This presentation premiered at WaterSmart Innovations

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2011 Water Smart Innovations Conference

Climate Change Technical Panel

Understanding the Impact of Climate Change on Water Resources Sustainability

Michelle Maddaus, PE

Maddaus Water Management - Danville, California

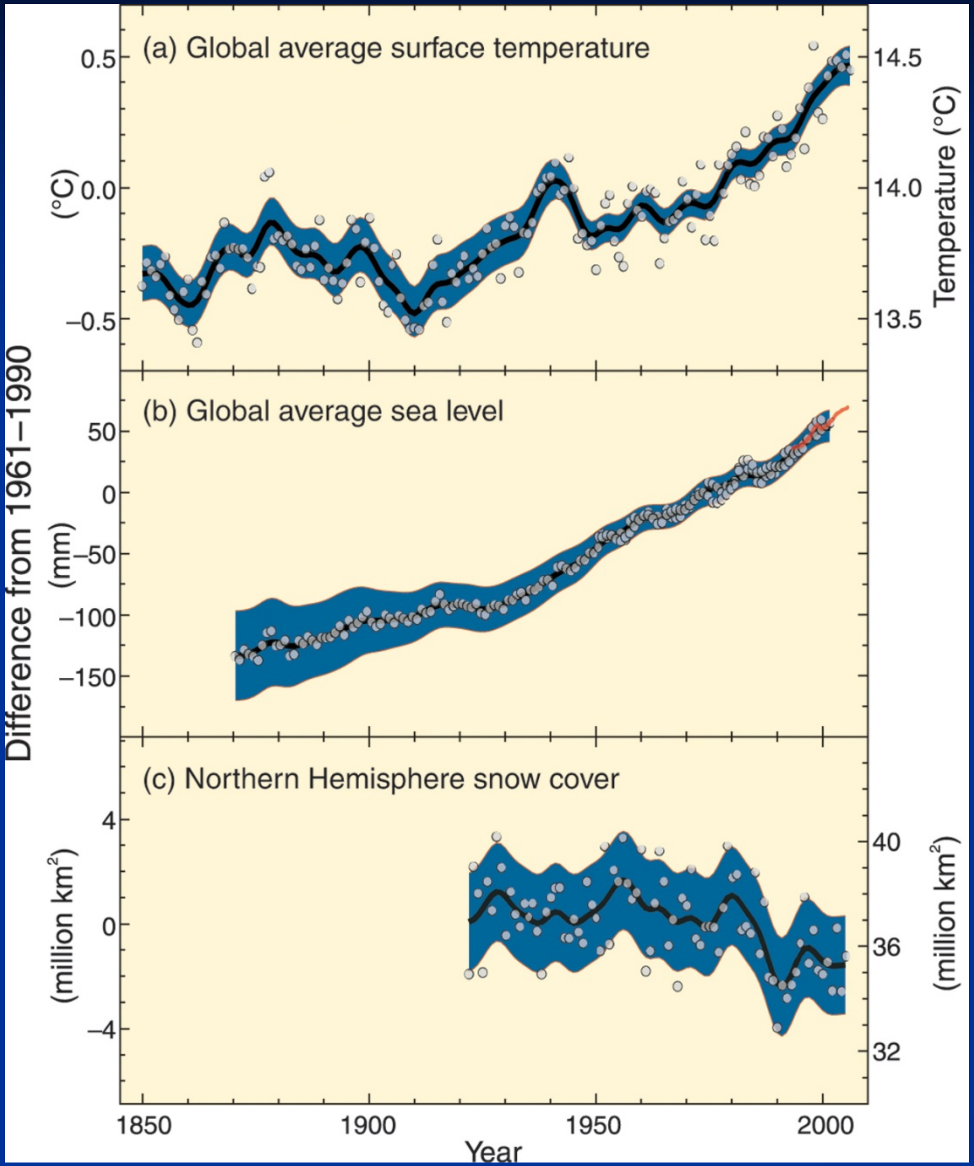
AGENDA

1. Climate Change is a Reality
2. Effects of Climate Change on the Utility
3. Climate Change & Water Resource Management
4. Current Research Activities
5. AWWA Climate Change Committee Role and Mission

1. Climate Change is a Reality

- **United Nations Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: The Physical Science Basis (*Paris, February 2009)**
  - Temperature is increasing
  - Sea level is rising
  - CO_2 & green house gasses (GHGs) increasing
  - Weather patterns are changing

Observed Historical Climate Change



TEMPERATURE

Last 100 years Earth warmed 0.76 °C

11 warmest years occurred in last 12 years

SEA LEVEL RISE

Rates almost doubled in 50 years:

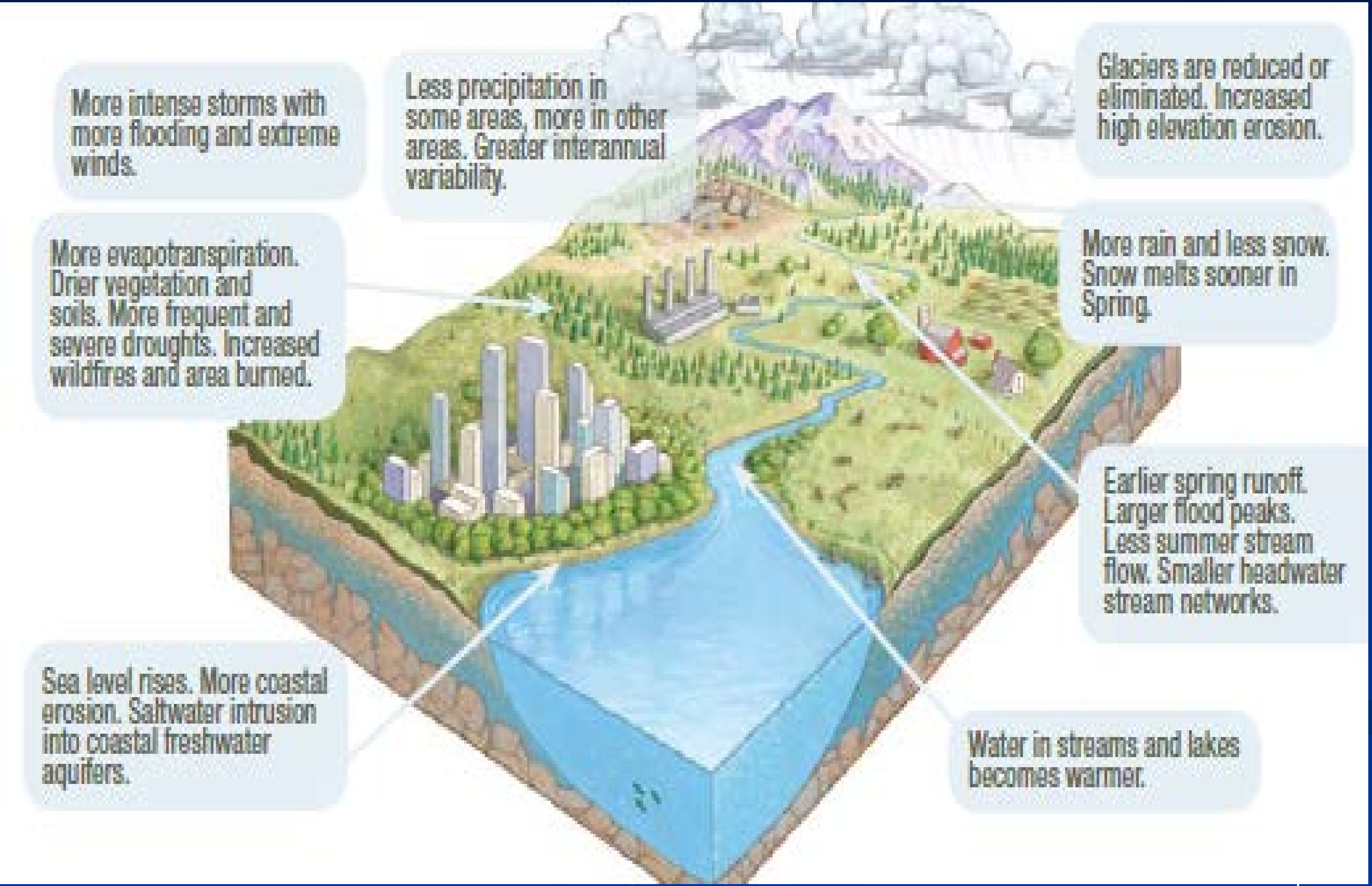
180 mm per century in 1961–2003
310 mm per century in 1993–2003

SNOW COVER

Northern Hemisphere snow cover is decreasing

Source: Climate Change and Water, IPCC Technical Paper IV, Intergovernmental Panel on Climate Change, June 2008

Climate Changes to the Hydrologic Cycle



Source: USDA, June 2008, FS 908 – Sustaining Healthy Watersheds

Effects of Climate Change on Water Utilities

- Water Quantity Impacts
  - Temperature and precipitation variability
    - Increased or decreased precipitation
    - Changes in snowmelt quantity and timing of runoff
    - Changes in aquifer recharge

- Water Quality Impacts
  - Increased precipitation intensity could causes change in:
    - Sediment, pathogen loading in urban runoff and increase in sewer flows
  - Increased temperature can cause:
    - Algal blooms,
    - Watershed vegetation,
    - Species growth/changing migration patterns
  - Salt water intrusion

Effects of Climate Change on Water Utilities

- Operational Reliability Impacts
  - Changes in quantity & quality can change operational reliability
  - Offsetting surface water supplies with increased groundwater pumping could lower the groundwater table
  - Possible expensive groundwater treatment and/or create hydrologic barriers to prevent salt water intrusion
  - Invasive species may cause complex operation and maintenance issues
- Financial and Institutional Impacts
  - Impacts to water supply quantity, quality, and operational reliability will necessitate changes in utility operations
  - Changes in operations may significantly increase costs

Climate Change & Water Resource Management

- Climate change impacts on water resources need to be managed through short & long term mitigation and adaptation strategies

- Adaptation = actions & responses to address potential impacts from climate change (adapt to new water resource conditions)

- Mitigation = actions to address possible causes of potential of climate change (e.g., reduce carbon footprint)

Water Resources Planning and Management Responses to Climate Change

Climate Change
By 2070 – 2100
Likely to see:
- Higher temperatures
- More/less precipitation
- Wider variations

Physical Changes
- Increasing flood events
- Increasing drought events
- Less snowpack
- Changing runoff patterns
- Changing stream flows
- Increasing sea levels
- Changing soil moisture
- Changing evapotranspiration

Impacts
Changes in:
- Water quality
- Water supply
- "Safe" yield
- Land use patterns
- Growth patterns
- Location of facilities
- Irrigation requirements
- Crop patterns
- Livestock production
- Saltwater intrusion
- Aquatic habitat
- Aquifer recharge

Green house Gasses

Mitigative Responses
Changes in:
- Operating rules
- Energy usage
- Chemical usage
- Transportation
- Supply chain

Planning
- Risk Management
- Integrated Resources Planning
- Holistic/System Thinking
- Decision-support Modeling

Adaptive Responses
Changes in:
- Operating rules
- Infrastructure
- Stormwater management
- Demand management
- Water allocation
- Water law

The Bottom Line: What Does It All Mean?

- Need for more flexibility & creativity
- Need to incorporate Climate Change into planning efforts and work regionally
- Need to budget more money for:
  - Reducing Carbon Footprint
  - Energy Management
  - Demand Management
  - Supplemental Supplies
  - Infrastructure

Climate Change Research Available

- AWWA: Climate Change Committee

  Publish "Climate Change Committee Report" June 2011

- AMWA: Association of Metropolitan Water Agencies

  http://www.amwa.net/cs/climatechange

  Publish "Climate Change Initiatives Plan" (updated annually)

- NOAA Climate Service:

  http://www.noaa.gov/climate.html

  Working on creating "regional" climate change centers

- US EPA:

  http://www.usepa.gov

  Published in 2009 "National Water Program Strategy: Response to Climate Change"

Climate Change Research Available

- US Bureau of the Reclamation:
  http://www.usbr.gov/research/docs/climatechangelitsynthesis.pdf
  Published in 2009 "The Literature Synthesis on Climate Change Implications for Reclamation's Water Resources"

- WUCA: Water Utility Climate Alliance (9 large metro utilities)
  http://www.wucaonline.org
  Published in January 2010:
  “Climate Science and Modeling”
  “Decision Support Tools for Climate Change”

- WRF: Water Research Foundation   (AWWA)
  http://www.waterresearchfoundation.org
  Focus on Research Projects and Workshops
  Project #4208
  “Identifying and Developing Climate Change Resources for Water Utilities: Content for Central Knowledge Repository Website”

Climate Change Research Available

- USGS: Unites States Geologic Survey
  http://geochange.er.usgs.gov/

  Published 2009 "Climate Change and Water Resources Management: A Federal Perspective"

- NCAR: National Center for Atmospheric Research
  http://www.ncar.ucar.edu/

  Multiple scientific publications

- Western Urban Water Coalition
  http://www.wuwc.org/html/wuwc_issues_climate.html

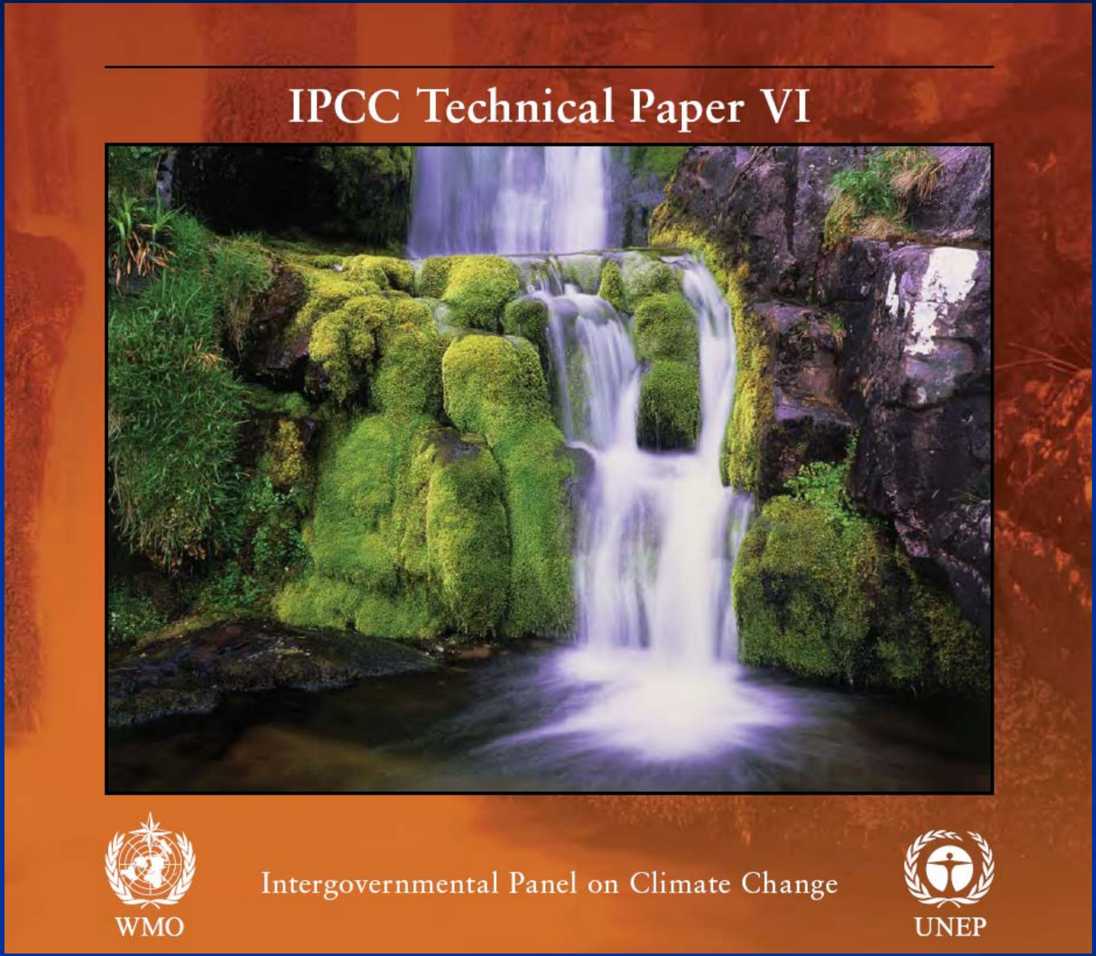
  Sent Climate change positions to Congress

- USDA: United States Department of Agriculture
  http://www.fs.fed.us/ccrc/files/CC%20and%20Water%20In%20Brief.pdf

  Published in June 2008 “Climate Change and Water from the Forest Service” Sustaining Healthy Watersheds

These are just a few of the great organizations and references available!

