Tree Rings, Gages and Climate Models:

Revising reservoir planning based on vulnerability to sustained drought in the past and future

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Water Resource Operations

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Climate Change and
Water Resource Management

Salt River Project

Salt River Valley Water Users Association

- Established 1903
- A Federal reclamation project
- A private corporation
- Delivers almost 1 million acre-feet per year

SRP Agricultural Improvement and Power District

- Established 1937 as a political subdivision of the state of Arizona
- 32,571 million kWh sold in FY10
- 942,000 customers in and around the Phoenix metro area

SRP manages 6 reservoirs on the Salt (4) and Verde (2) rivers, operates wells in the service area, and delivers nearly 1 million acre-feet of water per year.

Average Annual Precipitation

Arizona

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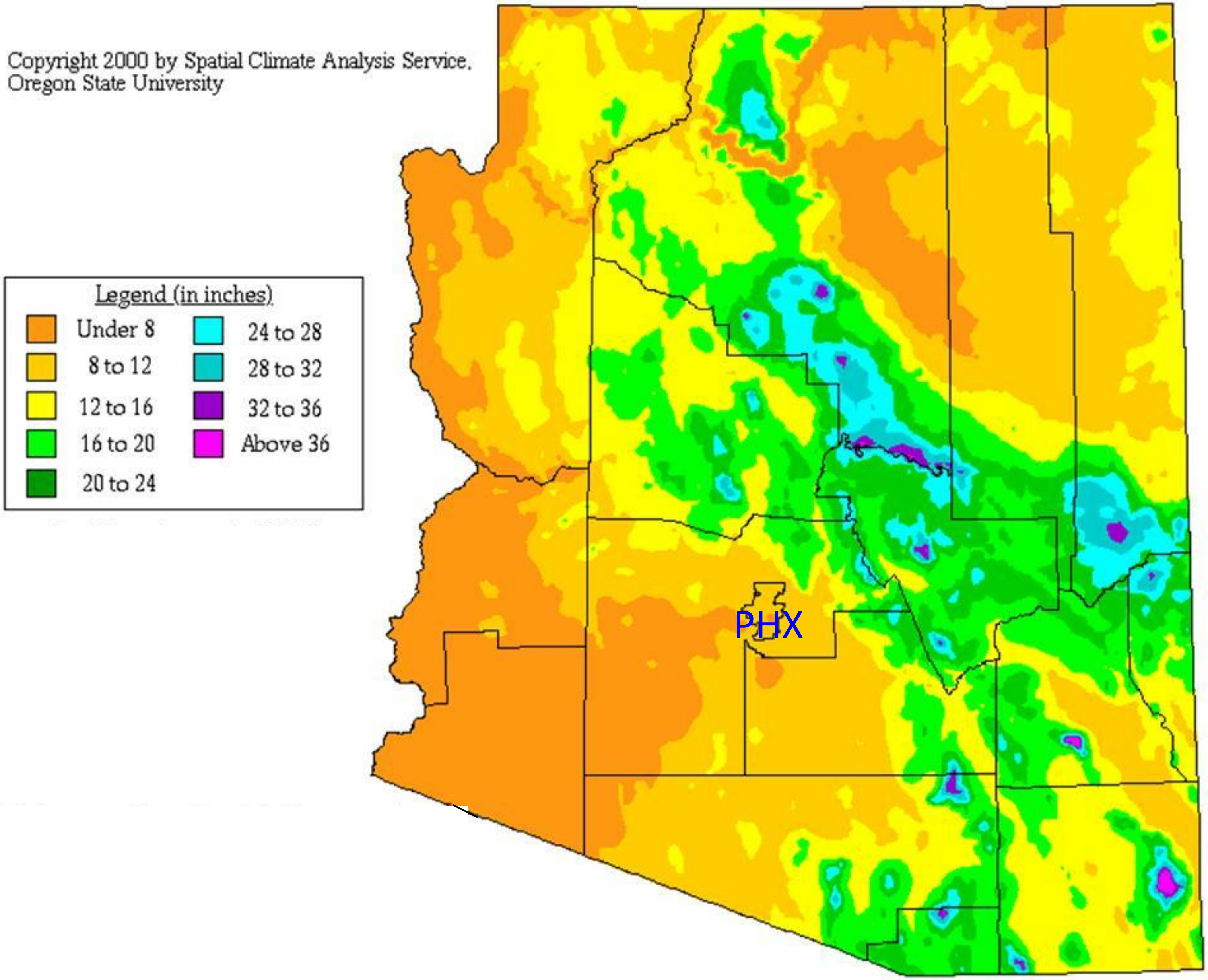
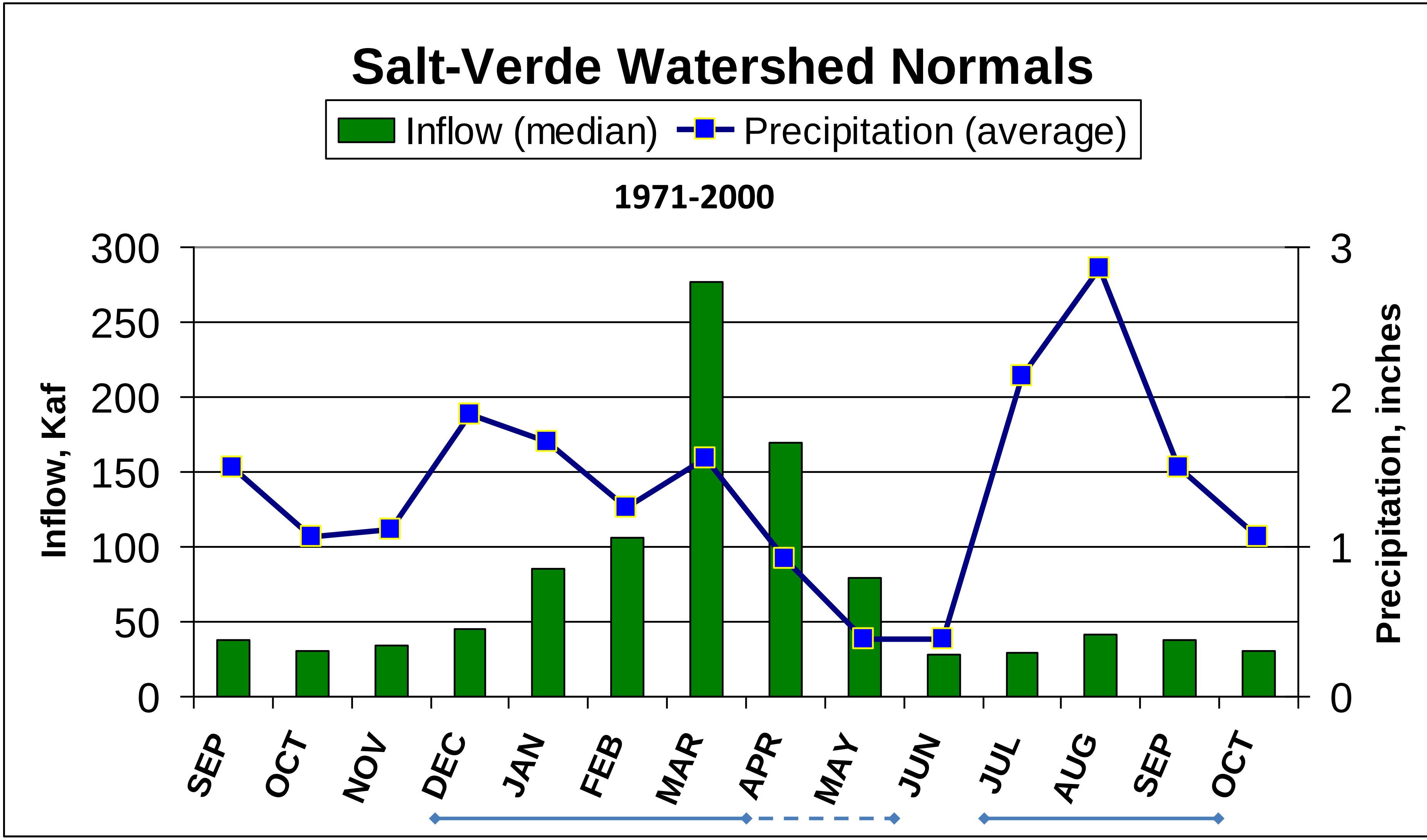




WINTER:

