BUREAU OF RECLAMATION

Colorado River Basin Post-2026 Integrated Technical Education Workgroup

Kickoff Webinar
December 7, 2022

Welcome & Introductions

- Purpose of this webinar is to kick-off Reclamation's Integrated Technical Education Workgroup
- The Technical Workgroup is being formed for the purpose of assisting our partners and stakeholders to gain a better understanding of the technical tools and approaches to be used in the Post-2026 process and help our partners improve technical capacity
- Workgroup "ground rule": Please refrain from publishing/posting presentation material until posted to Reclamation website
- Thank you for your participation in this Workgroup

Reclamation Team and Collaborators

- Reclamation's Post-2026 Technical Workgroup Team
  - Upper and Lower Colorado Basin Region's Modeling & Research Teams
- Collaborators
  - University of Colorado's Center for Advanced Decision Support for Water & Environmental Systems (CU-CADSWES)
  - Virga Labs

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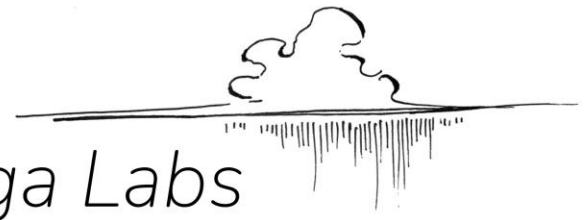
Center for Advanced Decision Support for Water and Environmental Systems (CADSWES)
UNIVERSITY OF COLORADO **BOULDER**



Workgroup Participants (thus far)

Tribes

- Tohono O'odham Nation
- Quechan Indian Tribe
- Ute Mountain Ute Tribe
- Southern Ute Indian Tribe
- Chemehuevi Indian Tribe
- Ak-Chin Indian Community
- Colorado River Indian Tribes
- San Carlos Apache Tribe
- Navajo Nation
- Jicarilla Apache Nation
- Hopi Tribe
- Fort McDowell Yavapai Nation
- Ute Indian Tribe of the Uintah & Ouray Reservation

Federal Agencies

- Bureau of Indian Affairs
- U.S. Fish and Wildlife Service
- International Boundary & Water Commission, U.S. Section
- International Boundary & Water Commission, Mexico Section
- Western Area Power Administration
- National Park Service

States

- Wyoming State Engineer's Office
- Arizona Department of Water Resources
- Colorado River Board of California
- New Mexico Interstate Stream Commission
- Colorado River Authority of Utah
- Colorado River Commission of Nevada
- Colorado Water Conservation Board
- Upper Colorado River Commission

Municipalities and Water/Irrigation Districts

- Coachella Valley Water District
- Imperial Irrigation District
- San Diego County Water Authority
- Metropolitan Water District of Southern California
- San Juan Water Commission
- Southern Nevada Water Authority
- Albuquerque-Bernalillo County Water Utility Authority
- Central Arizona Project
- Denver Water
- Colorado River District
- Southwestern Water Conservation District
- Front Range Water Council
- Colorado Springs Utilities
- Northern Water

Non-Governmental Organizations

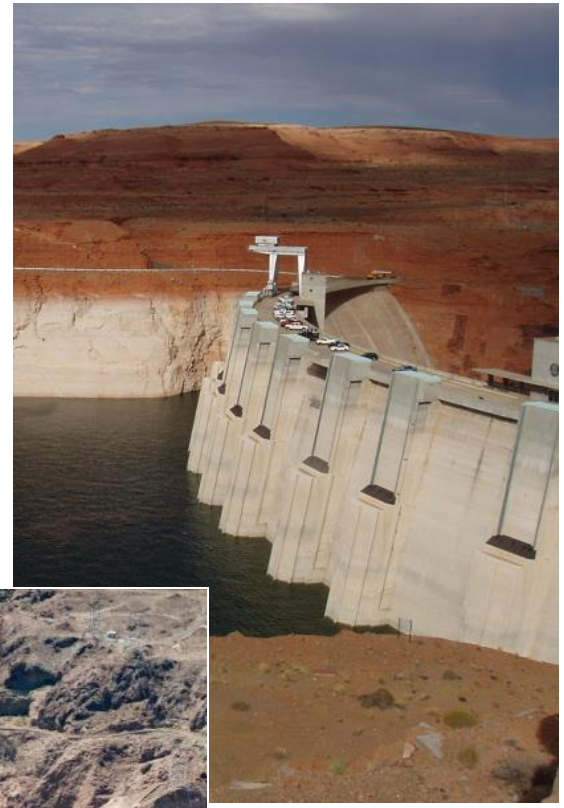
- Western Resource Advocates
- Trout Unlimited
- Grand Canyon Trust
- Pacific Institute
- Nature Conservancy
- American Rivers
- Environmental Defense Fund
- National Audubon Society
- CK Blueshift, LLC
- Culp & Kelly, LLP
- Virga Labs
- Colorado River Sustainability Campaign

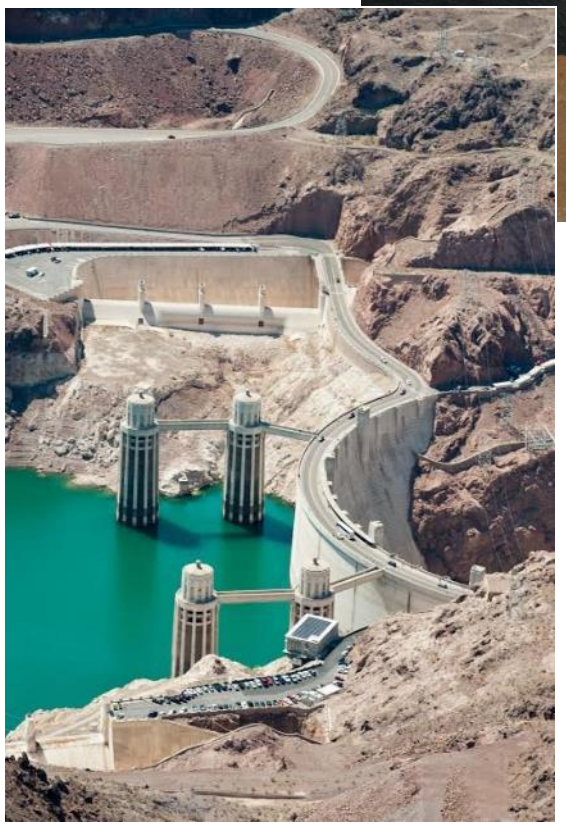
Universities

- University of New Mexico School of Law, Utton Center
- University of Arizona
- Utah State University
- University of Colorado Boulder, CADSWES
- University of Colorado Law School, Getches-Wilkinson Center
- Oxford University, Environmental Change Institute
- Colorado State University, Colorado Water Center
- University of Montana
- University of Arizona, Center for Climate Adaptation Science and Solutions

