
ARIZONA
RECONSULTATION
COMMITTEE
Modeling and Analysis
Work Group #2
November 10, 2020

Meeting Logistics Summary

- Roll Call
  - Members will unmute and acknowledge their attendance when their name is called.
- Modeling and Analysis Workgroup Members
  - Use the WebEx “raise hand” feature to request to speak or ask questions.
  - Wait to be recognized before speaking to ensure clear communication and remain muted when not speaking.
- Livestream Attendees
  - Electronic public comment forms are available at cap-az.com/ARC for anyone wishing to submit a comment or question during the meeting.
  - All submissions will be addressed during the Call to the Public at the end of the meeting, unless relevant to a specific topic in the presentation.
- Modeling and Analysis Workgroup and ARC Information
  - Meeting materials have been posted on the ADWR and CAP ARC pages: cap-az.com/ARC or new.azwater.gov/ARC.

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Meeting Agenda

- Welcome and Introductions
- MAWG Recap from Sept. 17 ARC Meeting
- Colorado River System Update
- MAWG Scenario Development Process
- Colorado River Simulation System – Modeling Background
- Review of Available Hydrologies
- Emerging Data and Research
- Next Steps
- Call to the Public

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ARC #2 - MAWG Purpose and Goals

- Purpose

  Support ARC decision making by providing fact-based analysis of risks, vulnerabilities and impacts to Arizona's overall Colorado River supply including On-River and CAP users.

- Goals
  - Analyze issues and answer technical questions posed by the ARC
  - Consider a range of future hydrologic conditions
  - Analysis of different operating scenarios including those provided by Reclamation
  - Consider a range of future demand conditions including analysis of different growth scenarios
  - Evaluate and validate technical enhancements to AZ specific modeling tools

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ARC #2 Summary for MAWG

- Work Group to develop multiple modeling scenarios
- Consider a range of future hydrologic conditions:
  - Potential consideration of observed conditions, climate change projected conditions, surrogate records (“tree ring” data), and statistical methods
- Consider a range of future Colorado River uses and depletions, including Upper Basin, Lower Basin, Arizona On-River and CAP uses for impact analysis
- Consider a range of future Colorado River system operating conditions

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ARC #2 Summary for MAWG

- ***November 10th MAWG #2 – Basin scale models: Hydrology***

- Jan 26th, 2021 MAWG #3 – Basin scale models: Demands/depletions, Use behaviors, Operations and Initial model visualizations

- February 2021 MAWG #4 – Arizona and CAP scale models: Demands, Use behaviors, Priorities and Visualizations

