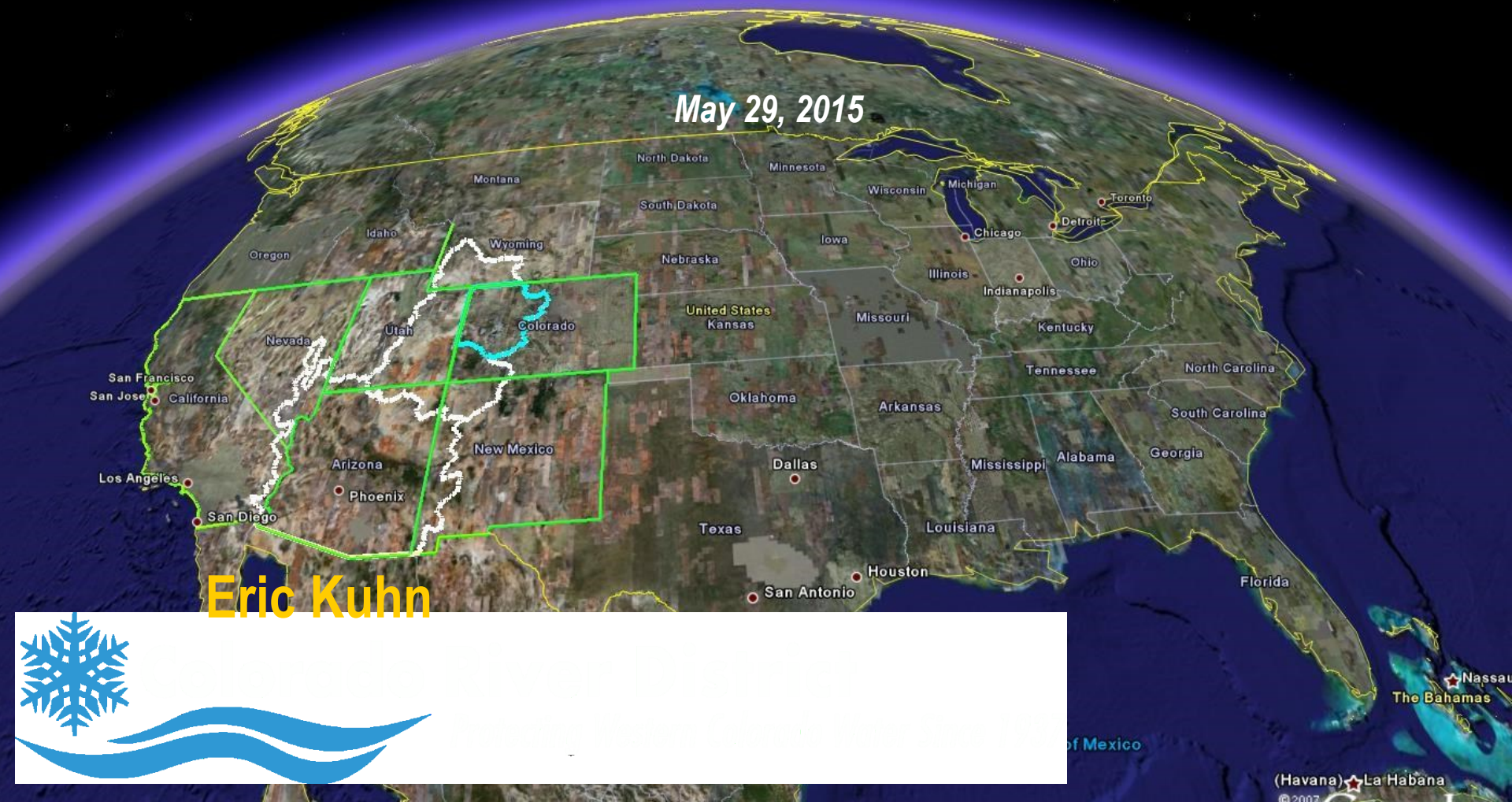


# Prediction needs of a Complicated River





# Law of the River Allocations

- 7.5 MAF to Upper Basin ( %'s)<sup>1</sup>
- 7.5 MAF to Lower Basin (4.4 CA; 2.8 AZ; 0.3 NV)<sup>2</sup>
- 1.0 MAF additional to Lower Basin<sup>3</sup>  
(i.e., tributary development)
- 1.5 MAF to Mexico<sup>4</sup>

