California Drought Perspective

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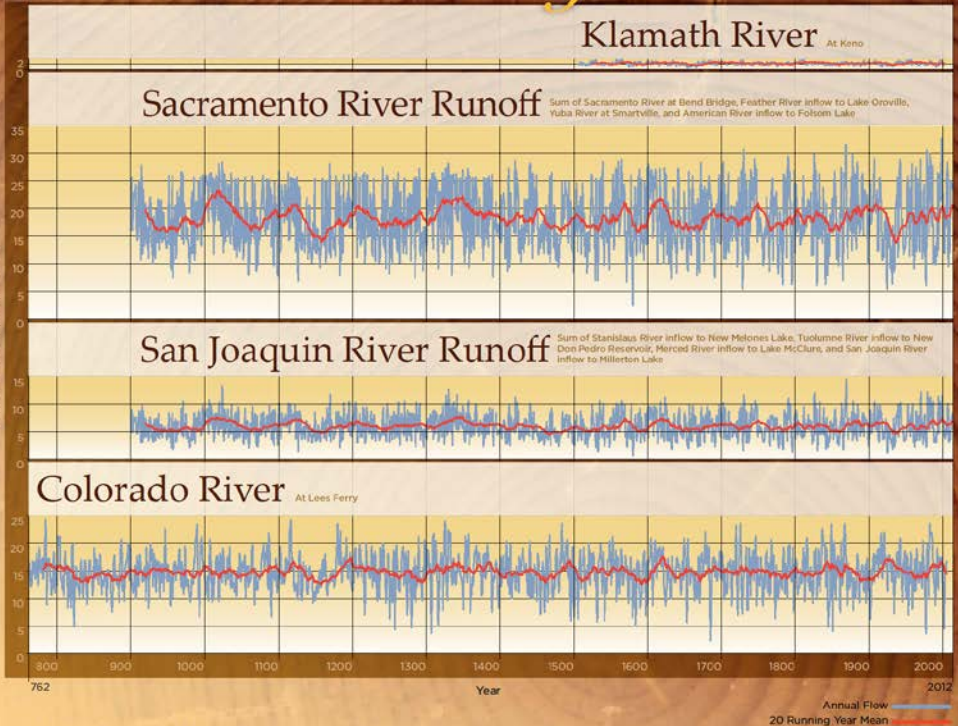
Reconstructed Streamflows & Drought Periods



USING TREE-RINGS TO RECONSTRUCT STREAMFLOW

A tree-ring reconstruction is a set of tree-ring width data that have been calibrated with an instrumental or gaged record of a hydrologic or climatic variable such as annual streamflow or precipitation. The reconstruction, based on a statistical model that describes the relationship between tree growth and the gage record, extends that record back hundreds of years into the past.

Tree growth in dry climates is limited by water availability. Trees that provide the best information about hydroclimatic variability are those particularly sensitive to variations in moisture. These include species such as blue oak, ponderosa pine, Douglas fir, and western juniper, usually growing at lower elevations in sparse stands on dry and rocky sites where soil moisture storage is minimal.

Tree-ring reconstructions of hydroclimatic variables are developed from tree-ring chronologies. A tree-ring chronology is a time-series of annual values derived from the ring-width measurements of 10 or more trees of the same species at a single site. To create a tree-ring chronology, cores from the sampled trees at each site are cross-dated (i.e., patterns of narrow and wide rings are matched from tree to tree) to account for missing or false rings, so that every annual ring is absolutely dated to the correct year. Then all rings are measured to the nearest thousandth of a millimeter using a computer-assisted measuring device. After growth-related trends unrelated to climate are statistically removed, the ring width values from all sampled trees for each year are averaged to create a time series of annual ring width indices. The complete series of ring width indices from a site is called a tree-ring chronology.

