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Managing Water in the West

Colorado River Basin Water Supply and Demand Study

Educational Outreach Session
Webinar
April 3, 2013

U.S. Department of the Interior
Bureau of Reclamation

Agenda (1:00 PM – 4:00 PM)

1:00	Introduction
1:15	Water Supply Assessment
1:30	Water Demand Assessment
1:45	Options and Strategies Development
2:05	Break
2:15	System Reliability Analysis Methodology
2:35	System Reliability Analysis Results
3:20	Study Limitations and Next Steps
3:30	Open Question and Answer Session
4:00	Closing Comments and Adjourn

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Introduction

Lake Mead

- Background
- WaterSMART Program
- Colorado River Basin Study Overview
- Reporting and Public Comments

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Colorado River Basin

- Basin approximately 250,000 sq. miles
- Annual allocations exceed the Basin's long-term average flow
- 15.0 maf average annual "natural" inflow into Lake Powell over past 100 years
- Inflows are highly variable year-to-year
- 60 maf of storage
- Managed in accordance with the Law of the River

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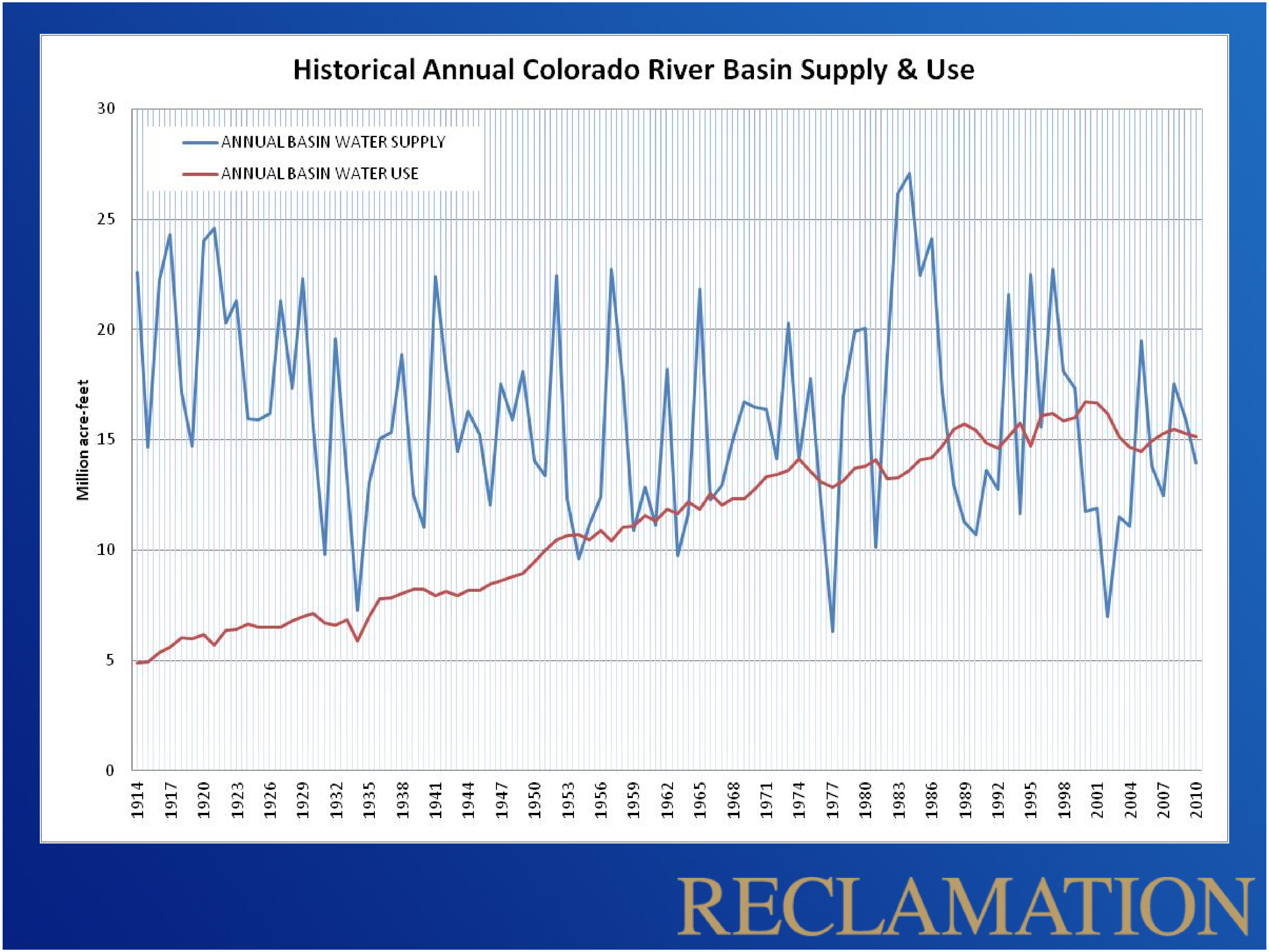

Historical Annual Colorado River Basin Supply & Use
ANNUAL BASIN WATER SUPPLY
ANNUAL BASIN WATER USE
Million acre-feet
30
25
20
15
10
5
0
1914
1917
1920
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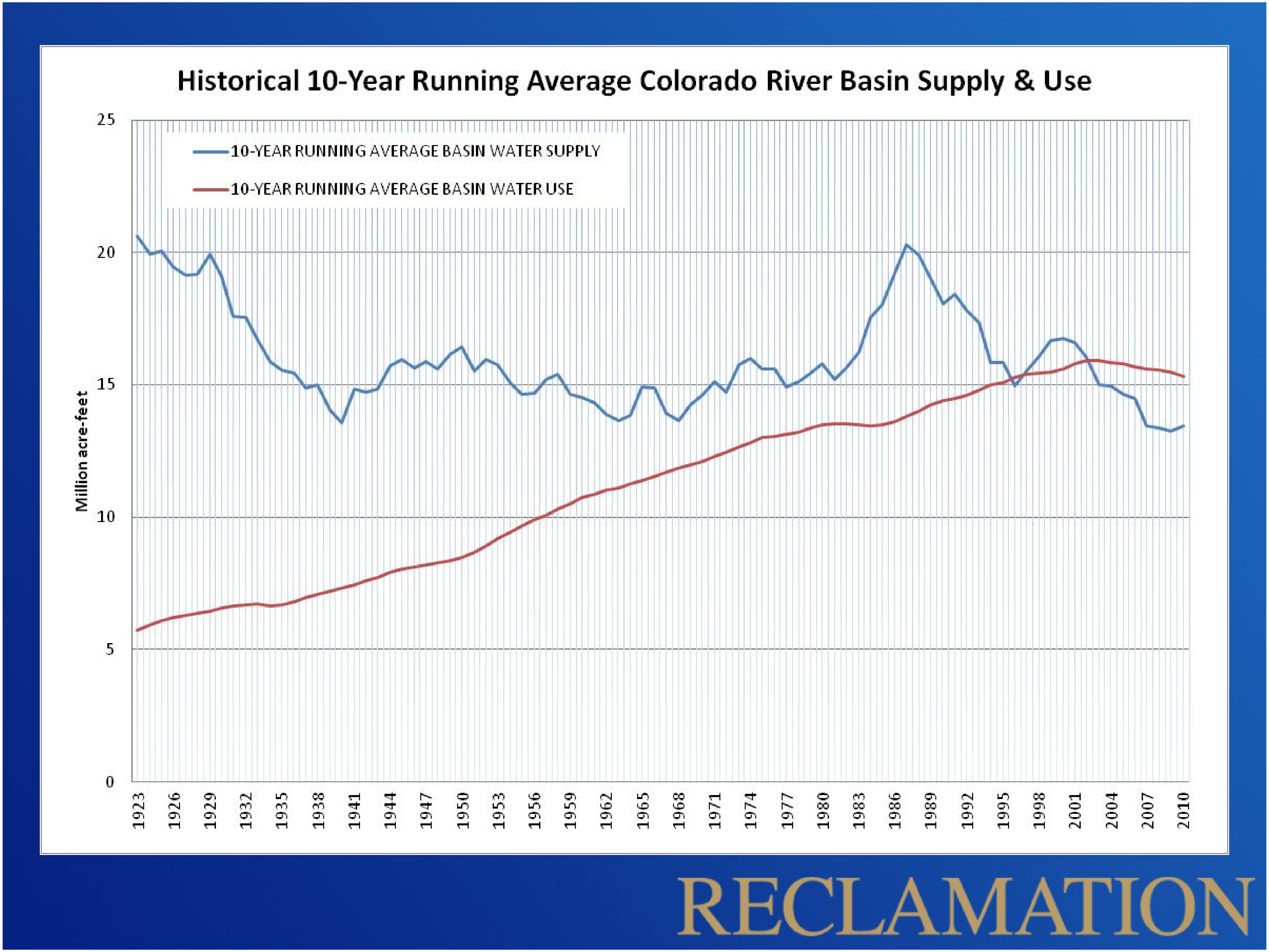
Historical 10-Year Running Average Colorado River Basin Supply & Use
10-YEAR RUNNING AVERAGE BASIN WATER SUPPLY
10-YEAR RUNNING AVERAGE BASIN WATER USE
Million acre-feet
25
20
15
10
5
0
1923
1926
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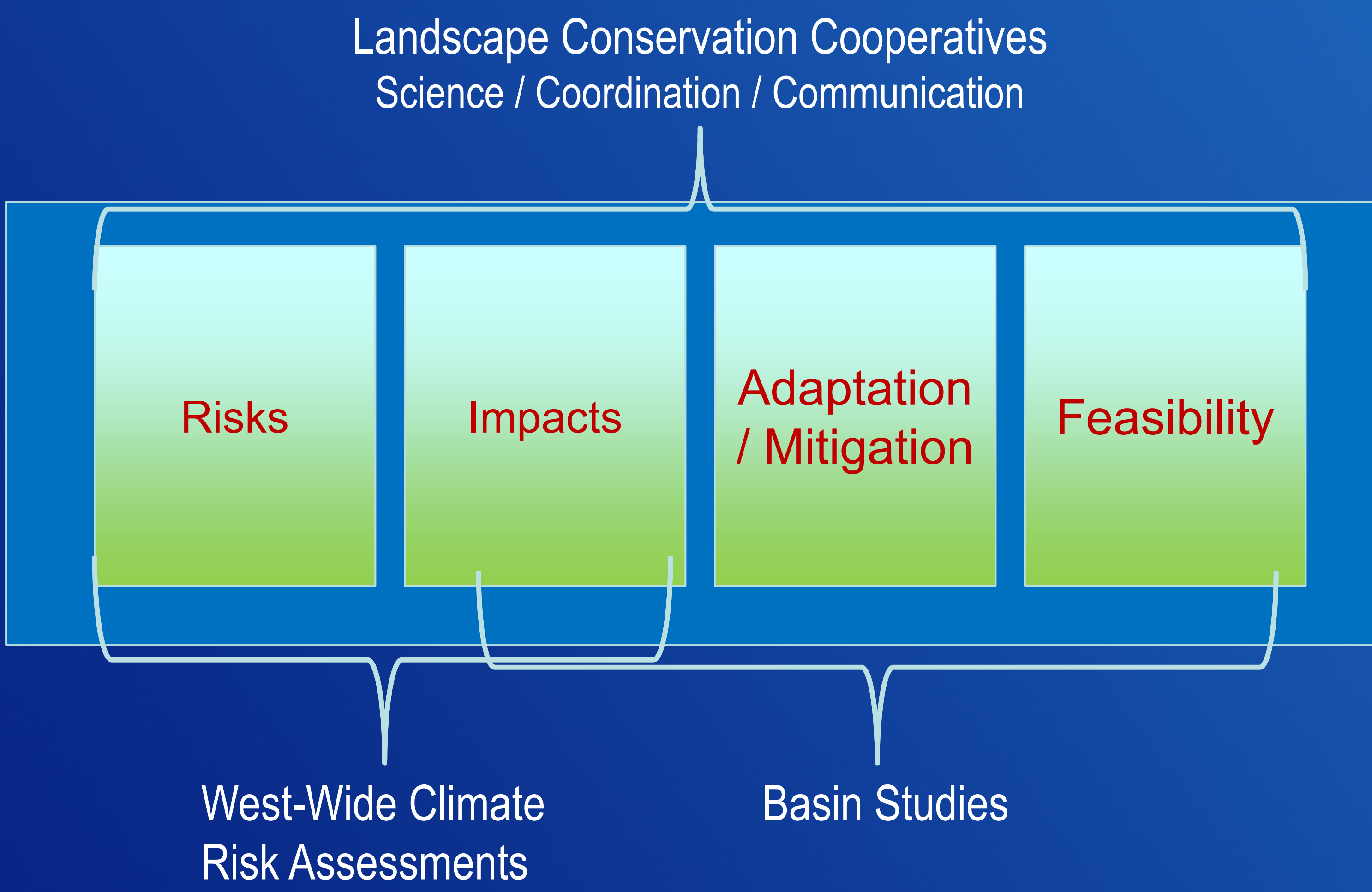
Reclamation WaterSMART (SECURE Water Act, Section 9503)



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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 conducted by Reclamation and the Basin States, in collaboration with stakeholders throughout the Basin
- Began in January 2010 and completed in December 2012
- A planning study – does *not* result in any decisions, but will provide the technical foundation for future activities

Cost-Share Partners
Arizona Department of Water Resources
(California) Six Agency Committee
Colorado Water Conservation Board
New Mexico Interstate Stream Commission
Southern Nevada Water Authority
Utah Division of Water Resources
Wyoming State Engineer's Office
Reclamation's Upper and Lower Colorado Regions

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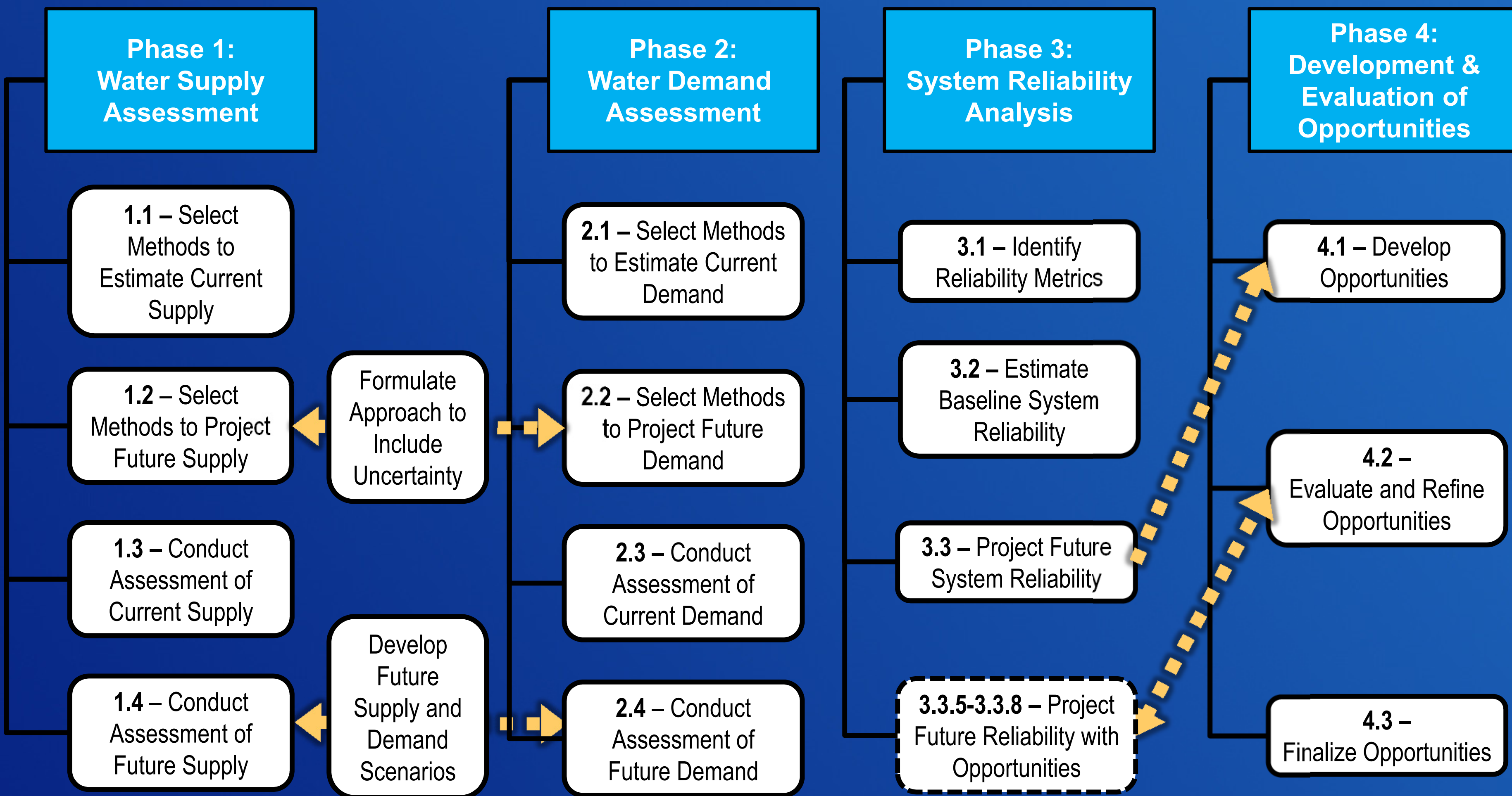
Study Phases and Tasks



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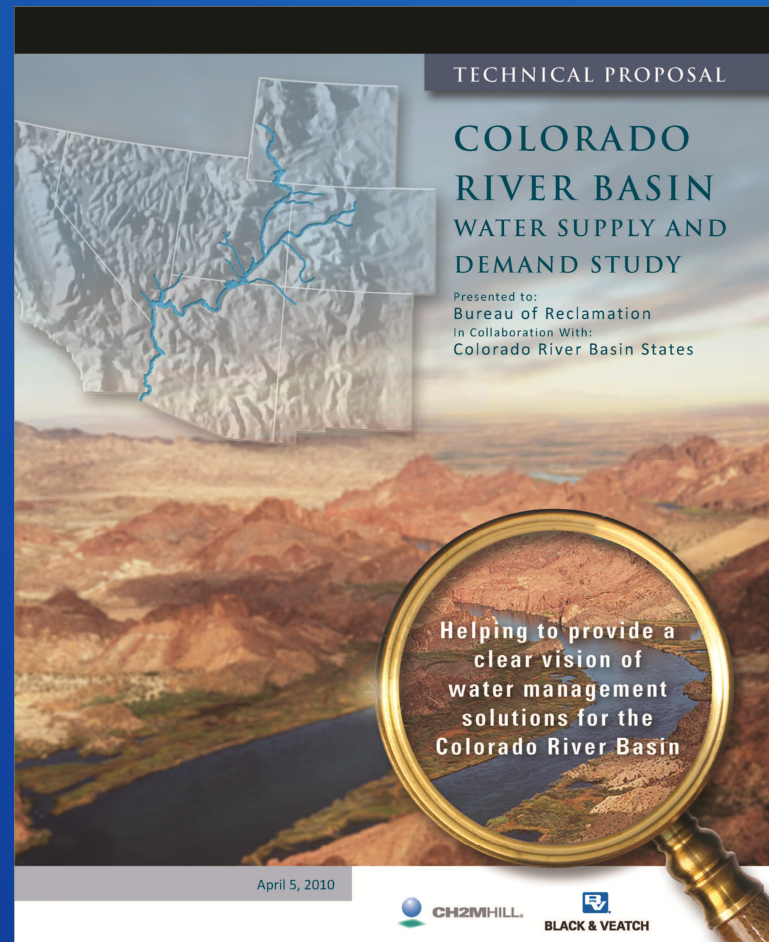
Contracted Services

