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Managing Water in the West

Colorado River Basin Water Supply and Demand Study

CMIP and Applications Meeting
October 3-4, 2012
College Park, MD

U.S. Department of the Interior
Bureau of Reclamation

Colorado River Basin Water Supply and Demand Study

- Study Objective
  - Assess future water supply and demand imbalances over the next 50 years
  - Develop and evaluate opportunities for resolving imbalances
- Study being conducted by Reclamation and the Basin States, in collaboration with stakeholders throughout the Basin
- Began in January 2010 and to be completed in November 2012
- A planning study – will *not* result in any decisions, but will provide the technical foundation for future activities

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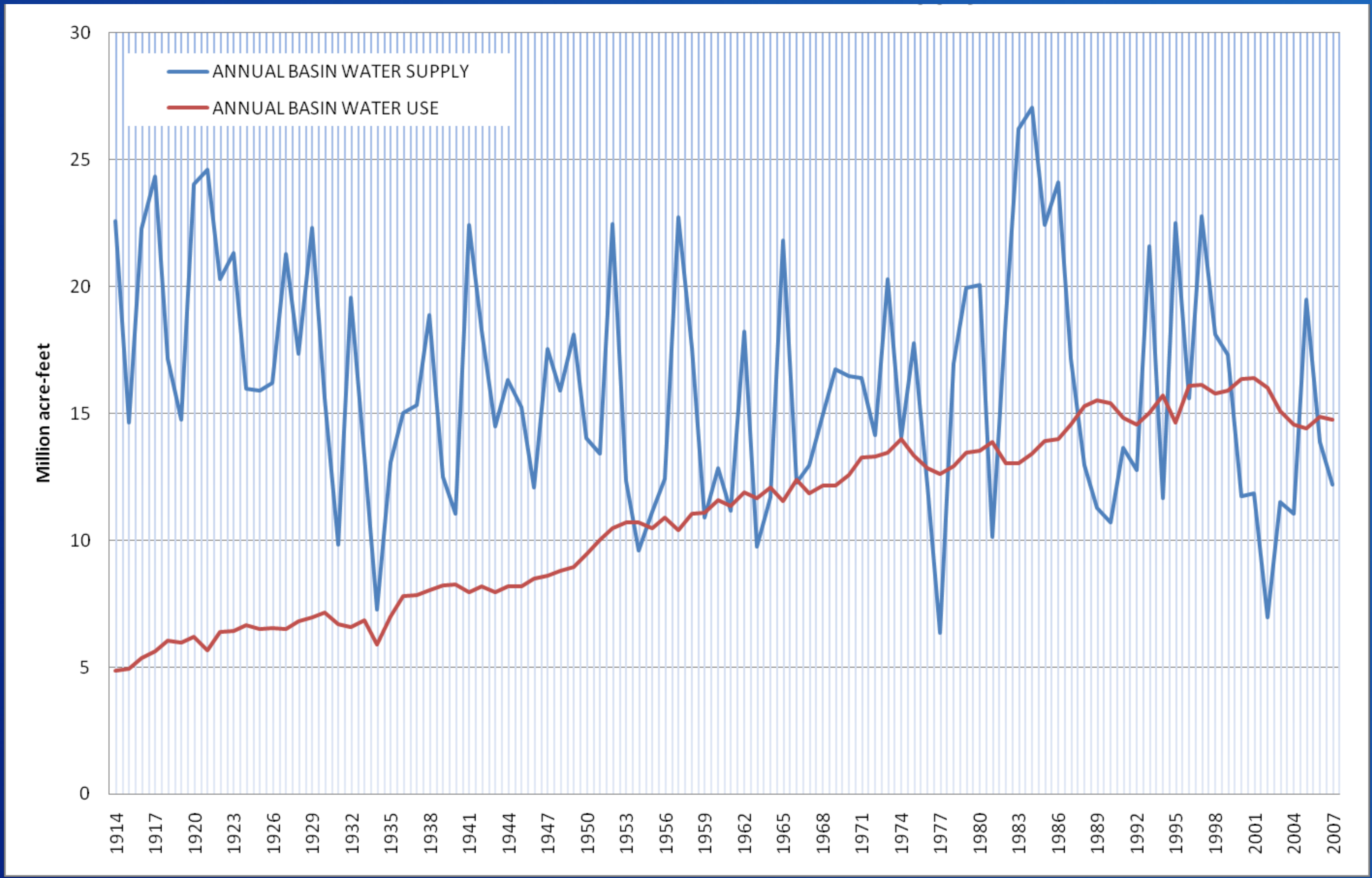
Historical Colorado River Water Supply & Use (Annual)



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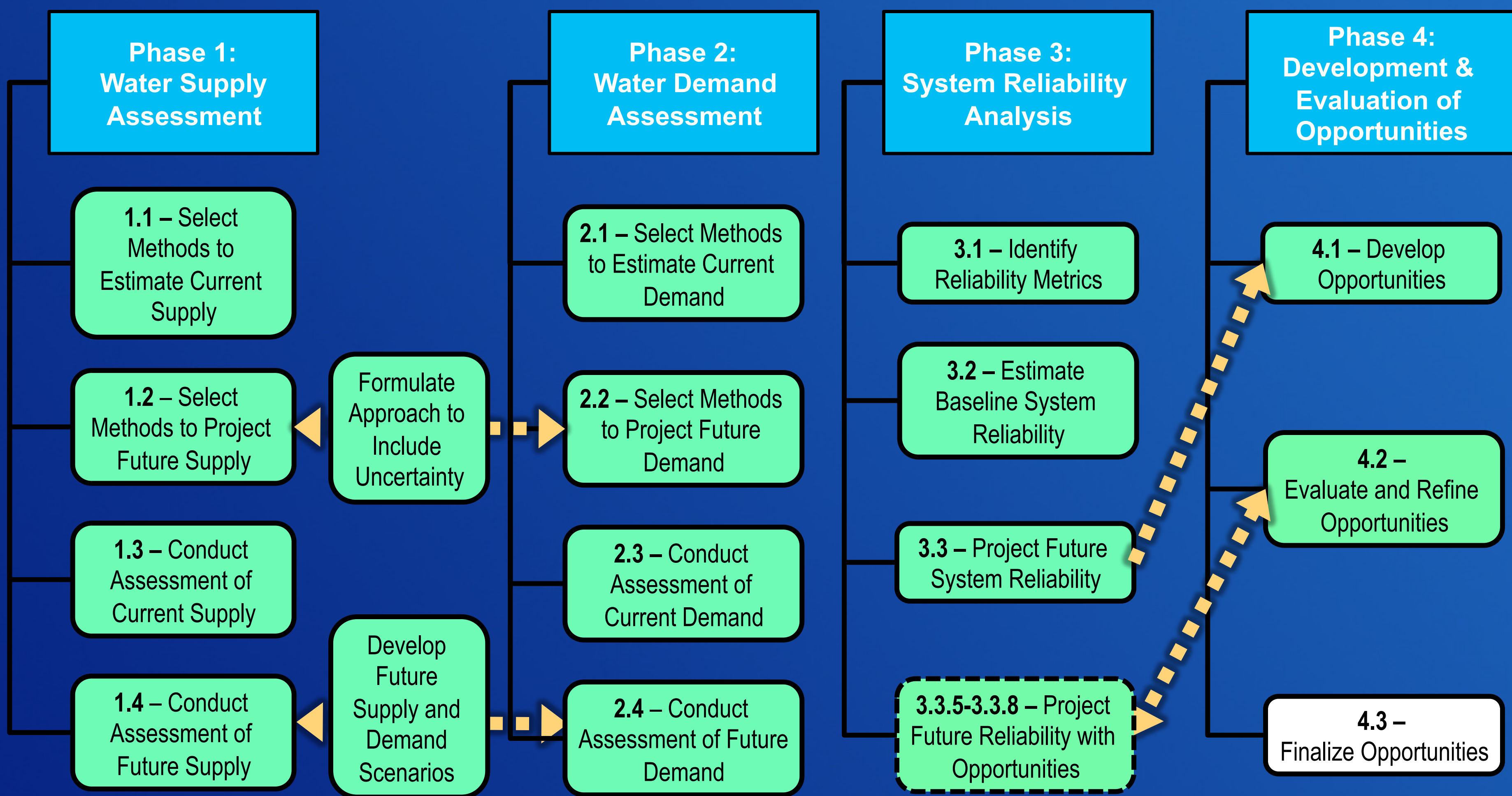
Study Phases and Tasks