**17.5 MAF Total Allocated 'on paper'**

<sup>1</sup> 1922 Colorado River Compact, 1948 Upper Colorado River Compact

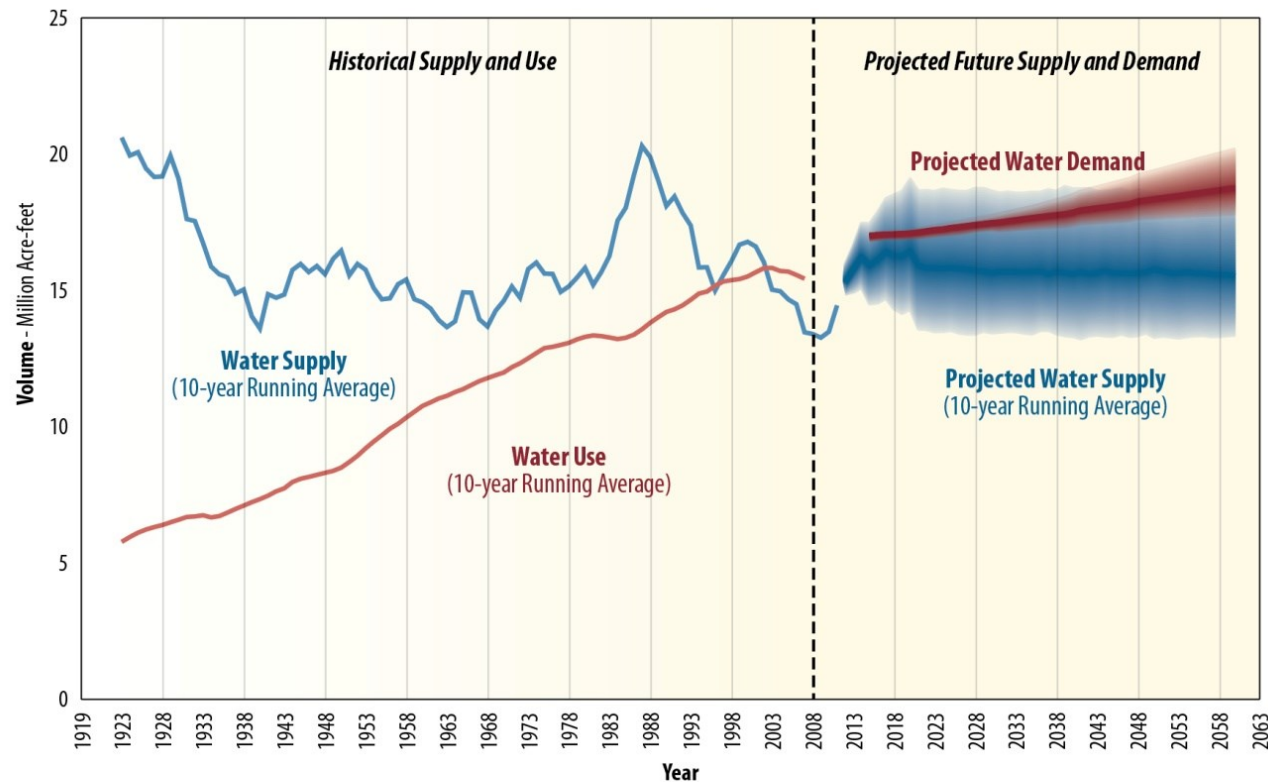
<sup>2</sup> Colorado River Compact, 1929 Black Canyon Project Act, 1964 AZ v. CA

<sup>3</sup> 1922 Colorado River Compact

<sup>4</sup> Treaty of 1944

# 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



## 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.

# SOME BASIC HYDROLOGY FOR LEES FERRY

- 1. 1906-2014 MEAN NATURAL FLOW - 14.82 MAF/YR
- 2. 2000-2014 MNF - 12.33 MAF/YR (83% OF 1906-2014)
- 3. 1988-2014 MNF - 13.19 MAF/YR (89% OF 1906 -2014)
- 4. 1953-2014 MNF - 13.90 MAF/YR (94% OF 1906 -2014)
- 5. AMO NEGATIVE – 16.23 MAF/YR (89% OF 1906 -2014)
- 6. AMO POSITIVE - 13.20 MAF/YR (110% OF 1906-2014)
- 7. 1118-1178 (MEKO, ET AL) – 12.7-13.2 MAF/YR (85-90%)
- 8. 1622-1671 (MEKO, ET AL) – 13.2-13.7 MAF/YR (90%)
- 9. THE BASIN STUDY (USBR) CC HYDROLOGY USED A 9% REDUCTION AT LEES FERRY -13.67 MAF/YR IN 2050 USING CMIP-3, NO CMIP-5 FLOWS AVAILABLE



# COLORADO RIVER BASIN

- Every drop of water is used
- Total storage exceeds 4 times the annual mean discharge
- Sophisticated & complex management
- Connected to the Sac – SJ Delta via MWD
- Exports are a major use
- 2007 Interim Guidelines
- Natural Flow Data Base
- CDSS
- 24 Month Study



OUTFLOW

>

INFLOW

Upper Basin



Lake  
Powell

*normal year operations releases from Lake Powell = 8.25 million acre-feet(maf) / year*

