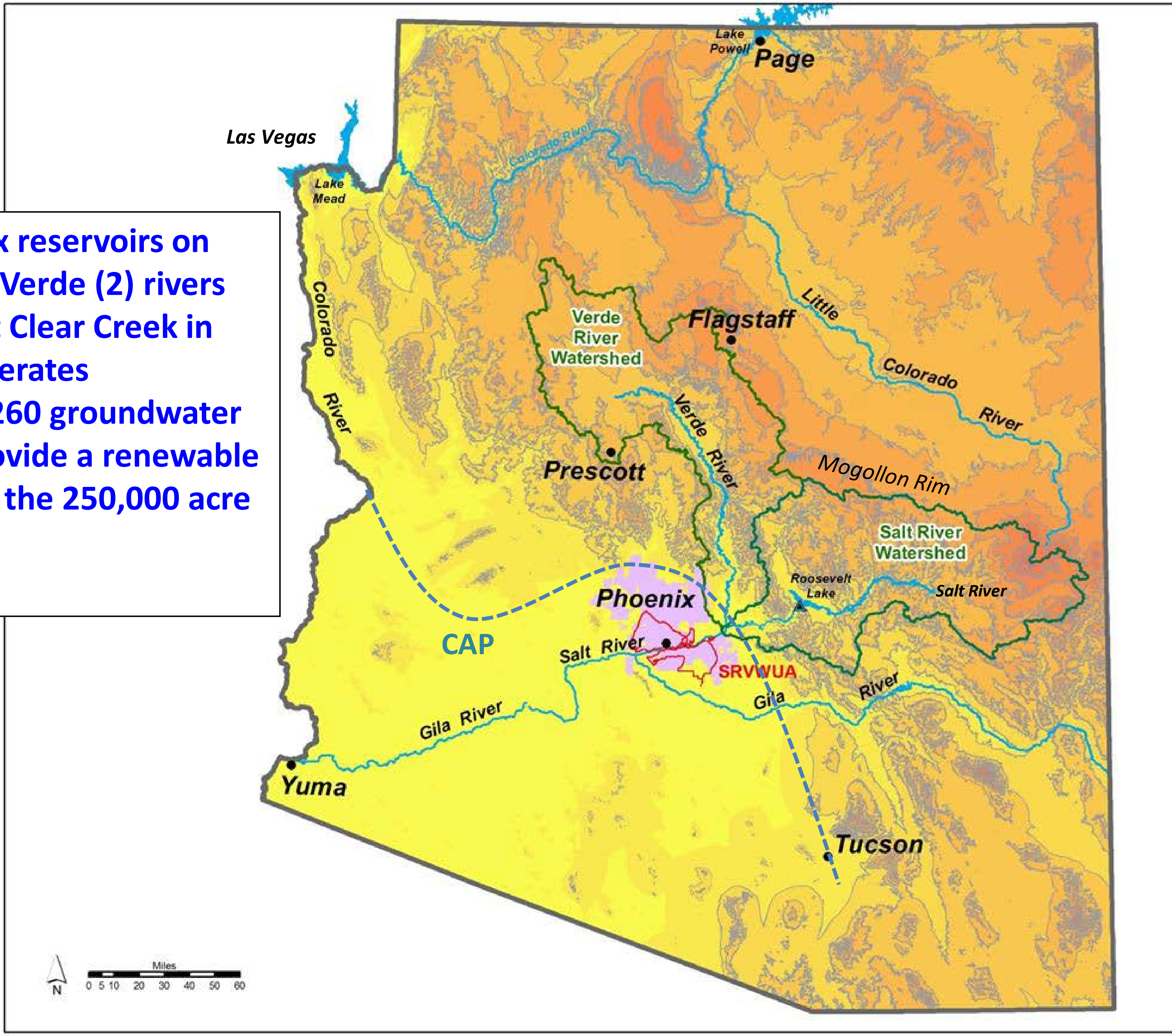
SRP and Research – Past, Present and Future

Charlie Ester, Manager, Water Resource Operations
SWAN; November 10, 2014

SRP manages six reservoirs on the Salt (4) and Verde (2) rivers and one on East Clear Creek in Arizona, and operates approximately 260 groundwater wells, which provide a renewable water supply to the 250,000 acre service area.



Water Resource Operations

Water Resource Operations is responsible for the development of conjunctive water resource management planning for reservoir and pumping operations, for the coordination of emergency reservoir operations and for weather forecasting in support of SRP's water and power business needs.

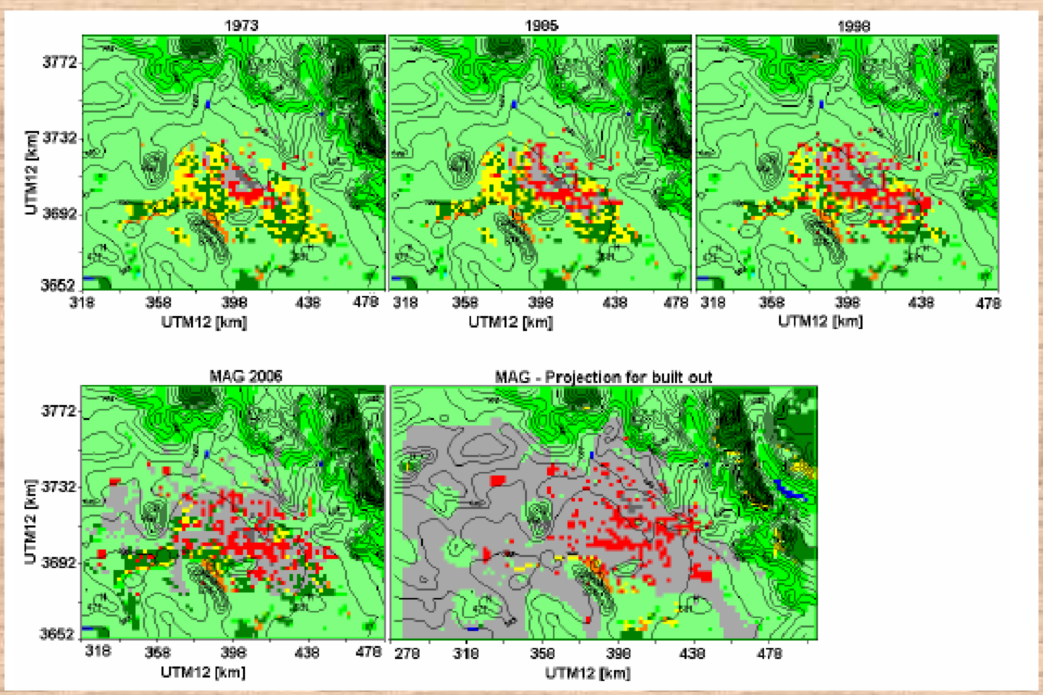
The water resource planning assures an adequate and reliable source of water for our shareholders. Emergency reservoir operations are vital to maintain the safety and integrity of the dams. Weather forecasting provides support for routine and emergency operation of the SRP's reservoir and electric distribution systems which increase system reliability and safety as well as augments energy resource planning.

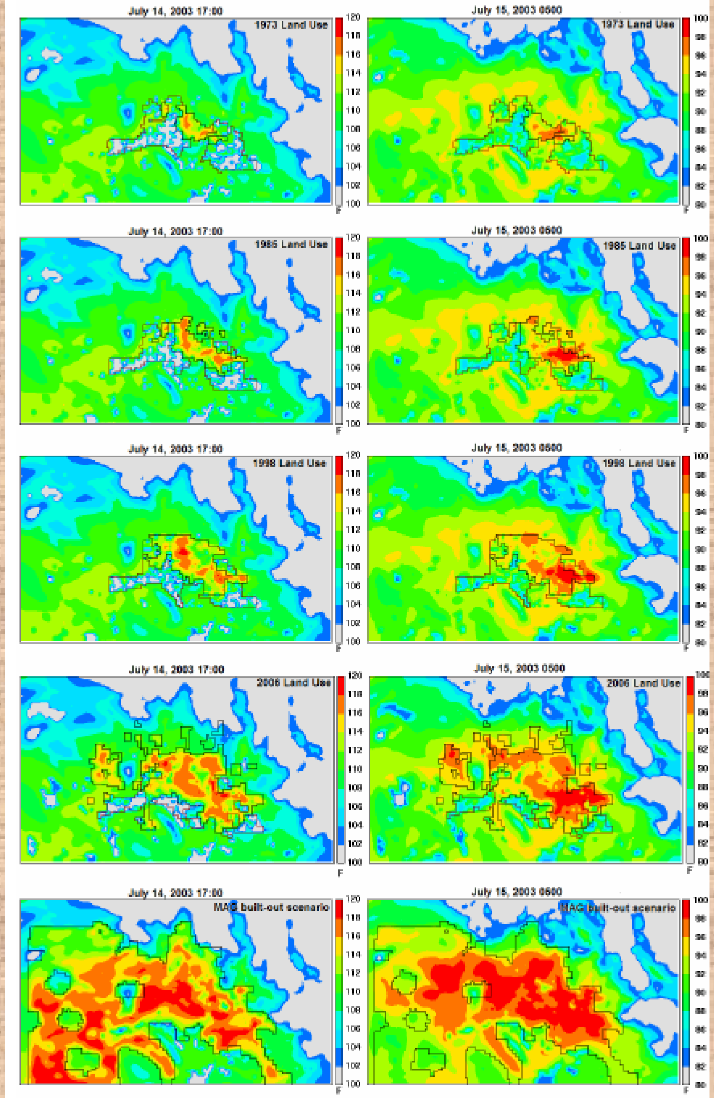
To accomplish this, our hydrologists, meteorologists and engineers monitor pertinent water and weather data. Our knowledge and experience in data analyses are paramount to our mission. We manage SRP's water resources to sustain life and economic viability in the Valley integrating our expertise and leadership in weather forecasting, hydrology, water operations, management and planning.

Past Research

- Urban Heat Island
- Global Warning and Arizona Climate Change
- North American Monsoon
- Watershed Snow Pack Evolution
- Weather Modification
- A Probabilistic Assessment of Threats to Surface Water Resources
  in Watersheds of the Lower Colorado River Basin
- Paleoclimate and Paleohydrology Of the Salt and Verde Watersheds as determined by Tree-ring Analysis
- Watershed Research and Education Program Directed Grant (WREP)
- WREP Flood Discharge Analysis

Urban Heat Island





SCHOOL OF Geographical Sciences & Urban Planning
ARIZONA STATE UNIVERSITY

GC11D-1022

A Probabilistic Assessment of Threats to Surface Water Resources in Watersheds of the Lower Colorado River Basin

contact: kwmurphy@asu.edu

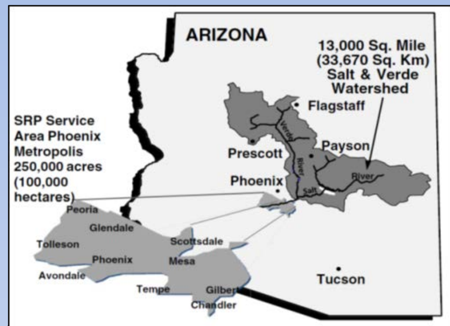
Kevin W. Murphy, Arizona State University
Andrew W. Ellis, Virginia Polytechnic Institute and State University

SALT & VERDE RIVER WATERSHEDS

High climate variability poses drought risk to a reservoir system serving 40% of Phoenix, AZ water demand.

A detailed threat assessment is required for:

- Sustainability planning
- Adaptation to future climate change scenarios



ANALYTIC CHALLENGES

122-year historical record – just one temporal sequence.

Distinct seasons: Winter = October 1 to April 30

Summer = May 1 to September 30

Covariance of flows from multiple watersheds.

Antecedent season runoff dependencies.

Highly skewed data, stationarity assessment, autocorrelations, spectral properties, …

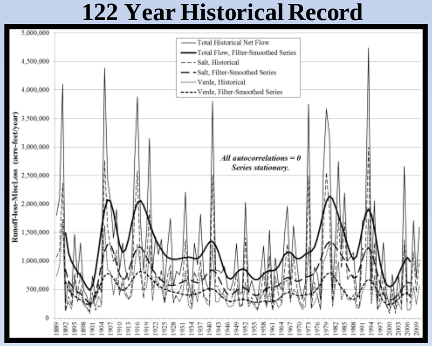
OBJECTIVES

I. Develop methodology for stochastic simulation modeling of net basin supply: Runoff - less Miscellaneous Losses

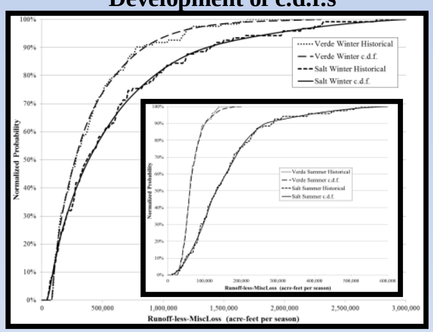
II. Generate 10,000 year multivariate time series, by watershed-season.

