

Water Resource Operations in Central AZ

Charlie Ester

Manager, Watershed Management



Outline

- **SRP Overview**
- **Balancing Flood Risk and Water Storage**
- **AZ Water Supplies**
 - **Colorado River vs Salt-Verde Rivers**
- **The Future**
 - **Natural Variability and Climate Change**
- **Winter 2022 Outlook**

Where does the water come from?

ARIZONA'S WATER SUPPLY



SOURCE: ADWR, 2020

<http://www.arizonawaterfacts.com/water-your-facts>

Salt River Project

Salt River Valley Water Users Association

- **Established 1903**
- **A Federal reclamation project**
- **Private corporation**
- **Delivers approximately 987 million m³ (800,000 acre-feet) per year**

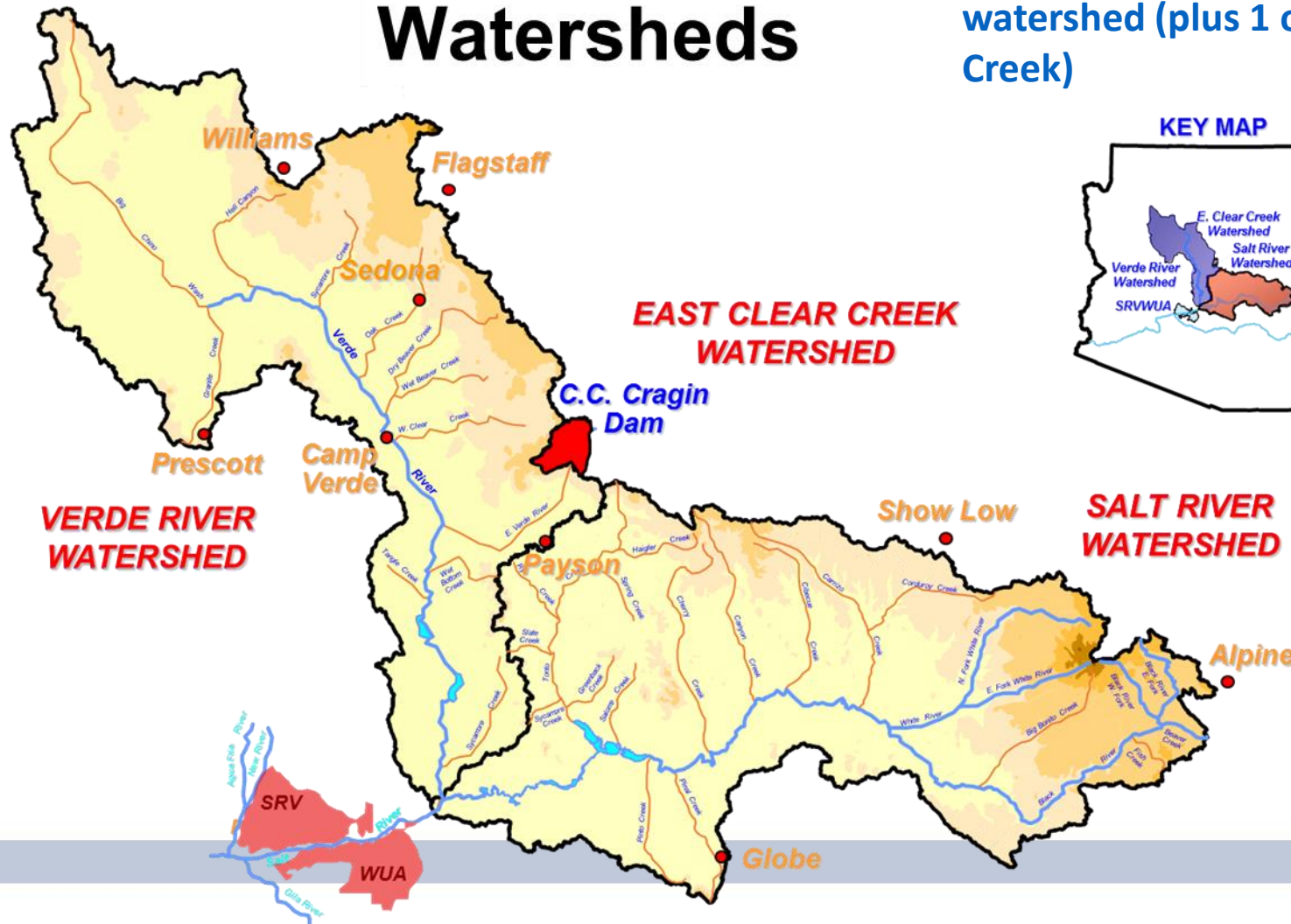


SRP Agricultural Improvement and Power District

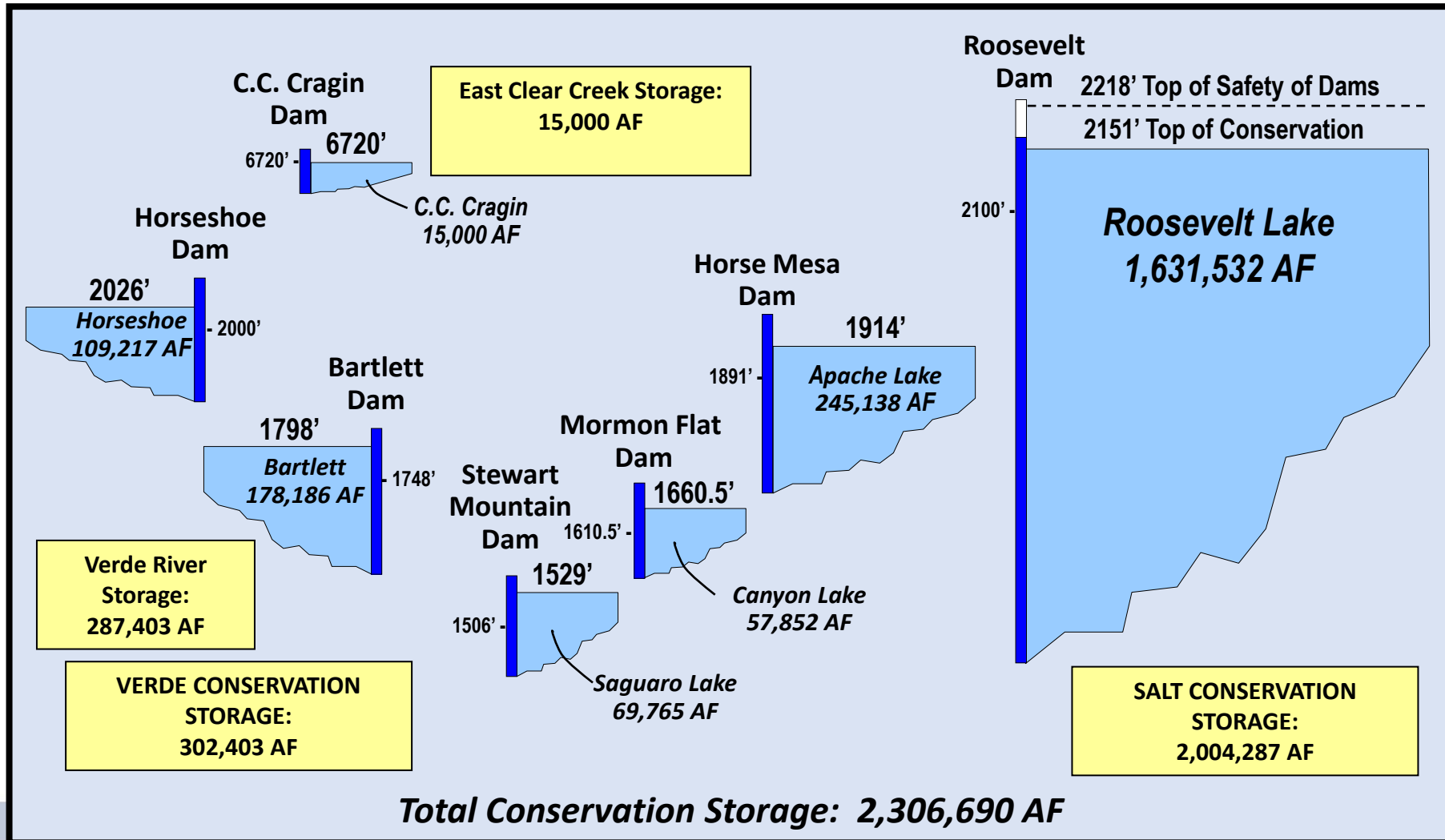
- **Established 1937-operates power side**
- **Over 35,500 million kWh sold**
- **Over 1,000,000 accounts**

Salt and Verde Watersheds

SRP manages seven reservoirs; 6 on the Salt (4) and Verde (2) rivers in Arizona for a 13,000 sq. mile watershed (plus 1 on East Clear Creek)