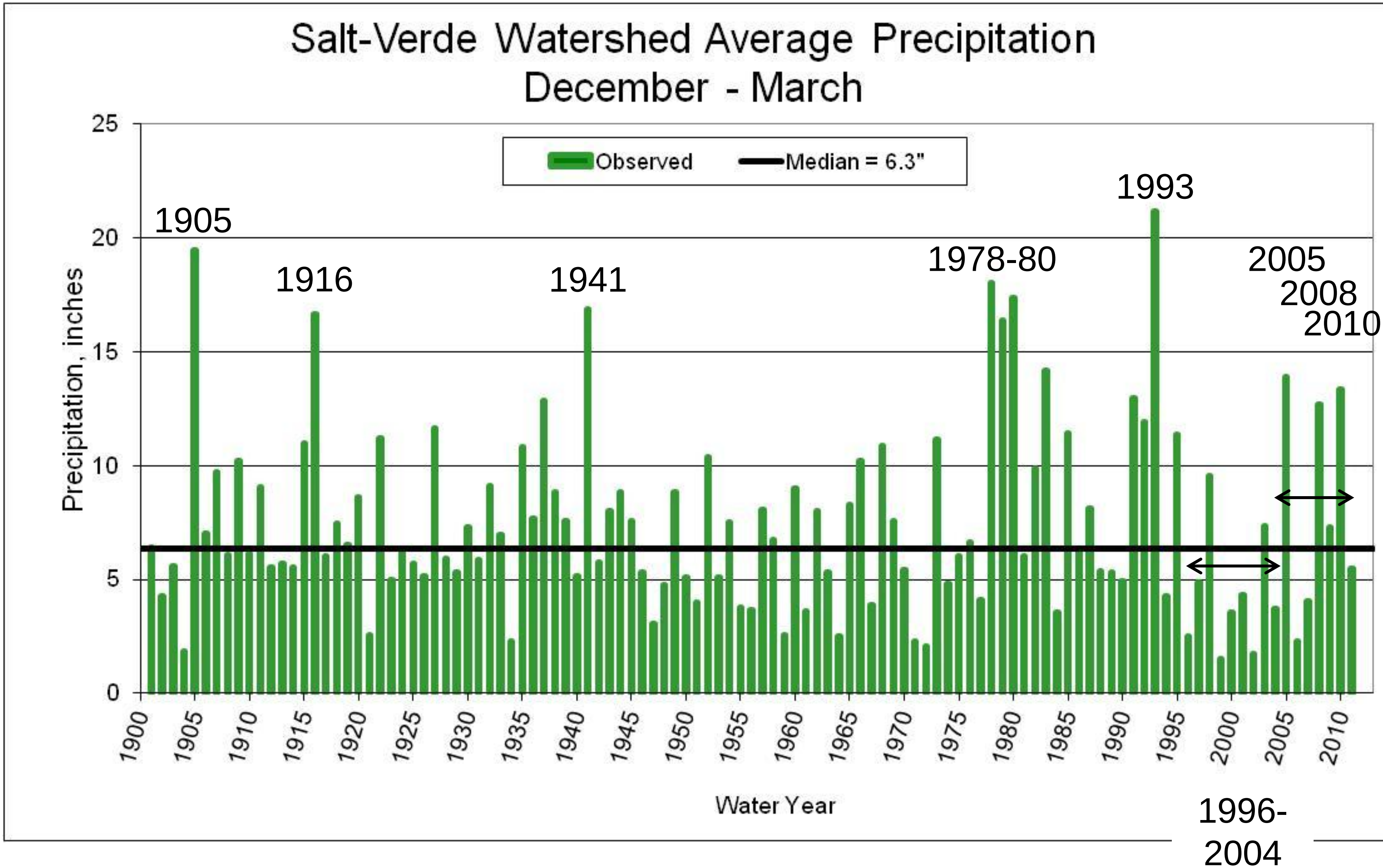
Precip. (Dec-Mar): 6.3 in

Runoff (Dec-May): 665 Kaf

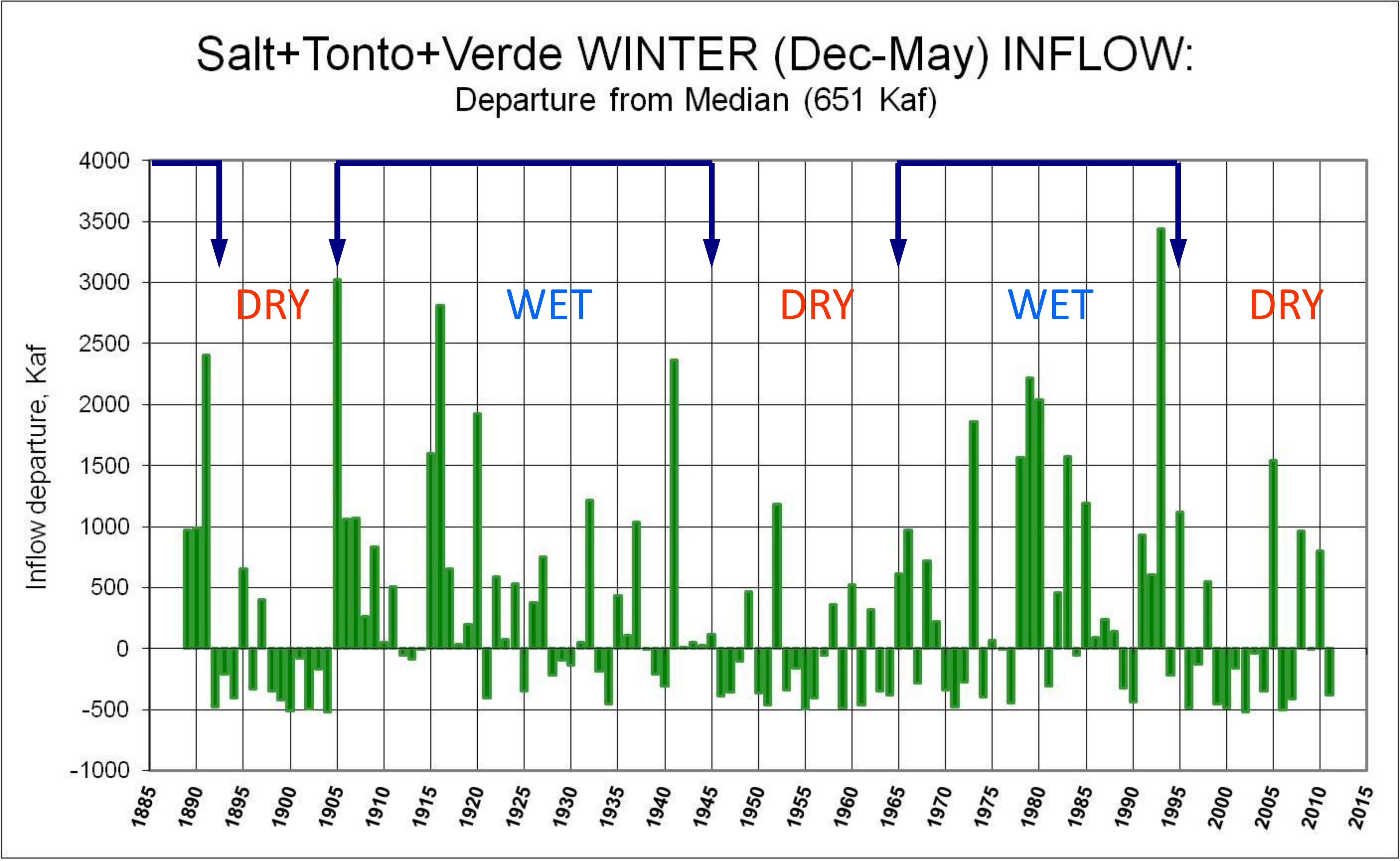
SUMMER:

Precip. (Jul-Sep): 6.8 in

Runoff (Jul-Sep): 120 Kaf



Salt-Verde Watershed Average Precipitation
December - March
Observed
Median = 6.3"
Precipitation, inches
Water Year
1905
1916
1941
1978-80
1993
2005
2008
2010
1996-
2004
0
5
10
15
20
25
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010



1892-1904: 2 wet, 11 dry	1905-45: 28 wet, 13 dry	1946-64: 5 wet, 14 dry	1965-95: 19 wet, 12 dry	1996-2011: 4 wet, 12 dry

SRP Water Resource Operations: jas 05/2011 decmayro

How Vulnerable Are We?

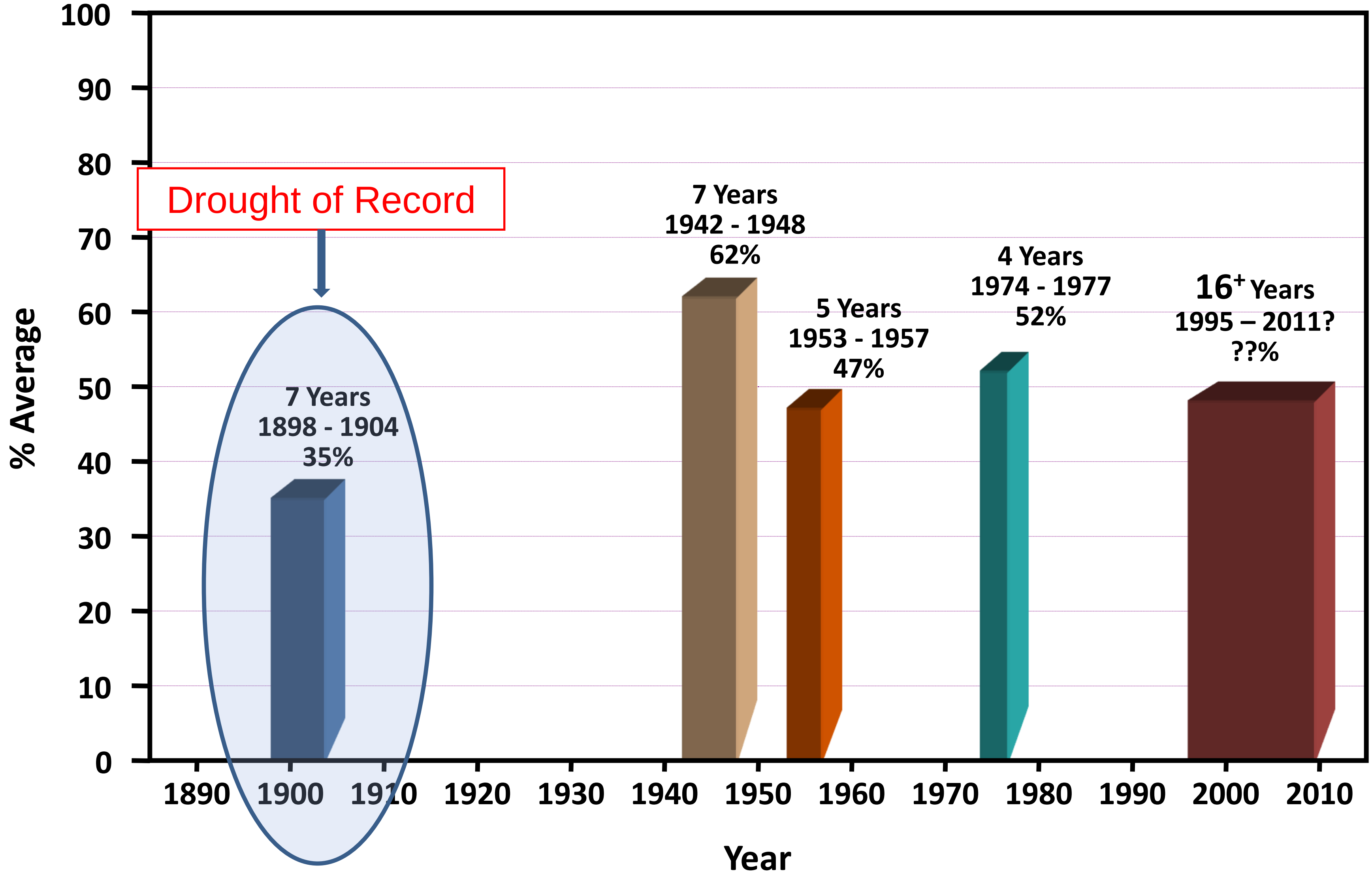
Key Question: What is minimum annual inflow that allows SRP to maintain carryover storage in perpetuity?

Examined:

- Historical, instrument-era record (110 years)
- Tree-ring record (600 years)
- Climate change, GCM scenarios (future decades)

Salt River Project Historic Drought Periods

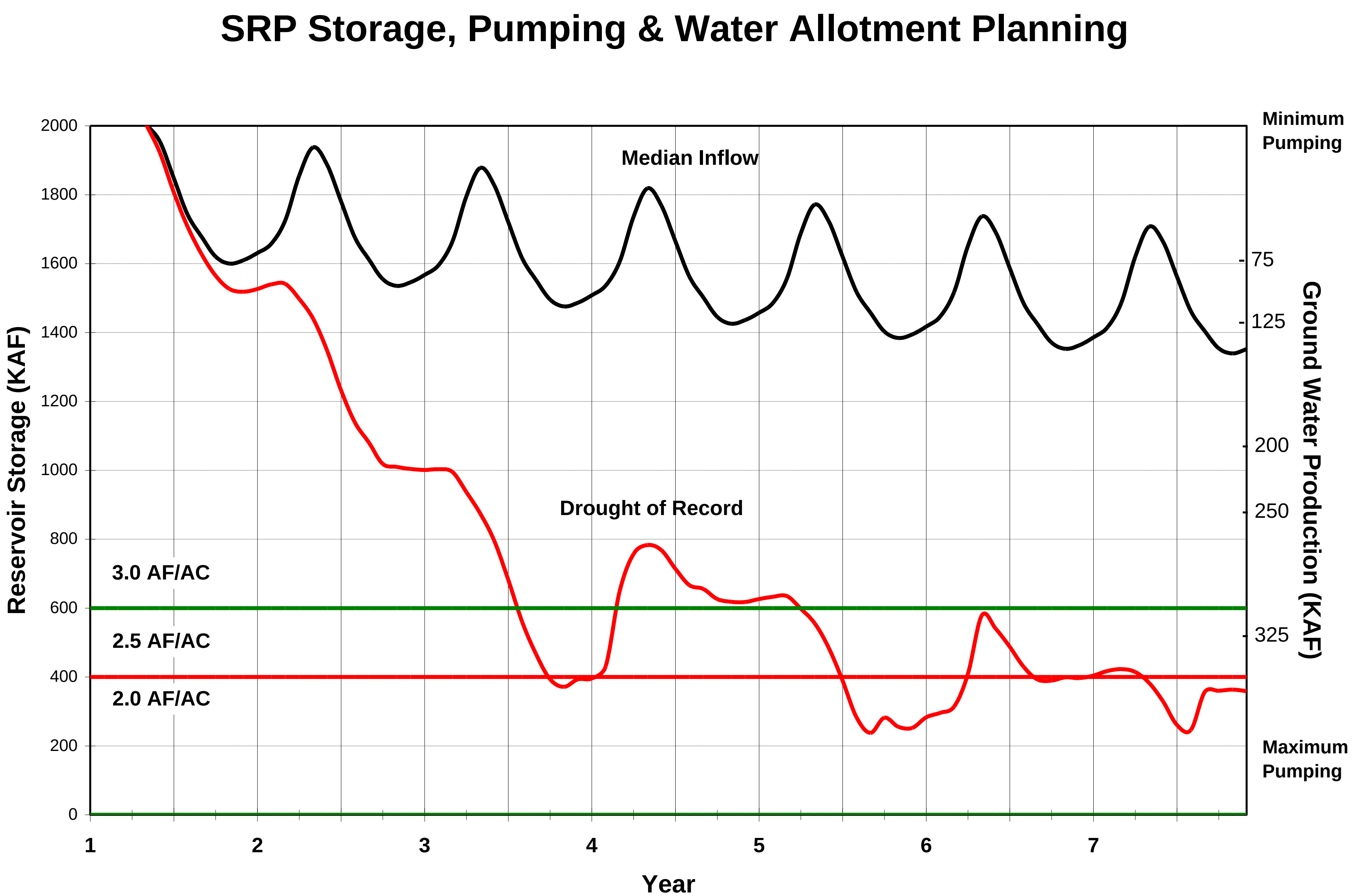
(Average Runoff 1913–2010 = 1,198,536 AF)



Planning Assumptions
Version 1.0 (1980s and 1990s)

- 950 kaf -- full demand
- 325 kaf -- maximum pumping
- Historical “drought of record”: 1898-1904
- Use allocation and pumping to manage for “drought of record”