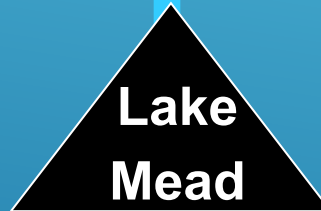
7.5 maf for Lower Basin

0.75 maf for Mexico

+ 8.23 maf from Lake Powell  
+ 0.02 maf Paria River

Colorado River Compact measuring point at Lee Ferry

Lower Basin



Lake  
Mead

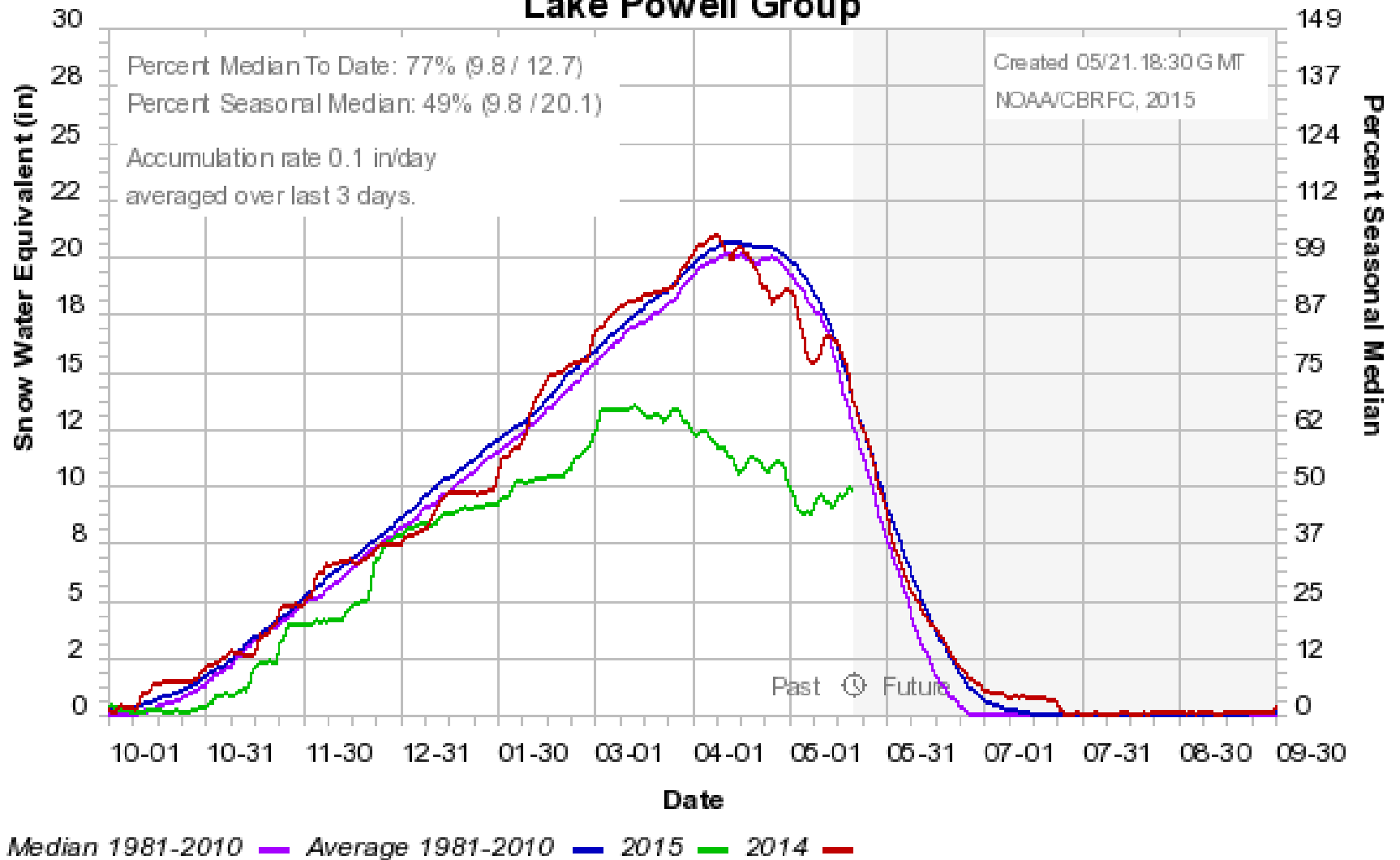
- 0.3 maf Nevada
- 4.4 maf California
- 2.8 maf Arizona
- 1.5 maf Mexico
- 1.0 maf losses

+ 0.75 maf tributary inflow

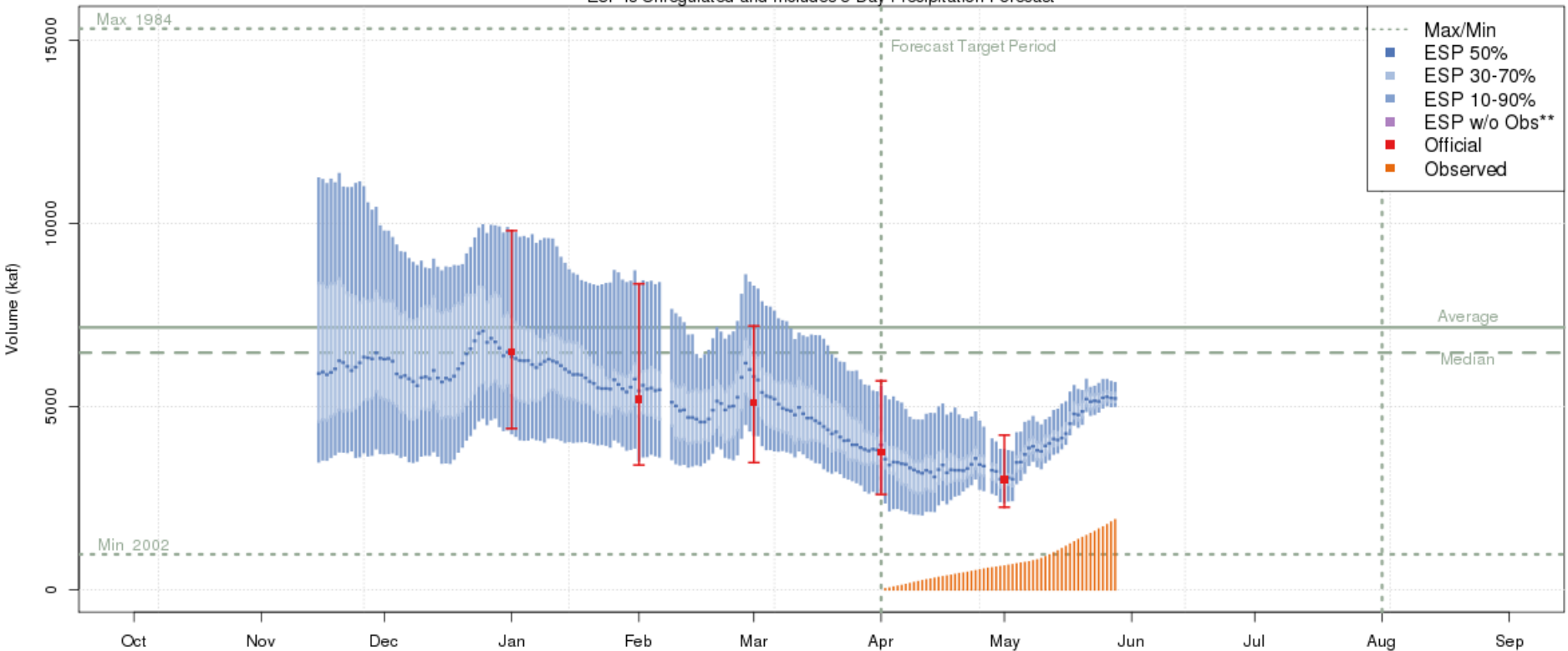
= 10.0 maf/year OUTFLOW

= 9.0 maf/year INFLOW

# Colorado Basin River Forecast Center Lake Powell Group



**Colorado - Lake Powell- Glen Cyn Dam- At (GLDA3)**  
**2015-05-01 Apr-Jul Official 50% Forecast: 3000 kaf (42% of average)**  
 ESP is Unregulated and Includes 5 Day Precipitation Forecast



**The latest (2015-05-28) 50% ESP forecast is 5220 kaf.**  
 Plot Created 2015-05-28 14:05:09, NOAA / NWS / CBRFC  
 Forecasts in the forecast target period include observed values.