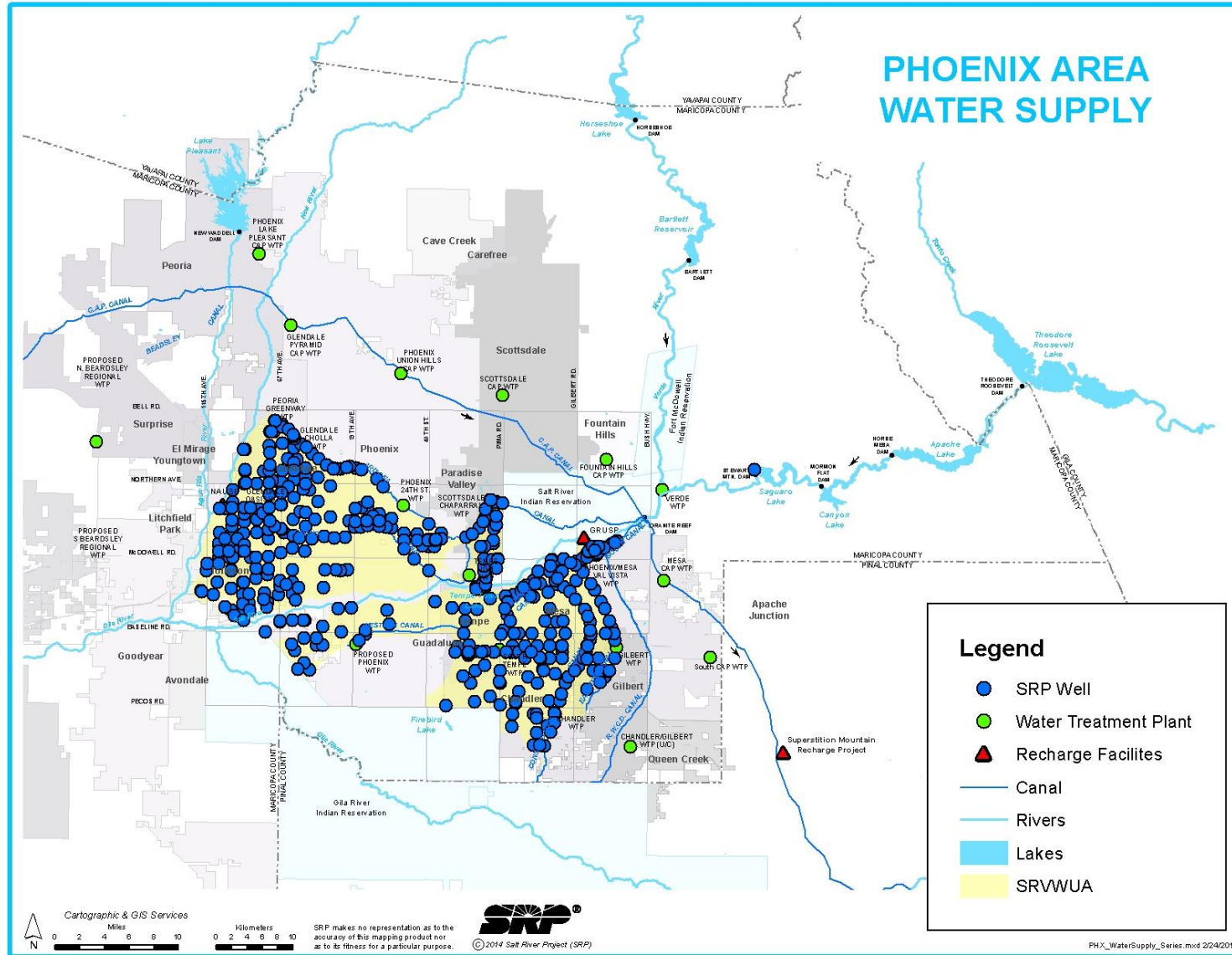


Salt River Project Reservoir System



01/09/07 REF/SVRSCIAF-6

SRP Water Delivery System

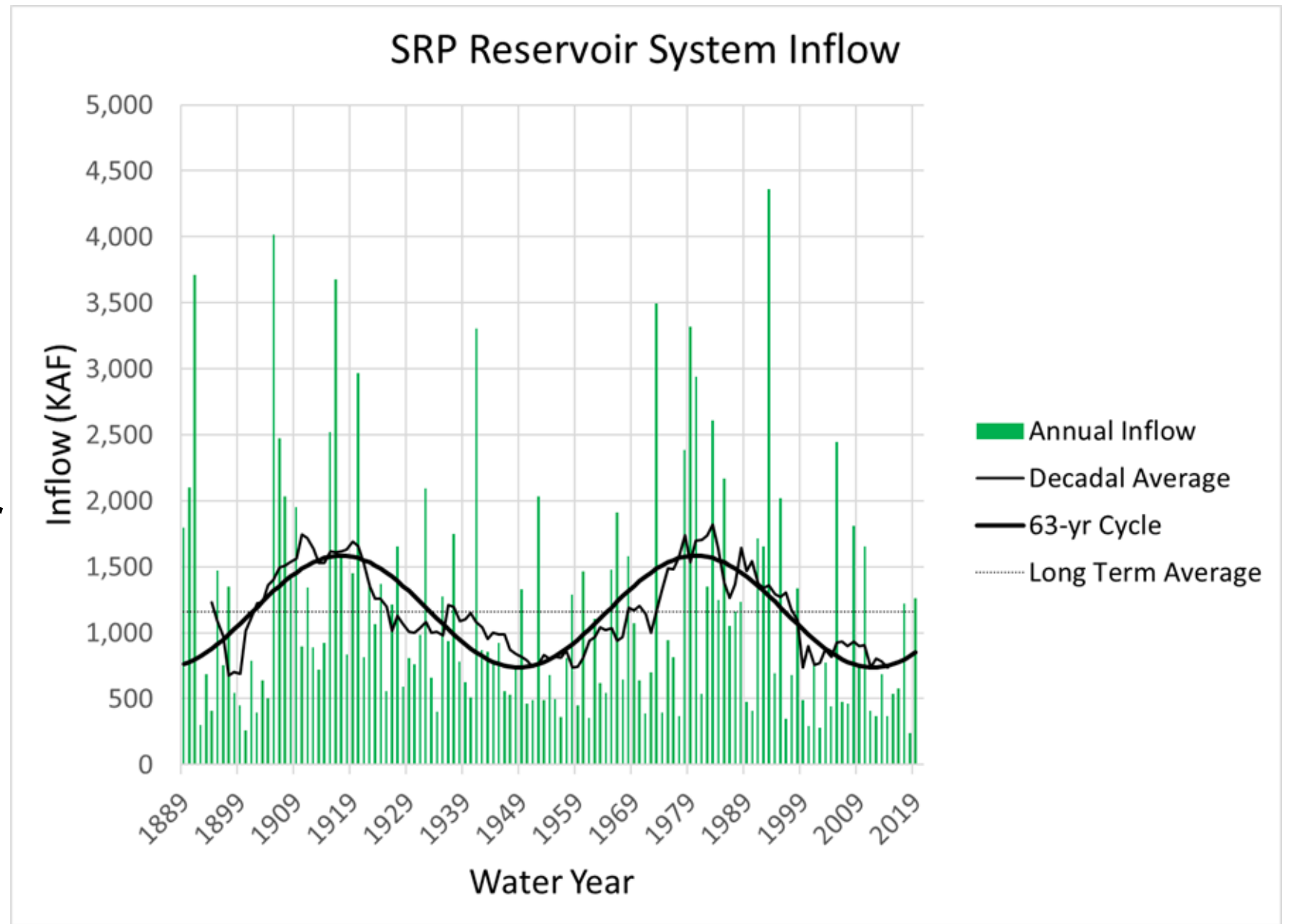


- **Ocean variability**
→ **natural variability**
in winter precipitation

(Ropelewski and Halpert 1986;
Mo et al. 2009; Yu et al. 2015)

- **Recent drought is**
most severe in over
600 yrs and is
attributed to
natural variability

(Lehner et al. 2018; Murphy and
Ellis 2019)

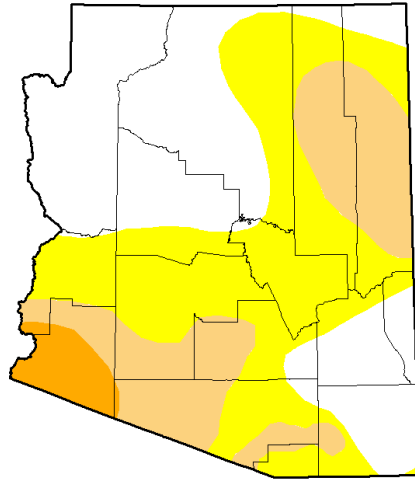


Natural Variability



Horseshoe Dam January 2010

U.S. Drought Monitor
Arizona



January 17, 2017
(Released Thursday, Jan. 19, 2017)
Valid 7 a.m. EST

	Drought Conditions (Percent Area)					
	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	38.68	61.32	24.76	3.65	0.00	0.00
Last Week 1/10/2017	38.68	61.32	24.76	3.65	0.00	0.00
3 Months Ago 10/18/2016	22.61	77.39	44.76	4.17	0.00	0.00
Start of Calendar Year 1/5/2017	38.68	61.32	24.76	3.65	0.00	0.00
Start of Water Year 9/27/2016	6.23	93.77	44.76	4.17	0.00	0.00
One Year Ago 1/19/2016	42.94	57.06	16.33	0.00	0.00	0.00

Intensity



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Richard Tinker
CPC/NIAA/NWS/NCEP



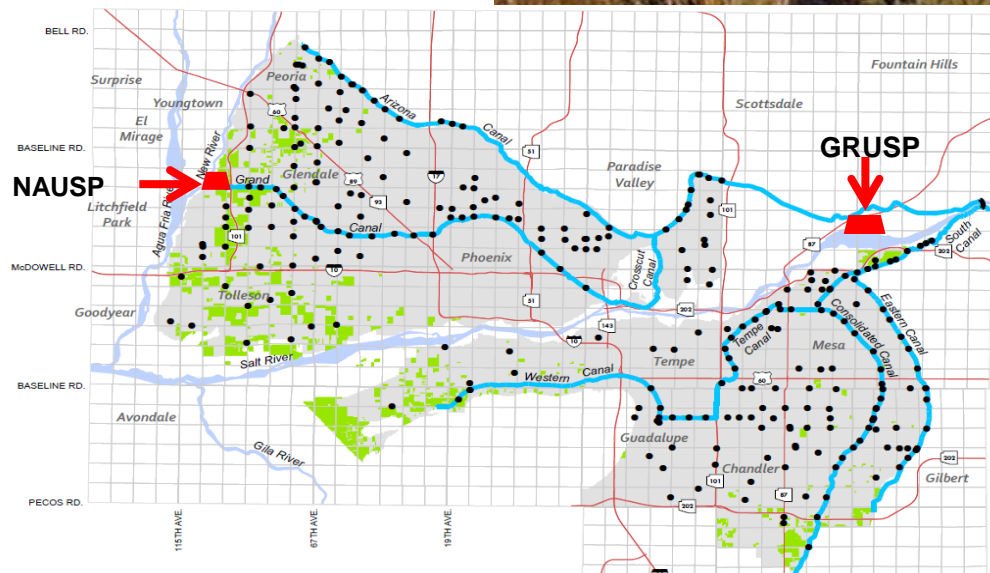
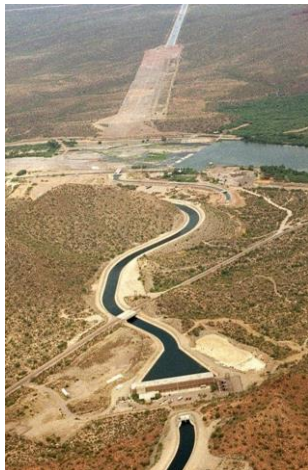
<http://droughtmonitor.unl.edu/>

Reservoir Planning



Horseshoe Lake

.....Mostly, It's
About Managing
For Times of
Scarcity

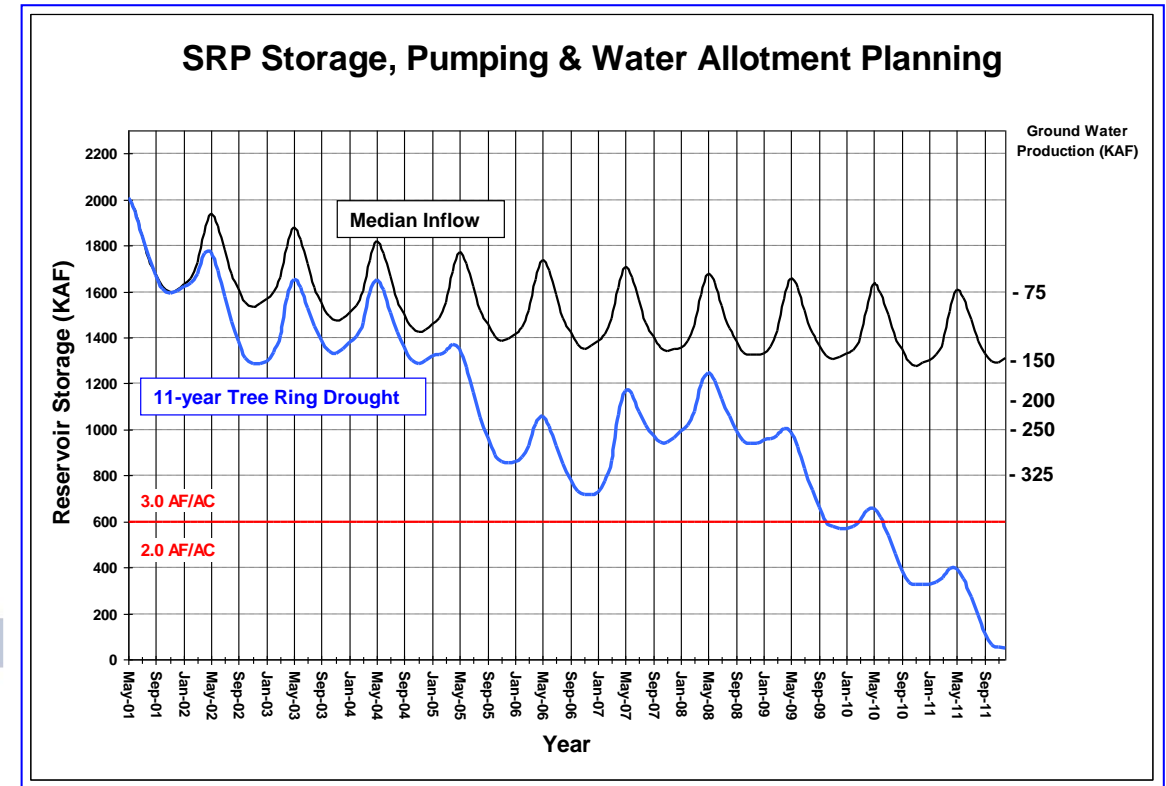
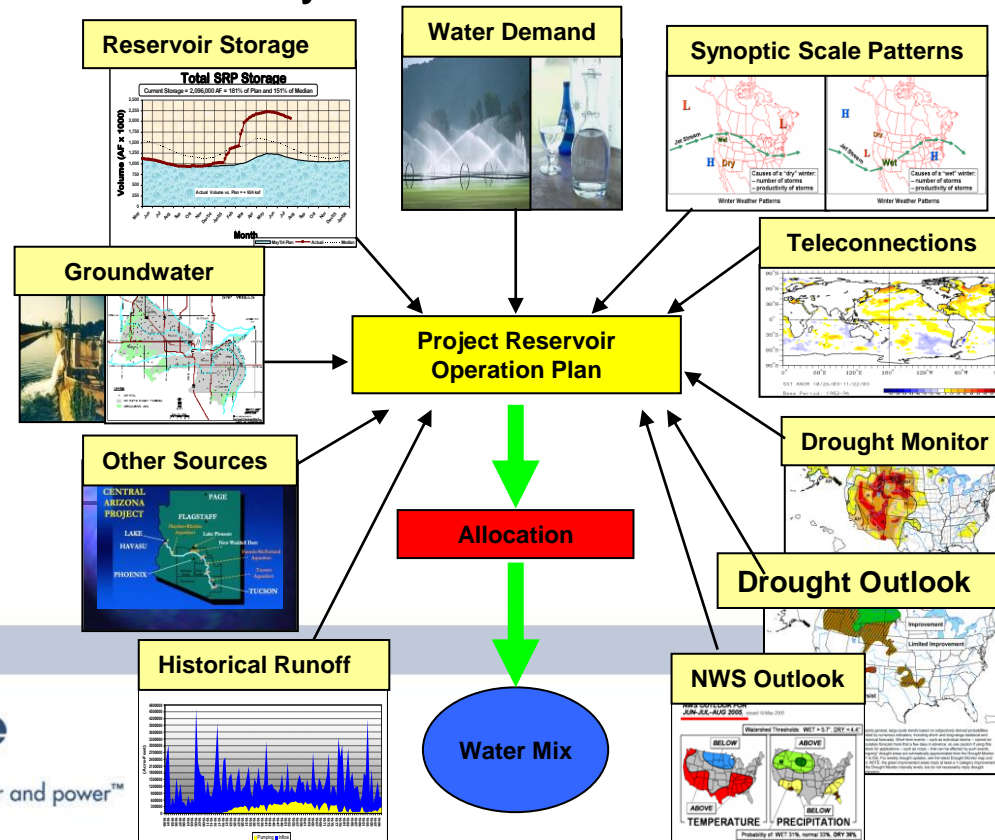