- April/May 2021 MAWG #5 – Initial Scenario Development

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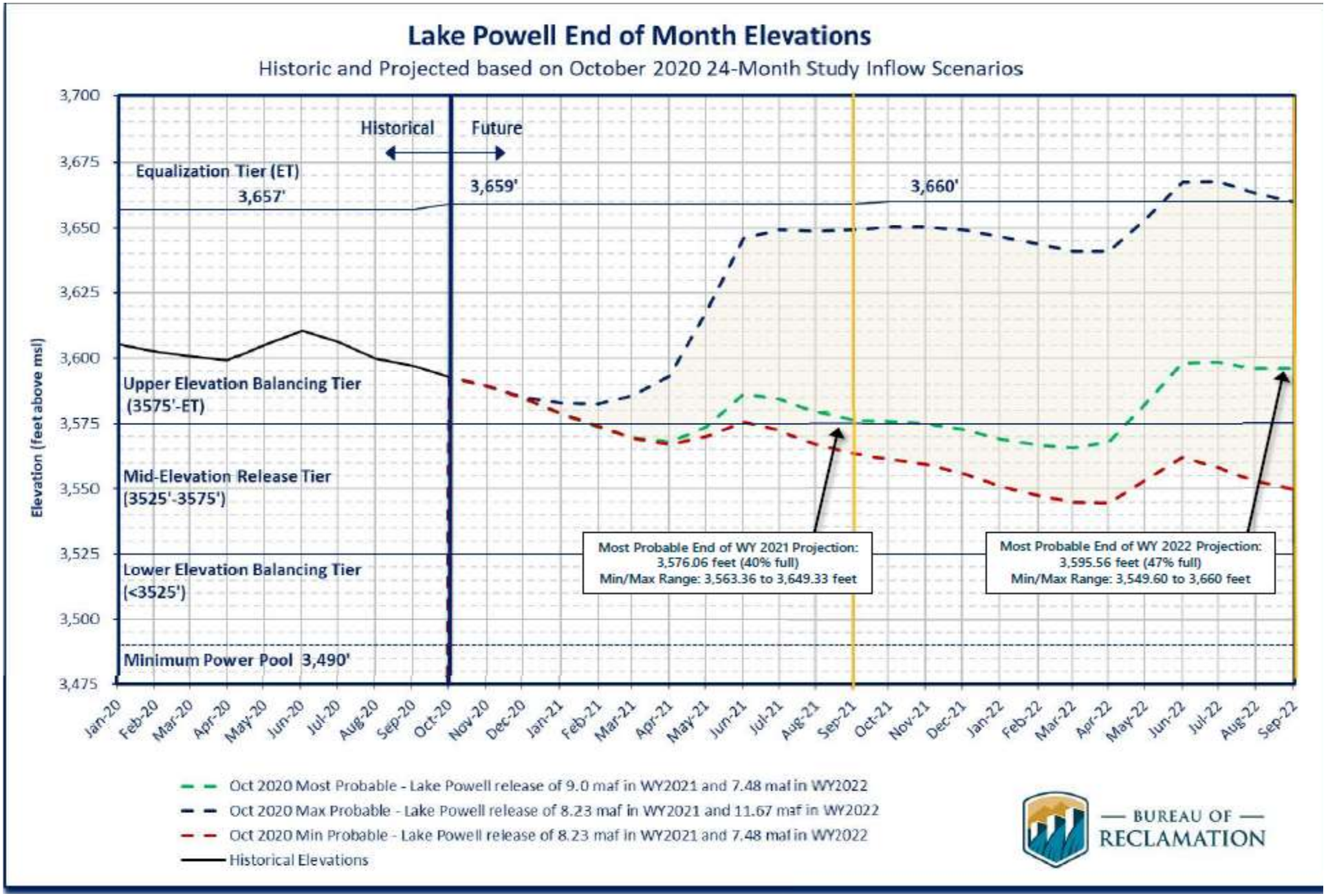
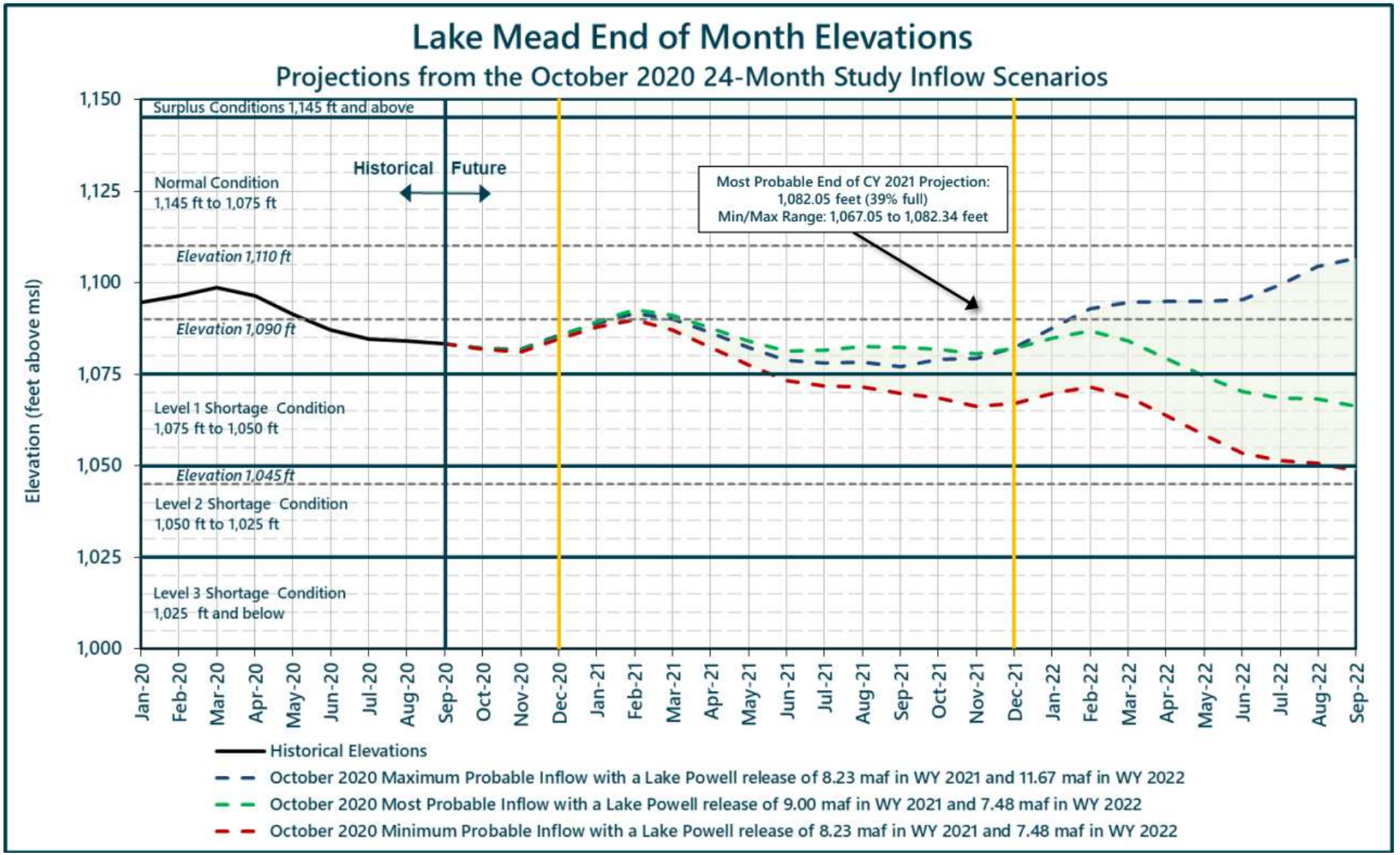
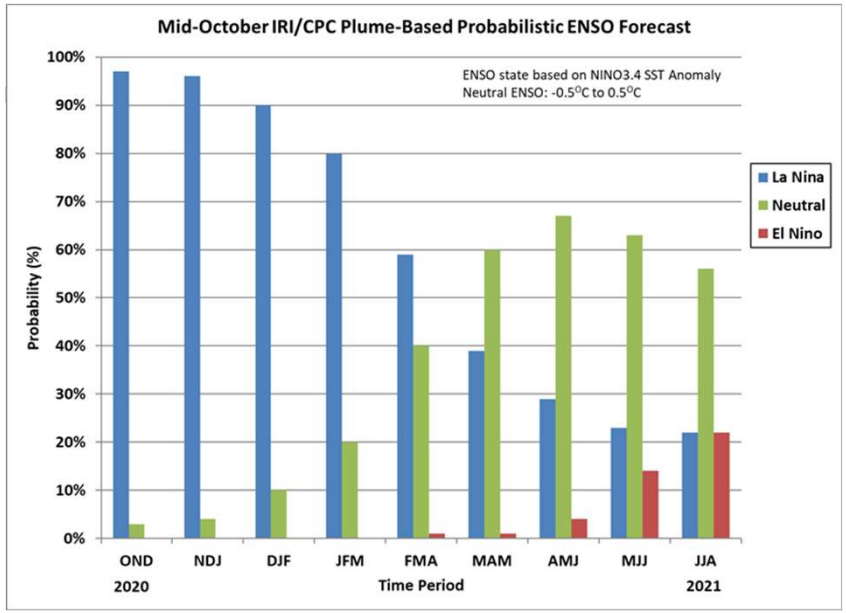
Colorado River System Update



