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Managing Water in the West

Reclamation's Long-Term Planning Model: Colorado River Simulation System (CRSS)

Colorado River Commission of Nevada
Las Vegas, NV
September 16, 2009

U.S. Department of the Interior
Bureau of Reclamation

CRSS Overview

- Background & Configuration
- Operating Policy
- Hydrology
- Results and Future Direction

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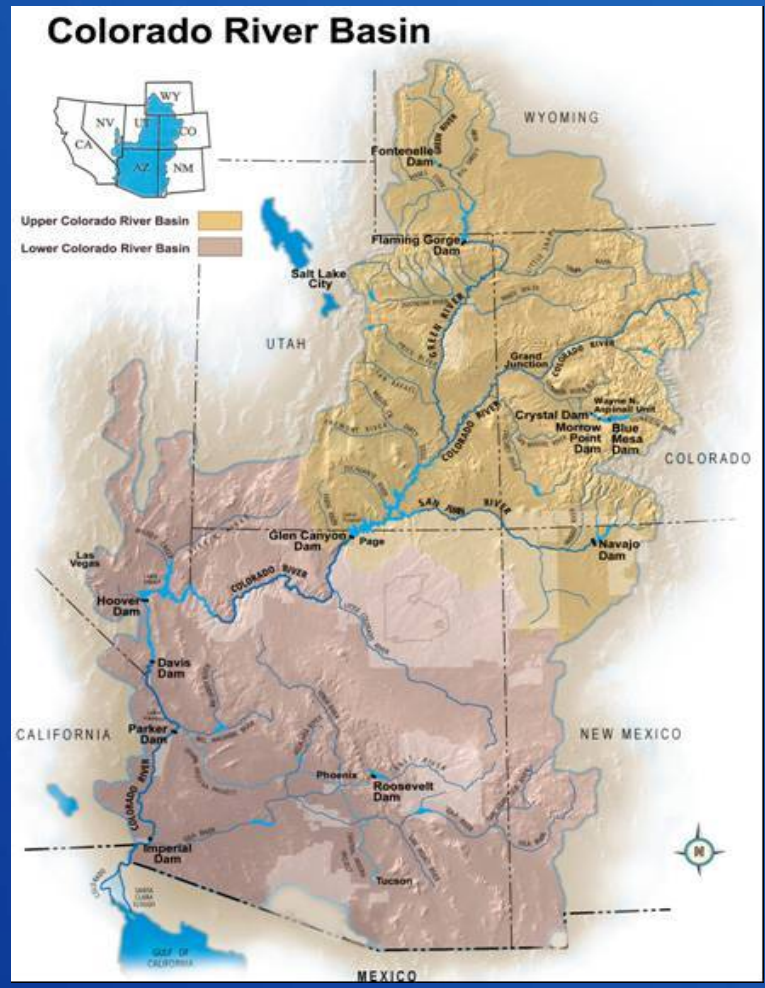
Background

- Comprehensive model of the Colorado River Basin
  - Developed by Reclamation in the early 1970s
  - Implemented in RiverWare™ in 1996
  - Primary tool for studying river operations and projected development
  - Used in a number of environmental compliance studies, most recently in the Shortage/Coordinated Operations EIS
- Updated and maintained continually by Reclamation's Colorado River Modeling Work Group
- Run by stakeholders in Colorado River Stakeholder Modeling Work Group
- Two "official" simulations are made each year (January and August)
  - Simulation in January begins in current year with initial reservoir conditions as actual end of the previous year
  - Simulation in August begins in next year with initial reservoir conditions as projected by the August 24-Month Study

CRSS: A Basin-Wide, Long-Term Planning and Policy Model

- Not a predictive model
- Excellent for comparative analysis
  - Hold most variables constant between model runs
  - Compare the differences due to changing the variables of interest
- Gives a range of potential future system conditions
- Examples:
  - Reservoir levels
  - Releases
  - River flows



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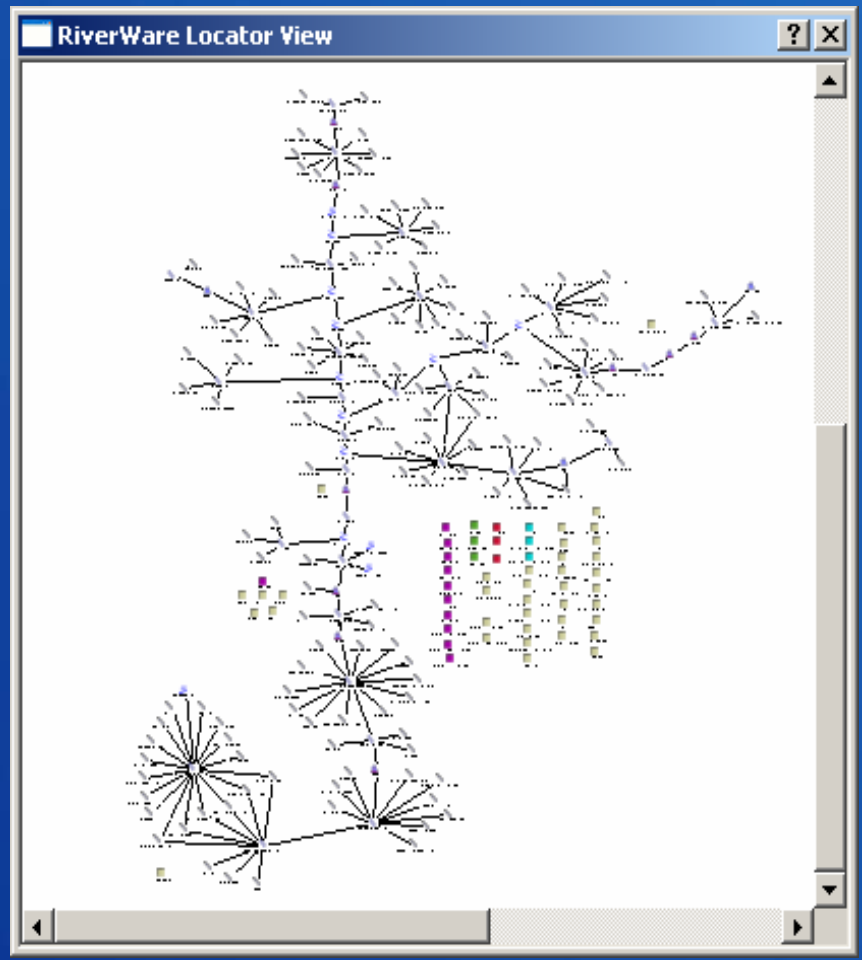
Configuration

- Physical layout:
  - Full basin model from the headwaters of the mainstem and major tributaries, down to the Northerly International Boundary with Mexico
  - Reservoirs: 12
  - Diversions: ~225
  - Natural inflow points: 29
- Simulates on a monthly timestep over decades to assess long-term system conditions