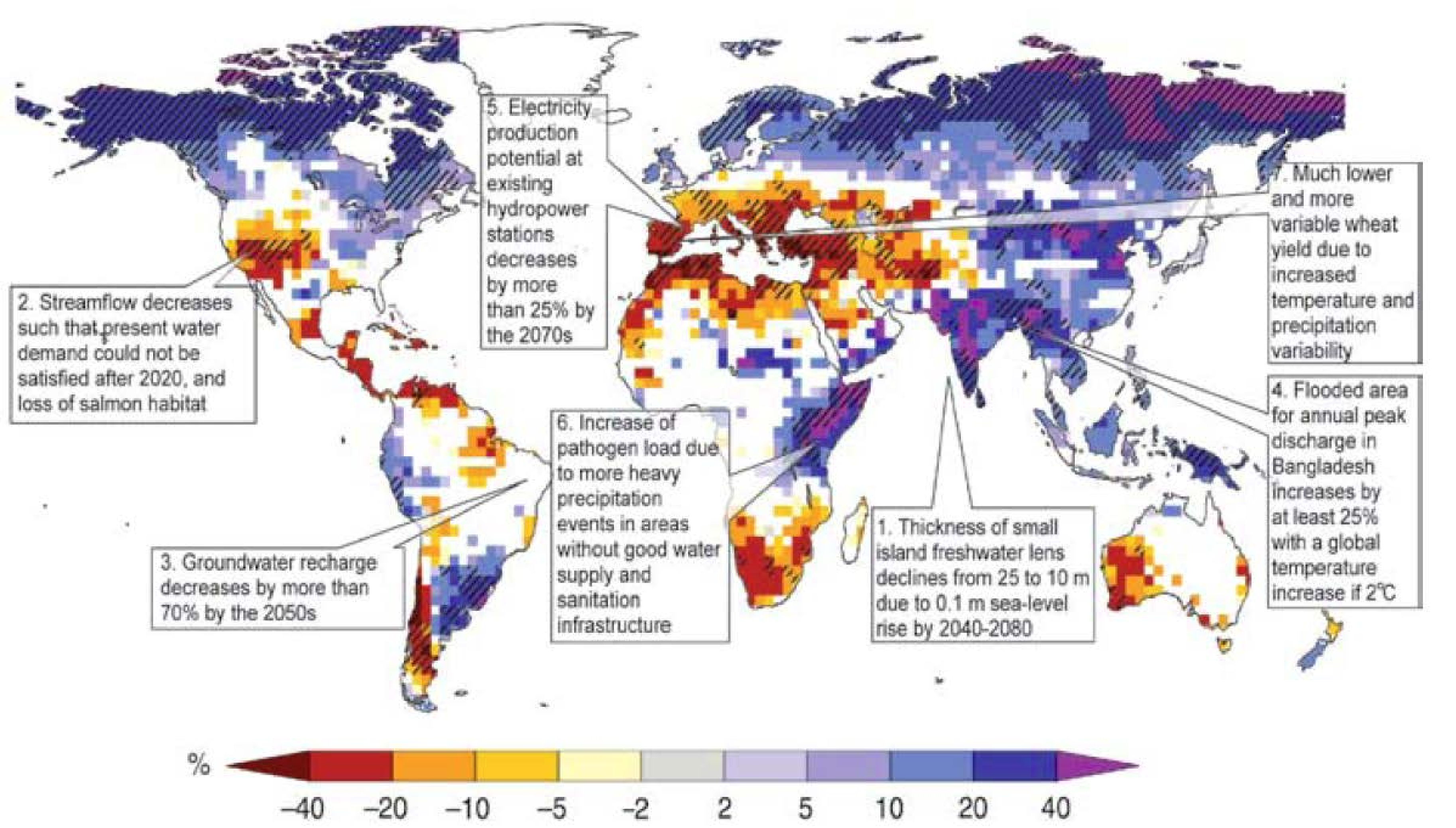
Examples of Research Available



2008 IPCC Report –
http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf

Examples of Research Available

Source: Climate Change and Water, IPCC Technical Paper VI, Intergovernmental Panel on Climate Change, June 2008



Illustrative Map of Future Climate Change Impacts

Examples of Research Available

Environmental factor	Observed changes	Time period	Location
Runoff/streamflow	Annual increase of 5%, winter increase of 25–90%, increase in winter base flow due to increased melt and thawing permafrost	1935–1999	Arctic Drainage Basin: Ob, Lena, Yenisey, Mackenzie
	1–2 week earlier peak streamflow due to earlier warming-driven snowmelt	1936–2000	Western North America, New England, Canada, northern Eurasia
Floods	Increasing catastrophic floods of frequency (0.5–1%) due to earlier break-up of river ice and heavy rain	Recent years	Russian Arctic rivers
Droughts	29% decrease in annual maximum daily streamflow due to temperature rise and increased evaporation with no change in precipitation	1847–1996	Southern Canada
	Due to dry and unusually warm summers related to warming of western tropical Pacific and Indian Oceans in recent years	1998–2004	Western USA
Water temperature	0.1–1.5°C increase in lakes	40 years	Europe, North America, Asia (100 stations)
	0.2–0.7°C increase (deep water) in lakes	100 years	East Africa (6 stations)
Water chemistry	Decreased nutrients from increased stratification or longer growing period in lakes and rivers	100 years	North America, Europe, Eastern Europe, East Africa (8 stations)
	Increased catchment weathering or internal processing in lakes and rivers	10–20 years	North America, Europe (88 stations)

Source: Climate Change and Water, IPCC Technical Paper VI, Intergovernmental Panel on Climate Change, June 2008

Panel Discussion

Future questions can be addressed to session moderator:

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RECLAMATION

Managing Water in the West

Addressing Climate Change, Water Supply, and Evolving Demand over the Colorado River Basin

W. Paul Miller

Bureau of Reclamation, Lower Colorado Region

Water Smart Innovations 2011

Climate Change and Water Efficiency – New and Exciting Tools and Efforts

October 6, 2011

U.S. Department of the Interior

Bureau of Reclamation

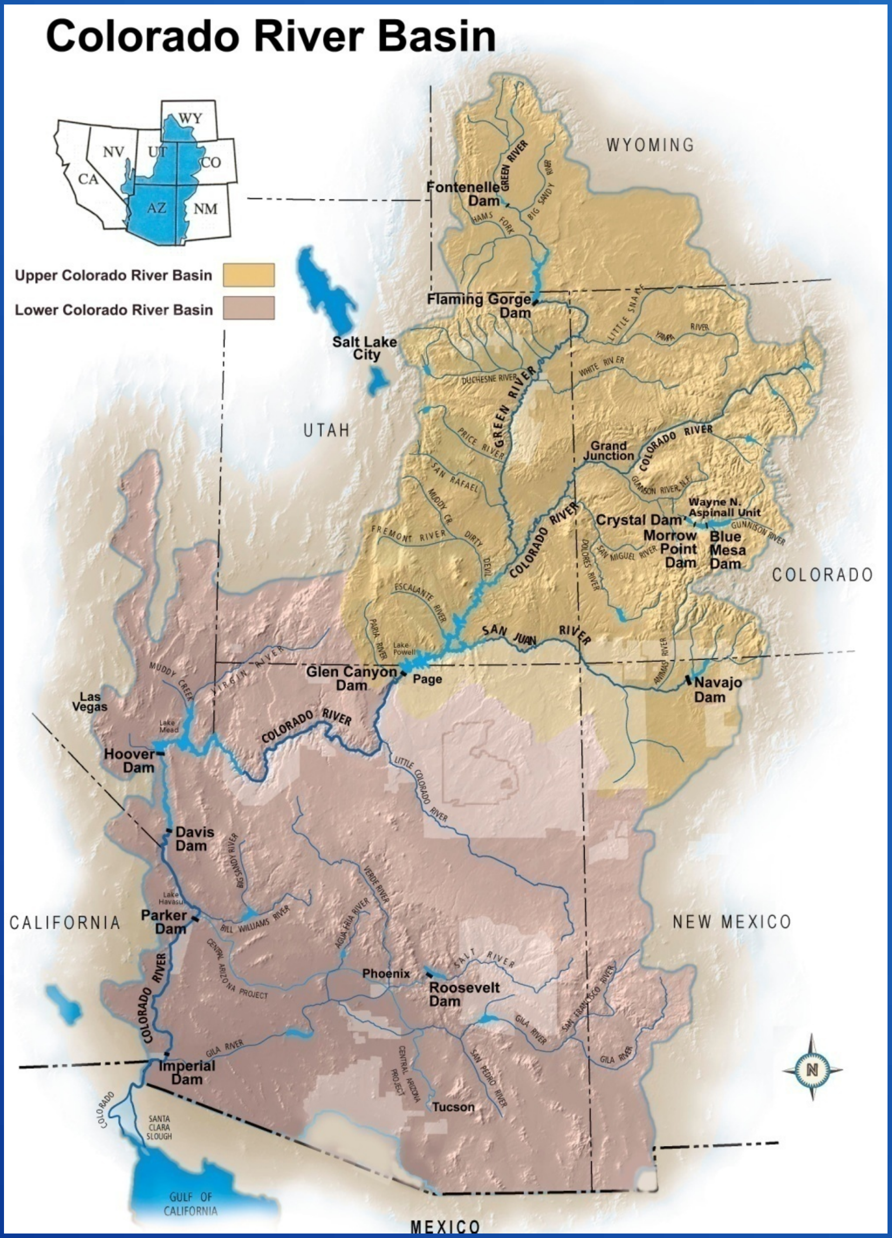
Operation of Colorado River Reservoirs in a Changing Climate

- Overview of the Colorado River System
- Historical and current state of the system
- Perspectives on the future of the system

RECLAMATION

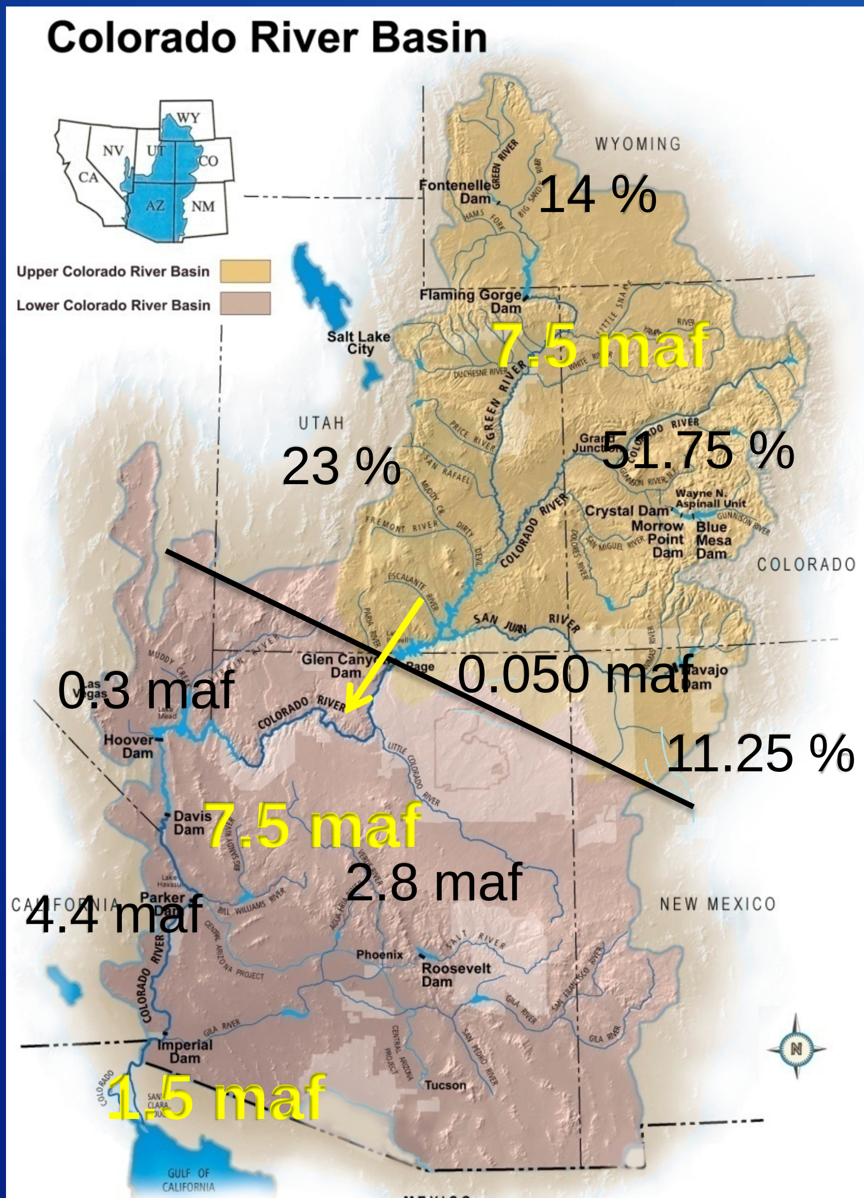
Colorado River Basin

- 16.5 million acre-feet (maf) allocated annually
- 13 to 14.5 maf of consumptive use annually
- 16.3 maf average annual “natural” inflow over past 100 years
- 60 maf of storage
- Inflows are highly variable year-to-year
- Operation governed by the “Law of the River”



RECLAMATION

Law of the River



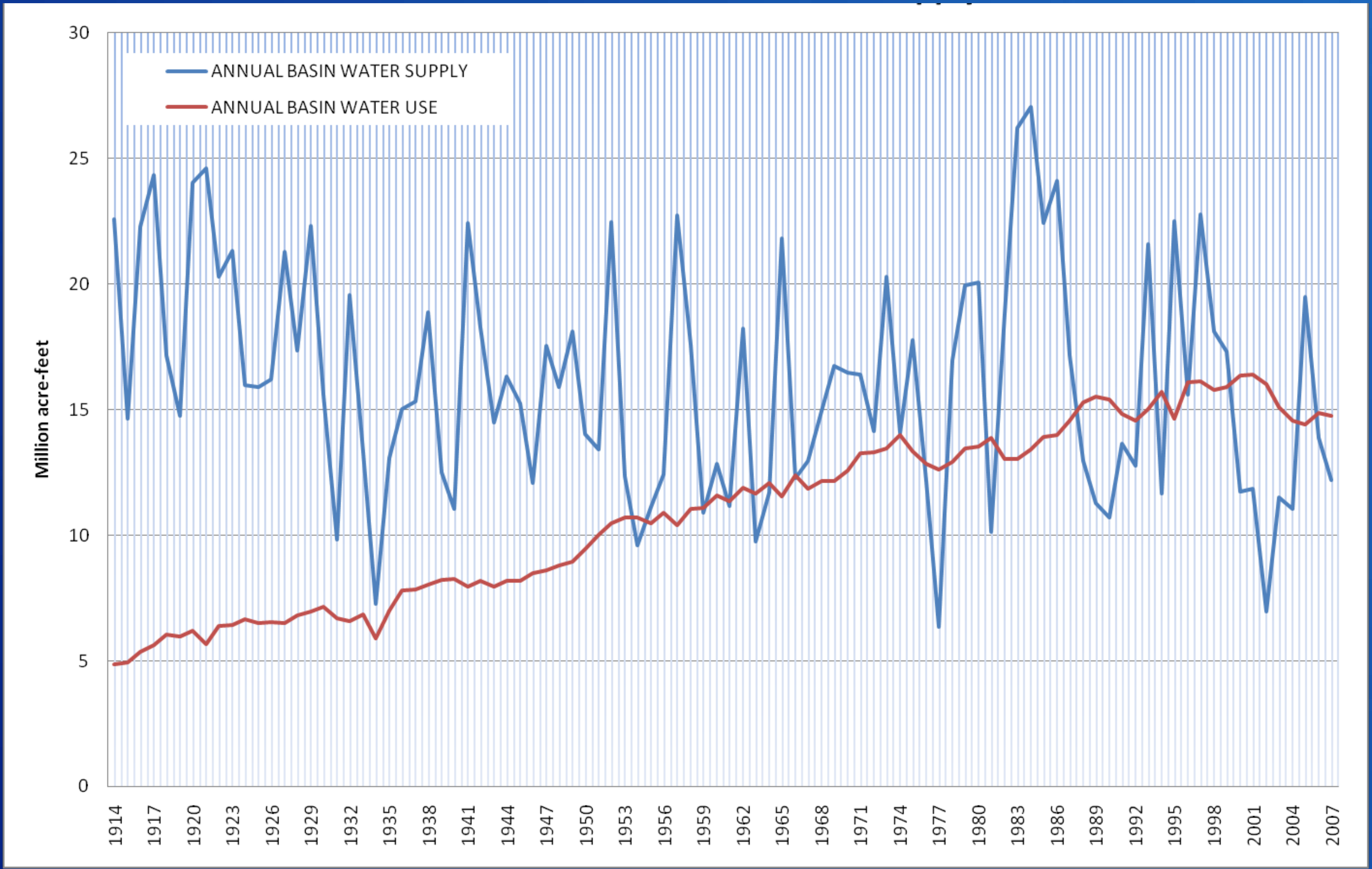
Other Key Components:

- Colorado River Storage Project Act, 1956
- Colorado River Basin Project Act, 1968
- Rece ns and agree g., Interim Guide 7)

RECLAMATION

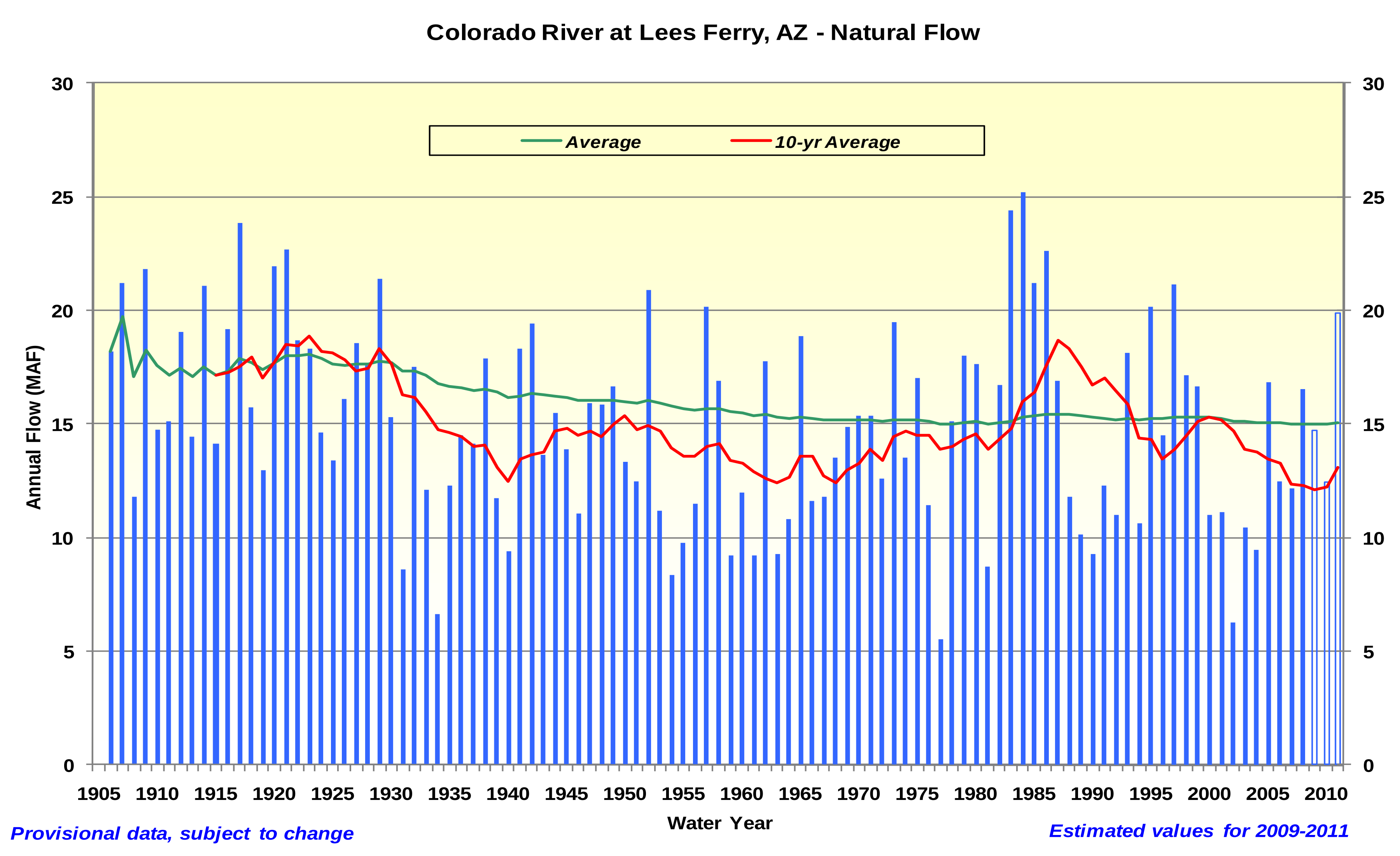
Spatial Resolution/ Time Horizon	Operational Activity	Decisions
Basin-wide over decades	Long-term Planning	Operating Criteria
Basin-wide over 1-2 years	Mid-term Operations	Annual Operating Plan
Sub-basin over 4-6 weeks	Short-term Scheduling	Water and Power Schedules
		Unit Commitment Economic Dispatch
Single project over 1-7 days	Real-time Control	Automatic Generation and Control