Roosevelt Lake

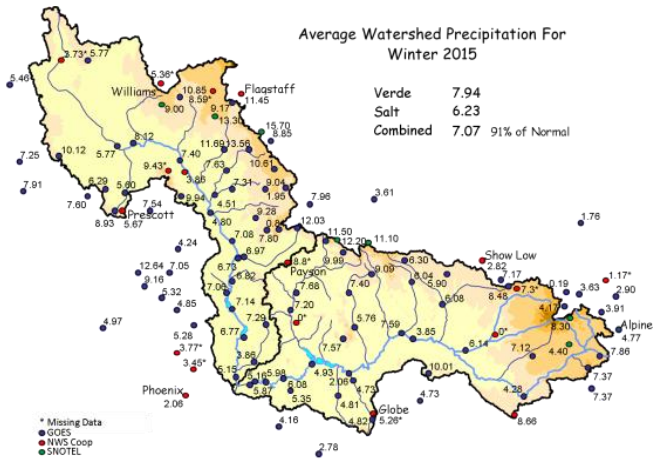
Management Philosophy

Objective: Provide an adequate and reliable water supply to our *shareholders*.

- Ensure carry-over storage to manage the worst drought on record.
- Reduce the probability of having to cut the allocation of water.
- **SRP Always Plans For Drought – Period!**
- The end of every wet runoff season is the start of the next severe sustained drought period.

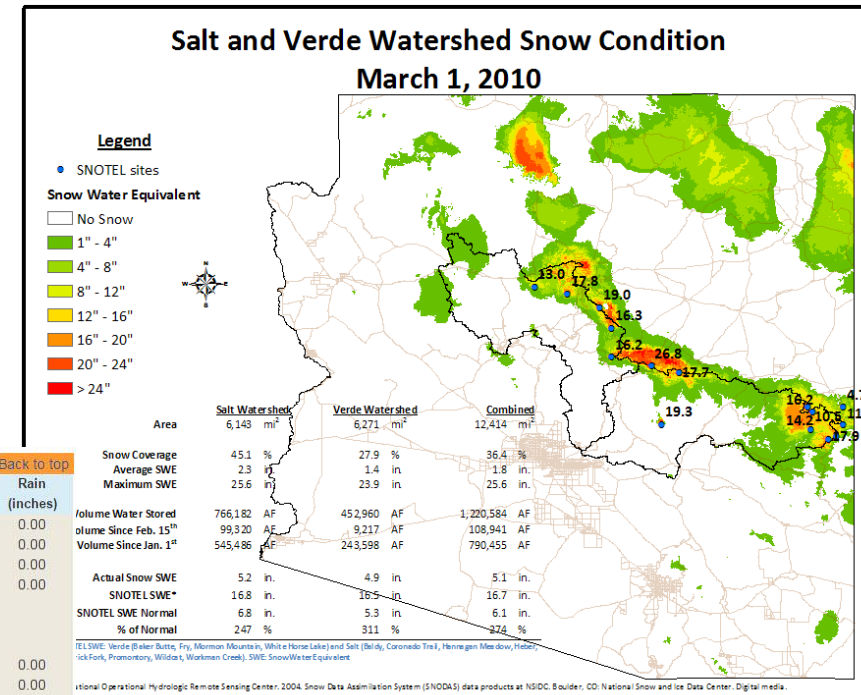
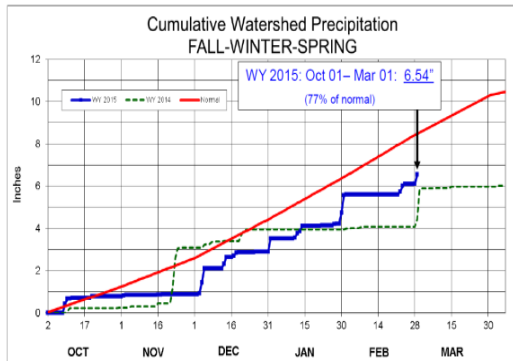
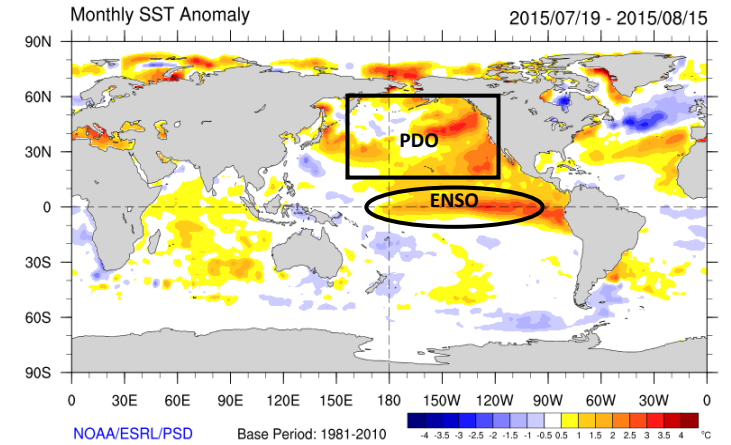


Balancing Flood Risk and Water Storage



Home

Sensor	Last 7 Days	Last Reading	Value
Horseshoe Reservoir		01/13/2015 08:54AM MST	230ur
Horseshoe Reservoir		01/13/2015 12:43PM MST	1,922.94ft
Bartlett Reservoir		01/13/2015 12:43PM MST	80,520ur
Bartlett Reservoir		01/13/2015 12:43PM MST	1,753.39ft
Verde River Near Paulden		01/13/2015 12:15PM MST	23frs
Verde River Near Clarkdale		01/13/2015 12:30PM MST	76frs
Oak Creek Near Sedona		01/13/2015 12:49PM MST	30frs
Oak Creek near Cornville		01/13/2015 12:49PM MST	40frs
Dry Beaver Creek Near Rimrock		01/13/2015 11:45AM MST	2frs
Wet Beaver Creek near Rimrock		01/13/2015 12:45PM MST	8frs



DEC '14: 2.64" (normal: 1.9") JAN '15: 2.09" (normal: 2.0") FEB '15: 0.93" (normal: 1.9") → DEC



Reservoir data [Back to top](#)

	Elevation (feet)		% Full	Storage (in acre feet)		24 hr. Change	Rain (inches)
	Current	Remaining		Current	Available		
Roosevelt	2,092.11	58.89	40	660,716	970,816	0	0.00
Horse Mesa	1,907.87	6.13	93	229,144	15,994	-641	0.00
Mormon Flat	1,656.67	3.83	94	54,254	3,598	-596	0.00
Stewart Mtn	1,524.70	4.30	92	64,447	5,318	436	0.00
Total Salt System			50	1,008,561	995,726	-801	
Horseshoe	1,989.93	36.07	30	33,087	76,130	277	0.00
Bartlett	1,771.43	26.57	64	113,750	64,436	-288	0.00
Total Verde system			51	146,837	140,566	-11	
Total reservoir system			50	1,155,398	1,136,292	-812	
Total system year ago			49				

Arizona's Water Supplies



Long-term balance?