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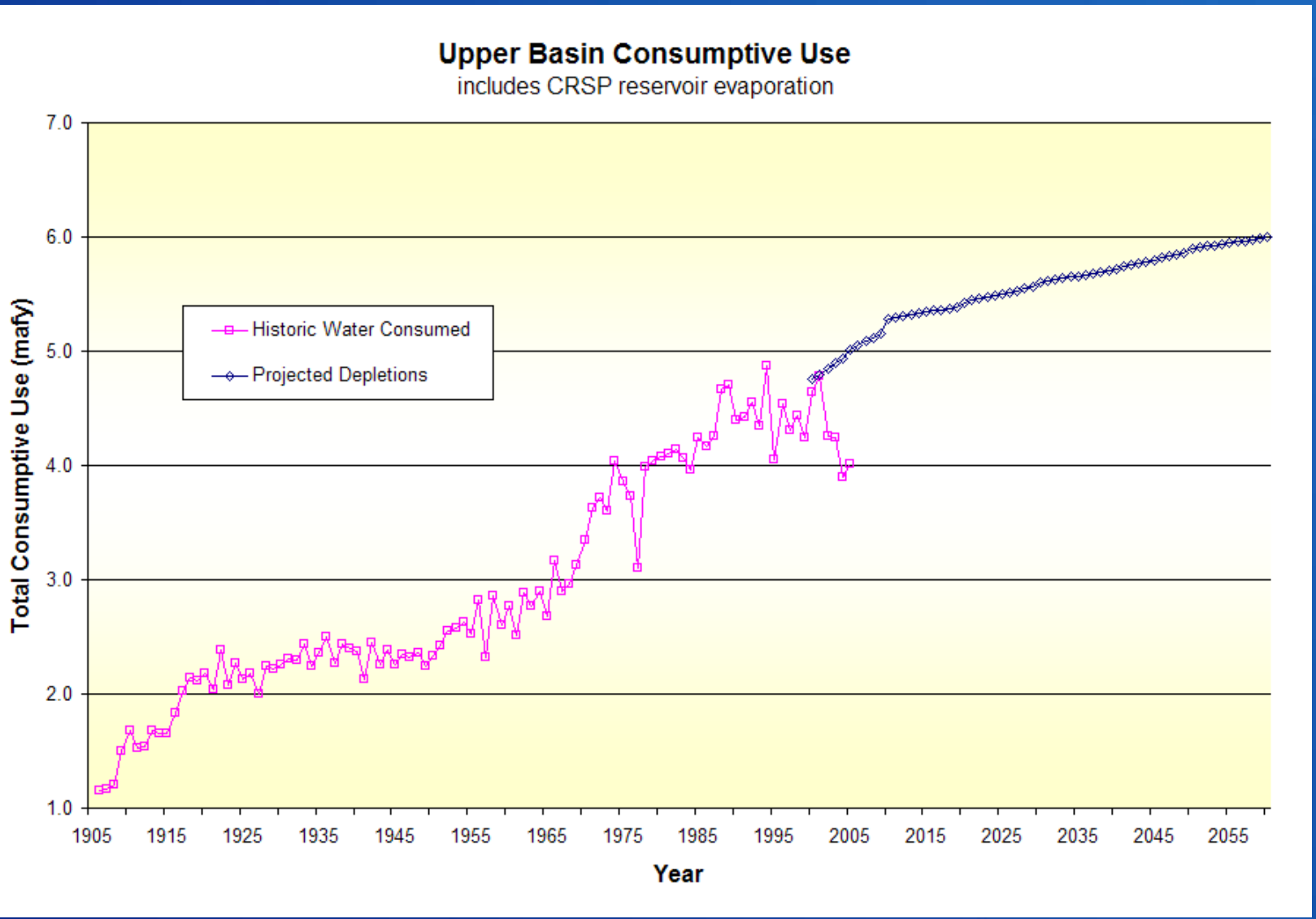
Major Inputs to Model

- Initial Reservoir Conditions
  - Historical or projected by the 24-Month Study
- Future Demands
  - Upper Basin from the Upper Colorado River Commission
  - Lower Basin from each state, including ICS schedules
- Operating Policy
  - Interim Guidelines in effect through 2026
  - Assumption needed to run past 2027, e.g. operations revert to Final EIS No Action Alternative
- Future Inflows
  - Results are most sensitive to future inflows
  - Deal with uncertainty by running multiple scenarios using historical and paleo inflows to postulate future inflows



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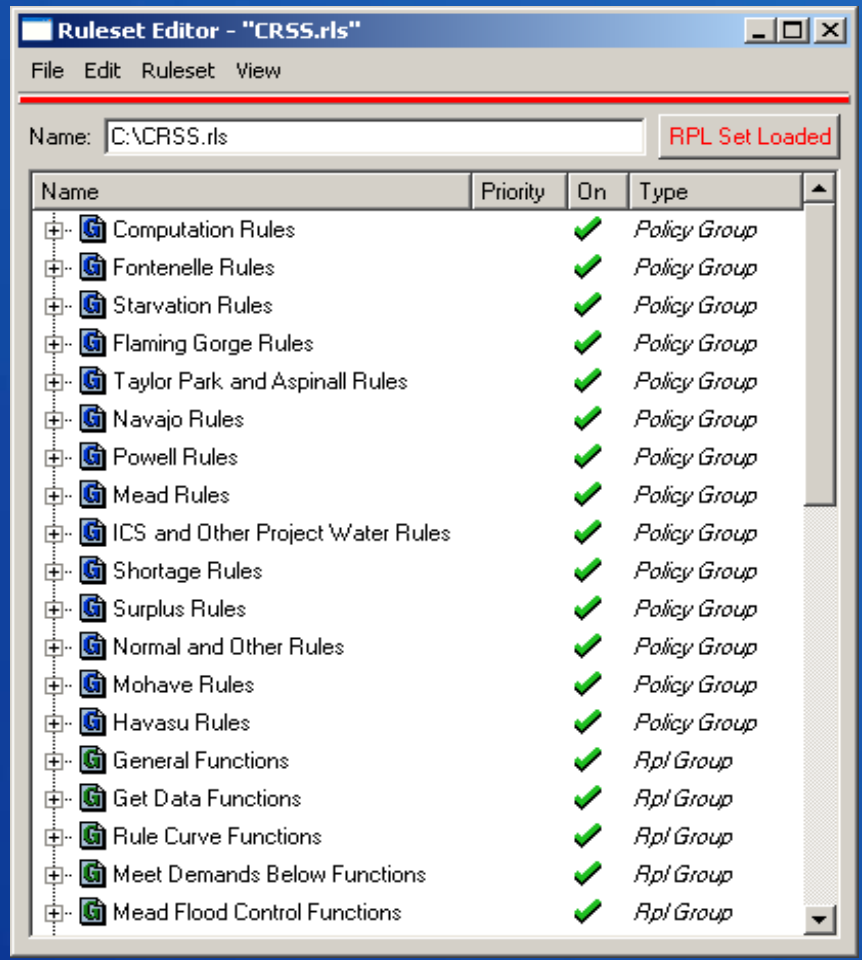
Operating Policy

- Operating policies are prioritized as “Rules”
- A group of rules and functions (a “Ruleset”), along with user inputs, provide the necessary information for the model to solve
- Rules drive simulation by providing the necessary logic (e.g., IF statements) to mimic how the system would be operated in practice



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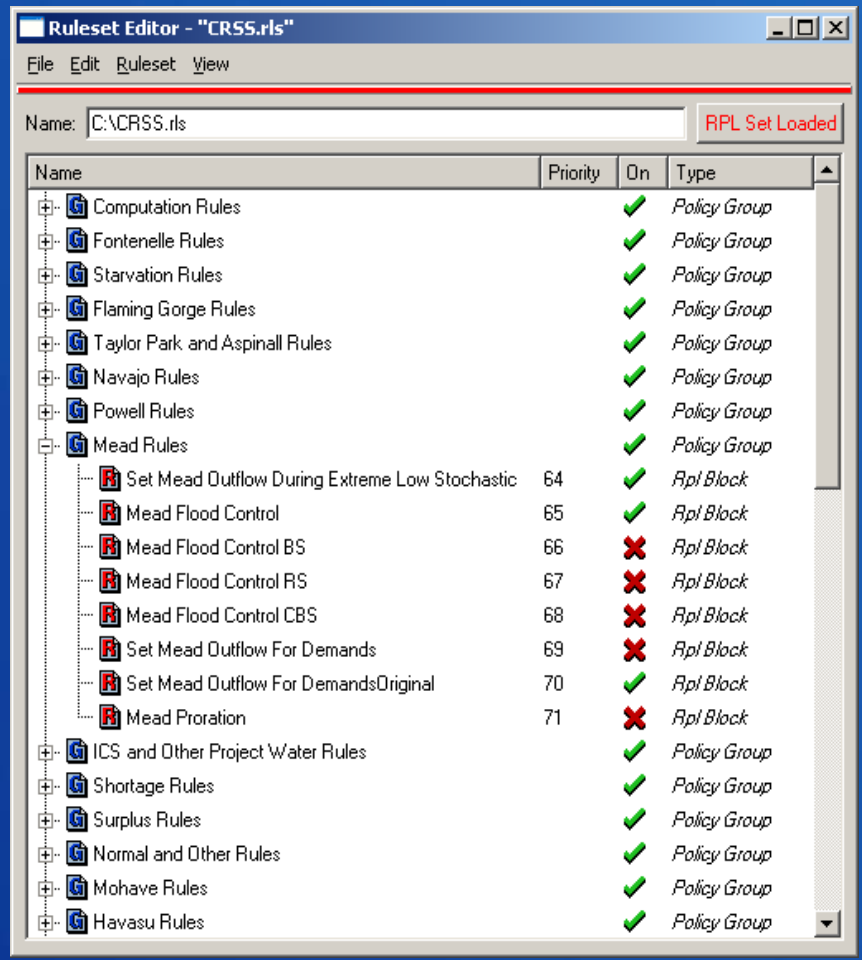
Major Operating Rules in CRSS