Storage Planning Diagram



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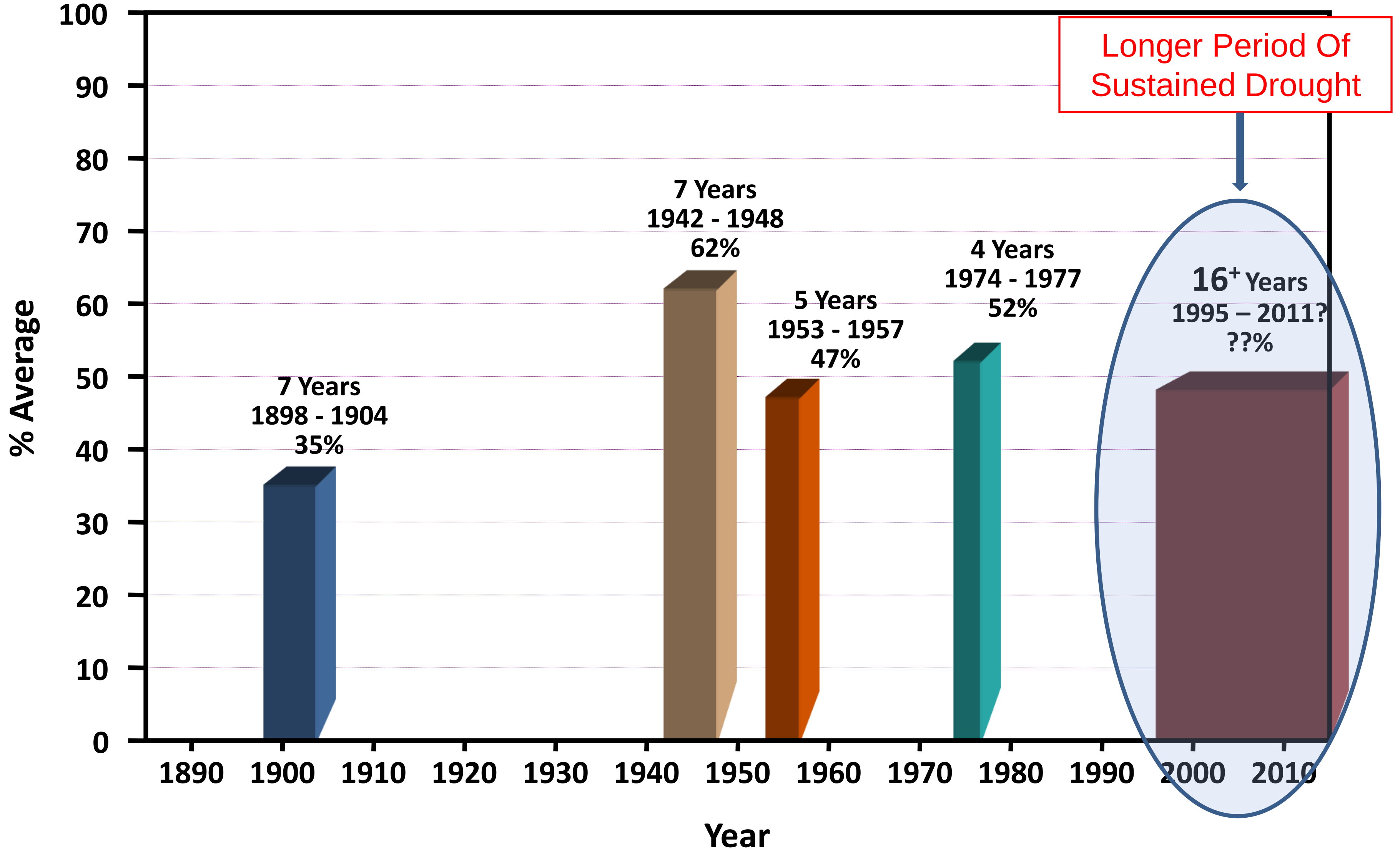
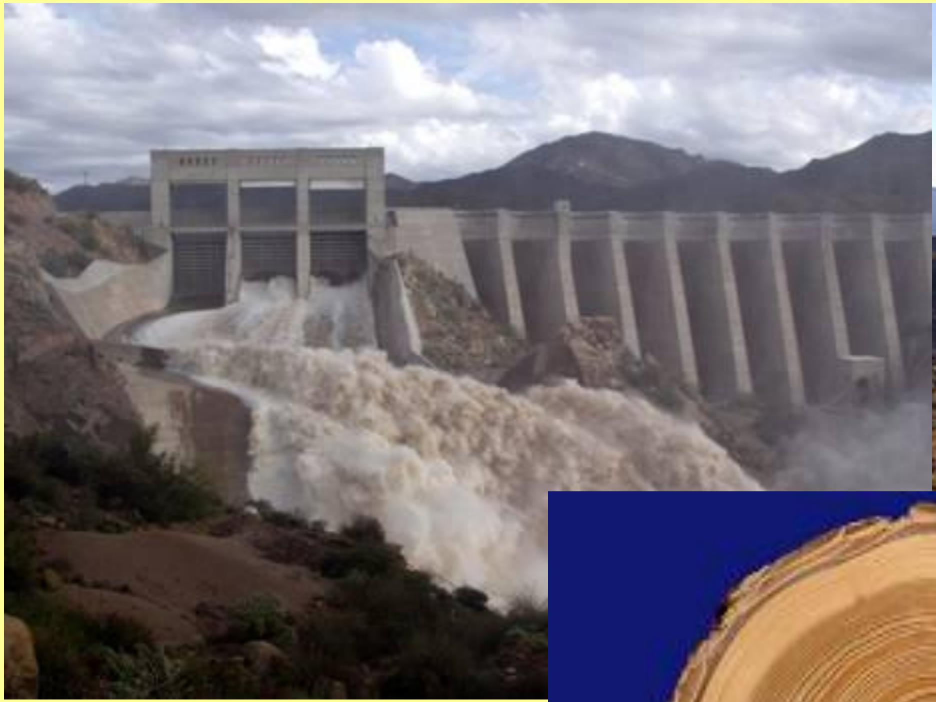
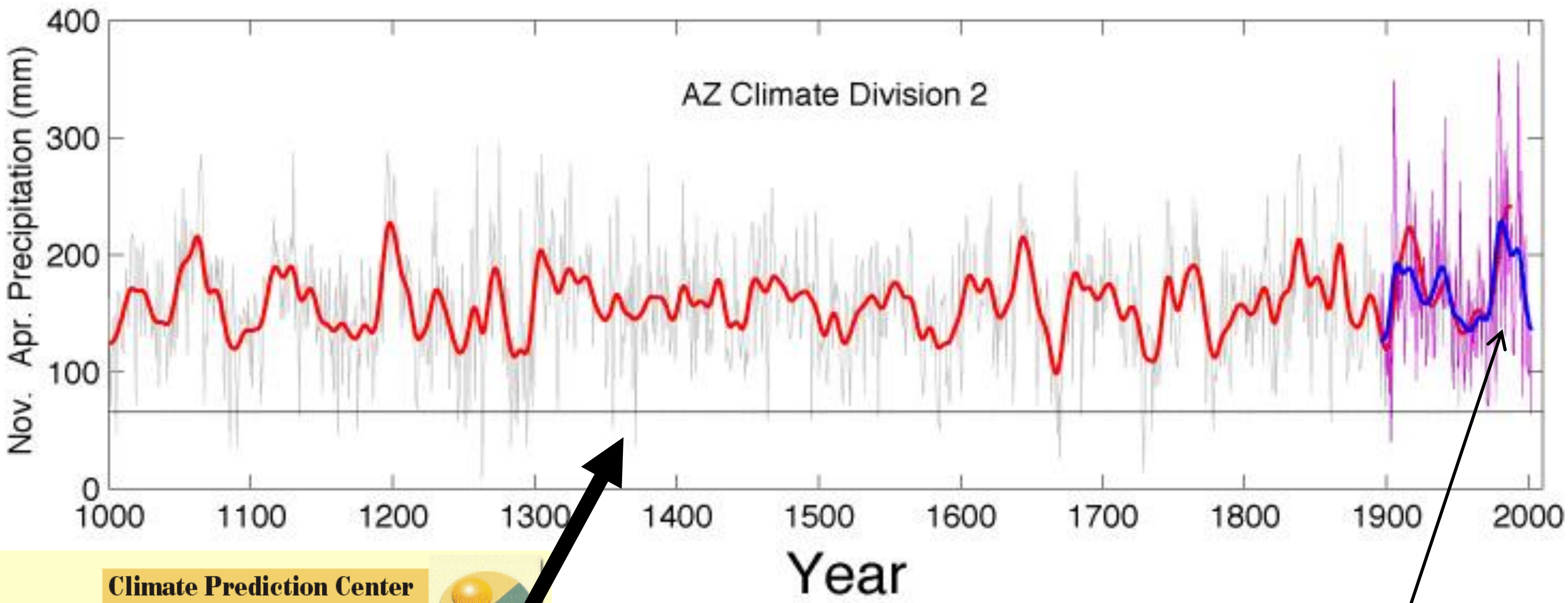
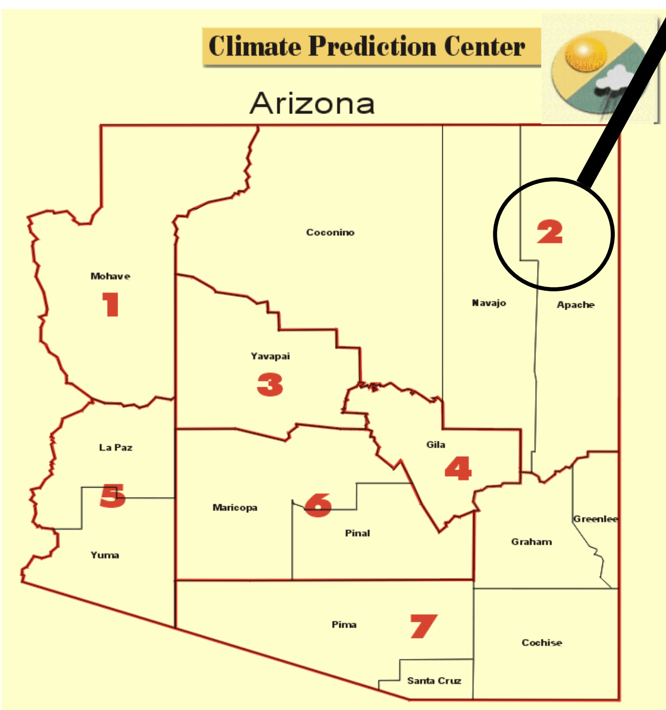


What can tree ring analysis tell us about pre-20th century floods and droughts?



1000-year Tree Ring Analysis

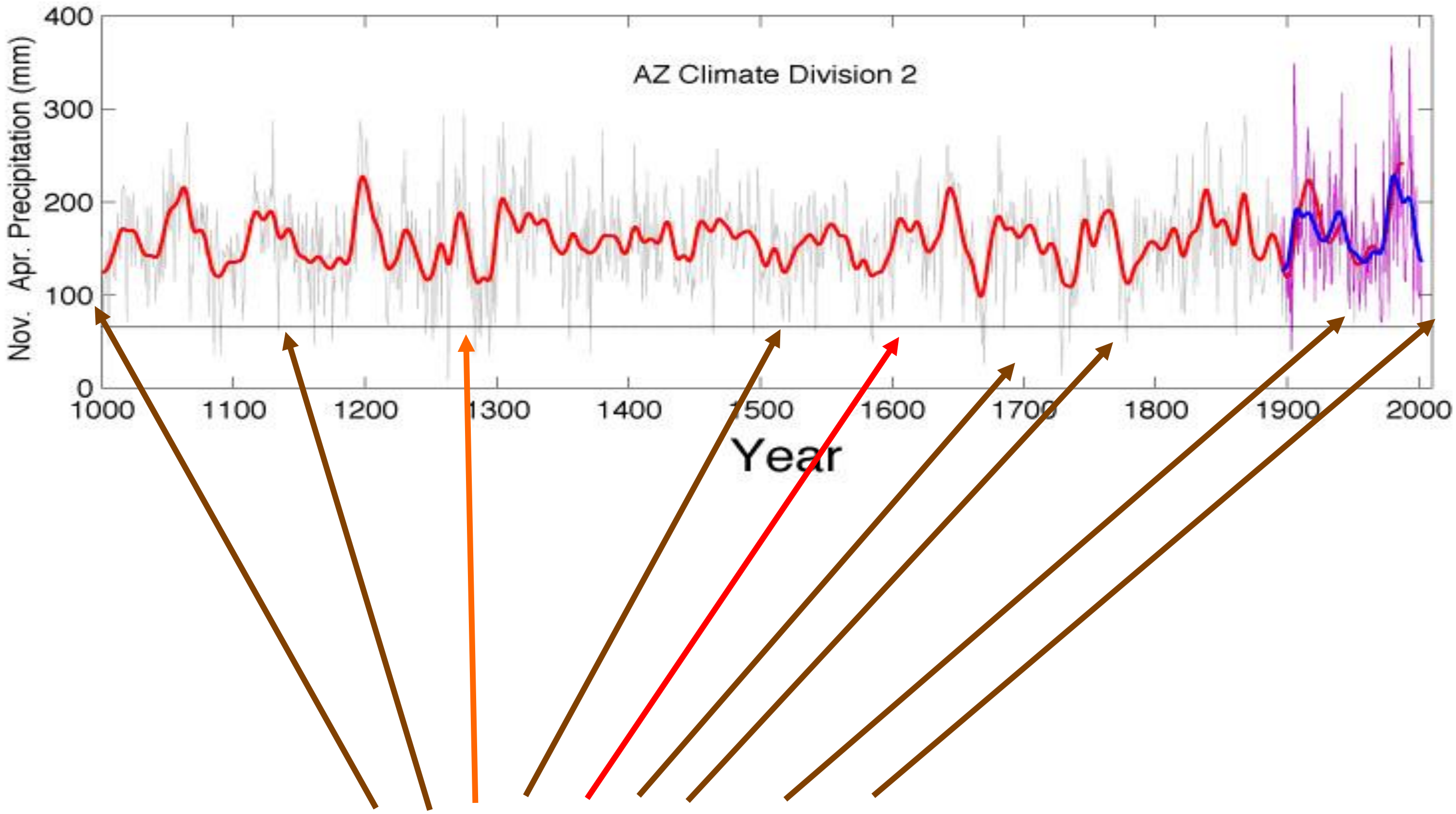




Analysis conclusions:

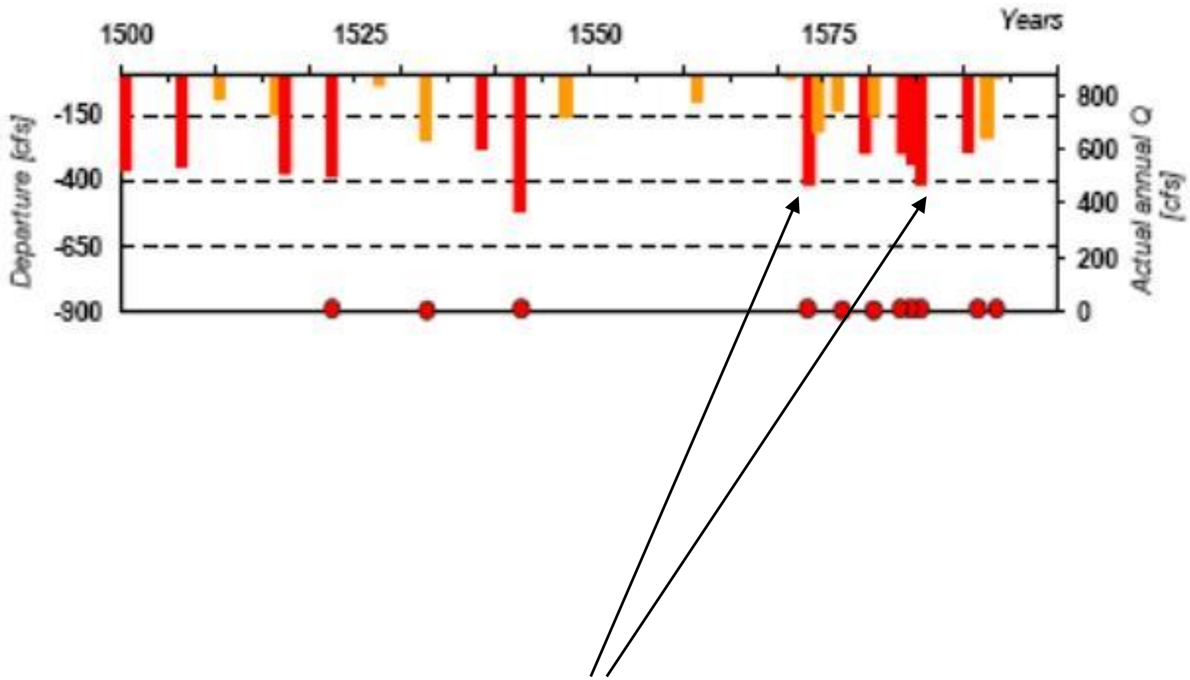
From 1975 to 1995, Arizona was <u>very wet</u> (25% more than average), and…

1000-year Tree Ring Analysis



…Droughts lasting a <u>decade or more</u> are not uncommon.