# 2000-2015 WATER BUDGET

- SUPPLY – 13 MAF/YR (12.3 LF +.7 LB)
  - USE – 15+ MAF/YR (ignoring Gila)
  - DEFICIT – 2+ MAF/YR
- 
- 12/1999 MEAD + POWELL > 50 MAF
  - 12/2015 MEAD + POWELL < 18 MAF



Colorado  
Department of  
Water Resources

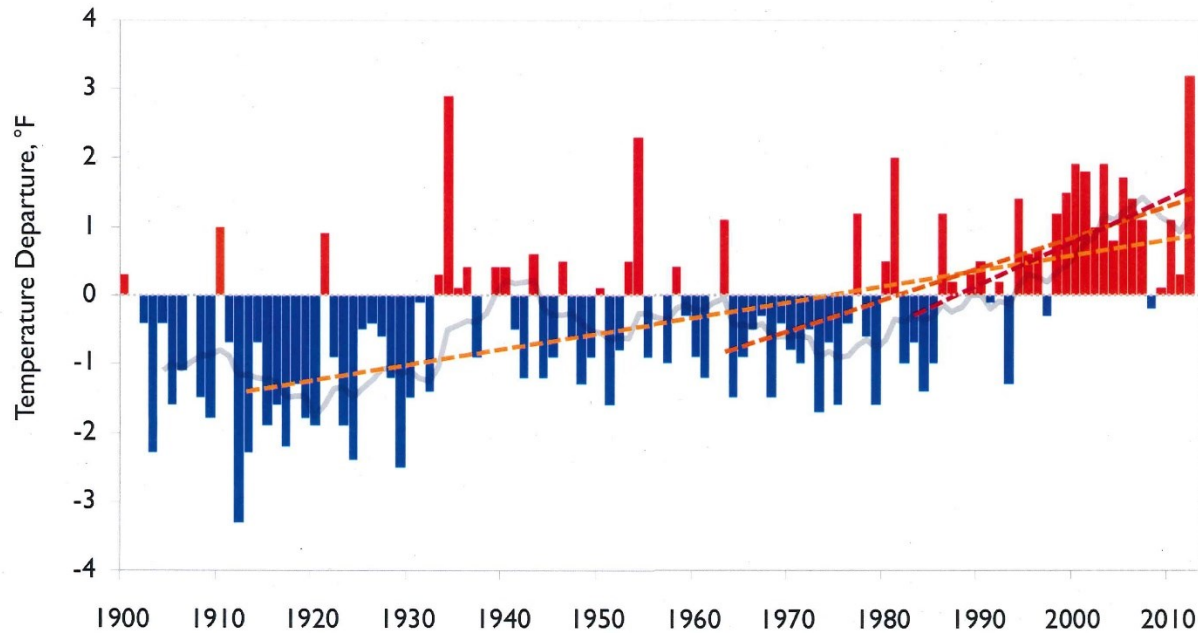
# FINDINGS FROM CHAPTER 5

## ■ COLORADO RIVER AT LEES FERRY

- PRECIPITATION CHANGE 2001-2010 V 1901-2000    -4%
- TEMPERATURE CHANGE 2001-2010 V 1901-2000    +0.7 C
- STREAMFLOW CHANGE 2001-2010 V 1901-2000    -16%
- “THE MOST SEVERE AND SUSTAINED PALEODROUGHTS OCCURRED DURING THE MCA FROM 900-1350, WERE ASSOCIATED WITH HIGH TEMPERATURES IN THE SOUTHWEST, AND... . LIKELY CAUSED BY PERSISTENTLY COOL LA NINAS”
- “OVERALL THE 20<sup>TH</sup> CENTURY EXPERIENCED LESS DROUGHT THAN MOST OF THE PRECEDING 4 TO 20 CENTURIES”
- NOTE; SIMILAR TRENDS FOR THE SACRAMENTO, RIO GRANDE & HUMBOLT RIVERS