Annual Colorado River Water Supply & Use



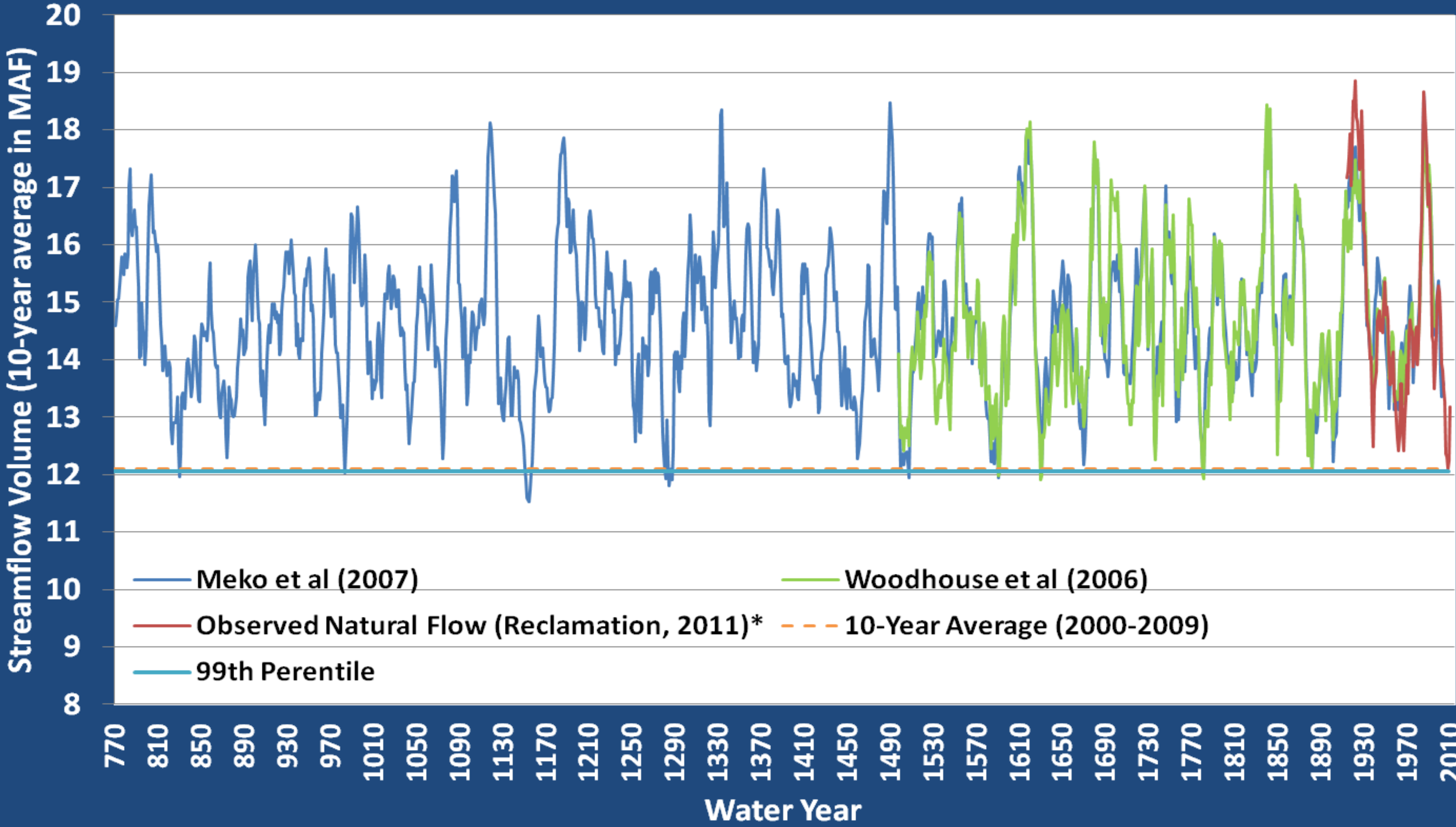
RECLAMATION

Natural Flow
Colorado River at Lees Ferry Gaging Station, Arizona
Water Year 1906 to 2011



RECLAMATION

Annual Natural Flow
Colorado River at Lees Ferry Gaging Station, Arizona
Running 10-Year Averages from 771 - 2011



**Estimated values for 2009-2011*

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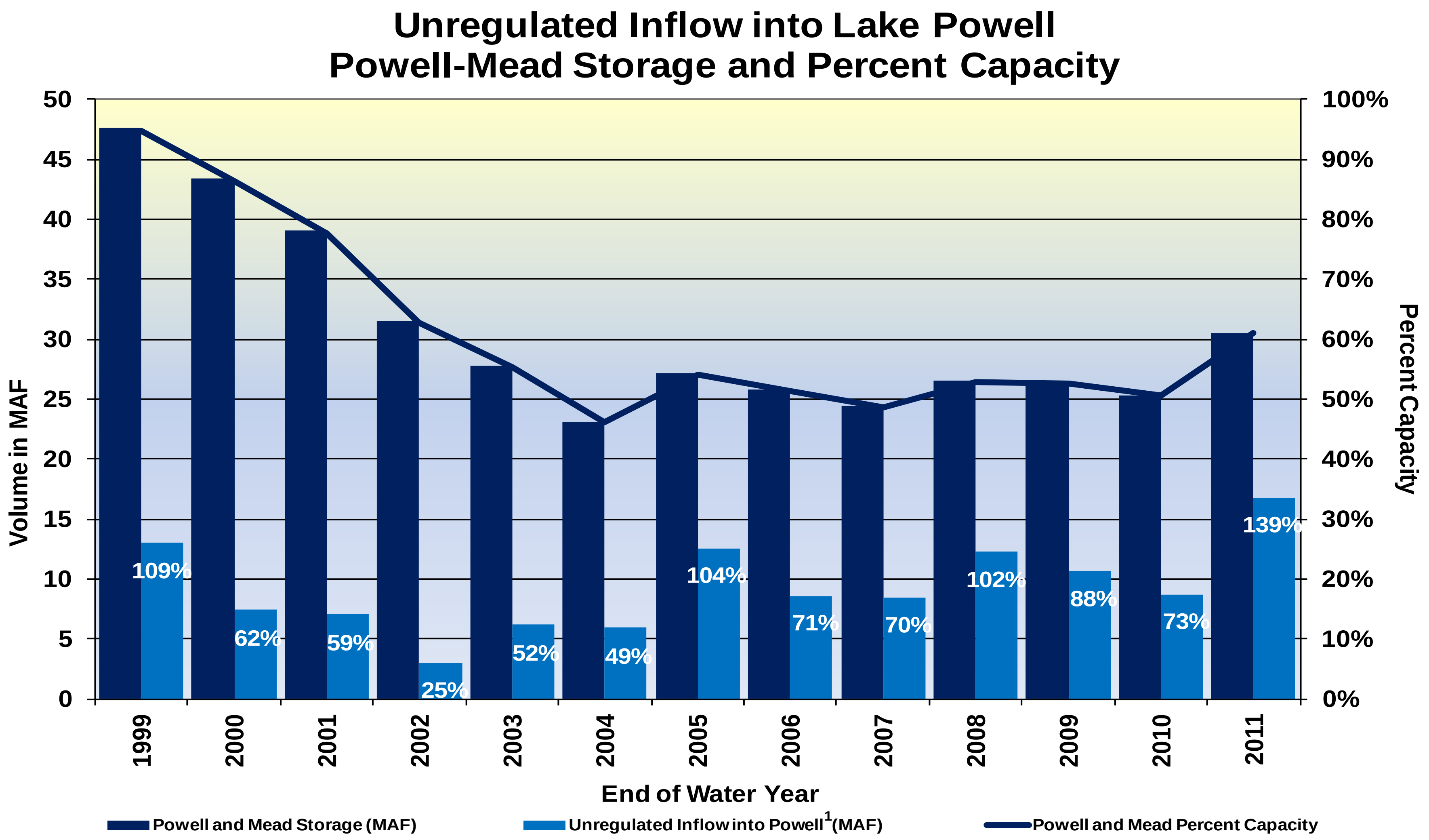
State of the System (Water Years 1999-2011)



[1] Percentages at the top of the light blue bars represent percent of average unregulated inflow into Lake Powell for a given water year based on the 30-year average from 1971 to 2000.

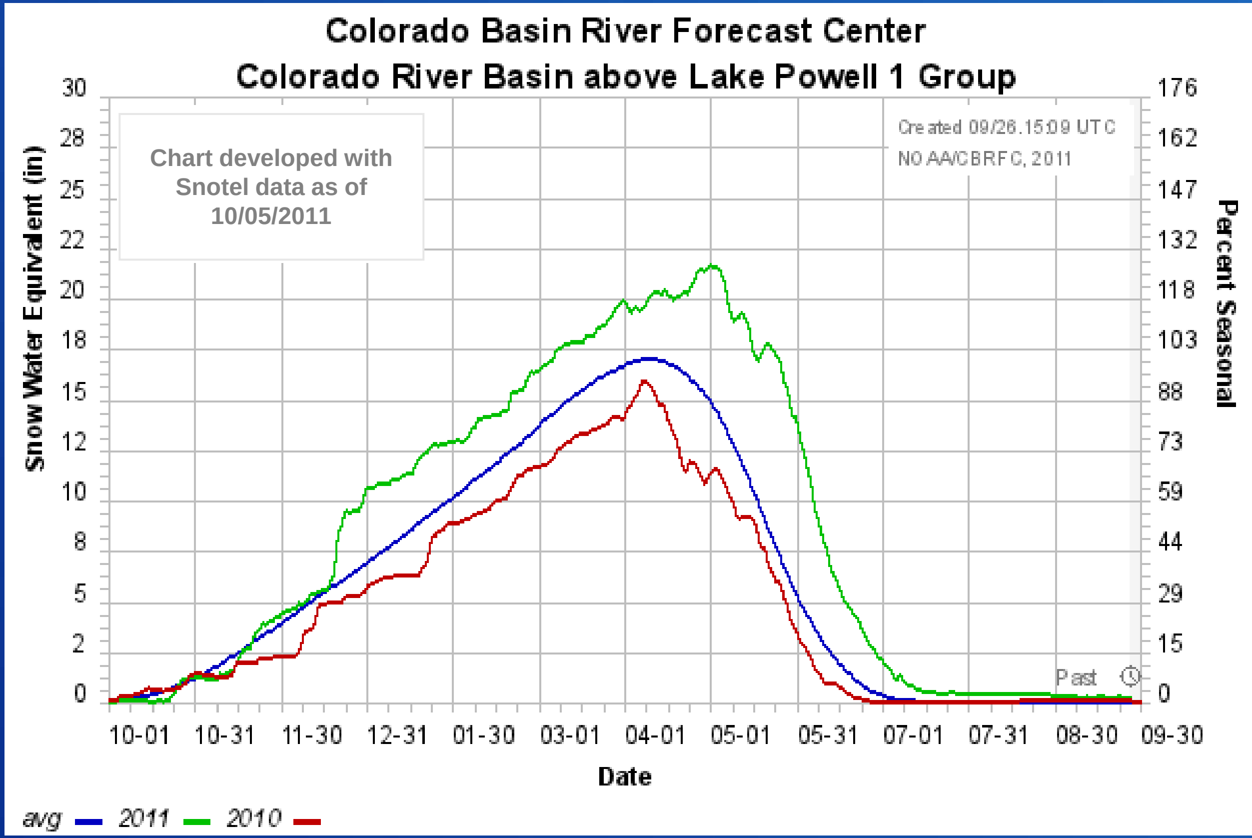
RECLAMATION

Water Year Snowpack and Precipitation
as of September 30, 2011

Colorado River Basin above Lake Powell

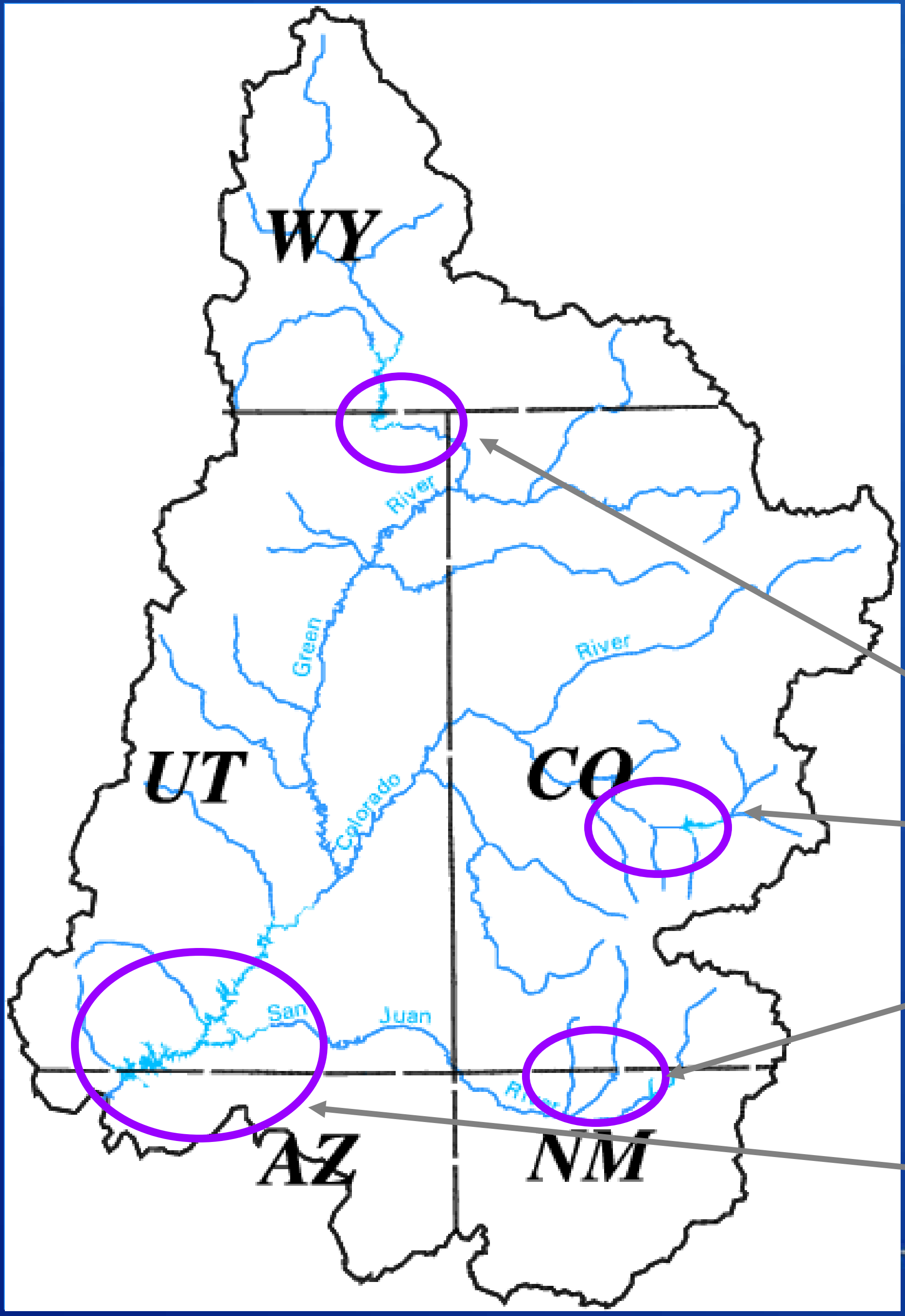
Water Year 2011 Precipitation

120%



Source: CBRFC

RECLAMATION



2011 Upper Colorado Observed Apr–Jul Inflow

Flaming Gorge – 162%

Blue Mesa – 124%

Navajo – 74%

Lake Powell – 162%

RECLAMATION

Colorado River Basin Storage
(as of October 5, 2011)

Current Storage	Percent Full	MAF	Elevation (Feet)
Lake Powell	72%	17.53	3,652
Lake Mead	51%	13.07	1,117
Total System Storage*	65%	38.63	NA