- CH2M Hill and Black & Veatch were brought on in April 2010
  - Overall support for the Study
  - Water supply and demand assessment; option development and characterization; and portfolio development and evaluation
  - Technical integration and Study documentation support

CH2MHILL BLACK & VEATCH

- The RAND Corporation was brought on in March 2012
  - Support for system reliability analysis
  - Vulnerability assessment; portfolio development and evaluation

RAND



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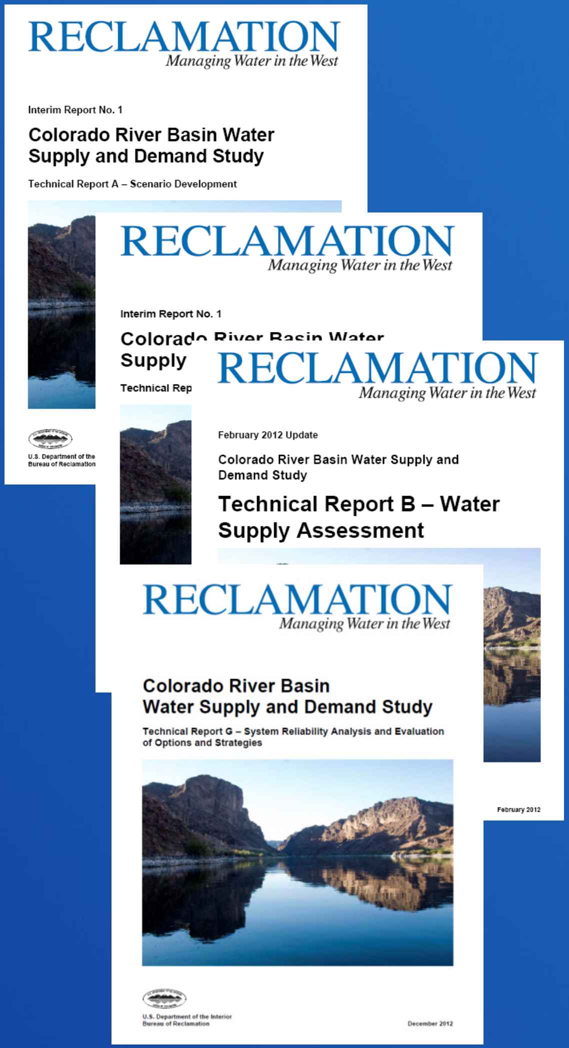
Final Study Reports

- The final Study is a collection of reports available at: **http://www.usbr.gov/lc/region/programs/crbstudy/report1.html**

Executive Summary
Study Report
Technical Report A – Scenario Development
Technical Report B – Water Supply Assessment
Technical Report C – Water Demand Assessment
Technical Report D – System Reliability Metrics
Technical Report E – Approach to Develop and Evaluate Opportunities to Balance Supply
Technical Report F – Development of Options and Strategies
Technical Report G – System Reliability Analysis and Evaluation of Options and Strategies



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Comments

- Should be submitted by April19, 2013
- May be submitted in the following ways:
  - Study website at: **http://www.usbr.gov/lc/region/programs/crbstudy.html**
  - E-mail to: **ColoradoRiverBasinStudy@usbr.gov**
  - U.S. mail to:

    U.S. Bureau of Reclamation

    Attention Ms. Pam Adams, LC-2721

    PO Box 61470

    Boulder City NV 89006-1470
  - Fax to: **702-293-8418**
- Comments will be summarized, posted to the website, and considered in future Basin planning activities

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Water Supply Assessment
Technical Report B

- Objective
- Development of Water Supply Scenarios
- Quantification of Water Supply Scenarios

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Objective of the Water Supply Assessment

- The objective of the Water Supply Assessment is to assess the probable magnitude and variability of historical and future natural flow[1] in the Basin
- The assessment includes the potential effects of future climate variability and climate change

[1]Natural flow represents the flow that would have occurred at a location had depletions and reservoir regulation not been present upstream of that location

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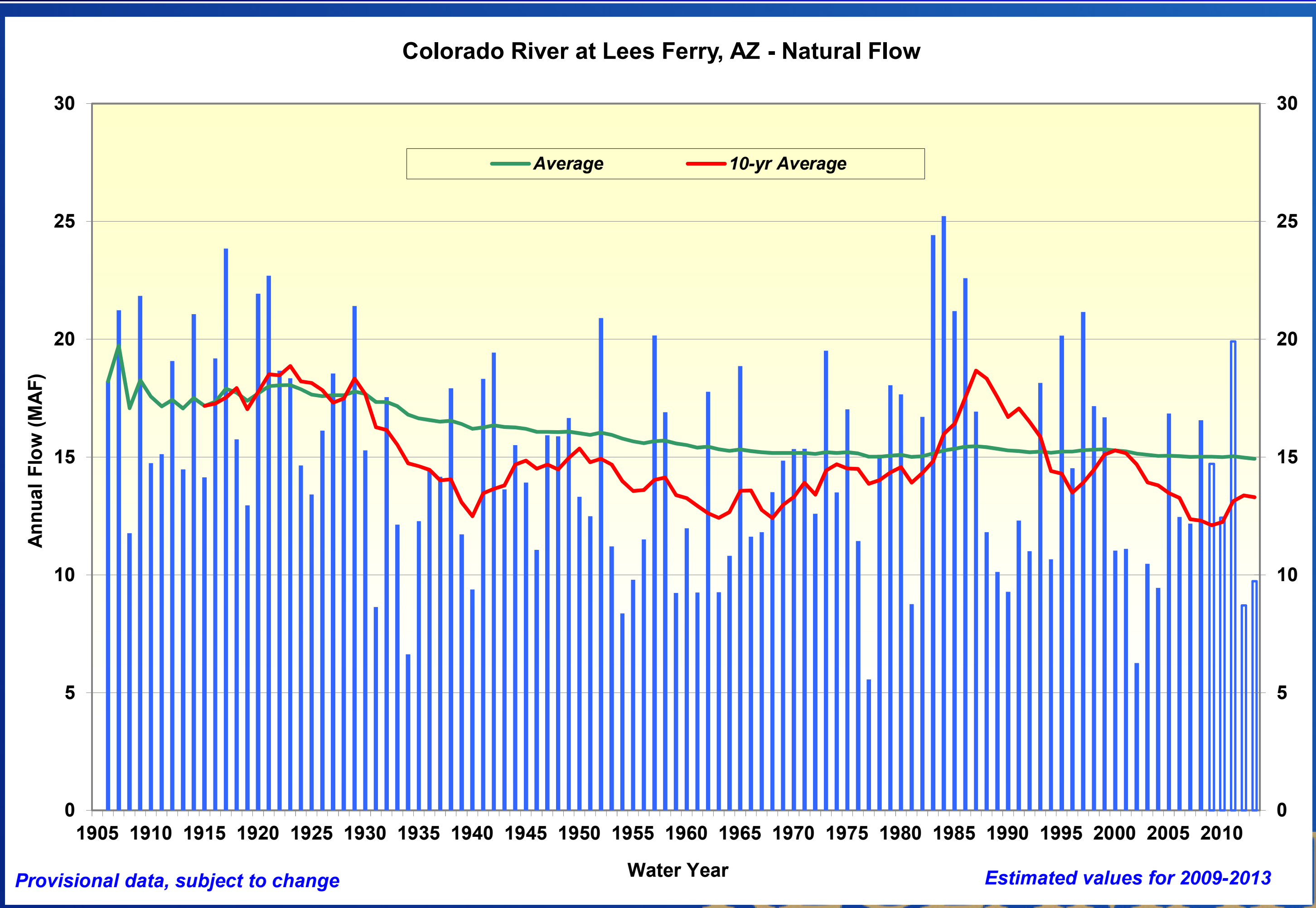
Water Supply Scenarios

Observed Resampled

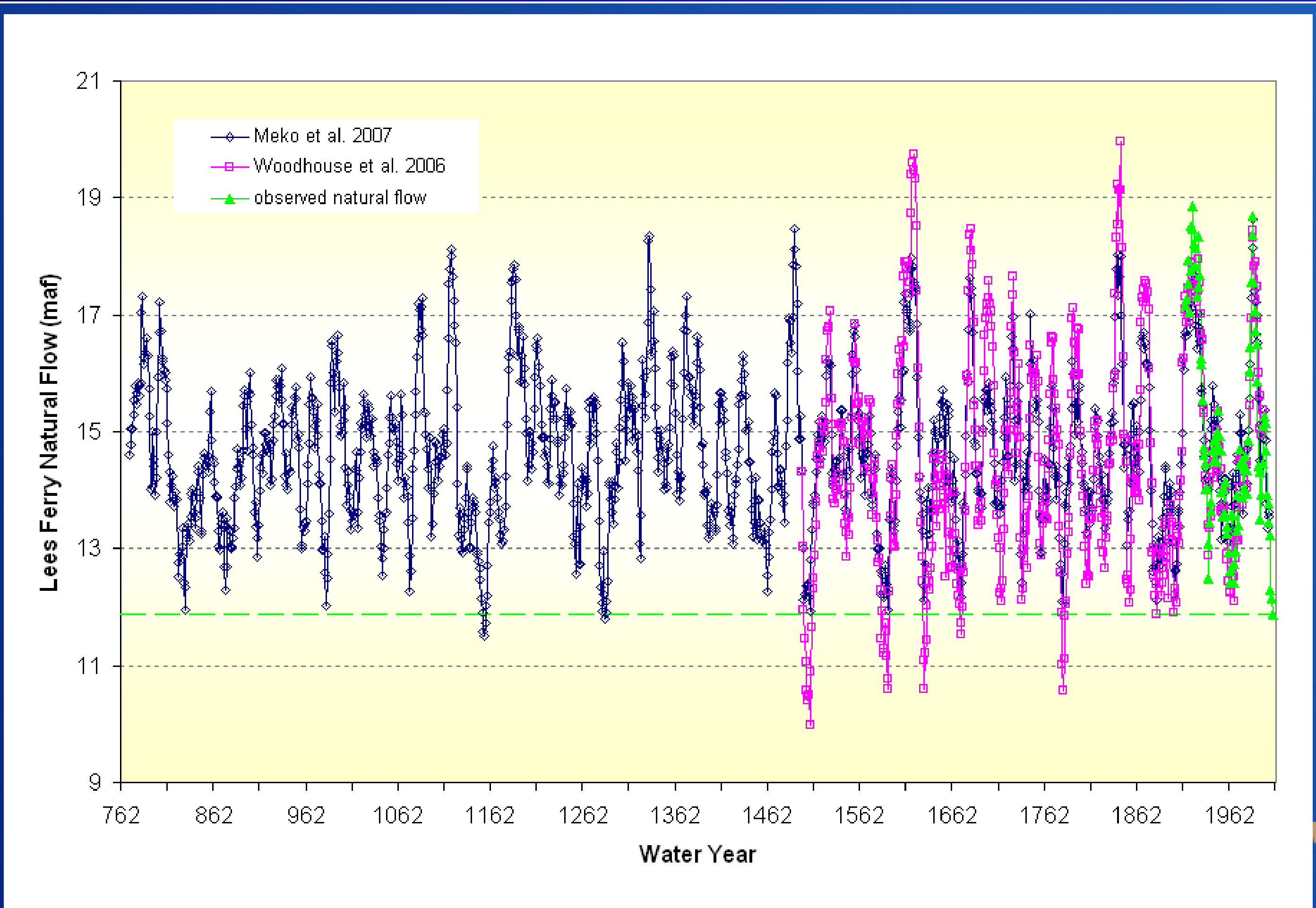
- ➢ future hydrologic trends and variability will be similar to the past 100 years
- ➢ 103 sequences of future streamflow



Water Supply Scenarios

Paleo Resampled

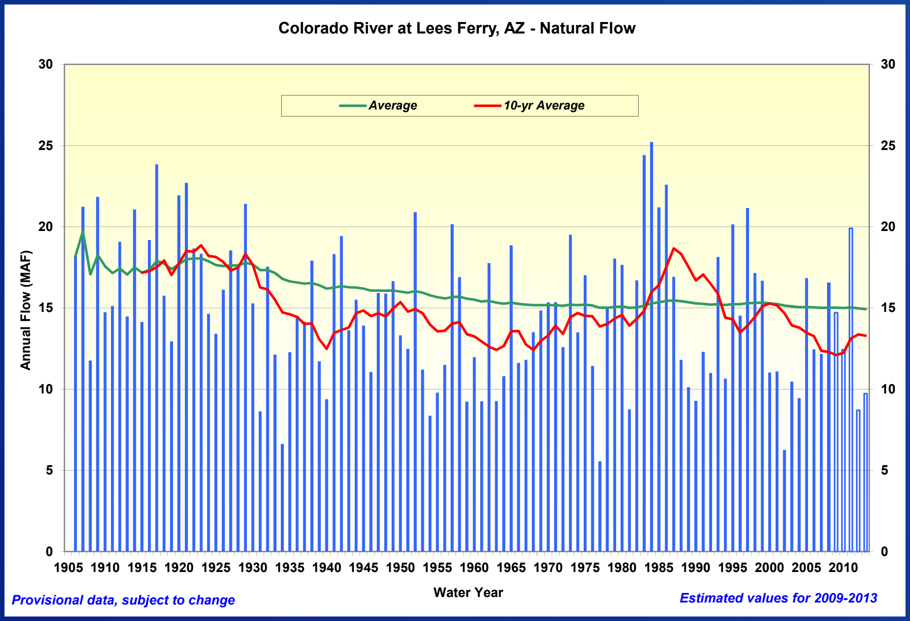
- future hydrologic trends and variability are represented by the distant past (approximately 1250 years)
- 1,244 sequences of future streamflow

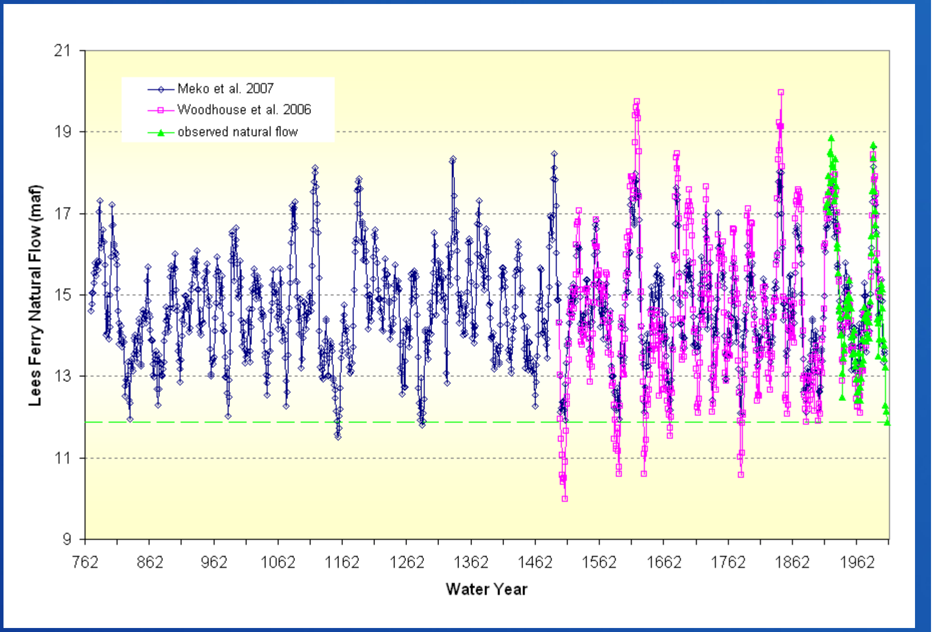


Water Supply Scenarios

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
- 500 sequences of future streamflow





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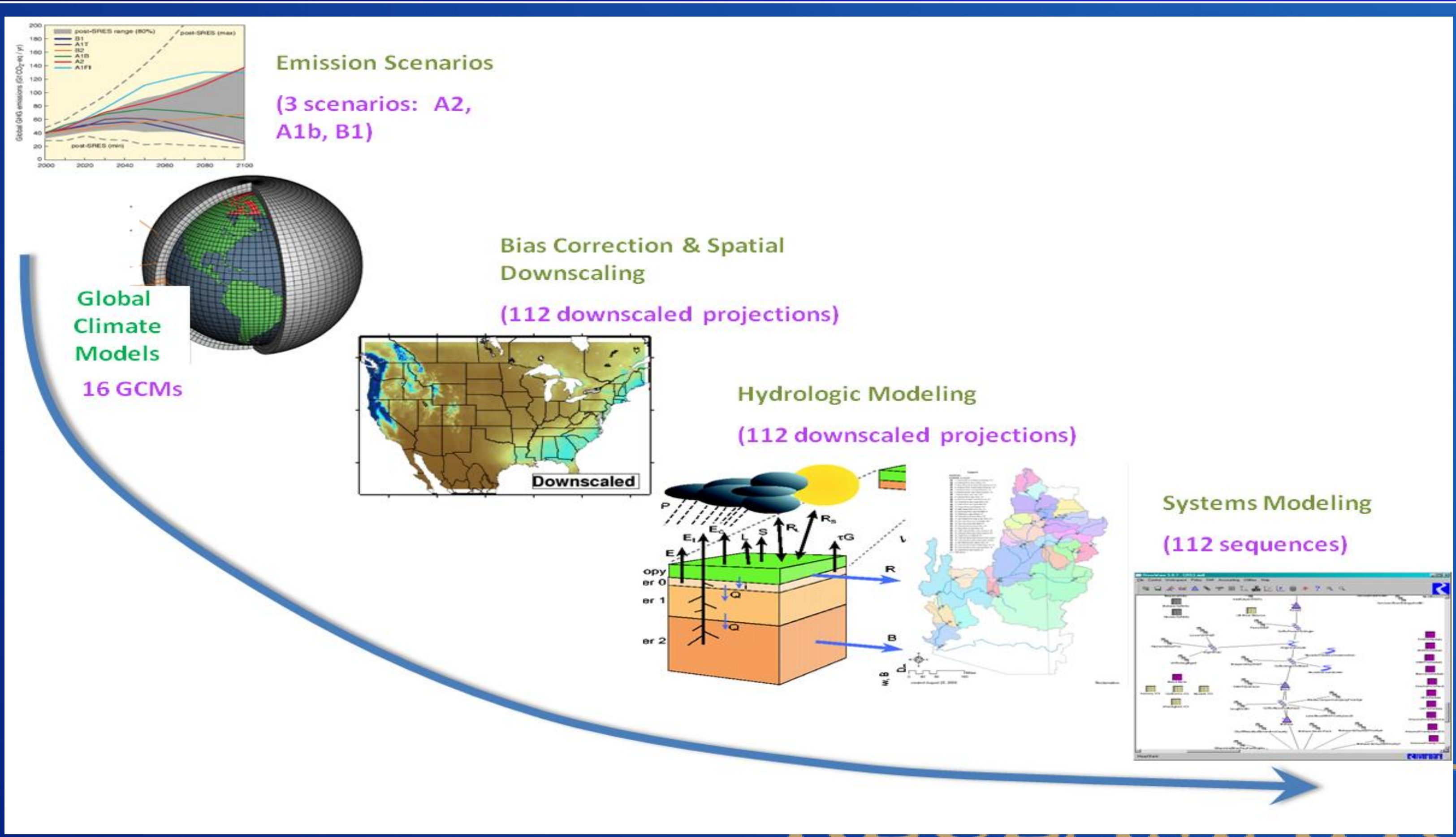
Water Supply Scenarios