ARIZONA'S WATER SUPPLY

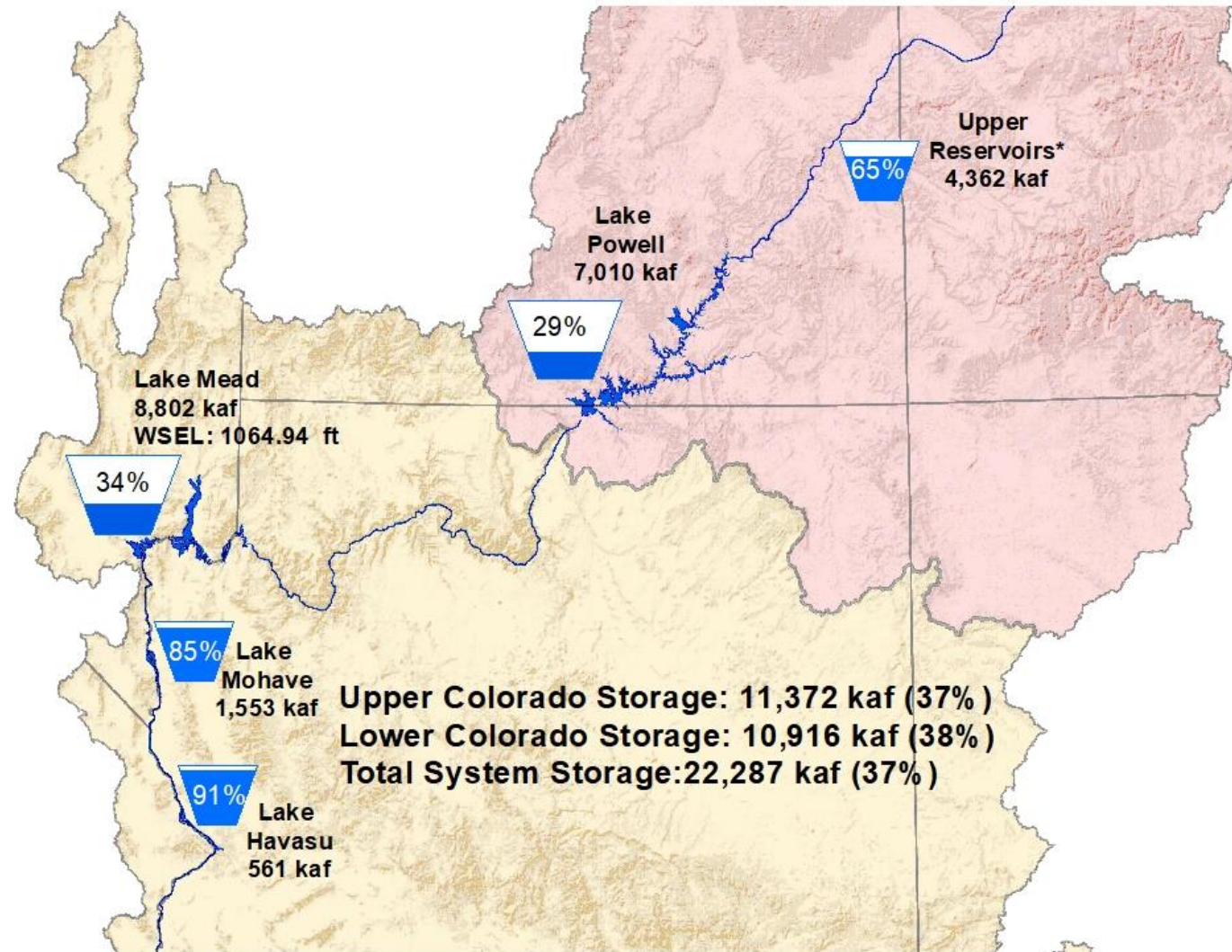


SOURCE: ADWR, 2020

<http://www.arizonawaterfacts.com/water-your-facts>

Colorado Basin Reservoir Status

December 1, 2021



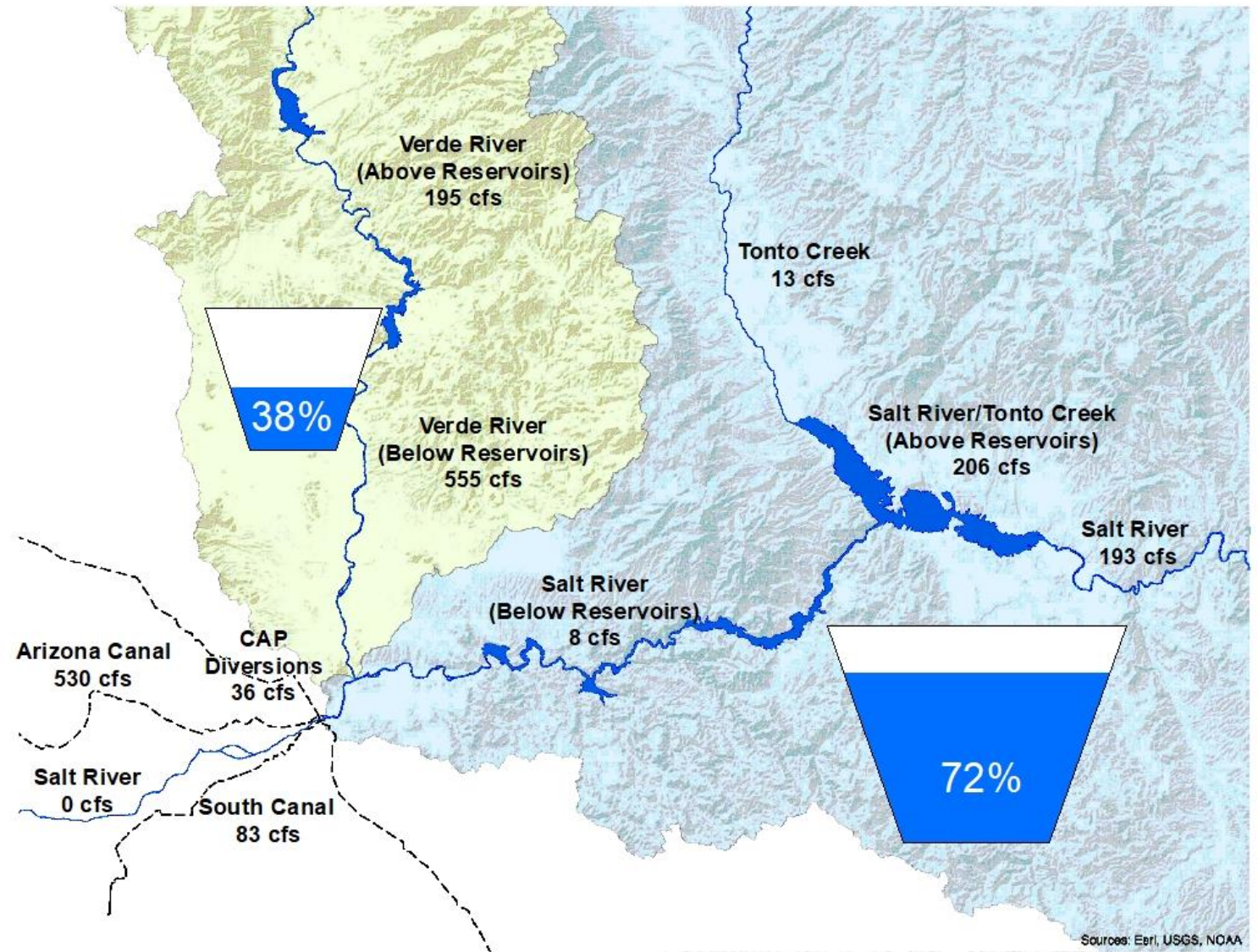
*Fontenelle, Flaming Gorge, Marrow Point, Blue Mesa, Crystal, Navajo

SRP Reservoir System Status

December 1, 2021

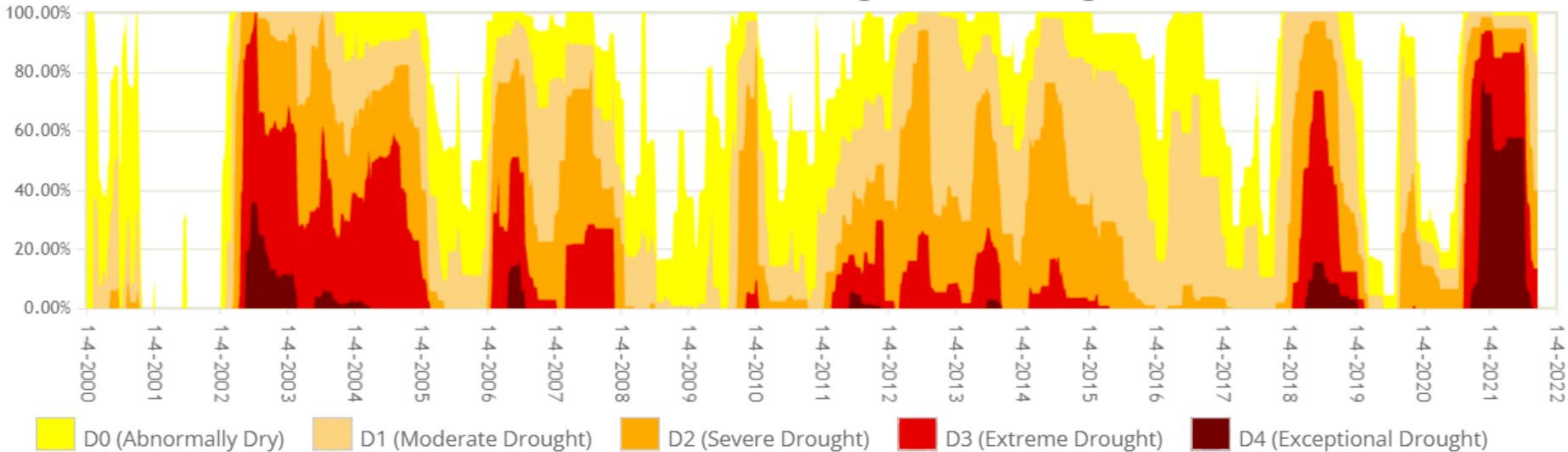
Current Storage:

Salt	1,441,601	AF
Verde	110,190	AF
Total	1,551,791	AF



Drought Since 2000 in AZ

Arizona Percent Area in U.S. Drought Monitor Categories

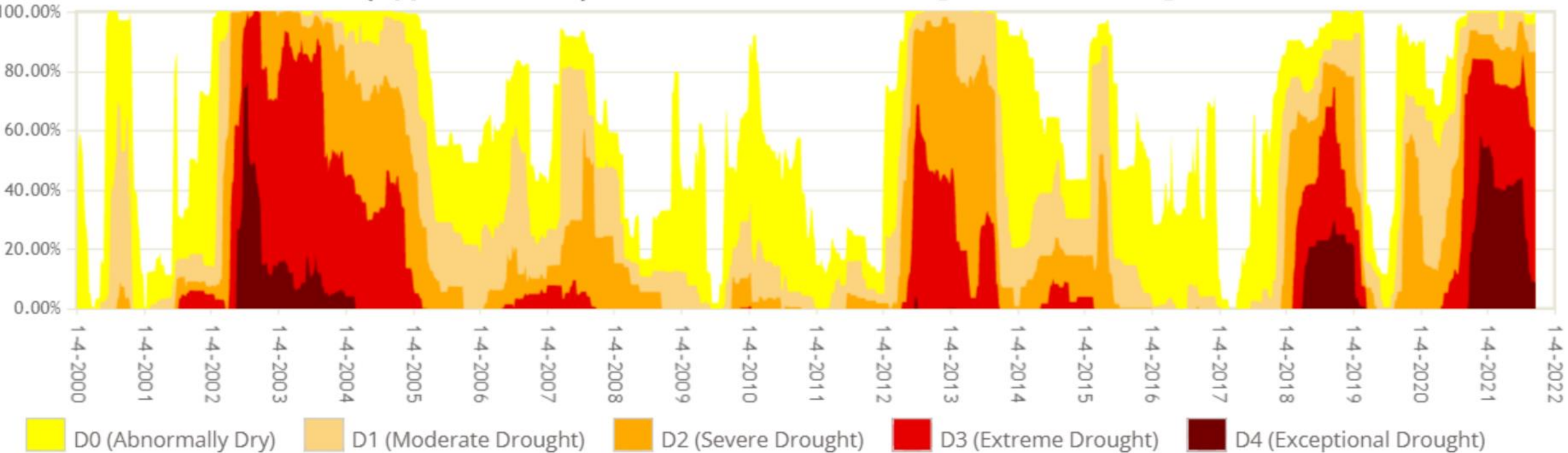


Drought = less surface water available and more groundwater use

<https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx>

Drought Since 2000 Upper Colorado Basin

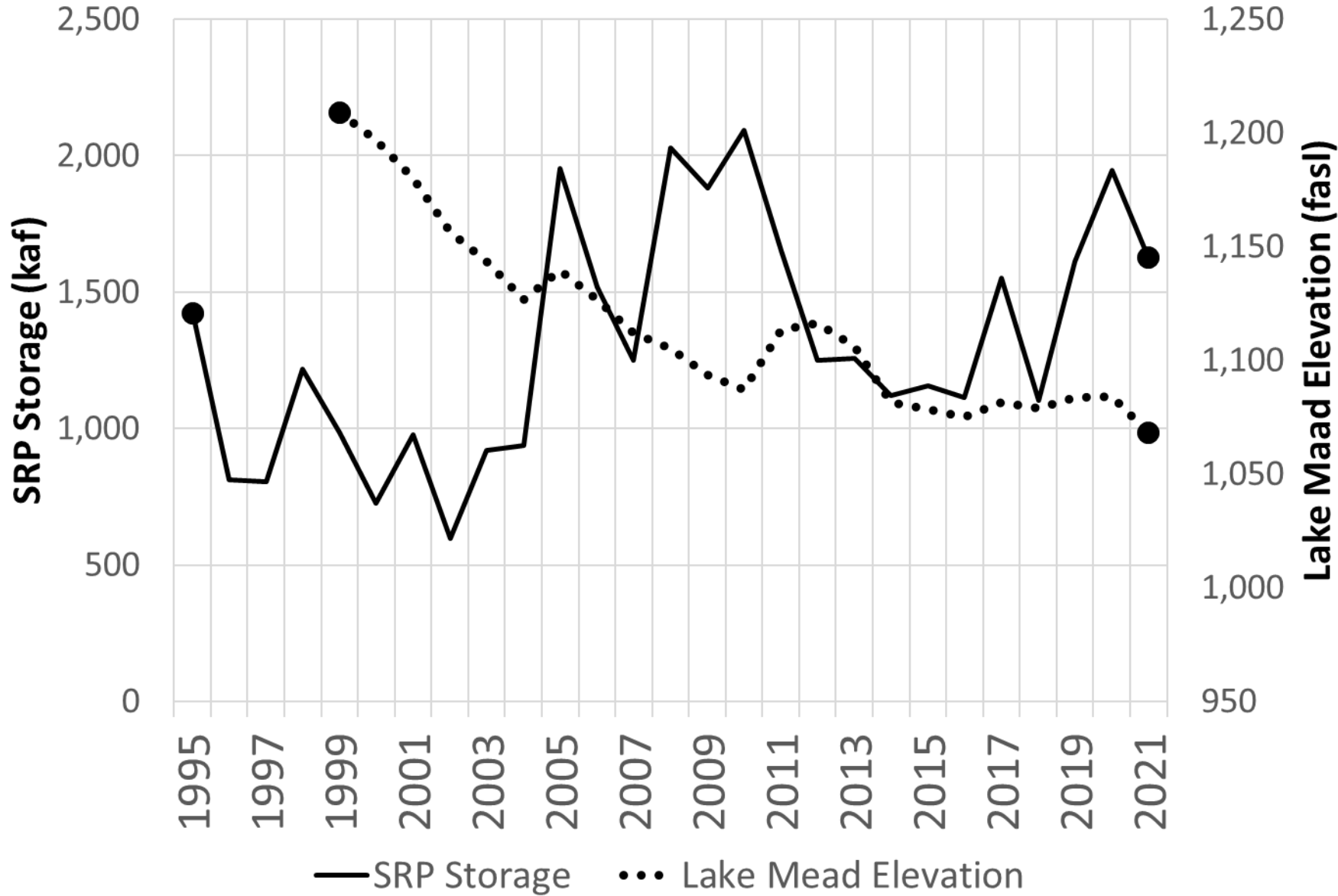
14 (Upper Colorado) Percent Area in U.S. Drought Monitor Categories



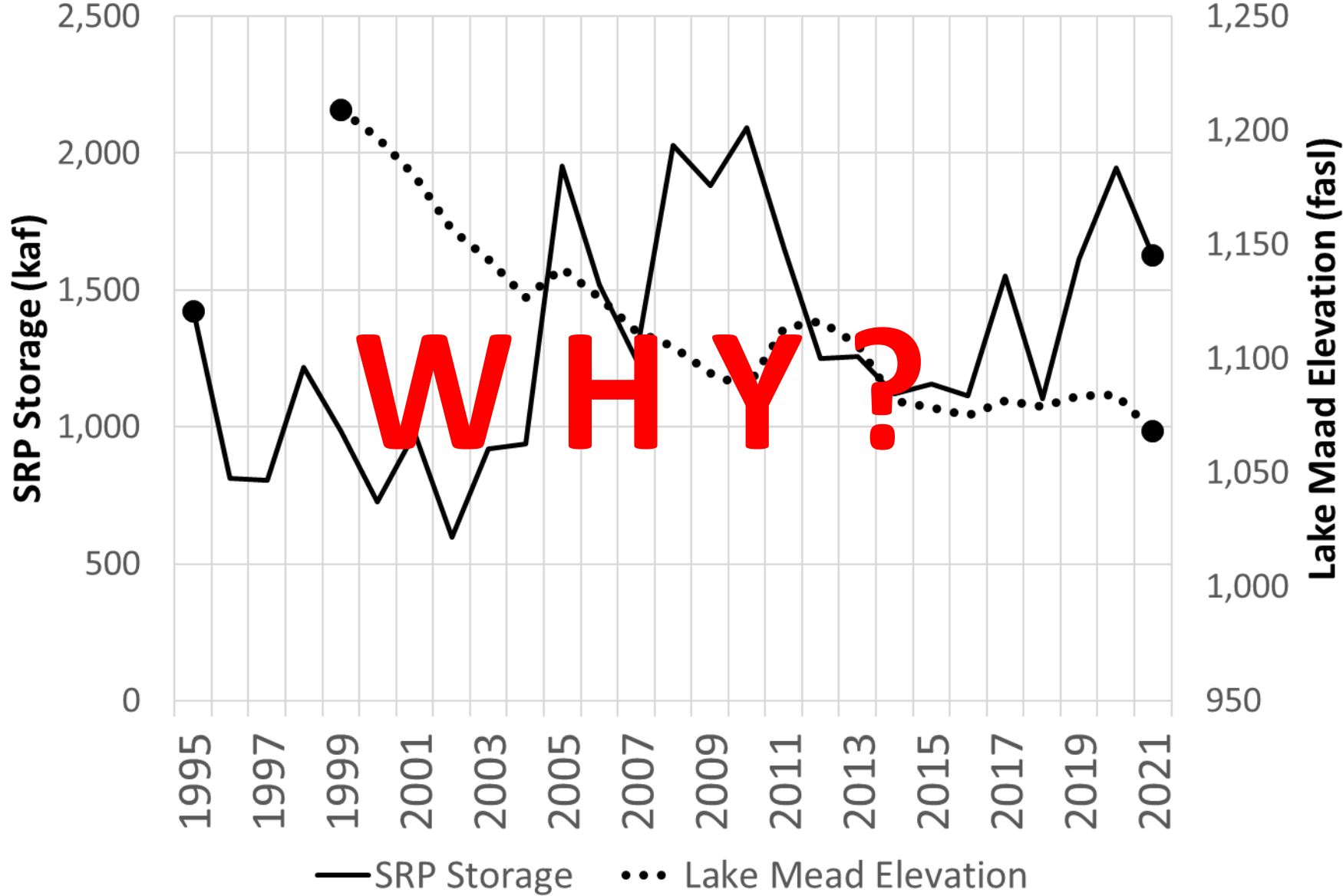
Drought = Less Water in Lake Mead

<https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx>

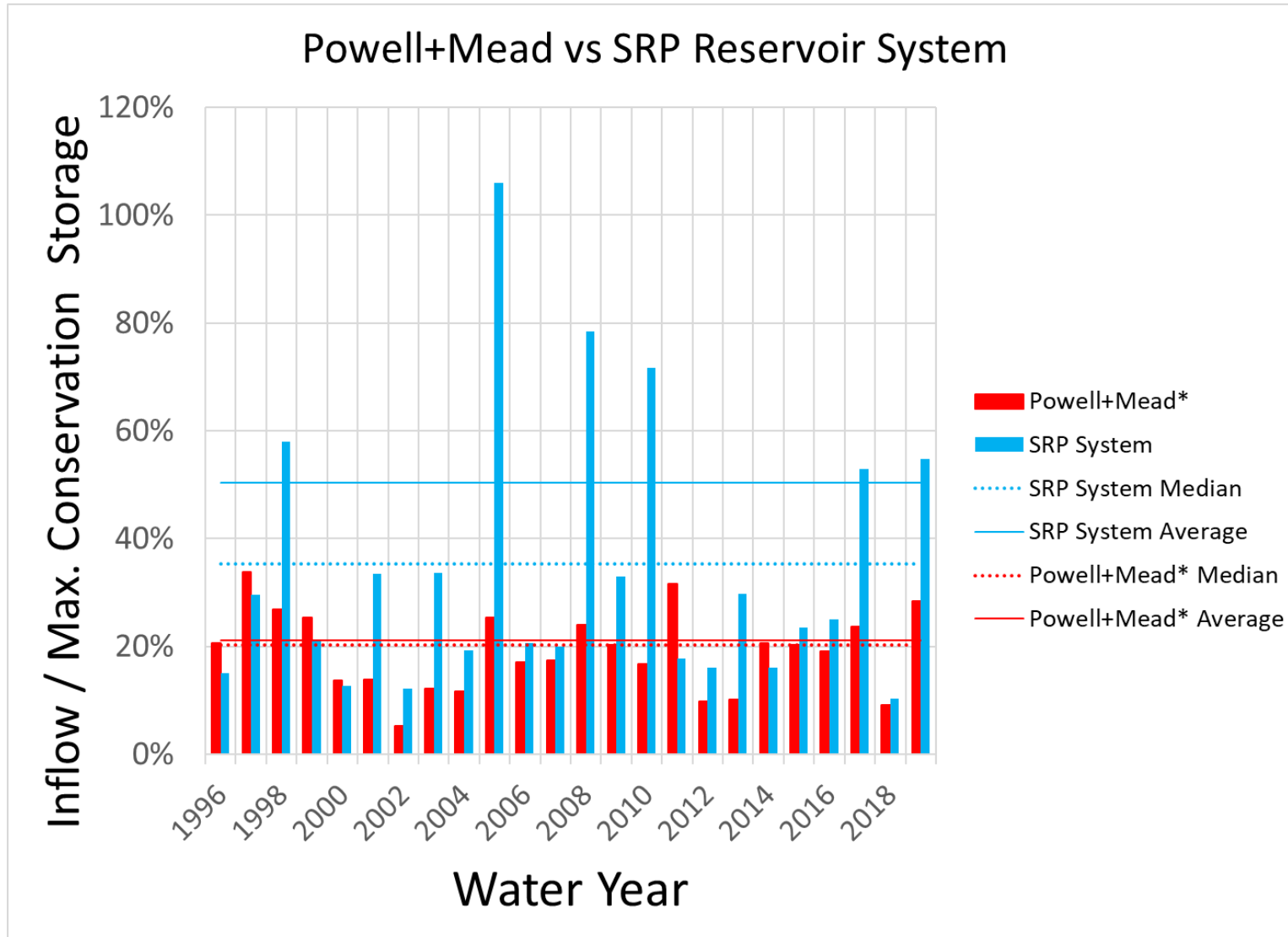
End of August Reservoir Conditions During Drought



End of August Reservoir Conditions During Drought



Inflow Relative to Maximum Conservation Storage During Current Drought



*Unregulated Lake Powell inflow relative to Lake Powell and Lake Mead total capacity