*Total system storage was 33.02 maf or 56% this time last year

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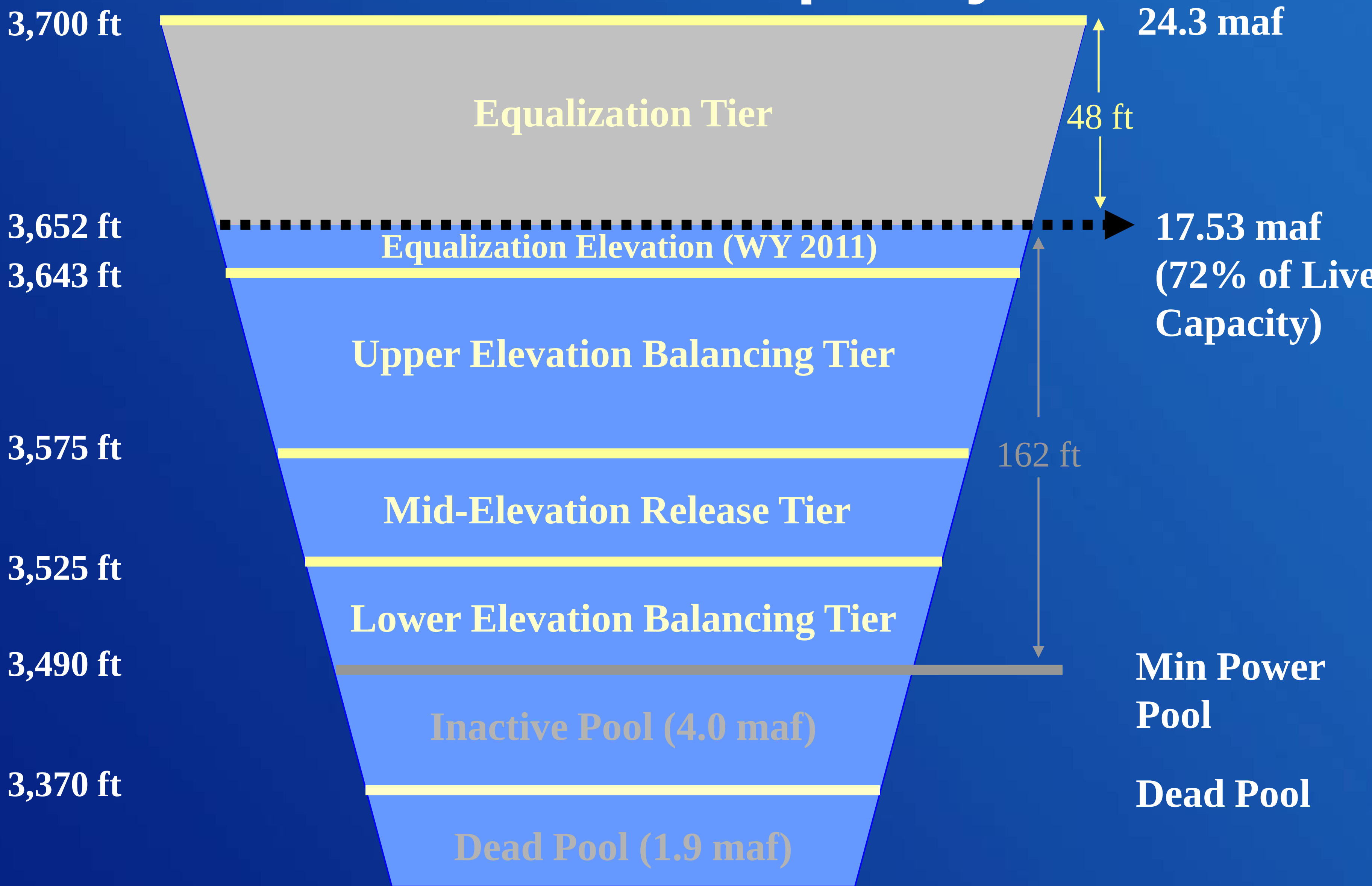
Lake Powell Capacity

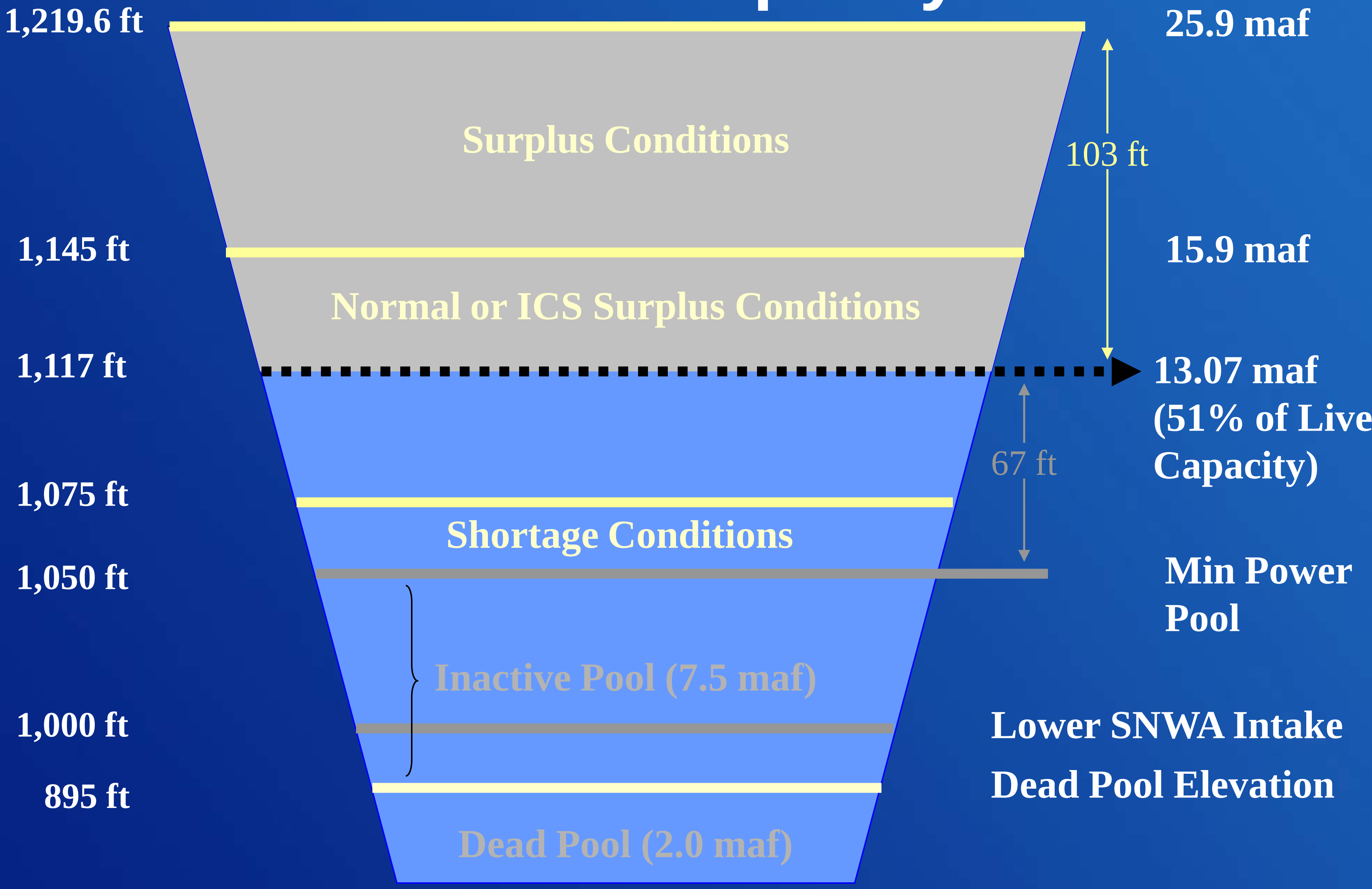


Not to scale

As of Oct 5, 2011

RECLAMATION

Lake Mead Capacity

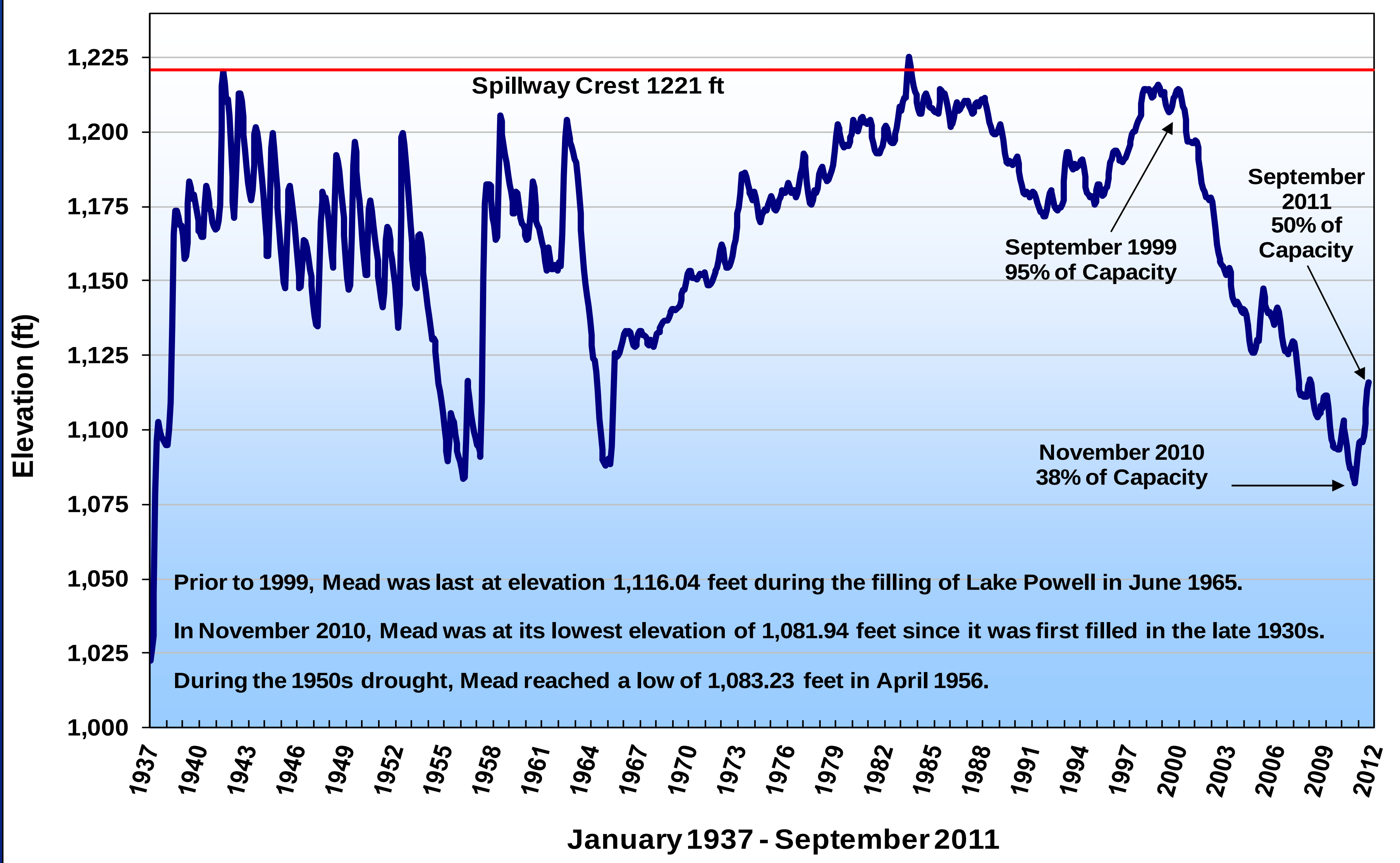


Not to scale

As of Oct 5, 2011

RECLAMATION

Lake Mead End of Month Elevation



RECLAMATION

2007 Interim Guidelines

- Operations specified for full range of operation for Lake Powell and Lake Mead
- Strategy for shortages in the Lower Basin
- Mechanism in Lower Basin to encourage efficient and flexible use and management of Colorado River water (ICS)
- In place for an interim period (through 2026)

RECLAMATION

Intentionally Created Surplus (ICS)

Warren H. Brock Storage Reservoir

- ICS may be created through “extraordinary conservation” measures including:
  - land fallowing, canal lining, desalination, importation, system efficiency
- There is a 5% “system assessment” when ICS is created (except for system efficiency projects)
- Delivery of ICS may occur in years after creation

RECLAMATION

Lake Powell & Lake Mead
Operational Diagrams and Current Conditions

Lake Powell

Elevation (feet)	Operation According to the Interim Guidelines	Live Storage (maf)[1]
3,700		24.3
	Equalization Tier Equalize, avoid spills or release 8.23 maf	
3,652 10/05/11		17.53 10/05/11
	Upper Elevation Balancing Tier[3] Release 8.23 maf; if Lake Mead < 1,075 feet, balance contents with a min/max release of 7.0 and 9.0 maf	
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)	Operation According to the Interim Guidelines	Live Storage (maf)[1]
1,220		25.9
	Flood Control Surplus or Quantified Surplus Condition Deliver > 7.5 maf	
1,200 (approx.)[2]		22.9 (approx.)[2]
	Domestic Surplus or ICS Surplus Condition Deliver > 7.5 maf	
1,145		15.9
1,117 10/05/11		13.07 10/05/11
	Normal or ICS Surplus Condition Deliver ≥ 7.5 maf	
1,075		9.4
	Shortage Condition Deliver 7.167[4] maf	
1,050		7.5
	Shortage Condition Deliver 7.083[5] maf	
1,025		5.8
	Shortage Condition Deliver 7.0[6] maf Further measures may be undertaken[7]	
1,000		4.3
895		0

Diagram not to scale

[1] Acronym for million acre-feet

[2] This elevation is shown as approximate as it is determined each year by considering several factors including Lake Powell and Lake Mead storage, projected Upper Basin and Lower Basin demands, and an assumed inflow.

[3] Subject to April adjustments which may result in a release according to the Equalization Tier

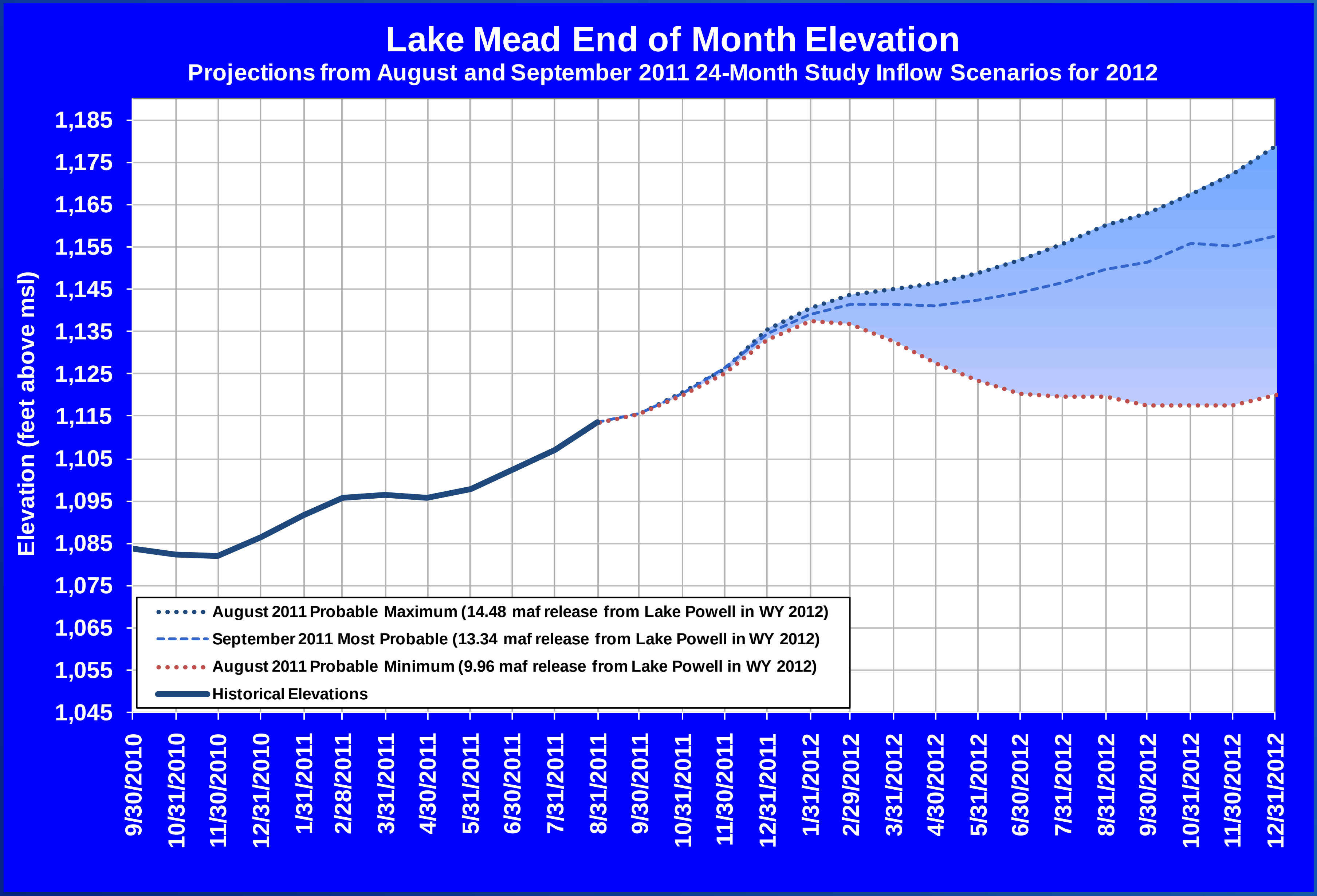
[4] Of which 2.48 maf is apportioned to Arizona, 4.4 maf to California, and 0.287 maf to Nevada

[5] Of which 2.40 maf is apportioned to Arizona, 4.4 maf to California, and 0.283 maf to Nevada

[6] Of which 2.32 maf is apportioned to Arizona, 4.4 maf to California, and 0.280 maf to Nevada