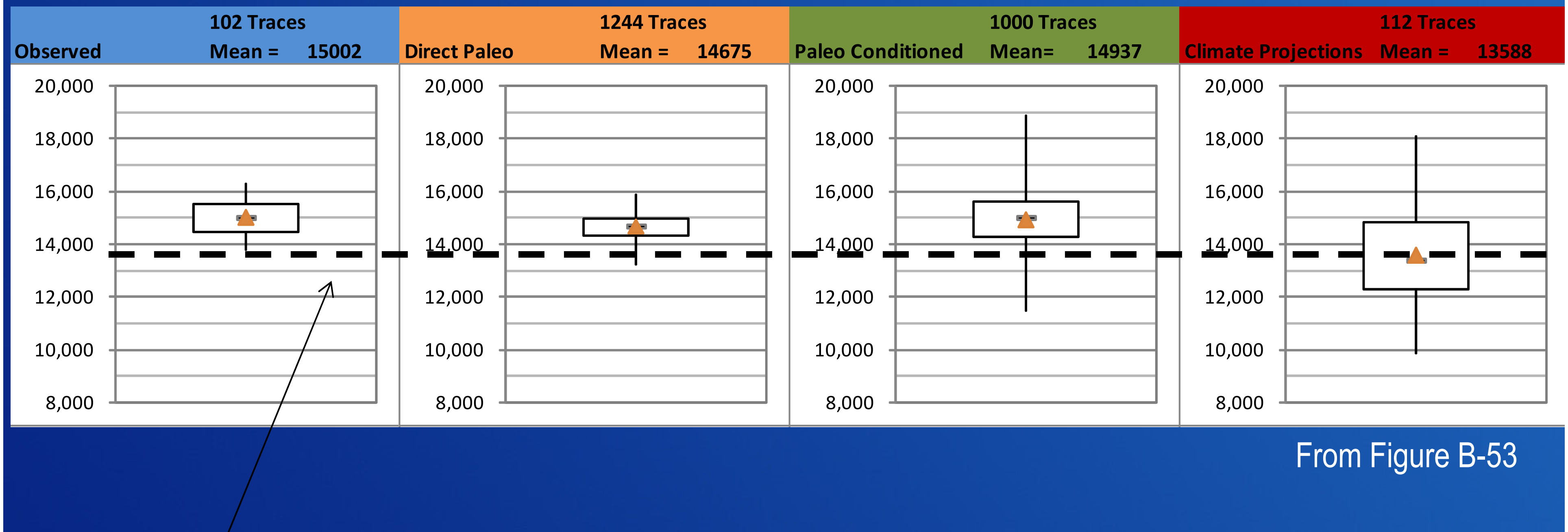
Downscaled Global Climate Model (GCM) Projected

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



Quantification of Water Supply Scenarios

Projections of 2011-2060 Average Natural Flow at Lees Ferry



From Figure B-53

1994 – 2013 average = 13.6 MAF

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

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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%	48%
Frequency of Surplus[1] lasting 5 years or longer	28%	15%	18%	<1%

From Table B-2

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

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Water Demand Assessment
Technical Report C

- Objective
- Development of Water Demand Scenarios
- Quantification of Water Demand Scenarios

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Objective of the Water Demand Assessment

- The objective of the Water Demand Assessment is to assess the quantity and location of current and future water demands in the Study Area[1] to meet the needs of Basin resources
- Basin resources include: municipal and industrial (M&I) use, hydropower generation, recreation, and fish and wildlife habitat

[1]The Study Area is defined as the hydrologic boundaries of the Basin plus the adjacent areas of the Basin States that receive Colorado River water

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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

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Approach to Quantifying Demand Scenarios

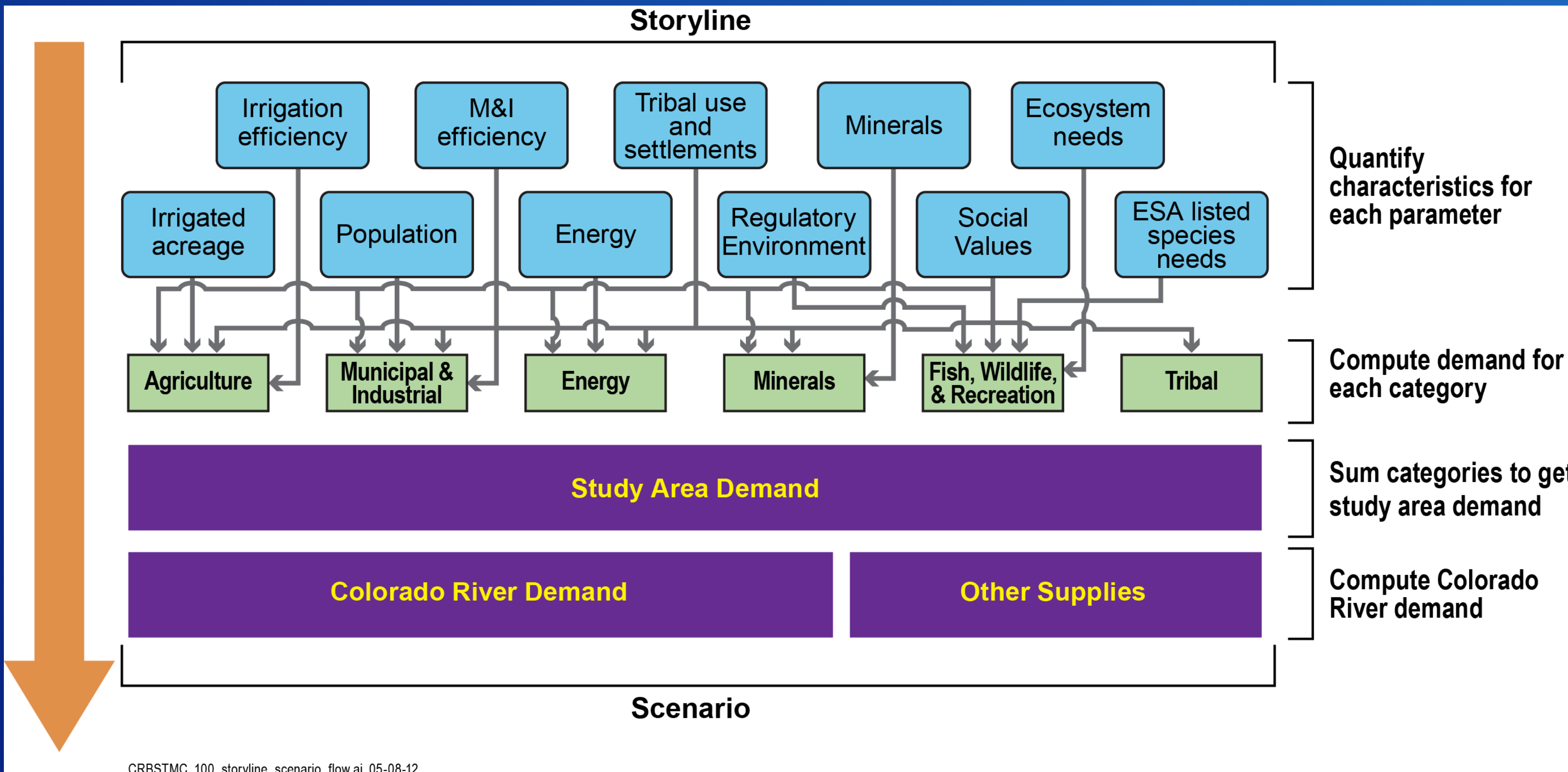

Figure C-2 Approach to Quantifying Demand Scenarios

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Water Demand Quantification Results

- 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)
- Approximately a 20% spread between the lowest (Slow Growth) and highest (Rapid Growth – C1) demand scenarios

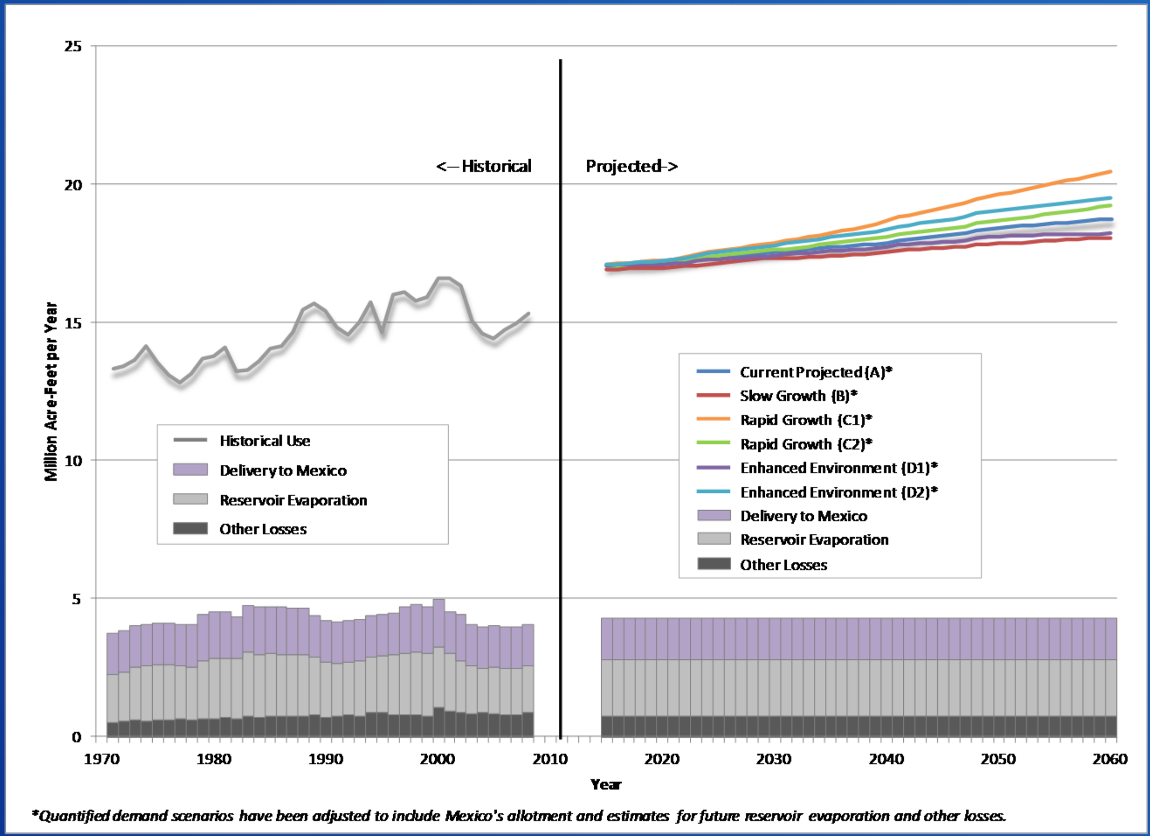

Figure C-4 Colorado River Basin Historical Use and Projected Demand

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Water Demand Quantification Results

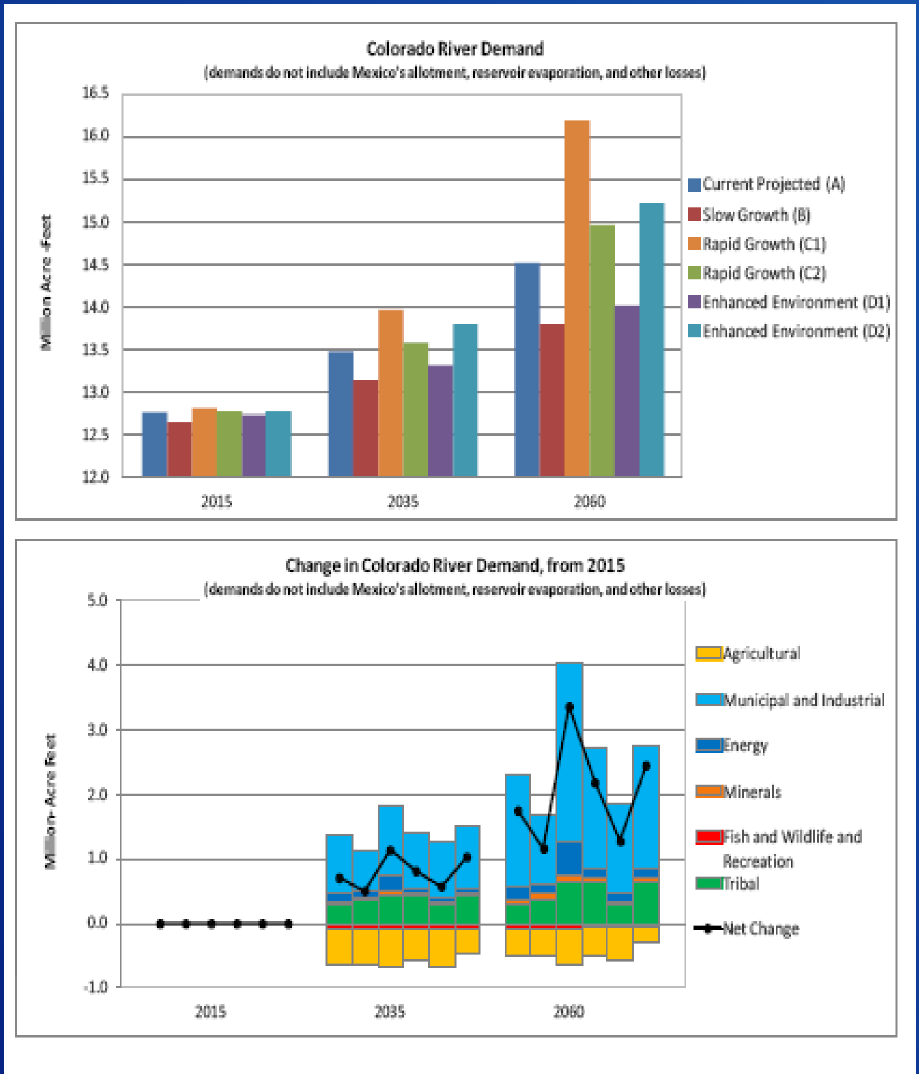

Figure C-7 Study Area, Colorado River, and Change in Colorado River Demand

Parameters driving demands include population, per capita water use, and irrigated acreage and are projected to change from 2015 to 2060:

- Population increase from about 40 million people by 23% (49 million) to 91% (77 million)
- Per capita water use decrease by 7% to 19%
- Irrigated acreage decrease from about 5.5 million acres by 6% (5.2 million) to 15% (4.6 million)

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Projected Future Colorado River Basin Water Supply and Demand

- Average supply-demand imbalances by 2060 are approximately 3.2 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

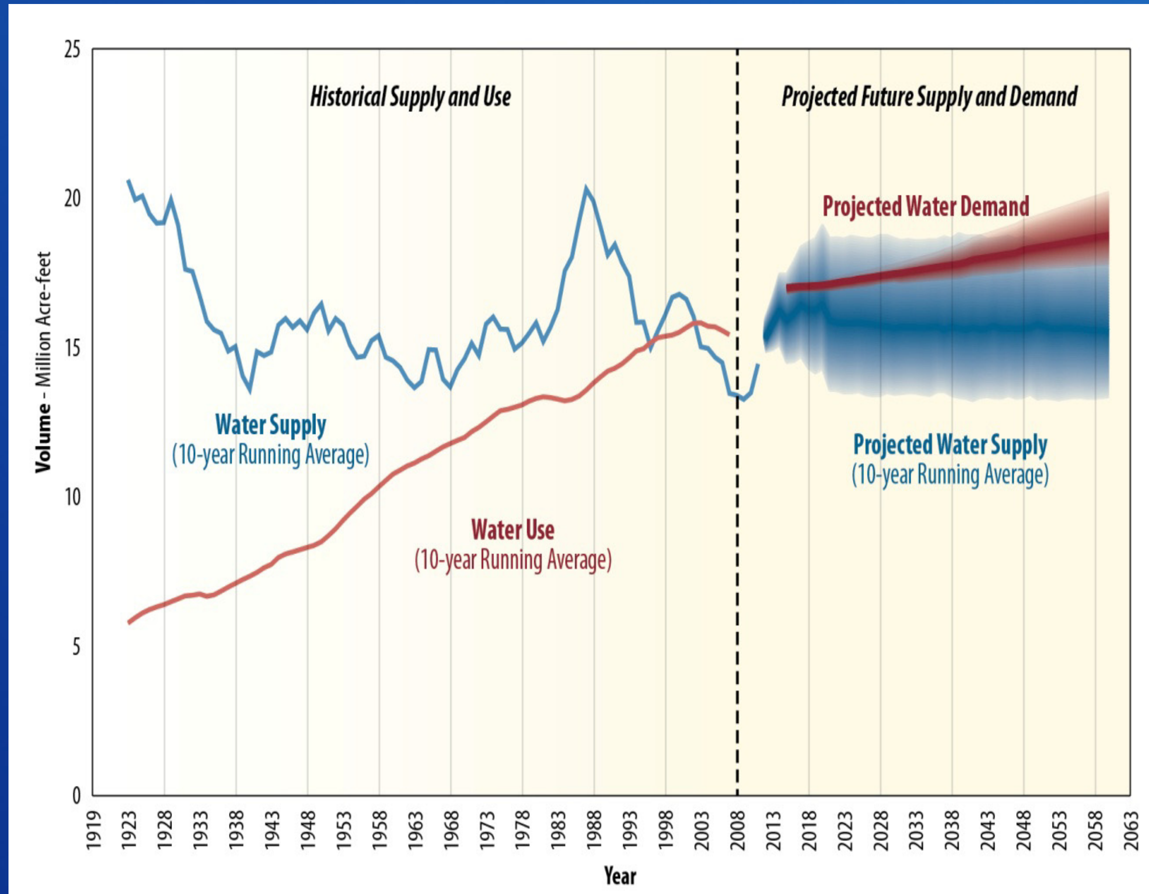

Figure C-9 Historical and Future Projected Colorado River Basin Use and Demand

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Options and Strategies Development
Technical Report F

Warren H. Brock Storage Reservoir

- Objective
- Options Considered
- Characterization of Options
- Development of Portfolios

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Objective of Options and Strategies Development

- The objective of the options and strategies development is to explore a broad range of options and groups of options (portfolios) for resolving future supply and demand imbalances
- The Study did not intend to result in the selection of a particular portfolio or option. Rather, the objective is to demonstrate the effectiveness of different strategies at resolving future supply and demand imbalances.

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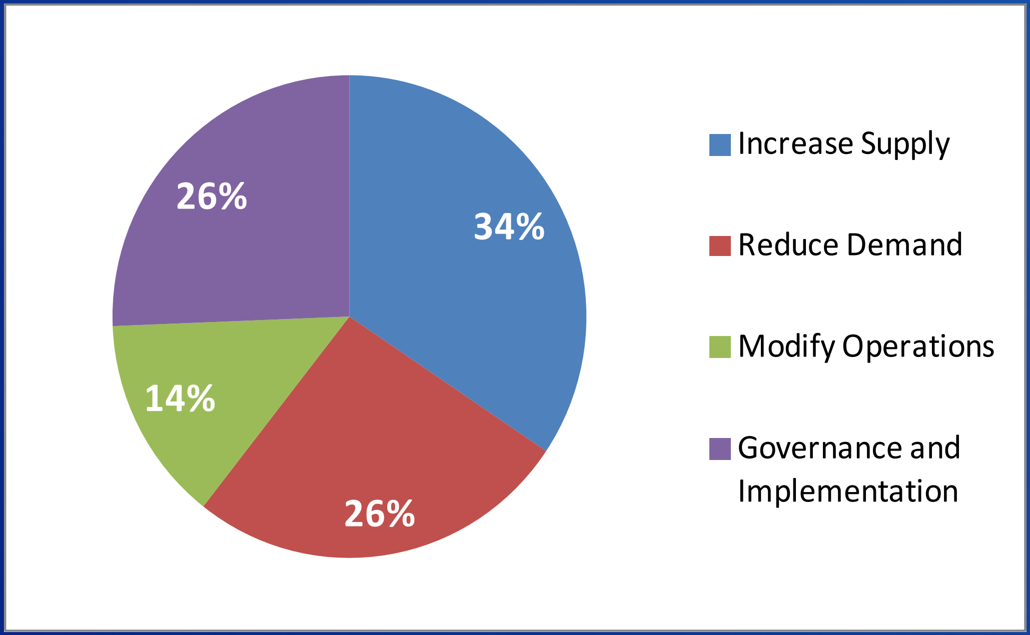
Summary of Options Submitted

- 160 options were submitted to the Study from Nov 2011 – Feb 2012
- All options received were included and are reflected in the Study



Increased Supply – reuse, desalination, importation, 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.

