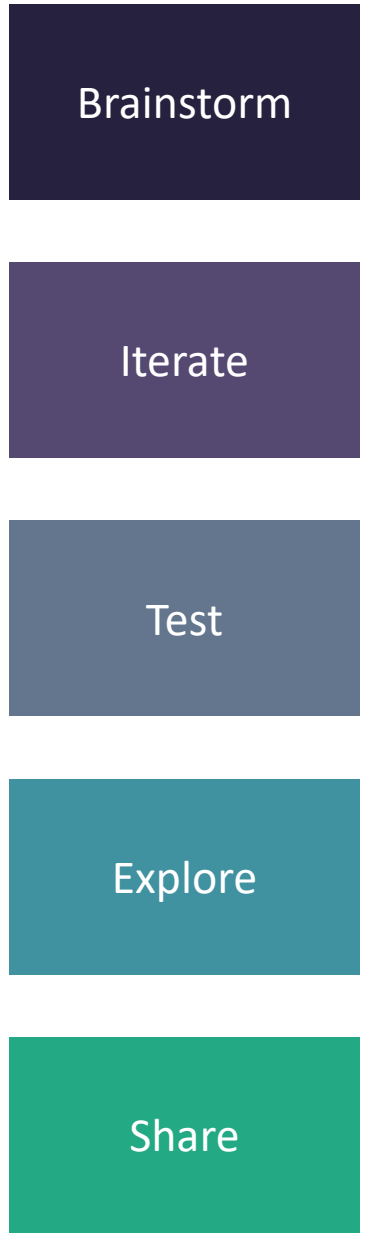


Important Uses of the Web Tool

- Brainstorm different approaches to Powell and Mead operations
  - Supports 48 different operational paradigms
  - Highly customizable strategies within the different paradigms
- Iterate on specific operational strategies
- Test fully developed operational strategies on a common platform
- Explore performance and robustness using 100+ metrics across many resource categories
- Share analysis with colleagues



Thank you

For more information on …

The Colorado River Post-2026 Operations Exploration Tool:

https://tool.crbpost2026dmdu.org/

The Colorado River Post-2026 Operations (General Info):

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https://www.usbr.gov/ColoradoRiverBasin/post2026/index.html