Application of Tree-Ring Data to Water Planning and Management

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Tree-ring-based streamflow reconstructions for the Middle Rio Grande basin
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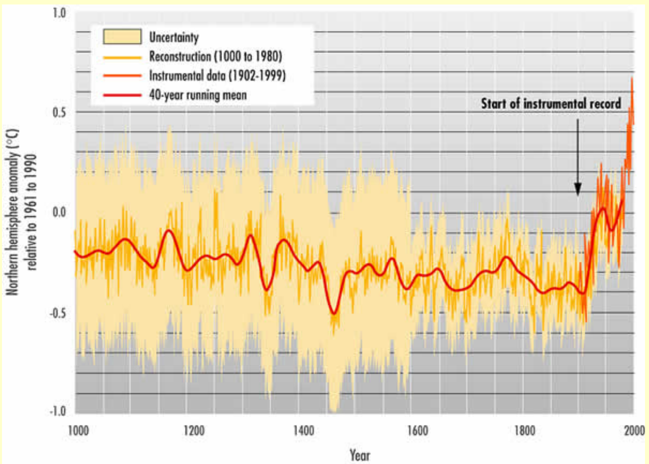
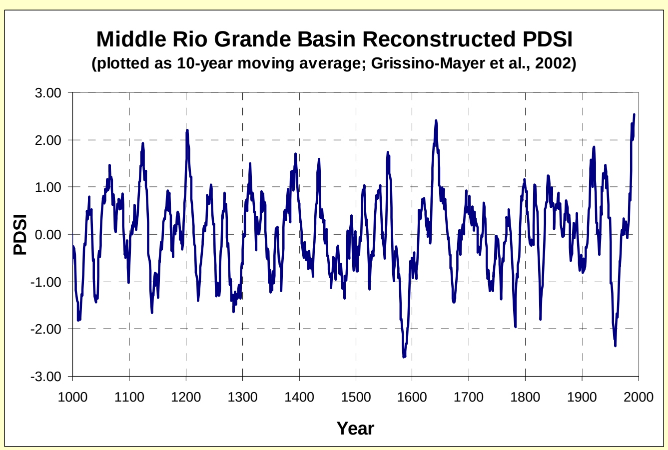
Overview

This talk presents Case studies from SSP&A's work in New Mexico, illustrating how tree-ring data can be used to support water- management decisions.





Tree Ring Reconstructions

Tree rings have been used to reconstruct

- stream flow,
- temperature,
- precipitation,
- drought indices,
- El Nino/ENSO, and
- Pacific Decadal Oscillation

Applications of Tree-Ring Reconstructions to Support Water Management

- Determination of the most appropriate period of record to use for water budgets
- Assessment of the relative severity of recent droughts, and the most appropriate base conditions for drought modeling
- Development of a climatic planning sequence which presents an historically-meaningful distribution of average, drought and wet conditions.