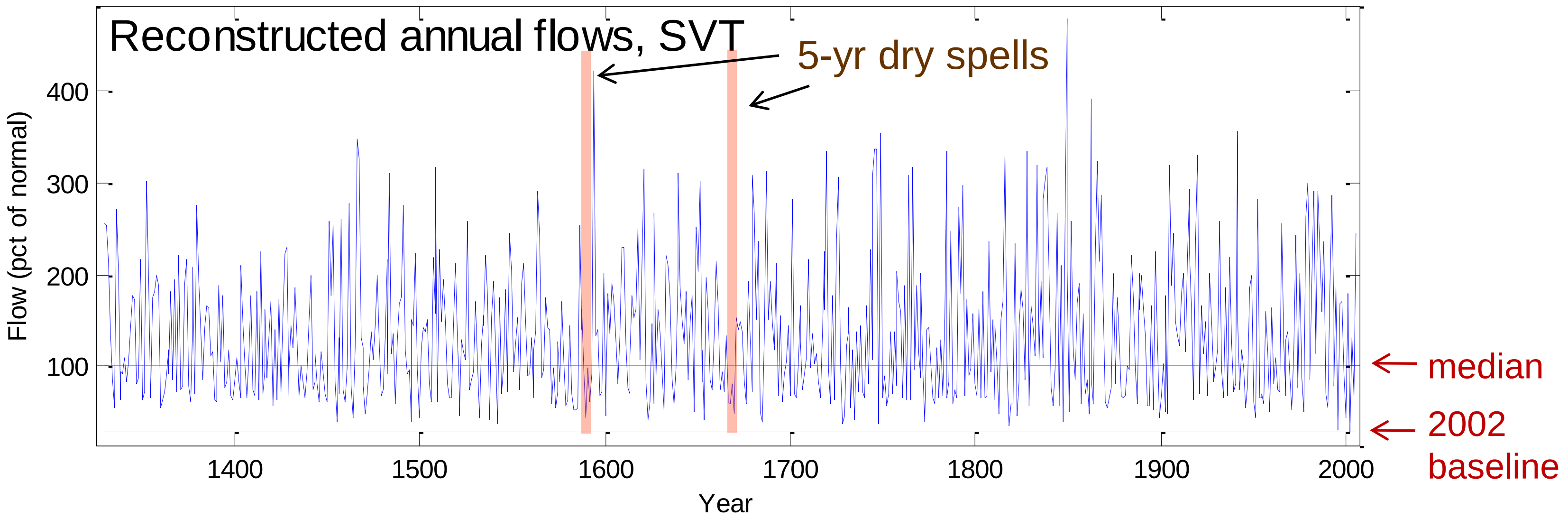
The mega-drought of 1575-85.



An 11-Year drought with 70 percent of historical gaged median inflow.

Annual Reconstructed Flows, 1330-2005

Plotted as percent of normal*
(*1914-2006 median of observed flows)



2002 and 1996 have the lowest reconstructed annual flows in the entire record (28% and 30% of normal* respectively).

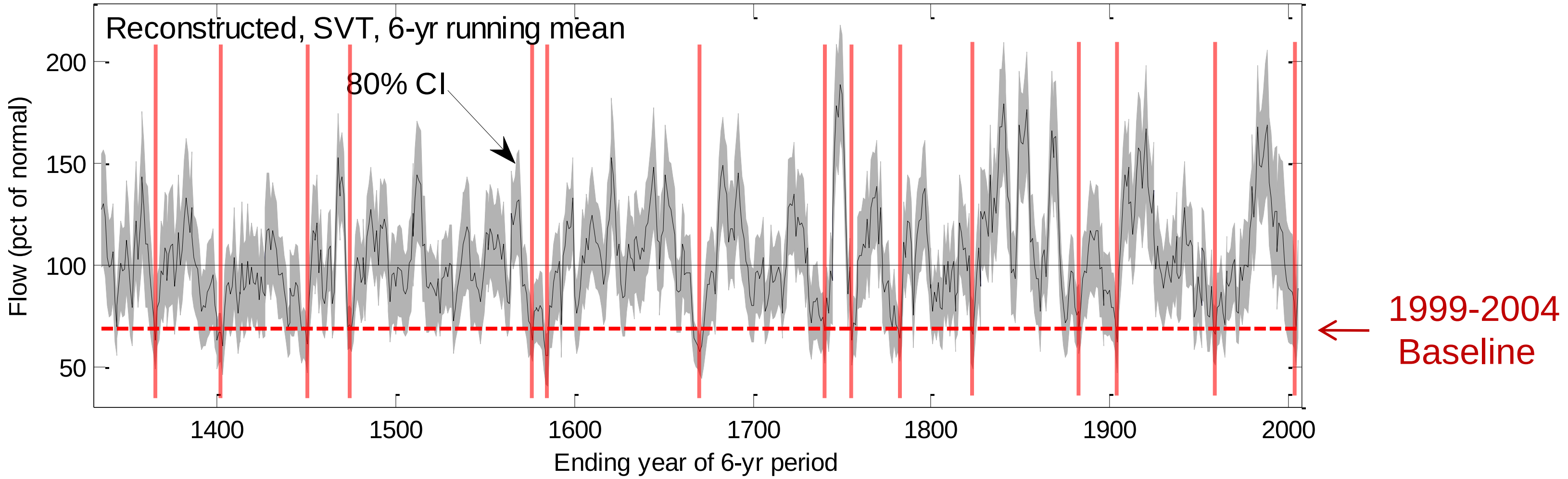
Maximum number of consecutive years below normal is 5 years (in 1590s and 1660s).

Longest stretch of consecutive years below normal in recent interval of 1914-2005 is 4 years (in 1950s).

LTRR, UA (2008)

Variations in Time-Averaged Flows

Plotted as % of normal*
*median of all 6-year running means

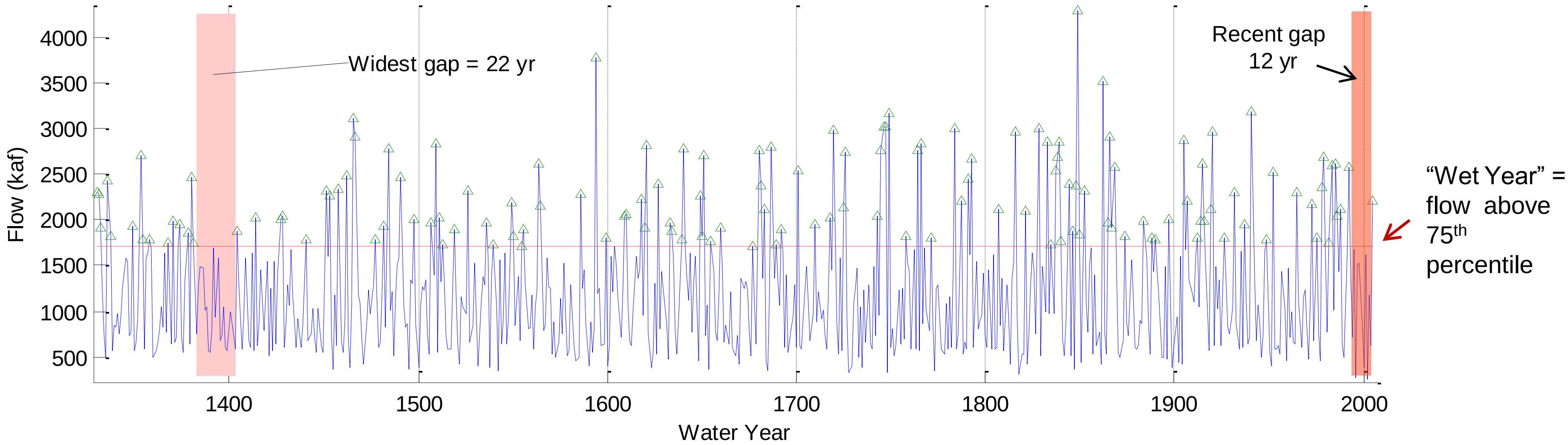


- 14 distinct prior occurrences of flow as low as 1999-2004 average
- 1- 3 occurrences in each century
- Most severe conditions at ~1590 and ~1670

LTRR, UA (2008)

Length of Intervals Between Wet Years

based on reconstructed flows, 1330-2005



Longest interval = 22 years (1382-1403)

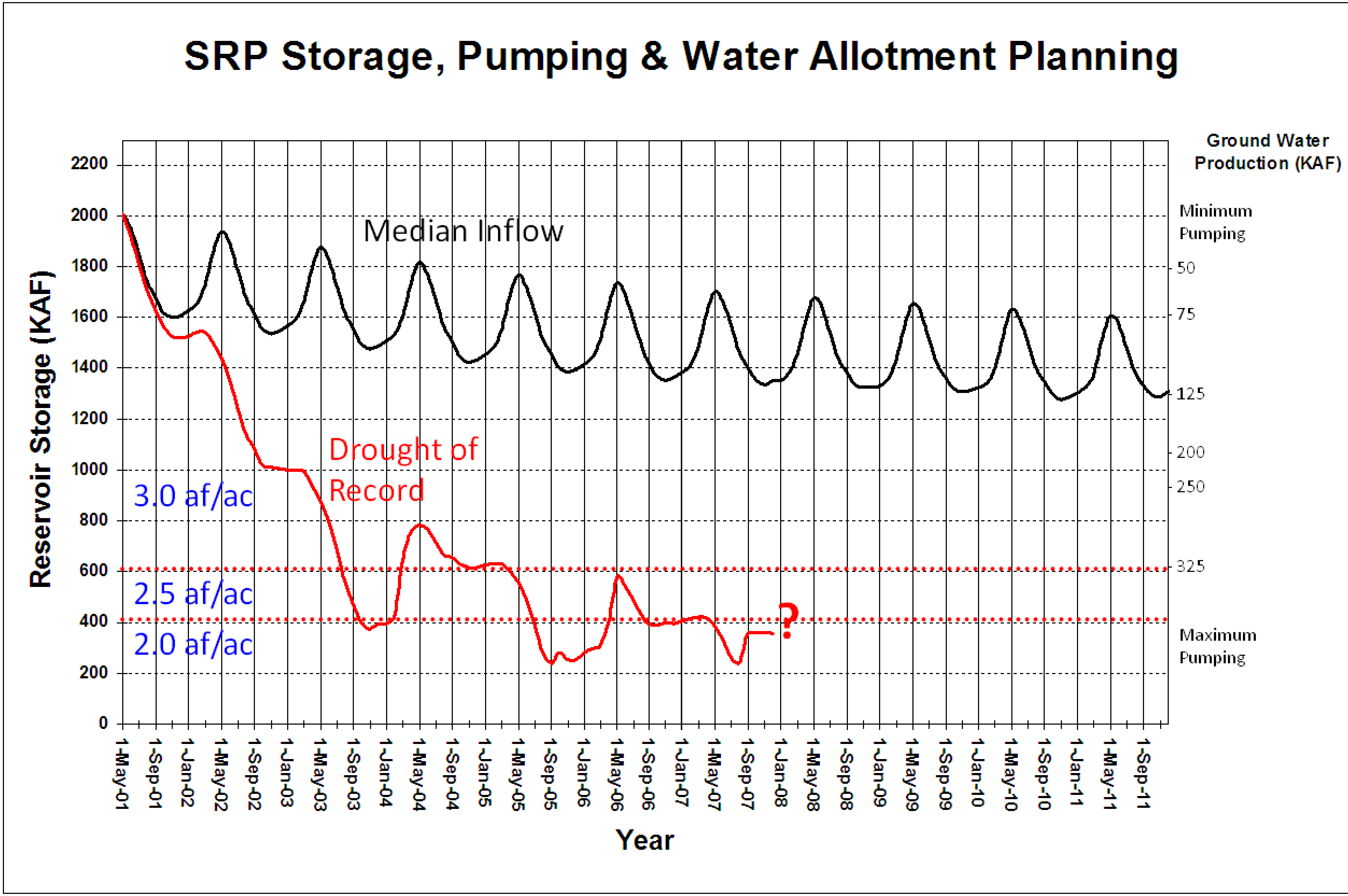
Recent interval = 12 years (1993-2004)