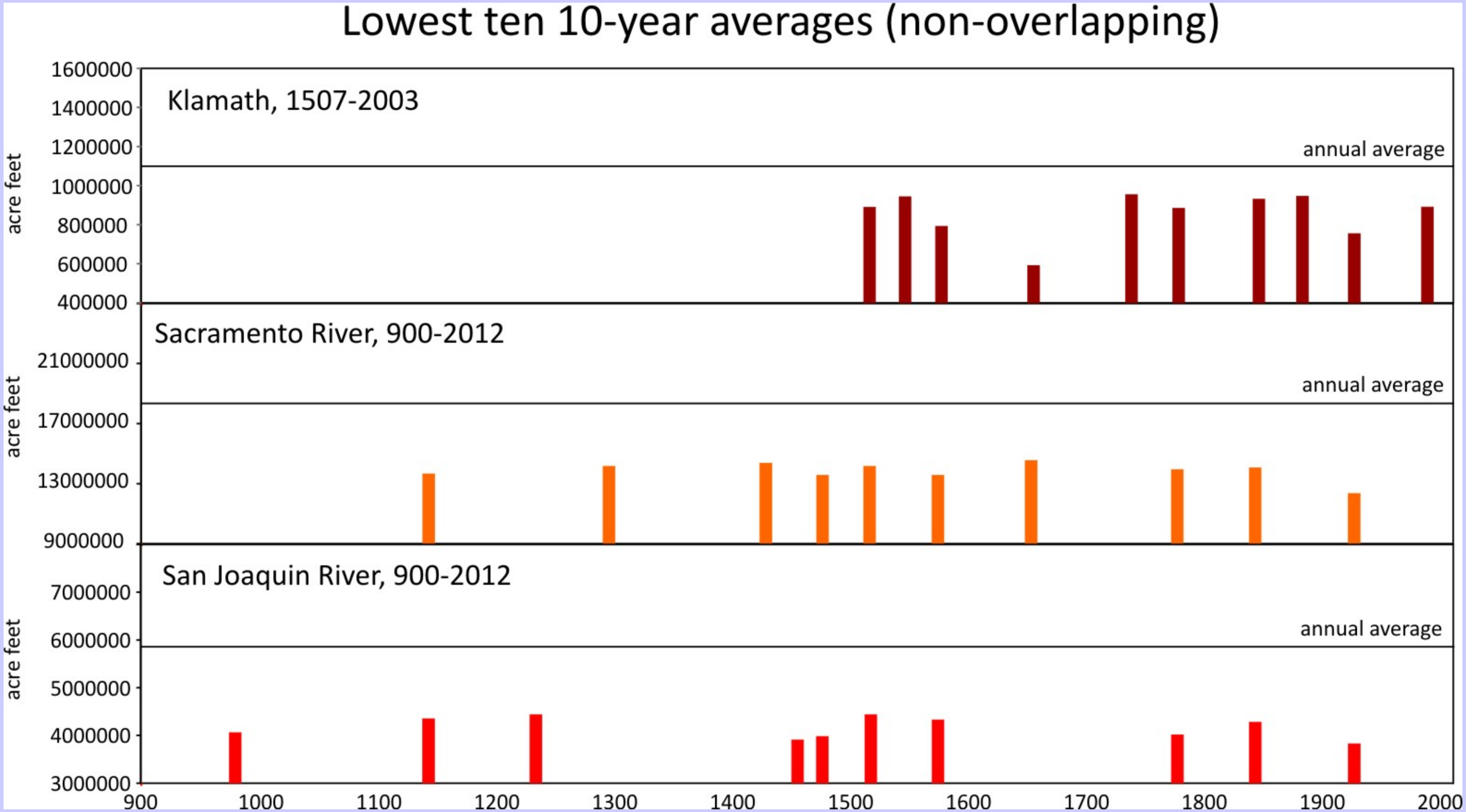
Once a gaged record of interest is selected for reconstruction, a set of tree-ring chronologies from the region near the gage is calibrated with the gage record to form a reconstruction model. A statistical technique called multiple linear regression is commonly used. The reconstruction is evaluated by comparing the observed gage values with the reconstructed values by assessing the amount of variance in the gage record that is explained by the reconstruction.