Green denotes essentially complete

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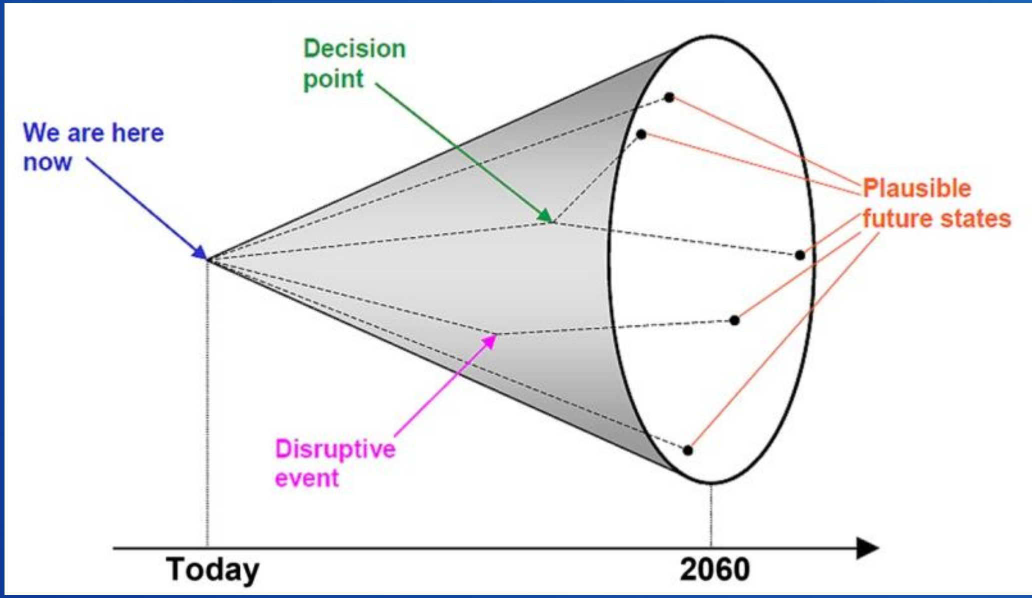
Addressing an Uncertain Future

- The path of major influences on the Colorado River system is uncertain and can not be represented by a single view
- An infinite number of plausible futures exist
- A manageable and informative number of scenarios are being developed to explore the broad range of futures



(adapted from Timpe and Scheepers, 2003)

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Water Supply Scenarios

Observed Resampled:

- future hydrologic trends and variability will be similar to the past 100 years

Paleo Resampled:

- future hydrologic trends and variability are represented by the distant past (approximately 1250 years)

Paleo Conditioned:

- future hydrologic trends and variability are represented by a blend of the wet dry states of the paleo-climate record but magnitudes are more similar to the observed period

Downscaled GCM Projected:

- future climate will continue to warm with regional precipitation trends represented through an ensemble of future GCM projections

Water Demand Scenarios

Current Projected (A):

- growth, development patterns, and institutions continue along recent trends

Slow Growth (B):

- low growth with emphasis on economic efficiency

Rapid Growth (C1 and C2):

- economic resurgence (population and energy) and current preferences toward human and environmental values
  - C1 – slower technology adoption
  - C2 – rapid technology adoption

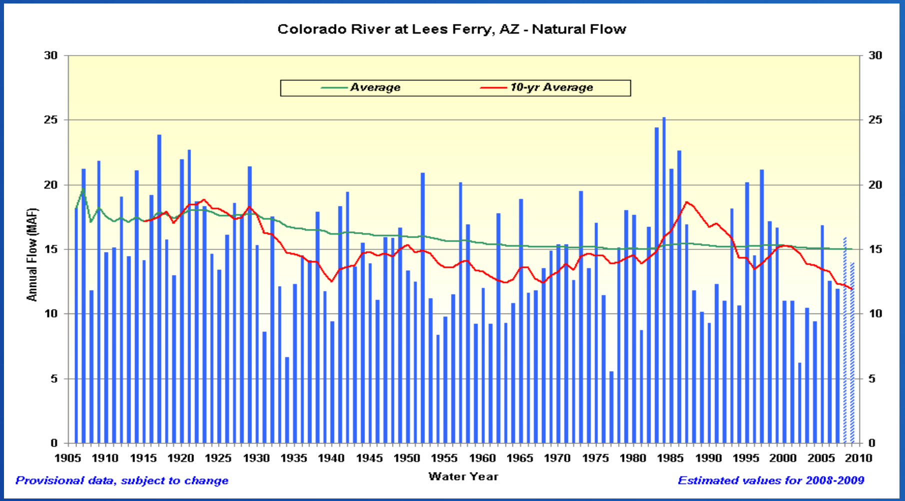
Enhanced Environment (D1 and D2):

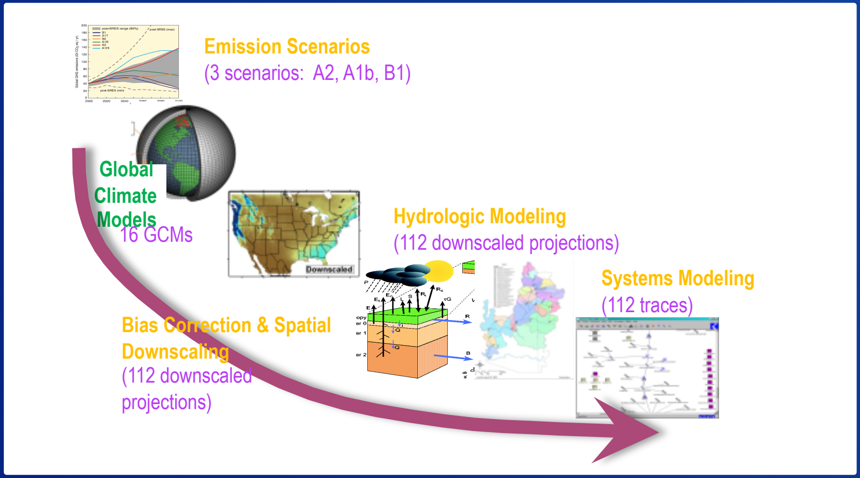
- expanded environmental awareness and stewardship with growing economy
  - D1 – with moderate population growth
  - D2 – with rapid population growth