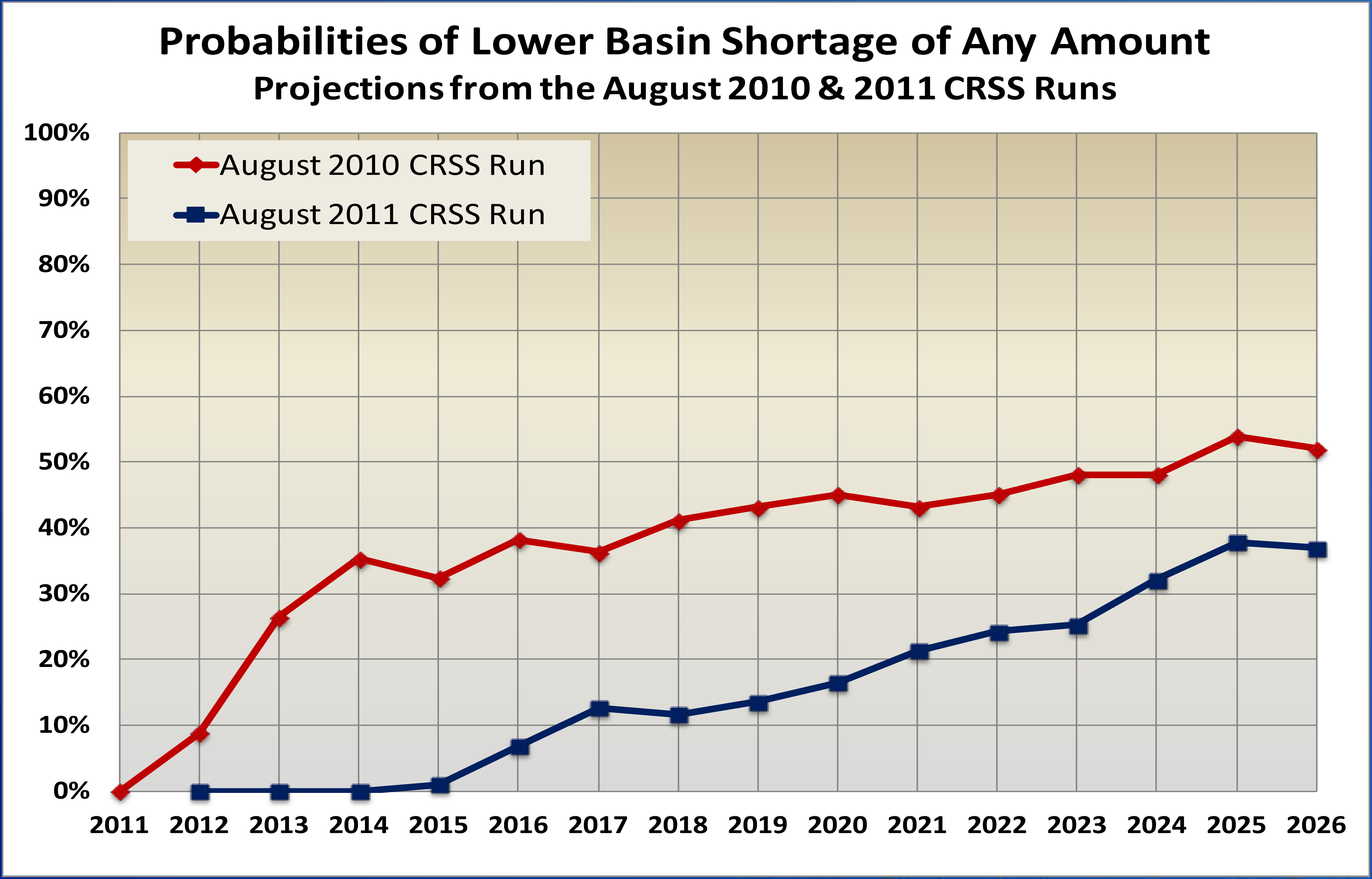
[7] Whenever Lake Mead is below elevation 1,025 feet, the Secretary shall consider whether hydrologic conditions together with anticipated deliveries to the Lower Division States and Mexico is likely to cause the elevation at Lake Mead to fall below 1,000 feet. Such consideration, in consultation with the Basin States, may result in the undertaking of further measures, consistent with applicable Federal law.

RECLAMATION



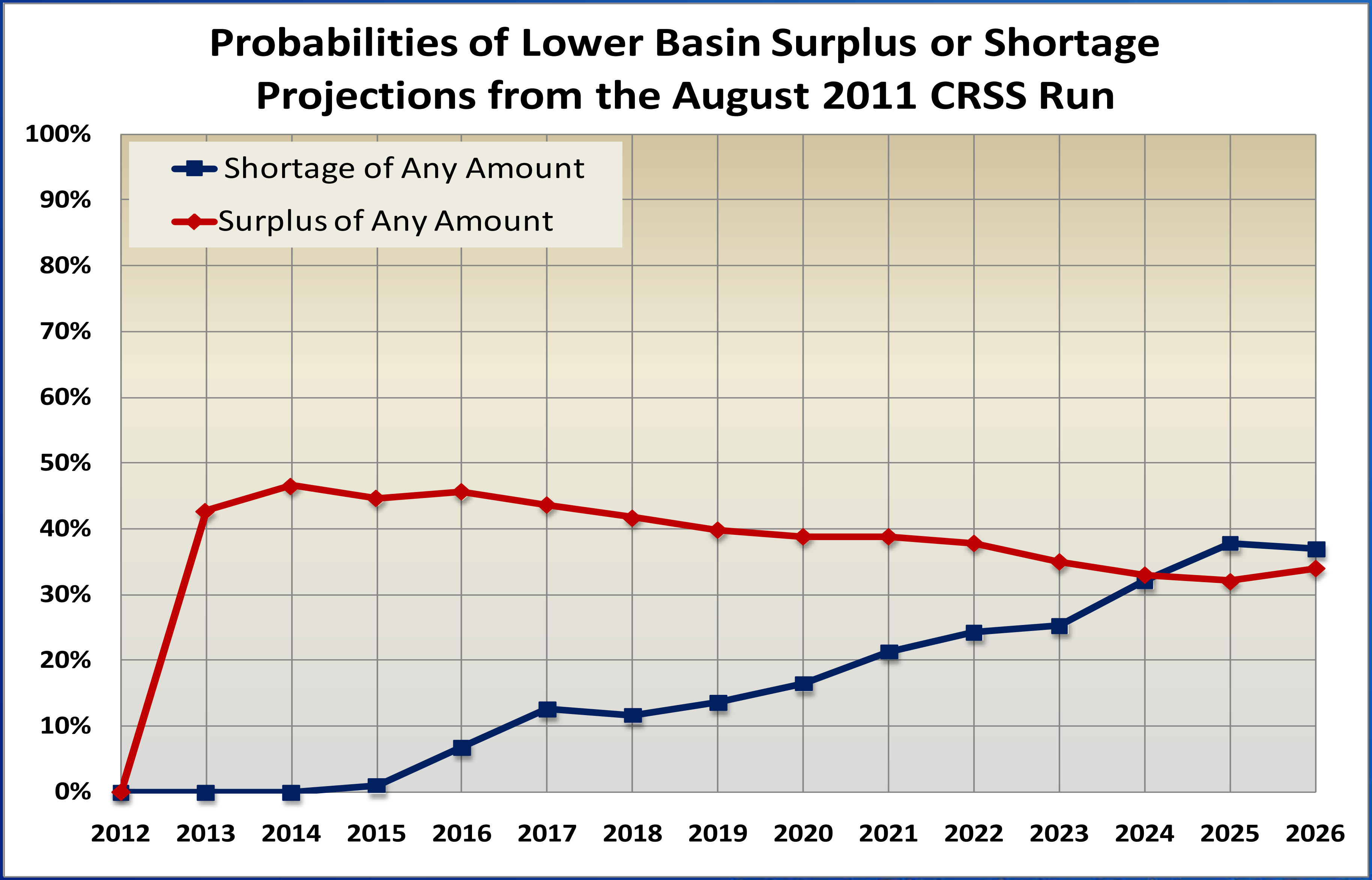
Lake Mead End of Month Elevation
Projections from August and September 2011 24-Month Study Inflow Scenarios for 2012
Elevation (feet above msl)
1,185
1,175
1,165
1,155
1,145
1,135
1,125
1,115
1,105
1,095
1,085
1,075
1,065
1,055
1,045
August 2011 Probable Maximum (14.48 maf release from Lake Powell in WY 2012)
September 2011 Most Probable (13.34 maf release from Lake Powell in WY 2012)
August 2011 Probable Minimum (9.96 maf release from Lake Powell in WY 2012)
Historical Elevations
9/30/2010
10/31/2010
11/30/2010
12/31/2010
1/31/2011
2/28/2011
3/31/2011
4/30/2011
5/31/2011
6/30/2011
7/31/2011
8/31/2011
9/30/2011
10/31/2011
11/30/2011
12/31/2011
1/31/2012
2/29/2012
3/31/2012
4/30/2012
5/31/2012
6/30/2012
7/31/2012
8/31/2012
9/30/2012
10/31/2012
11/30/2012
12/31/2012
RECLAMATION

Lower Basin Shortage through 2026



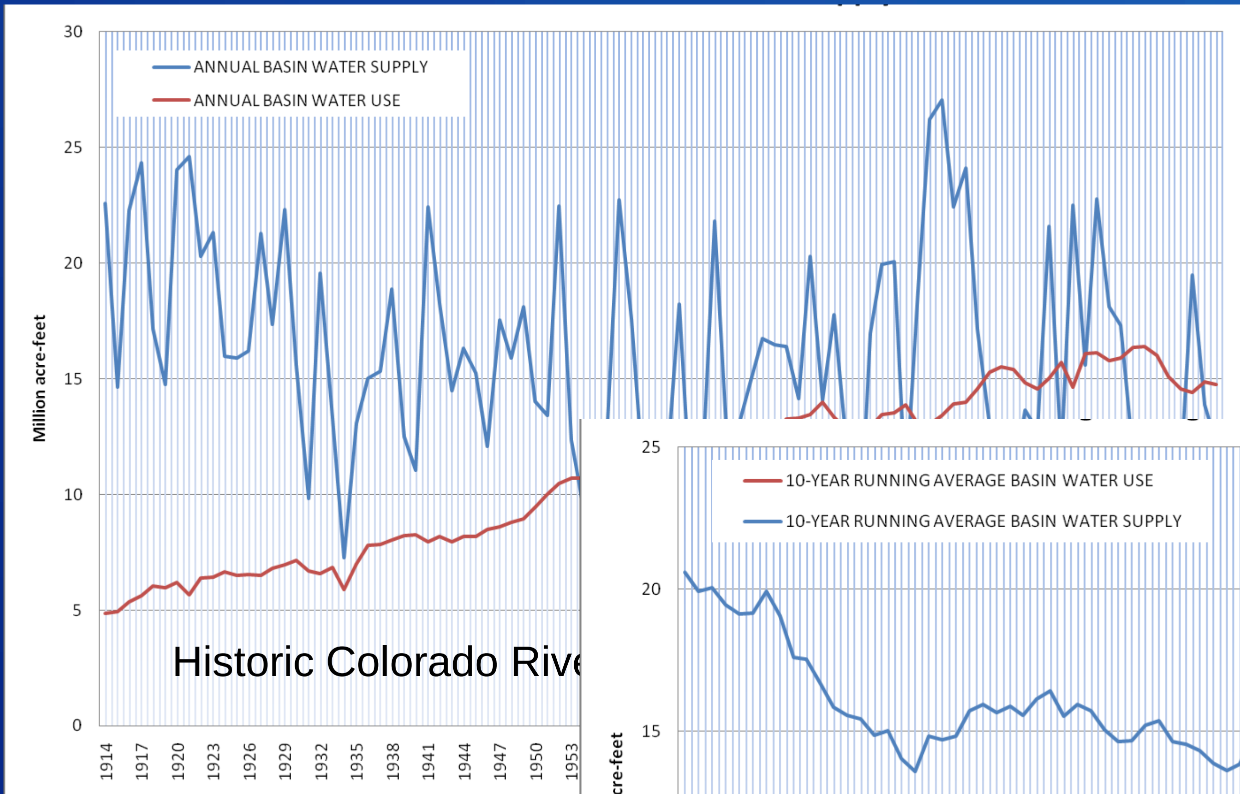
RECLAMATION

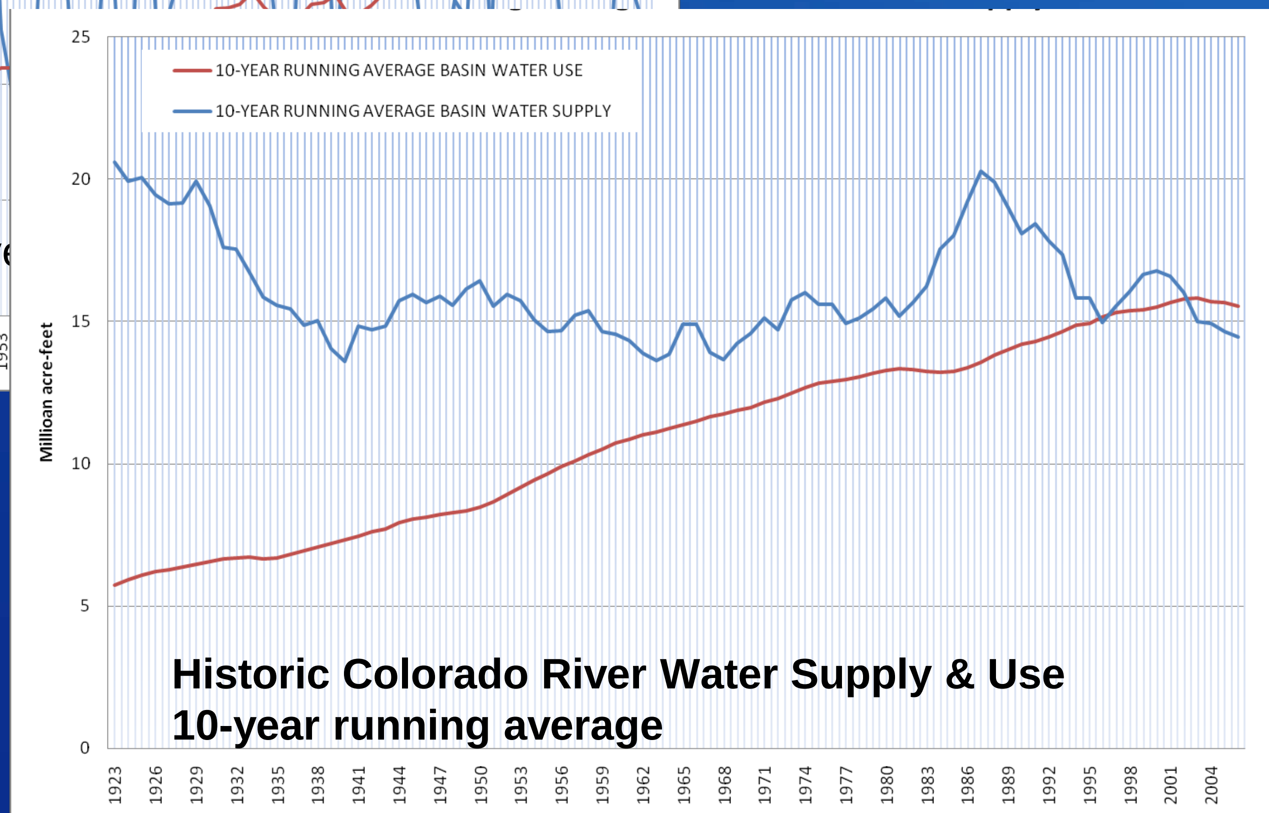
Lower Basin Surplus & Shortage through 2026



RECLAMATION

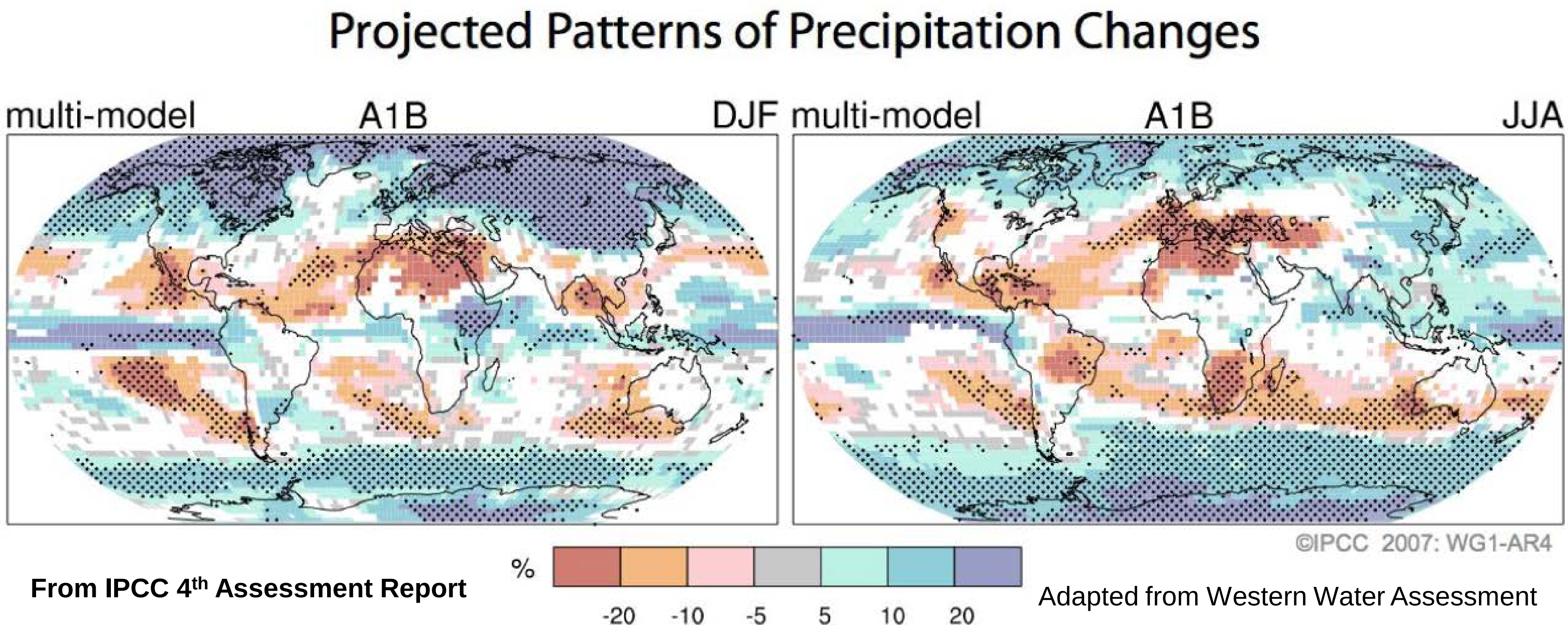
Colorado River Basin Water Supply and Demand Study





Potential Impacts of Climate Change

- Wet get wetter and dry get drier…and the Southwest likely to get drier; variability likely to increase
- Wide range of projected declines in Colorado River average inflow (0 to 40%)
- Lot's of research on-going (and needed)