1950s interval = 12 years (1953-1964)

10 intervals ≥ 12 years

Median interval is 3 years

LTRR, UA (2008)



SRP Storage, Pumping & Water Allotment Planning
Reservoir Storage (KAF)
Ground Water Production (KAF)
Median Inflow
Drought of Record
3.0 af/ac
2.5 af/ac
2.0 af/ac
Minimum Pumping
Maximum Pumping
?
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
50
75
125
200
250
325
1-May-01
1-Sep-01
1-Jan-02
1-May-02
1-Sep-02
1-Jan-03
1-May-03
1-Sep-03
1-Jan-04
1-May-04
1-Sep-04
1-Jan-05
1-May-05
1-Sep-05
1-Jan-06
1-May-06
1-Sep-06
1-Jan-07
1-May-07
1-Sep-07
1-Jan-08
1-May-08
1-Sep-08
1-Jan-09
1-May-09
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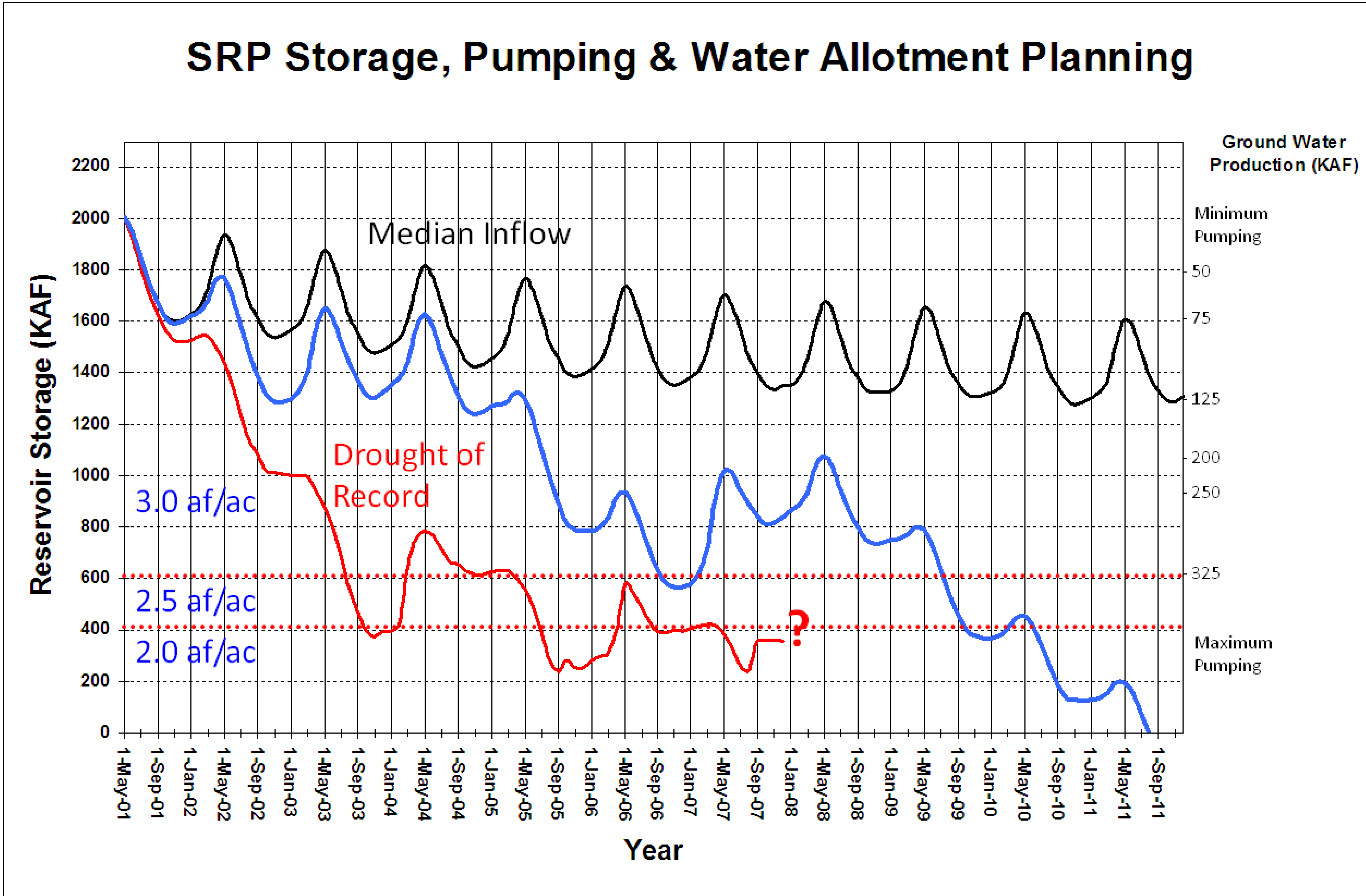
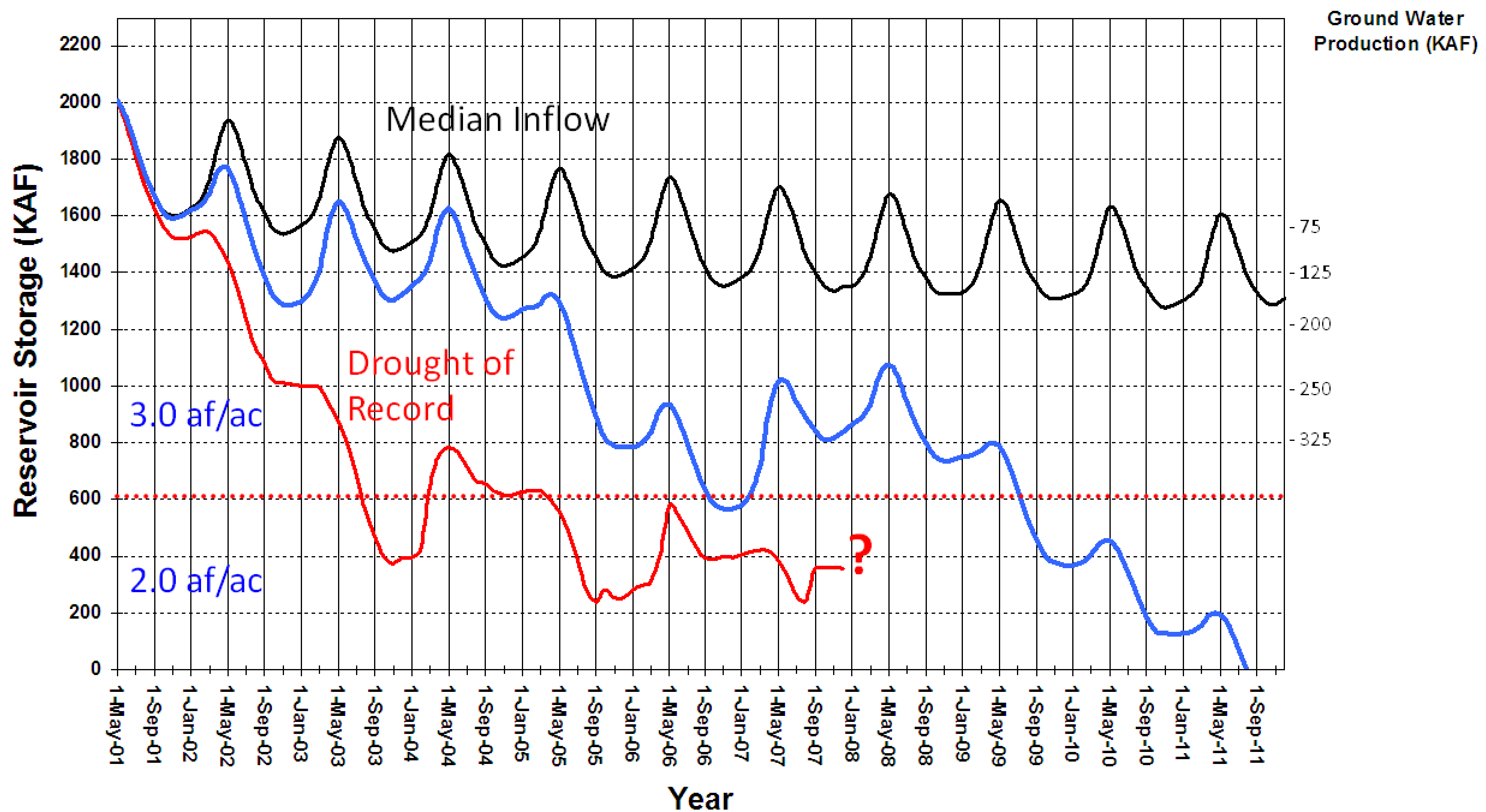
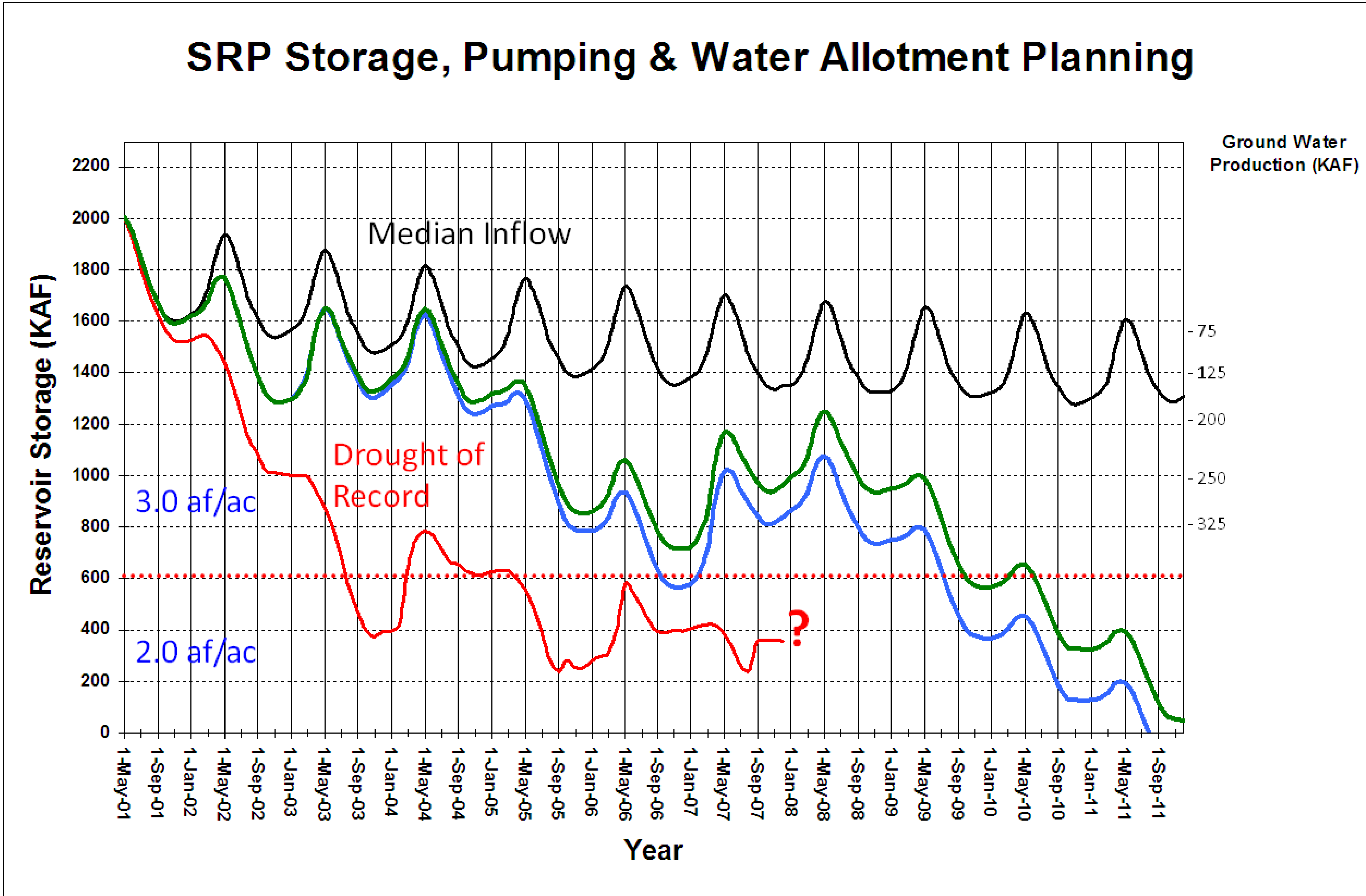
1-May-10
1-Sep-10
1-Jan-11
1-May-11
1-Sep-11
Year