Colorado River Structural Deficit

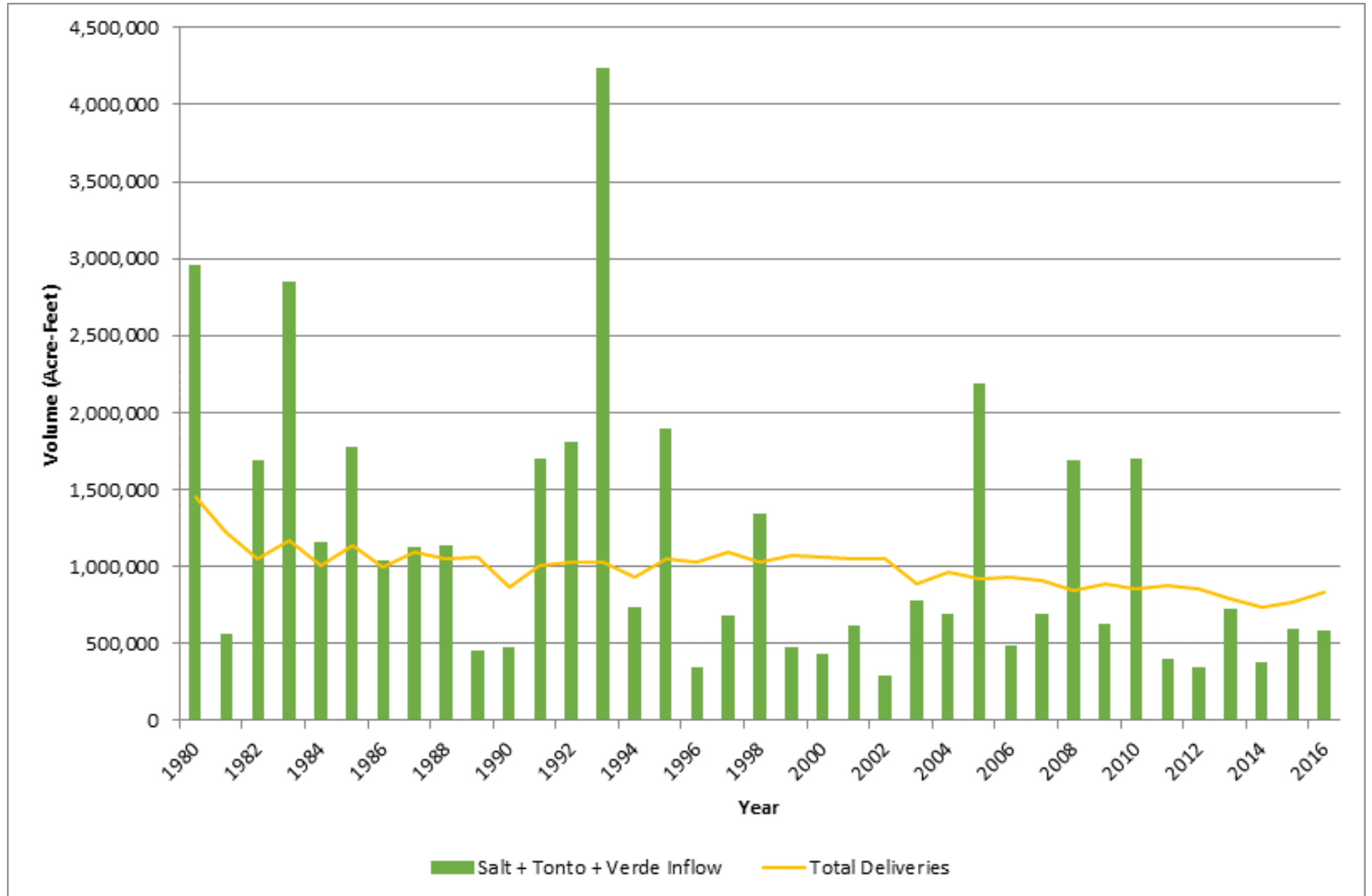
LAKE MEAD WATER BUDGET	
<i>Abbreviations: maf (million acre-feet)</i>	
Approximate annual inflow into Lake Mead (8.23 maf release from Lake Powell plus average intervening flows between Lake Powell and Lake Mead)	9.0 maf
Approximate annual outflow from Lake Mead (Lower Basin apportionments to States and Mexico Treaty allocation plus downstream regulation including side inflows, evapotranspiration, transmission losses, etc.)	-9.6 maf
Approximate annual Lake Mead evaporation loss	-0.6 maf
Water balance	-1.2 maf[†]

[†]Given current average water demands over the past 10 years in the Lower Basin and Mexico, and a minimum objective release from Lake Powell (8.23 maf), Lake Mead storage is reduced on average by about 1.2 maf each year, which is the equivalent of about 12 feet in elevation at Lake Mead.

Data from Bureau of Reclamation

Demand > Inflow

Trends in Demand



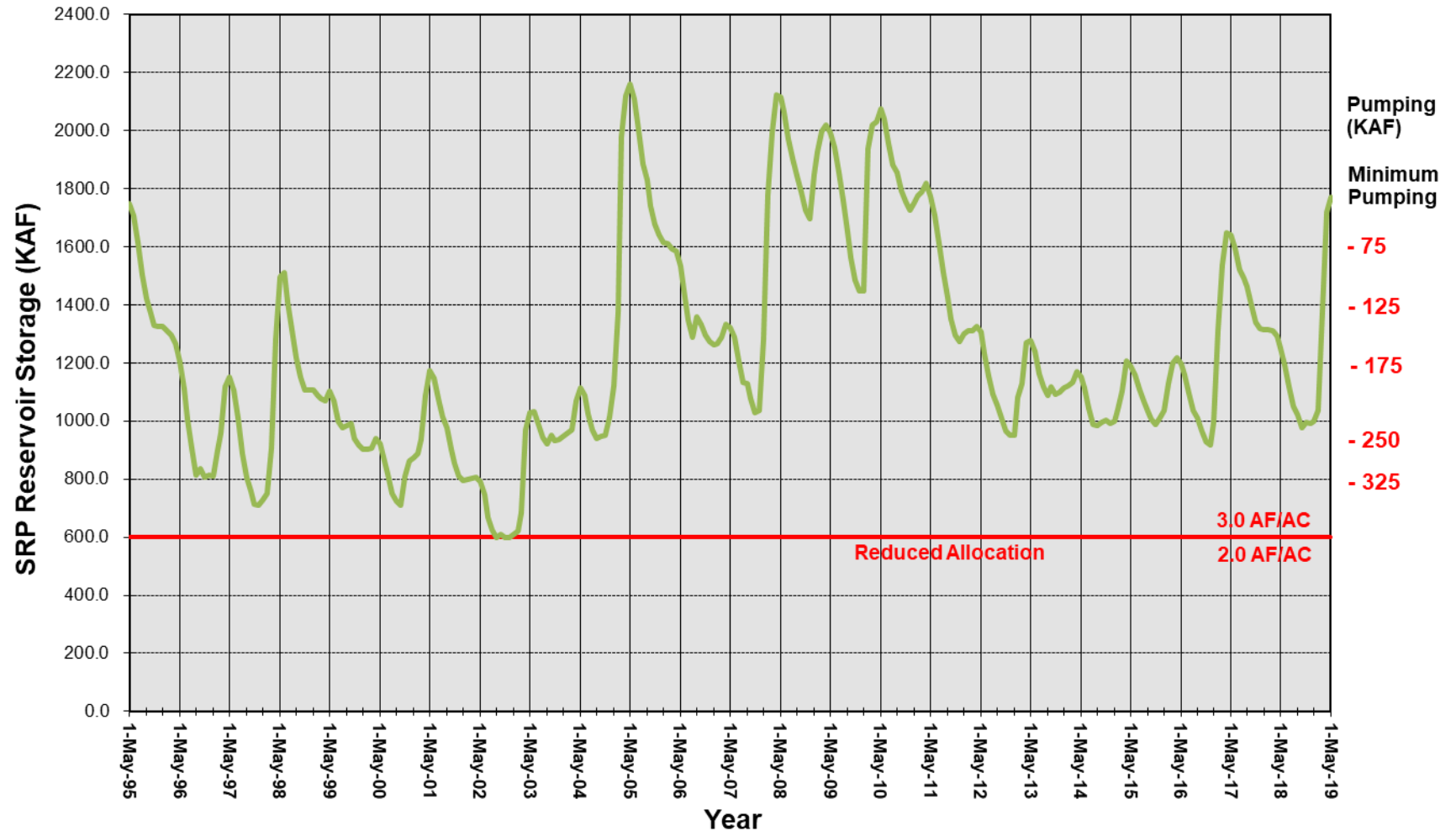
SRP Total Reservoir Storage Storage Planning Diagram

1995-2019 Contents:

- Similar amount in May 1995 as May 2019

2003-2004 – Reduced allocation

Decreased storage = increased pumping



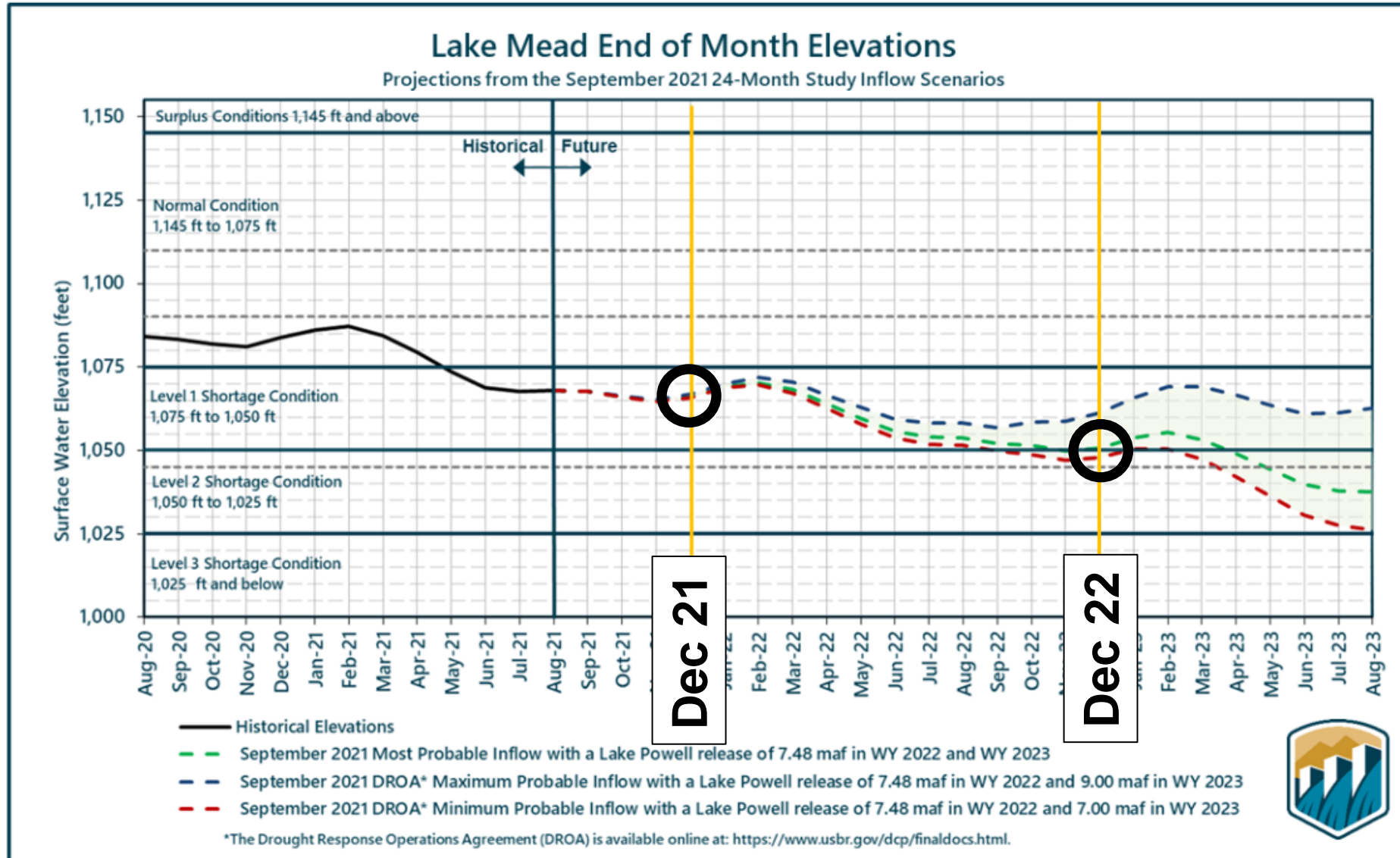
Colorado River

1. Large storage decrease during drought
2. Average annual inflow 21% of max. conservation storage
3. Structural deficit
4. Limited conjunctive use with alternative water supplies