III. Characterize drought periods by extreme value statistical analysis.

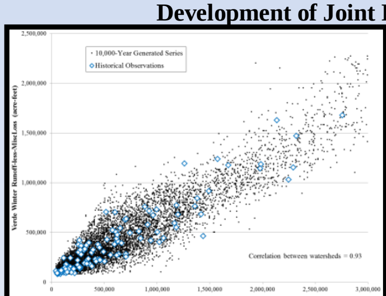
122 Year Historical Record

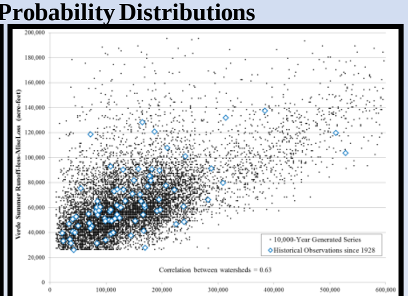


Development of c.d.f.s

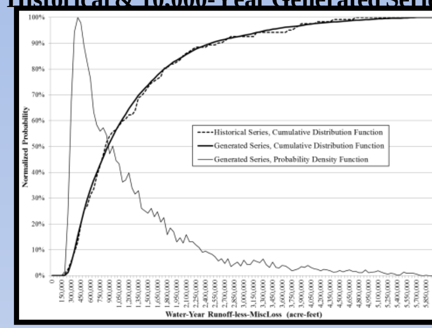


Development of Joint Probability Distributions

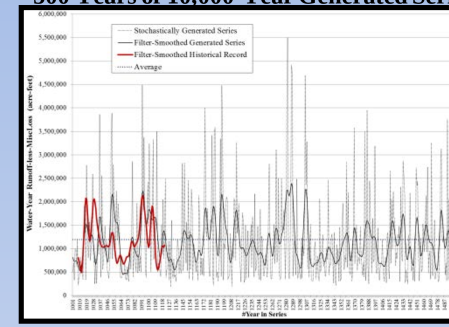


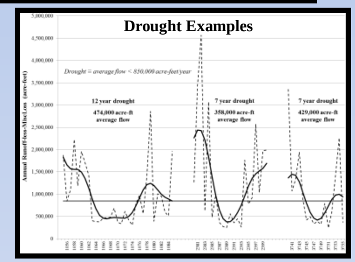


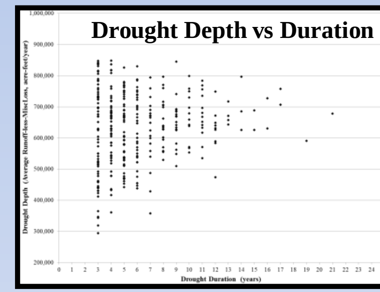
Probability Distributions Historical & 10,000-Year Generated Series



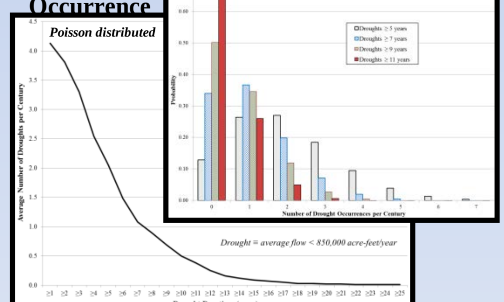
500 Years of 10,000-Year Generated Series





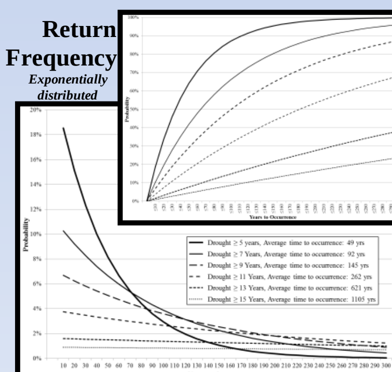


Rate of Occurrence



Return Frequency

Exponentially distributed



Correlations	Historical Series	10,000-Year Series
Winter, Salt to Verde	0.932	0.929
Summer, Salt to Verde	0.625	0.624
Winter to Summer, Salt	0.608	0.610
Winter to Summer, Verde	0.279	0.349
Summer to Winter, Salt	0.240	0.252
Summer to Winter, Verde	0.045	0.168

CONCLUSION: *Stochastic modeling illuminates the full range of potential drought severity, providing quantitative guidance to risk management.*

Support provided by: *The Salt River Project, and the ASU Graduate and Professional Student Association*

Applied Research

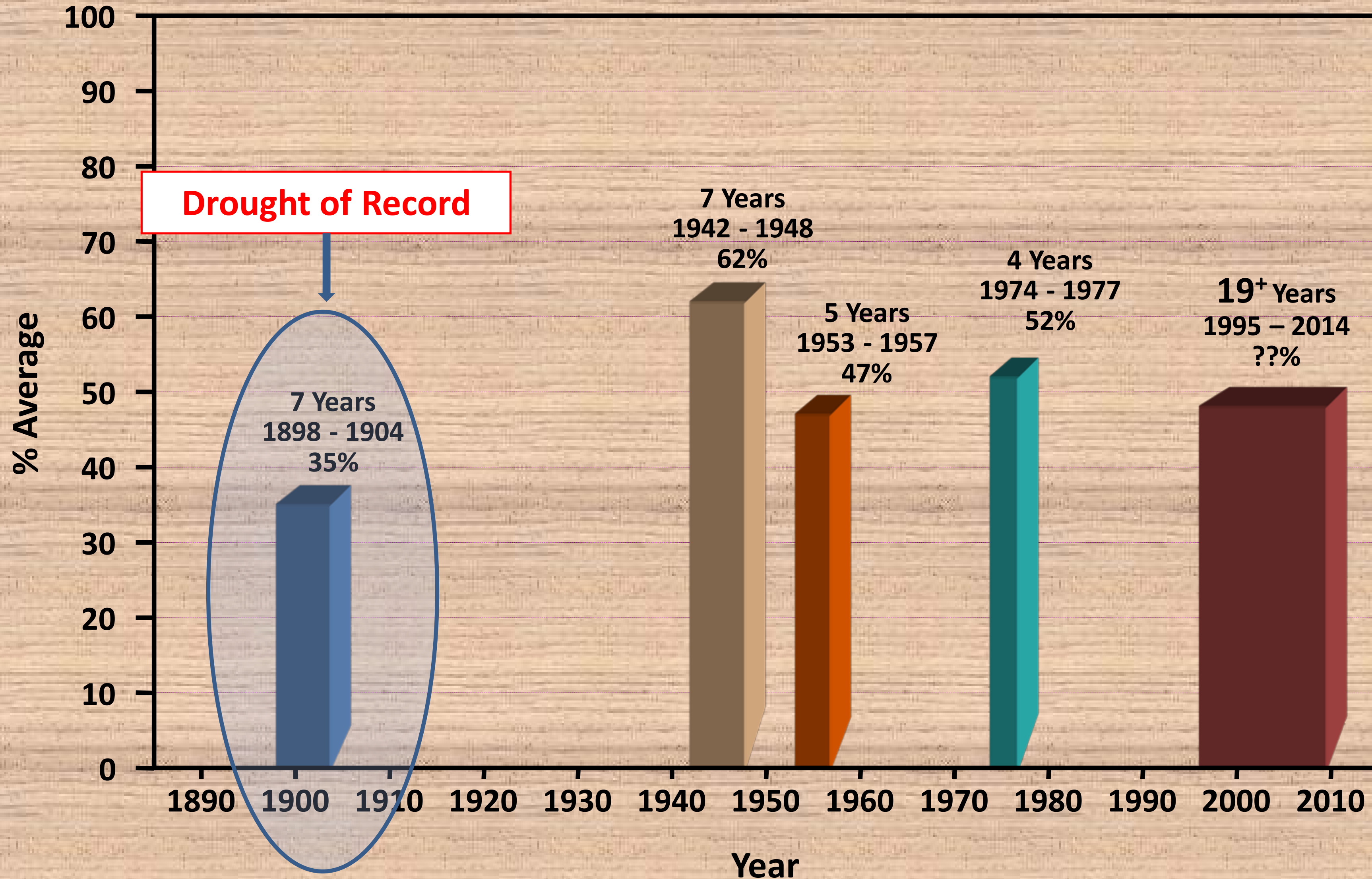
- Urban Heat Island
- Climate Change Analysis
- Tree Ring Streamflow Reconstruction

Example of Applied Research Used in Water Resource Planning at SRP

Revising Reservoir Planning Based On Vulnerability To Sustained Drought In The Past And Future

- **Tree Ring Streamflow Reconstruction**
- **ASU Climate Change Sensitivity Analyses (Ellis et al, 2008):**

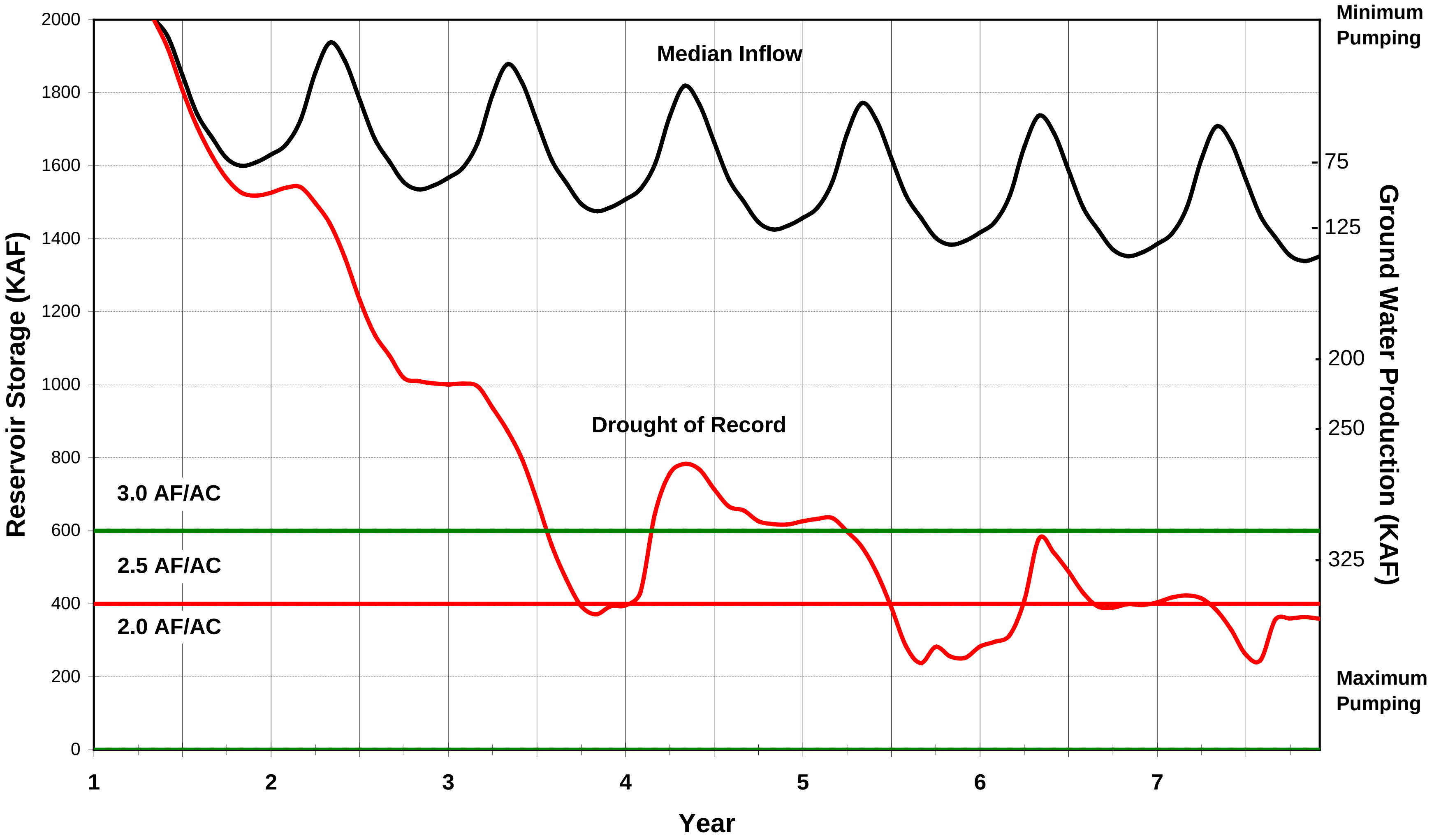
Salt River Project Historic Drought Periods
(Average Runoff 1913–2010 = 1,172,215 AF)