11-yr Tree-ring Drought with previous planning scenario

SRP Storage, Pumping & Water Allotment Planning



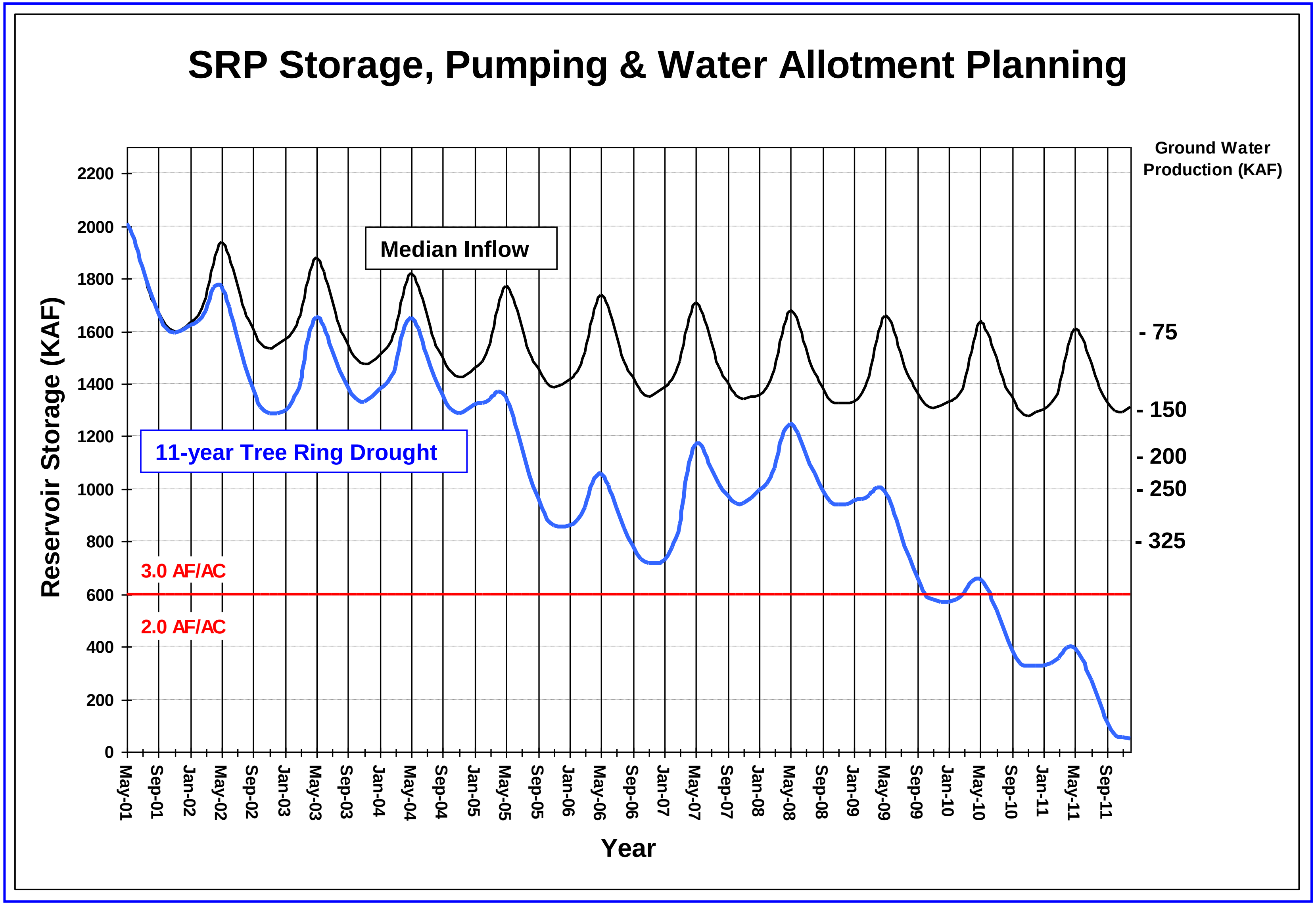


11-year Tree-ring Drought with new planning scenario

Version 2.0 Planning Guidelines

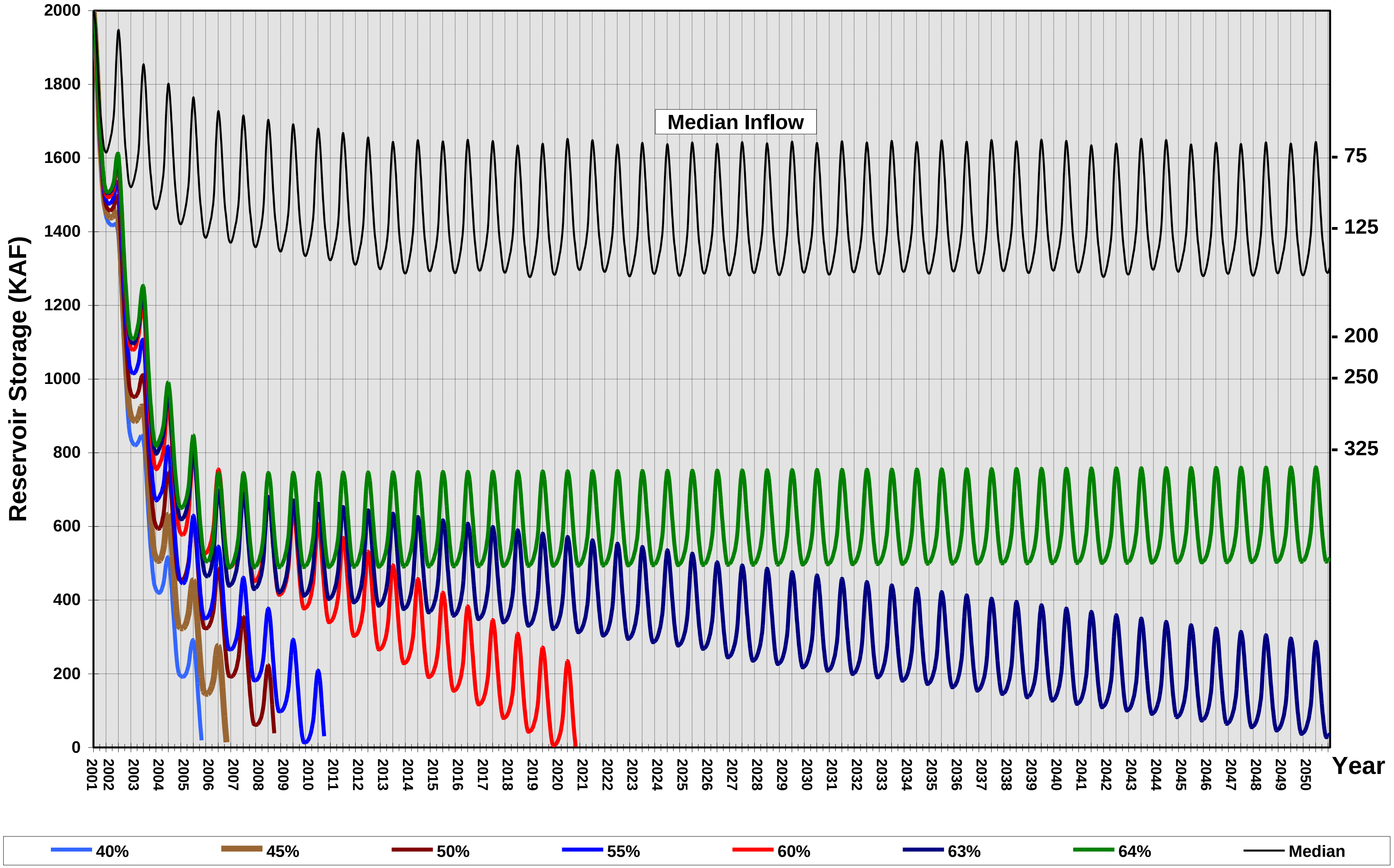
- 950 kaf -- full demand
- 325 kaf -- maximum pumping (start earlier)
- Tree-ring drought of record, 1575-1585
- Use allocation and pumping to manage for the 11-year tree-ring drought

Version 2.0 Planning Guidelines



Simulated Reservoir Storage for a Range of Perpetually Reduced Inflows (as a percent of historical median)

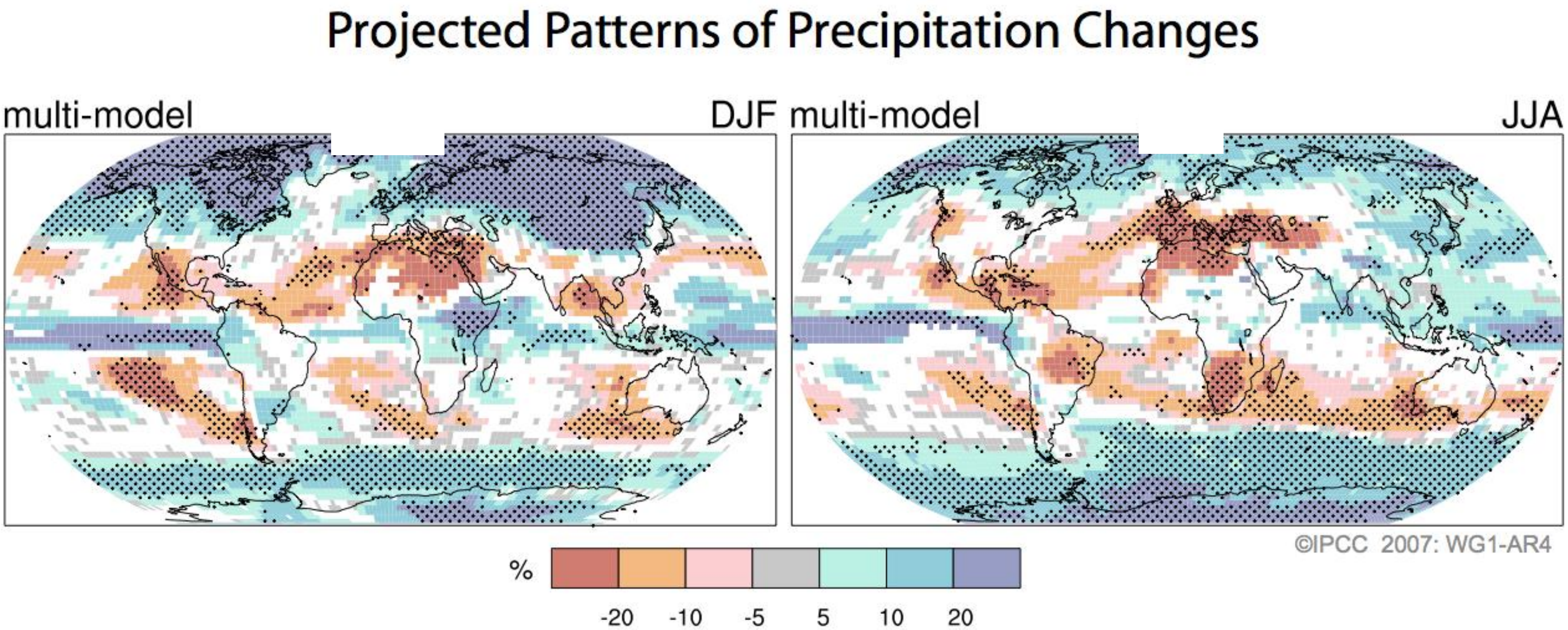
SRP Storage, Pumping & Water Allotment Planning



Simulated Reservoir Storage for a Range of Perpetually Reduced Inflows (as a percent of historical median)

PERCENT OF MEDIAN INFLOW	YEARS TO RESERVOIR DRYUP
64	INDEFINITE
63	50+
60	19.5
55	9.3
50	7.3
48	6.4
45	5.4
40	4.4

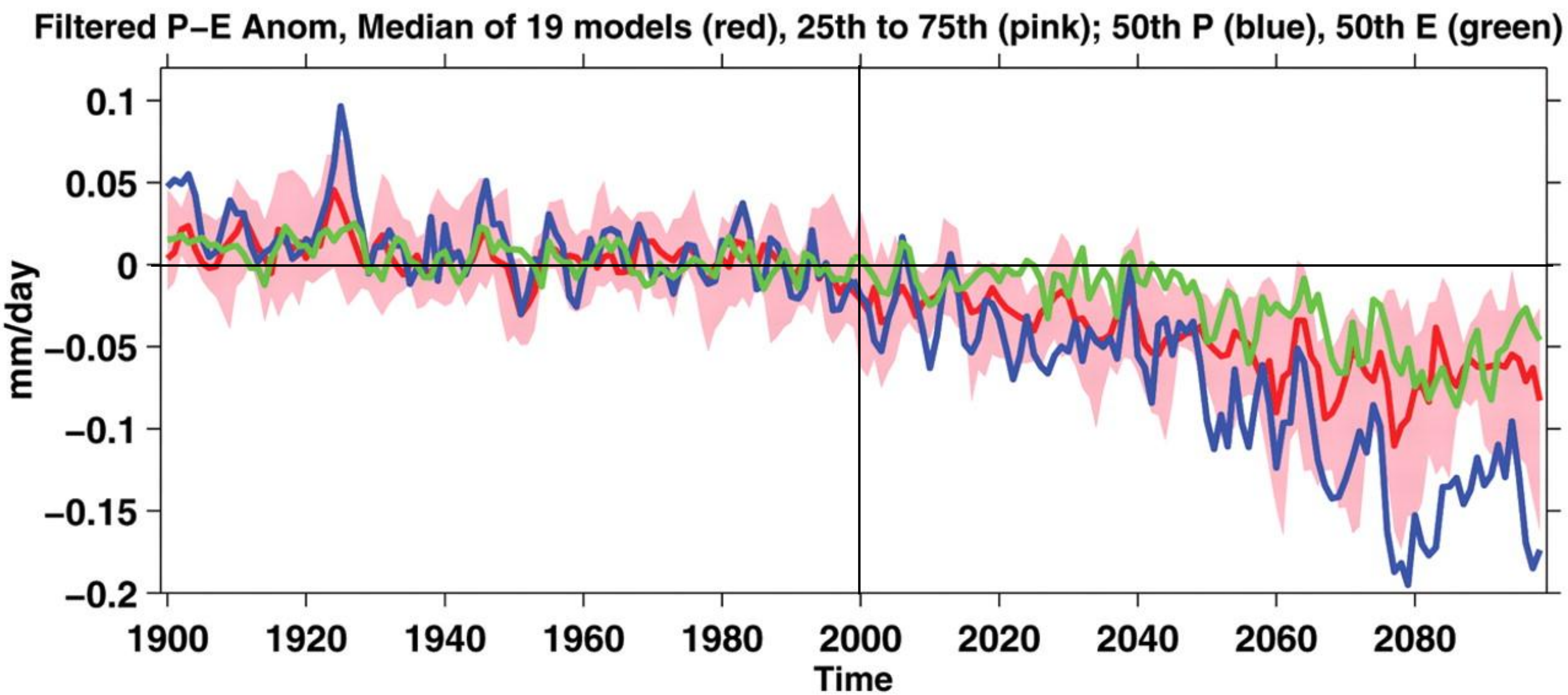
Projections of Future Changes in Climate



Precipitation increases *very likely* in high latitudes

Decreases *likely* in most subtropical land regions

Projections of Future Changes in Climate



Modeled changes in annual mean precipitation minus evaporation over the American Southwest…(Seager et al, 2007)

Projections of Future Changes in Climate

ASU sensitivity analyses (Ellis et al, 2008):

- Each 1 degree C of temperature rise yields a 6 to 7 percent reduction in streamflow.