- Upper Basin Reservoirs above Lake Powell
- Lake Powell
- Lake Mead
- Lakes Mohave and Havasu



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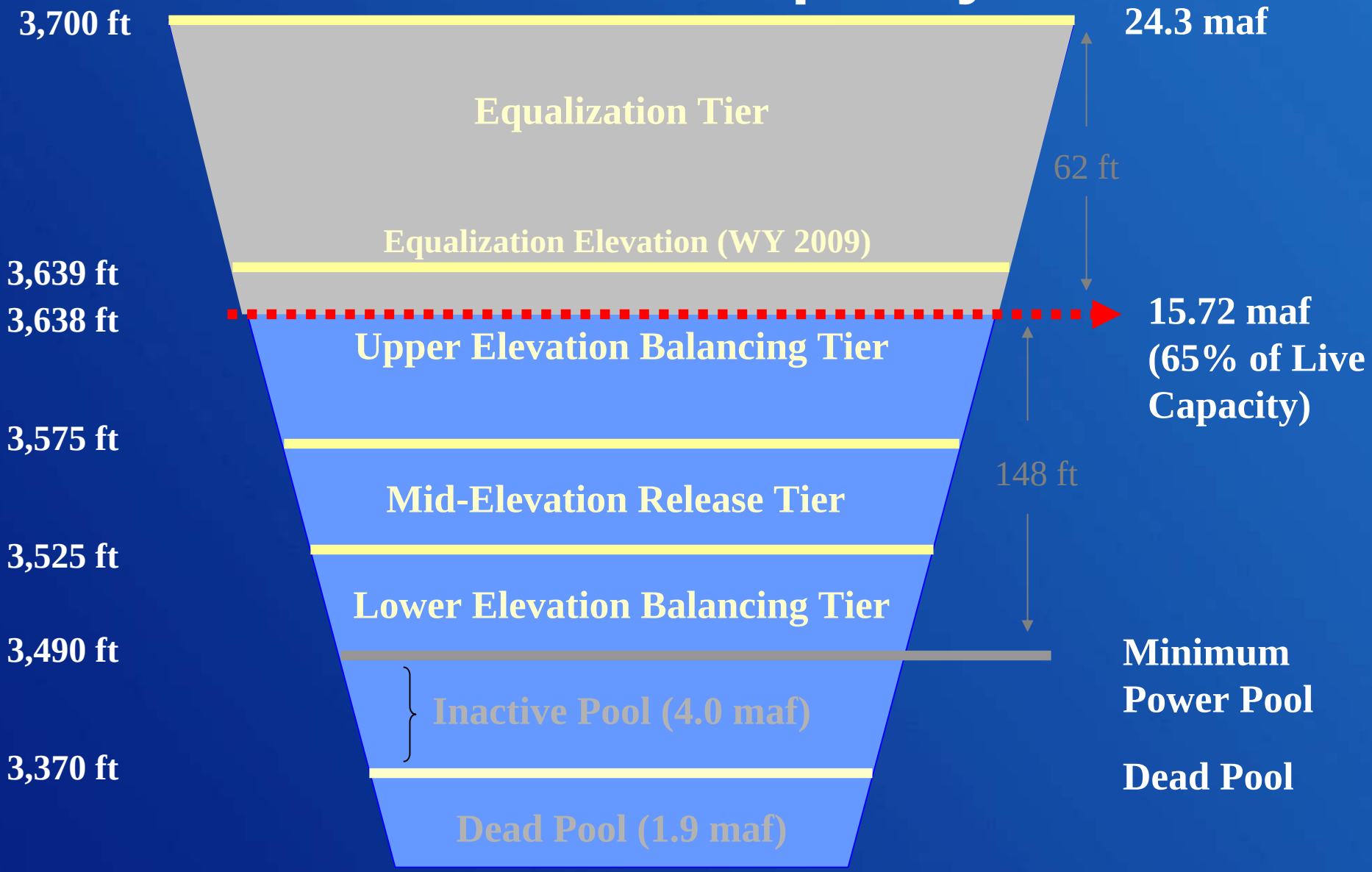
Operating Policy
Upper Basin Reservoirs Above Lake Powell

- For the following Upper Basin Reservoirs:
  - Fontenelle and Flaming Gorge (Green River)
  - Taylor Park, Blue Mesa, Morrow Point, Crystal (Gunnison)
  - Navajo (San Juan)
- Basic operation:
  - Release water sufficient to meet monthly storage targets (or “rule curves”) and downstream demands, within fixed minimum and maximum releases
- Upcoming Development:
  - Update operations to reflect new operational policies recently adopted (Flaming Gorge, Blue Mesa, Morrow Point, Crystal and Navajo)
  - Anticipate the development will be complete by summer of 2010

Simulated Inflow Forecast for Lake Powell in CRSS

- Lake Powell Inflow forecast is simulated from January through July
- Inflow forecast is based on:
  - observed natural flow for the current year
  - monthly error term
  - previous months error
  - random error component
- Inflow forecast changes each month

Lake Powell Capacity



Not to scale

As of Aug 30, 2009

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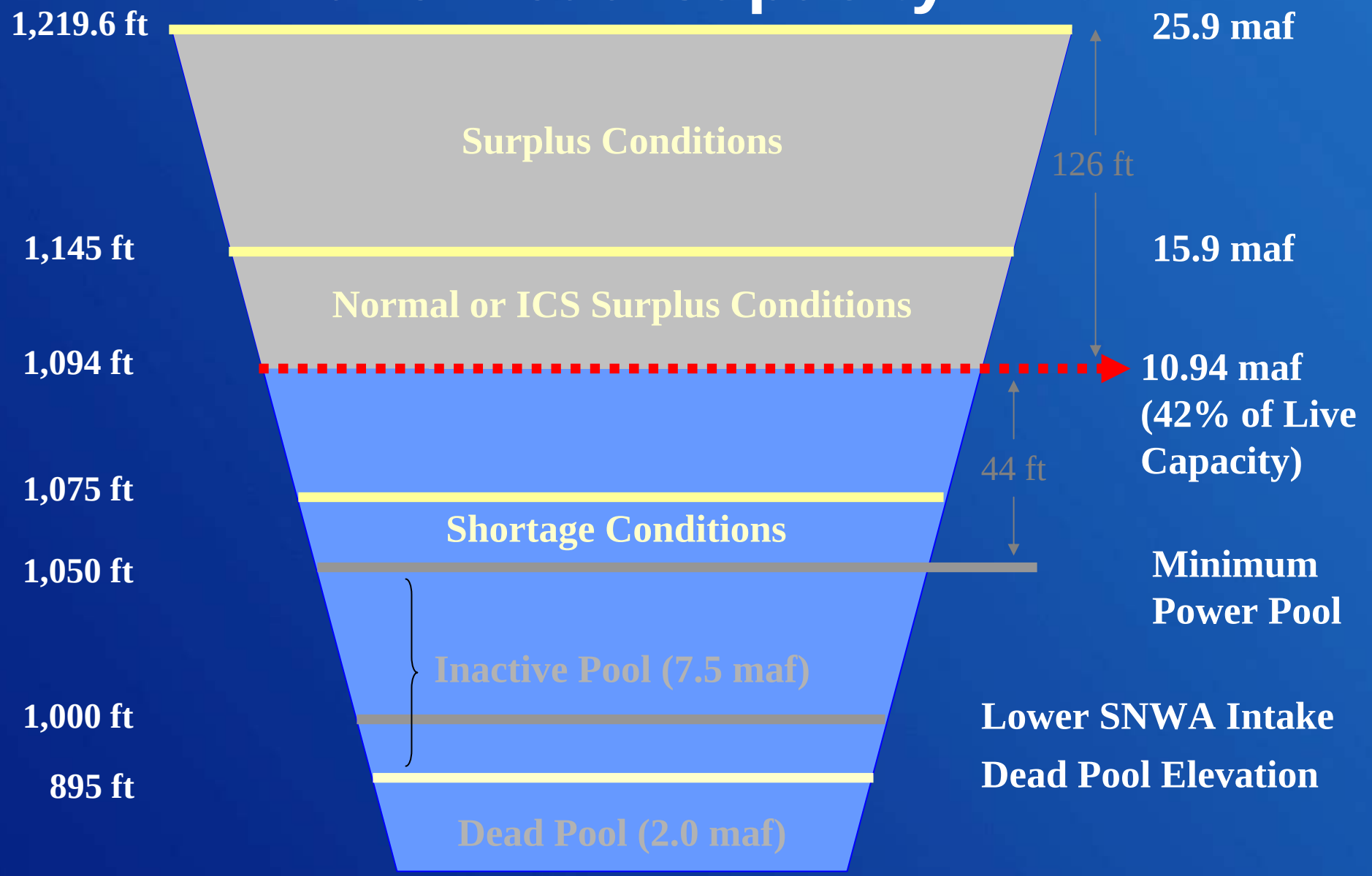
Operating Policy
Lake Mead – Hoover Dam