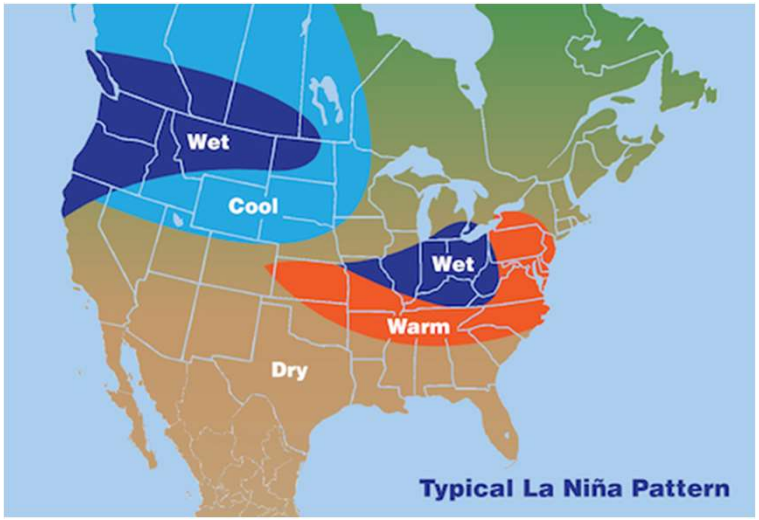
Colorado River System Update



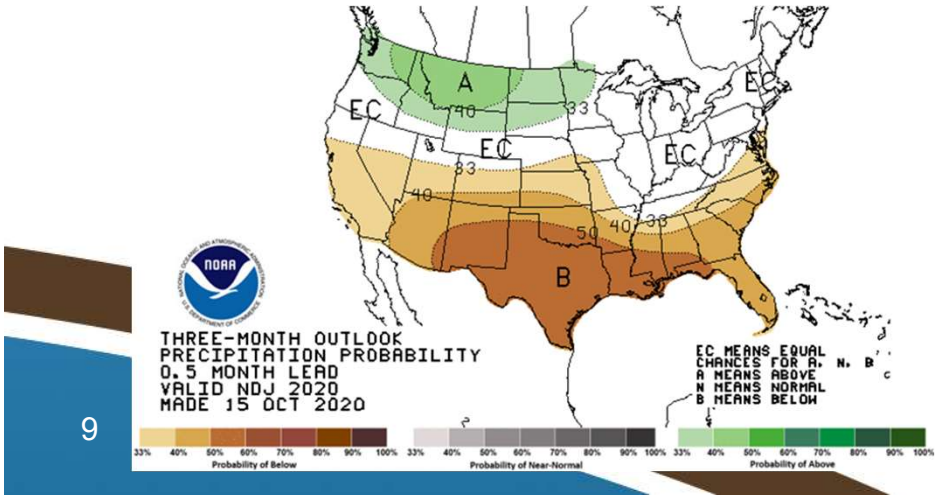
Climate Forecast Information

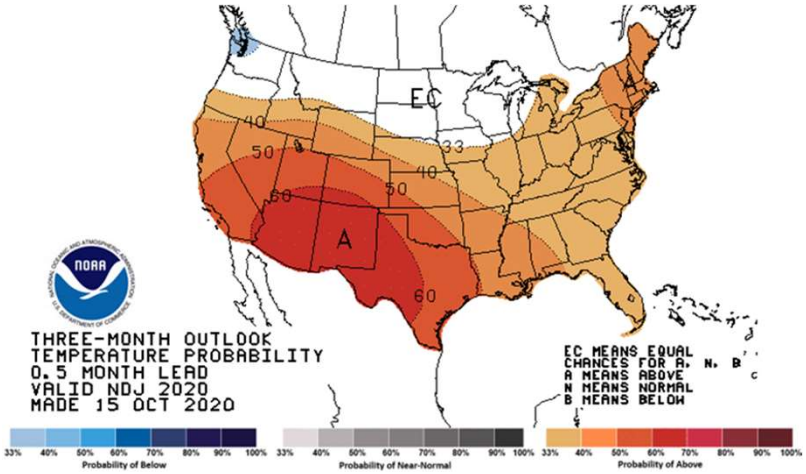


ENSO Outlook



90 Day Precipitation and Temperature Outlook





Reclamation 7.D Review Report

- Draft report released for comment on October 23, 2020
- Comments due November 13, 2020
- Goal for final report by end of 2020

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MAWG Scenario Development Process

- Consistent and plausible description of future changes
- Defined scenarios must maintain logical consistency across the different modeling environments used in this analysis
- Broad scenario descriptions to key variables can be translated and implemented in the different models depending and constrained by a model's prescribed inputs, factors, and outputs
- Once initial baseline futures are developed, we will work on developing CR operating scenarios (concepts for new guidelines) as well as examining others' proposals to inform Arizona's negotiating perspective

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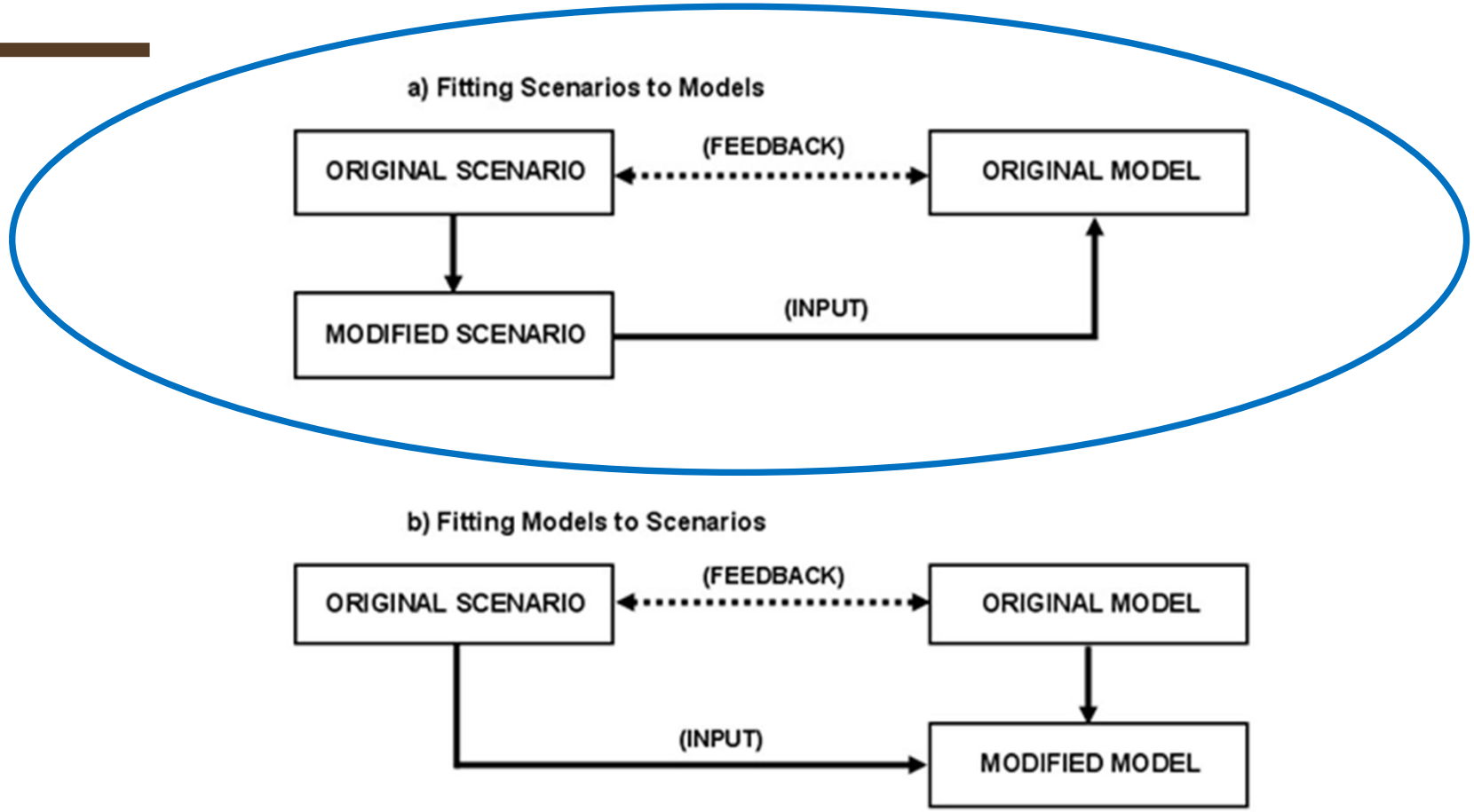
Connecting Scenarios to Models