From IPCC 4th Assessment Report

Adapted from Western Water Assessment

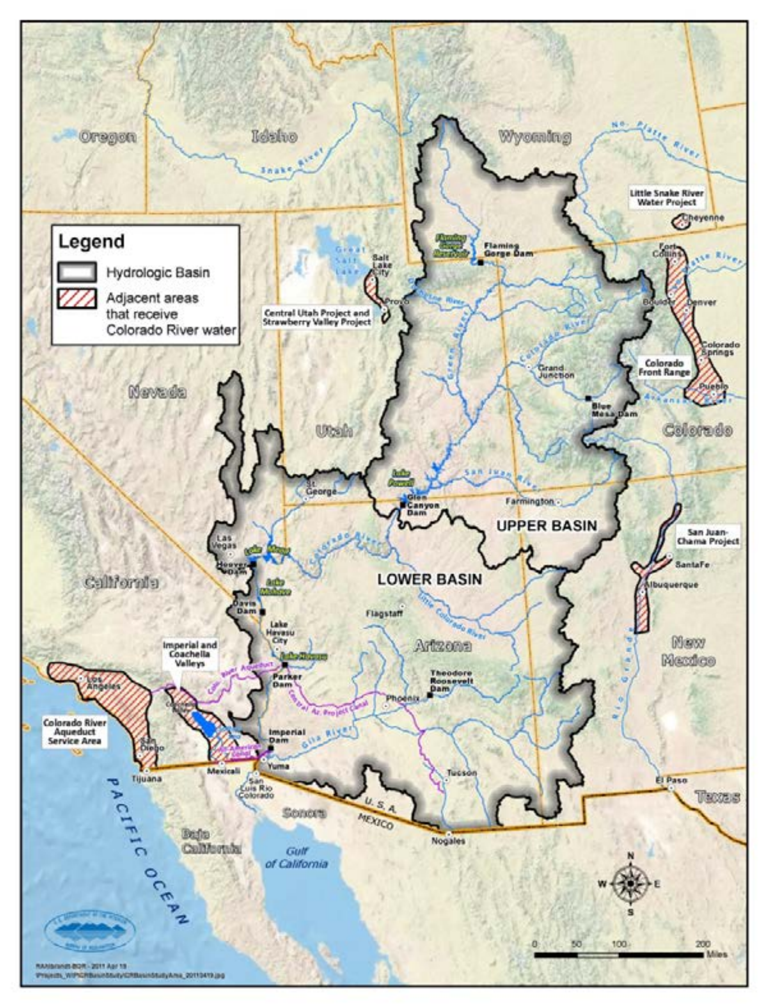
Colorado River Basin Water Supply and Demand Study

- Study Objective

  Assess future water supply and demand imbalances and develop/evaluate opportunities for resolving imbalances

- Study conducted by Reclamation and the Basin States in collaboration with stakeholders throughout the Basin
- Study began in January 2010 and is scheduled be completed by July 2012
- A planning study – will *not* result in any decisions

- Email: ColoradoRiverBasinStudy@usbr.gov
- Website: http://www.usbr.gov/lc/region/programs/crbstudy.html



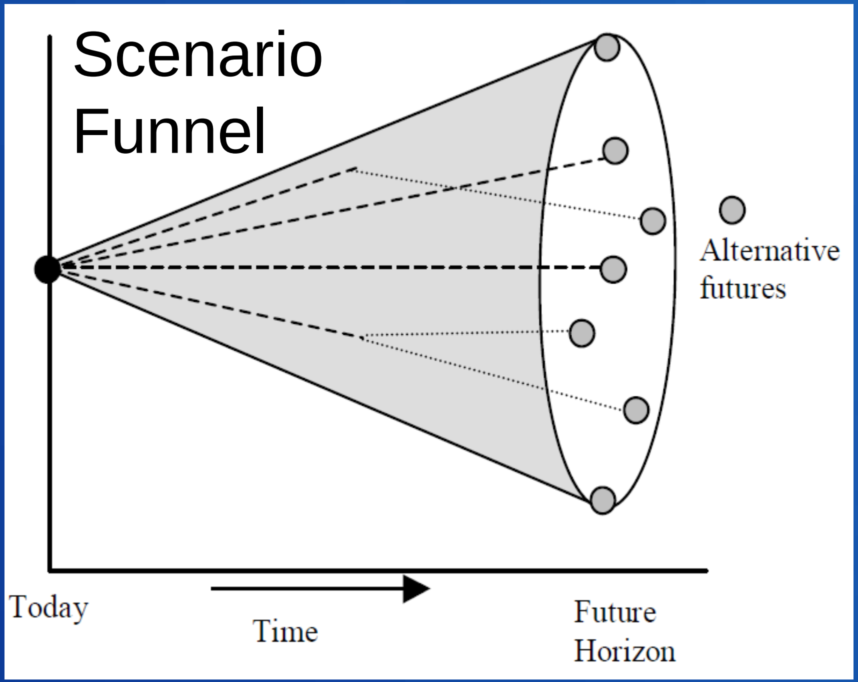
RECLAMATION

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



RECLAMATION

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 Global Climate Model (GCM) Projected:

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

Water Demand Scenarios *

Current Trends:

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

Economic Slowdown:

- low growth with emphasis on economic efficiency

Expansive Growth:

- economic resurgence (population and energy) and current preferences toward human and environmental values *

Enhanced Environment and Healthy Economy:

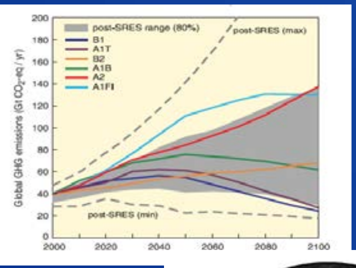
- expanded environmental awareness and stewardship with growing economy*

* Additional "branches" possible depending upon assumed trajectory of specific socio-economic factors.

*** Preliminary – Subject to change**

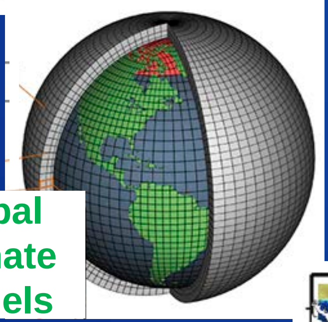
RECLAMATION

Methodology for Incorporating Climate Projections in Future Supply



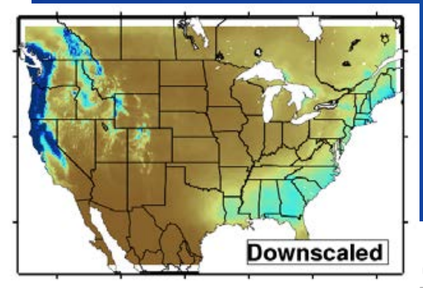
Emission Scenarios

(3 scenarios: A2, A1b, B1)



Global Climate Models

16 GCMs

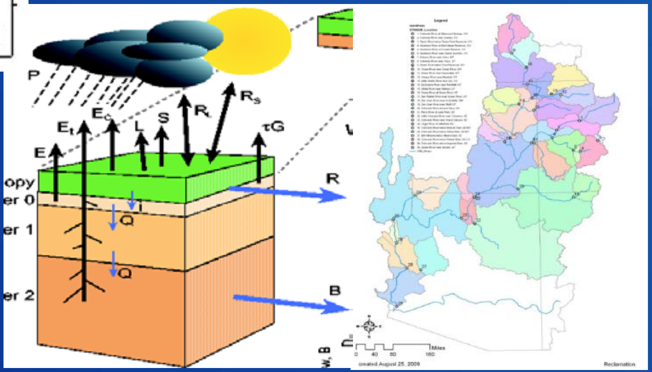


Bias Correction & Spatial Downscaling

(112 downscaled projections)

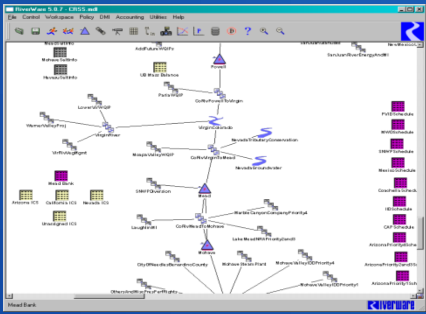
Hydrologic Modeling

(112 downscaled projections)



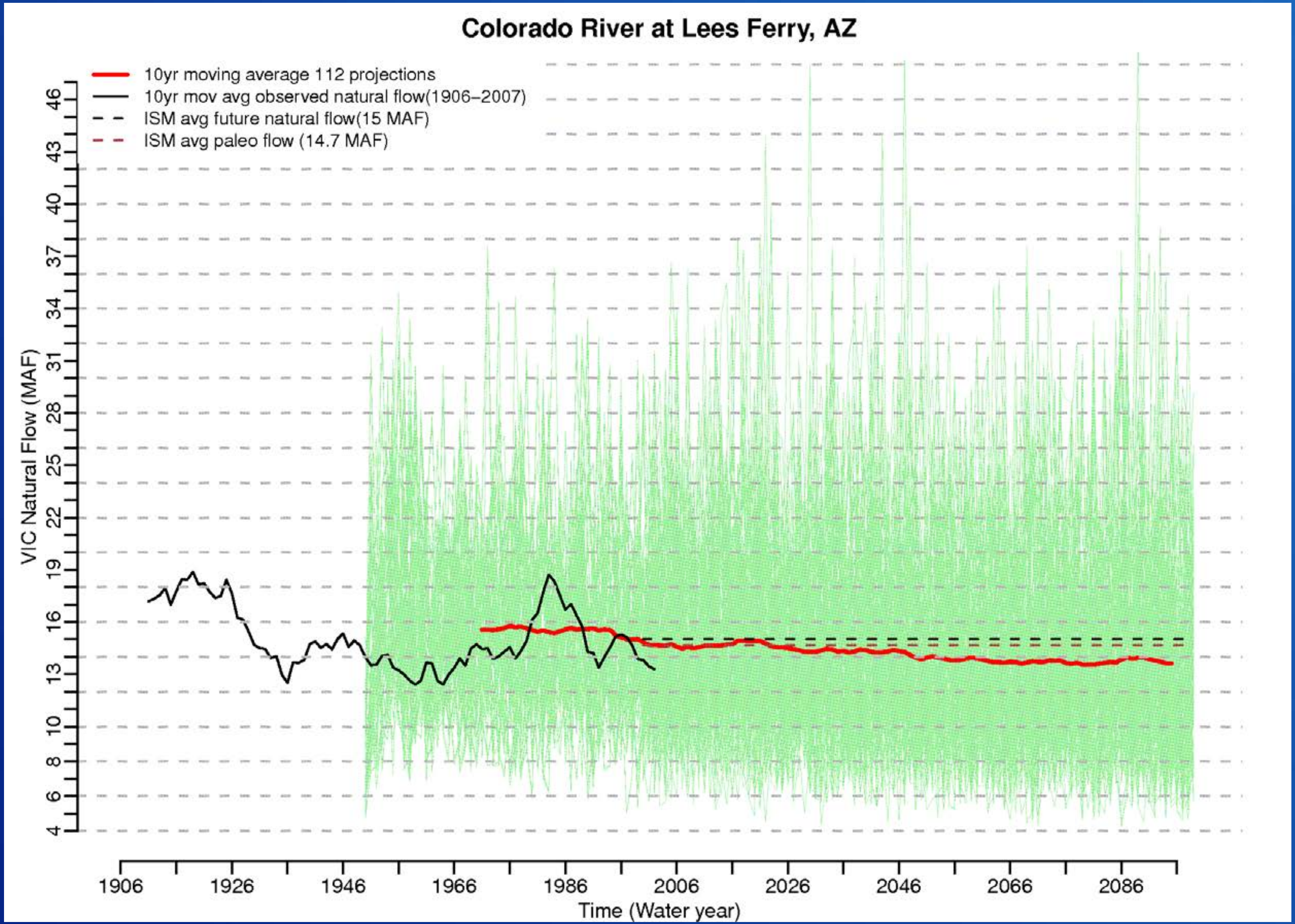
Systems Modeling

(112 traces)



RECLAMATION

Preliminary Results of 112 Inflow Projections



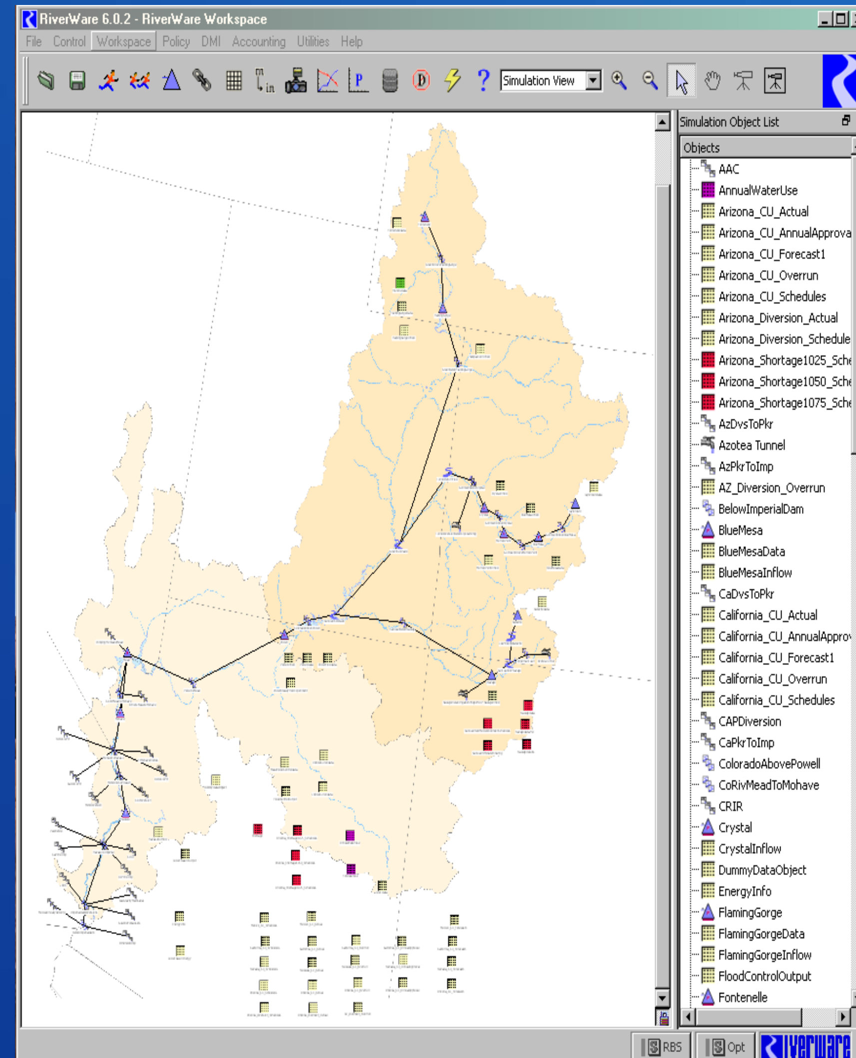
RECLAMATION

Mid-Term Probabilistic Operations Model (MTOM)

Motivation:

- Current 24-Month Study is a deterministic model
- Need to better quantify range of possible operations in the Colorado River Basin

- Simulate multiple traces for a probabilistic output and analysis
- Additional tool to evaluate risk and uncertainty in Colorado River Basin



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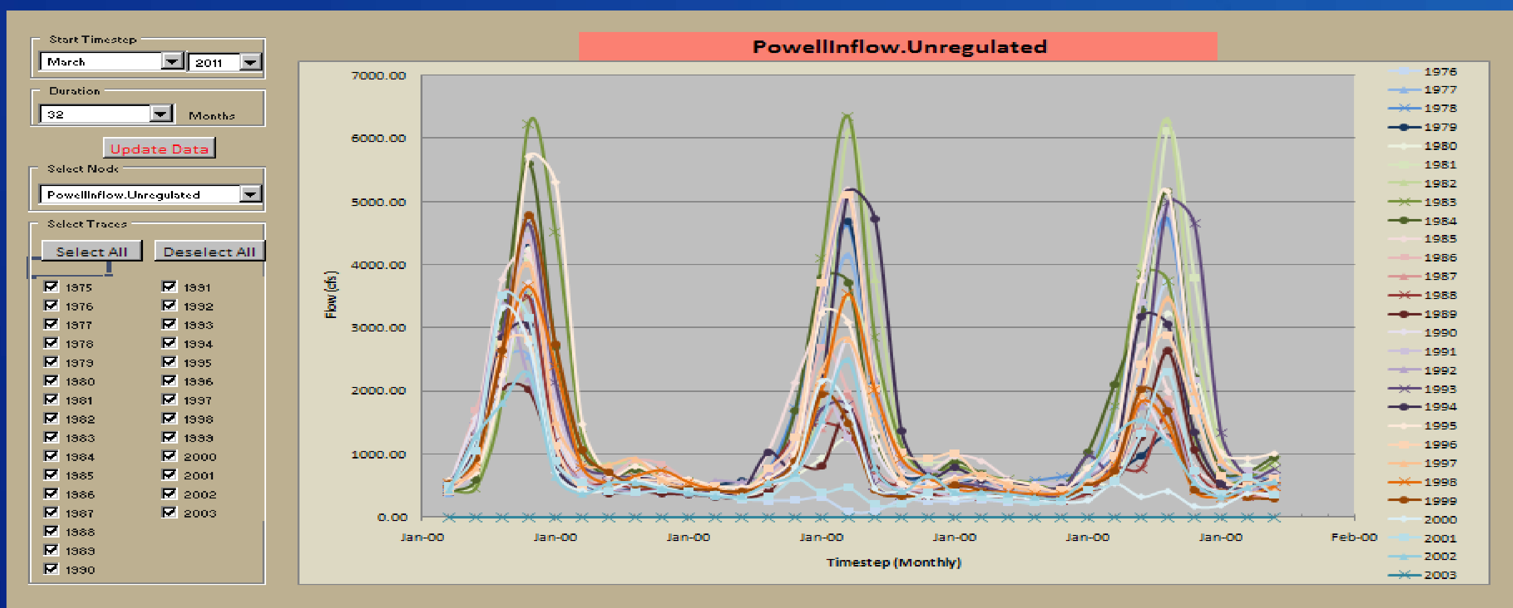
MTOM Inflows