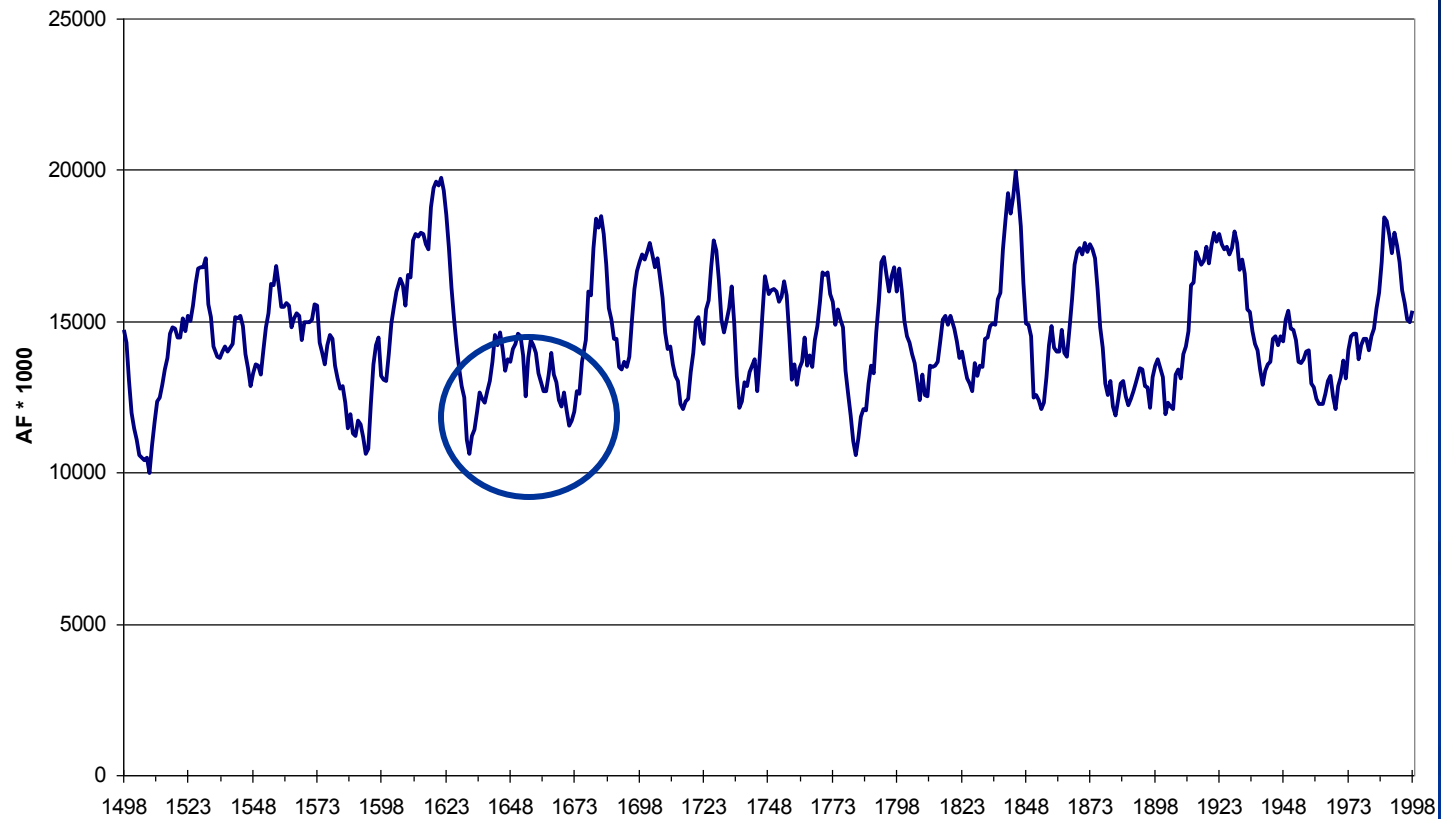
## Colorado has warmed significantly, 2° F over the past 30 years