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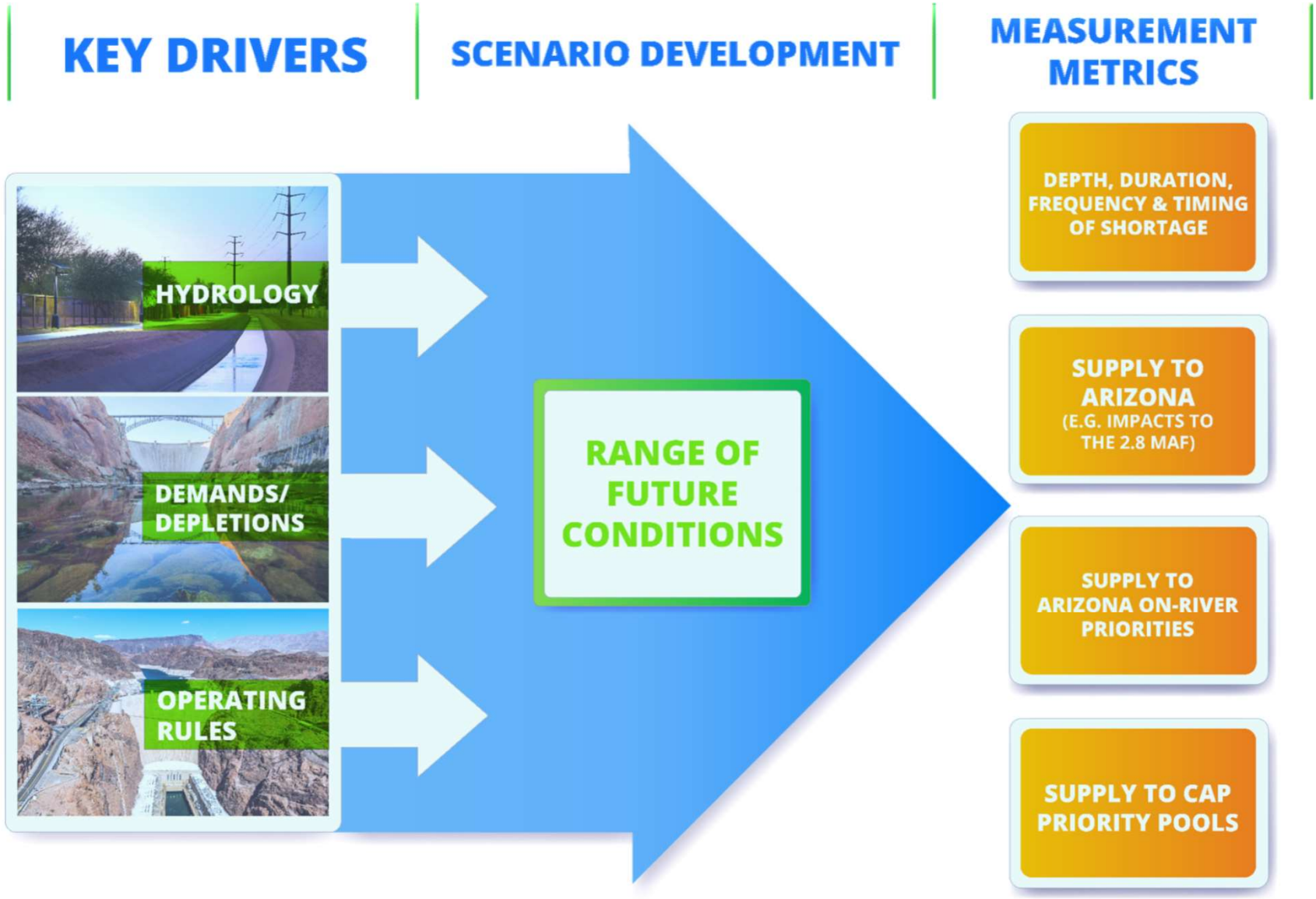
MAWG Scenario Development Process



Initial effort (now through April 2021) is to develop a range of plausible future baseline conditions as the means to compare the impact/sensitivity to different (future) operating conditions

ARC and MAWG Scenario Terms

Initial Conditions Scenarios

- Scenarios that explore several hydrologic possibilities and demand schedules to represent a range of future conditions, operations held constant
- Will be used as baseline for comparison with proposed operating scenarios

Operating Scenarios

- Proposed changes to river operations explored as ARC and Reconsultation options that will be simulated in MAWG models
- Results can be compared against Initial Conditions to evaluate impacts

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Scenario Development: Matrix of Initial Conditions Key Drivers

Scenario Drivers	Assumptions	Notes
Hydrology		
Demands - Upper Basin - Lower Basin		
Operational Rules Post-2026	'07 Guidelines + DCP Extended	
Model Duration	2060	
Mainstem AZ Demands		
CAP User Demands		

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Available Modeling and Analysis Tools

- **Colorado River (interstate tools)**
  - **24-Month Study:** Lower Basin shortages and the Coordinated Operations of Lake Powell and Lake Mead
  - **MTOM:** Risk-based operational planning and analysis
  - **CRSS:** Long-term planning studies, operational criteria development and risk analysis
- **Arizona (intrastate tools)**
  - **On-River Models:** Estimates demands and available supplies to Arizona On-River Colorado River users and salinity
  - **CAP Joint Shortage Analysis Model:** Model to evaluate the impact of variations in CAP supply to CAP users