DROUGHTS PRIOR TO THE HISTORICAL RECORD

The period of reliably measured streamflows for rivers throughout the West seldom reaches beyond 100 years, which represents only a fraction of climatologically modern time. As these streamflow reconstructions show, there have been droughts prior to the historical period that were more severe – particularly in duration – than those in the measured record. The reconstructed record captures a broader range of hydrologic variability than does the historical record, making reconstructions useful for drought preparedness planning. Of particular interest from a scientific perspective is the Medieval Climate Anomaly, a time during which sustained severe drought gripped much of the western United States, as exemplified illustrated in the Sacramento, San Joaquin, and Colorado River reconstructions.

Data source: Work performed by the University of Arizona under contract to the California Department of Water Resources. CDWR Agreements 4600003682 (David Meko, 2006) and 4600008850 (David Meko, Connie Woodhouse, Ramzi Touchan, 2014)

Tree-Ring Reconstructions of Streamflow in Major Basins



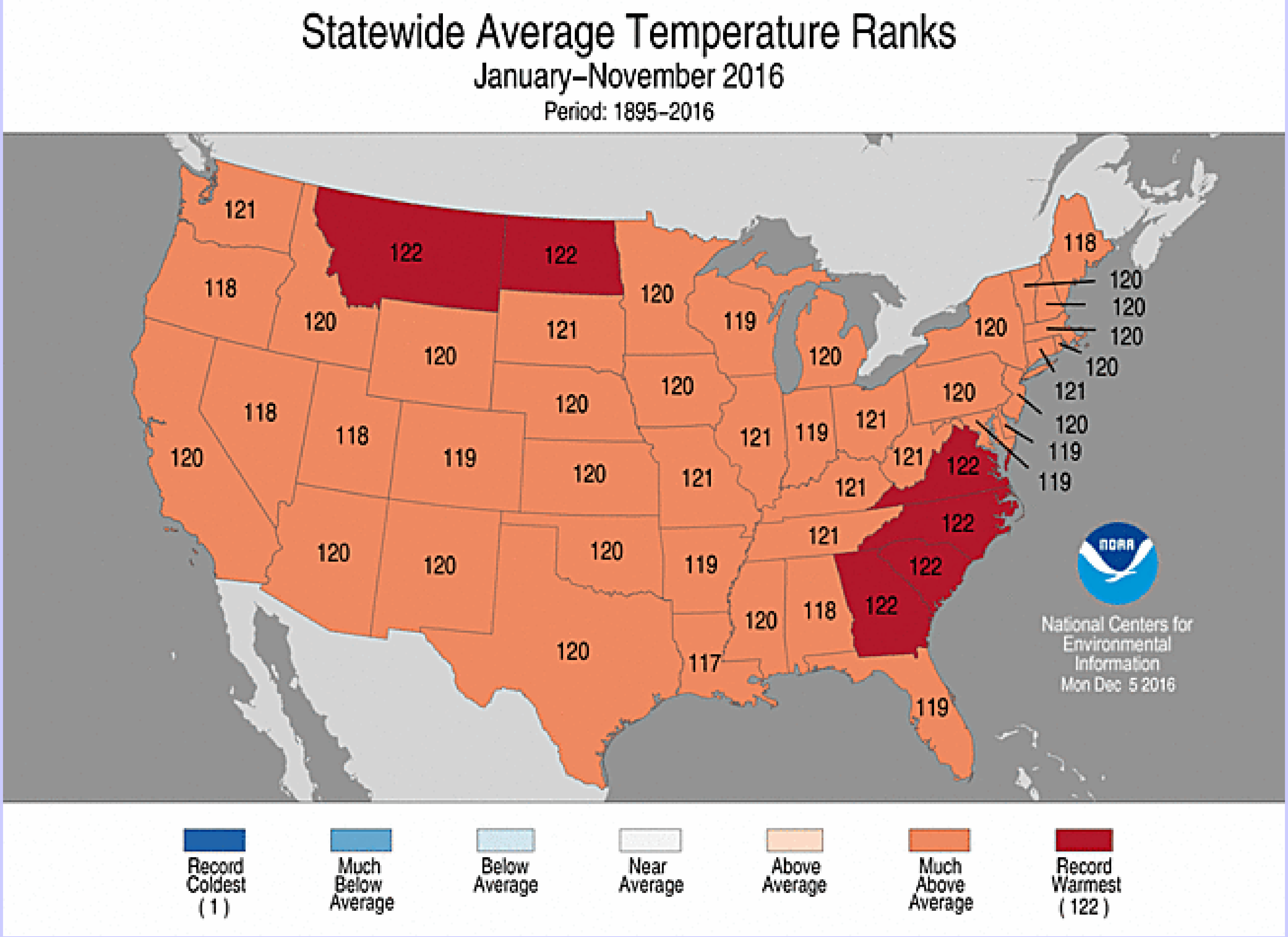
Courtesy of Connie Woodhouse

California's 20th & 21st Century Statewide Droughts

- 1918-20
- 1922-24
- 1929-34
- 1947-50
- 1959-61
- 1976-77
- 1987-92
- 2007-09

Where We've Been in Past Water Years

- 2007 – dry
- 2008 – dry
- 2009 – dry
- 2010 – normal
- 2011 – wet
- 2012 – dry
- 2013 – dry
- 2014 – dry
- 2015 – dry
- 2016 – dry



Statewide Average Temperature Ranks
January–November 2016
Period: 1895–2016
121
122
122
118
120
121
120
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119
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121
120
118
117
119
National Centers for Environmental Information
Mon Dec 5 2016
Record Coldest (1)
Much Below Average
Below Average
Near Average
Above Average
Much Above Average
Record Warmest (122)

Driest 4 Consecutive Water Years Based on Statewide Precipitation

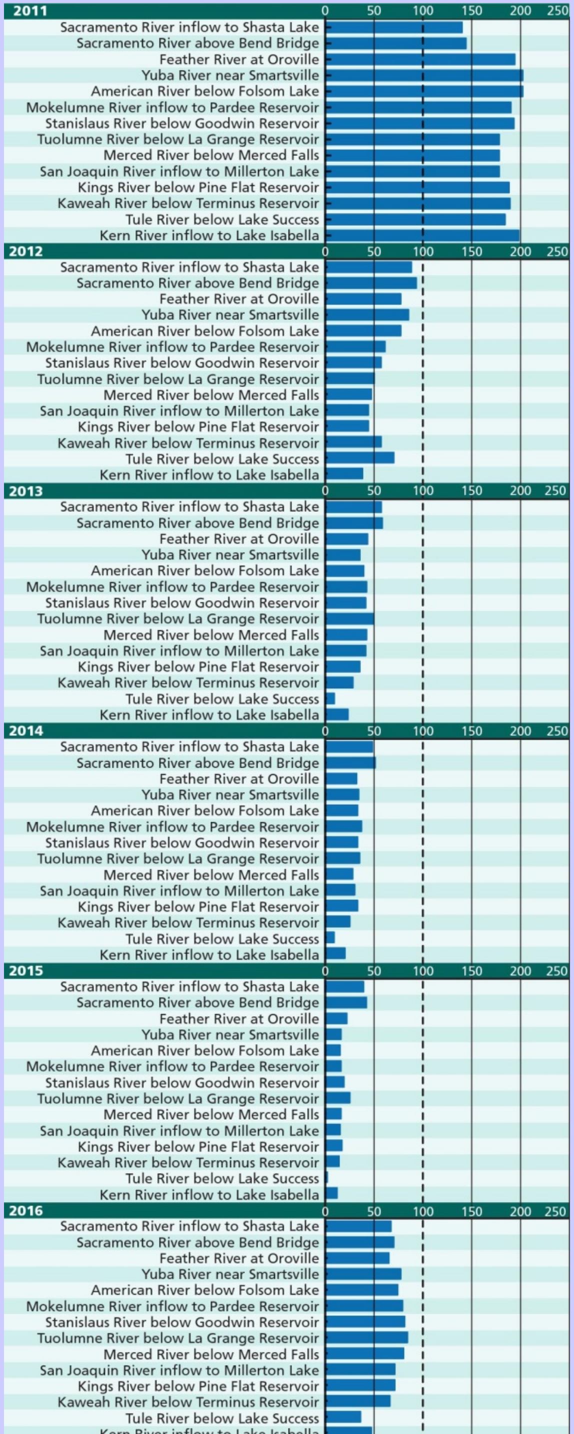
Year	4-Year Total, inches
2012-2015	62.2
1917-1920	63.1
1923-1926	63.3
1928-1931	64.5
1931-1934	65.1
1921-1924	65.7
1922-1925	65.9
1918-1921	66.8
1929-1932	67.3
1987-1990	67.3
1930-1933	68.0