Session Overview

- Welcome & Introductions
- Purpose of Workgroup
- Review of Technical Approaches in Past Efforts
- Introduction to Decision Making under Deep Uncertainty (DMDU)
- Implementation of DMDU in Post-2026
- Future Workgroup Sessions
- Summary & Closing Remarks
- Discussion and Q&A





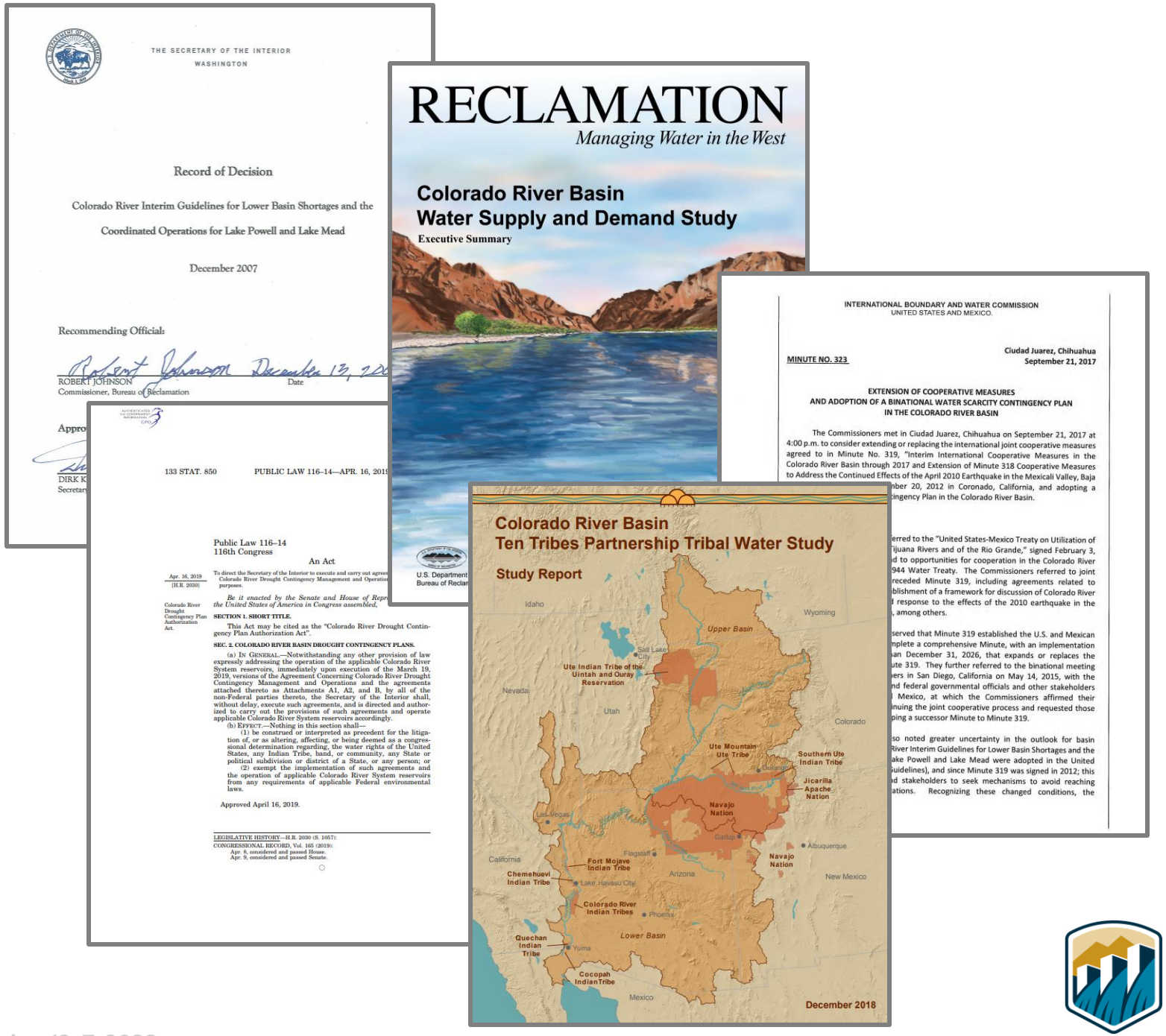
Purpose of Technical Workgroup

- The purpose of the Workgroup is for Reclamation to offer education about the technical approach, tools, and data frequently used in its long-term planning studies and to specifically share information about the technical framework that will support the Post-2026 Process
  - The Workgroup will be led through a set of technical education sessions into 2023
- The goal is to increase technical capacity and build a solid technical foundation to facilitate meaningful involvement in the Post-2026 Process
- The purpose of the Workgroup is NOT to develop operational alternatives for Post-2026 as a group or to discuss other non-technical aspects of the Process
  - There will be other opportunities to engage with Reclamation on those aspects in separate venues
- The Workgroup does not replace Reclamation's commitment to providing technical support to individual partners upon request