- 10 percent less precipitation yields 15 to 20 percent less streamflow.

- +3 degrees C with 10 percent less precipitation yields 37 to 42 percent less streamflow.

Projections of Future Changes in Climate

Bottom Line for the Southwest:

- Continued warming.
- 20 to 50 percent decrease in runoff over the next several decades.

Version 2.1 Planning Guidelines

Response To Decreasing Supply:

-- augment supply to the "63 percent" line.

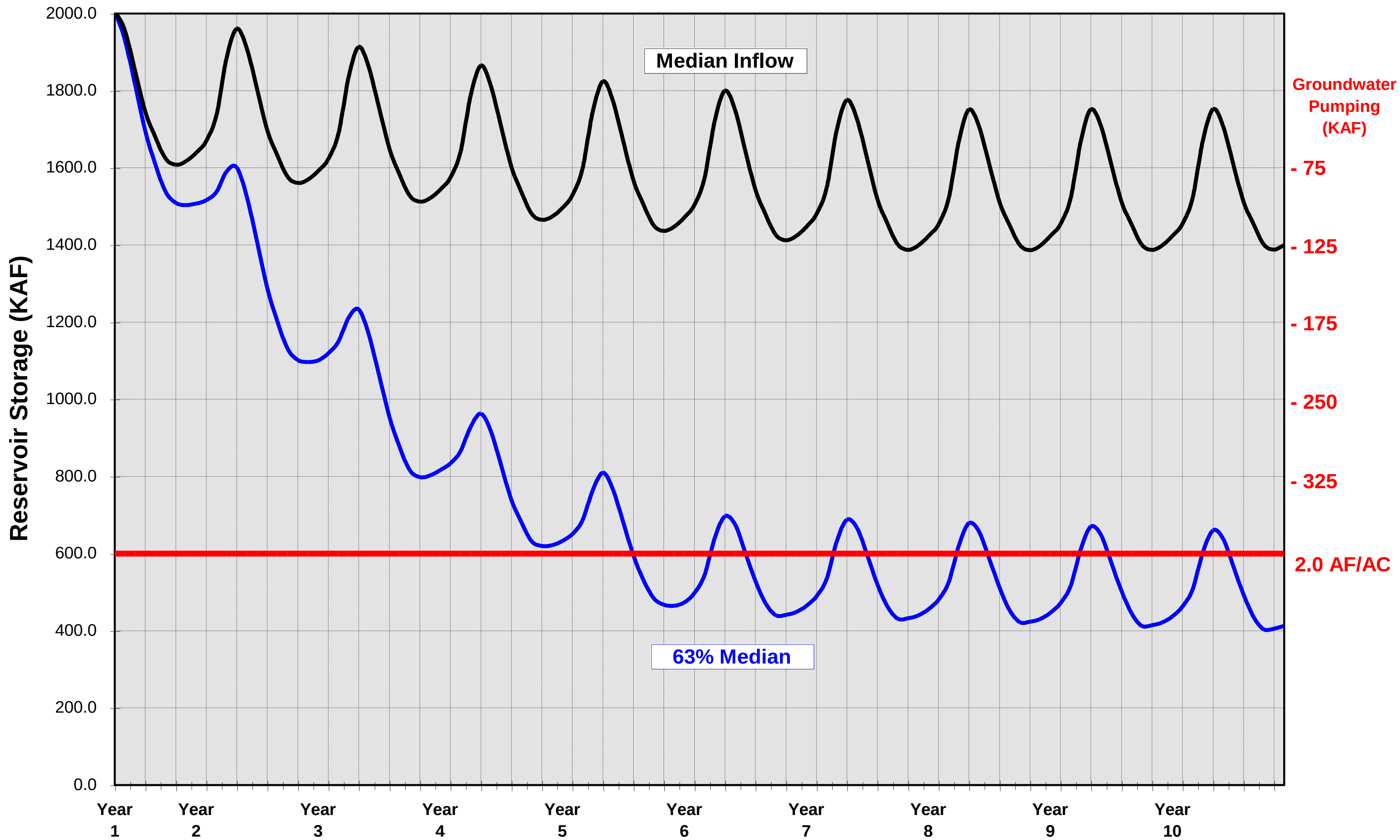
When storage drops below the target "63 percent" line, activate augmentation efforts to raise storage back to the 63 percent line.

Severe Droughts Capable of Depleting Surface Water Supply

(with the noted reduction in flow)

Period	Source	Duration (yrs)	"What If" Flow Reduction	Average Annual % of Median
1214-1217	Tree-ring	4	20%	40%
1579-1585	Tree-ring	7	15%	50%
1666-1670	Tree-ring	5	20%	45%
1817-1823	Tree-ring	6	20%	48%
1898-1904	Historical	7	20%	48%
1999-2002	Historical	4	20%	40%

SRP Storage, Pumping & Water Allotment Planning



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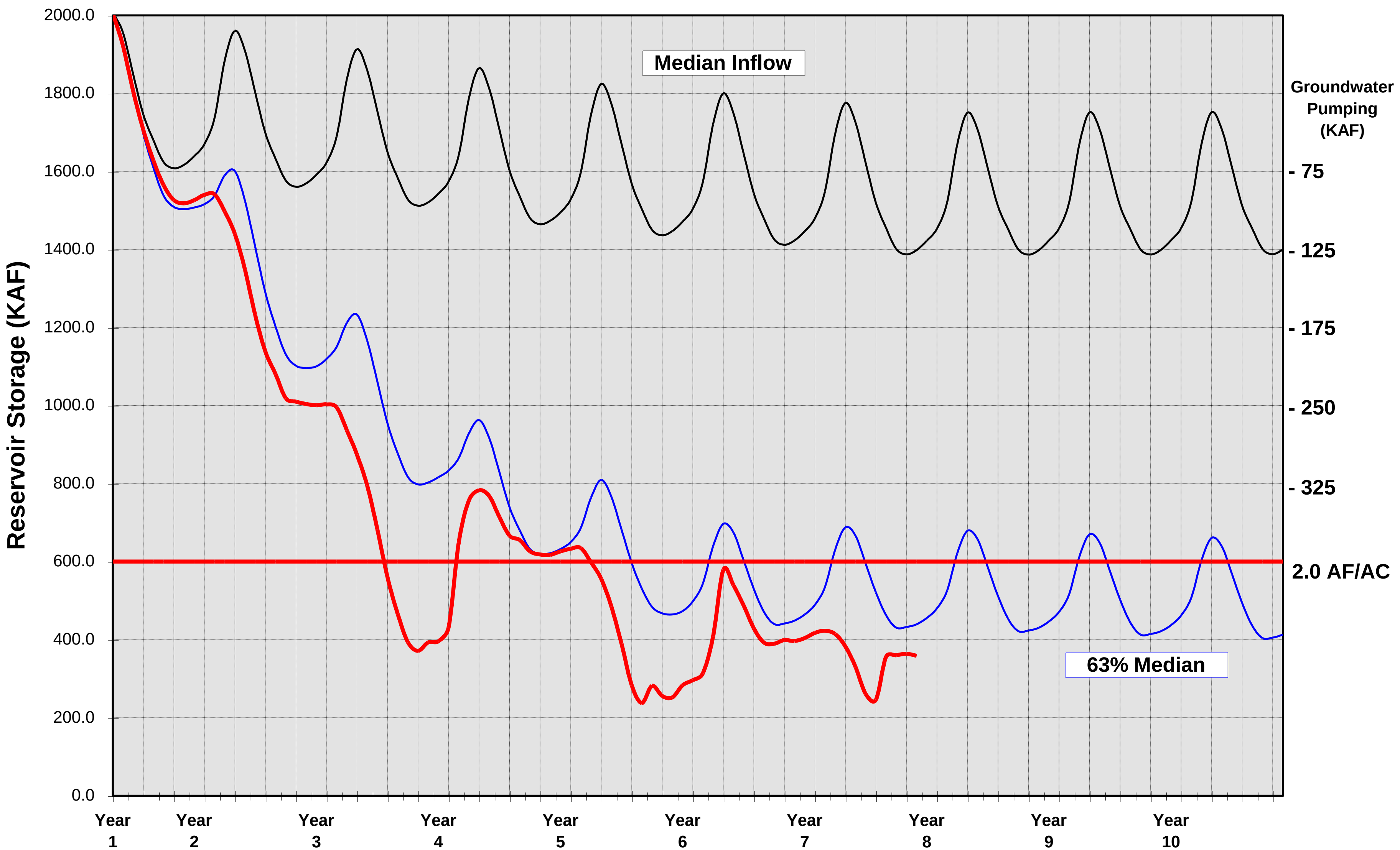

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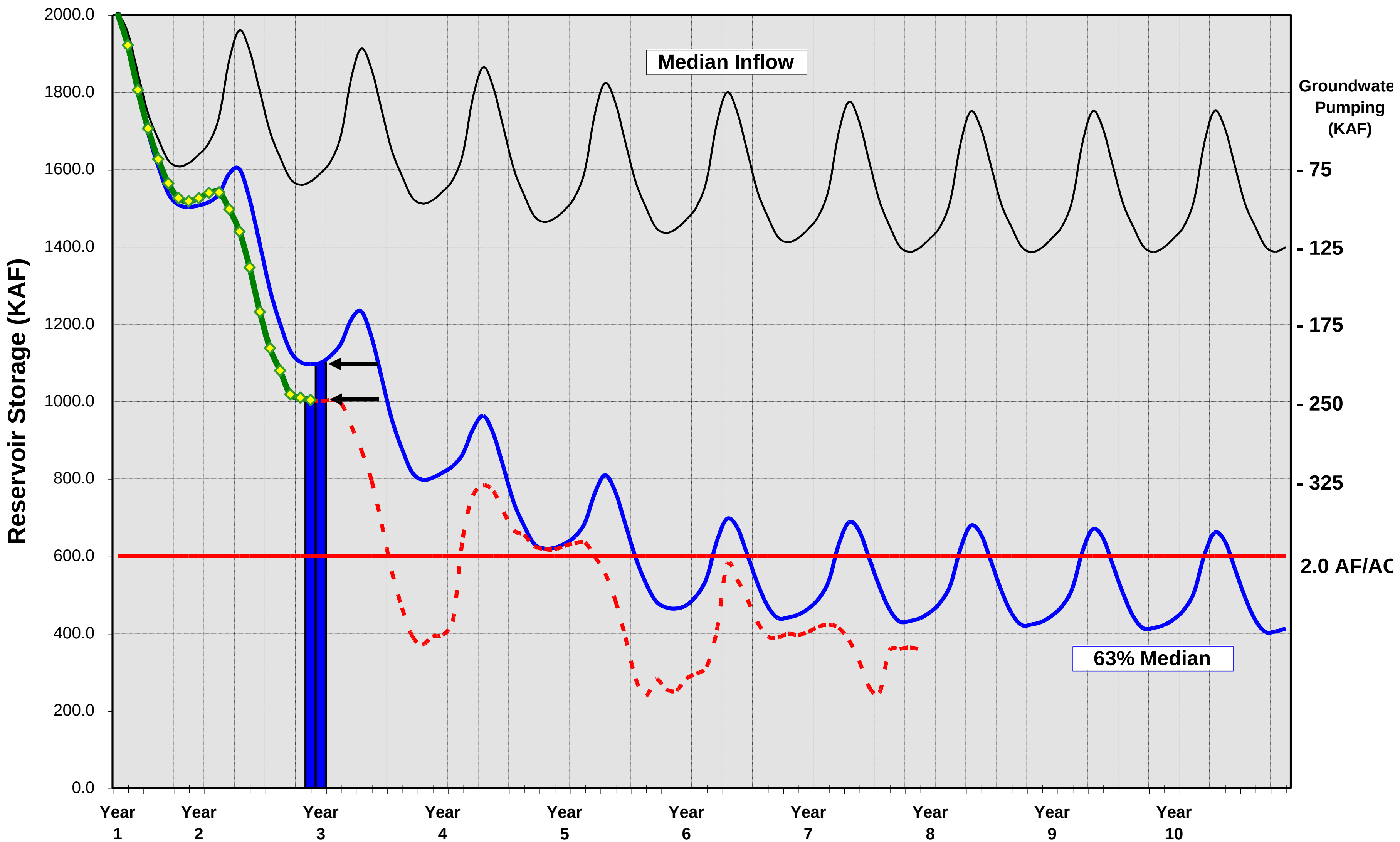