WRCC data

USGS Computed CA WY Runoff
Dozen Driest years -- (rank out of 115)

1.	1977	115th	7.	1990	109th
2.	1931	114th	8.	2015	108th
3.	1924	113th	9.	2001	107th
4.	2014	112th	10.	1934	106th
5.	1991	111th	11.	1992	105th
6.	1994	110th	12.	1976	104th

April – July Runoff in Major River Basins – Water Years 2011-2016



Drought Impacts

- Reduced surface and groundwater supplies
- Water shortages for small water systems & private well owners
- Declining groundwater levels and land subsidence
- Agricultural land fallowing
- Increased urban water costs
- Tree mortality, wildfire risk
- Fishery impacts

State Drought Response Actions

- May 2013 Executive Order on water transfers
- Dec 2013 formation of Governor's Drought Task Force
- Jan 2014 Governor's emergency proclamation
- March 2014 drought relief legislation
- April 2014 proclamation of continued state of emergency
- Sep 2014 Executive Order for emergency drinking water assistance
- Dec 2014 Executive Order continuing CEQA waiver for specified actions
- March 2015 drought relief legislation
- April 2015 Executive Order
- October 2015 emergency proclamation on tree mortality
- November 2015 Executive Order, continuing conservation/small water systems
- May 2016 Executive Order, conservation requirements

Example State Activities

- SWP/CVP drought contingency planning, Shasta temperature operations
- Emergency assistance for small water systems & private well owners
- SWRCB regulatory actions, water conservation requirements
- Increased focus on groundwater conditions (CASGEM & SGMA)
- Impact monitoring (fallowed ag land, Central Valley land subsidence)
- Ongoing state financial assistance programs