- Two modes of governing annual Lake Mead releases:
- Meet Downstream Demands
  - Downstream demands include:
    - California 4.4 maf
    - Arizona 2.8 maf
    - Nevada 0.3 maf
    - Mexico 1.5 maf
    - Regulation of Lakes Mohave and Havasu
    - System gains and losses
  - Demands can be modified based on Surplus or Shortage
- Flood Control Operations
- Rules decide operating mode for each year of simulation

Lake Mead Capacity



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Lake Powell and Lake Mead
Operational Diagrams for 2009

Lake Powell

Elevation (feet)	Opertaions According to the Interim Guidelines	Live Storage (MAF)
3,700	**Equalization Tier** Equalize, Avoid Spills or Release 8.23 MAF	24.3
3,636 - 3,666 (2008-2026)		15.5 - 19.3 (2008-2026)
3638	**Upper Elevation Balancing Tier**[1]	15.72
8/30/09	Release 8.23 MAF; if Lake Mead < 1,075 feet, balance contents with a min/max release of 7.0 and 9.0 MAF	8/30/09
3,575		9.5
	Mid-Elevation Release Tier Release 7.48 MAF; if Lake Mead < 1,025 feet, Release 8.23 MAF;	
3,525		5.9
	Lower Elevation Balancing Tier Balance contents with a min/max release of 7.0 and 9.5 MAF	
3,490		4.0
3,370		0

Lake Mead

Elevation (feet)	Opertaions According to the Interim Guidelines	Live Storage (MAF)
1,220	**Flood Control or 70R Surplus**	25.9
1,200		22.9
	Domestic Surplus or ICS Surplus	
1,145		15.9
1,105	**Normal Operations or ICS Surplus**	11.9
1094		10.94
8/30/09		8/30/09
1,075		9.4
	Shortage 333 KAF[2]	
1,050		7.5
	Shortage 417 KAF[2]	
1,025		5.8
	Shortage 500 KAF[2] **and Consultation**[3]	
1,000		4.3
895		0

1 Subject to April adjustments that may result in balancing releases or releases according to the Equalization Tier.
2 These are amounts of shortage (i.e., reduced deliveries in the United States).
3 If Lake Mead falls below elevation 1,025 ft msl, the Department will initiate efforts to develop additional guidelines for shortages at lower Lake Mead elevations.

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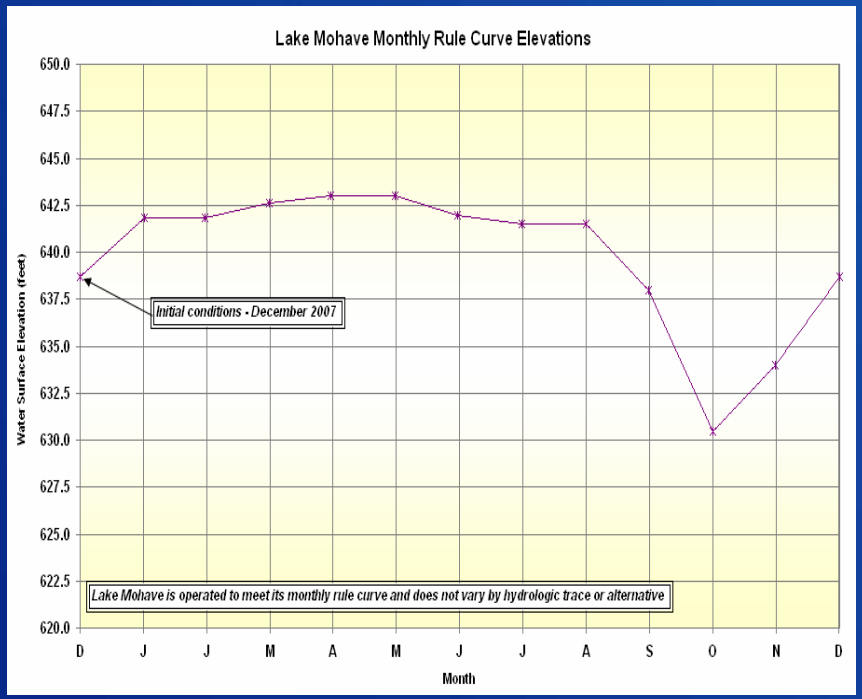
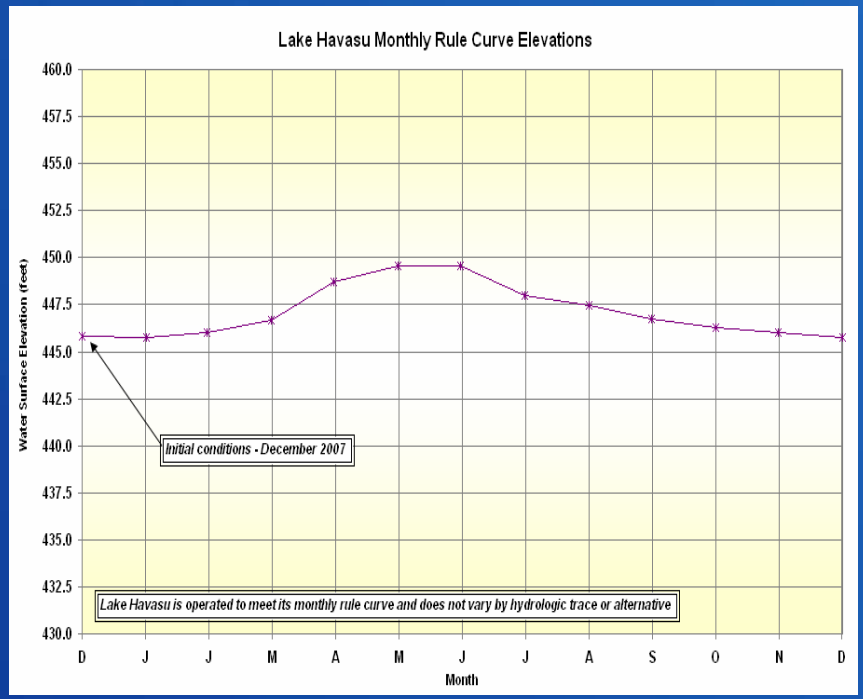
Operating Policy
Lakes Mohave & Havasu Rules





- **Both follow fixed rule curves**
- **Target storage (or elevation) for each month is always met**