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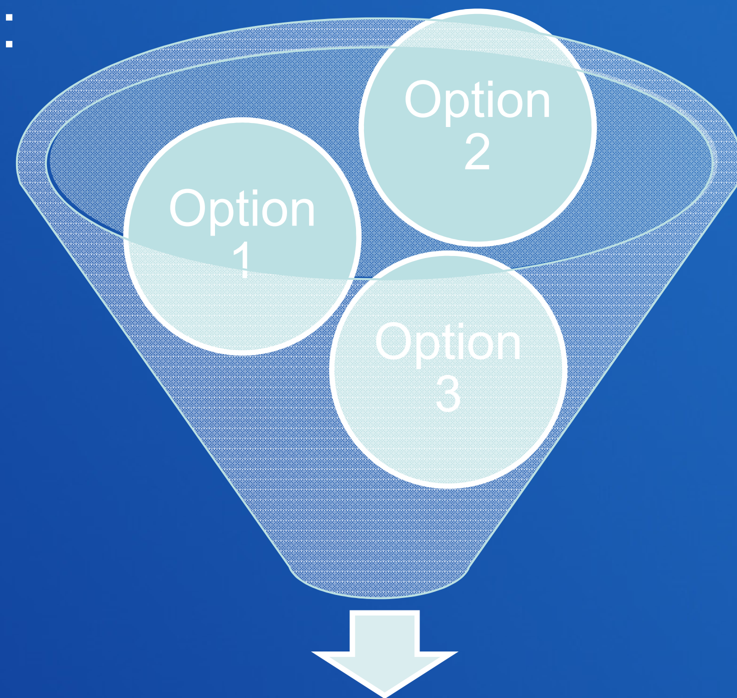
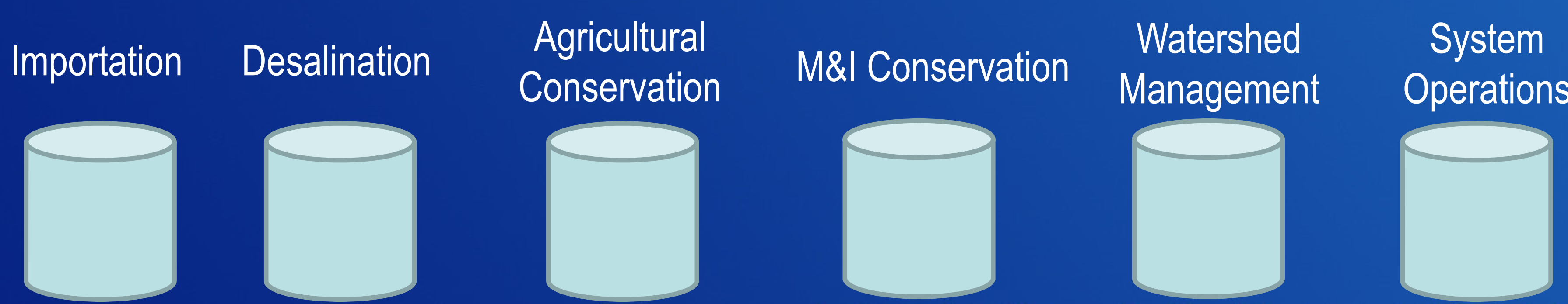
Organizing and Characterizing Options

- Characterization Criteria includes:
  - Quantity of yield
  - Timing of implementation
  - Technical feasibility
  - Energy needs
  - Cost
  - Permitting
  - Legal and policy considerations
  - Implementation risk





Does not represent all option categories

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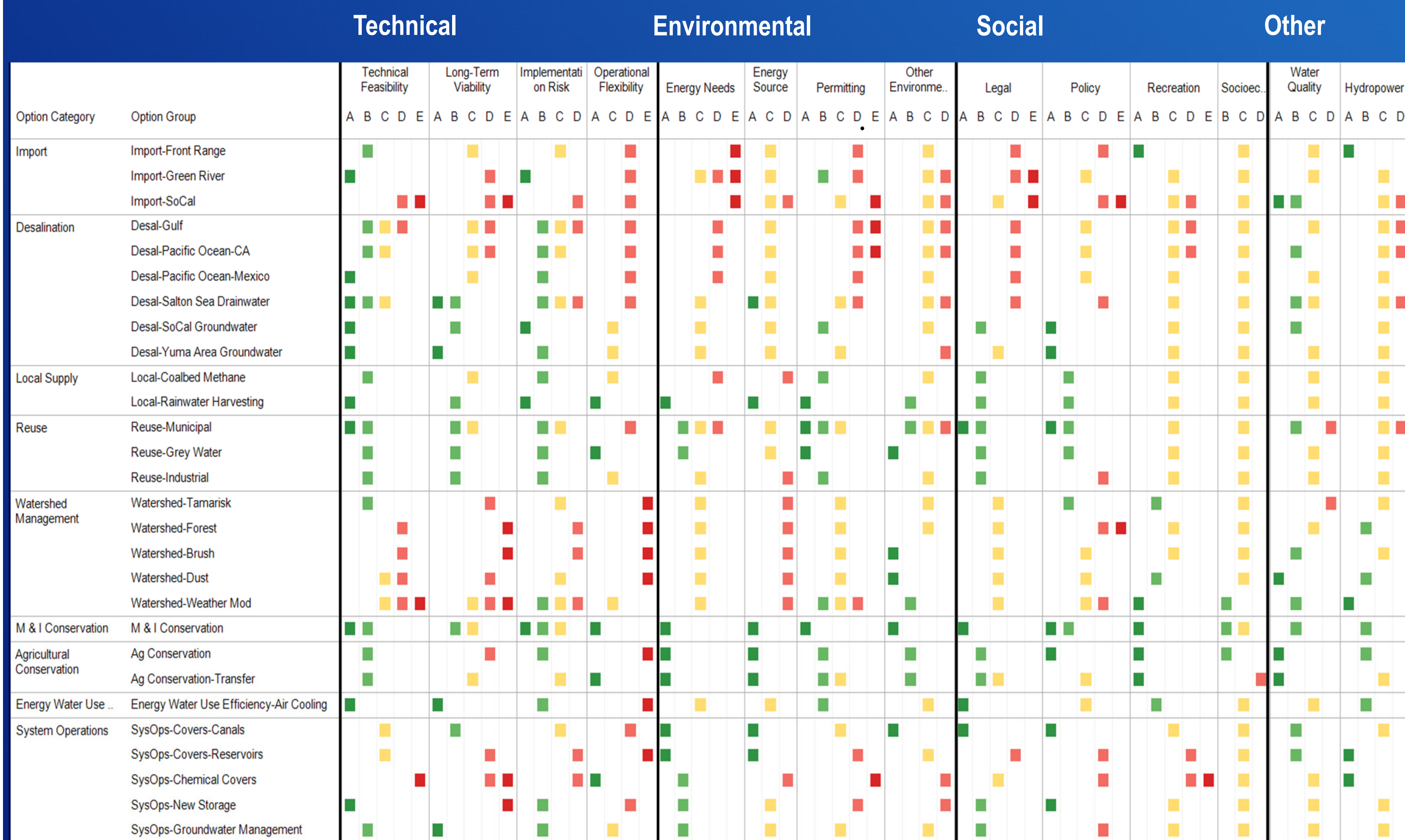
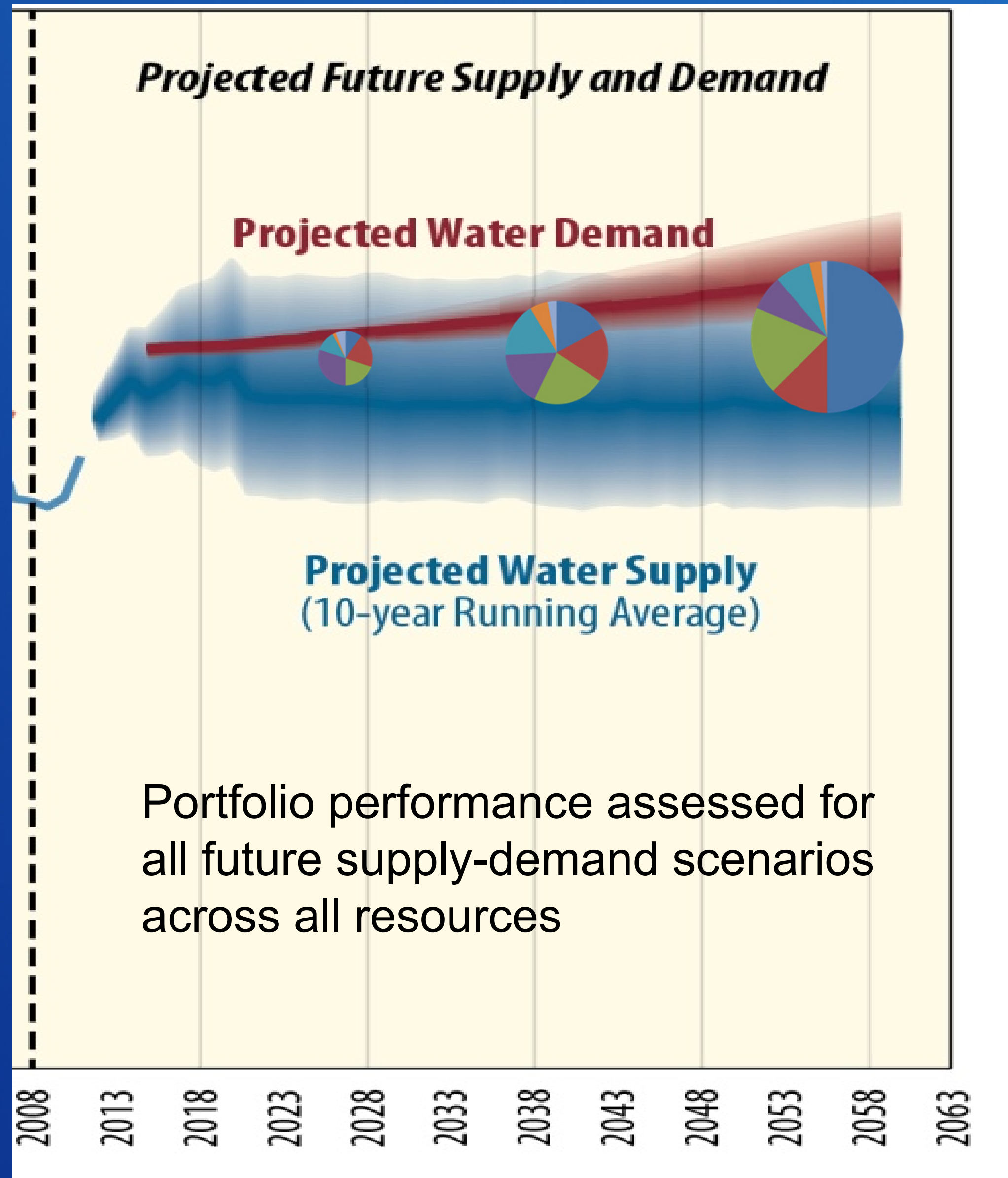
Option Characterization Results



Portfolio Development

- “Portfolios” are combinations of options that implement a particular strategy
- Strategy expressed through characterization criteria which determines how options are combined
- Four portfolios were developed to demonstrate potential ways options could be combined



Portfolio performance assessed for all future supply-demand scenarios across all resources

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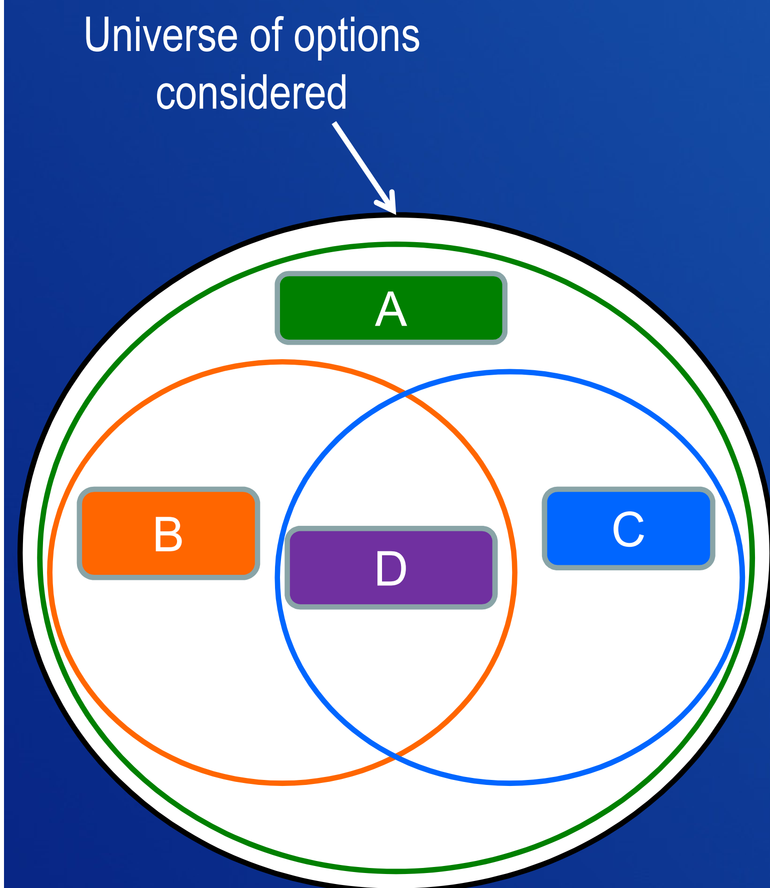
Summary of Portfolios



Option Selection
• Least restrictive resulting in a highly inclusive set of option preferences • Considers the largest set of options
• Low-risk strategy in the long-term with high reliability • High technical feasibility • Excludes options with high permitting, legal and policy risks
• Prioritizes options that have low environmental impacts and long-term flexibility • Excludes options with high permitting risk
• High technical feasibility and long-term reliability • Low energy intensity • Excludes options with high permitting, legal, and policy risk • Considers smallest set of options

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Summary of Option Inclusion Across Portfolios

Option Category	Option Group	Portfolios			
		Portfolio A	Portfolio B	Portfolio C	Portfolio D
Importation	Imports to the Colorado Front Range from the Missouri or Mississippi Rivers	X	X		
Desalination	Gulf of California	X	X		
	Pacific Ocean in California	X	X		
	Pacific Ocean in Mexico	X	X		
	Salton Sea Drainwater	X	X	X	X
	Groundwater in Southern California	X	X	X	X
	Groundwater in the Area near Yuma, Arizona	X	X	X	X
Reuse	Municipal Wastewater	X	X	X	X
	Grey Water	X		X	
	Industrial Wastewater	X	X	X	X
Local Supply	Treatment of Coal Bed Methane-Produced Water	X	X		
	Rainwater Harvesting	X		X	
Watershed Management	Dust Control	X		X	
	Tamarisk Control	X		X	
	Weather Modification	X	X	X	X
M&I Water Conservation	M&I Conservation	X	X	X	X
Agricultural Water Conservation	Agricultural Water Conservation with Transfers	X	X	X	X
Energy Water Use Efficiency	Power Plant Conversion to Air Cooling	X	X	X	X
Water Banking	Upper Basin Water Bank	X		X	

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BREAK 2:05 – 2:20 PM

Study website: http://www.usbr.gov/lc/region/programs/crbstudy.html

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System Reliability Analysis Methodology
Technical Report E, G

Glen Canyon Dam

- Overall Approach
- Model and Methods to Perform System Reliability Analysis
- Evaluation of System Performance
- Identification of Conditions Causing Vulnerability
- Modeling of Portfolios