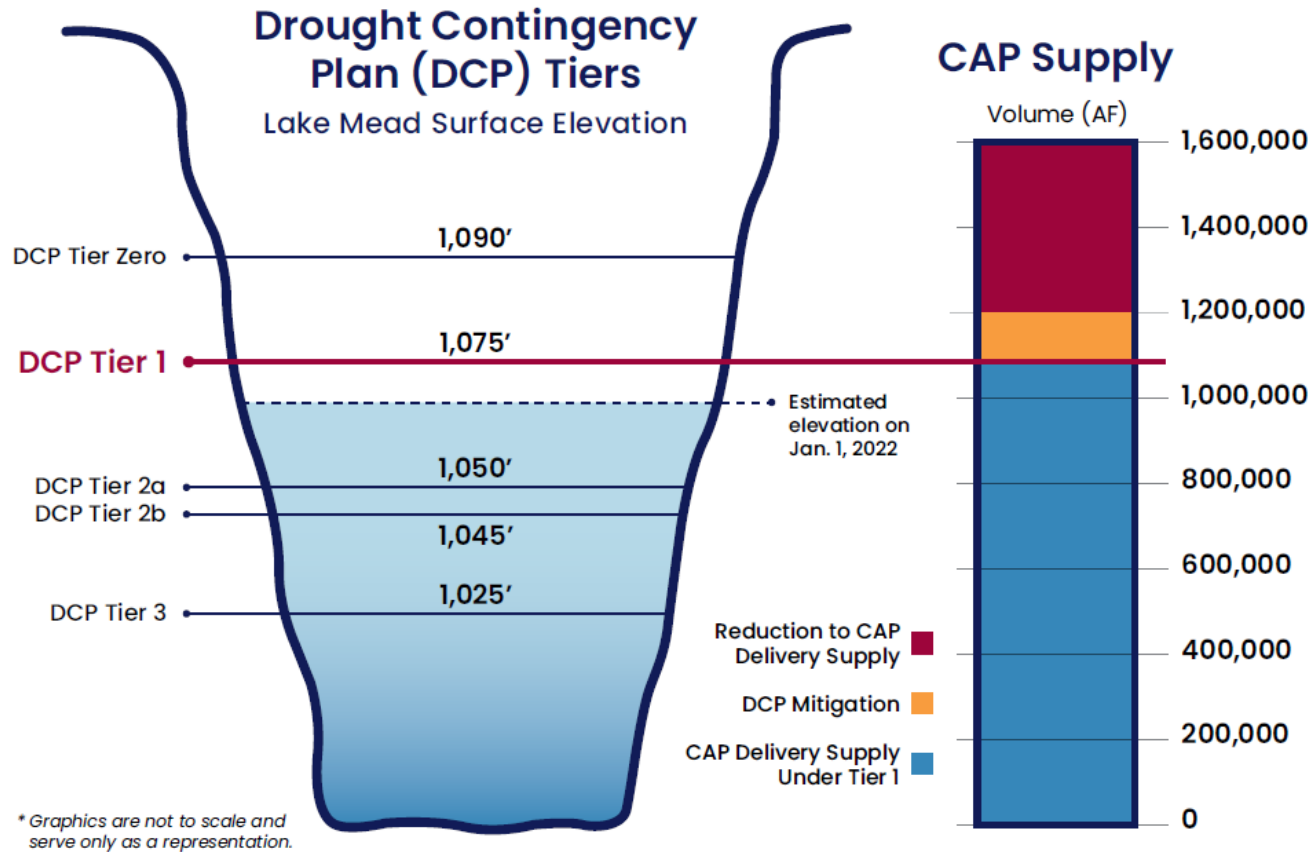
Salt River

1. Small storage increase during drought
2. Average annual inflow 50% of max. conservation storage
3. Long-term balance and recent decreasing demand
4. Conjunctive use with alternative supplies (groundwater)

USBR 24-month Study and Tier 1 Shortage Declaration

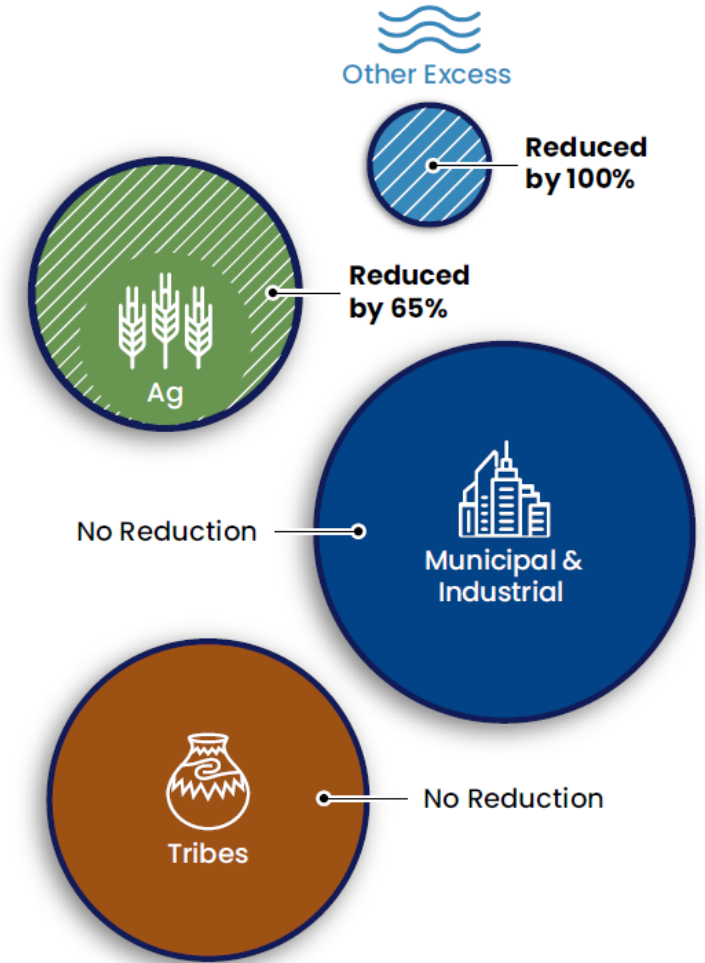


Tier 1 Shortage: CAP Reductions



To learn more, please visit: www.cap-az.com/colorado-river-shortage

2022 Reduction to CAP Users After DCP Mitigation



The Future: Natural Variability and Climate Change



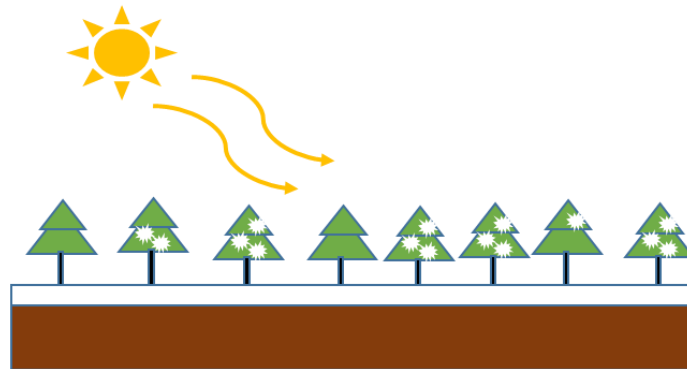
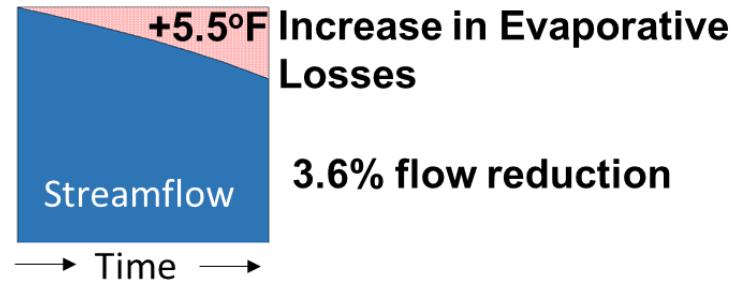
Impacts from Warming not Directly Included in USBR 24-month Study

The peak energy available for evaporative loss occurs 3 months after peak streamflow on the Salt-Verde (Robles et al. 2020).

This is not case for the UCRB partly contributing to a 5 times greater streamflow sensitivity to warming on the UCRB than the Salt-Verde (BOR 2020).

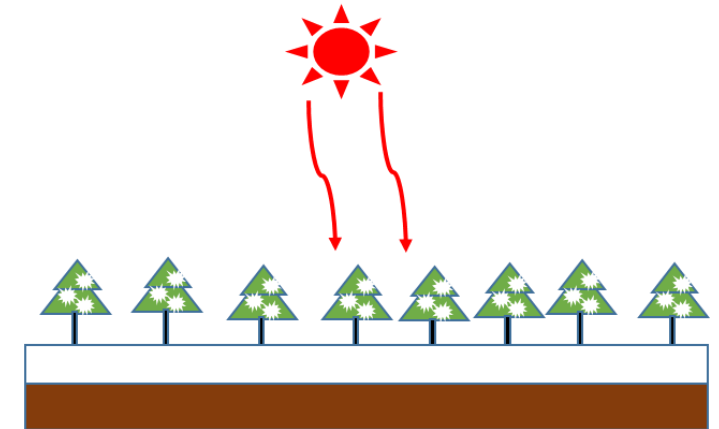
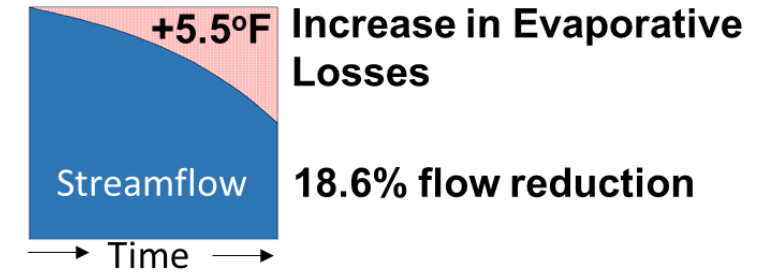
Salt-Verde Runoff Season

January-April



Colorado River Runoff Season

April-July



Regional Solutions

SRP-to-CAP Interconnection Facility (SCIF)



Delivering water and power™

Regional Solutions

Underground Storage Projects

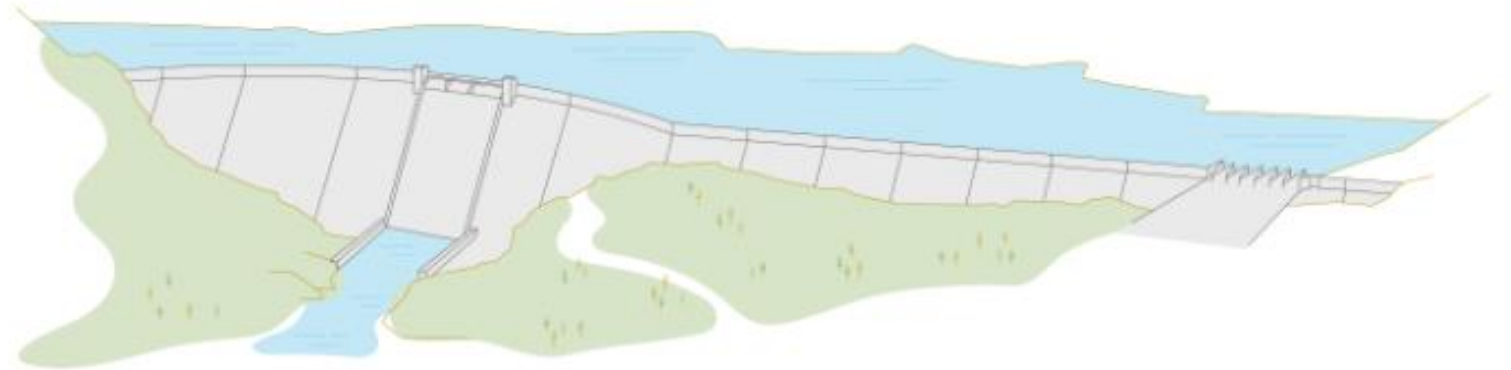


Regional Solutions

Existing Bartlett Dam



Modified Bartlett Dam



Summary

- **AZ's main supplies = CO River, Salt-Verde, and Groundwater**
- **Odds stacked against CO River water supply**
- **Drought and warmer temperatures make it worse**
- **Drought won't last forever and decreasing SRP demand is helping**
- **Need to capitalize on future wet years under climate change**

Winter 2022 Outlook



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December – February 2021/2022 Precipitation Outlook