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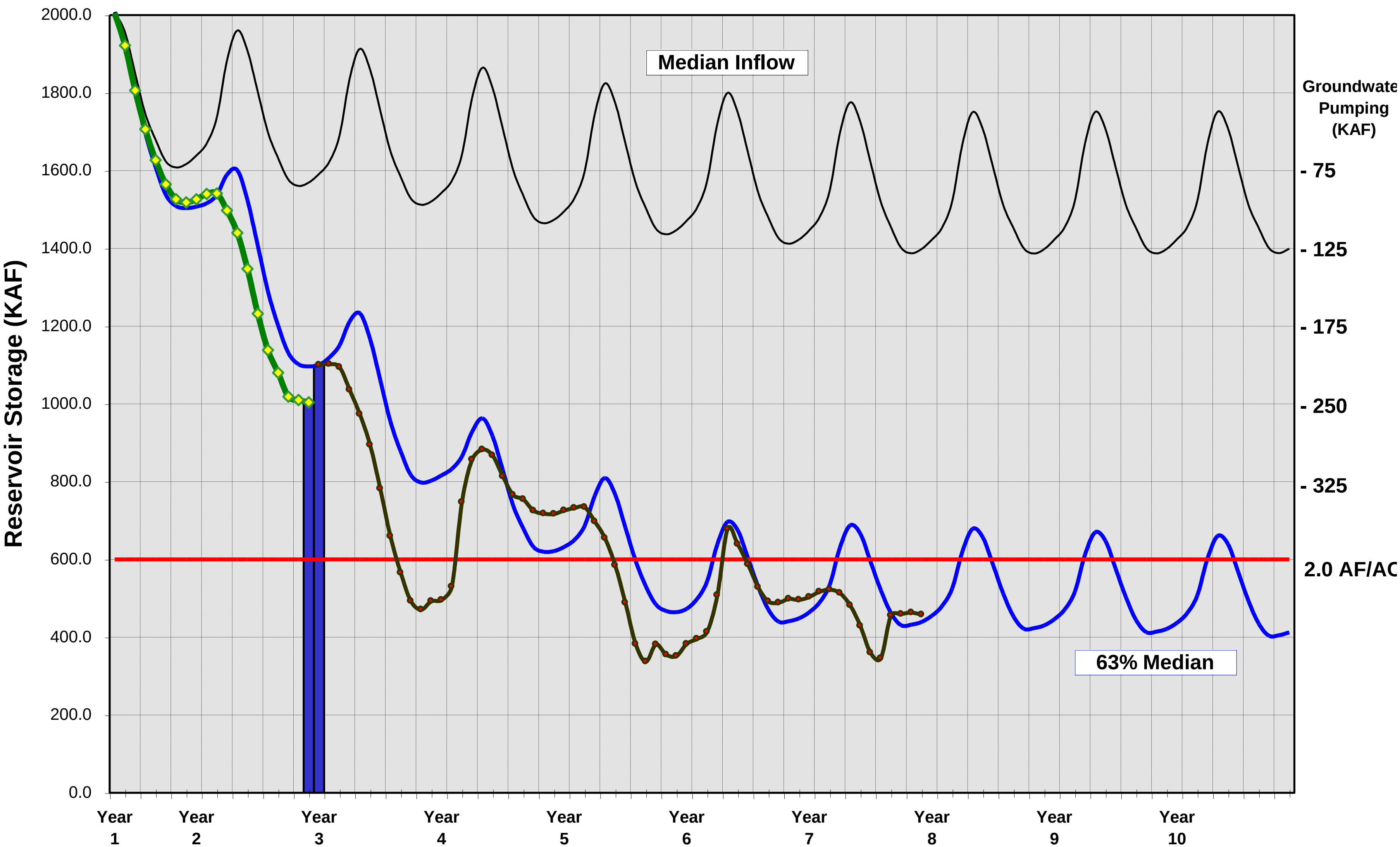

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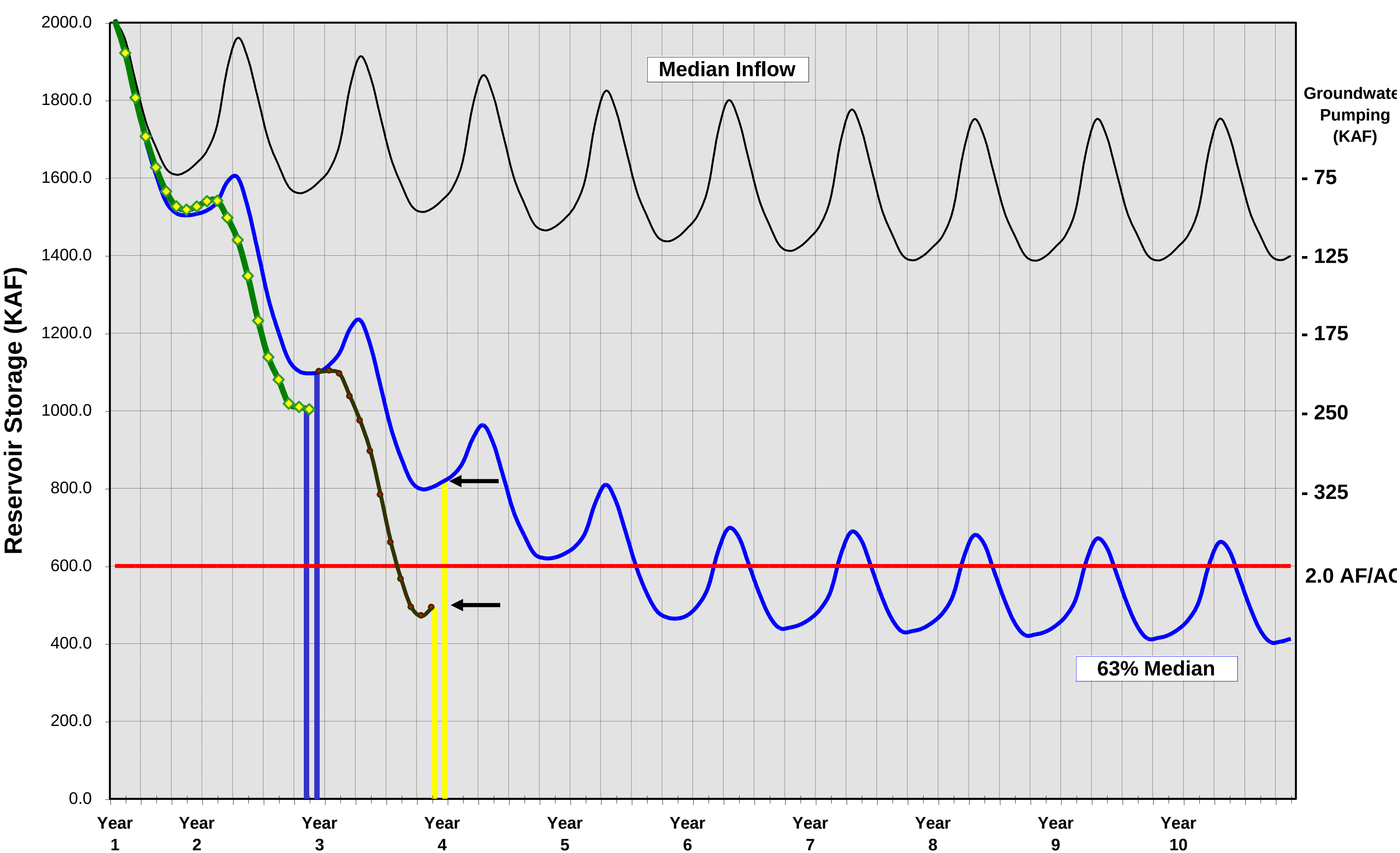

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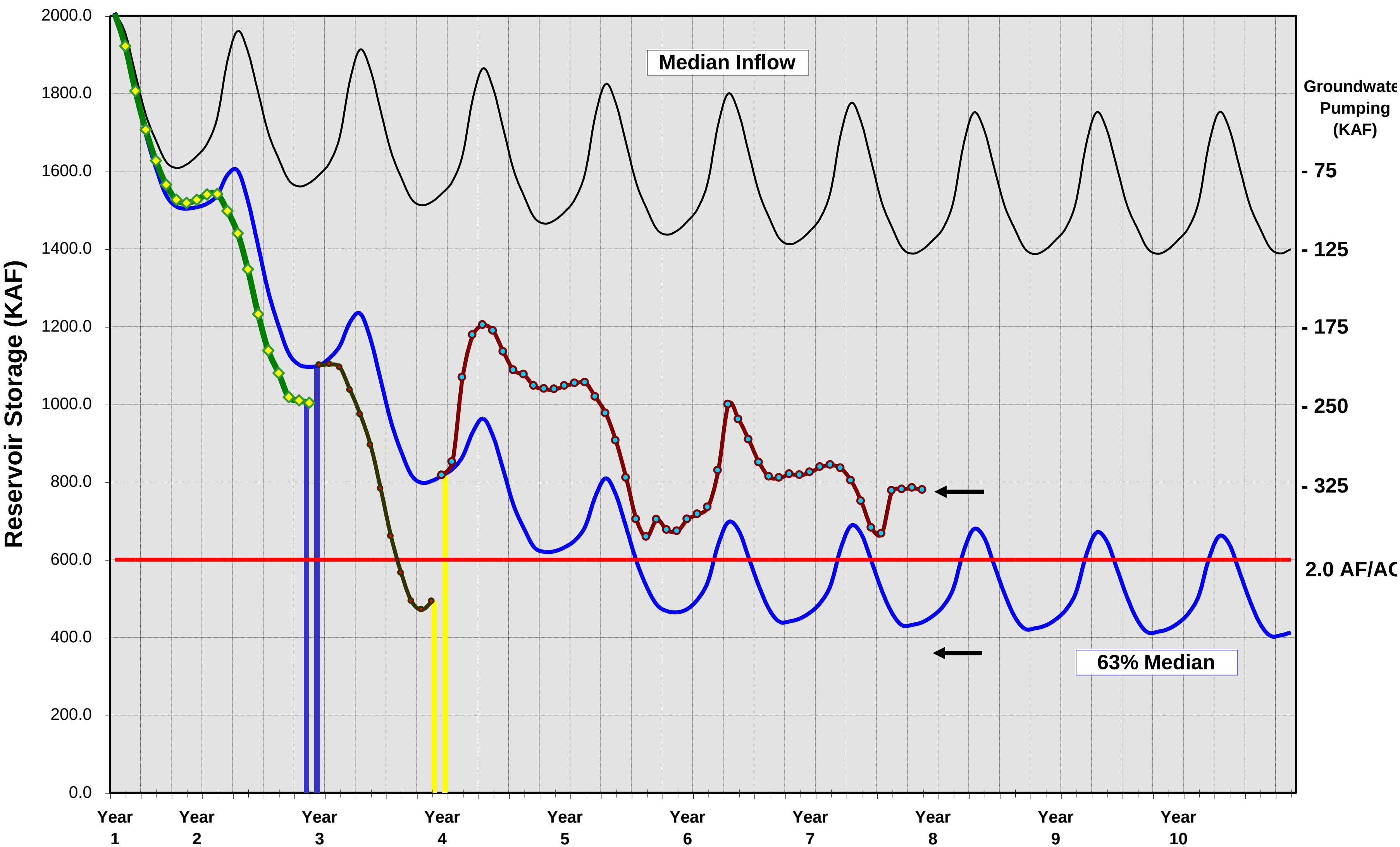

Augmented Storage Necessary to Recover to the Target 63 percent Line

Historical Drought		Recovery Water (KAF)											
	Reduction	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Total**
1212-1218	20%					132	114	298					544
1576-1586	15%			169				143	285	316			913
1665-1671	20%			29	190	40		256					515
1817-1824	20%			337	140	261		19	112				869
1895-1905	20%							298	180	38			516
1998-2004	20%			19	242		283						544

Menu Of Options:

Increase groundwater pumping (well restoration program)

Reduce allocation of water

Purchase Central Arizona Project (CAP) water

Exercise lease options—Indian and non-Indian agriculture

Recover long-term underground storage credits

Increased conservation efforts

Watershed management

Weather modification

Increase water-use efficiency

Other…

Discussing Water Rights, A Western Pastime

References and Links

DH Phillips; Reinink, Y; Skarupa, T; Ester C; and Skindlov, J. (2009). Water resources planning and management at the Salt River Project, Arizona, USA. *Irrigation and Drainage Systems* 23 (2-3), 109-124.

AW Ellis; Hawkins, T; Balling, Jr, R; and Gober, P. (2008). Estimating future runoff levels for a semi-arid fluvial system in central Arizona, USA. *Climate Research* 35, 227-239.

R Seager et al (2007). Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* 316 (25 May 2007), 1181-1184.

LTRR/SRP [Phase 1]: A Tree-Ring Based Assessment of Synchronous Extreme Streamflow Episodes in the Upper Colorado & Salt-Verde-Tonto River Basins (2005): http://fp.arizona.edu/kkh/srp.htm

LTRR/SRP [Phase 2: The Current Drought In Context: A Tree-Ring Based Evaluation Of Water Supply Variability for the Salt-Verde River Basin (2008): http://fp.arizona.edu/kkh/srp2.htm


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Questions?

6th Symposium on Southwest Hydrometeorology

27-28 September 2011
ASU Campus
Tempe AZ

Short papers and panel discussions on these themes:

-- Effects of drought, climate variability and long-term climate change in the upper and lower Colorado Basin.

-- Use and utility of the NOAA (and other) drought and outlook products.

-- Climate Services – A look at NOAA's new Climate Service and the current climate services.

-- Water resources monitoring, management, supply, demand and conservation.

-- Severe weather in arid climates. Forecasts and warnings: needs, production, dissemination and use. Vulnerability of communities to extreme weather.

Organized by the ASU Office of Climatology and NWS Phoenix.
"Call for papers" due out shortly (http://www.wrh.noaa.gov/psr/).