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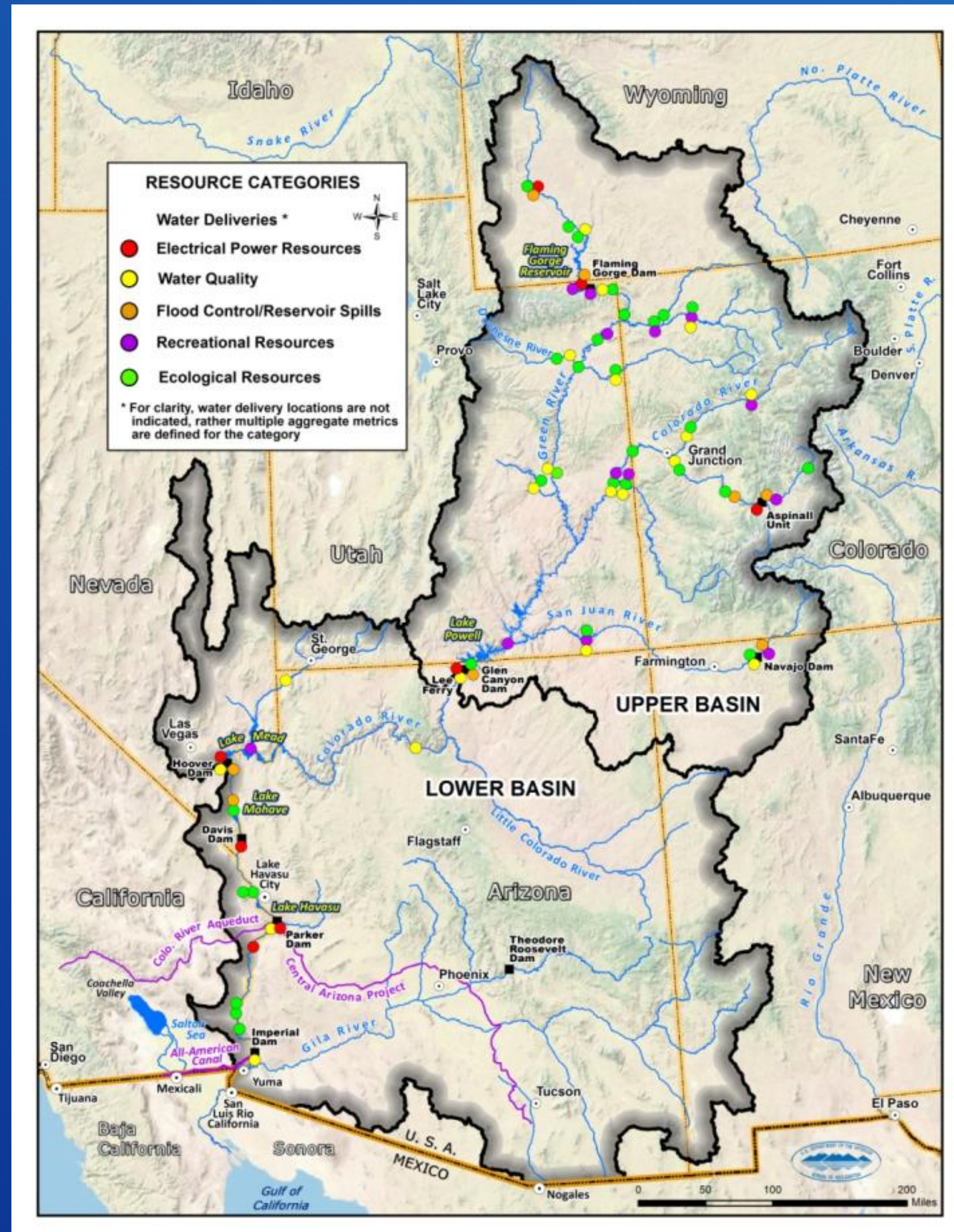
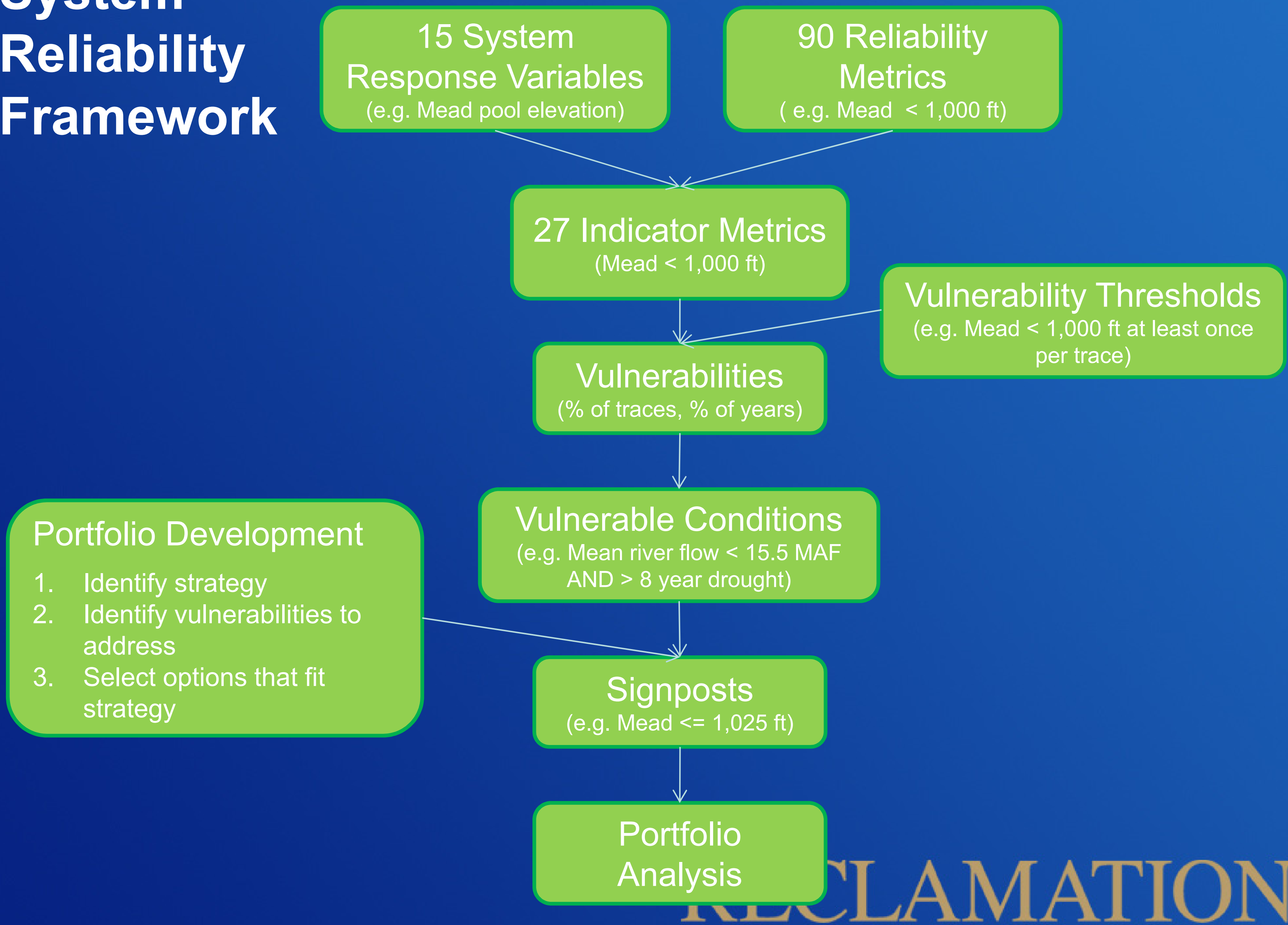
System Reliability Analysis

- Simulate the state of the system over the next 50 years for each scenario, with and without options and strategies
- Use metrics and vulnerabilities to quantify impacts to Basin resources
- **Resource Categories**
  - ➢ Water Deliveries
  - ➢ Electrical Power Resources
  - ➢ Water Quality
  - ➢ Flood Control
  - ➢ Recreational Resources
  - ➢ Ecological Resources



System Reliability Framework



Colorado River Simulation System (CRSS)

- Reclamation's official Basin-wide long-term planning model
- Implemented in RiverWare™
- Simulates operations at 12 reservoirs and deliveries to over 500 individual 'water users'
- Simulates at a monthly time-step
- Model logic reflects reservoir operations
- Gives a range of potential future system conditions

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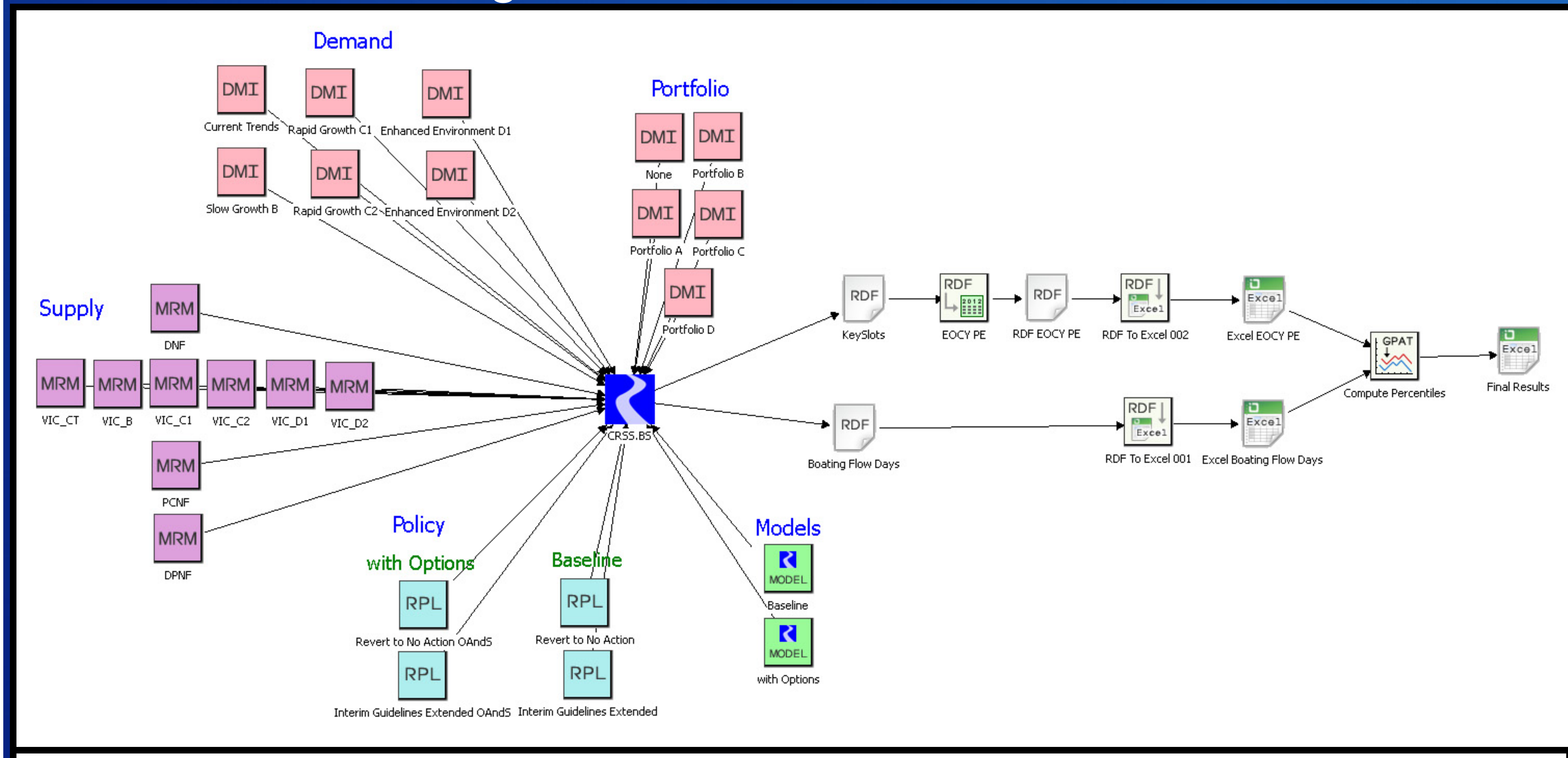
RiverWare™ Study Manager

- Manage input and output for all 240 scenarios
- Automate simulation process
- Can automate generation of results



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Computation of Daily Flows in CRSS

- CRSS simulates at a monthly time-step, however daily information was needed to assess many ecological and recreational resource metrics
- Ecological
  - Can monitor daily flow targets below Navajo and Flaming Gorge
  - Use monthly, volumetric approximations of daily targets at other locations, e.g., Colorado River near UT/CO State Line, Gunnison River near Whitewater

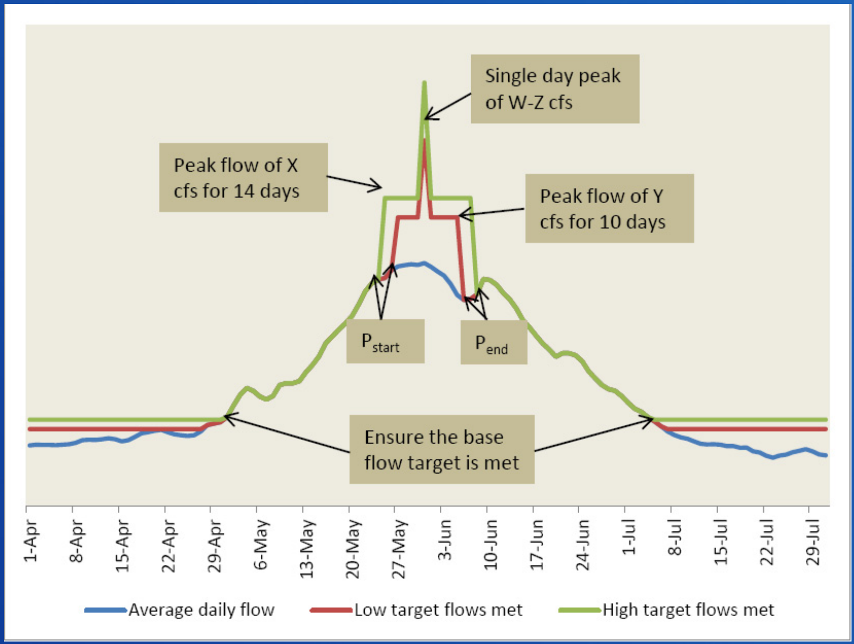

Figure D3-1

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Recreational Resources: Boating Flow Days Metric

- Developed with American Whitewater and Hydros Consulting
- Public survey determined ranges for optimal and acceptable boating flow days
- Evaluates number of optimal and acceptable boating flow days by converting monthly volume from CRSS to daily flows
  - Uses 30 years of historical gage data to create an ensemble of plausible daily flow patterns
- 8 locations

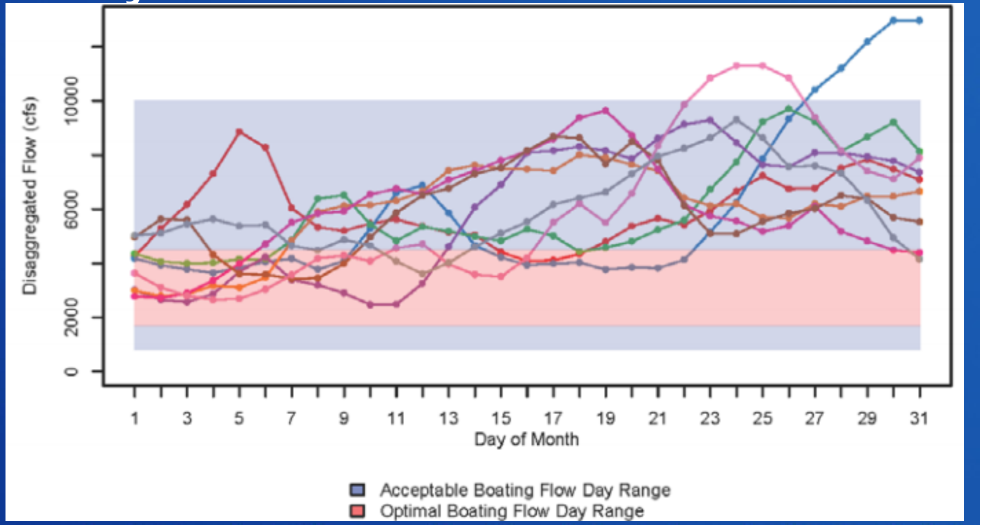

Figure D2-2

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Indicator Metrics

- For each resource category, indicator metrics were developed to offer a summary of the full suite of metrics within that category
- Water Delivery (6)
  - Examples: Lee Ferry Deficit, Lower Basin shortage
- Electric Power (3)
  - Example: Total Upper Basin power generated
- Water Quality (1)
- Flood Control (1)
- Recreational (11)
  - Examples: Upper Colorado Basin boating flow days, Powell shoreline recreation
- Ecological (5)
  - Examples: Yampa near Maybell, Colorado near Stateline

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Example Path of Metric to Vulnerability

Resource Category	System Reliability Metric (90 total)	Indicator Metric (27 total)	Vulnerability Threshold (27 total)
Water Delivery	Lake Mead elevation < 1,000'	Lake Mead elevation < 1,000'	One occurrence in any month
Electrical Power	Upper Basin Electrical Power Generated	Upper Basin Electrical Power Generated	Generation < 4,450 GWh/yr for more than 3 consecutive years
Recreational	Boating flow days on the Yampa River at Maybell and Deerlodge; Green River at Jensen and Greendale	Total Boating Flow Days in the Green River Basin	Days less than current conditions with variable hydrology

Flood control and water quality followed path similar to water delivery; ecological followed path similar to recreational.

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Vulnerable Conditions

- Determine what external conditions lead to vulnerabilities for water delivery indicator metrics
- Reduce dimensionality and inform sign post selection

- External Conditions Considered:
  - Natural flow at Lees Ferry
    - Mean, trends, minimum annual flows, maximum annual flows, number of dry years, dry spell length, minimum mean flows during 5/8/10-year drought
  - Demand
    - Post 2040 demand
    - Demand trend
  - Post-2026 operation of Lakes Powell and Mead

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Lee Ferry Deficit Vulnerable Conditions

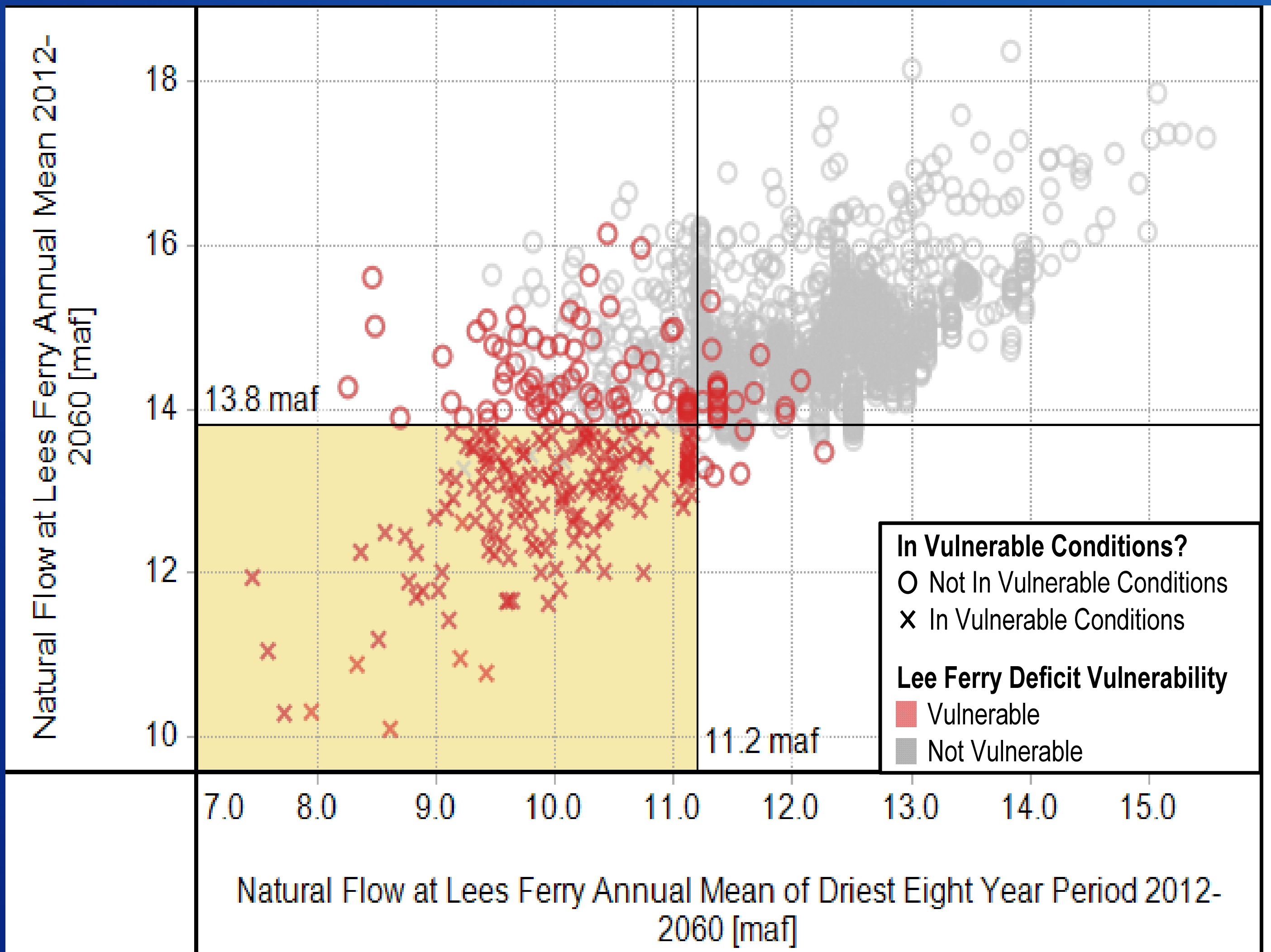

Figure G-15

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Summary of Vulnerable Conditions for Lee Ferry Deficit

Vulnerable Condition Name: **Below Average Long-Term Flow**	
Metric: Lee Ferry Deficit	
Vulnerable Traces: 19%	Definition of Vulnerability: • Flow at Lees Ferry annual mean < 13.8 MAF AND 8 year drought < 11.2 MAF
Vulnerability Statistics: • Explains 78% of all vulnerabilities • 80% of traces meeting this condition are vulnerable	