Planning Assumptions

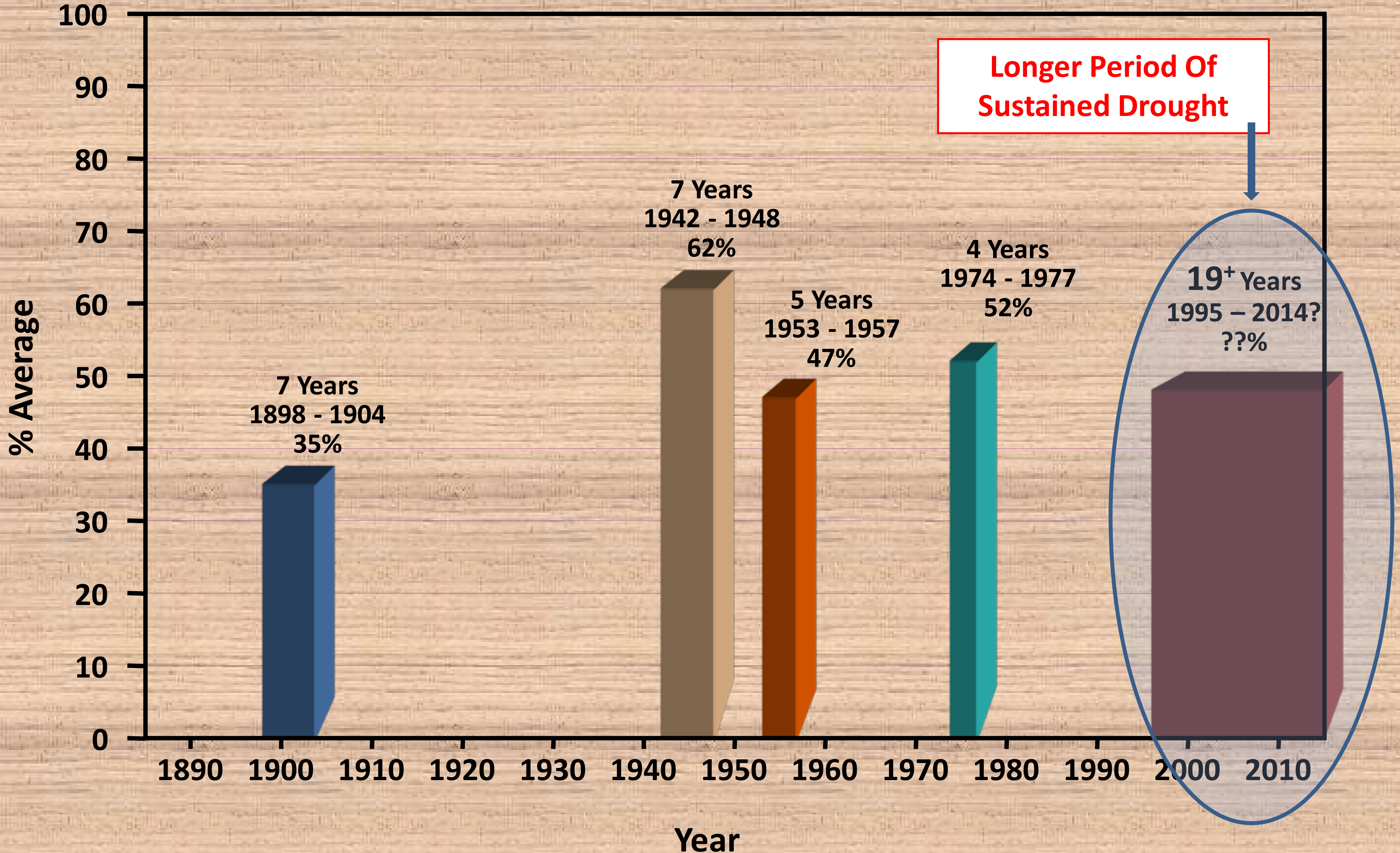
- 950 KAF Full Demand
- 325 KAF Maximum Pumping
- Historical Drought Of Record 1898-1904
- Allocation/Pumping To Manage For DOR

SRP Storage, Pumping & Water Allotment Planning



Salt River Project Historic Drought Periods

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



What Can Tree-Ring Analysis Tell Us About Pre-20th Century Droughts?

Delivering More Than Power.

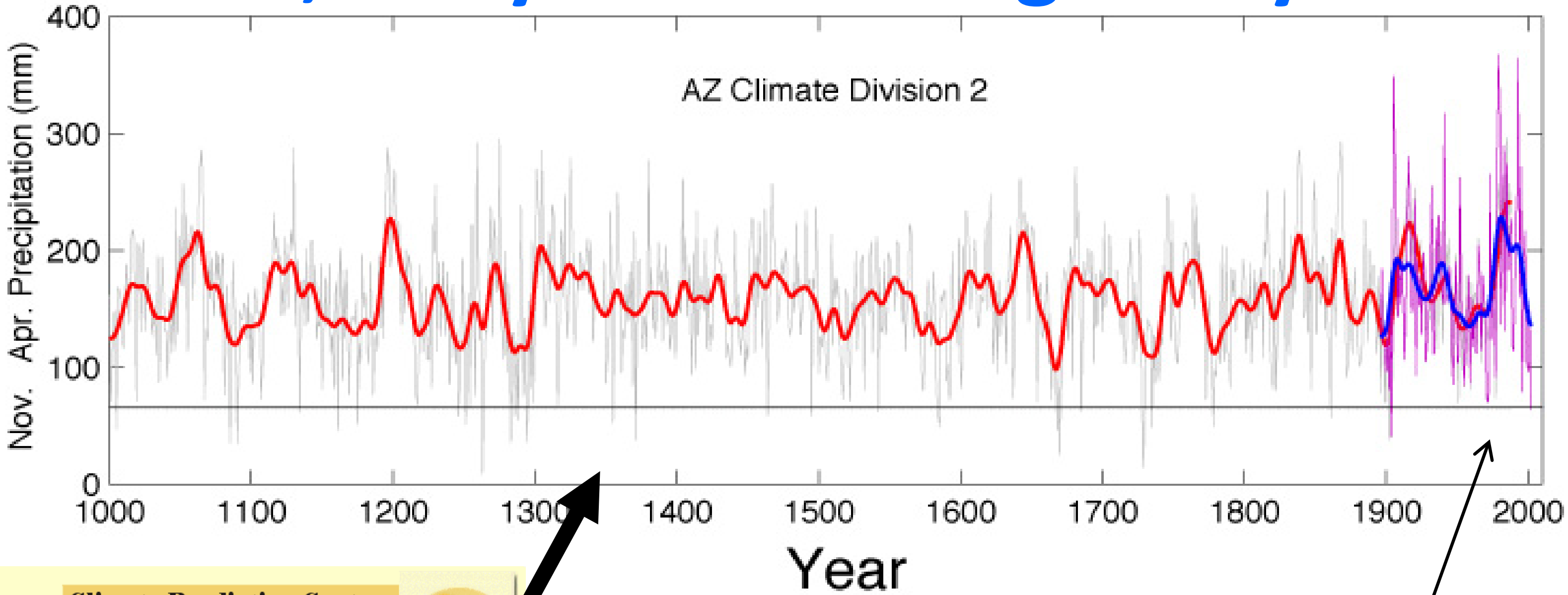
LABORATORY OF TREE-RING RESEARCH

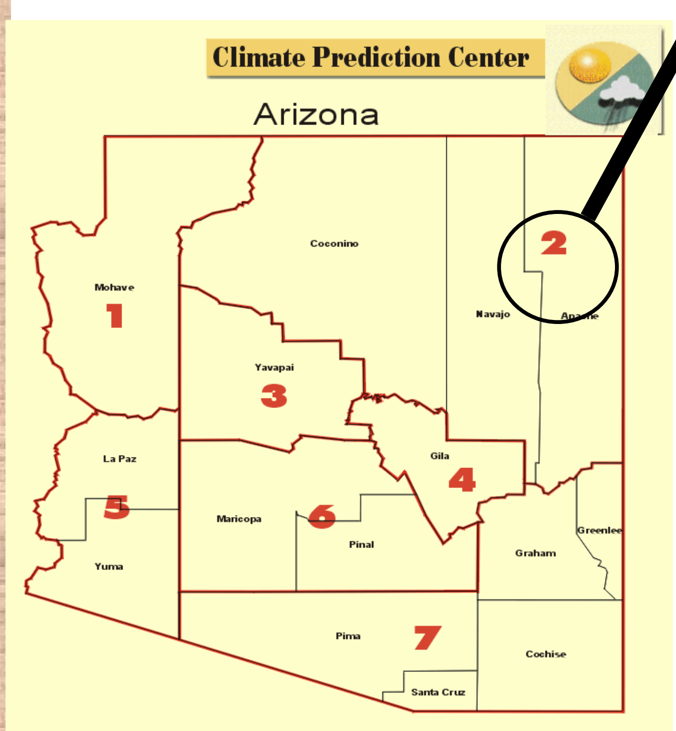
UA SCIENCE

Conclusions

- **Water deficits due to Arizona droughts are unlikely to be offset by water excesses in the Upper Colorado River Basin (UCRB)**
- **Reservoir storage and the high volume water supply of the large UCRB reservoirs may allow continued buffering during climate stress**
- **Increasing demand in the Colorado River basin and climatic change are additional factors that may exacerbate the effects of joint drought**
- **Preliminary examination of El Niño, La Niña influences and oceanic indices such as the Pacific Decadal Oscillation (PDO), and the Atlantic Multi-decadal Oscillation (AMO) suggest linkage to some – but not all joint droughts**

1,000-year Tree Ring Analysis





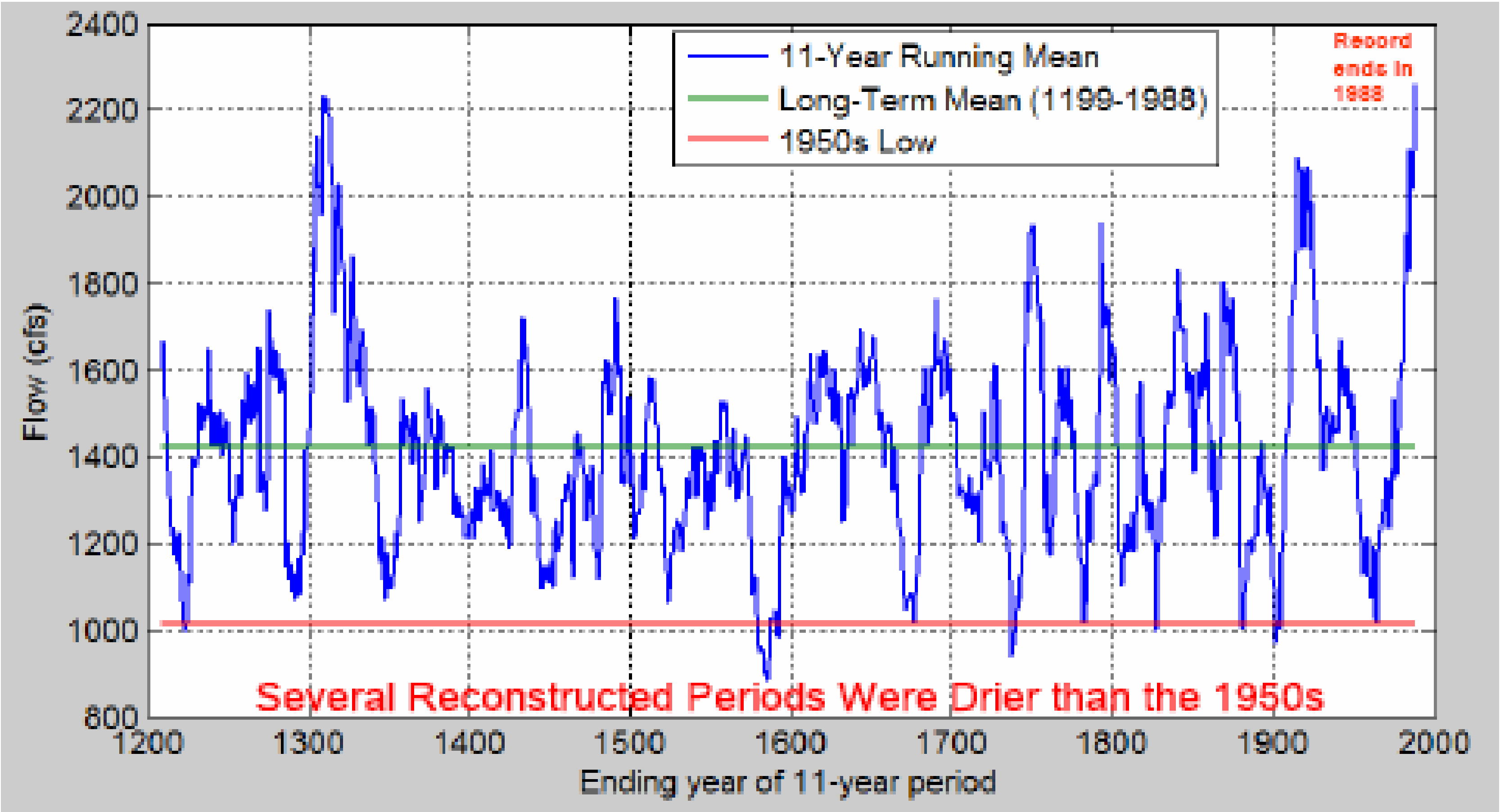
Analysis conclusions:

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

UA LTRR (2005)

Severity of Current Drought in Context of Reconstructed Record: Salt + Verde + Tonto Reconstruction

Figure 23b

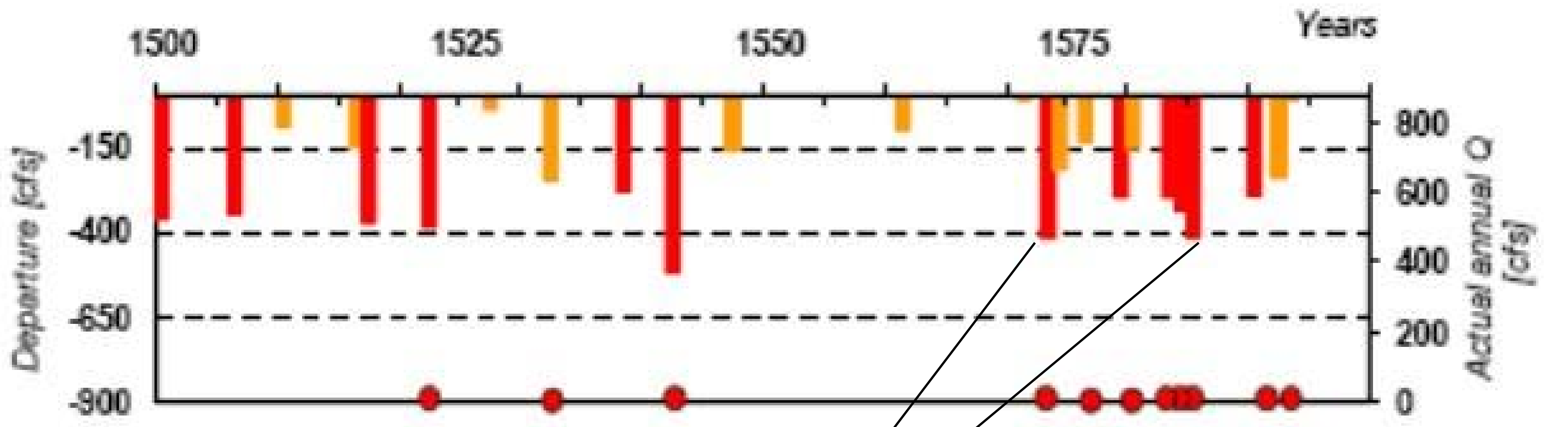


-- Current drought was about as severe as 1950s in terms of flows averaged over 11 years

-- 8 other droughts were as severe, according the tree-ring record

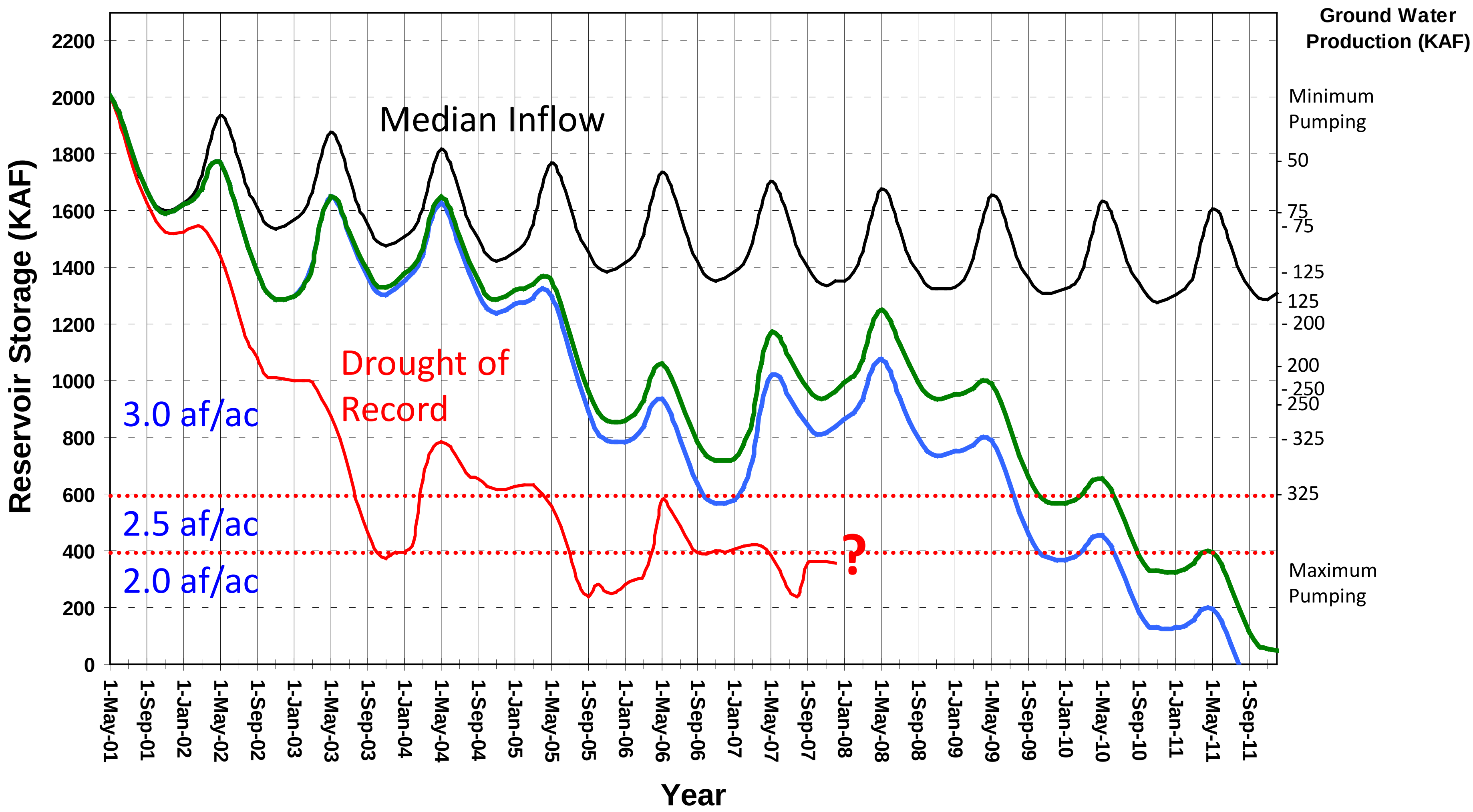
-- Late 1500s megadrought was much more severe

The 11-year period was 1575 – 1585.



11-Year Drought With 70% Of Historical Gaged Median Inflow

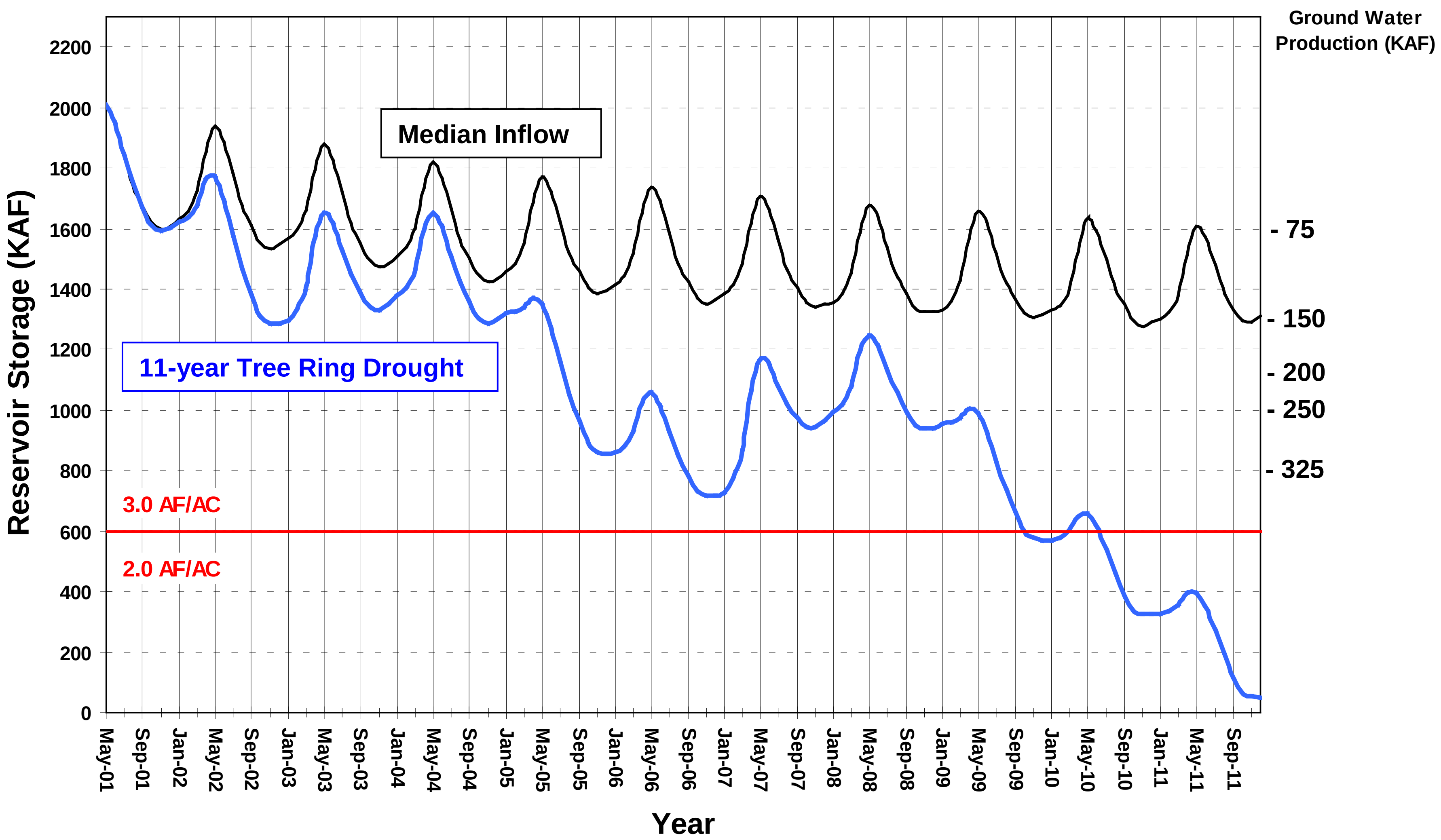
SRP Storage, Pumping & Water Allotment Planning