Review of Technical Approaches in Past Efforts

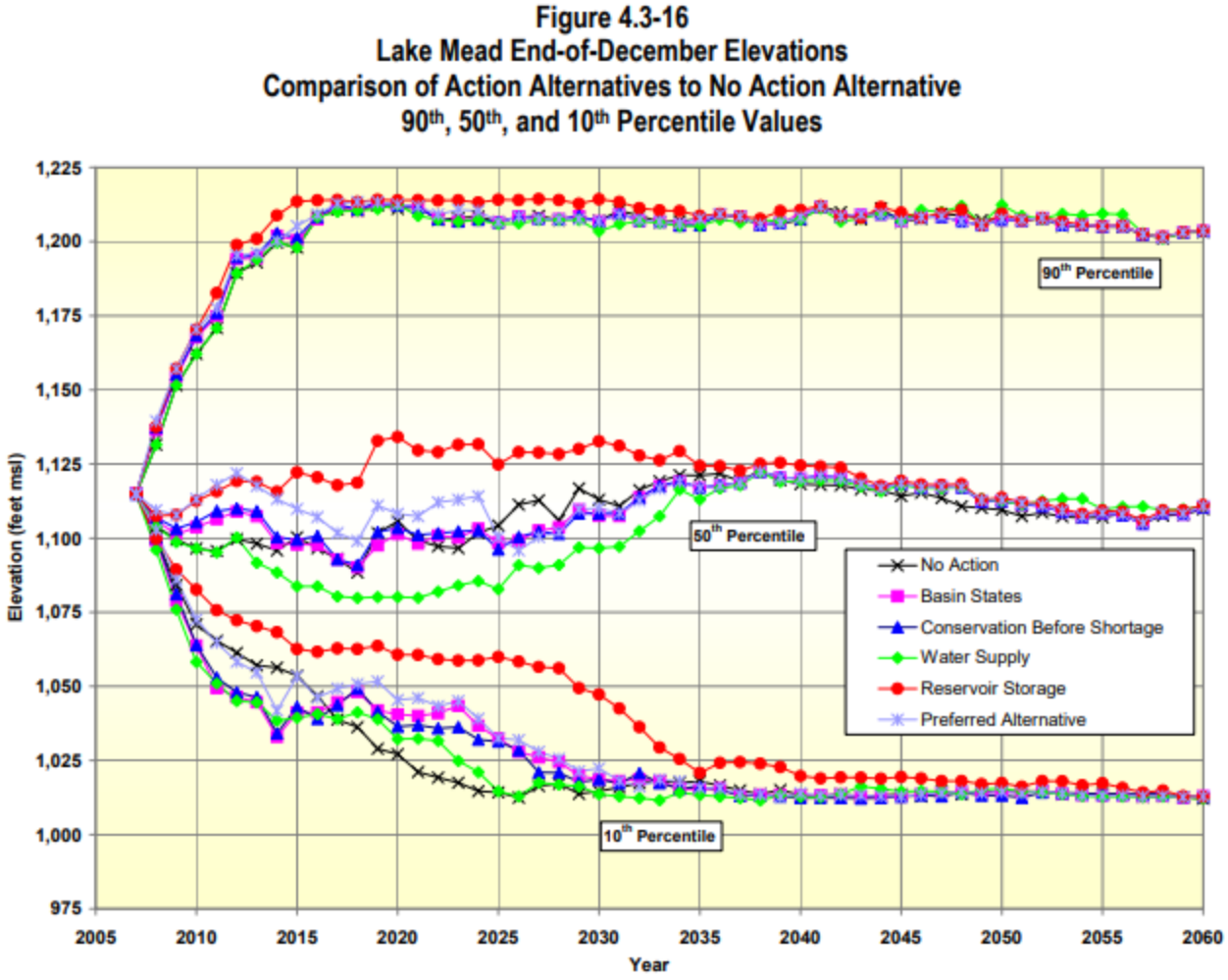
Past Planning Efforts

- 2007 Interim Guidelines (2007)
- Colorado River Basin Water Supply and Demand Study (2012)
- Minute 319 and 323 to the 1944 Water Treaty (2012 and 2017)
- Ten Tribes Partnership Tribal Water Study (2018)
- Drought Contingency Plans (2019)

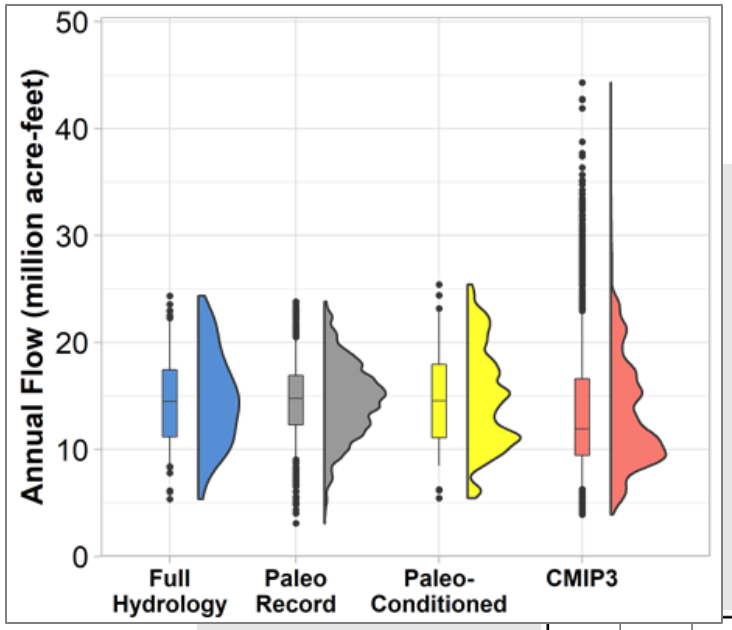


2007 Interim Guidelines

- Representation of uncertainty
  - Single demand projection
  - Observed hydrology
  - Sensitivity analysis with Paleo and Paleo-Conditioned hydrology
- Policy development
  - Primarily Reclamation-run policy simulations based on stakeholder input
  - ~200 potential policies explored in CRSS Lite (screening model)
- Analytical approach
  - Risk- percent of traces
  - Probability - 10/50/90 percentile ranges