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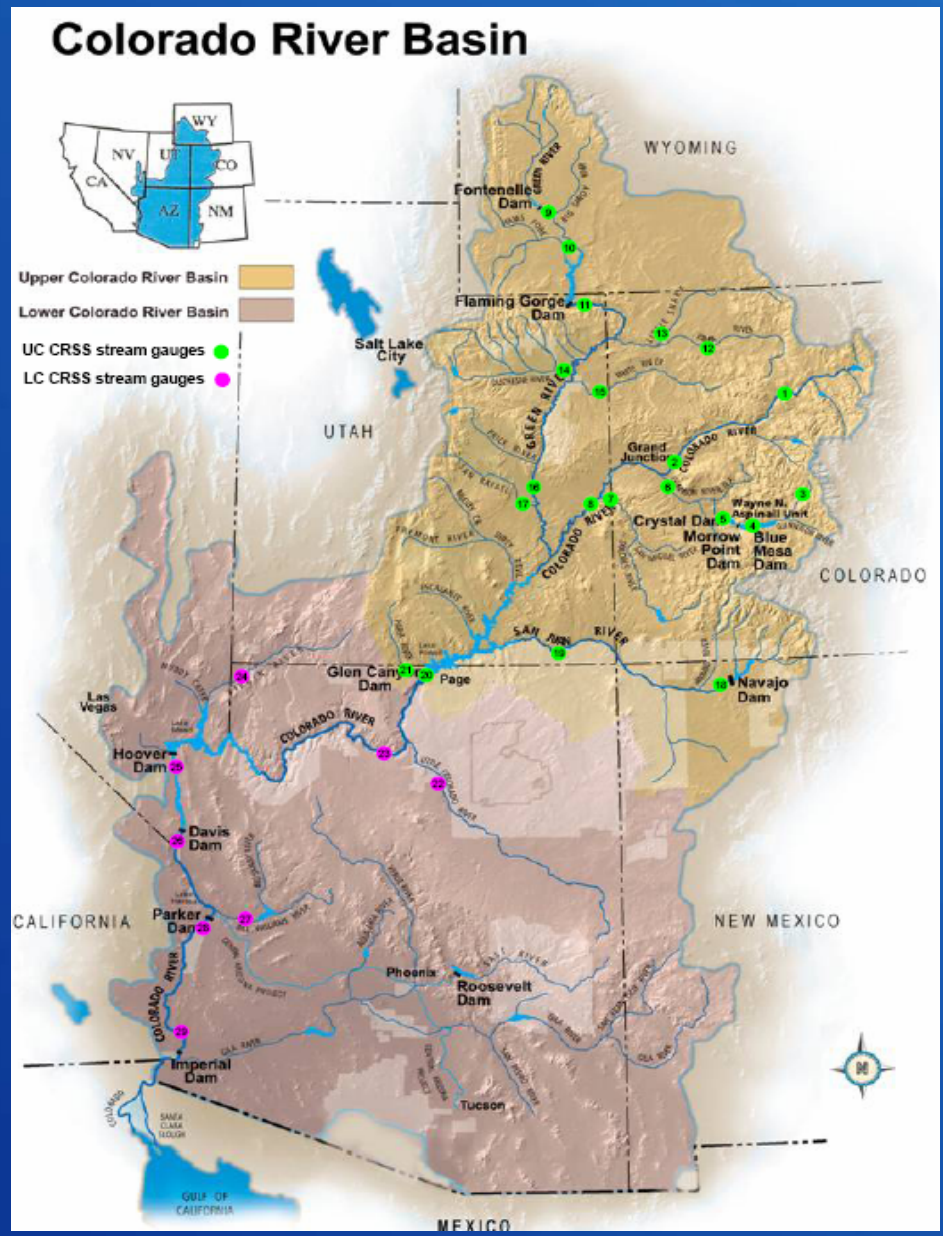
Modeling Hydrologic Variability

- Quantify uncertainty due to future streamflows
- Possible future streamflows generated from historic observed flow (1906-2006) and paleo reconstructed flow (762-2005)
- Two stochastic techniques used to re-sample flows (Indexed Sequential Method and Nonparametric Paleo Conditioned)
- Probabilistic based model results

29 Natural Inflow Stations in CRSS

1	Colorado River at Glenwood Springs, CO
2	Colorado River near Cameo, CO
3	Taylor River below Taylor Park Reservoir, CO
4	Gunnison River below Blue Mesa Reservoir, CO
5	Gunnison River at Crystal Reservoir, CO
6	Gunnison River near Grand Junction, CO
7	Dolores River near Cisco, UT
8	Colorado River near Cisco, UT
9	Green River below Fontenelle Reservoir, WY
10	Green River near Green River, WY
11	Green River near Greendale, UT
12	Yampa River near Maybell, CO
13	Little Snake River near Lily, CO
14	Duchesne River near Randlett, UT
15	White River near Watson, UT
16	Green River at Green River, UT
17	San Rafael River near Green River, UT
18	San Juan River near Archuleta, NM
19	San Juan River near Bluff, UT
20	Colorado River at Lees Ferry, AZ
21	Paria River at Lees Ferry, AZ
22	Little Colorado River near Cameron, AZ
23	Colorado River near Grand Canyon, AZ
24	Virgin River at Littlefield, AZ
25	Colorado River below Hoover Dam, AZ-NV
26	Colorado River below Davis Dam, AZ-NV
27	Bill Williams River below Alamo Dam, AZ
28	Colorado River below Parker Dam, AZ-CA
29	Colorado River above Imperial Dam, AZ



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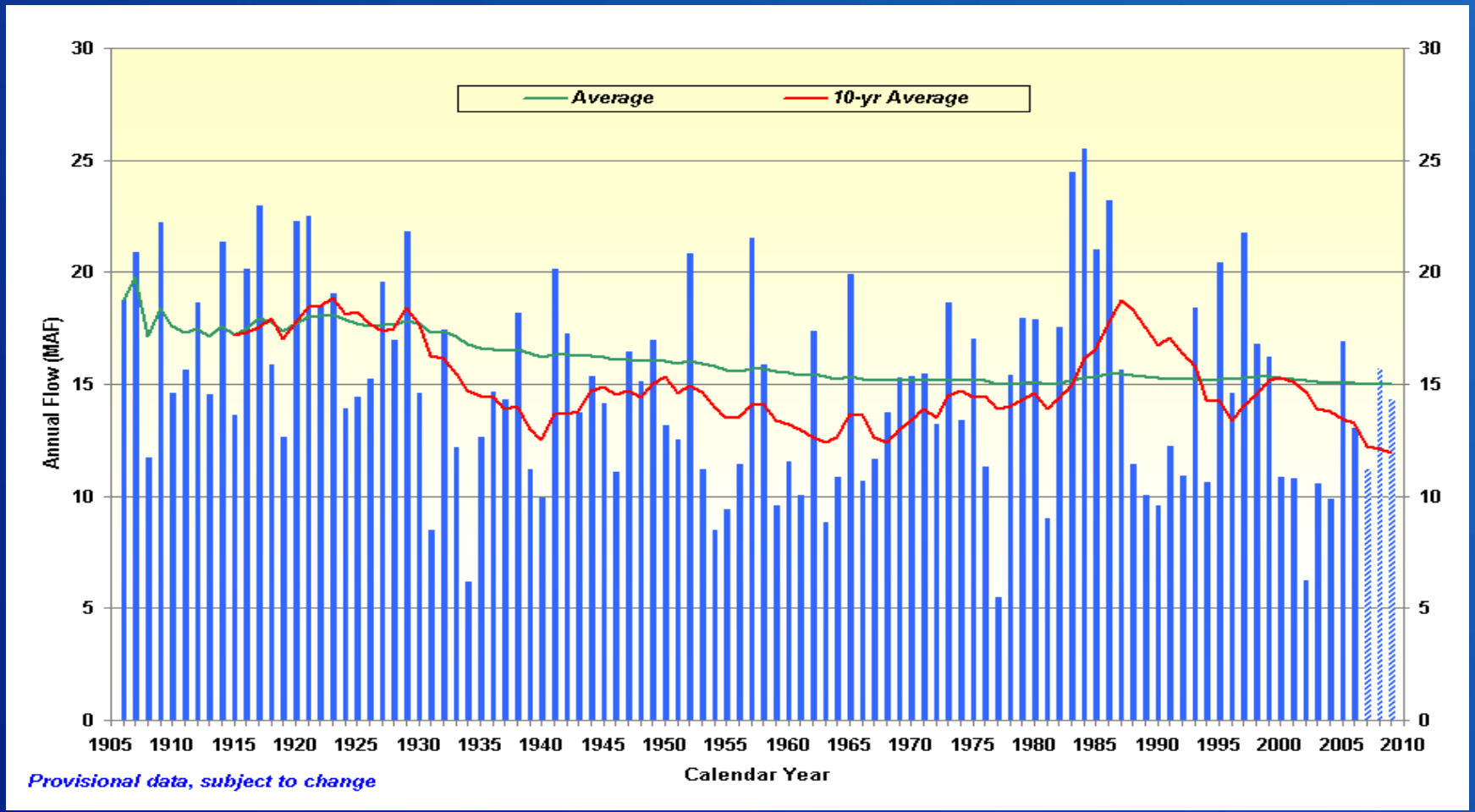
Annual Natural Flow
Colorado River at Lees Ferry Gaging Station, Arizona
Calendar Year 1906 to 2009