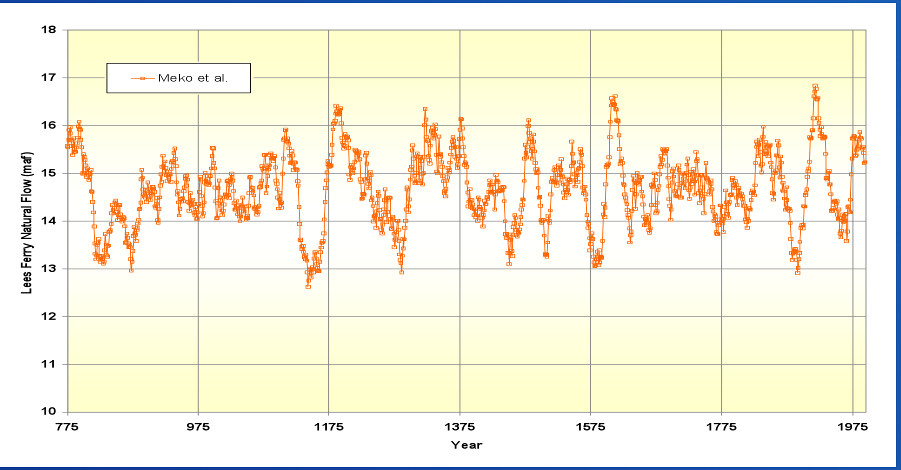
Phase 1: Water Supply Assessment

<u>Scenarios</u> *:

- Observed Resampled
- Paleo Resampled
- Paleo Conditioned
- Downscaled GCM Projected







* Multiple realizations for each scenario

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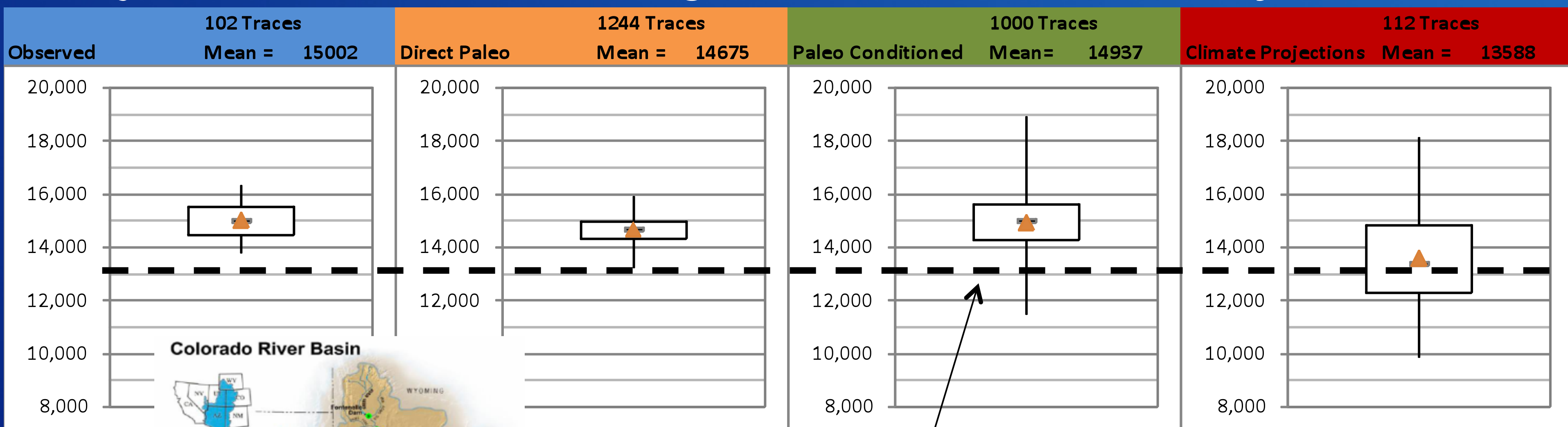
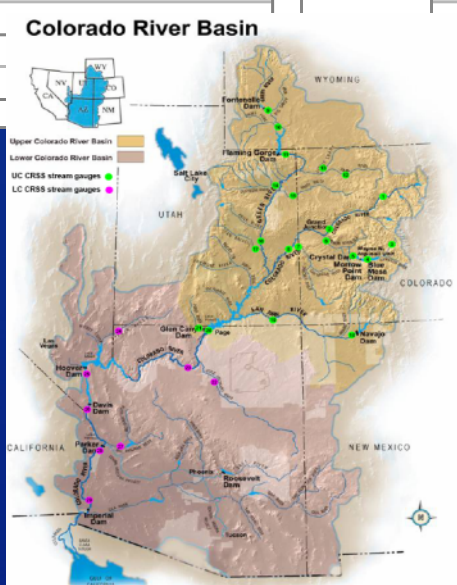
Quantification of Water Supply Scenarios

Projections of 2011-2060 Average Natural Flow at Lees Ferry





Box represents 25th – 75th percentile, whiskers represent min and max, and triangle represents mean of all traces

1988 – 2007 average

Projections of Natural Flow at Lees Ferry

Deficit and Surplus Statistics

Computed over the 2011-2060 Period

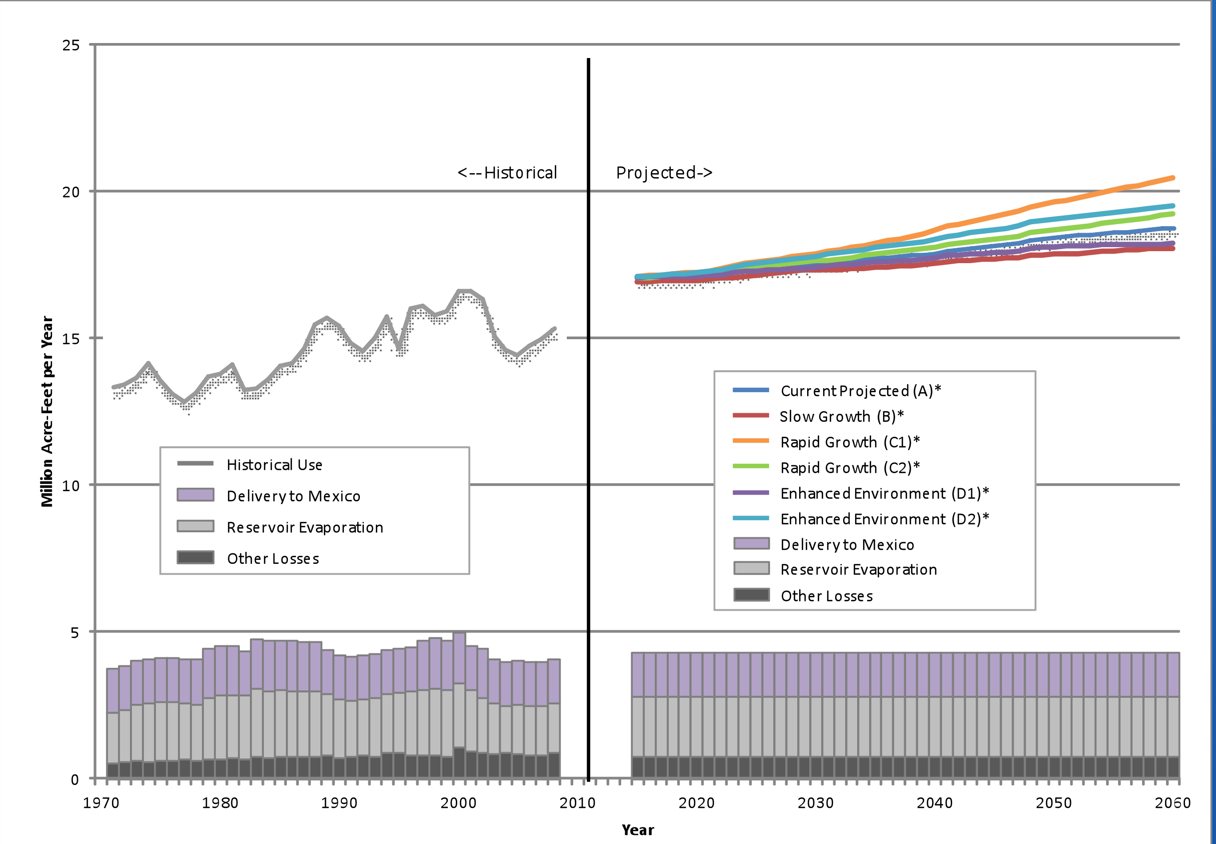
Statistic	Observed Resampled	Paleo Resampled	Paleo Conditioned	Downscaled GCM Projected
Frequency of Deficit[1] lasting 5 years or longer	22%	30%	25%	40%
Frequency of Surplus[1] lasting 5 years or longer	28%	15%	18%	<1%