2012 Water Supply and Demand Study

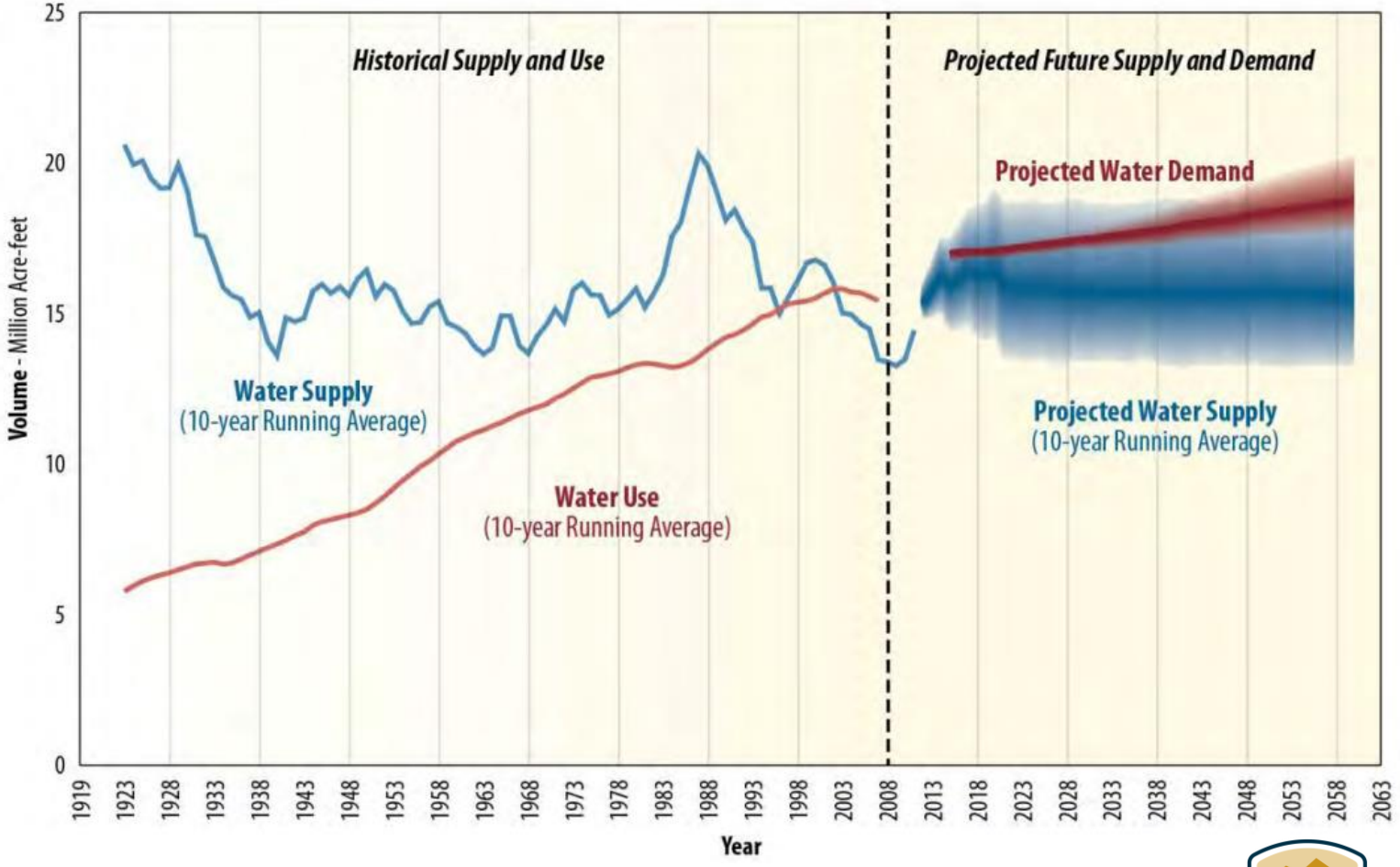


	Population	M&I Per Capita Use	Self Served Industrial Demand[1]	Agricultural Irrigated Acreage	Agricultural Per Acre Delivery	Energy Water Demand	Minerals Demand	Fish, Wildlife, Recreation Demand	Tribal Demand
Current Projected (A)	↑	↓	↑	↓	–	↑	–	–	↑
Slow Growth (B)	↑	↓	↑	↓	↑	↑	–	–	↑
Rapid Growth (C1)	↑↑	↓	↑	↓↓	↑	↑	↑	–	↑↑
Rapid Growth (C2)	↑↑	↓↓	↑	↓↓	↓	↓	↓	↑	↑↑
Enhanced Environment (D1)	↑	↓	↑	↑	–	↓	↓	↑	↑
Enhanced Environment (D2)	↑↑	↓↓	↑	↑	↓	↓	↓	↑	↑↑