11-year Tree-ring Drought with new planning scenario

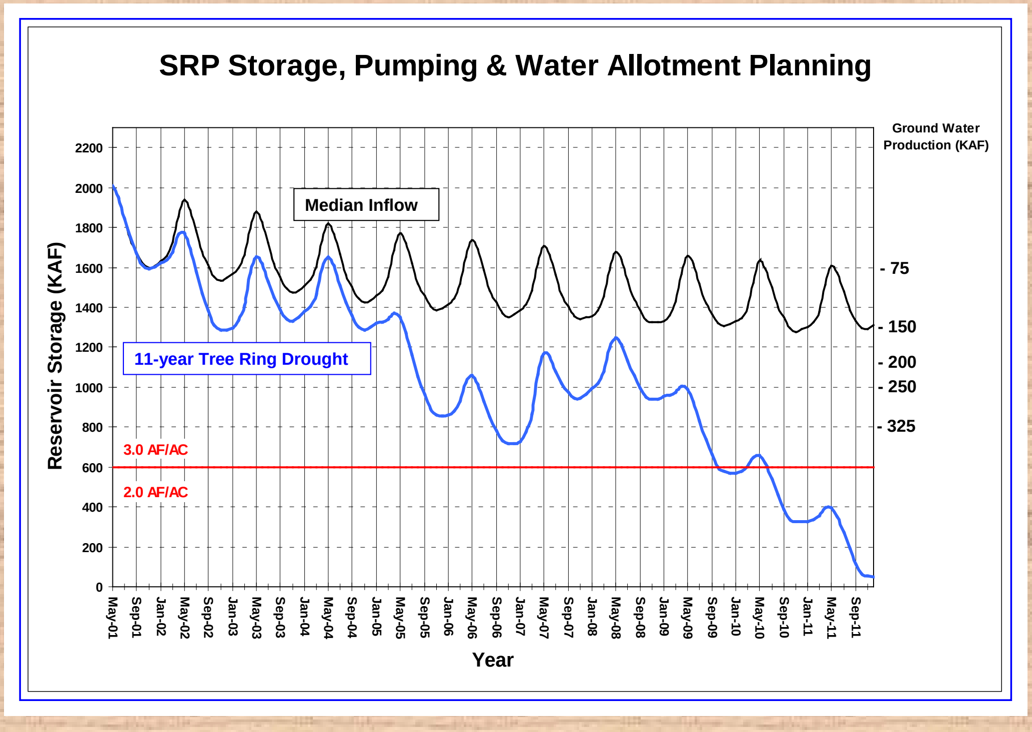
11-yr Tree-ring Drought with previous planning scenario

SRP Storage, Pumping & Water Allotment Planning



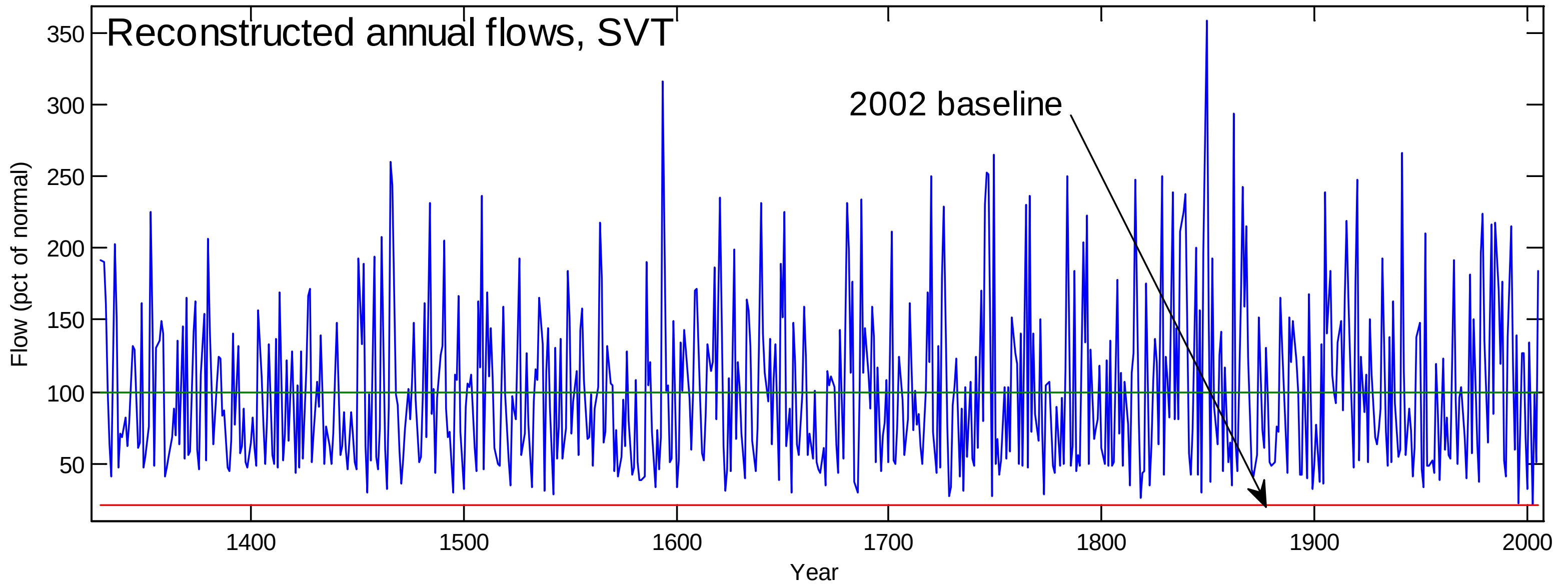
New Planning Guidelines

- 900,000 AF -- full demand
- 325,000 AF -- maximum pumping (start earlier)
- Tree-ring drought of record, 1575-1585
- Use revised allocation and pumping plan to manage for the 11-year tree-ring drought
- Demand mostly urban

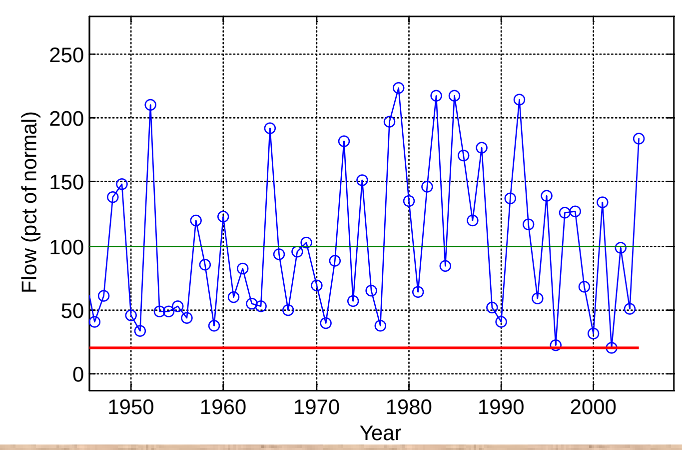


Time To Rethink Old Assumptions

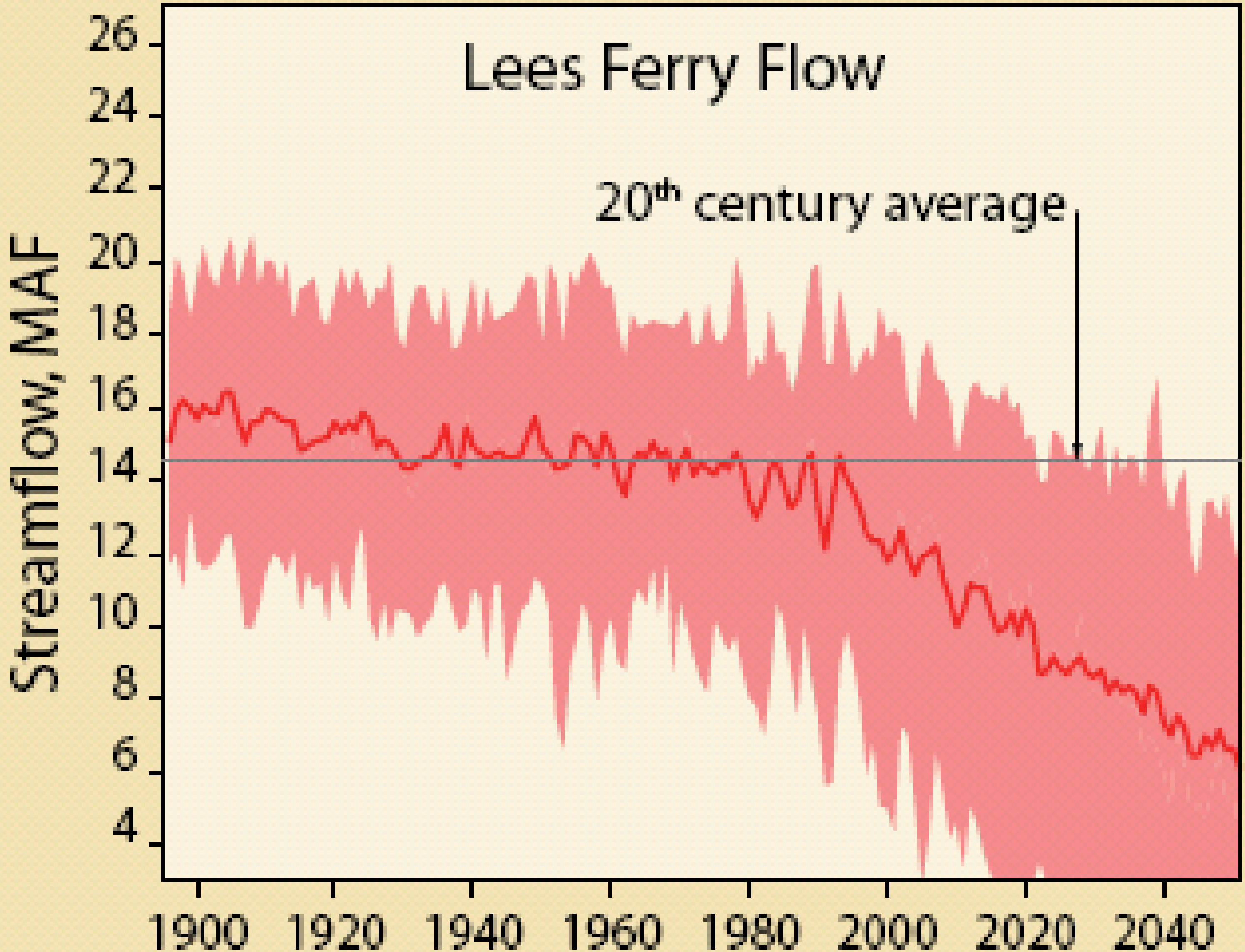
2002 and 1996: long-term extreme lows



- Reconstructed flow was 21% of normal* in 2002, 22% of normal in 1996
- No other reconstructed flow from 1330 to 2005 was lower than 25% of normal.
- Tree growth recovered with wetter conditions in 2005



*normal is 1914-2007 mean, water year, Salt+Verde+Tonto



42-Model Run Average and 10% and 90% Range of Individual Simulations

From Martin Hoerling, NOAA, and Jon Eischeid, U of CO, Past Peak Water in the Southwest, Southwest Hydrology, Jan/Feb 2007. Results of Intergovernmental Panel on Climate Change Fourth Assessment Report, 2007.

Projections of Future Changes in Climate

Precipitation increases *very likely* in high latitudes

Decreases *likely* in most subtropical land regions

ASU sensitivity analyses (Ellis et al, 2008):

- **Each 1 degree C of temperature rise yields a 6 to 7 percent reduction in streamflow (increased ET).**
- **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.**

How Vulnerable Are We?

What is minimum annual inflow that allows SRP to maintain carryover storage in perpetuity? (i.e., the reservoir system does not dry up)