[1]A deficit/surplus period occurs whenever the 2-year running mean is below/above the observed mean of 15.0 maf

Quantification of Water Demand Scenarios

- Demand for consumptive uses ranges between 13.8 and 16.2 maf by 2060 (including Mexico and losses 18.1 and 20.4 maf by 2060)
- About a 20% spread between the lowest (Slow Growth) and highest (Rapid Growth – C1) demand scenarios

Colorado River Basin Historical Use and Future Projected Demand



*Quantified demand scenarios have been adjusted to include Mexico's allotment and estimates for future reservoir evaporation and other losses.

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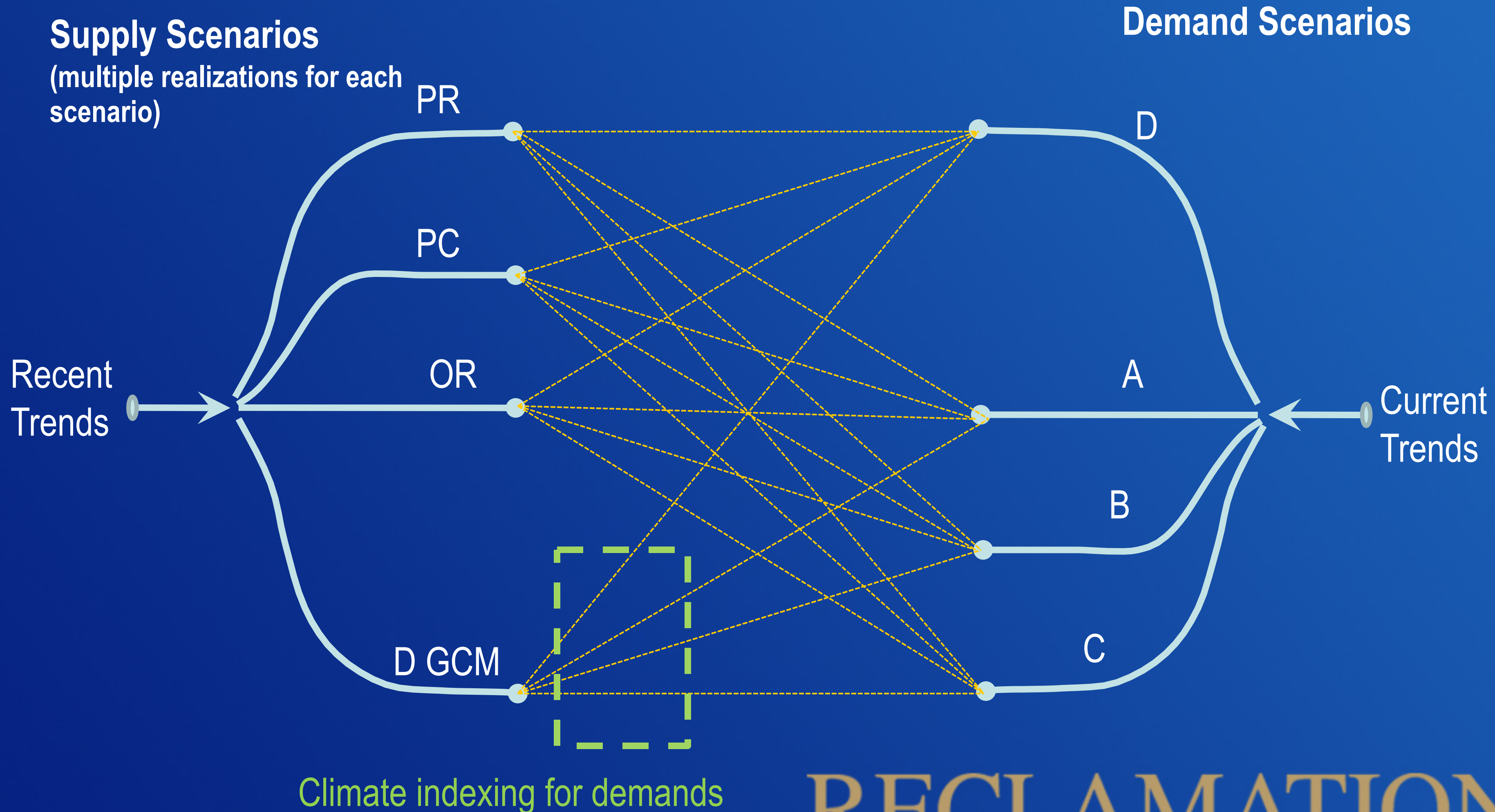
Integration of Supply and Demand Scenarios



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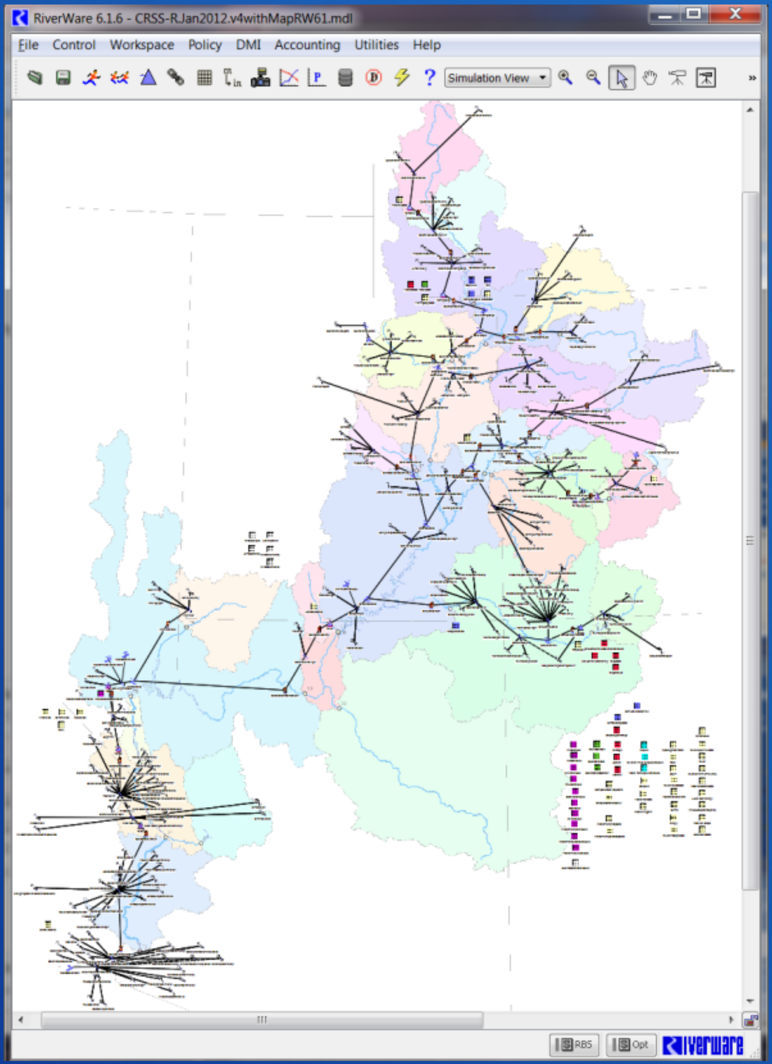
Colorado River Simulation System (CRSS)