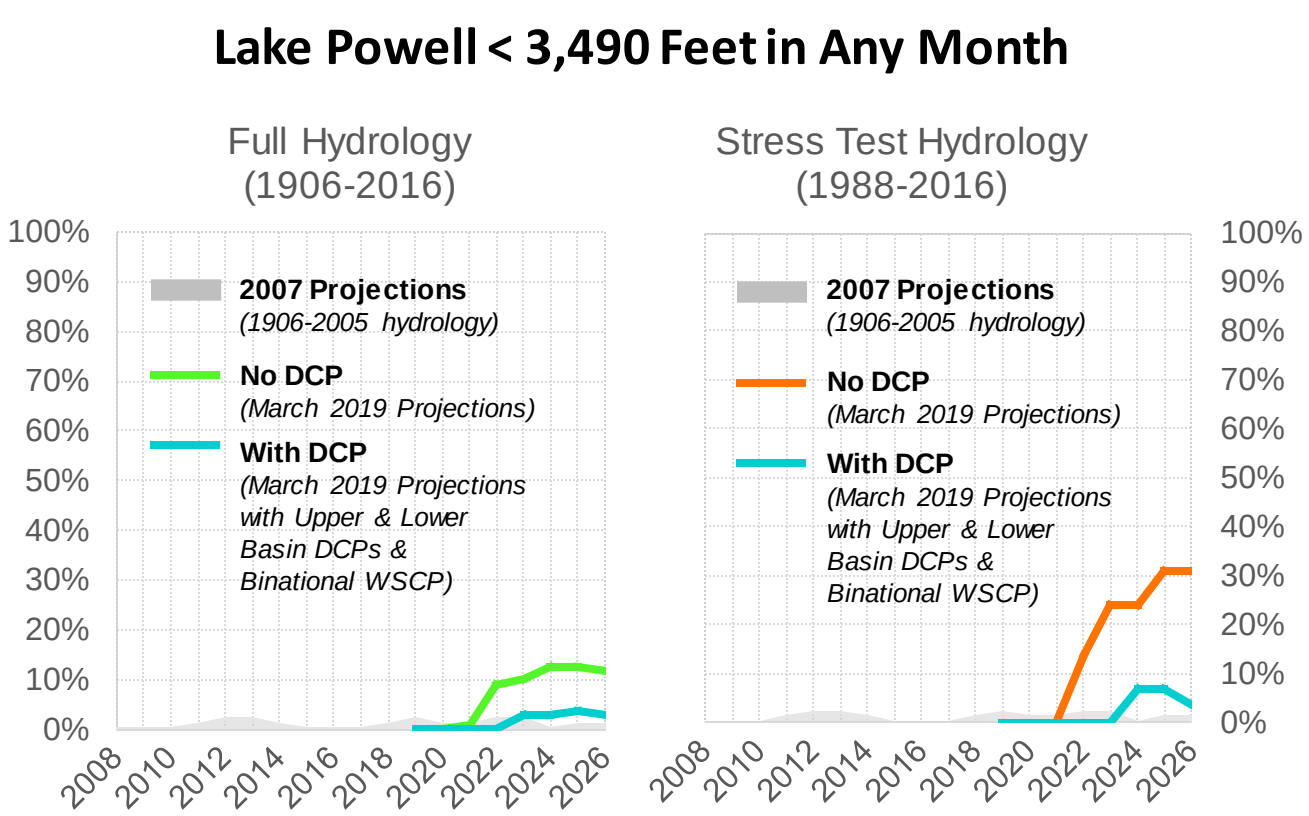
- Purpose
  - In-depth exploration of future supply and demand imbalance
  - Non-decisional exploration of potential future options and strategies
- Representation of uncertainty
  - Multiple demand projections developed through scenario planning approach
    - Tribal Water Study further explored the drivers of Tribal water demand
  - Multiple supply scenarios
    - Observed (full) hydrology
    - Paleo
    - Paleo-Conditioned
    - Climate change (CMIP3)

2012 Water Supply and Demand Study

- Policy development
  - Grouped portfolios of actions based on stakeholder preferences to mitigate supply-demand imbalance
  - Used CRSS to adaptively implement different actions based on different portfolios
- Analytical approach
  - Expanded on past approaches by introducing Robust Decision Making (RDM) approach — vulnerability, signposts, and tradeoff analysis



2019 Drought Contingency Plan & Minute 323



- Representation of uncertainty
  - Single demand projection
  - Observed hydrology: "Full", "Stress Test" & "Pluvial Removed"
- Policy development
  - Reclamation and stakeholder-run policy simulations based on stakeholder input
  - Goal of policy was to restore risk to that projected during the 2007 Interim Guidelines development
- Analytical approach
  - Risk-based

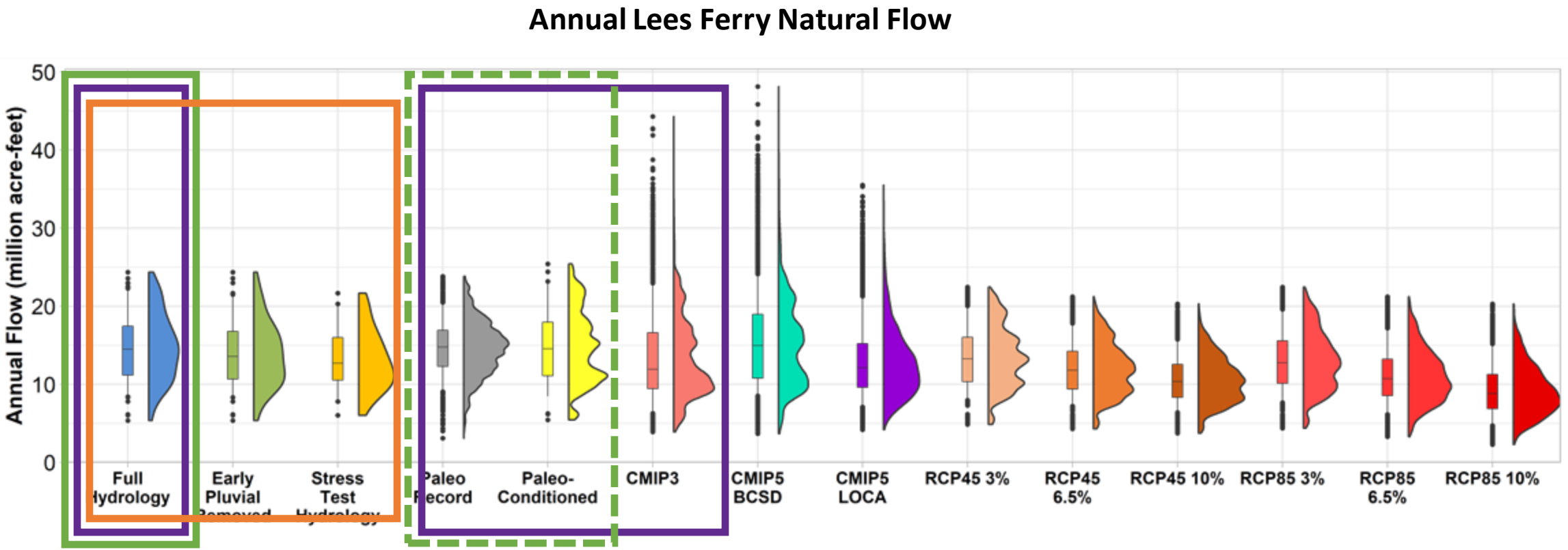
Changed Circumstances Since Adoption of the 2007 Interim Guidelines