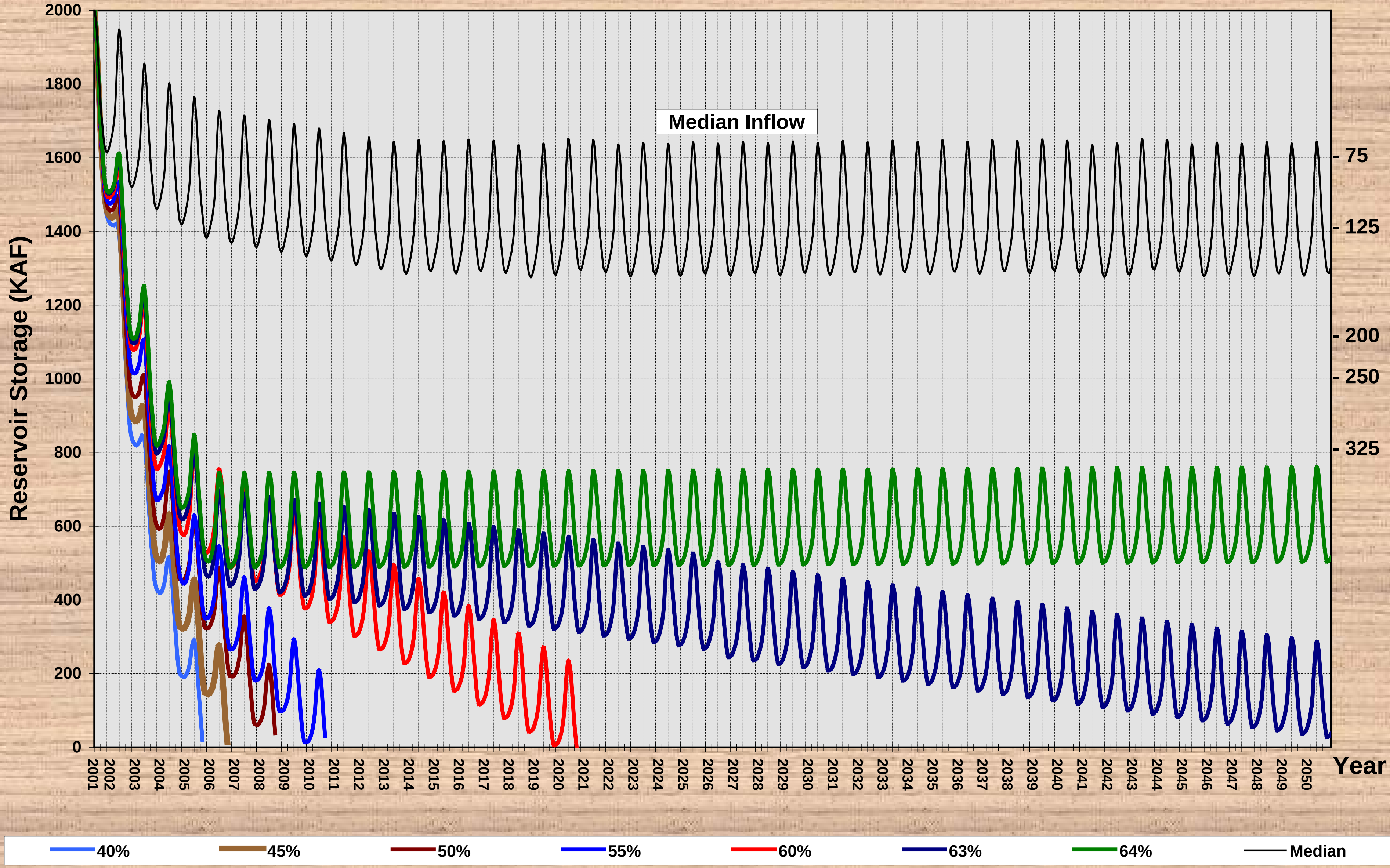
Examined:

- **Historical, instrument-era record (110 years)**
- **Tree-ring record (1,000 years)**
- **Climate change, GCM scenarios (future decades)**

How Vulnerable Are We?

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

SRP Storage, Pumping & Water Allotment Planning



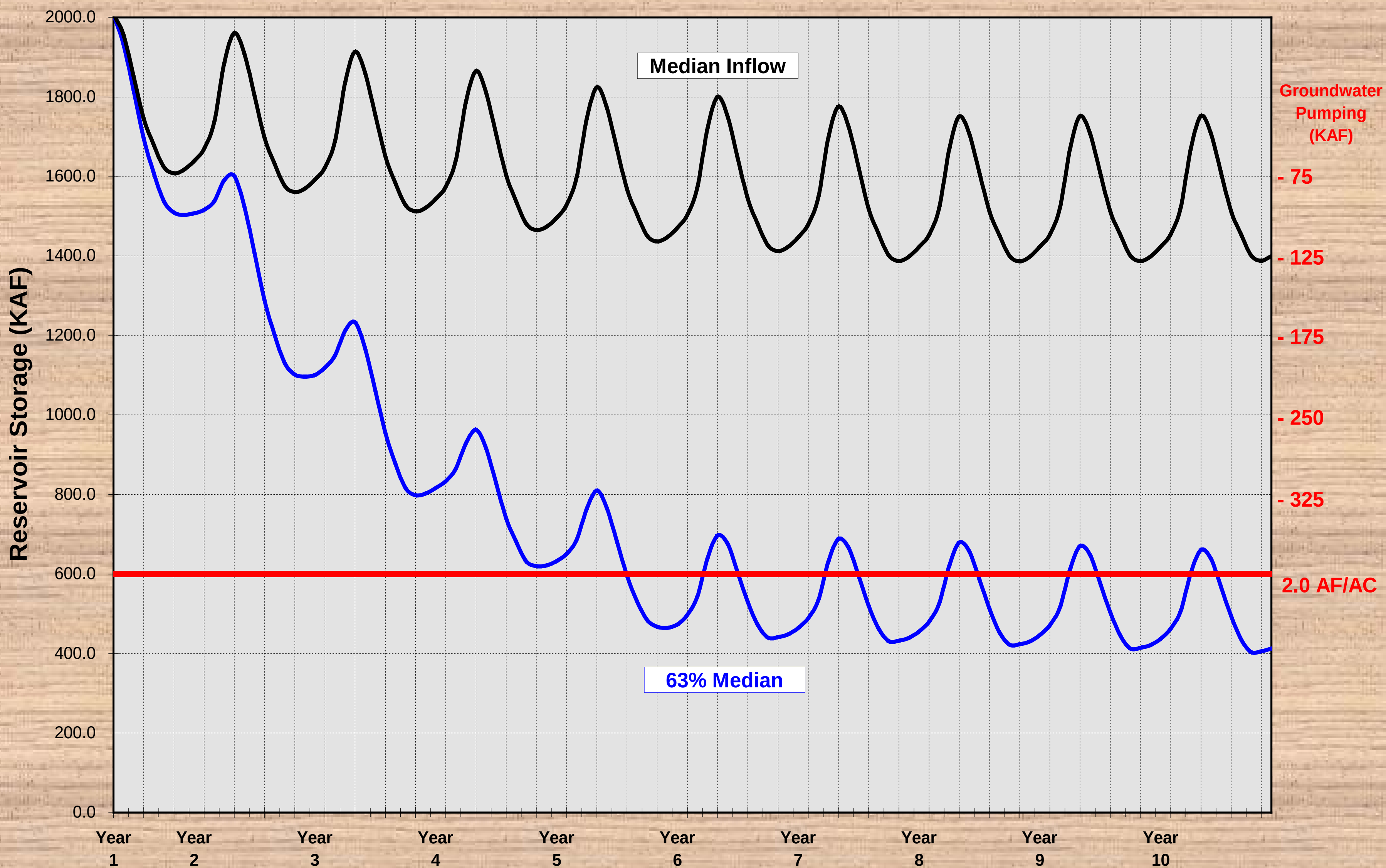
Simulated Reservoir Storage for a Range of Perpetually Reduced Inflows
(as a percent of historical median)

In a climate changing world the question becomes: How much worse (drying) before previous droughts become a problem?

Severe Droughts Capable of Depleting Surface Water Supply With The Noted Reduction In Flow

Period	Source	Duration (yrs)	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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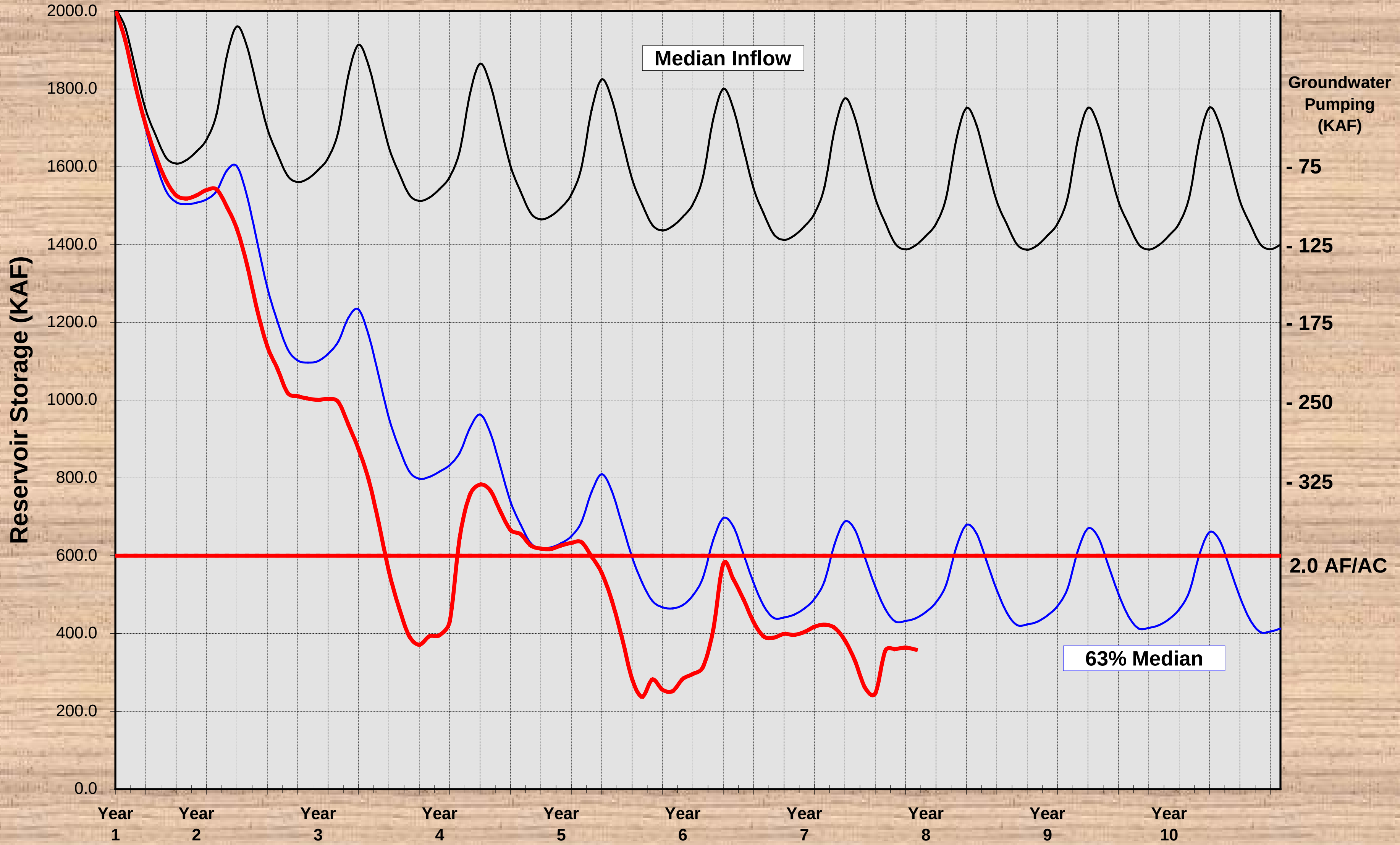

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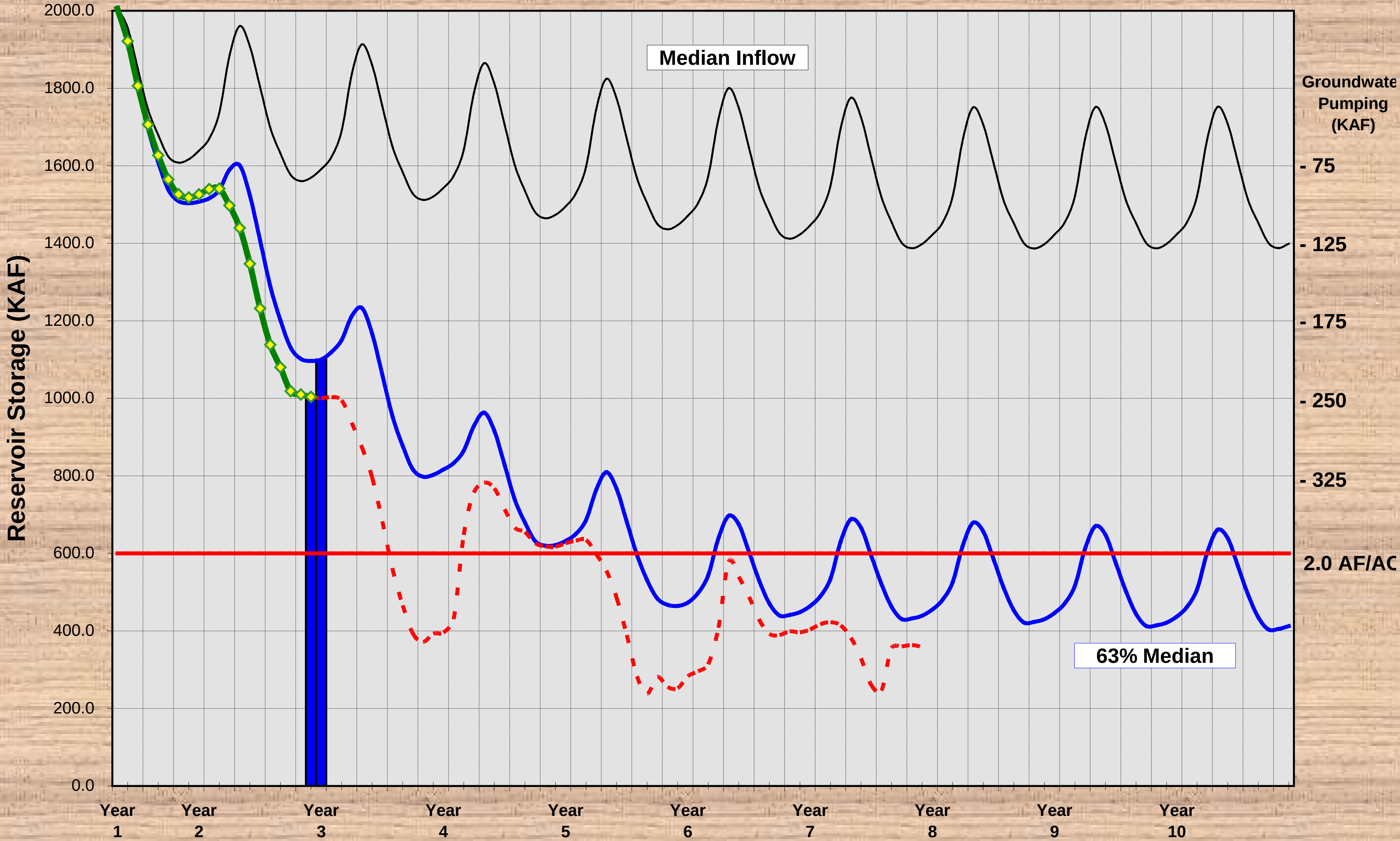