- Comprehensive model of the Colorado River Basin
- Developed by Reclamation (early 1970s) and implemented in RiverWare™ (1996)
- Primary tool for analyzing future river and reservoir conditions in planning context (NEPA EIS)
- A projection model, not a predictive model
- Excellent for comparative analysis
- Gives a range of potential future system conditions (e.g., reservoir elevations, releases, energy generation)
- Simulates on a monthly time step over decades
- Operating policy is represented by “rules” that drive the simulation and mimic how the system operates



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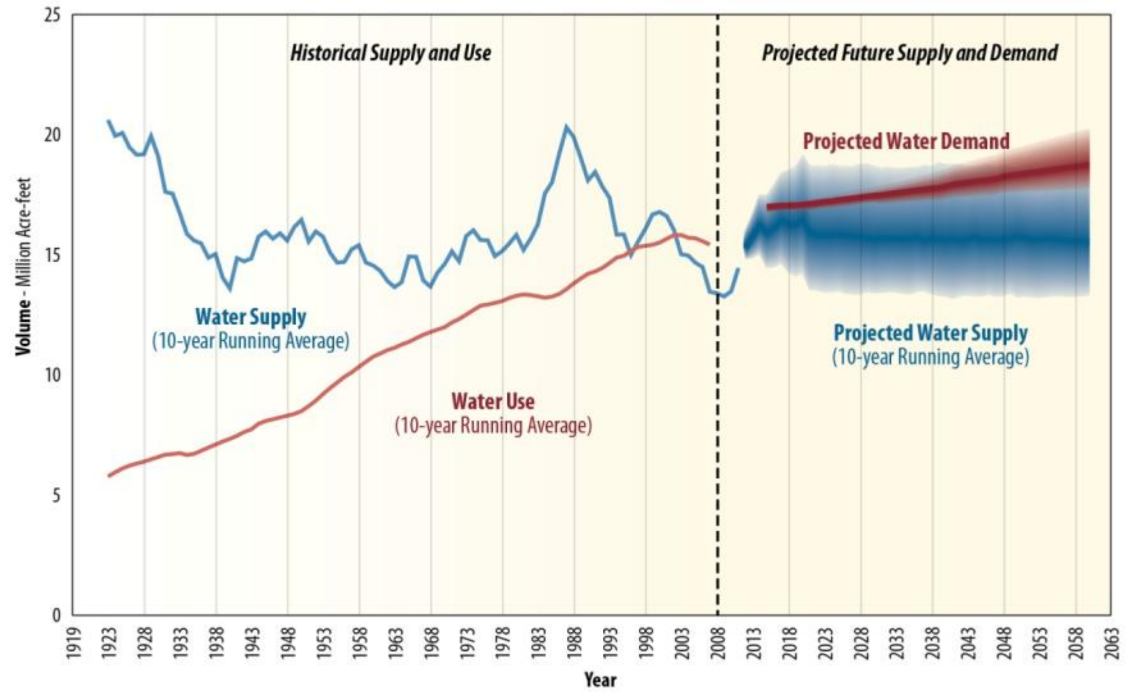
Projected Future Colorado River Basin Water Supply and Demand

- Average supply-demand imbalances by 2060 are approximately 3.5 million acre-feet
- This imbalance may be more or less depending on the nature of the particular supply and demand scenario
- Imbalances have occurred in the past and deliveries have been met due to reservoir storage



Notes:

Water Supply represents natural flow as measured at the Colorado River above Imperial Dam, Arizona

Water Use and Demand include deliveries to Mexico in accordance with the 1944 Treaty with Mexico and losses such as those due to reservoir evaporation, native vegetation, and operational inefficiencies.

Projected Water Supply is computed as the average 10th, 50th (median), and 90th percentiles of the Study's 4 water supply scenarios. The average of the medians is indicated by the darker shading.

Projected Water Demand is represented by the Study's 6 water demand scenarios. The median of the scenarios is indicated by the darker shading.

CRBS_103

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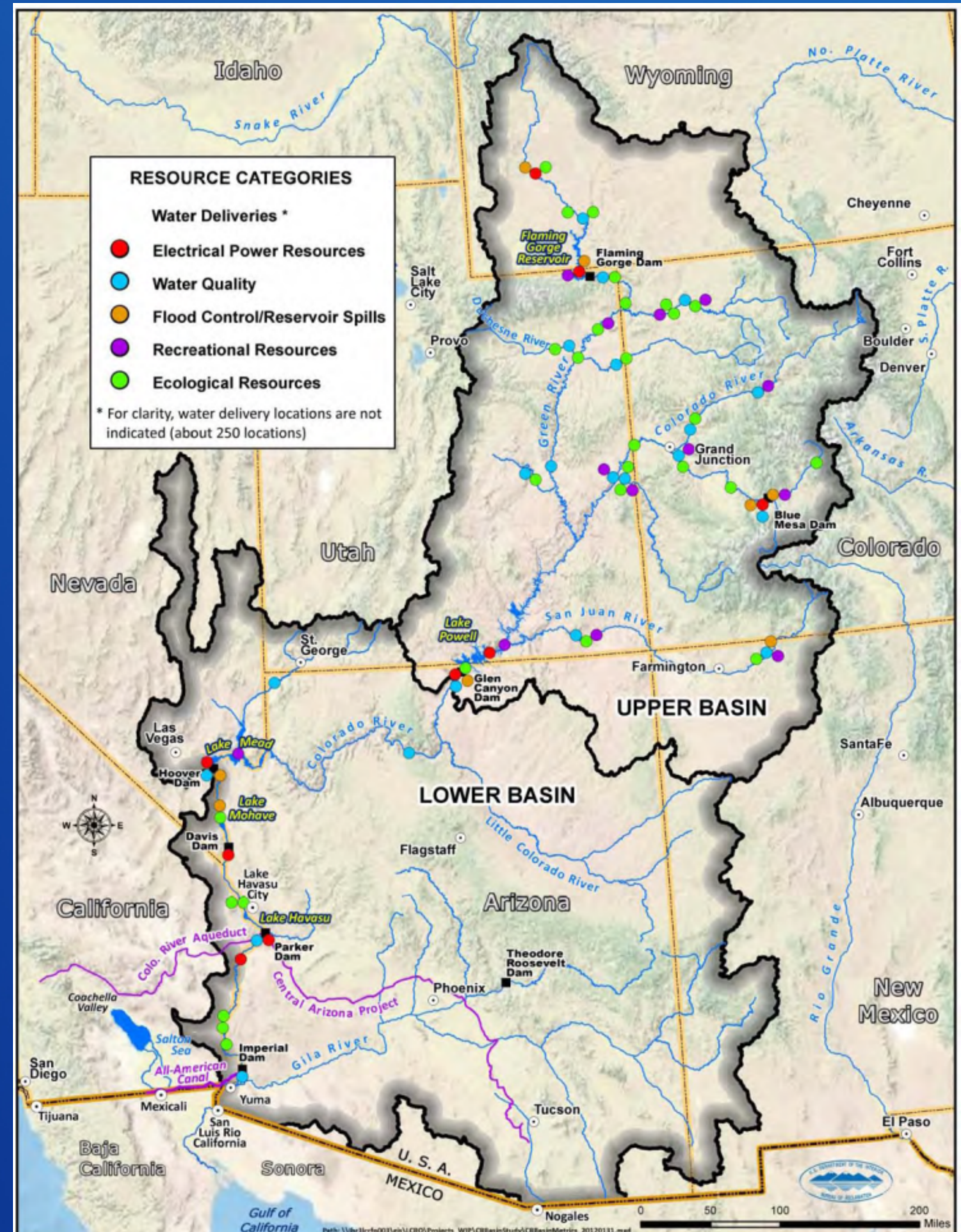
System Reliability Analysis