- Unprecedented drought, exacerbated by climate change, and declining reservoir storage
- **Increasing uncertainty about future water supply and demand**
- Need to explore a wide range of creative solutions
- Advances in technical methods and tools
- Increased need for expanded partner-stakeholder engagement in Colorado River decision-making

These factors are described in the June 2022 Federal Register Notice requesting input on the development of Post-2026 Colorado River Reservoir operational strategies for Lake Powell and Lake Mead

Decision Making under Deep Uncertainty

Distributions of Hydrology Ensembles

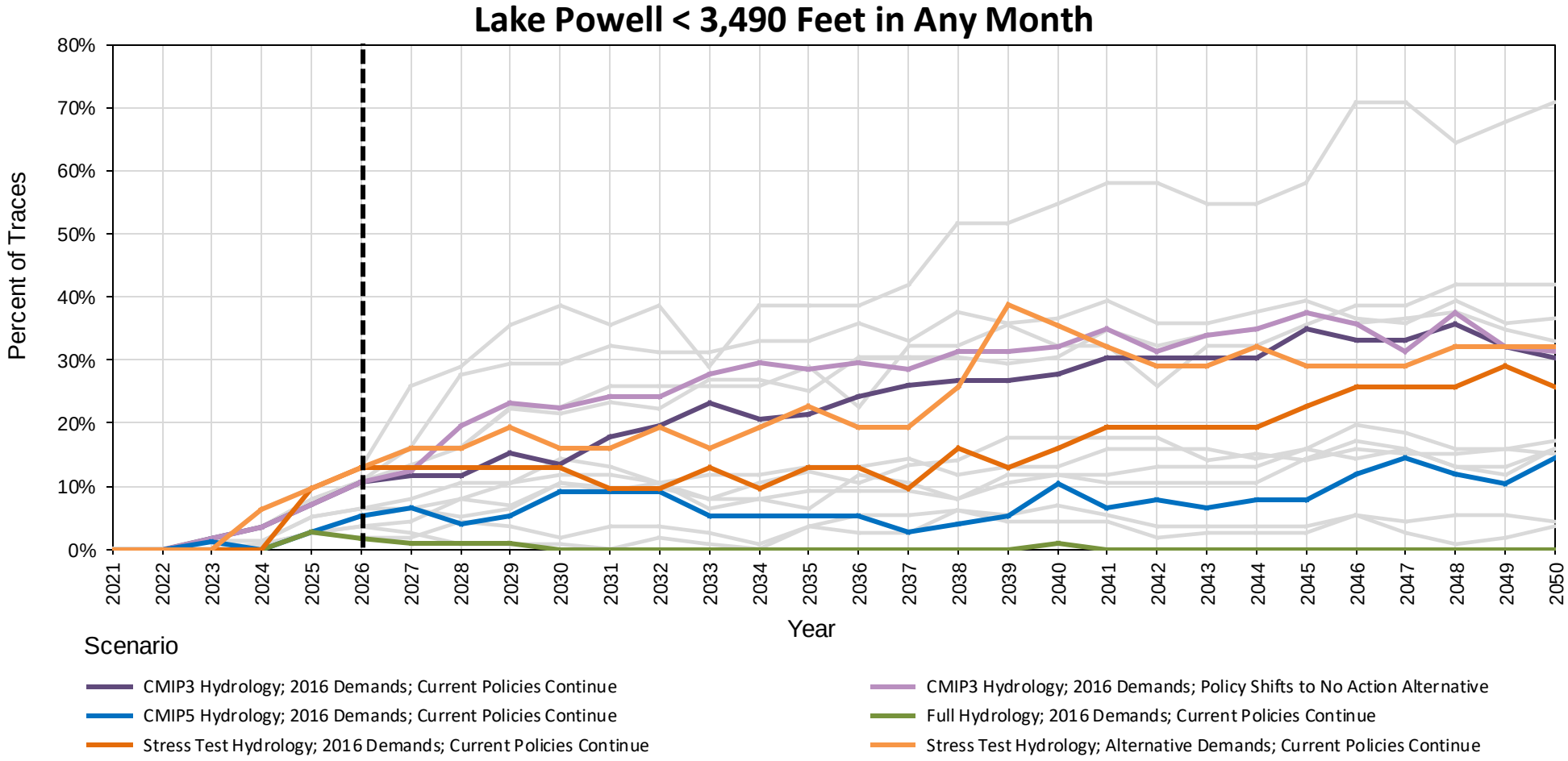


Ensembles used in support of **2007 Interim Guidelines**

2012 Basin Study & 2018 Tribal Water Study

2019 DCP & 2017 Minute 323

Long-term risk outlooks using different supply, demand, and policy assumptions*



*All projections are from August 2020 CRSS modeling with Lake Powell initial elevation of 3,592'. Lake Powell's current elevation is ~3,528'
CMIP5 ensemble based on BCSD downscaling

Challenges of Planning under Deep Uncertainty

- Deep uncertainty (broadly defined) exists if
  1. It is impossible to determine the most appropriate planning assumptions;
  2. There is no universally agreed upon way to balance different system priorities; or
  3. Stakeholders disagree about how to best represent the system in a model.

- **In the Colorado River Basin**, 1 & 2 are major challenges[1]
  - Climate change is impacting hydrology and there is no scientific agreement on the best representation of supply
  - Future demands are uncertain
  - Water must be shared across many diverse Basin resources and interests

- Most previous planning efforts have relied primarily on achieving an acceptable level of "risk", i.e., percent of traces that have a bad outcome
  - Completely dependent on the chosen ensemble of hydrology traces and other assumptions
  - Changes over time as the system responds to new conditions
  - Can be particularly problematic when reservoirs are near critical thresholds

Decision Making under Deep Uncertainty

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

Key Elements

- Consider a *wide range* of future conditions without assigning likelihood beforehand
- 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 fail?