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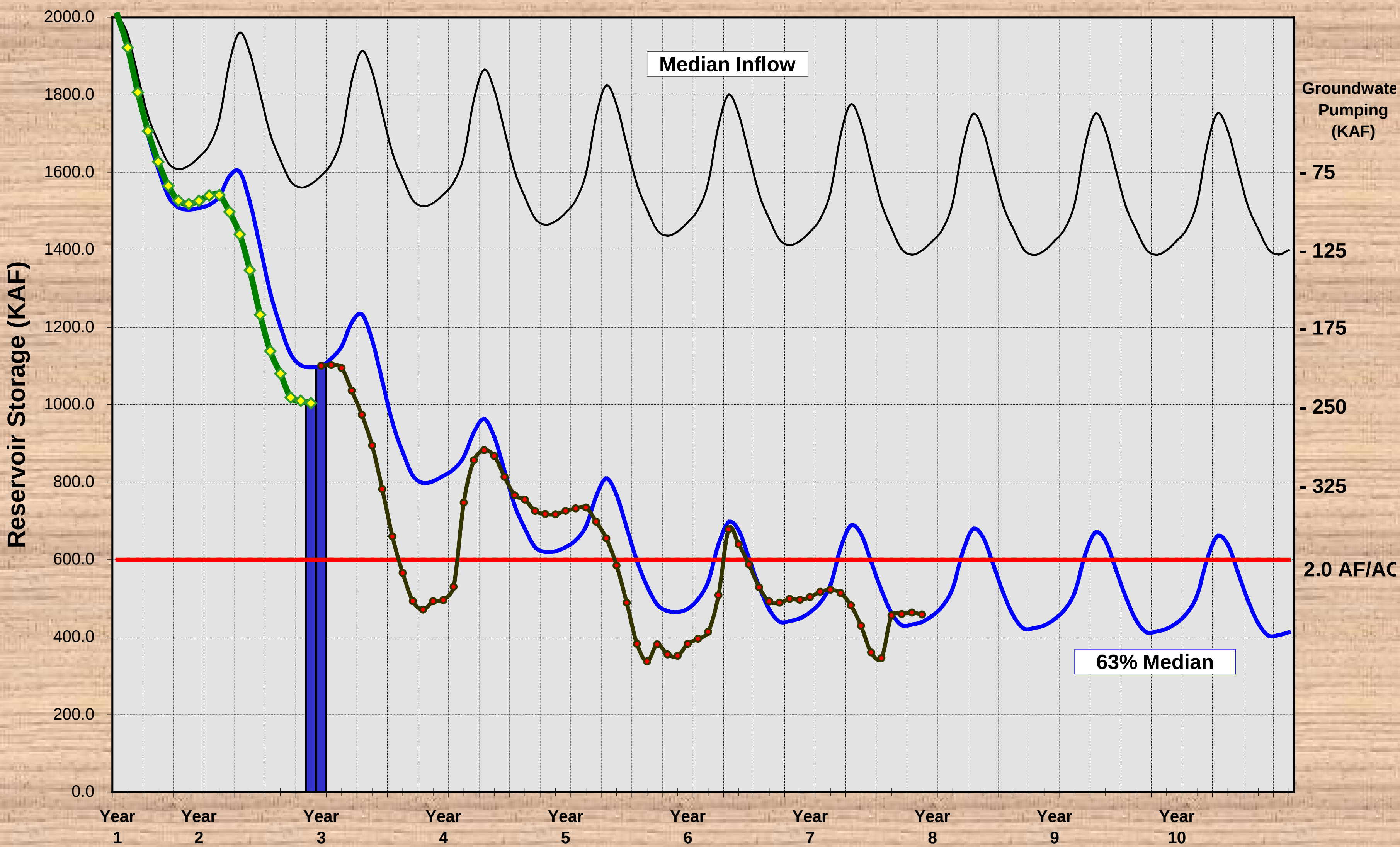

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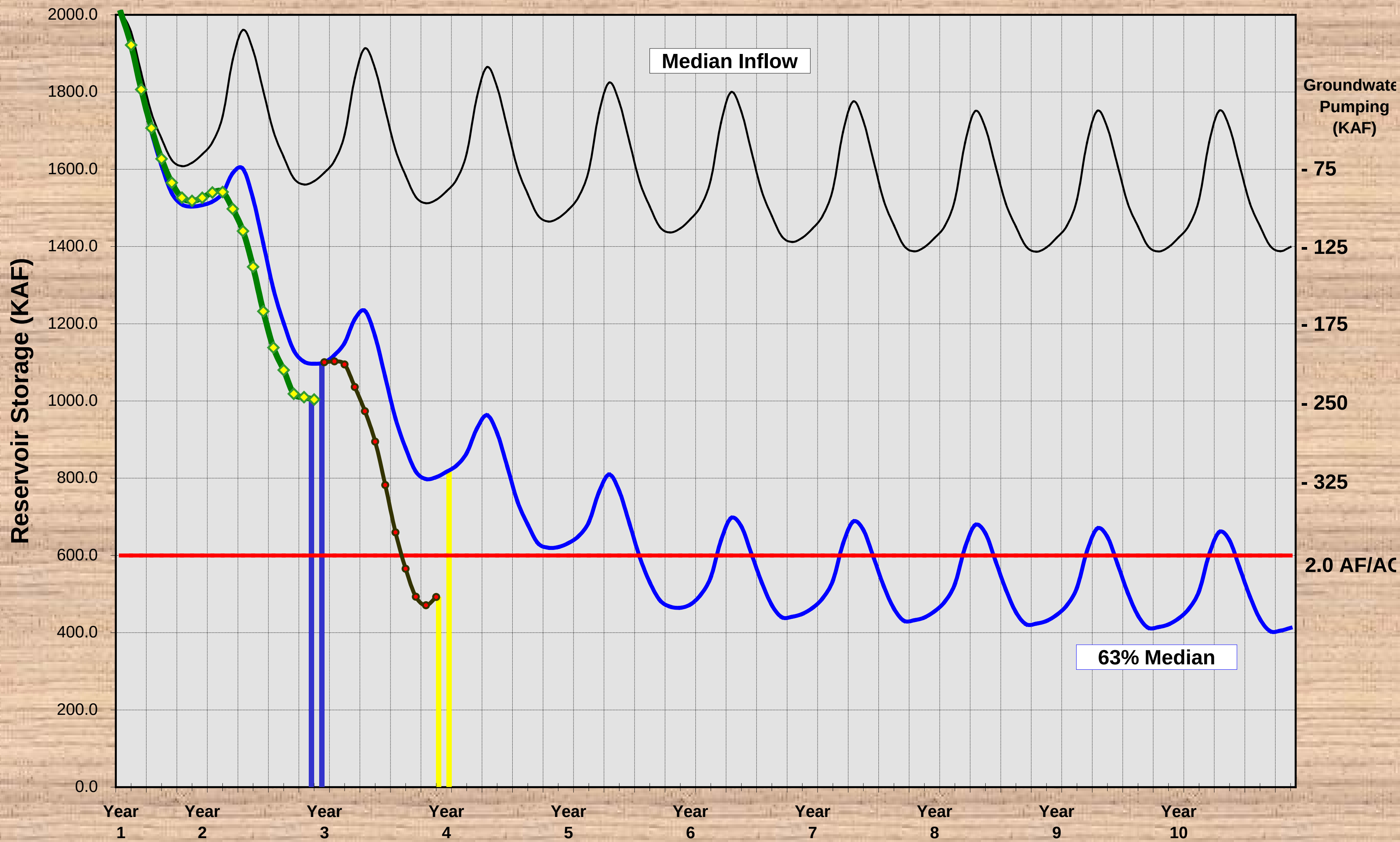
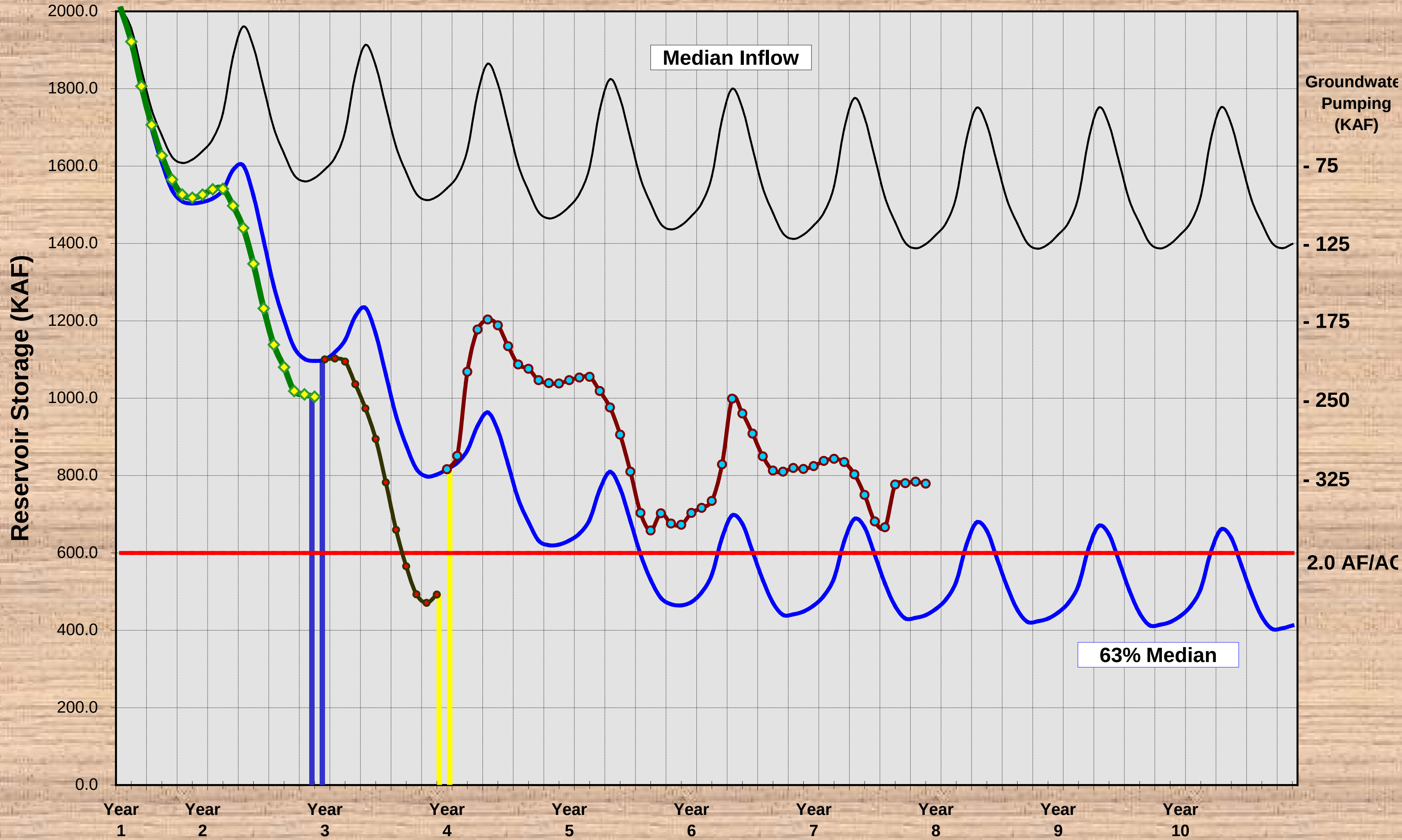