- Model input consists of a range of probable inflows developed by CBRFC
  - CBRFC's ESP forecasts (28 traces) will drive first and second years of model
  - Ongoing research to develop forecasting techniques for beyond 2 years (2-10 yrs)



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For further information:
http://www.usbr.gov/lc/region

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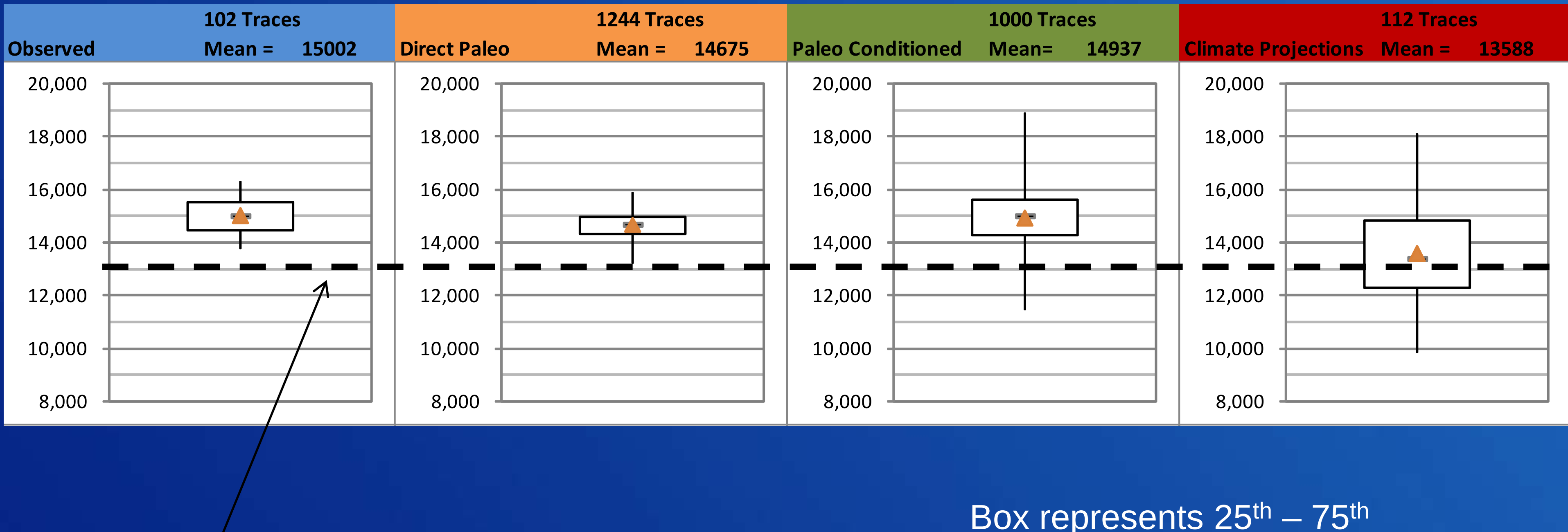
Extra Slides

Current Estimates of Natural Flow at Lees Ferry

2011 – 2060 Period Mean Annual Flows



1988 – 2007 period mean

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

Preliminary

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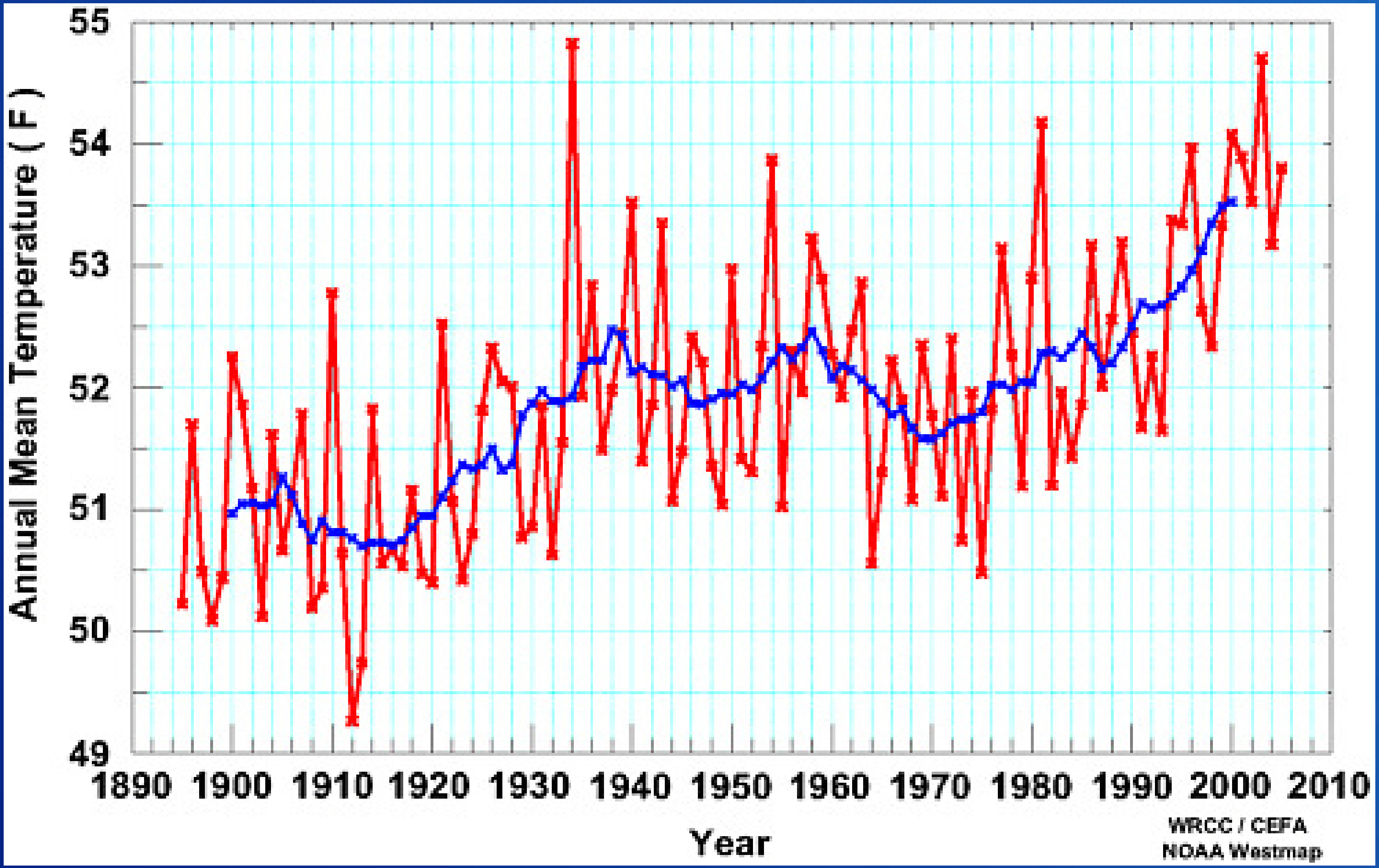
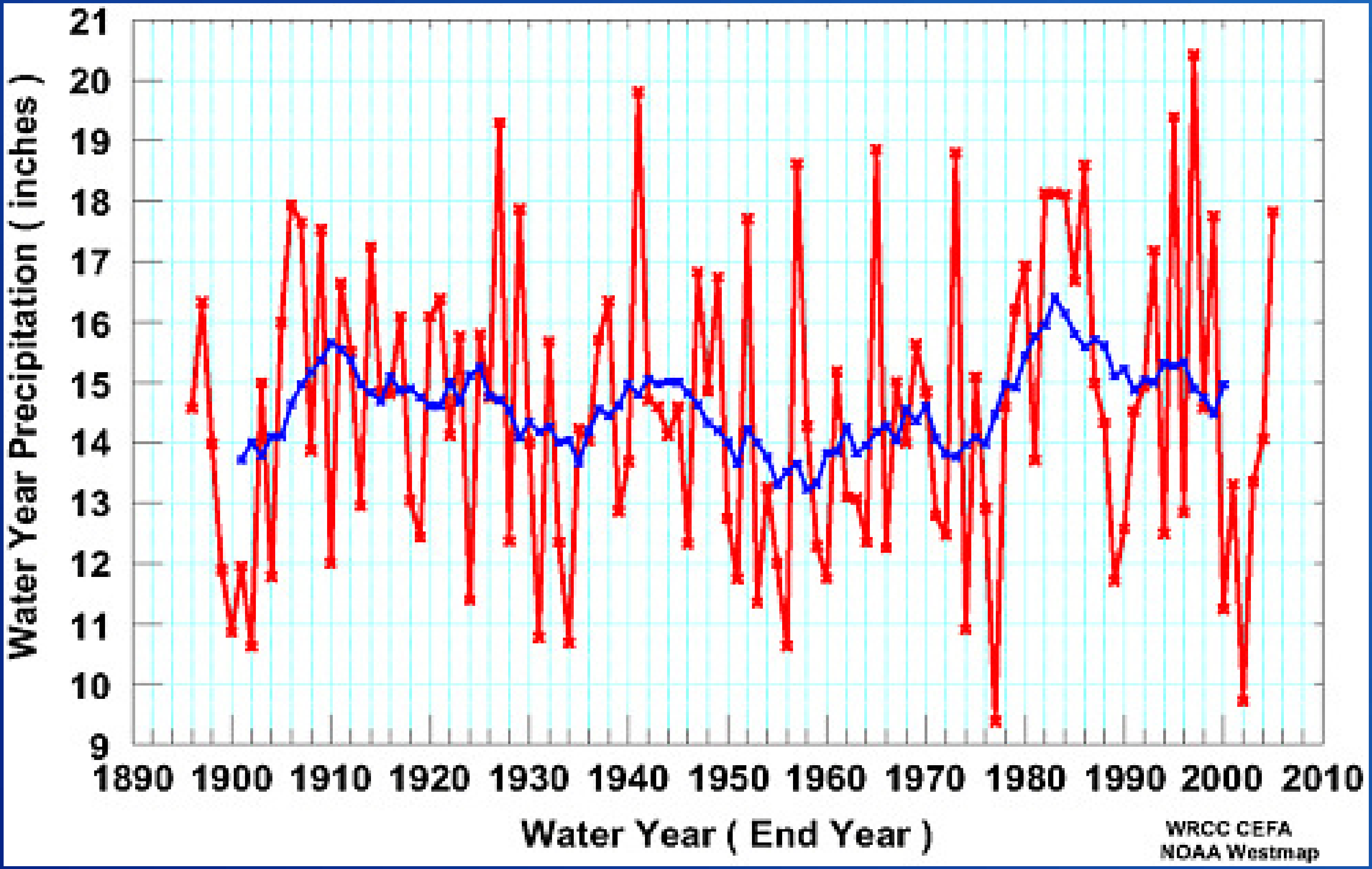
Average Annual Surface Air Temperature



RECLAMATION

Average Annual Precipitation above Lees Ferry



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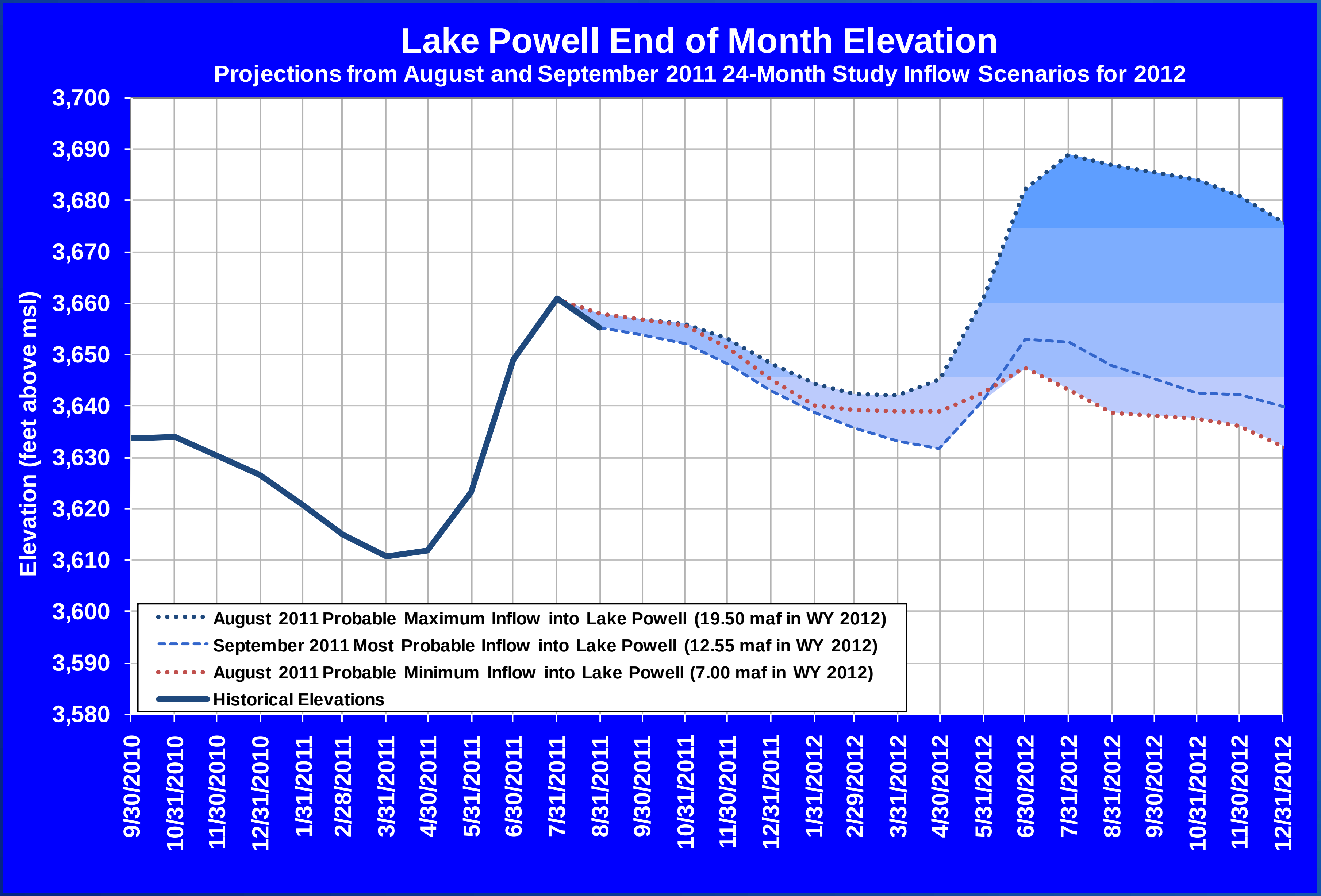

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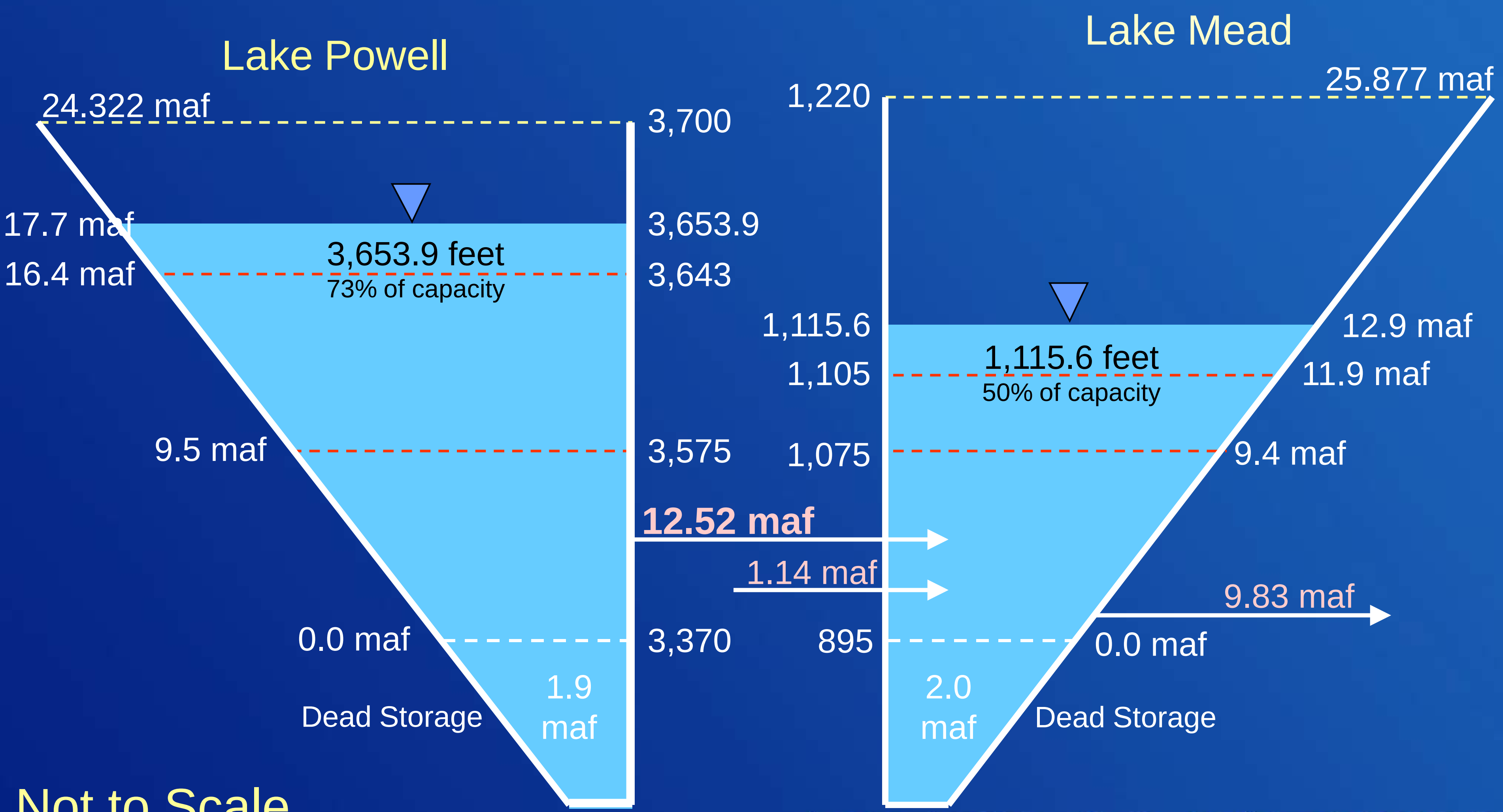
Water Year 2011 Projections