Table G-7

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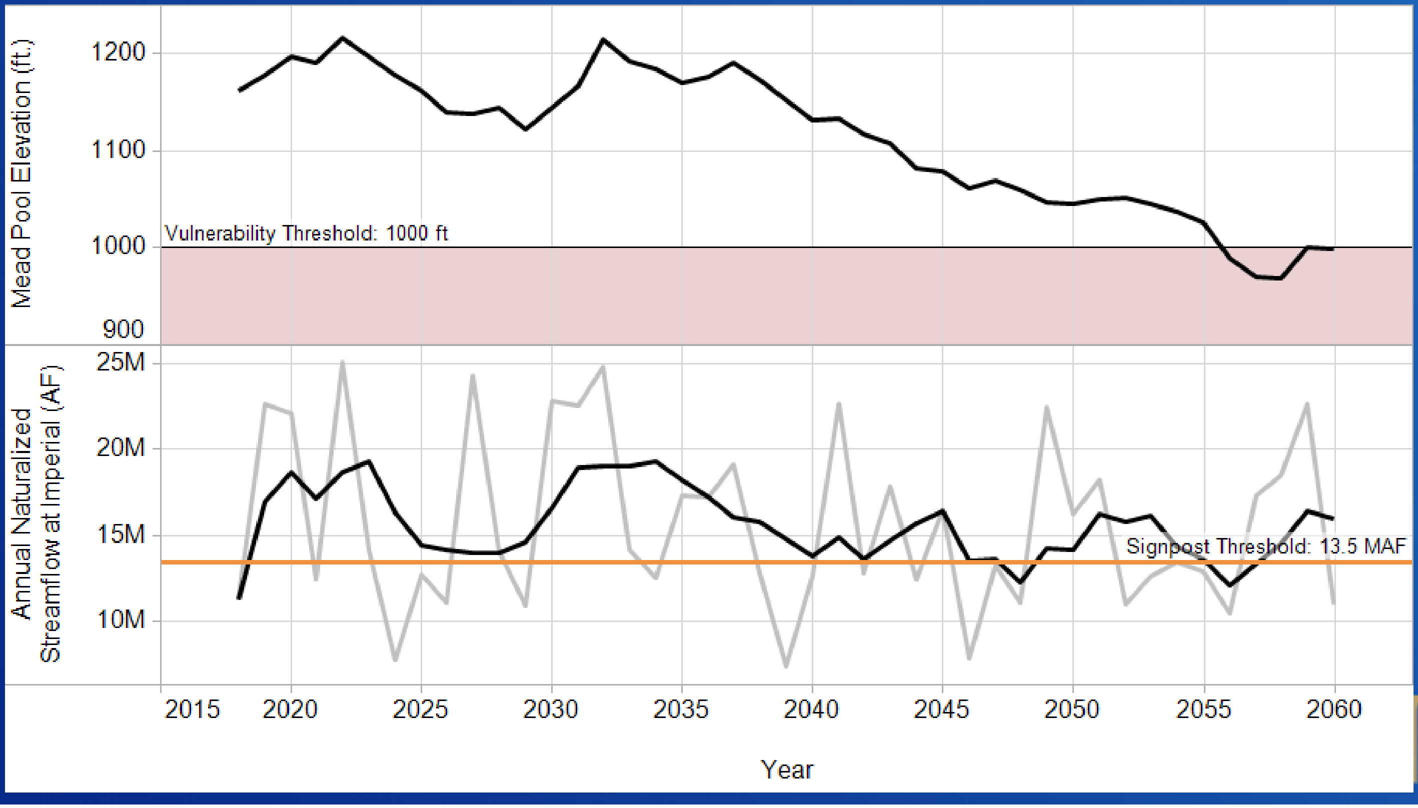
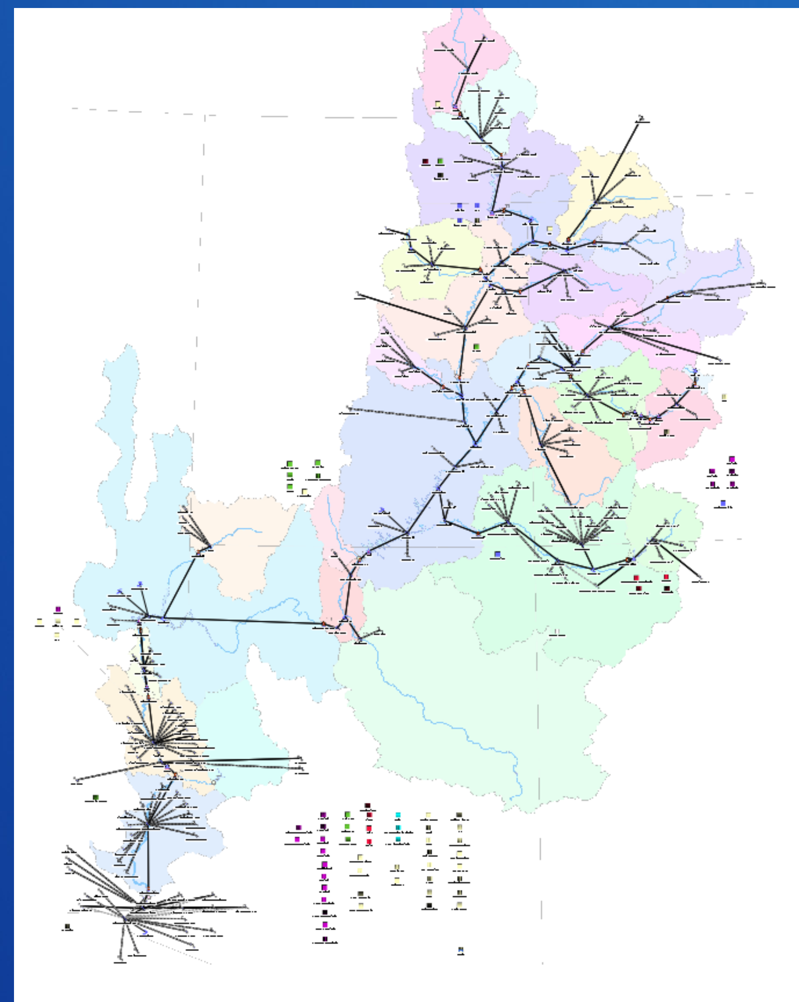
Signposts

- *Signposts* are observable conditions that anticipate vulnerable conditions
- Used to trigger options in dynamic portfolios
- Identify with exploratory analysis and skill tradeoffs



Approach to Implement and Analyze Portfolios

- Input to CRSS included option timing, yield, and cost
- Options were implemented, based on cost-effectiveness, when signposts indicated an approaching vulnerability
  - This dynamic approach avoids implementing options when not needed
  - Once options are selected, they remain 'on' for the duration of the simulation
- All portfolios were assessed across all future conditions



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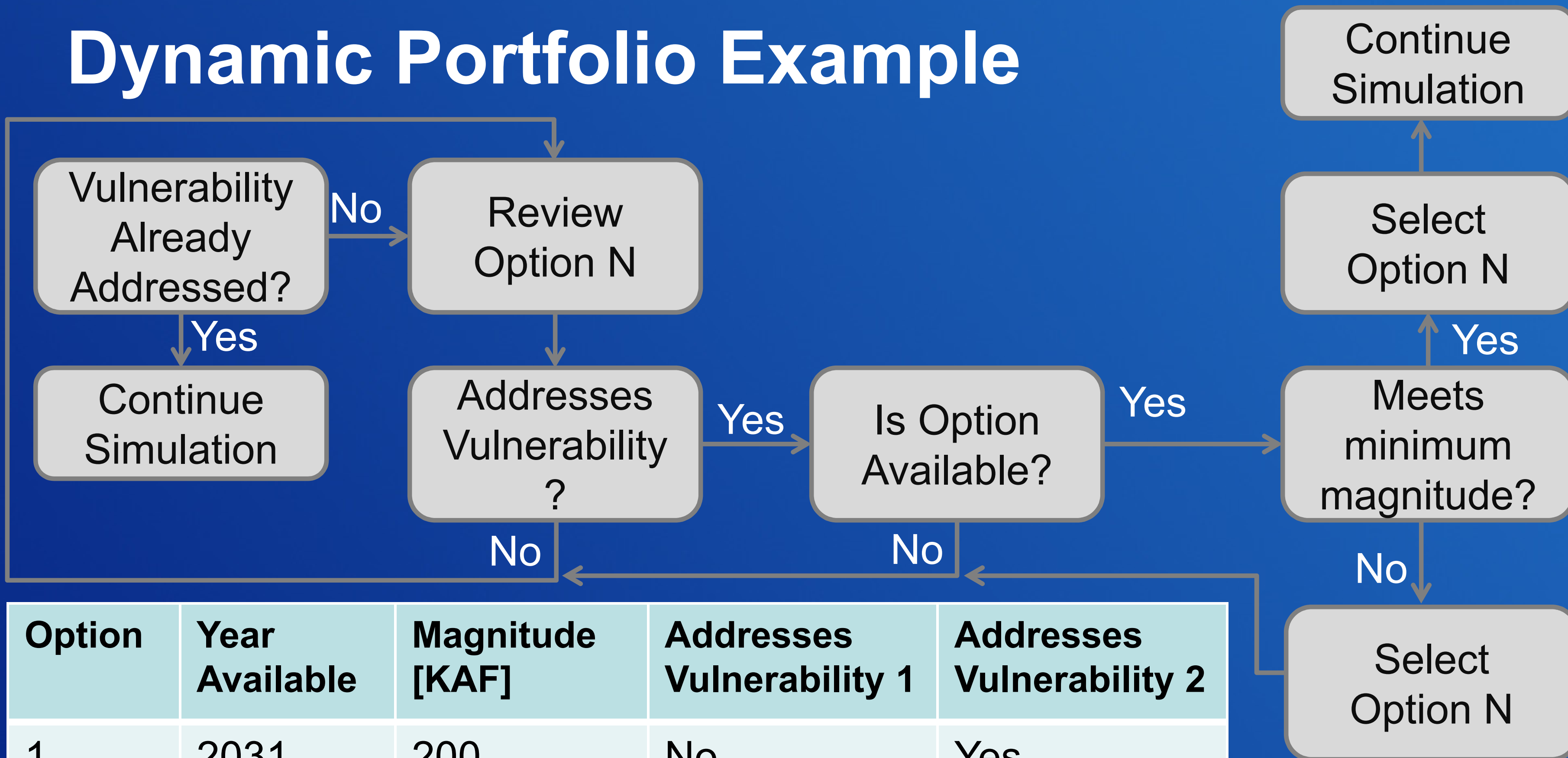
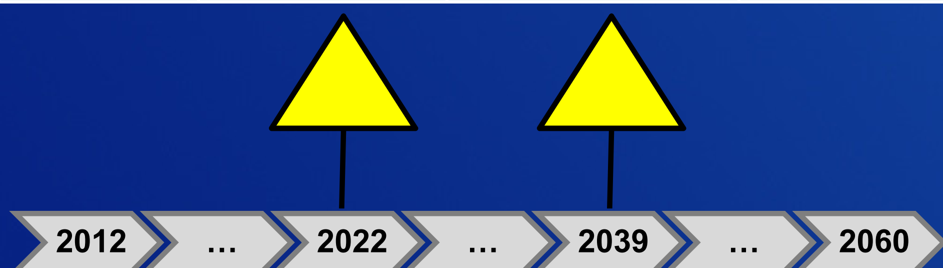
Dynamic Portfolio Example



Option	Year Available	Magnitude [KAF]	Addresses Vulnerability 1	Addresses Vulnerability 2
1	2031	200	No	Yes
2	2021	75	Yes	No
3	2045	150	Yes	Yes



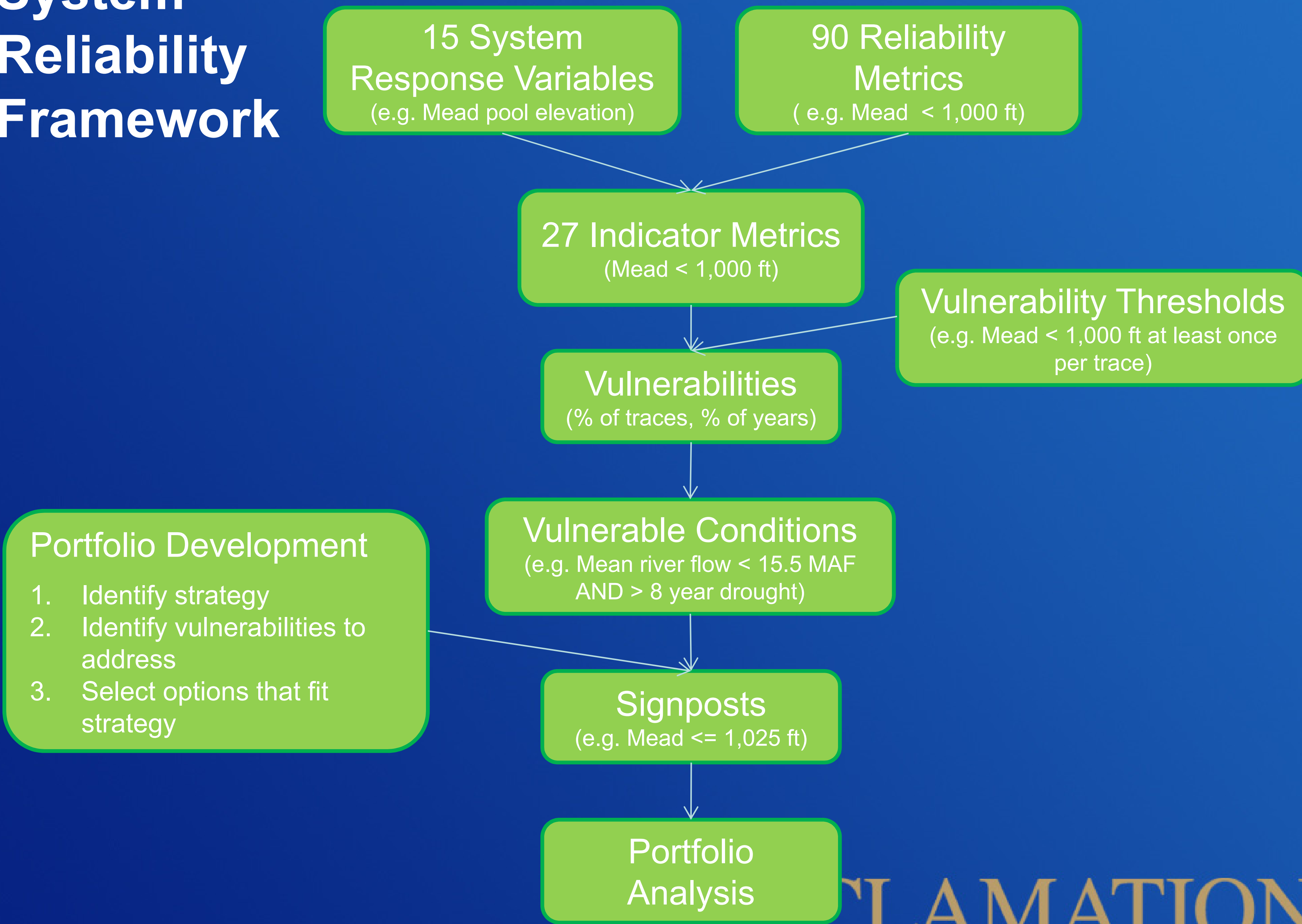
RECLAMATION

System Reliability Analysis Results

- Key Modeling Assumptions
- System Response Variables
- Resource Metrics
- Resource Vulnerabilities
- Vulnerable Conditions
- Portfolio Tradeoff and Options

RECLAMATION

System Reliability Framework



System Reliability Analysis
Key Modeling Assumptions

- All combinations (6 x 4 = 24) of supply/demand are modeled both with and without options and strategies
- 2 assumptions for Powell and Mead operations from 2027 - 2060
  - Continuation of the 2007 Interim Guidelines (IG) and revert to Interim Guidelines EIS No Action Alternative
- Upper Basin Shortage
  - Shortages are primarily hydrologic
  - Import deficit water above Powell to ensure 75 MAF over 10 years arrives at Lee Ferry, AZ
    - Report as "Lee Ferry Deficit" and do not assign to any particular state or user
- Lower Basin Shortage
  - For shortages beyond the IG (or No Action), do not assign to any particular state or user
  - Mexico shortage assumed to be 16.67% of total Lower Basin shortage (consistent with modeling supporting the IG EIS)

RECLAMATION

System Reliability Analysis
Key Modeling Assumptions

- "Baseline" Simulations: Demands above apportionment
  - Deliveries in accordance with the Law of the River
  - Deliveries above apportionments in the Lower Basin occur only during Surplus Conditions
- Simulations with Options and Strategies: Demands above apportionment
  - Conservation in the Lower Basin is applied first towards demands above apportionment in the Lower Basin
  - For options that import water in the Lower Basin, the imported water is assumed to go towards a system benefit when Lake Mead is < 1,050 feet

RECLAMATION

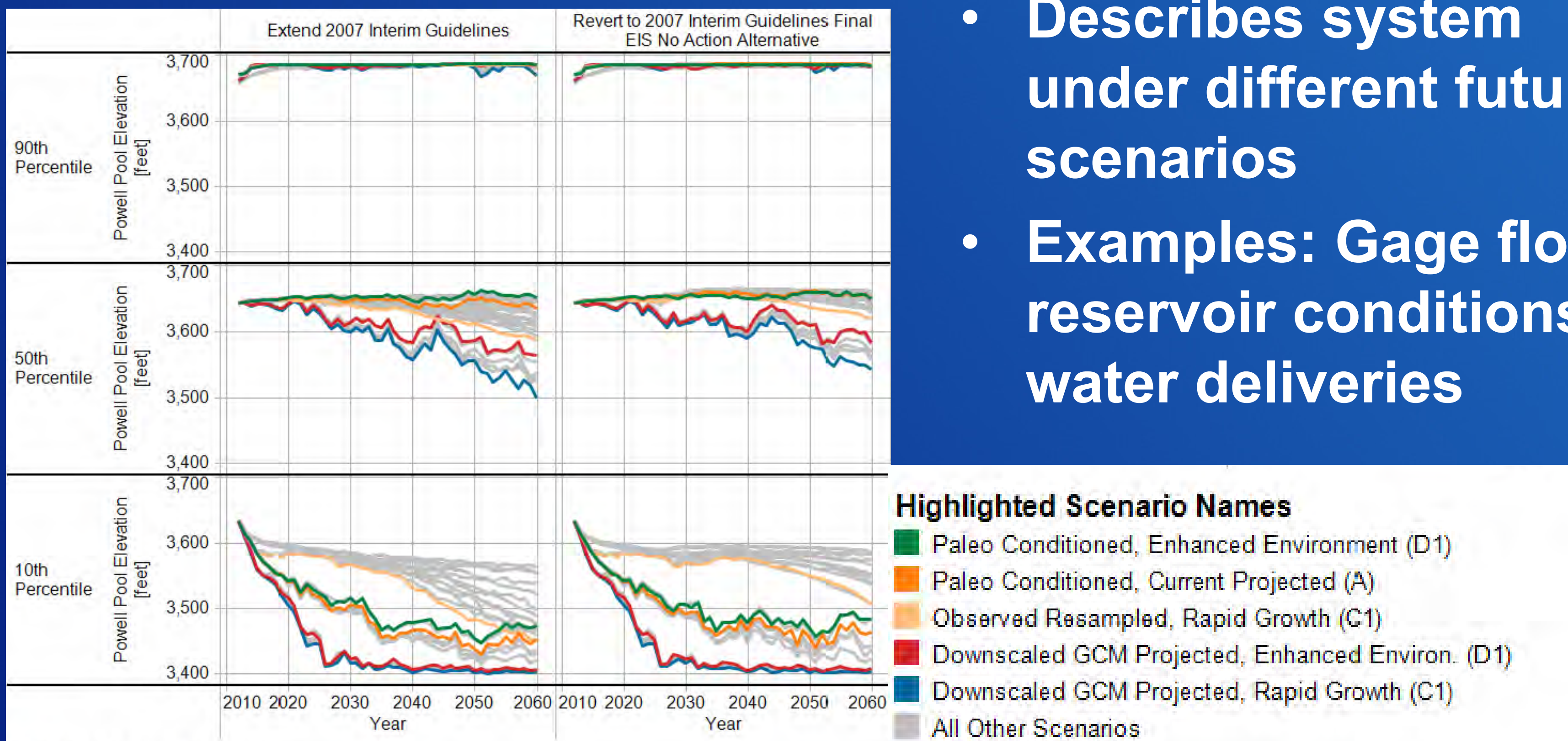
Modeled Scenarios

- Utilize CRSS to model system conditions over next 50 years
- Evaluate system reliability through reliability metrics
- 23,508 traces/portfolio
- 5.8 million years of data across all portfolios