Benefits

- Eliminates the need to choose specific hydrology and demand assumptions at the beginning of a planning process
- Helps prevent misperceptions of low risk that can accompany probabilistic analyses
- Encourages dialogue about balancing priorities and preferred vs. acceptable levels of performance
- Facilitates ability to adapt based on observable conditions as they unfold

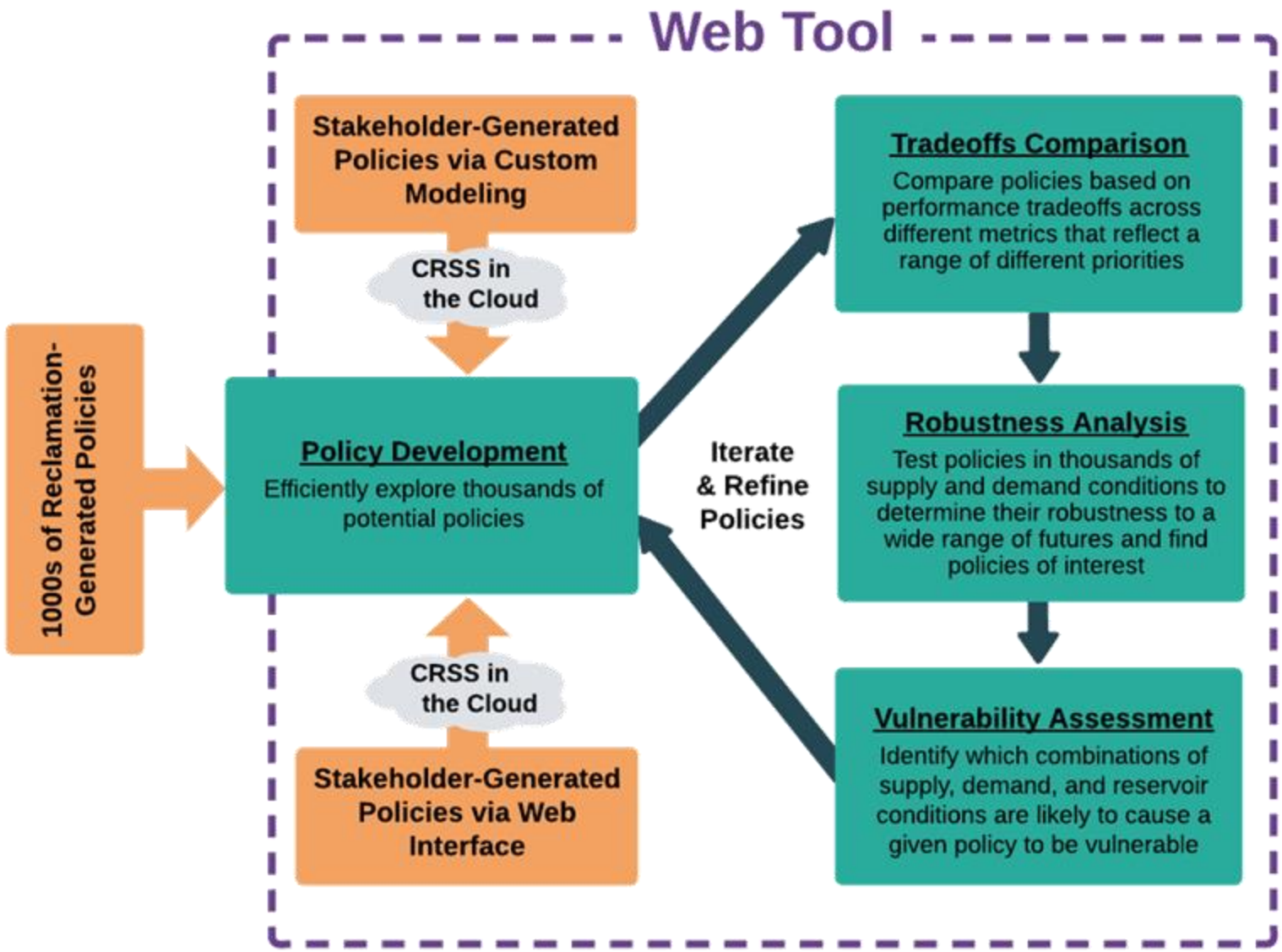
Different frameworks can be used to apply DMDU methods

Many Objective Robust Decision Making

- The Post-2026 Process will employ the DMDU framework *Many Objective Robust Decision Making* (MORDM)[2]
- Representation of uncertainty
  - Multiple hydrology scenarios
  - Multiple demand scenarios
  - Multiple sets of initial reservoir conditions
- Policy development
  - Algorithm searches through thousands of policies to find ones that exhibit good performance across multiple competing objectives
  - Stakeholders generate custom policies to compare to those produced by Reclamation and other stakeholders
- Analytical approach
  - Tradeoff comparison
  - Robustness analysis
  - Vulnerability assessment
- Used to screen potential post-2026 operational alternatives
- Supported by CRB Post-2026 DMDU Web Tool (Web Tool)