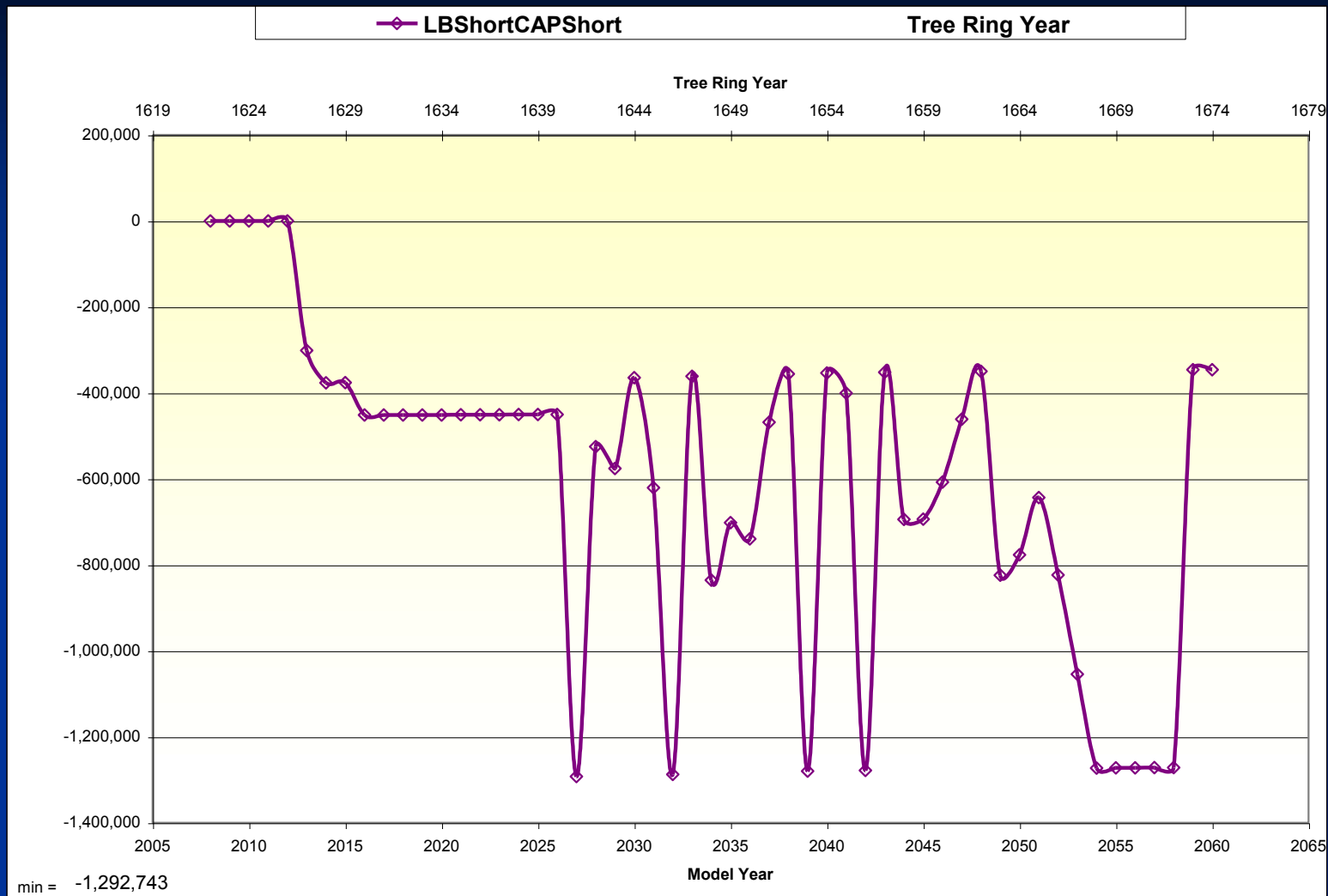


Observed

Figure ES-1 & 2-8

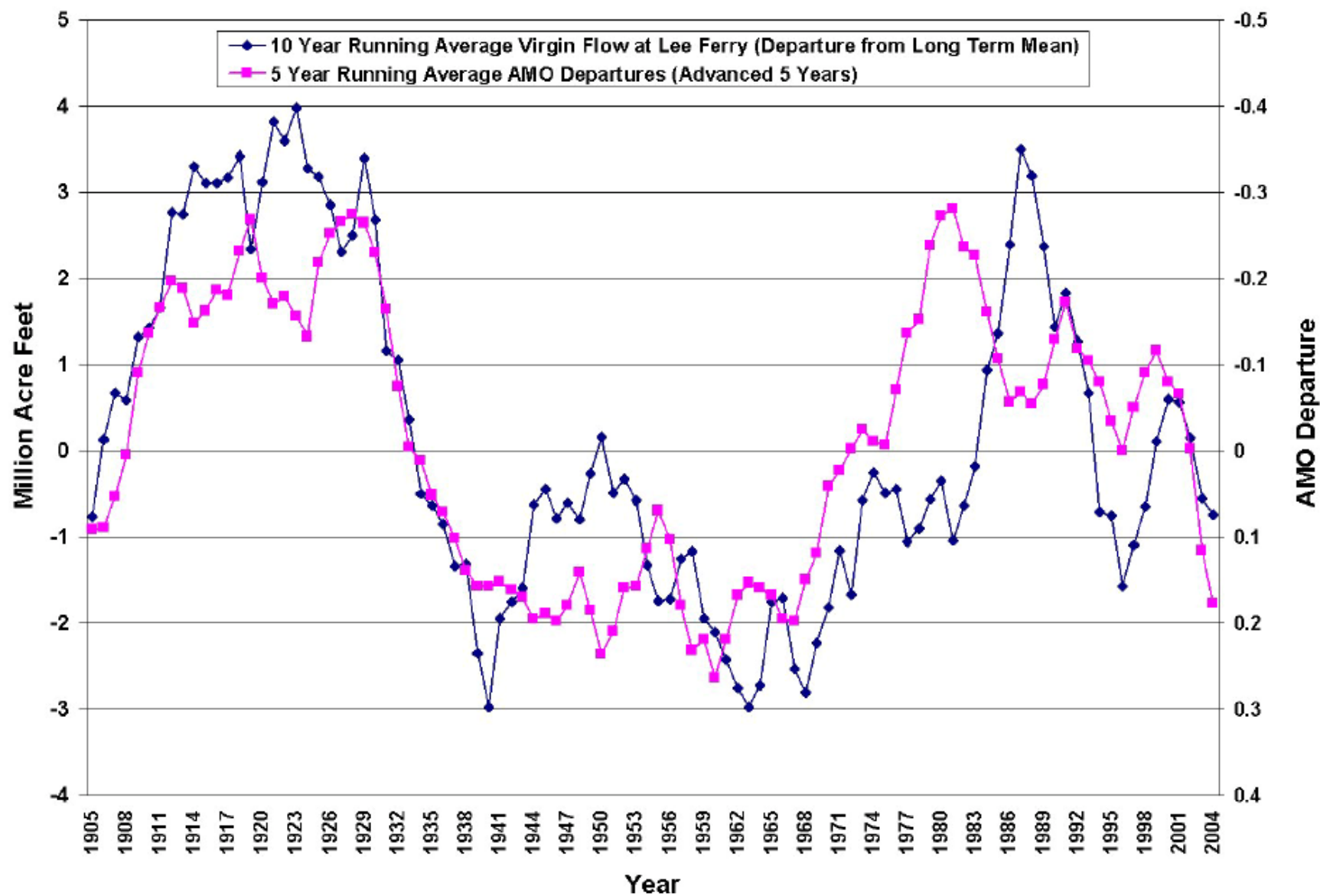
**Paleo Reconstruction - LEES "B"**  
**10 YEAR MOVING AVERAGE**





WATER QUALITY  
ANALYSIS

# Atlantic Ocean Impact on Colorado River Flows



# Percent of Traces with Event or System Condition

## Results from April 2015 CRSS<sup>1,2,3</sup> (values in percent)

|                           | Event or System Condition                                                                 | 2016      | 2017          | 2018      | 2019      | 2020      |
|---------------------------|-------------------------------------------------------------------------------------------|-----------|---------------|-----------|-----------|-----------|
| Upper Basin – Lake Powell | <b>Equalization Tier</b>                                                                  | <b>1</b>  | <b>16</b>     | <b>17</b> | <b>24</b> | <b>25</b> |
|                           | <i>Equalization – annual release &gt; 8.23 maf</i>                                        | 1         | 16            | 17        | 23        | 23        |
|                           | <i>Equalization – annual release = 8.23 maf</i>                                           | 0         | 0             | 0         | 1         | 2         |
|                           | <b>Upper Elevation Balancing Tier (Powell &lt; Eq level and ≥ 3,575 ft)</b>               | <b>42</b> | <b>47</b>     | <b>53</b> | <b>49</b> | <b>44</b> |
|                           | <i>Upper Elevation Balancing – annual release &gt; 8.23 maf</i>                           | 29        | 44            | 44        | 42        | 35        |
|                           | <i>Upper Elevation Balancing – annual release = 8.23 maf</i>                              | 13        | 3             | 8         | 7         | 9         |
|                           | <i>Upper Elevation Balancing – annual release &lt; 8.23 maf</i>                           | 0         | 0             | 1         | 0         | 0         |
|                           | <b>Mid-Elevation Release Tier (Powell &lt; 3,575 and ≥ 3,525 ft)</b>                      | <b>57</b> | <b>35</b>     | <b>20</b> | <b>15</b> | <b>16</b> |
|                           | <i>Mid-Elevation Release – annual release = 8.23 maf</i>                                  | 0         | 0             | 0         | 0         | 2         |
|                           | <i>Mid-Elevation Release – annual release = 7.48 maf</i>                                  | 57        | 35            | 20        | 15        | 14        |
|                           | <b>Lower Elevation Balancing Tier (Powell ≤ 3,525 ft)</b>                                 | <b>0</b>  | <b>2</b>      | <b>10</b> | <b>12</b> | <b>15</b> |
| Lower Basin – Lake Mead   | <b>Powell below Minimum Power Pool (Powell ≤ 3,490 ft)</b>                                | <b>0</b>  | <b>&lt; 1</b> | <b>8</b>  | <b>9</b>  | <b>10</b> |
|                           | <b>Shortage Condition – any amount (Mead ≤ 1,075 ft)</b>                                  | <b>33</b> | <b>75</b>     | <b>74</b> | <b>70</b> | <b>66</b> |
|                           | <i>Shortage – 1<sup>st</sup> level (Mead ≤ 1,075 and ≥ 1,050)</i>                         | 33        | 71            | 45        | 36        | 29        |
|                           | There are no occurrences of a 10-year compact volume < 75 MAF assuming historic hydrology |           |               |           |           |           |
|                           | <b>Surplus Condition – any amount (Mead ≥ 1,145 ft)</b>                                   | <b>0</b>  | <b>0</b>      | <b>3</b>  | <b>6</b>  | <b>10</b> |
|                           | <i>Surplus – Flood Control</i>                                                            | 0         | 0             | 0         | 1         | 2         |
|                           | <b>Normal or ICS Surplus Condition</b>                                                    | <b>67</b> | <b>25</b>     | <b>23</b> | <b>24</b> | <b>24</b> |