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BREAK

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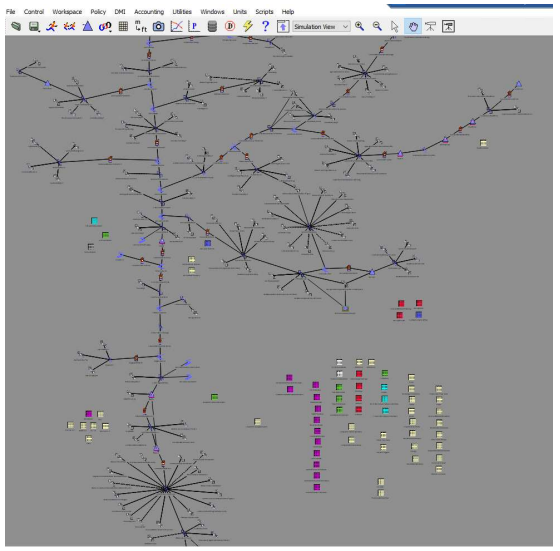
November 9, 2020

CR Modeling Tools:

Colorado River Simulation System (CRSS)

- Index Sequential Method (Probabilistic) and Single Trace Capabilities
- Rule-based
  - "Official" = 2007 Interim Guidelines + DCP
- ≥ 10 yr planning
- Hydrology inputs
  - Natural Flows
  - "Official Model" = Direct Natural Flow aka "Observed"
    - 113 yr record - 1906-2018)
  - Other CRSS hydrologic inputs available
- Run parameters
  - Duration: variable
    - "Official" runs till Dec. 2060
  - Initial conditions: Actual or predicted Jan.
  - Monthly time-step



- Outputs of interest
  - Lake Mead pool elevation
  - Lake Powell pool elevation
  - Conservation volumes
    - State
    - USBR
    - Users

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CRSS Framework and Key Drivers

CRSS is a mass balance and hydraulic routing model. The mass is the hydrology. Mass is depleted through demands and the hydraulic elements are the reservoirs

Key Drivers

- Hydrology
- Demands/Depletions
- Reservoir Operations

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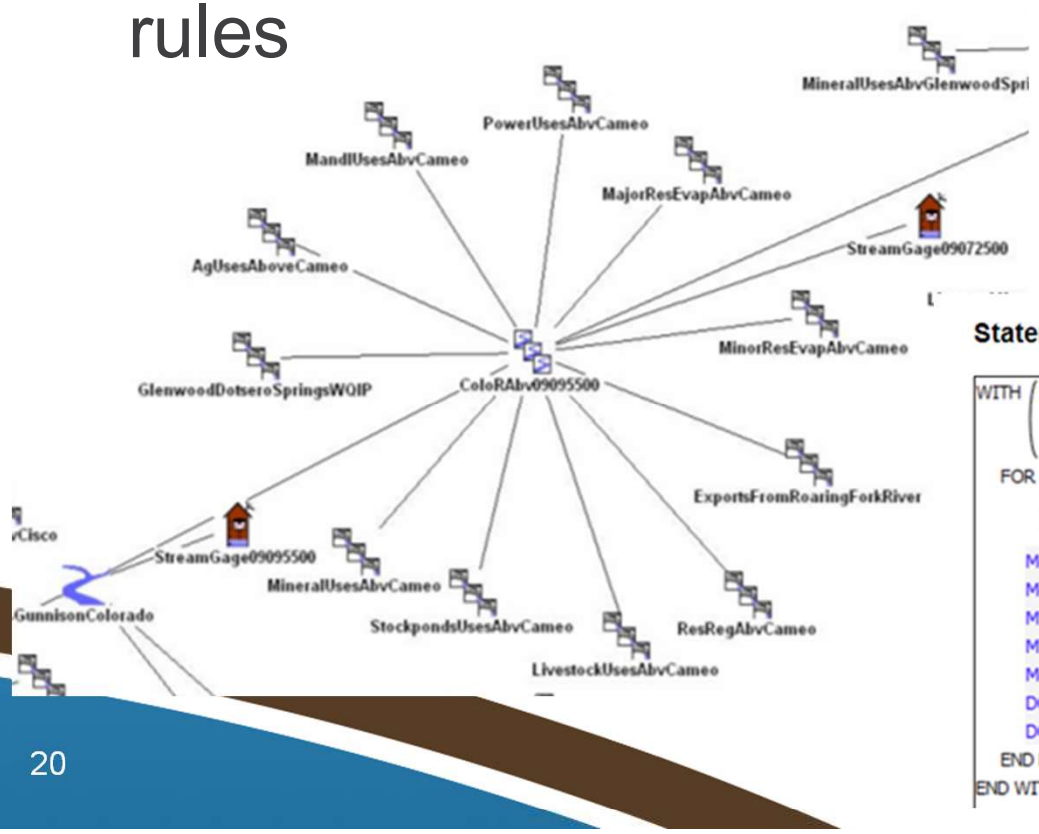
CRSS – Model Structure

- Objects and their relationships to other objects are built in the model
- Rulesets reflect system operations and priority of rules



Statements

```
WITH (DATETIME end_plus_10 = OffsetDate (RunEndDate (), 10.00, "1 years")) DO
  FOR (DATETIME year IN GetDates (@"24:00:00 December Max DayOfMonth, Current Year", RunEndDate (), "1 years")) DO
    Mead Bank.LastYearForPuts [year] = DateToNumber (RunEndDate ())
    Mead Bank.LastYearForTakes [year] = DateToNumber (end_plus_10)
    MWD ICS.MWDICSStep1PutEndDate [year] = DateToNumber (RunEndDate ())
    MWD ICS.MWDICSStep1TakeEndDate [year] = DateToNumber (end_plus_10)
    MexicoSchedule.Minute323Expires [year] = DateToNumber (RunEndDate ())
    DCP.EndDCP [year] = DateToNumber (RunEndDate ())
    DCP.LastYearForRecovery [year] = DateToNumber (end_plus_10)
  END FOR
END WITH
```