SRP Storage, Pumping & Water Allotment Planning



Storage Necessary to Recover to the Target 63% 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
1895-2005													
1998-2004													

Current Research

- Northern Arizona University
- U of A: SWANN
- Flowtography
- Others

NORTHERN ARIZONA UNIVERSITY
Ecological Restoration Institute

Understanding hydrologic and natural resource responses to Forest restoration

Salt River Project and Northern Arizona University Collaboration

Snow and Soil Moisture in Thinned Forests

Biophysical Monitoring

Fractional snow cover and SWE estimation in alpine-forested environments using remotely sensed data and artificial intelligence

Elzbieta Czyzowska, Katherine Hirschboeck, Willem van Leeuwen, Stuart Marsh, Wit Wisniewski

University of Arizona, Tucson, USA

presented to Salt River Project, 2014-07-24

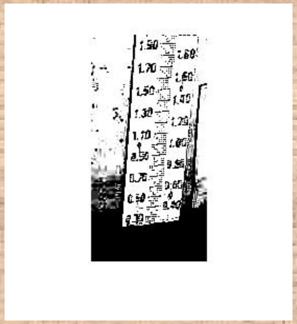
ARIZONA

Arizona Remote Sensing Center

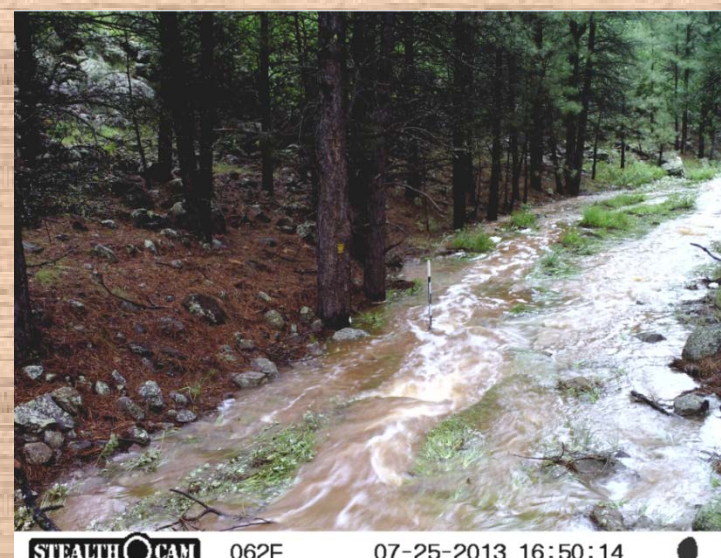
The Laboratory of Tree-Ring Research

Mountain Studies Institute

Flowtography

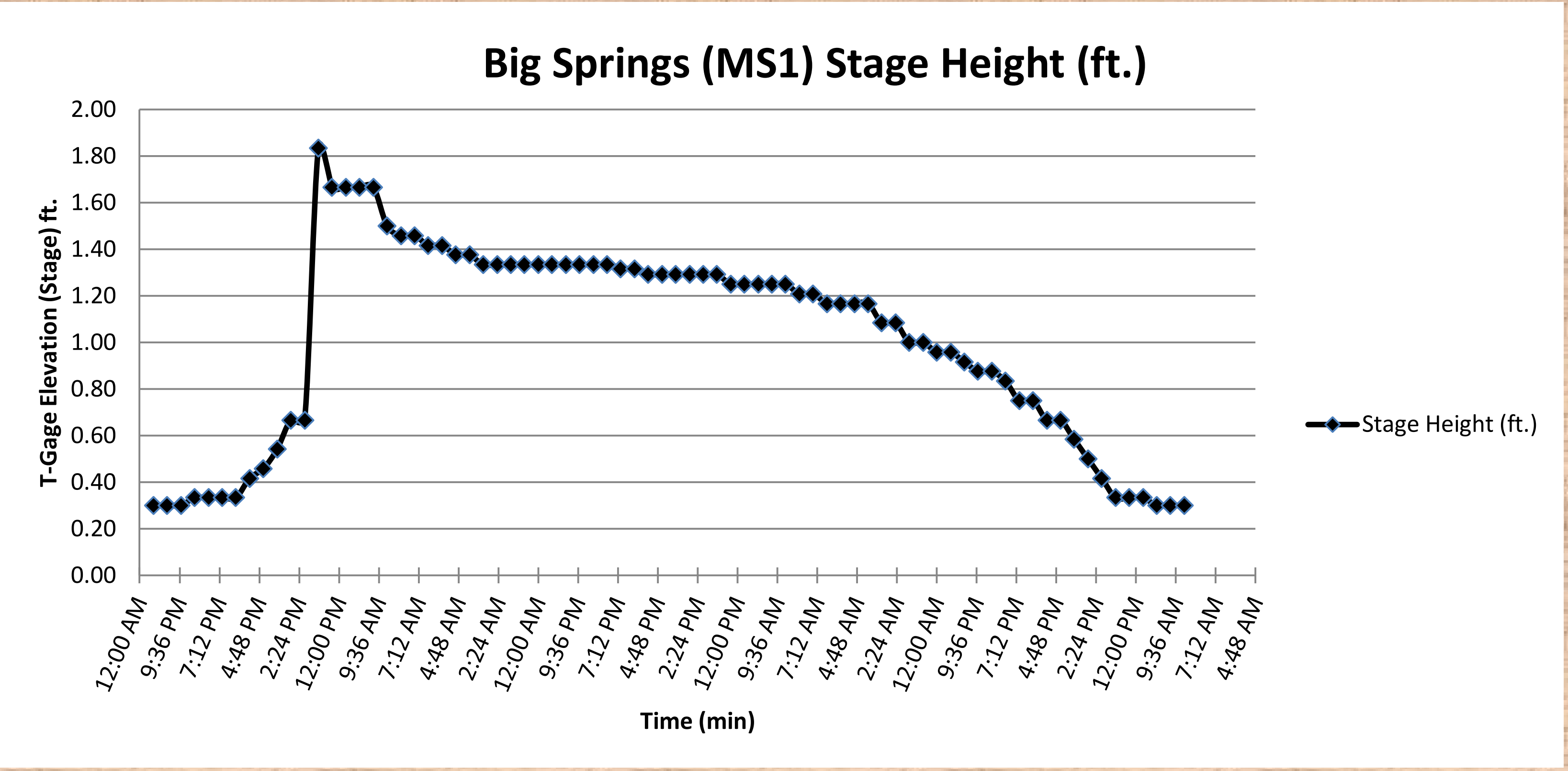


Flowtography



Flowtography

Flowtography



Flowtography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042F
08-14-2013 06:18:59


STEALTH CAM
060F
07-27-2014 07:19:01


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082F
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068F
07-04-2014 12:42:54


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077F
08-16-2013 18:11:55


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055F
08-17-2013 06:59:36


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075F
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Future - SRP Research Objectives

Quantified the effects of forest restoration treatments on:

a. Surface water discharge
b. Evapotranspiration
c. Precipitation quantity/distribution
d. Snow accumulation/distribution
e. Snow quantity, retention and melt
f. Sublimation
g. Partitioning radiation balance
h. Partitioning energy balance
i. Air and soil temperature patterns
j. Near surface/above canopy winds
k. Microscale and mesoscale climate
l. Soil-moisture storage
m. Groundwater storage/discharge
n. Sediment yield and deposition
o. Water quality

- The research should include the source areas for surface water and groundwater as it relates to the water budget of a specific research basin.
- Because we are dealing with climate variability and restoration at the same time, we expect the research to address what hydrologic response can be attributed to restoration and what hydrologic response may be due to climate variability.


If I restore it, it will come!


That can't be true?

Research

How do we know forest restoration is working?

What impacts do forest restoration treatments (and specifically the treatments as defined by the Four Forest Restoration Initiative, 4FRI) for the Salt and Verde watershed have on the hydrologic function at various temporal and spatial scales?

Research Collaborative

(ASU, UA, NAU, TNC, University of Utah, Rocky Mountain Research Center, Others)

- **Addressing research objectives with an integrated effort.**
- **Creating efficiency by avoiding unnecessary duplication of effort.**
- **Strive to incorporate top-level and cutting edge research.**
- **Eliminate barriers for researchers to work across universities by enabling them to apply for funding and perform research jointly.**
- **Transparency among research institutions.**

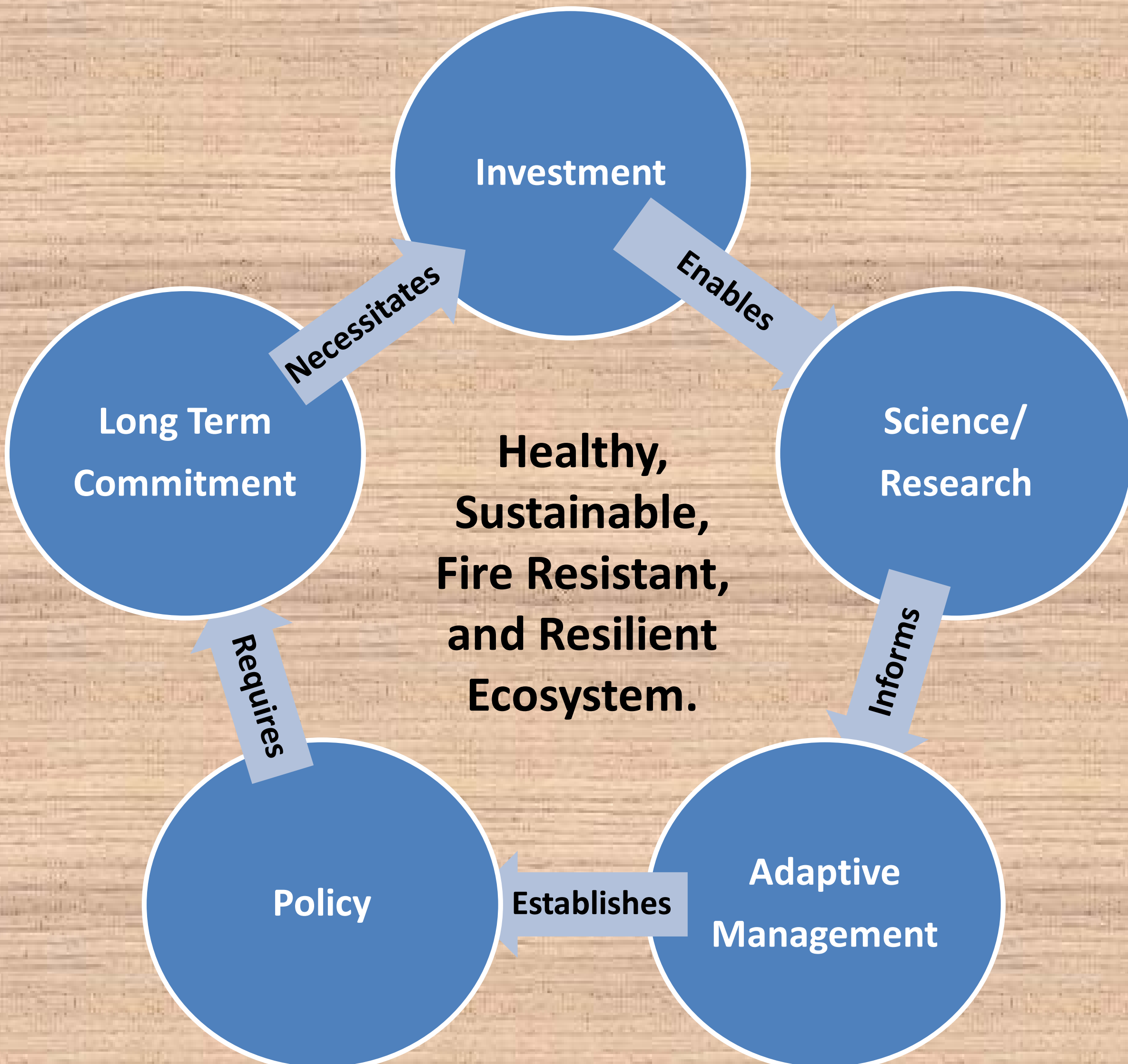
Management

How are research findings integrated into forest management?

- Leadership
- Implementation of Adaptive Management
- Policy
- Industry (Long-term Maintenance Plan)
- Education and Outreach
- Investment (Not just $$$)

Partnerships and Stakeholders

It takes a village!




Our Choice
Pay Some Now?
Pay a Lot Later?