RECLAMATION

System Response Variables

Lake Powell Pool Elevation Figure G-6



- **Raw modeling output**
- **Describes system under different future scenarios**
- **Examples: Gage flow, reservoir conditions, water deliveries**

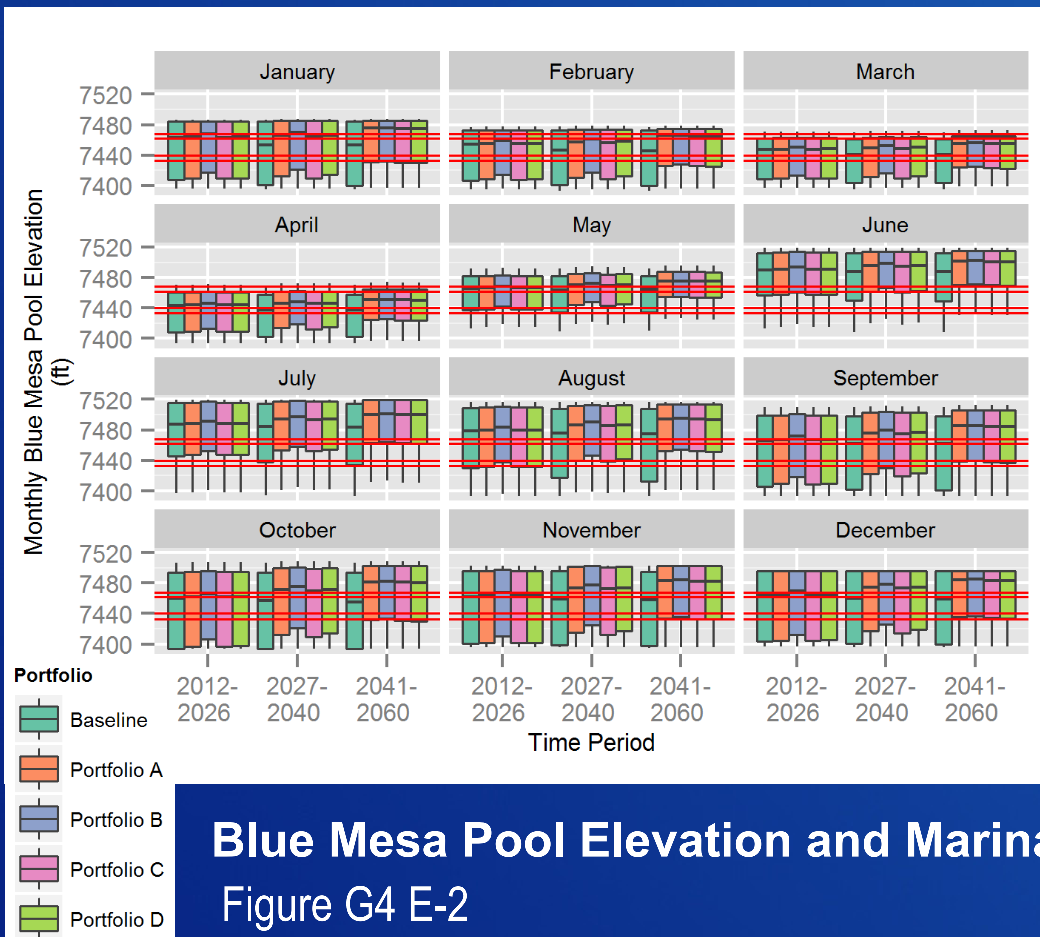
RECLAMATION

System Response Variables

See Tableau Workbook

RECLAMATION

Resource Metrics



- **Raw modeling output processed to offer resource and location specific insight**
- **Examples: Flow or pool elevation for recreation, releases within safe channel capacity, water delivery shortages**

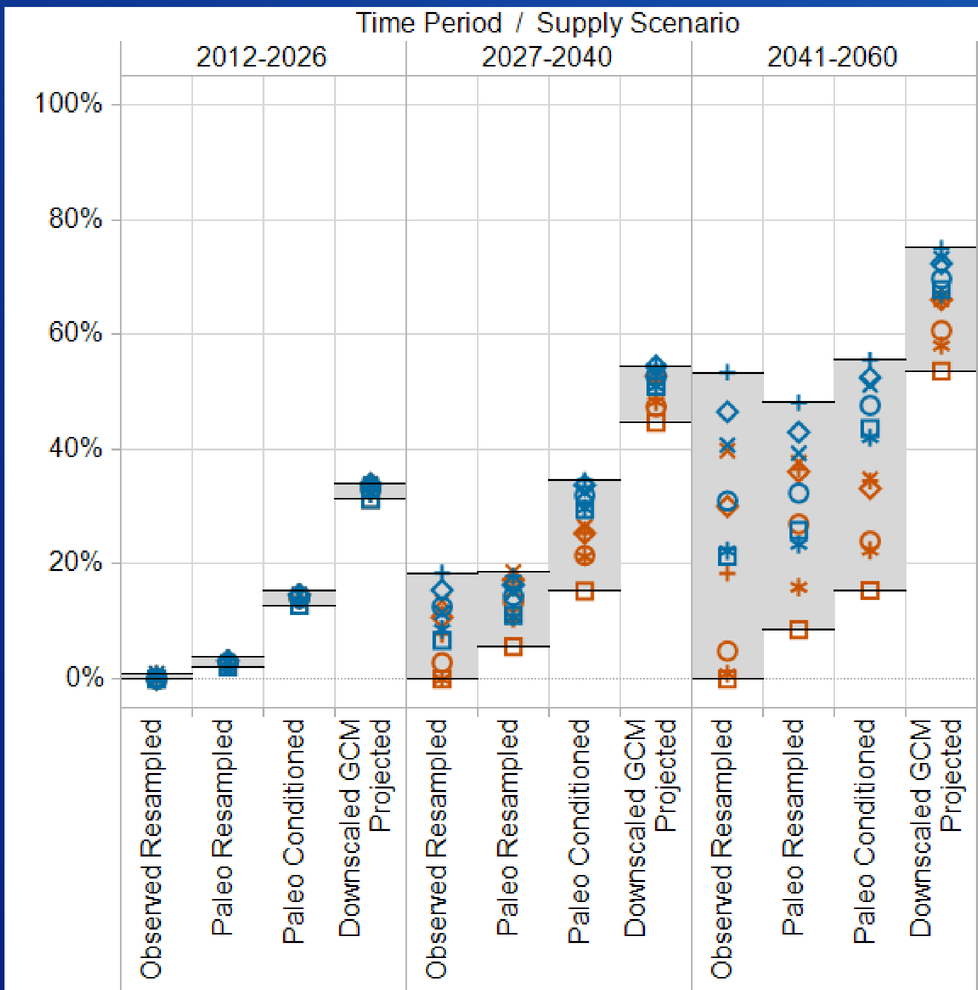
Blue Mesa Pool Elevation and Marina/Boat Ramp Reference Values

Figure G4 E-2

RECLAMATION

Vulnerability Results

- **Vulnerability combines metrics and threshold**
- **Provides resource specific perspective on system condition**
- **Results presented as percent of traces and percent of years**



Lake Mead Percent of Traces Below 1,000' Pool Elevation Figure G-9

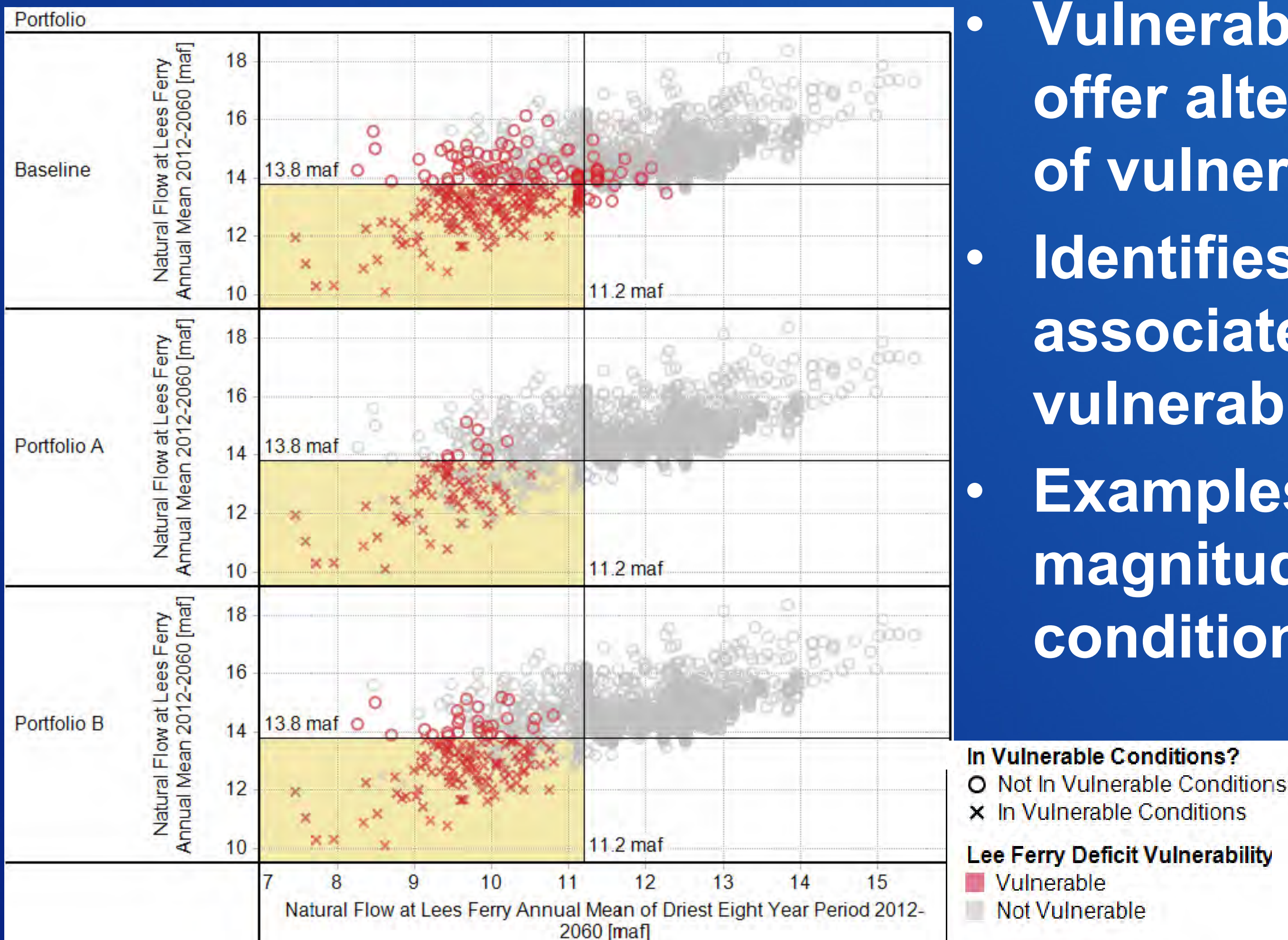
RECLAMATION

Vulnerability Results

See Tableau Workbook

RECLAMATION

Vulnerable Conditions



Lee Ferry Deficit Vulnerable Conditions
Figure G-32

- **Vulnerable conditions offer alternate analysis of vulnerability**
- **Identifies conditions associated with vulnerability**
- **Examples: Drought magnitude, reservoir conditions, demands**

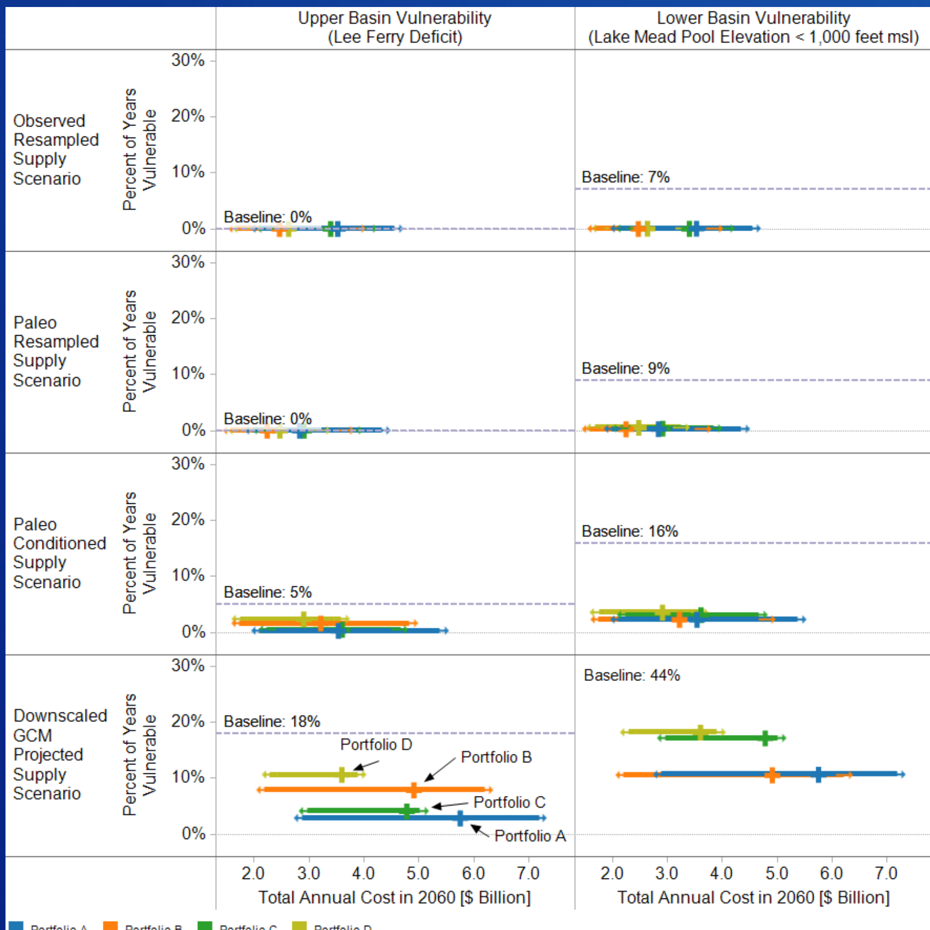
RECLAMATION

Vulnerable Conditions

See Tableau Workbook

RECLAMATION

Portfolio Tradeoffs and Options



Percent of Years Vulnerable (2041-2060) and Cost Figure G-51

- **Analysis explores portfolio differences**
- **Examples:**
  - **Vulnerability reductions**
  - **Cost**
  - **Options implemented**
- **Not intended to identify a 'best' portfolio, but understand strategy tradeoffs**

RECLAMATION

Portfolio Tradeoffs and Options

See Tableau Workbook

RECLAMATION

Summary, Study Limitations and Next Steps


Lake Powell

- Summary
- Study Limitations
- Next Steps

RECLAMATION

Summary

- The system is vulnerable if we do nothing
- Doing something greatly reduces that vulnerability and makes us more resilient to adverse conditions but does not eliminate vulnerability
- In the near term, all portfolios show that conservation, transfers, and reuse are cost-effective ways to reduce vulnerability
- In the longer term, more tradeoffs emerge to achieve an acceptable level of risk in terms of options, cost, resources, and other implications.

RECLAMATION

Study Limitations

- The detail and depth to which analyses were performed was limited by the availability of data, methods, and capability of existing models.

- Some of these limitations include:
  - Ability to assess impacts to Basin resources
  - Options characterization process
  - Consideration of options
  - Treatment of Lower Basin tributaries

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Next Steps

- The Study lists 10 areas where next steps should be taken:
  - M&I and Agricultural Water Conservation and Reuse
  - Water Banks
  - Watershed Management
  - Augmentation
  - Water Transfers
  - Tribal Water
  - Environmental Flows
  - Data and Tool Development
  - Climate Science Research
  - Partnerships

RECLAMATION

Next Steps

- Educational Outreach Sessions
  - March 25 in Salt Lake City, UT
  - March 26 in Phoenix, AZ
  - April 3 via Webinar
- Reduce uncertainties related to water conservation, reuse, water banking, augmentation, and weather modification concepts
- Further study of tribal water issues
- Advance science and modeling tools used in the Study
- Consider strategies that provide a wide-range of benefits to all water users

RECLAMATION

RECLAMATION

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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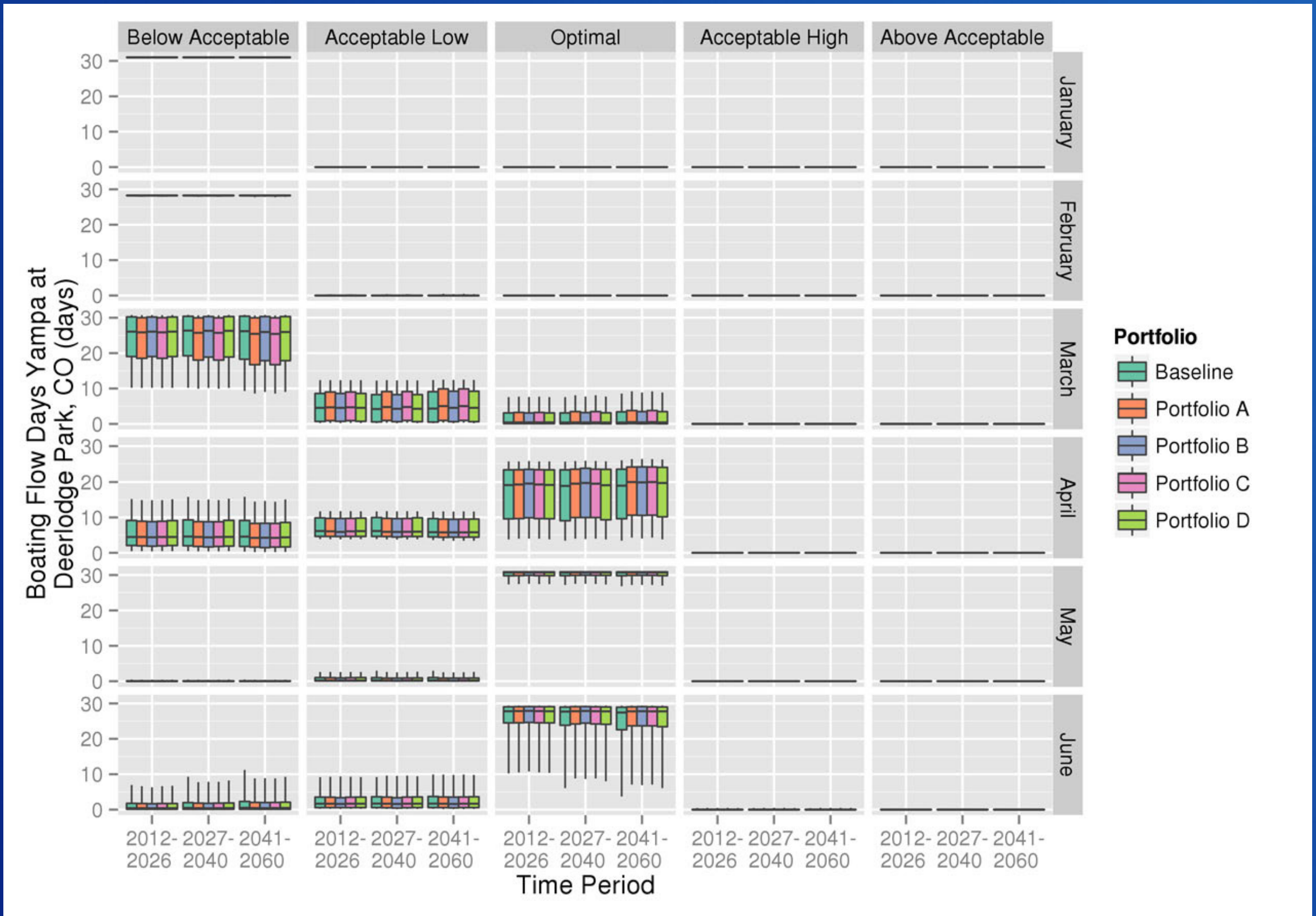
Extra Results