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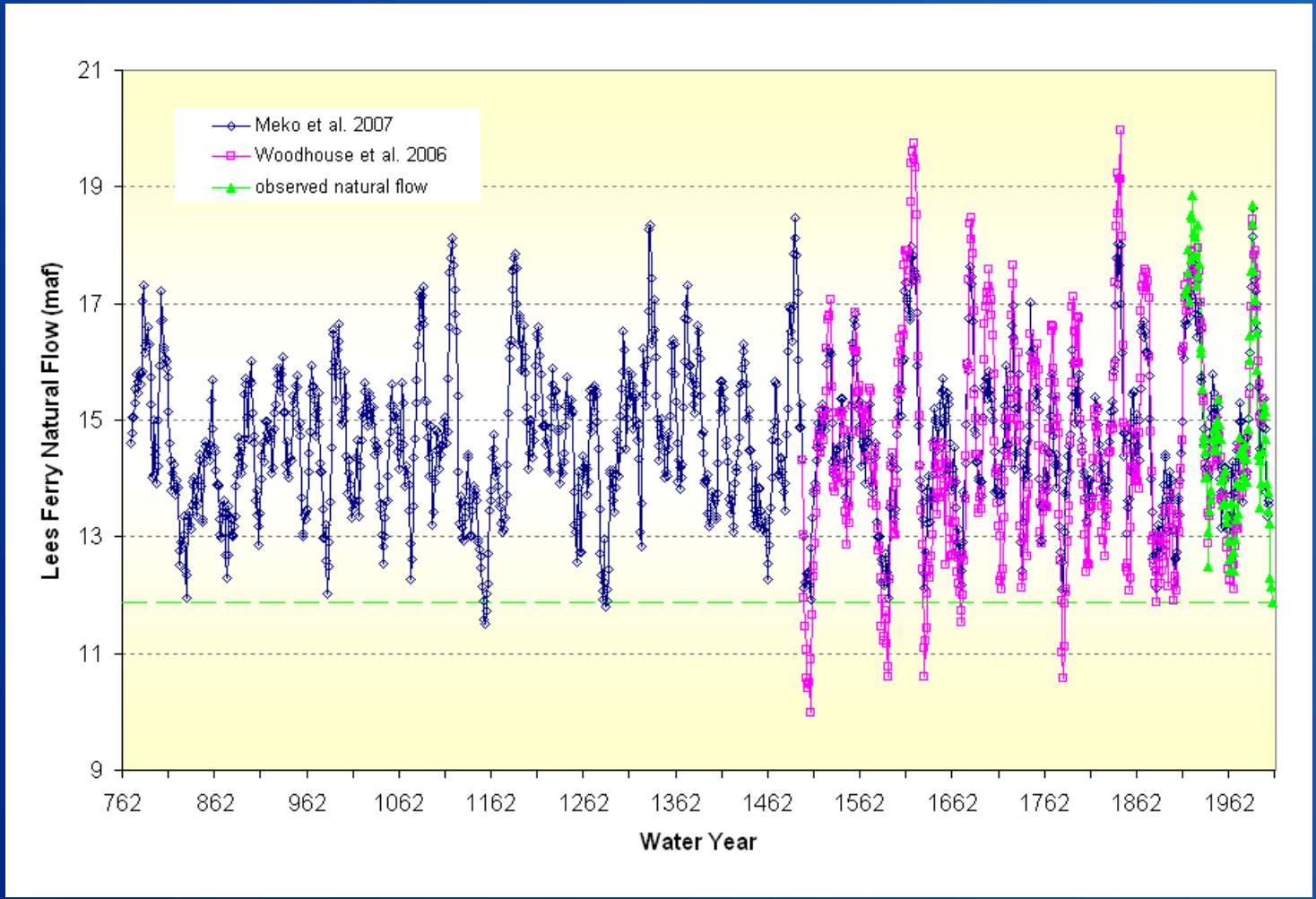
Annual Natural Flow at Lees Ferry
Tree-ring Reconstruction and Observed Record
10-Year Running Mean



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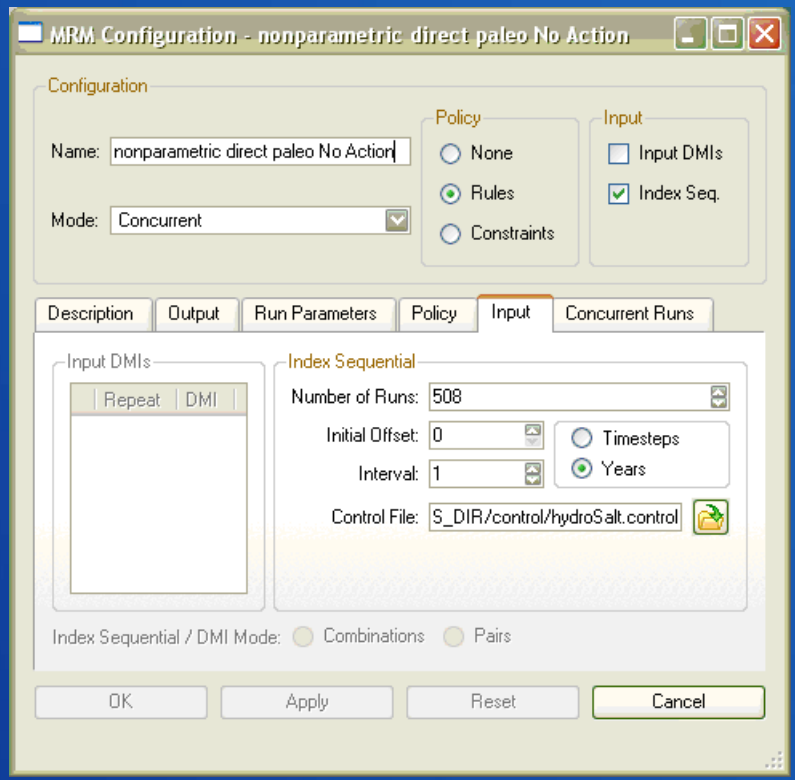
Indexed Sequential Method (ISM)
Stochastic Technique

- Sequentially re-samples blocks of flow data
- Can only produce:
  - Observed flow magnitudes
  - Observed flow sequences
- Easily generates data for multi-site model
- Easily preserves observed data statistics



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Indexed Sequential Method

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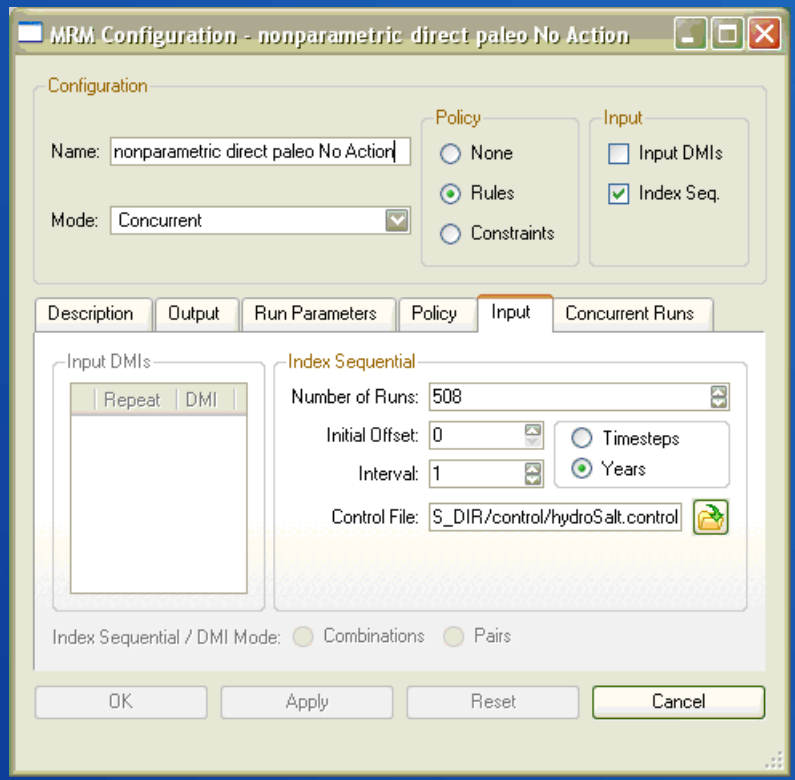
Nonparametric Paleo Conditioned (NPC)