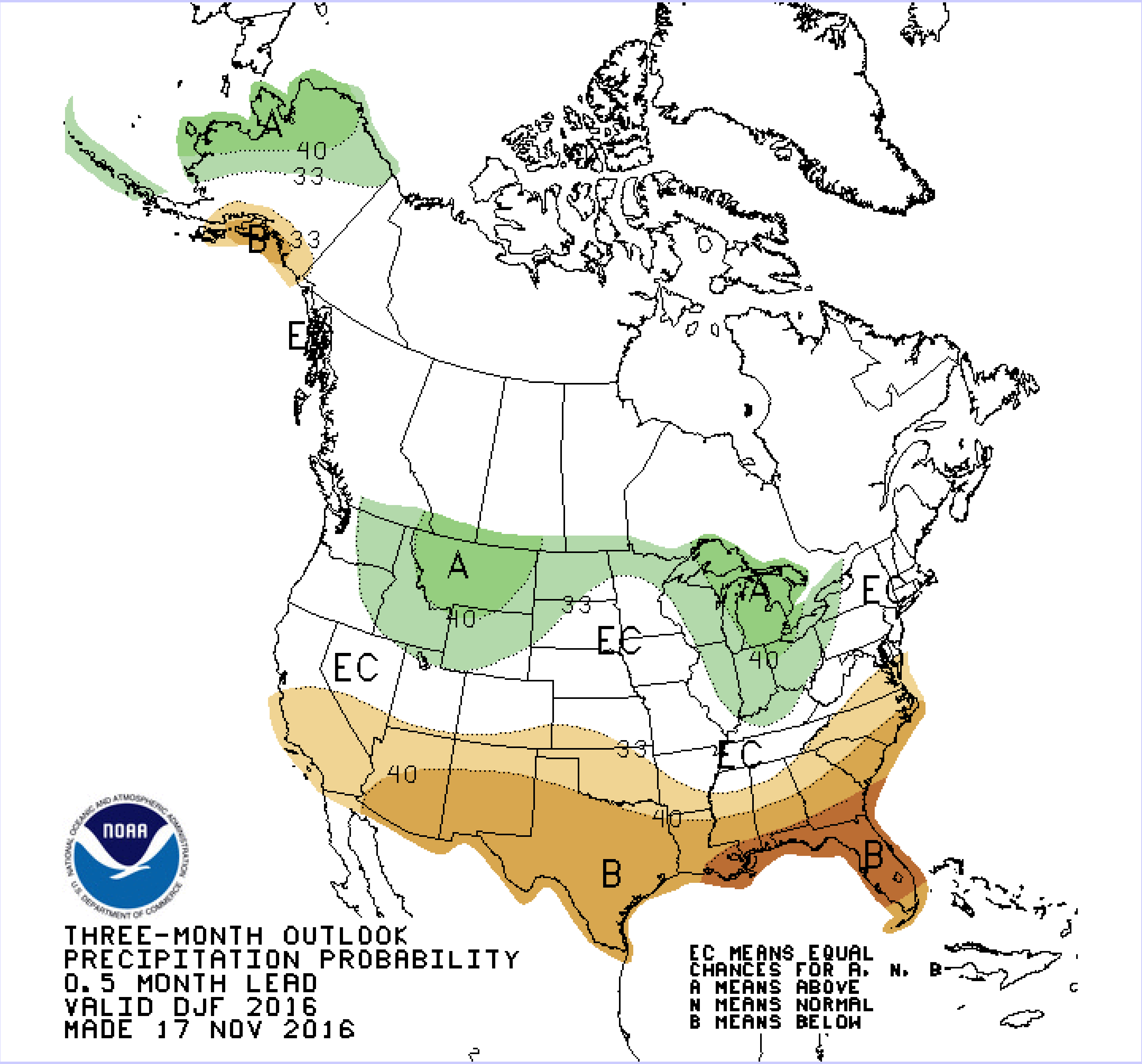

Major Rivers
State Projects
Federal Projects
Local Projects
Redding
Sacramento
San Francisco
Fresno
Los Angeles
San Diego

Recent Policy Changes

- Sustainable Groundwater Management Act, 2014
- Mandatory consolidation of public water systems, 2015
- Ag Water Management Plan requirements for suppliers to 10,000 – 25,000 acres, 2015
- Urban Water Management Plan requirement for 5-year drought, 2016

Challenges

- Small water system drought vulnerability
- San Francisco Bay/Sacramento-San Joaquin River Delta water management
- Will the winter be wet or dry – inability to forecast sub-seasonal to seasonal precipitation


A
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33
B
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EC
A
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33
EC
A
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EC
EC
33
40
40
EC
EC
B
B
THREE-MONTH OUTLOOK
PRECIPITATION PROBABILITY
0.5 MONTH LEAD
VALID DJF 2016
MADE 17 NOV 2016
EC MEANS EQUAL
CHANCES FOR A, N, B
A MEANS ABOVE
N MEANS NORMAL
B MEANS BELOW

NOAA CPC Historical Skill Scores