CRSS – Hydrology Inputs

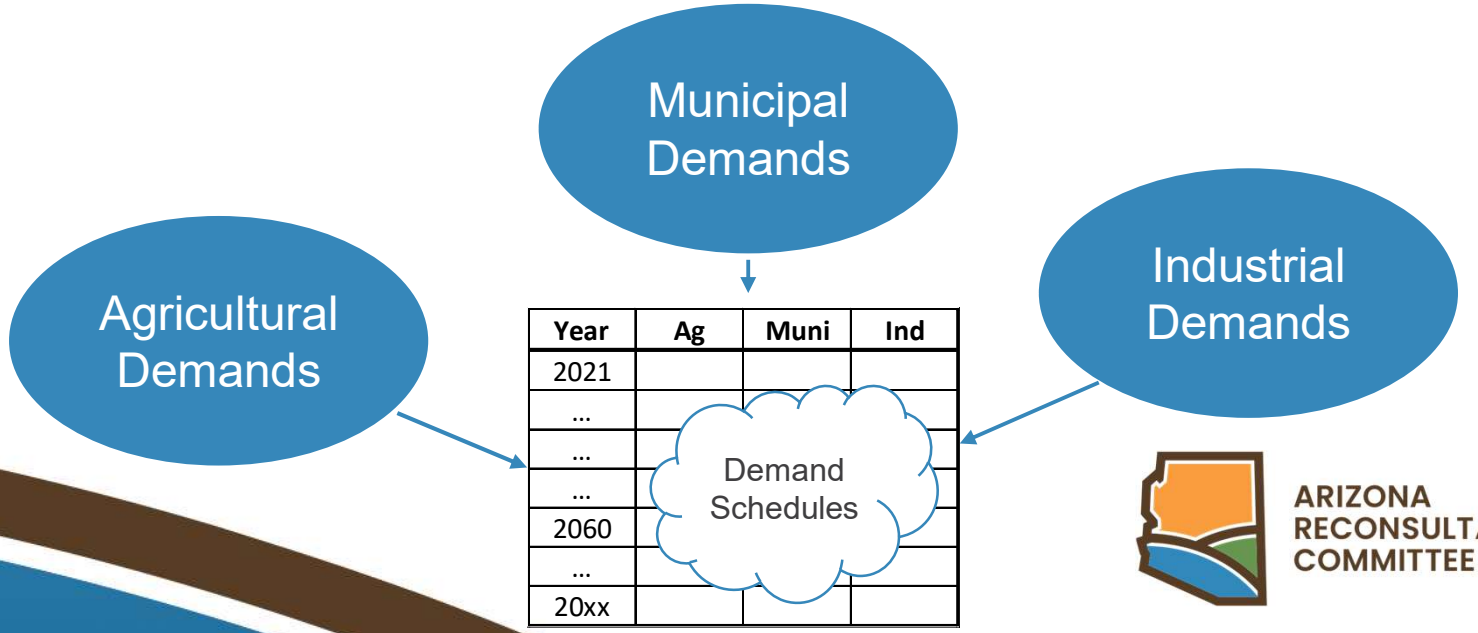
Projected hydrology is model input

- Source data input through Natural Flow at nodes
- Indexed Sequential Method (ISM) rotates the sequences of annual hydrologic data as equally likely occurrences
  - Captures uncertainty of hydrologic sequence
  - Outputs represent the range of possible outcomes providing probabilistic analysis

CRSS – Demand Schedules

Demand schedules are other inputs to model

- Demands are input for the 115 diversion points
- Schedules are created to cover the length of the model run
- Diversion points are linked at the model nodes, where the mass balance equations for the river flows are calculated.



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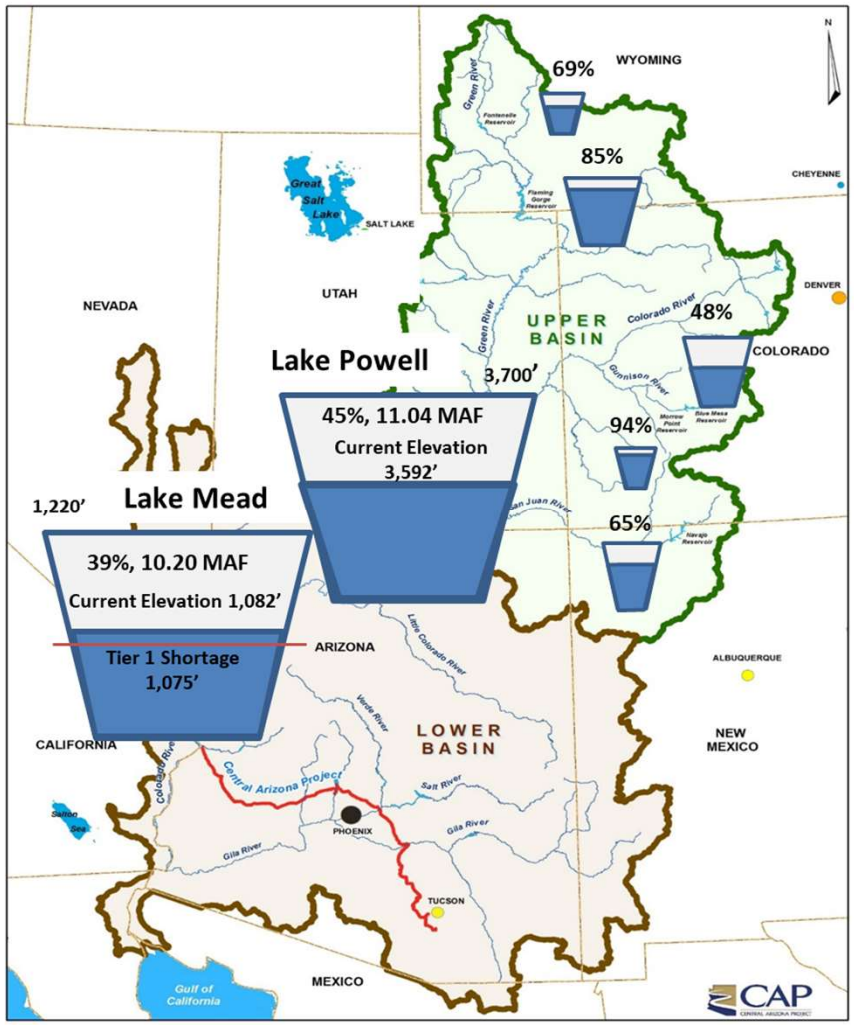
CRSS – Reservoir Operations

12 reservoirs and their operations

- Represented by Ruleset
- Minimum and maximum reservoir releases to meet operational and environmental requirements
- Inflow forecasts
- Reservoir operating rules – flood control, minimum objective releases, storage, balancing volumes, consistency with RODs, Lower Basin shortage operations, Minute 323 requirements



CRSS Hydrology Overview

Categories

- Observed – based on measurements since 1906
- Surrogate – developed from indicators influenced by water supply/precipitation
- Synthetic – based on models of future climate conditions (down-scaled global circulation models)
- Hybrid – blend of statistical and observed data

CRSS Hydrology Overview

Observed Hydrologies

- Observed Hydrology
  - AKA: “Full” Hydrology, Direct Natural Flow (DNF)
  - 113 traces from 1906-2018
- Pluvial Removed Hydrology
  - AKA: Non-Pluvial
  - 88 traces from 1931-2018
- Stress Test Hydrology
  - AKA: Stress Test, ST
  - 31 traces from 1988-2018