- Simulate the state of the system on a monthly time step over the next 50 years for each scenario, with and without options and strategies

- Metrics will be used to quantify impacts to Basin resources

- **Resource Categories**
  - ➢ Water Deliveries
  - ➢ Electrical Power Resources
  - ➢ Water Quality
  - ➢ Flood Control
  - ➢ Recreational Resources
  - ➢ Ecological Resources



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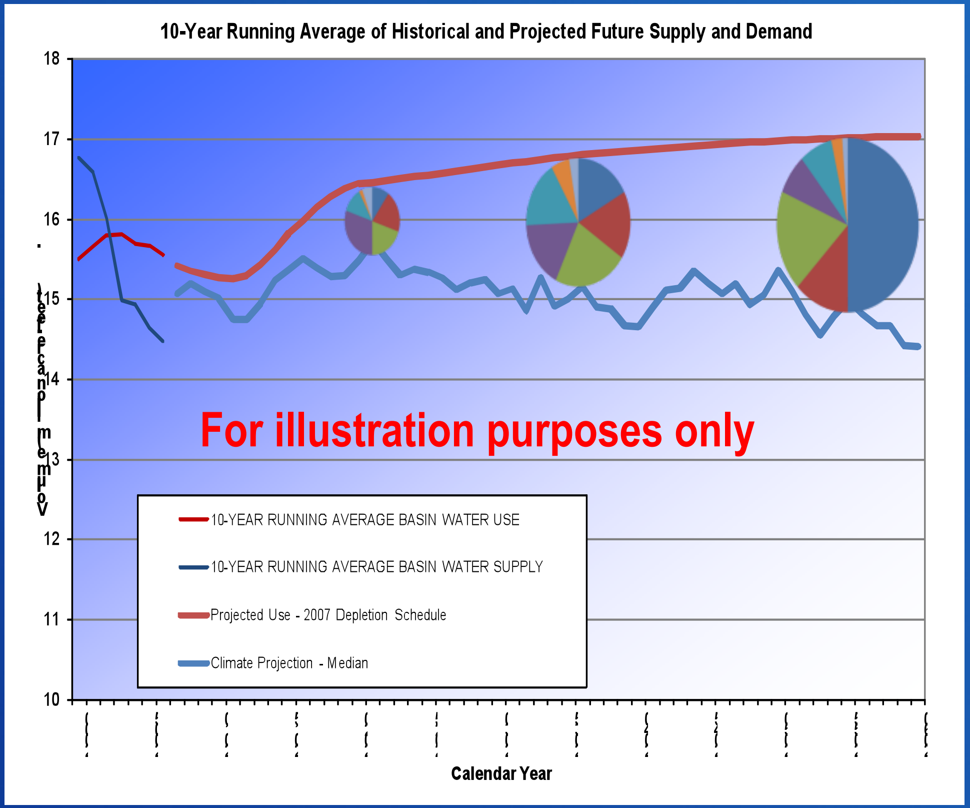
Options and their Characterization

- Over 150 options were submitted to the Study
  - Increased Supply – importation, reuse, desalination, etc.
  - Reduced Demand – M&I and agricultural conservation, etc.
  - Modify Operations – transfers & exchanges, water banking, etc.
  - Governance & Implementation – stakeholder committees, population control, re-allocation, etc.
- Organizing and Characterizing Options
  - Potential yield
  - Timing of implementation
  - Technical feasibility
  - Cost
  - Environmental impacts/permitting requirements
  - Legal/public policy
  - Risk/uncertainty

Portfolio Development

- "Portfolios" or unique combinations of options implement a particular strategy
- Characterization criteria drives selection of options that comprise portfolios
- Assess performance for all future supply-demand scenarios across all resources



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Downscaled GCM projected scenario highlights

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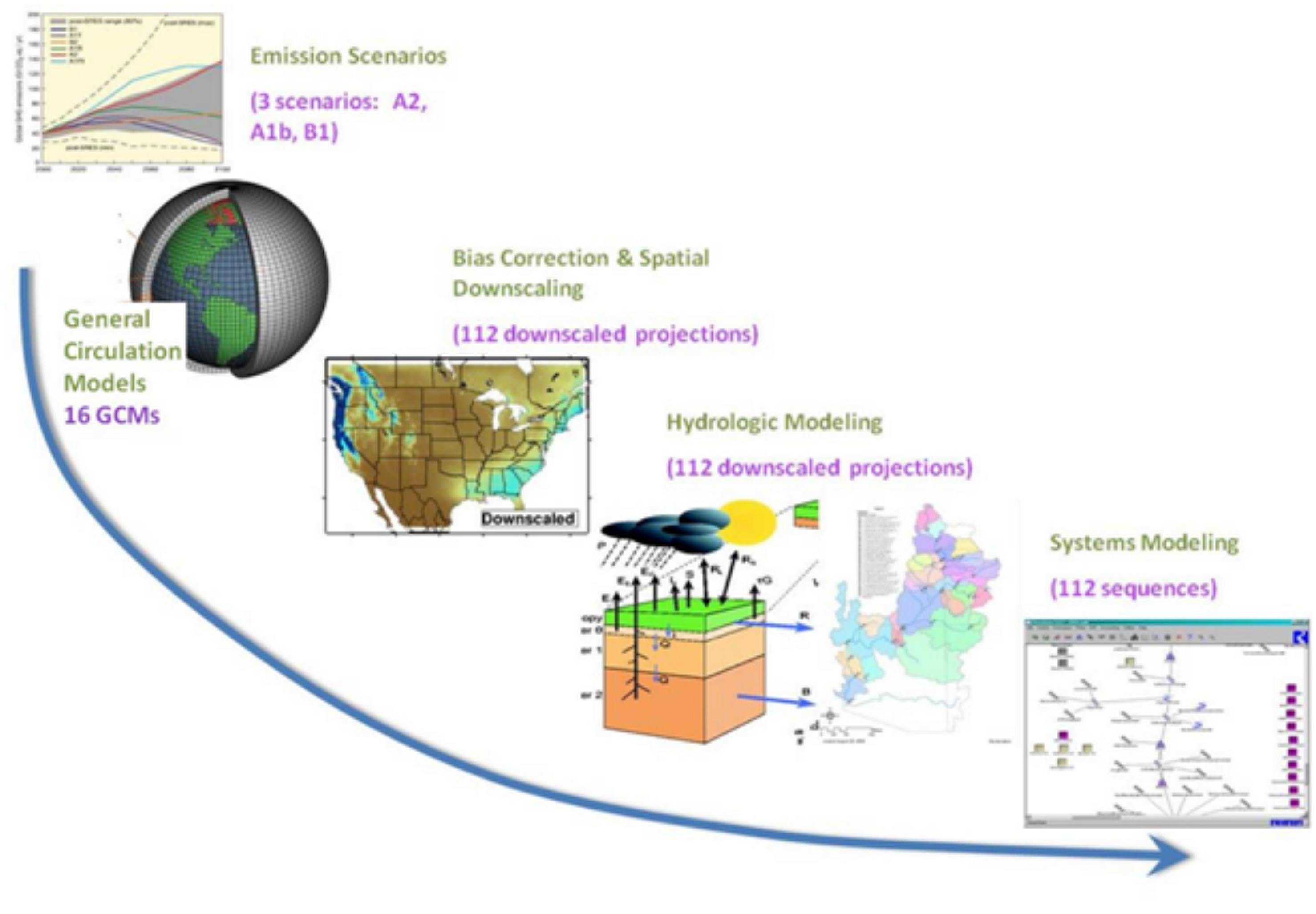
Methodological Approach for the Development of the Downscaled GCM Projected Scenario