Implementation of MORDM in the Post-2026 Process

Implementation of MORDM

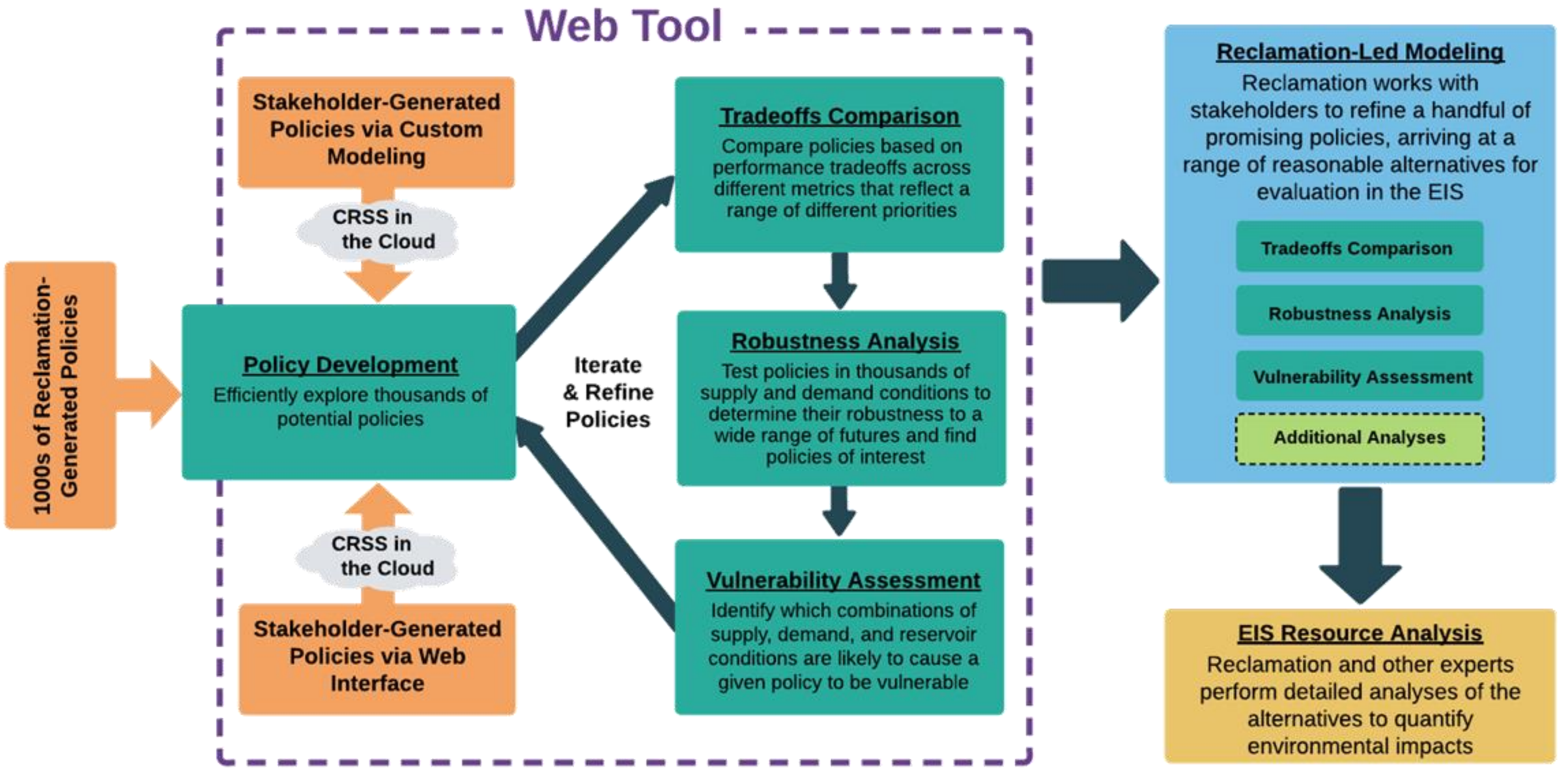


Dozens of **performance metrics** will be developed by Reclamation in collaboration with stakeholders; users can dynamically choose different combinations of metrics to use for comparing performance tradeoffs across different policies.

Users can dynamically develop criteria for **robustness**, i.e., create a custom definition of what it means for a policy to perform well, and analyze the robustness of all policies

Users can dynamically develop criteria for **vulnerability**, i.e., create a custom definition of policy failure, and apply it to policies of interest

MORDM & the Web Tool in the Post-2026 Process



Recap of Post-2026 MORDM Approach

- MORDM and the Web Tool provide many benefits, including the ability to
  - Efficiently model thousands of different policies, producing a rich landscape that supports comparison of stakeholder policy ideas
  - Dynamically explore performance tradeoffs and robustness across many different metrics and policies
  - Learn what causes policies to be vulnerable and consider which conditions we want to prepare for now vs. the conditions we want to monitor in case adaptation is needed
- Familiar components, e.g.
  - Custom stakeholder policies
  - CRSS for all modeling
  - Existing and/or intuitive sources of supply and demands
- New tools, e.g.
  - Enhanced representation of uncertainty
  - Policy search algorithm
  - Cloud computing
- Builds upon
  - Well established field of decision science
  - 2012 Basin Study (used RDM)
  - 8 subsequent years of Reclamation research
  - Advances in CRSS and computing capabilities

Upcoming Technical Topics (dates TBD)

- Next session (February, date TBD) - in person and virtual
  - Review of MORDM framework
  - Overview of CRSS
- Future sessions – will occur approximately every 4-5 weeks
  - Hydrologic uncertainty
  - Demand uncertainty
  - MORDM analytical methods: performance metrics, tradeoffs, robustness, and vulnerability
  - Introduction to the CRB Post-2026 DMDU Web Tool
  - Web Tool training and feedback
  - Special topics upon request

Summary & Closing Remarks

- Thank you for your interest and participation in this Workgroup
- A shared technical foundation is important both in the Post-2026 Process and for Basin conversations going forward
- We encourage participants to be committed to attending all sessions
- We look forward to continued collaboration in future sessions

- Please submit any follow-up questions to CRB-info@usbr.gov

References & Resources

1. *Decision Science Can Help Address the Challenges of Long-Term Planning in the Colorado River Basin* (JAWRA, 2022) https://onlinelibrary.wiley.com/doi/10.1111/1752-1688.12985
2. *Many objective robust decision making for complex environmental systems undergoing change* (Environmental Modeling & Software, 2013) https://www.sciencedirect.com/science/article/pii/S1364815212003131

- 2007 Interim Guidelines FEIS: https://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html
- Colorado River Basin Water Supply and Demand Study: https://www.usbr.gov/lc/region/programs/crbstudy/finalreport/index.html
- Reclamation's Post-2026 Website: https://www.usbr.gov/ColoradoRiverBasin/Post2026Ops.html
- June 2022 Federal Register Notice: Federal Register :: Request for Input on Development of Post-2026 Colorado River Reservoir Operational Strategies for Lake Powell and Lake Mead Under Historically Low Reservoir Conditions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