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CRSS Hydrology Overview

Surrogate Hydrology

- Paleo Resampled Hydrology aka Direct Paleo
  - 1,244 records derived from tree-ring analyses

Synthetic Hydrology

- Downscaled GCM Projected Hydrology
  - AKA: VIC, CMIP3
  - 112 records

Hybrid Hydrology

- Paleo Conditioned Hydrology
  - Statistical so can be generated out as far as needed
  - +500 records

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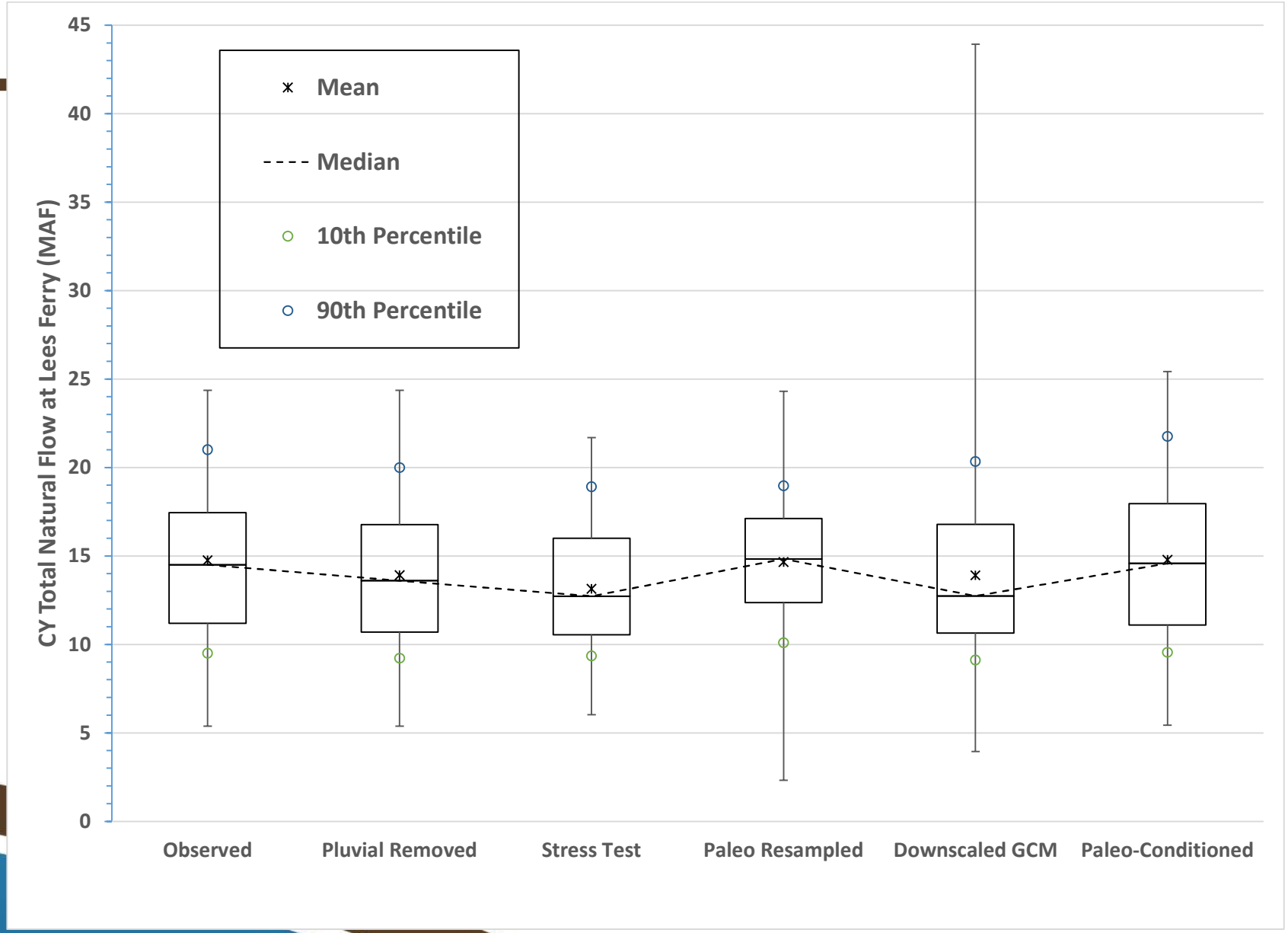
Comparison of Hydrologies



Comparison of Hydrologies

		Observed	Pluvial Removed	Stress Test	Paleo Resample	Downscale GCM	Paleo Cond.
Category		Observed	Observed	Observed	Surrogate	Synthetic	Hybrid
Duration (# Records)		113	88	31	1,244	112	+500
Annual at Powell (MAF)	**Min**	5.38	5.38	6.02	2.32	3.94	5.44
	10%	9.50	9.22	9.35	10.10	9.12	9.55
	Avg.	14.76	13.92	13.14	14.65	13.91	14.78
	Median	14.51	13.60	12.72	14.83	12.73	14.58
	90%	21.01	19.98	18.92	18.97	20.34	21.76
	Max	24.36	24.36	21.69	24.31	43.93	25.43
Use		"Official" Model	Sensitivity analysis with Mexico	DCP and 5 year table	Sensitivity analysis '07 Guidelines	2012 Basin Study	Sensitivity analysis '07 Guidelines