Stochastic Technique

- Blends paleo state with observed magnitude
- Can only produce:
  - Observed flow magnitudes
  - But with unique sequences
- Nonparametric disaggregation generates data for multi-site model
- Easily preserves observed data statistics



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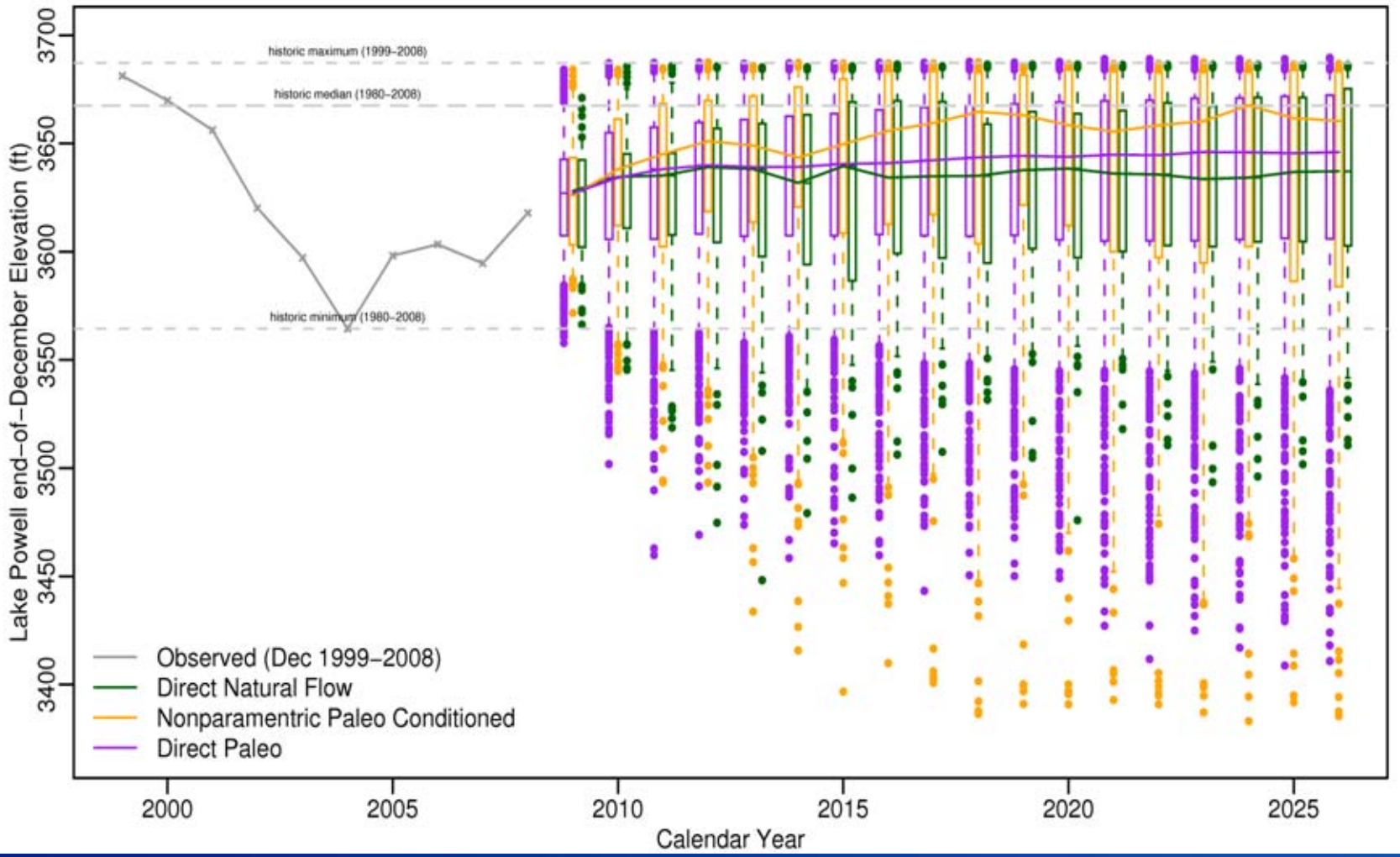
Analyzing Hydrologic Sensitivity

- 3 hydrologic inflow scenarios analyzed
  - **Direct Natural Flow**
    - ISM applied to observed flow record (1906-2006)
    - 101 hydrologic sequences or traces
  - **Direct Paleo**
    - ISM applied to paleo flow record (762-2005) (Meko et al., 2007)
    - 1244 traces
  - **Nonparametric Paleo Conditioned**
    - NPC applied to observed and paleo flow record (Prairie, 2006)
    - 125 traces

Results: Lake Powell Elevation



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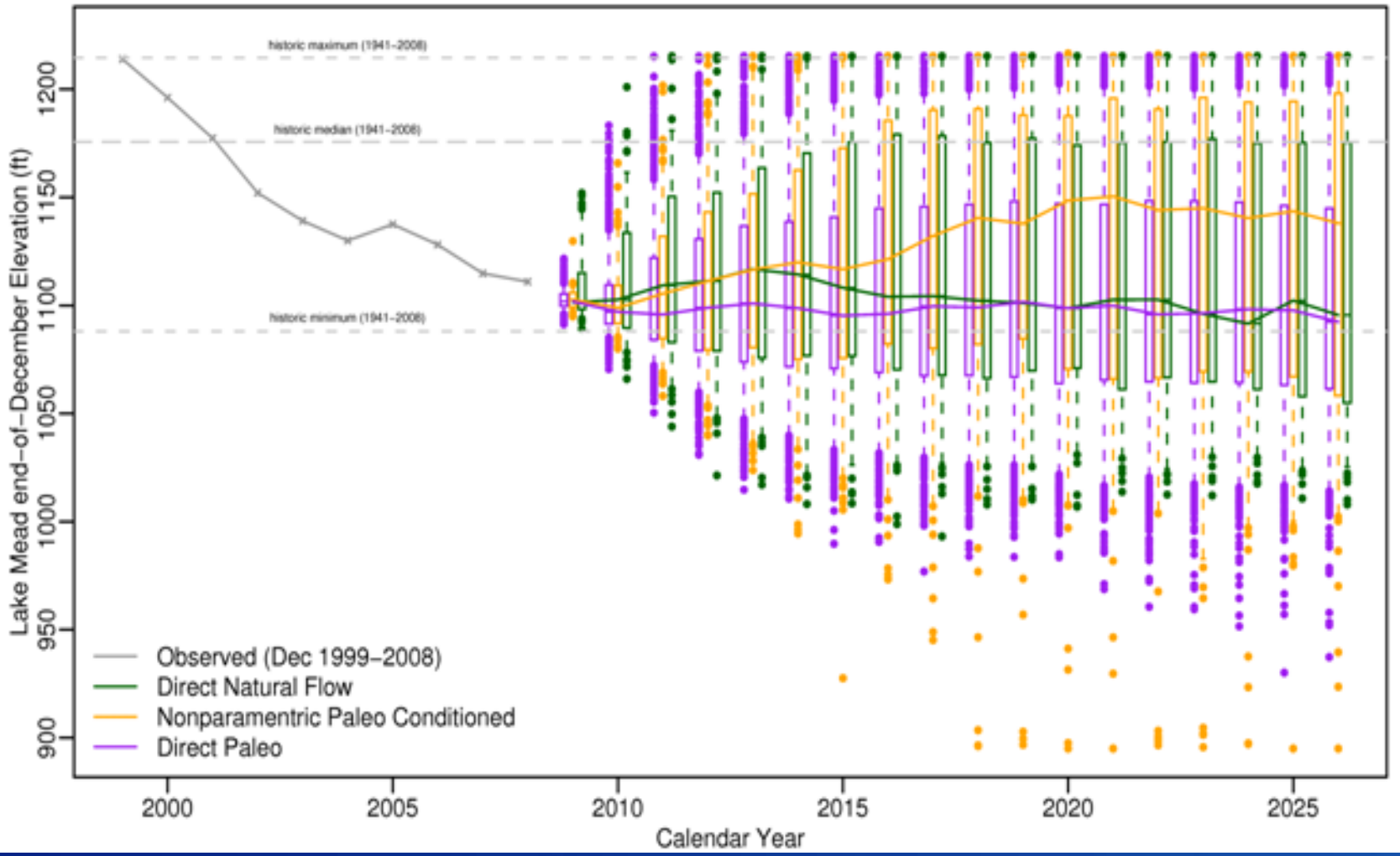
Results: Lake Mead Elevation