<sup>1</sup> Reservoir initial conditions based on results from 30 simulations of December 31, 2015 conditions using the Mid-term Probabilistic Operations Model.

<sup>2</sup> Each of the 30 initial conditions were coupled with 107 hydrologic inflow sequences based on resampling of the observed natural flow record from 1906-2012 for a total of 3,210 traces analyzed.

<sup>3</sup> Percentages shown may not be representative of the full range of future possibilities that could occur with different modeling assumptions.

# RECLAMATION

# CONTINGENCY PLANNING

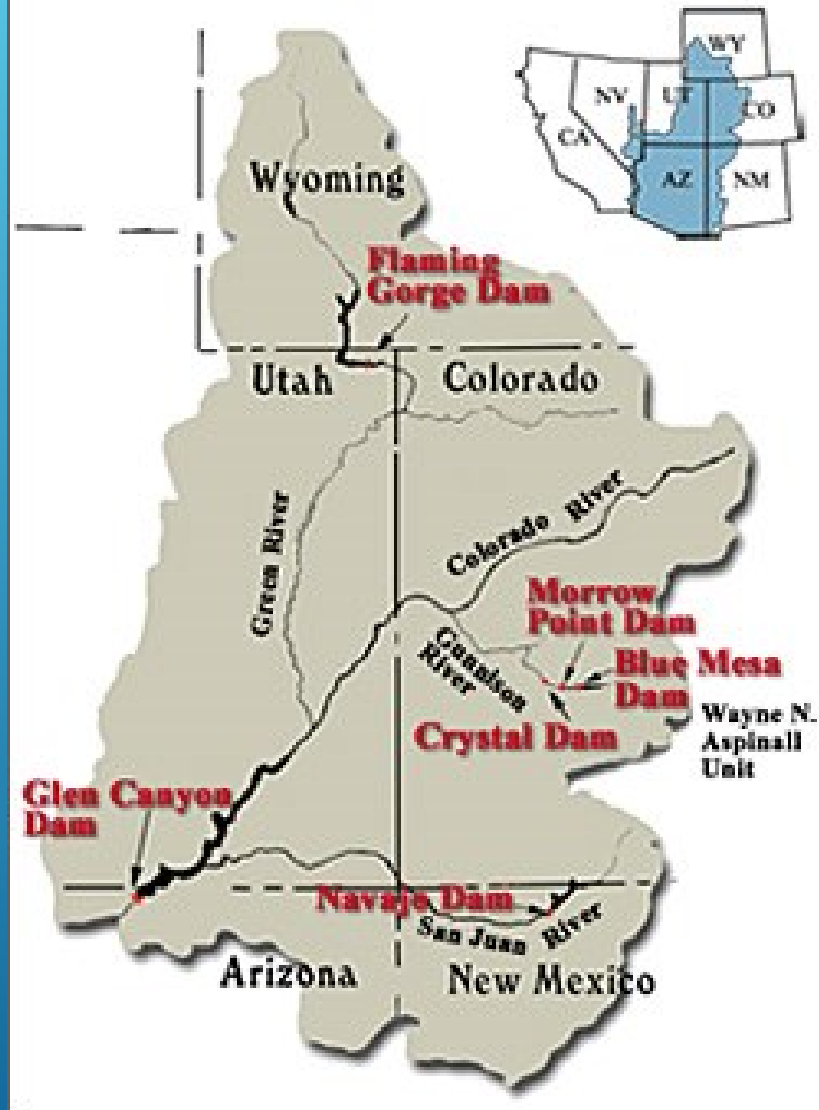
- ▶ Challenge from Interior:
    - ▶ What if the current drought were to continue into the future?
    - ▶ Have a plan in place by 2015 (MOA or similar)
  - ▶ The Goal:
    - ▶ Identify actions that can “bend the curve”, i.e., reduce the risk of losing power production or being unable to deliver water
  - ▶ Possible Solutions:
    - ▶ **Extended Operation of CRSP reservoirs**
    - ▶ **Demand Management**
    - ▶ Cloud seeding / other augmentation
- 
- Several white lines of varying lengths and angles are positioned in the bottom right corner of the slide, creating a modern, abstract graphic element.