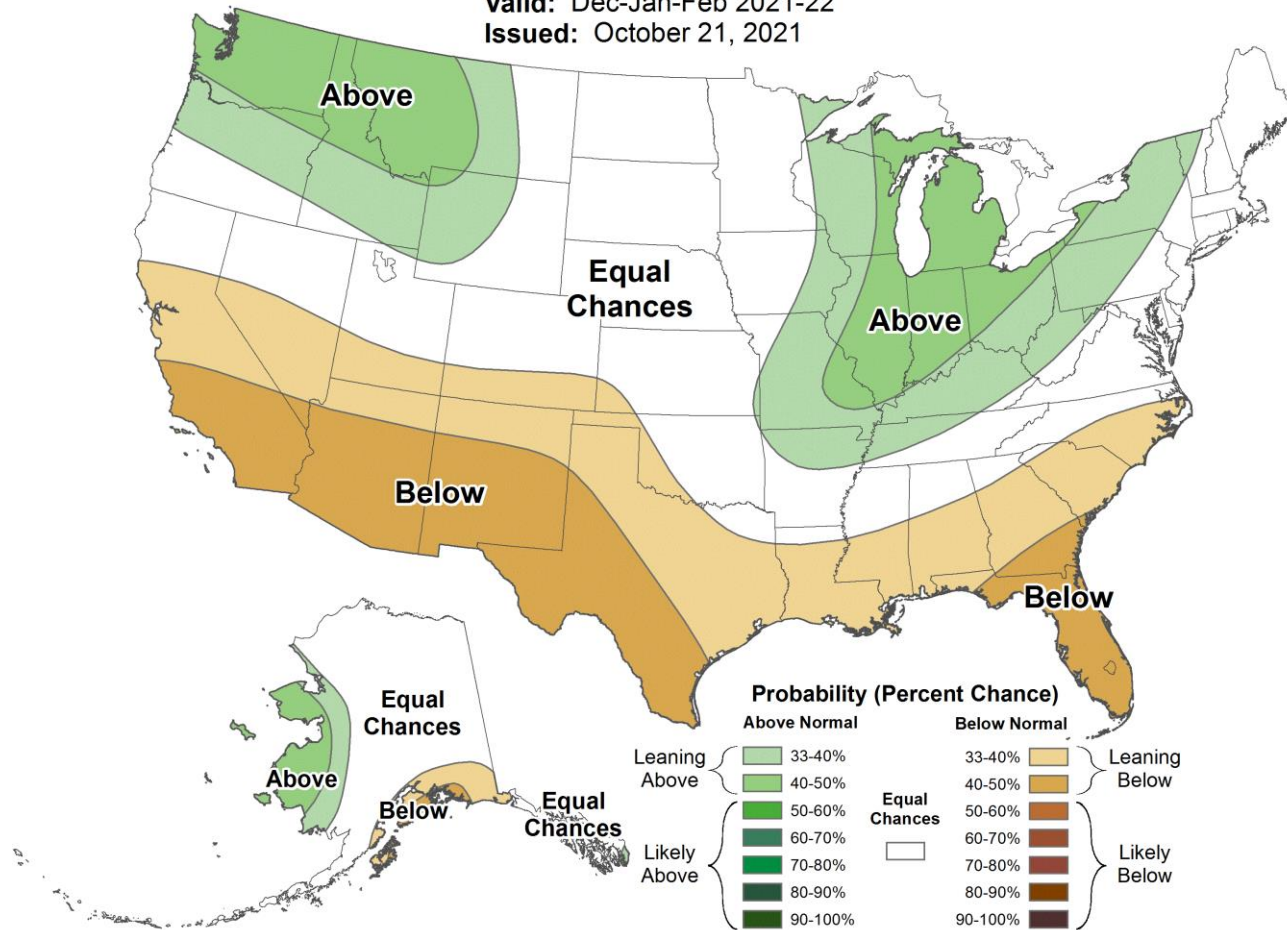


Seasonal Precipitation Outlook



Valid: Dec-Jan-Feb 2021-22

Issued: October 21, 2021



- 44% chance of Below Normal Precipitation
- 33% chance of Near Normal precipitation
- 23% chance of Above Normal Precipitation



Questions

- Plan for the Future – Drought
- Prepare for Operations – Flood
- Protect for Resilience – Wildfire



Delivering water and power™

References

BOR 2020; https://www.usbr.gov/watersmart/pilots/docs/reports/Final_Reservoir_Operations_Pilot_Report-Salt_and_Verde_Az.pdf

Barnes, EA, and L Polvani, 2013, Response of the midlatitude jets, and of their variability, to increased greenhouse gases in the CMIP5 models. *J. Climate*, 26, 7117–7135, <https://doi.org/10.1175/JCLI-D-12-00536.1>.

Gangopadhyay, S., McCabe, G., Pederson, G. *et al.* Risks of hydroclimatic regime shifts across the western United States. *Sci Rep* 9, 6303 (2019). <https://doi.org/10.1038/s41598-019-42692-y>

Robles, M.D., J.C. Hammond, S.K. Kampf, J.A. Biederman, E.M.C Demaria. 2020. Winter Inputs Buffer Streamflow Sensitivity to Snowpack Losses in the Salt River Watershed in the Lower Colorado River Basin. *Water*, 13, 3.

Ellis AW and K. Sauter, 2017, The significance of snow to surface water supply: an empirical case study from the southwestern United States, *Physical Geography*, DOI: 10.1080/02723646.2017.1281014

[Hammond and Kampf \(2020\). WRR. https://doi.org/10.1029/2019WR026132](https://doi.org/10.1029/2019WR026132)

Harpold AA and PD Brooks, 2018, Humidity determines snowpack ablation under a warming climate. *PNAS*. doi/10.1073/pnas.1716789115

Hawkins GA, Vivoni ER, Robles-Morua A, MascaroG, Rivera E, and Dominguez F, 2015, A climate change projection for summer hydrologic conditions in a semiarid watershed of central Arizona. *Journal of Arid Environments*, 118, 9–20. <https://doi.org/10.1016/j.jaride.2015.02.022>

Pierce, DW, DR Cayan, and BL Thrasher, 2014, Statistical Downscaling Using Localized Constructed Analogs (LOCA), *Journal of Hydrometeorology*, 15(6), 2558-2585.

Lehner, F. C. Deser, IR Simpson, and L. Terray. (2018). Attributing the US Southwest's recent shift into drier conditions. *Geophysical Research Letters*, 45,6251-6261, <https://doi.org/10.1029/2018GL078312>

Luong, TM *et al.*, 2017, The more extreme nature of North American monsoon precipitation in the southwestern US as revealed by a historical climatology of simulated severe weather events. *J. Appl. Meteor. Climatol.* 56, 2509–2529.

Lu J, X Daokai, G Yang, G Chen, LR Lueng, and P Staten, 2018, Enhanced hydrological extremes in the western United States under global warming through the lens of water vapor wave activity. *NPJ -Climate and Atmospheric Sciences*.

Mahmood TH and ER Vivoni, 2014, Forest ecohydrological response to bimodal precipitation during contrasting winter to summer transitions. *Ecohydrology*. 7, 998–1013.

[McCabe et al. \(2018\) https://doi.org/10.1175/JHM-D-17-0227.1](https://doi.org/10.1175/JHM-D-17-0227.1)

Mo KC, JE Schemm, and S Yoo, 2009, Influence of ENSO and the Atlantic Multidecadal Oscillation on Drought over the United States. *Journal of Climate*. doi:10.1175/2009JCLI2966.1

Murphy K and AW Ellis, 2019, An analysis of past and present megadrought impacts on a modern water resource system. *Hydrological Sciences Journal*. doi: 10.1080/02626667.2019.1571274.

Painter TH, SM Skiles, JS Deems, WT Brandt, and J Dozier, 2018, Variation in rising limb of Colorado River snowmelt runoff hydrograph controlled by dust radiative forcing in snow. *Geophysical Research Letters*, 45, 797–808. <https://doi.org/10.1002/2017GL075826>

Robles MD, DS Turner, JA Haney, 2017, A century of changing flows: Forest management changed flow magnitudes and warming advanced the timing of flow in a southwestern US river. *PLoS ONE* 12 (11): e0187875.

Robles MD, RM Marshall, F O'Donnell, EB Smith, JA Haney, 2014, Effects of Climate Variability and Accelerated Forest Thinning on Watershed-Scale Runoff in Southwestern USA Ponderosa Pine Forests. *PLoS ONE* 9(10): e111092. doi:10.1371/journal.pone.0111092

Ropelewski C, and M Halpert, 1986, North American precipitation and temperature patterns associated with the El Niño-Southern Oscillation (ENSO). *Monthly Weather Review*, 114,2352-2362, doi:10.1175/1520-0493

Yu JY, P Kao, H Paek, HH Hsu, C Hung, M Lu, S AN, 2015, Linking Emergence of the Central Pacific El Niño to the Atlantic Multidecadal Oscillation. *Journal of Climate*. doi:10.1175/JCLI-D-14-00347.1

Seager R and GA Vecch, 2010, Greenhouse warming and the 21st century hydroclimate of southwestern North America. *PNAS*. doi/10.1073/pnas.0910856107

Singh I, F Dominguez, E Demaria, and J Walter, 2018, Extreme landfalling atmospheric river events in Arizona: Possible future changes. *Journal of Geophysical Research: Atmospheres*, 123. <https://doi.org/10.1029/2017JD027866>

Svoma BM, 2017, Canopy Effects on Snow Sublimation from a Central Arizona Basin. *Journal of Geophysical Research-Atmospheres*. DOI: 10.1002/2016JD025184

Vano JA, T Das, and DP Lettenmaier, 2012, Hydrologic sensitivities of Colorado River runoff to changes in precipitation and temperature. *J. Hydrometeor.*, 13, 932–949, doi:10.1175/JHM-D-11-069.1.

Vano, JA et al. 2014. *BAMS*. <https://doi.org/10.1175/BAMS-D-12-00228.1>

Woodhouse CA, and GT Pederson, 2018, Investigating runoff efficiency in upper Colorado river streamflow over past centuries. *Water Resources Research*, 54, 286–300. <https://doi.org/10.1002/2017WR021663>

Woodhouse CA, GT Pederson, K Morino, SA McAfee, and GJ McCabe, 2016, Increasing influence of air temperature on upper Colorado River streamflow, *Geophys. Res. Lett.*, 43, 2174–2181, doi:10.1002/2015GL067613.

SRP Reservoir System

Verde River Dams

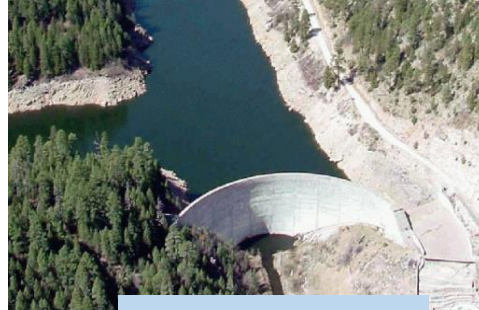


Horseshoe Dam
(1951)

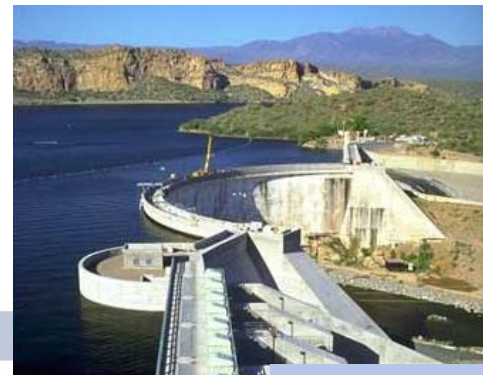


Bartlett Dam
(1939, 1997)

East Clear Creek Dam

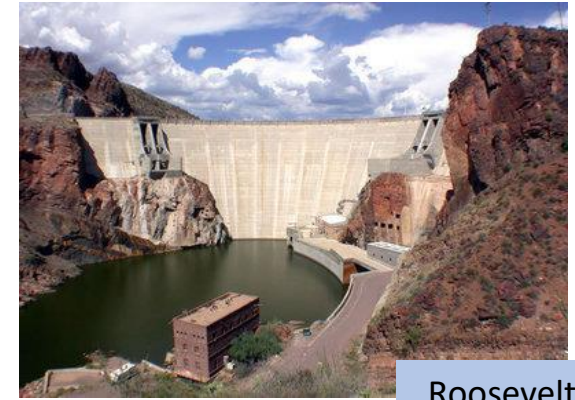


C.C. Cragin Dam
(1965)



Stewart Mt Dam
(1930, 1992)

Salt River Dams



Roosevelt Dam
(1911, 1996)



Horse Mesa Dam
(1927)



Mormon Flat Dam
(1925)