Emerging Data and Research

Previous Studies and Assessments informing Colorado River Planning

Modeling tools and inputs continue to evolve

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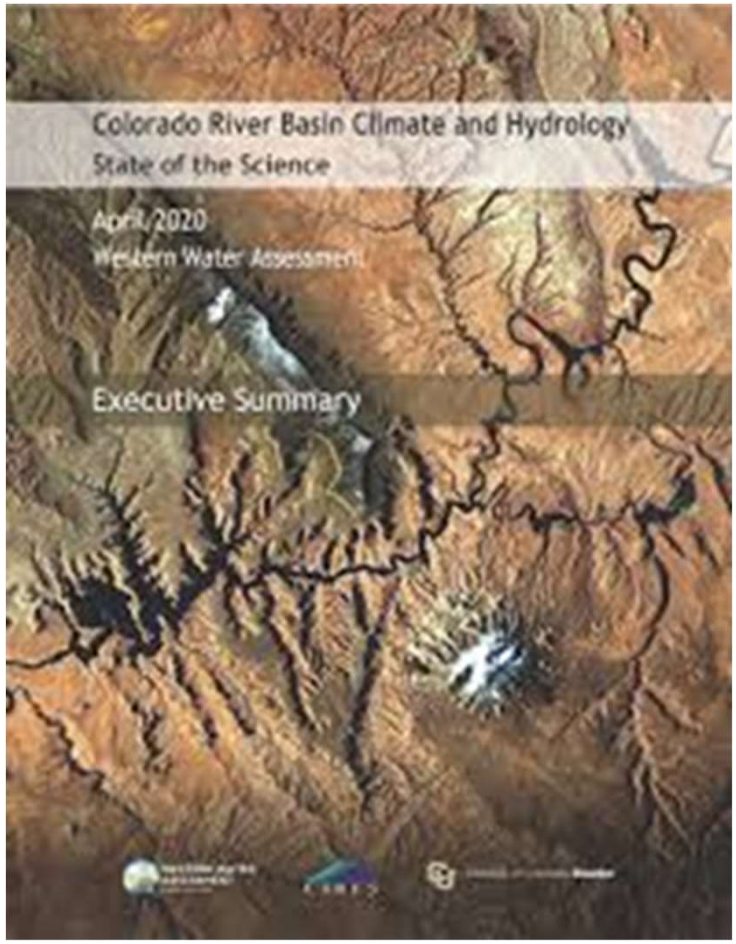
Climate Change Considerations for Scenario Planning: *State of the Science Report*



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Colorado River Basin Climate and Hydrology State of the Science Report

Baseline assessment of Colorado River data, tools, and research

- Historical basin hydrology, observations and forecasts in weather and climate, and hydrologic planning models

Impact of warming on Colorado River streamflow:

- Fall and spring precipitation increasingly occurs as rain vs. snow, reducing runoff efficiency
- Higher snowpack sublimation losses in winter and spring due to warmer atmosphere
- Earlier spring snowmelt causing slower average melt rates, reducing runoff efficiency
- Earlier melt exposes soils sooner in the warm season, allowing for more solar radiation absorption at land surface, increasing seasonal evaporation
- Crop growing season starts earlier and lasts longer, increasing seasonal transpiration
- Evapotranspiration rates increasing with warmer temperatures

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Exploring the Response of the Colorado River Basin to Future Climate (CMIP5)

Long-term projections (through 2100) of Colorado River streamflow using statistically down-scaled CMIP5 data

<u>Key outcomes from 2019 CAP/ASU Study</u>

Precipitation:

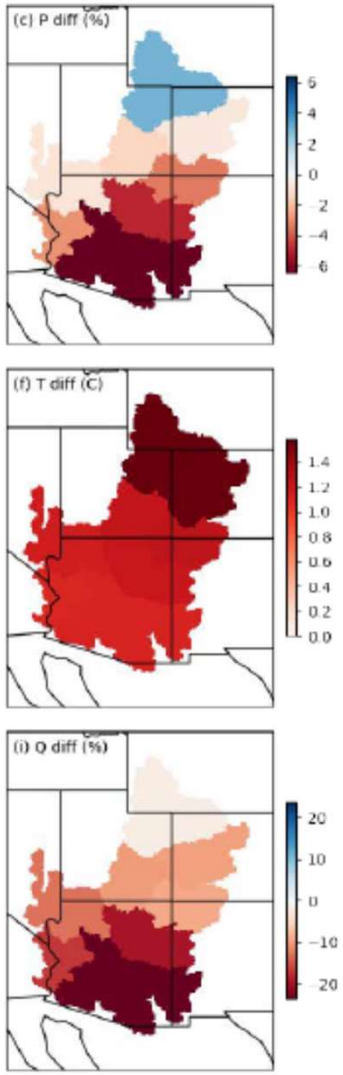
- Lower in the future period vs the historic period with the exception of wetter conditions in the Green River Basin

Temperature:

- Warming across the basin by about 2 degrees Celsius

Streamflow:

- Mild declines in the Upper Basin and severe declines in the Lower Basin

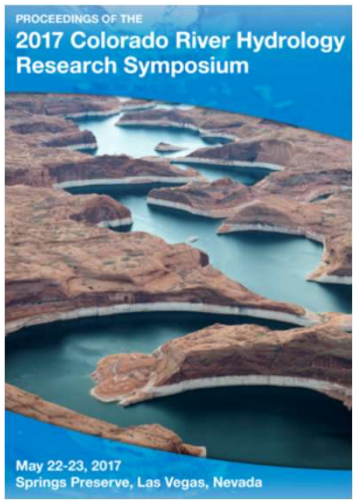


Colorado River Climate and Hydrology Workgroup

- Workgroup projects:
  - Understanding effect of different climate data downscaling techniques on Colorado River Basin climate and water supply
  - Developing temperature-conditioned streamflow ensembles to improve hydrological forecasting
  - Incorporation and improvement of consumptive use models to enhance CBRFC streamflow forecasting products

Participants:

- Central Arizona Project
- Bureau of Reclamation
- Southern Nevada Water Authority
- Colorado Water Conservation Board
- Metropolitan Water District of Southern California
- Arizona Department of Water Resources
- New Mexico Interstate Stream Commission
- Colorado River Board of California
- Denver Water
- Colorado River District
- Wyoming State Engineer's Office
- Colorado Basin River Forecast Center
- Utah Division of Water Resources



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Summary

- MAWG will be developing Initial Conditions Scenarios as the basis to compare depth, duration, frequency and timing of shortages:
  - Arizona's Colorado River supply, On-River priorities, and CAP priority pools
- Key drivers in the scenarios include: hydrology, user demands and reservoir operations,
- Currently, there are 6 available hydrologies in CRSS median annual natural inflow to Powell ranging from 14.7 maf to 12.7 maf,
- The modeling tools and inputs will evolve through applied research during the Reconsultation & ARC/MAWG efforts.

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MAWG Next Steps

- January 26 - MAWG Proposed Agenda - Basin Scale Models
  - Demands/Depletions
  - Use Behaviors
  - Operating conditions
  - Initial CRSS visualizations
- February (tbd) MAWG Proposed Agenda - Arizona Scale Models
  - Demands/Depletions
  - Use Behaviors
  - Operating conditions
  - On-River and CAP visualizations
- April (tbd) MAWG Proposed Agenda - Initial Conditions Scenario Development
  - Review scenario process
  - Review models and key drivers
  - Develop initial condition scenarios and key drivers
- Report to ARC Spring Meeting

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Call to the Public

Submit questions or comments using the electronic public comment form at cap-az.com/ARC.

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