September 2011 24-Month Study Most Probable Inflow Scenario

Projected Unregulated Inflow into Powell[1] = 16.87 maf (140% of average)



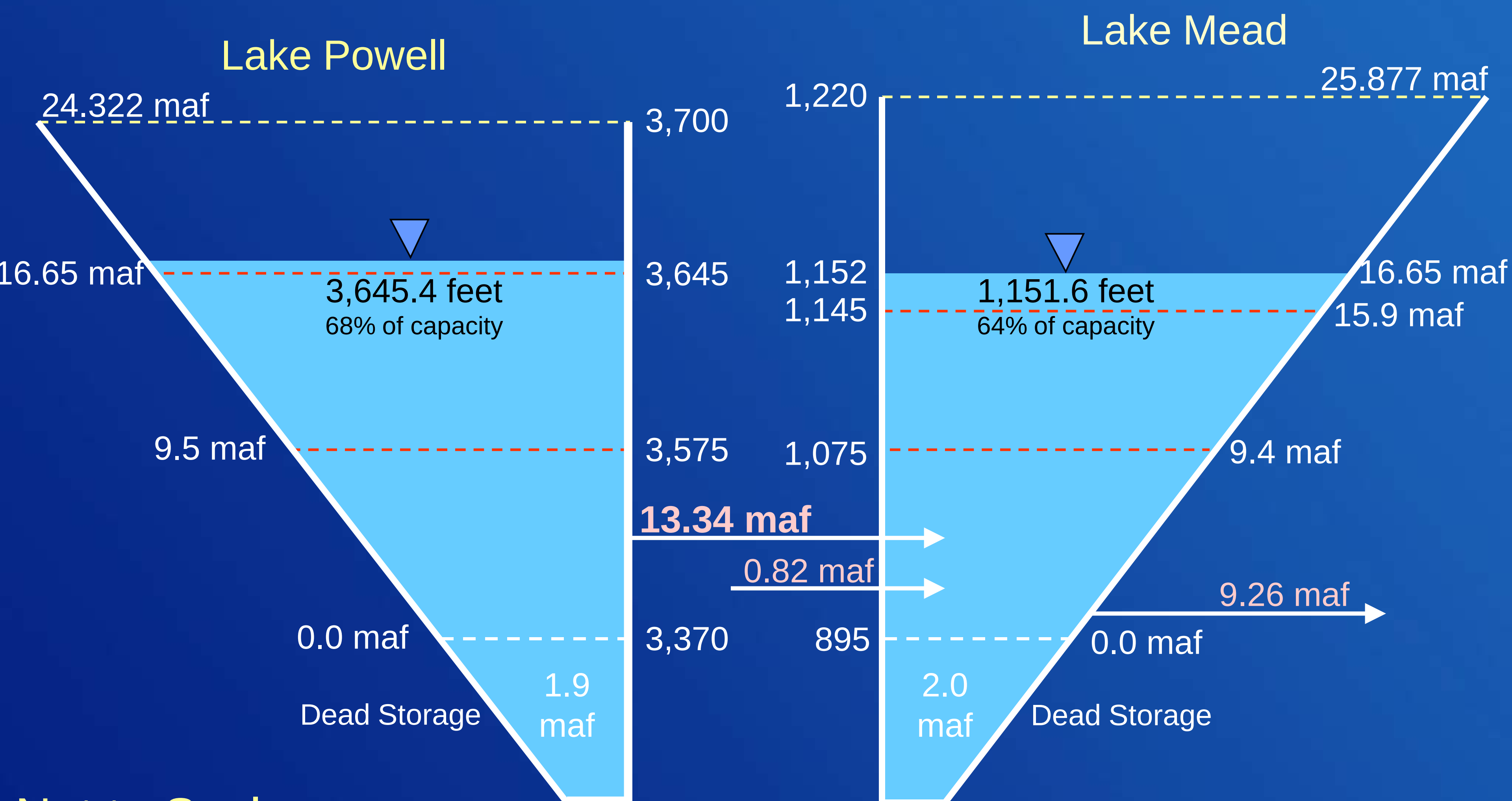
Not to Scale

[1] WY 2011 volume projected in the September 2011 24-Month Study is based on the CBRFC forecast dated September 1

Water Year 2012 Projections

September 2011 24-Month Study Most Probable Inflow Scenario

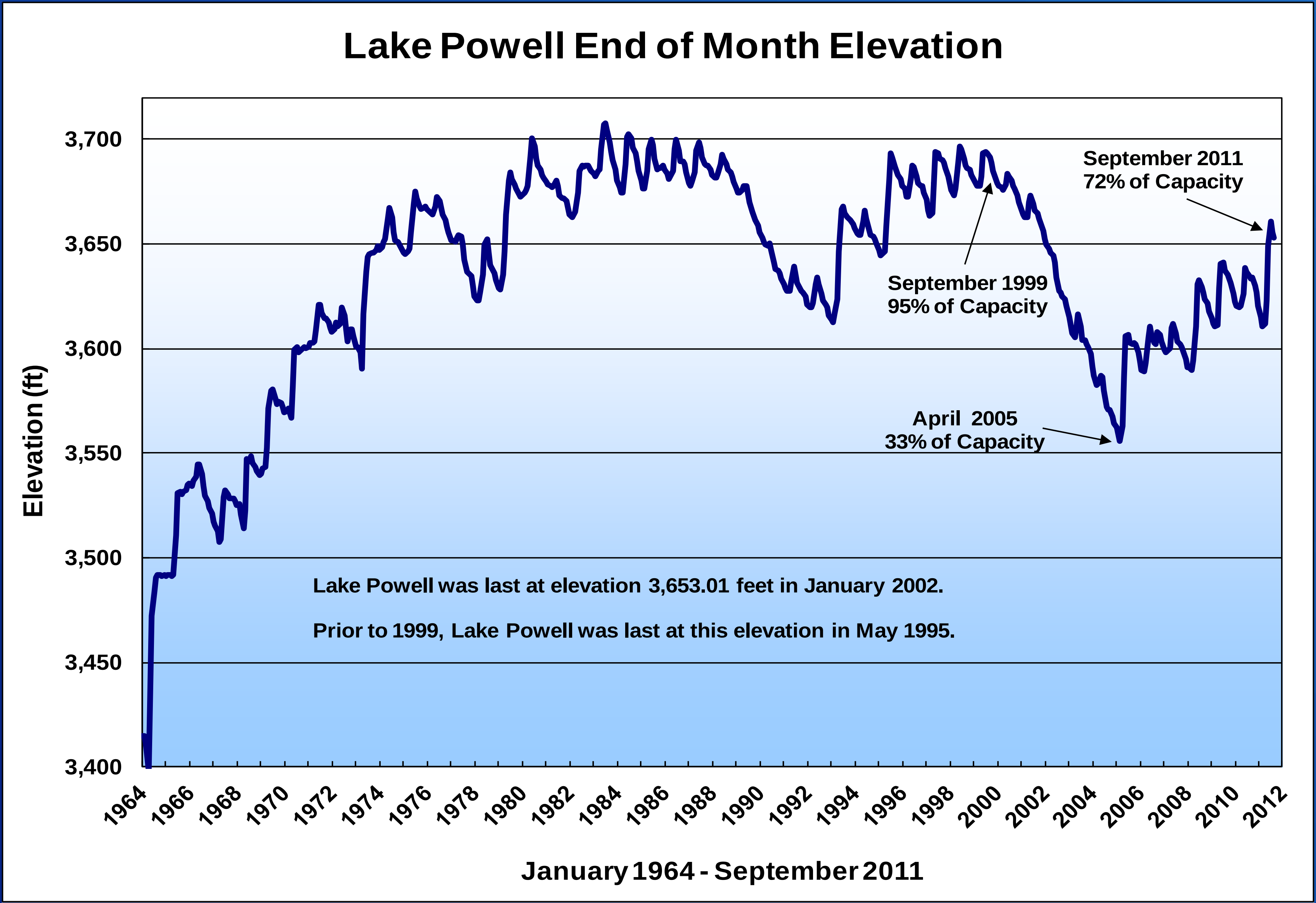
Projected Unregulated Inflow into Powell[1] = 12.55 maf (104% of average)



Not to Scale

[1] WY 2011 volume projected in the September 2011 24-Month Study is based on the CBRFC 2012 Outlook and forecast dated September 1

RECLAMATION



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Water Budget at Lake Mead

- Inflow = 9.0 maf
  (release from Powell + side inflows)
- Outflow = - 9.6 maf
  (AZ, CA, NV, and Mexico delivery
  + downstream regulation and gains/losses)
- Mead evaporation losses = - 0.6 maf
- Balance = - 1.2 maf

Given basic apportionments in the Lower Basin, the allotment to Mexico, and an 8.23 maf release from Lake Powell, Lake Mead storage declines 10 – 12 feet each year

Lake Powell Equalization Table

Water Year	Lake Powell Elevation (feet)
2008	3,636
2009	3,639
2010	3,642
2011	3,643
2012	**3,645**
2013	3,646
2014	3,648
2015	3,649
2016	3,651
2017	3,652
2018	3,654
2019	3,655
2020	3,657
2021	3,659
2022	3,660
2023	3,662
2024	3,663
2025	3,664
2026	3,666

Landscape Conservation Cooperatives (LCCs)

- Stakeholder partnership for sharing information and discussing science needs to ensure science-based adaptation and mitigation responses to potential impacts of climate change
- Partnering with Climate Science Centers throughout the U.S.
- Reclamation is co-lead with FWS in the Desert and Southern Rockies LCC

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Current Research and Development

- Two Reclamation groups work together to research and incorporate climate information into operations
  - Colorado River Hydrology Work Group
  - Colorado River Modeling Work Group
- Current Research under the Hydrology Work Group addresses recommendations of Climate Technical Work Group
  - Appendix U of the Shortage/Coordinated Operations Final EIS

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Current Research under the Hydrology Work Group

- Current Research Groups
  - University of Colorado/Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES)
  - Western Water Assessment (WWA)
  - University of Arizona (UA)
  - National Oceanic and Atmospheric Administration (NOAA)
  - AMEC Earth & Environmental
  - University of Nevada, Las Vegas (UNLV)

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Work Group Effort: *CU-CADSWES/WWA*

- "Review of Stochastic Streamflow Simulation at Interannual and Interdecadal Time Scales and Implications to Water Resources Management in the Colorado River Basin"
  - Seasonal scale forecasts: use large-scale climate, (e.g., ENSO, PDO, AMO)
  - Probabilistic mid-term operations model
  - Interdecadal scale: multivariate frequency domain technique (Kwon et al. 2007)
  - Explore adaptive management strategies at both time scales

Work Group Effort: *UA*

- "Enhancing Water Supply Reliability Through Improved Predictive Capacity and Response"
  - Develop tree-ring reconstruction of Lower Basin tributaries and explore incorporation in 24-Month Study
  - Develop a tool to improve seasonal to interannual forecasting that links SST and SLP to hydroclimate at the sub-basin scale
  - Develop a "best practices guidebook" summarizing forbearance program features

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Work Group Effort: *Post Docs Applying Climate Expertise (PACE) Program*

- NOAA / Reclamation / SNWA
  - Co-sponsorship of post-doc with SNWA to test skill of GCMs in projecting precipitation and impact of data variations on runoff
  - Completed May 2010
- NOAA / Reclamation
  - Explore high elevation changes due to climate change
  - Compare downscaling methods and uncertainty
    - Simple vs. Statistical vs. Dynamical
  - Explore impacts to decision making

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Work Group Effort: *AMEC Earth & Environmental*

- Nonparametric framework for paleo streamflow reconstruction
- Generate 112 transient runoff sequences from climate projections using the Variable Infiltration Capacity (VIC) model

amec

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Work Group Effort: *UNLV*

- Compare trends in precipitation and streamflow in the Colorado River Basin (Miller and Piechota 2008)
- Make use of recently available downscaled climate projections to develop projected runoff using CBRFC hydrologic model (Miller et al., 2010)
- Incorporate projections of streamflow into operational and planning models (Miller et al., 2011)
- Improve out-year forecasting and relationship with teleconnections (Lamb et al., 2011)

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

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Climate Projections

- Global Climate (or Circulation) Models (GCMs)
- Large scale, 2 degree (~200 km) gridded results
- Need for downscaling
  - Hydrologic models
  - Basin scale

Need for downscaling

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Santa Clara University CLIMATE CENTRAL
SCRIPPS INSTITUTION OF OCEANOGRAPHY

Bias Corrected and Downscaled WCRP CMIP3 Climate and Hydrology Projections

This site is best viewed with Chrome (recommended) or Firefox. Some features are unavailable when using Internet Explorer. Requires JavaScript to be enabled.

Summary

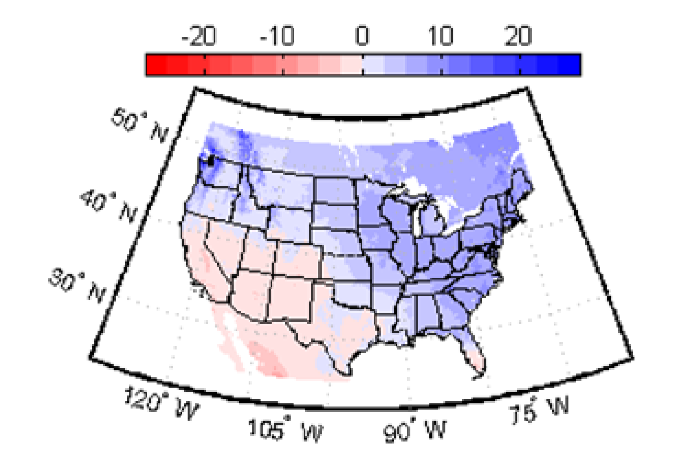
This archive contains fine spatial-resolution translations of:

- climate projections over the contiguous United States (U.S.) developed using two downscaling techniques (monthly BCSD Figure 1, and daily BCCA Figure 2), and
- hydrologic projections over the western U.S. (roughly the western U.S. Figure 3) corresponding to the monthly BCSD climate projections.

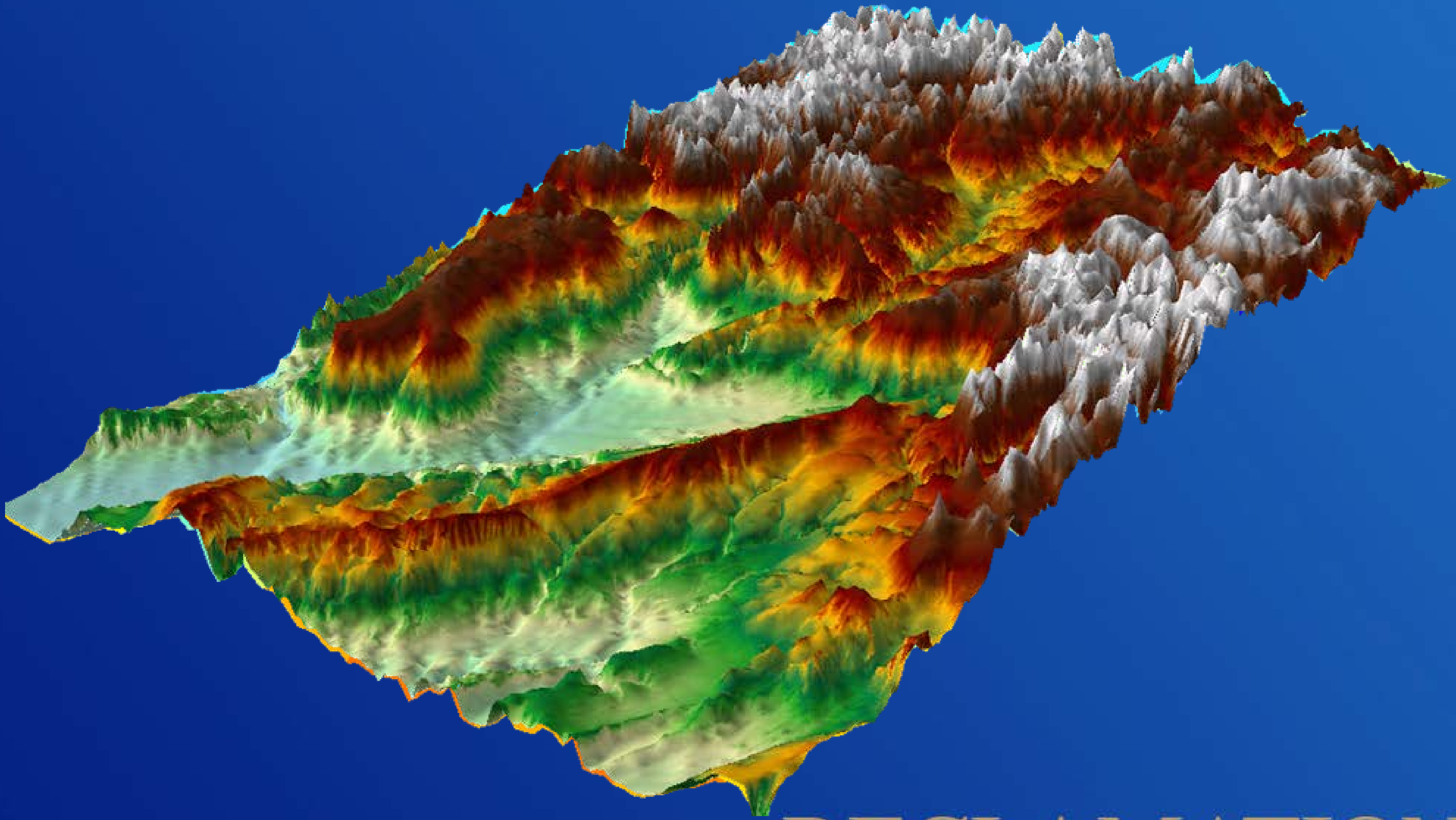
Archive content is based on global climate projections from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. Please see the "About" page for information on projection development, including the methodology to perform climate model bias-correction and spatial downscaling.

Purpose

Figure 1: BCSD CMIP3 Monthly Climate Analysis example - Median projected change in average-annual precipitation (cm/year), 2041-70 versus 1971-2000.



Need for downscaling



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