# LAKE POWELL RELEASES

- ▶ Controlled by the 2007 Interim Guidelines
- ▶ Based on storage levels in both Powell AND Mead
- ▶ What happens in the LB impacts Powell and what happens in the UB impacts Mead
- ▶ As long as Powell has storage – NO compact problems for UB

| Lake Powell Operational Tiers<br>(subject to April adjustments or mid-year review modifications) |                                                                                                                                                           |                                     |
|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| Lake Powell Elevation<br>(feet)                                                                  | Lake Powell Operational Tier                                                                                                                              | Lake Powell Active Storage<br>(maf) |
| 3,700                                                                                            | <b>Equalization Tier</b><br>equalize, avoid spills or release 8.23 maf                                                                                    | 24.32                               |
| 3,636 – 3,666<br>(see table below)                                                               | <b>Upper Elevation Balancing Tier</b><br>release 8.23 maf;<br>if Lake Mead < 1,075 feet,<br>balance contents with a min/max release of<br>7.0 and 9.0 maf | 15.54 – 19.29<br>(2008 – 2026)      |
| 3,575                                                                                            | <b>Mid-Elevation Release Tier</b><br>release 7.48 maf;<br>if Lake Mead < 1,025 feet,<br>release 8.23 maf                                                  | 9.52                                |
| 3,525                                                                                            | <b>Lower Elevation Balancing Tier</b><br>balance contents with a min/max release of<br>7.0 and 9.5 maf                                                    | 5.93                                |
| 3,370                                                                                            |                                                                                                                                                           | 0                                   |

## Colorado River Storage Project Mainstem Units

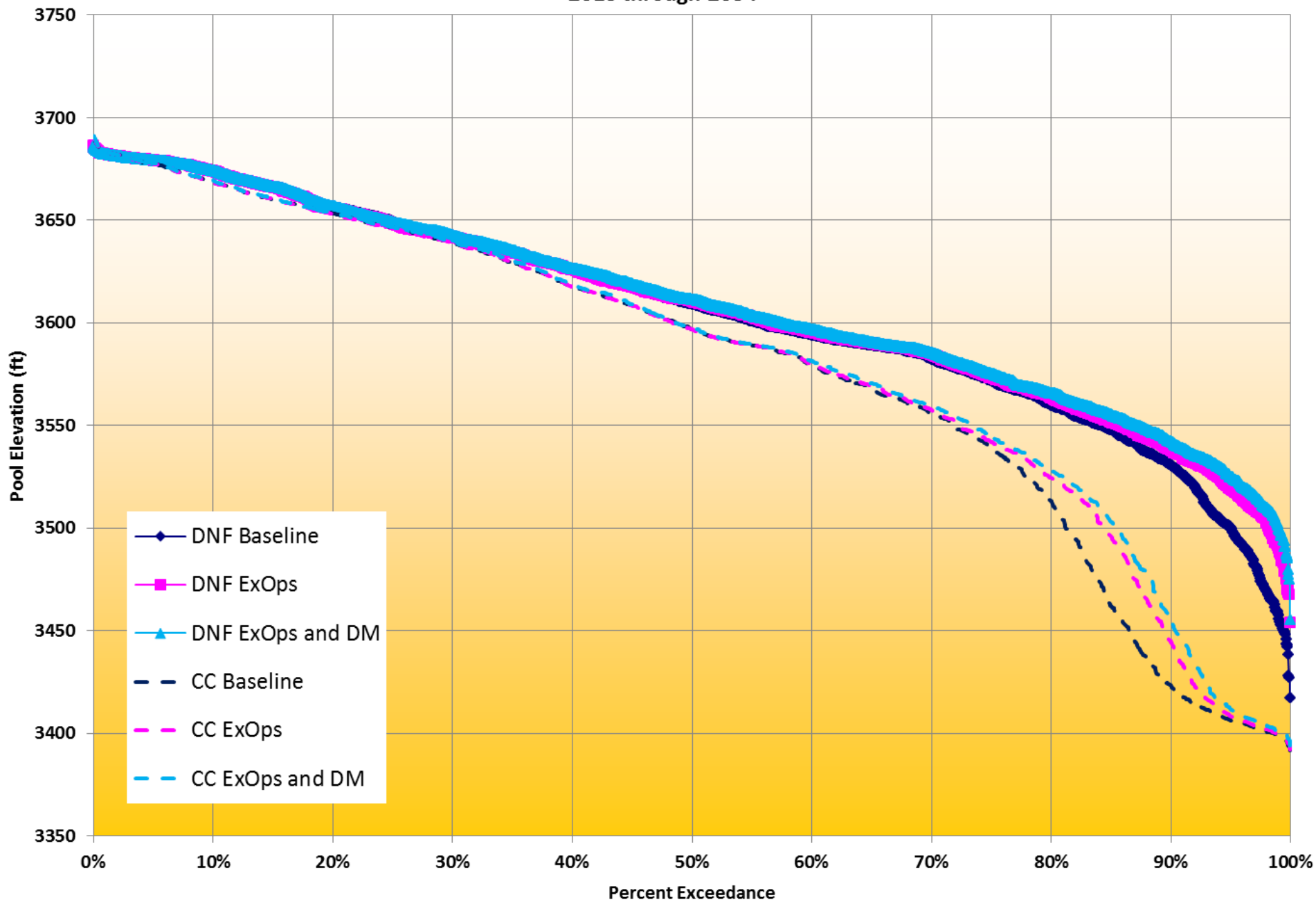


# BASELINE RUN: POWELL POOL ELEVATION

- ▶ In our “continuing drought” runs, Powell is below power pool almost 20% of the time
- ▶ Powell drops below 3490 in **19 of 20 traces**, and as early as 2018.



Powell Elevation - Climate Change  
2015 through 2034



# KEY WORDS

- SEAMLESS
- TRANSITIONS
- MULTI-DECADAL
- PERSISTENCE
- ALL COMES DOWN TO PRECIPITATION
- SEASONAL
- EL NINO GRANDE
- TEMPERATURE
- BOTTOM LINE – A RISING TIDE LIFTS ALL BOATS!



# THE SOURCE.

Colorado Rocky Mountains



[www.ColoradoRiverDistrict.org](http://www.ColoradoRiverDistrict.org)



Photo credit: NOAA