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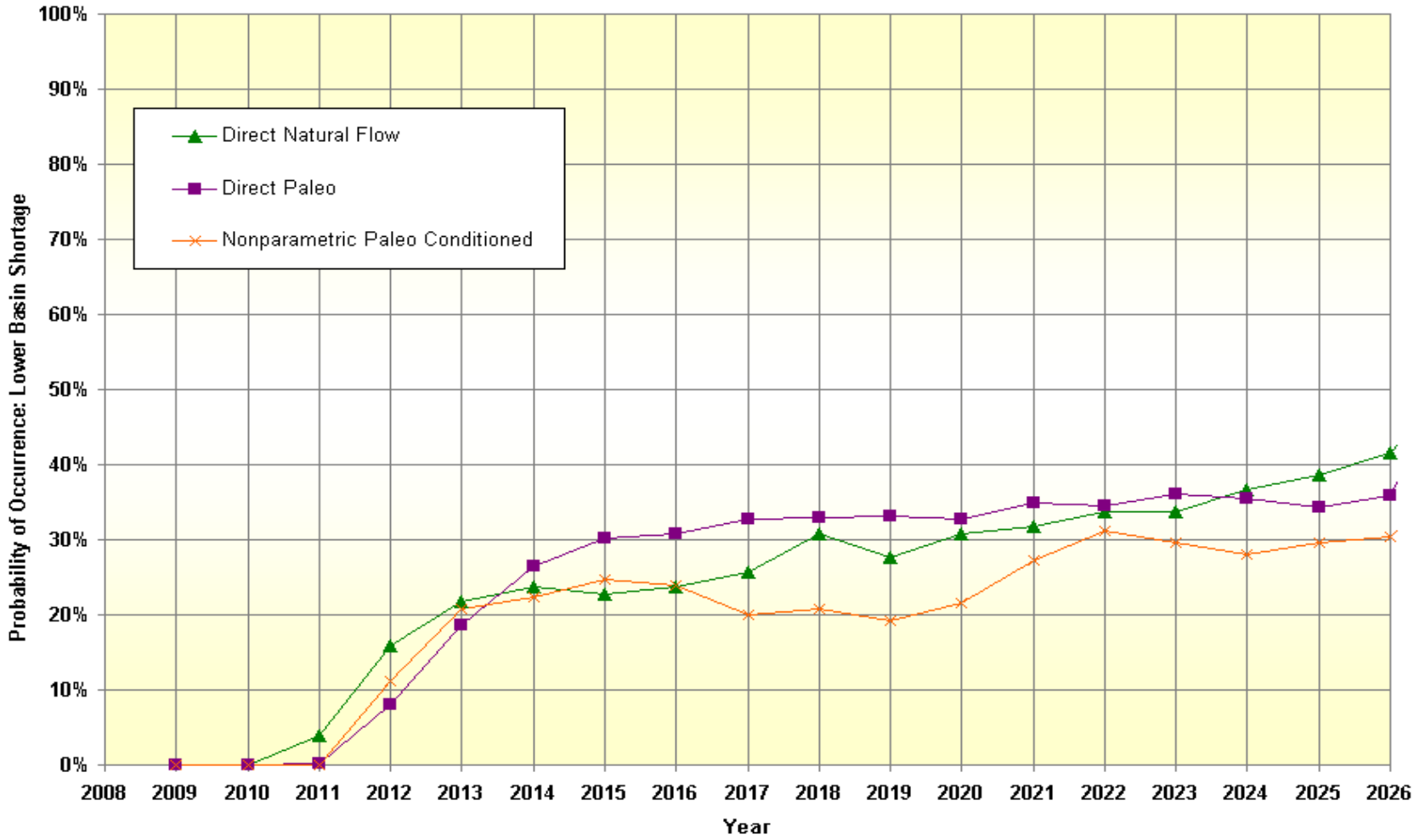
Results: Probability of Shortage



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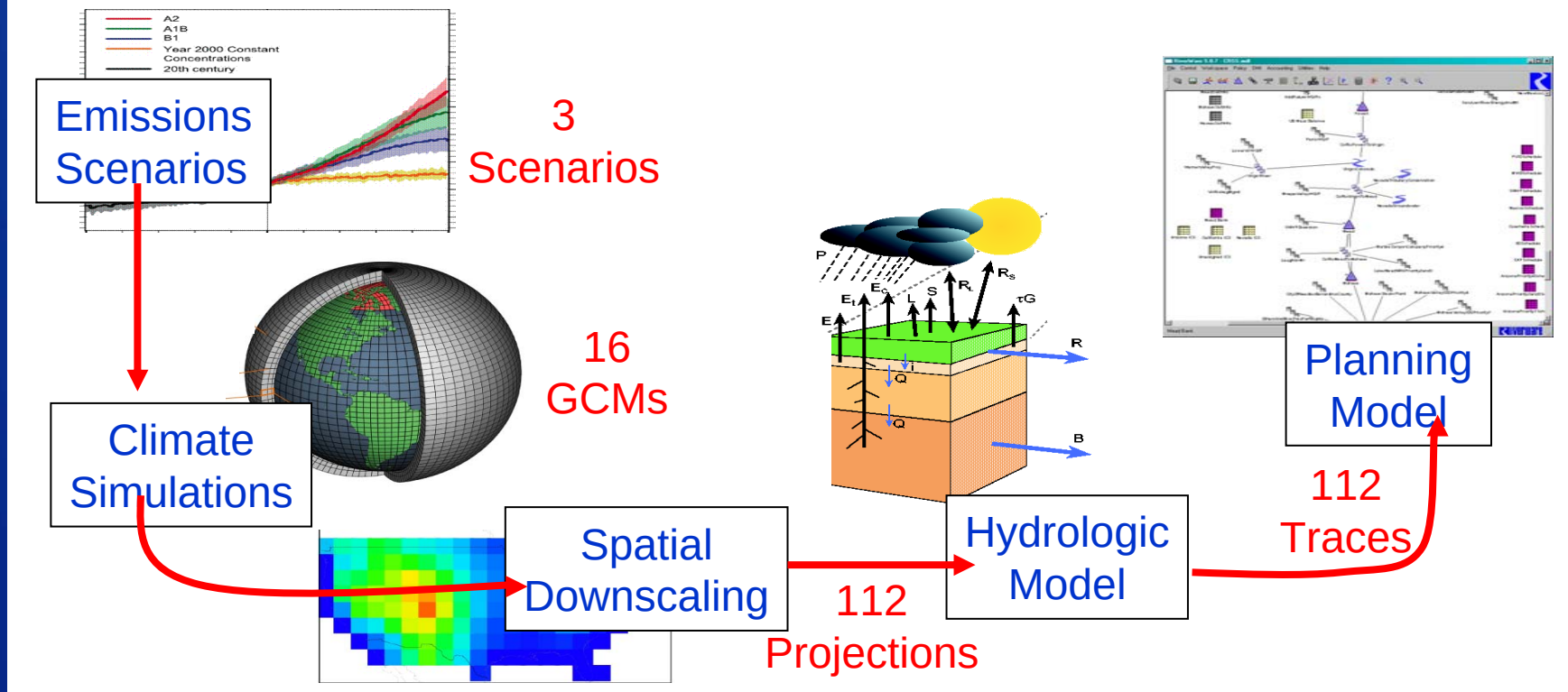
Assessing Projected Impacts to Colorado River System



- Joint research project with AMEC Earth and Environmental and Reclamation
- Anticipate CRSS results by December 2009
- Anticipate peer reviewed publication in early 2010

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Reclamation’s Long-Term Planning Model:
Colorado River Simulation System (CRSS)
Questions?