RECLAMATION

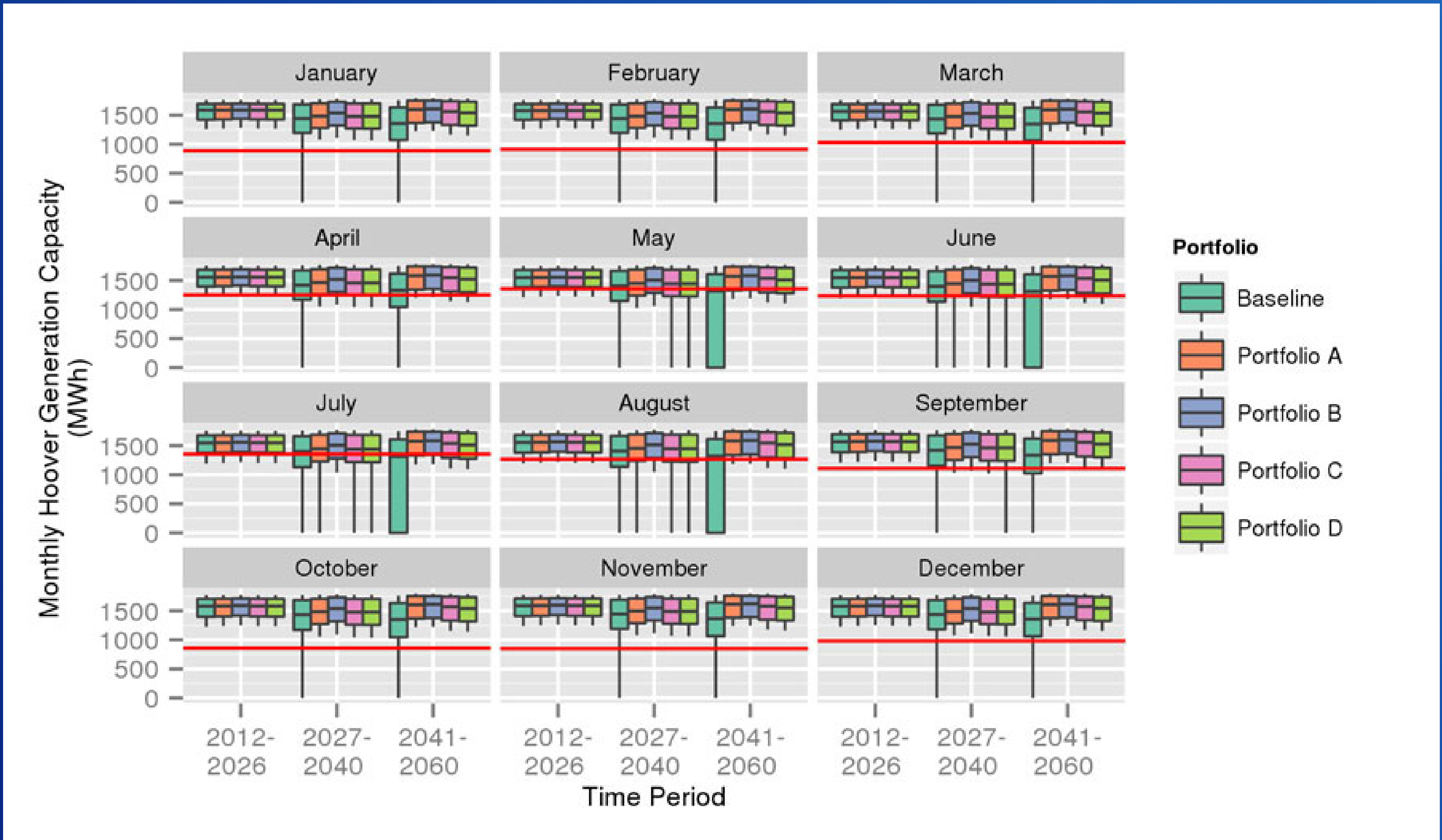
Recreation Resource Metrics



Yampa Boating Flow Days Figure G4 E-11a

RECLAMATION

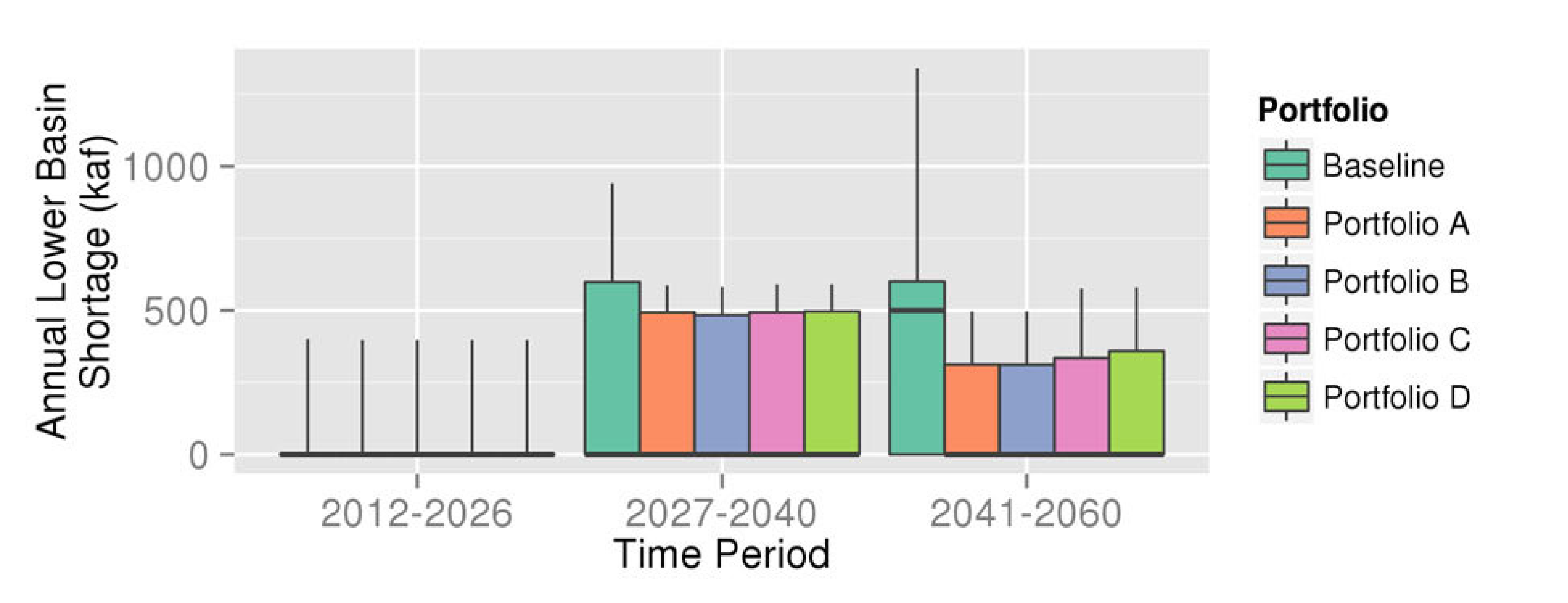
Power Resource Metrics



Hoover Generation Capacity Figure G4 B-6

RECLAMATION

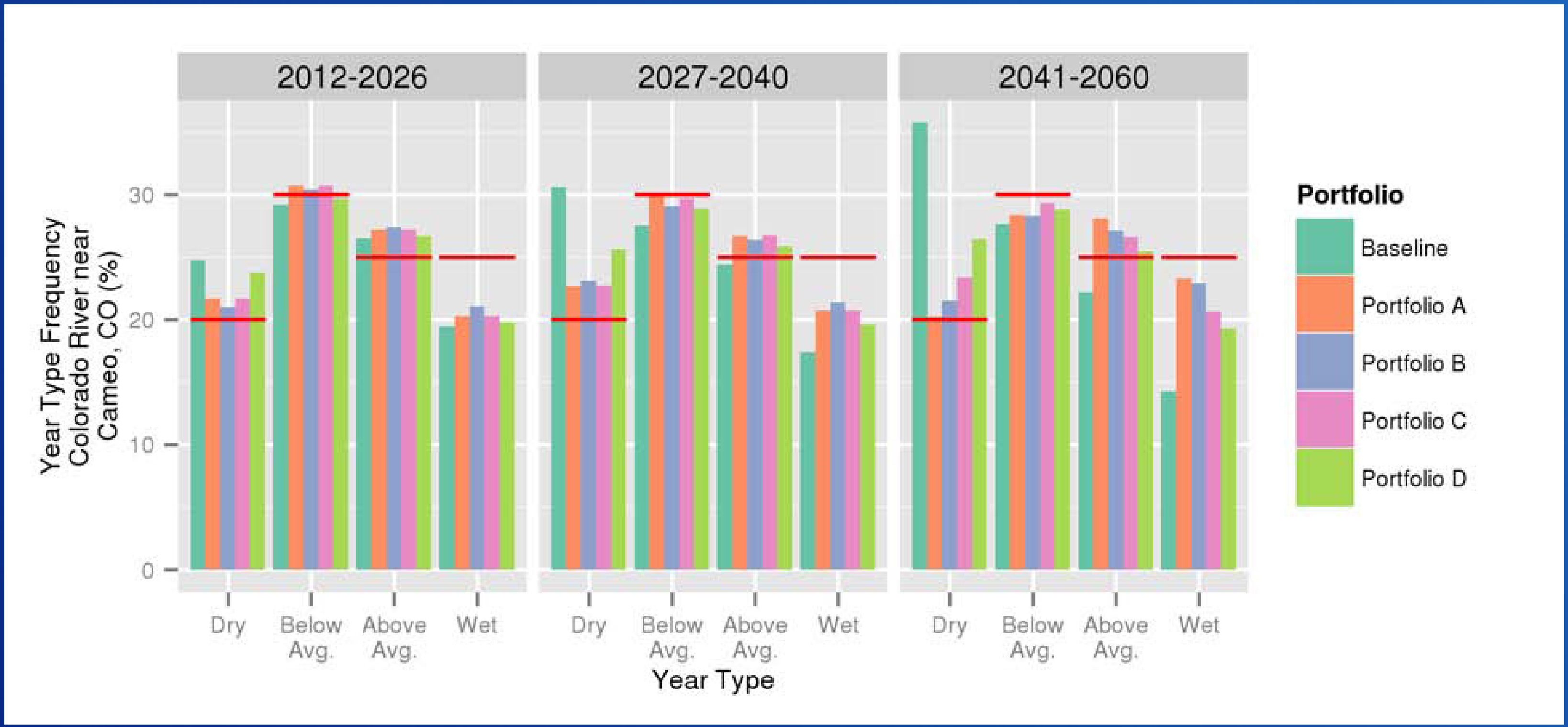
Water Delivery Resource Metrics



Annual Lower Basin Shortage Figure G4 A-3

RECLAMATION

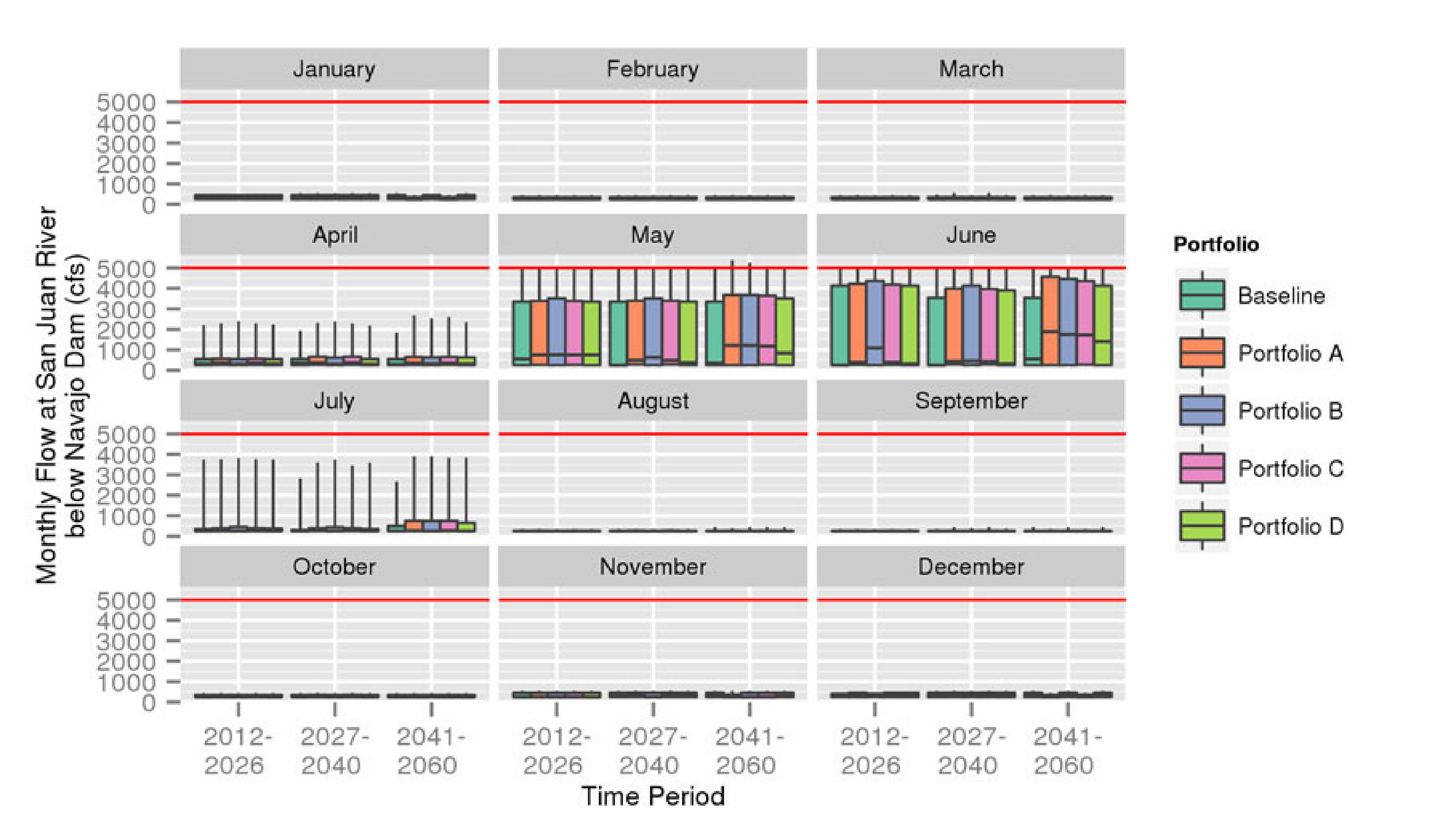
Ecological Resource Metrics



Year Type Frequency Colorado River near Cameo, CO and Target Reference Values Figure G4 F-3

RECLAMATION

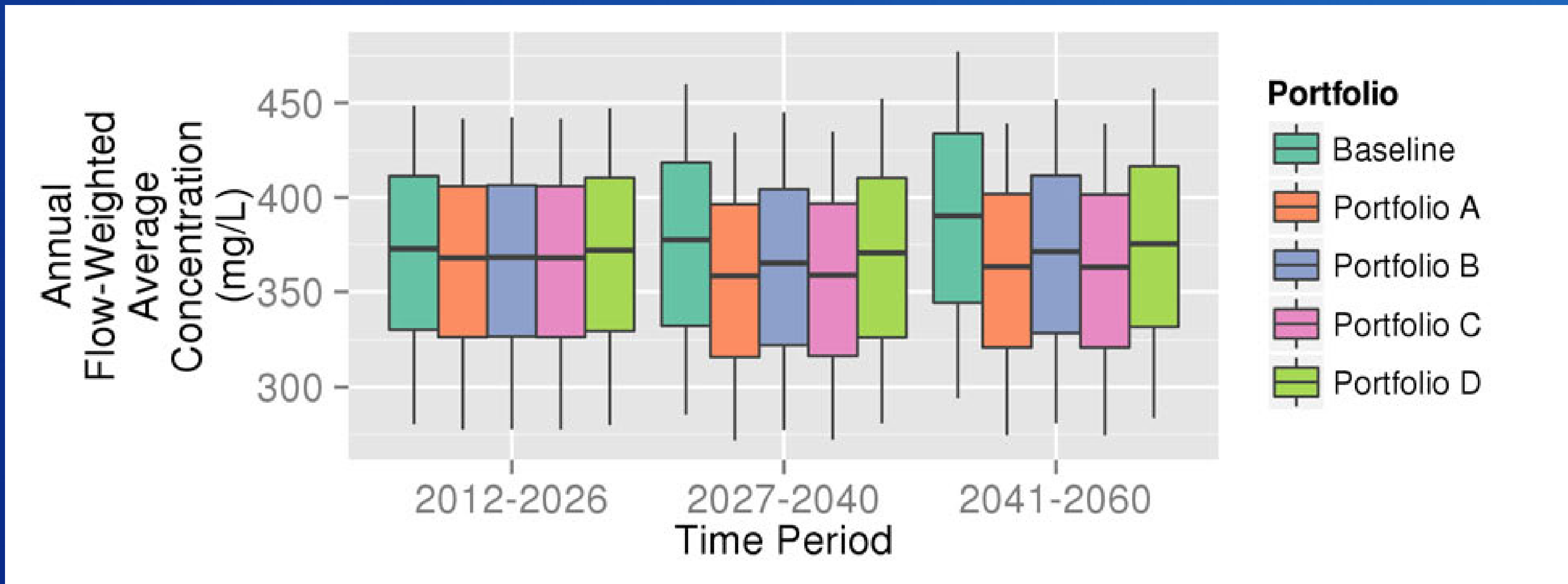
Flood Control Resource Metrics



Flow Below Navajo Dam and Safe Channel Capacity Figure G4 D-8

RECLAMATION

Water Quality Resource Metrics



Green River near Green River, UT Annual Salinity Figure G4 C-14

RECLAMATION