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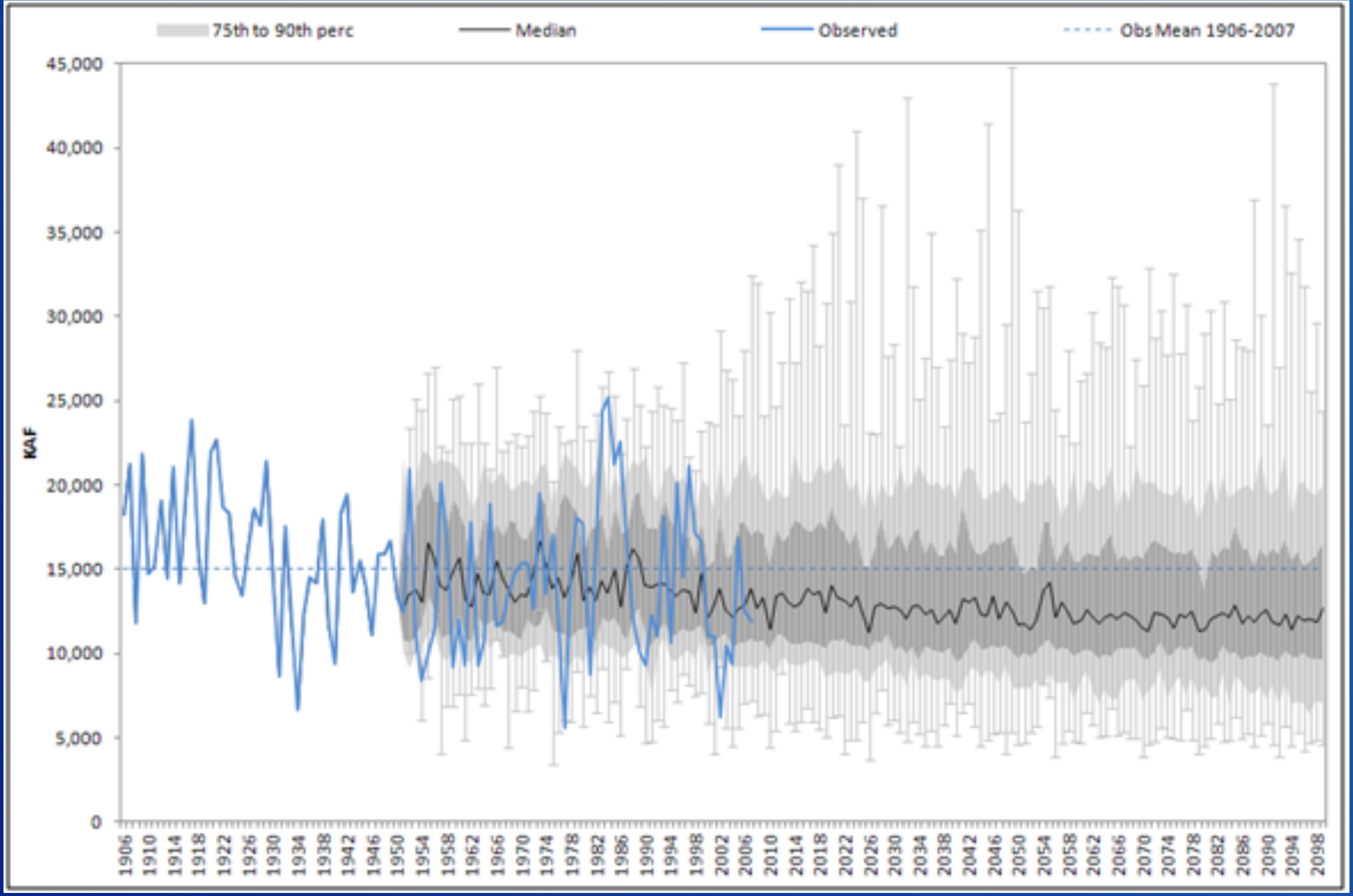
Colorado River at Lees Ferry, Arizona Natural Flow Statistics for the Downscaled GCM Projected Scenario as Compared to Observed Flow



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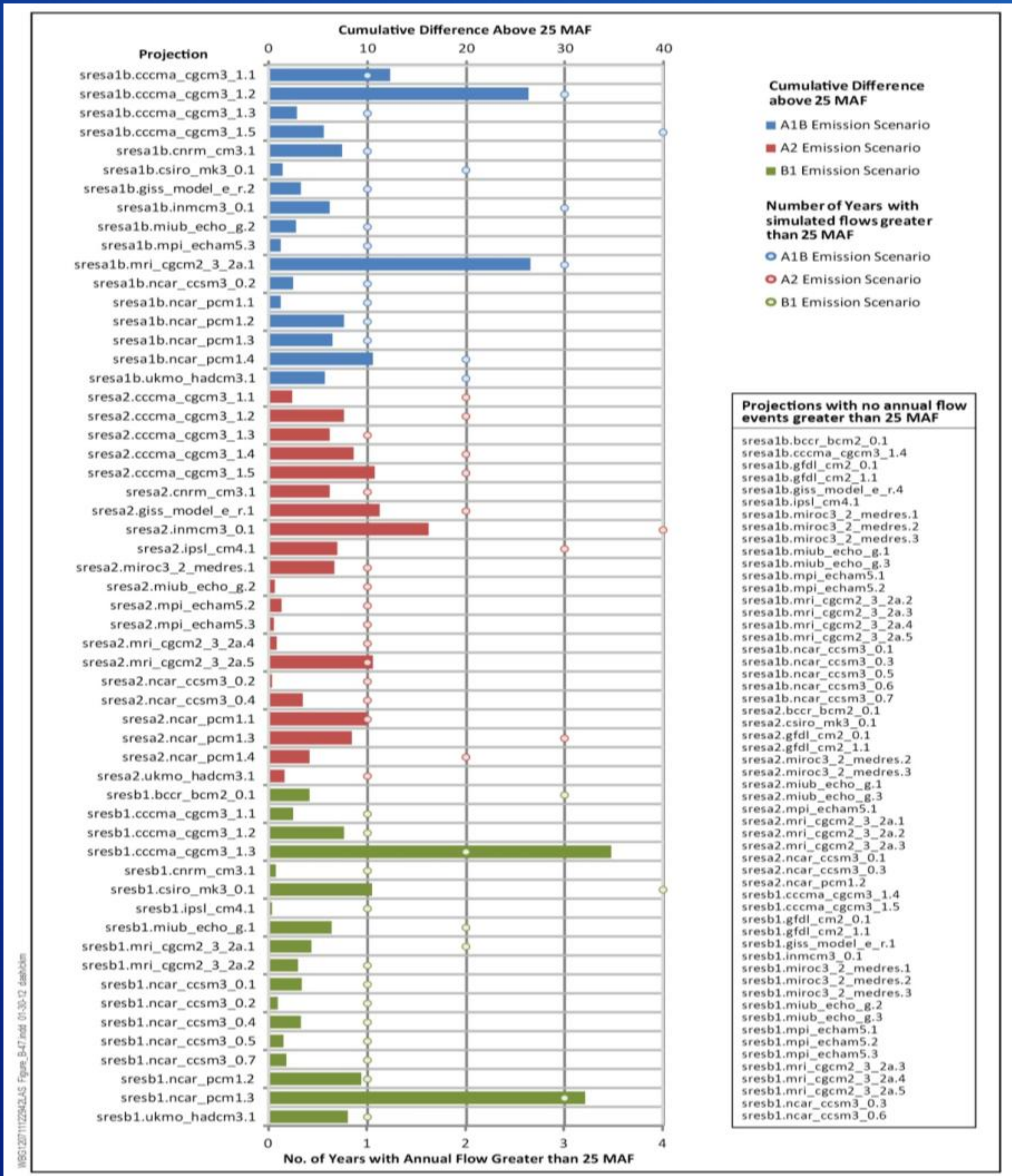
Summary of Annual and Monthly Streamflow Statistics for the Downscaled GCM Projected Scenario for the 3 Future 30 Year Time Periods: 2011–2040 (2025), 2041-2070 (2055), and 2066-2095 (2080)

	Statistic	Downscaled GCM Projected 2011-2040 (2025)	Downscaled GCM Projected 2041-2070 (2055)	Downscaled GCM Projected 2066-2095 (2080)
Annual (Water Year)	Average Annual Flow (maf)	13.9	13.4	13.1
	Percent Change from Long-Term Mean (1906–2007)	-7.5%	-10.9%	-12.4%
	Median (maf)	13.8	13.3	13.4
	25th Percentile (maf)	12.8	12.0	11.2
	75th Percentile (maf)	15.1	14.6	14.5
	Minimum Year Flow (maf)	4.4	3.9	3.7
	Maximum Year Flow (maf)	43.8	44.3	44.3
Monthly	Peak Month	June	May	May
	Peak Month Mean Flow (kaf)	3,535	3,388	3,495
	Peak Month Maximum Flow (kaf)	14,693	10,830	12,991
	Month at Which Half of Annual Flow (Water Year) is Exceeded	June	May	May

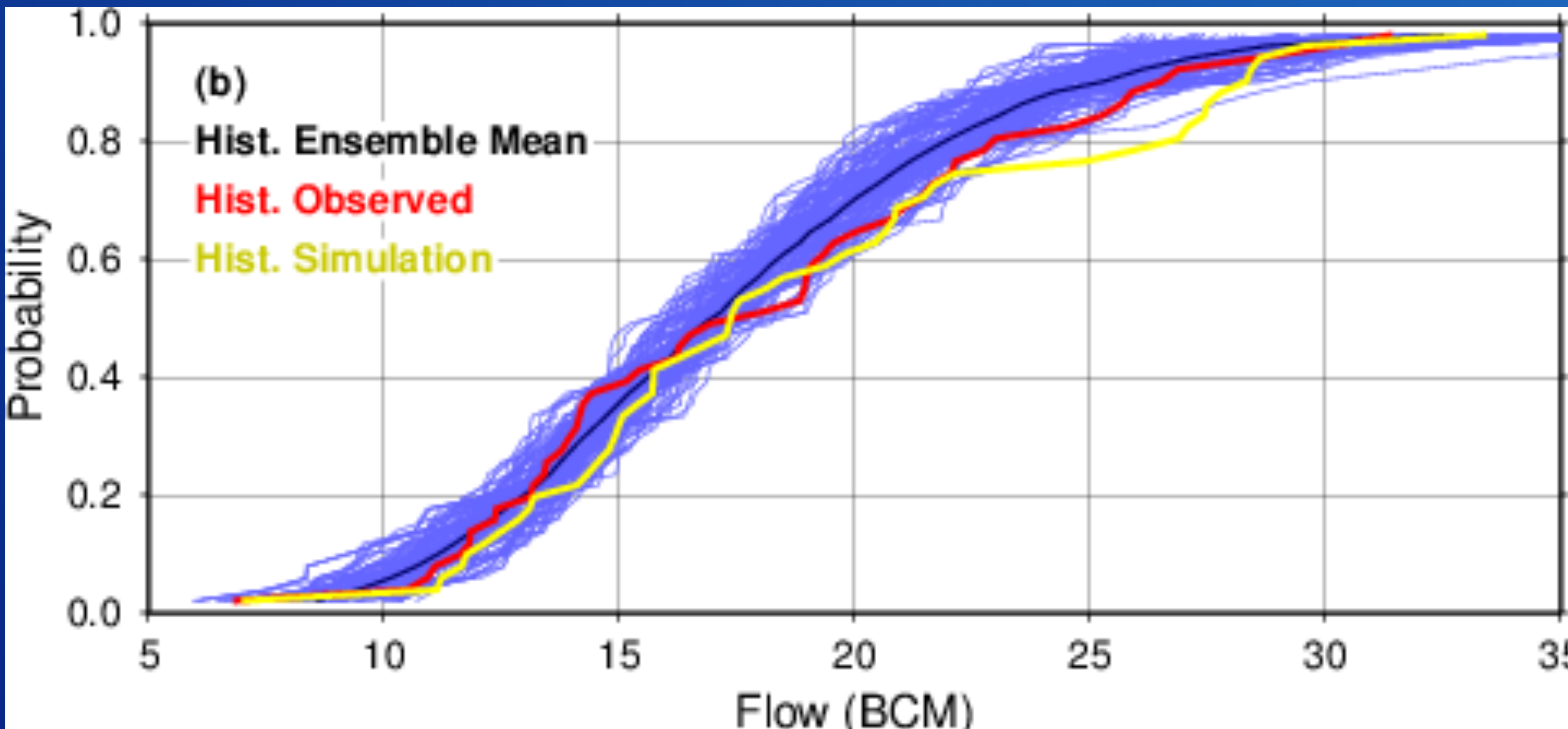


- Extreme flow analysis
- 2011-2060 simulation period
- Cumulative difference above observed maximum

Hurtles Encountered

- GCMs
  - Uneven number of Ensemble Members
- Downscaling
  - Limited data available
- Hydrologic Model
  - Data requirements
    - Daily T_{min}, T_{max}, P, winds
  - Versioning
  - Calibration
- System Modeling
  - Required Secondary Bias Correction

ECDFs of downscaled simulated flows on the Colorado River at Lees Ferry AZ, 1950 through 1999, compared with observed and historical simulated flows.



.L. Harding et al., hess-2011-405

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Areas Identified in Need of Further Study

- Elevational sensitivity of snowpack
- Effect of warming and increased carbon dioxide on ET
- Role of summer and fall soil moisture on water supply
- Use of Newer
  - GCM results
    - How should CMIP5 replace or add to CMIP3 results
  - Downscaling techniques
- Modeling changes in land use and vegetative cover
  - Assumed static in hydrologic model
  - Unsure if there is a standard for GCMs

Colorado River Basin Water Supply and Demand Study

Study Contact Information

- Website: http://www.usbr.gov/lc/region/programs/crbstudy.html
- Email: ColoradoRiverBasinStudy@usbr.gov
- Telephone: 702-293-8500; Fax: 702-293-8418

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