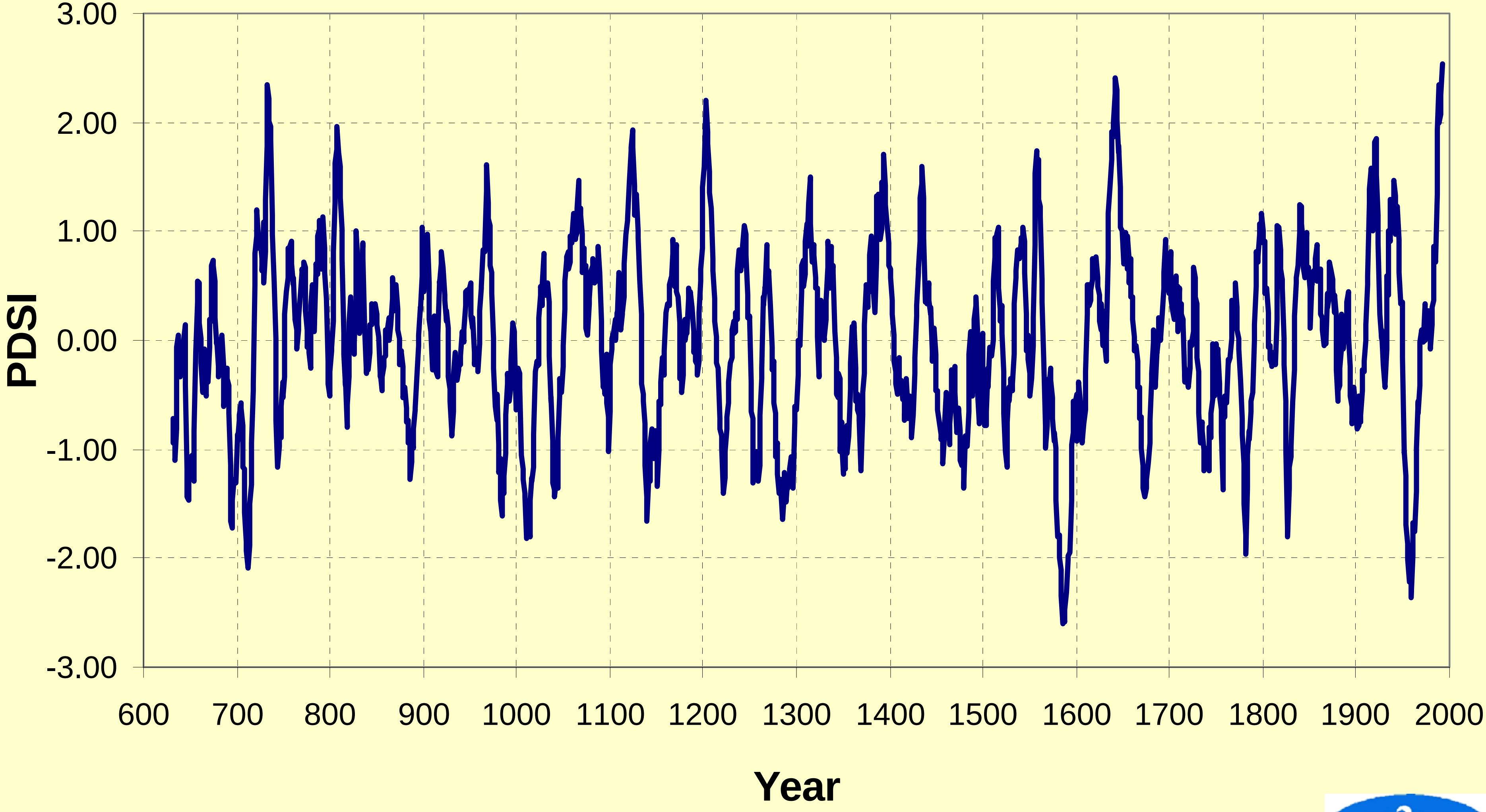
Middle Rio Grande Reconstructions used by SSPA

- Reconstructions by Henry Grissino-Mayer, including:
  - a 2129-year reconstruction of precipitation at El Malpais (Grissino-Mayer et al., 1996)
  - a 1350-year reconstruction of the *Palmer Drought Severity Index (PDSI)* for the Middle Rio Grande Basin (Grissino-Mayer et al., 2002)
- Pacific Decadal Oscillation Reconstruction of Biondi et al. (2001)


Otowi Bridge
Santa Fe
Cochiti Dam
Sandia Mtns
Albuquerque
El Malpais
National Monument
Middle Rio Grande
Magdalena Mtns
Socorro
Rio Grande
Elephant Butte Dam
25
40
10
SAN JUAN
RIO ARRIBA
COLFAX
UNION
MORA
HARDING
MCKINLEY
SANTA FE
SAN MIGUEL
SANDOVAL
CIBOLA
QUAY
GUADALUPE
TORRANCE
VALENCIA
CURRY
DE BACA
CATRON
SOCORRO
ROOSEVELT
LINCOLN
CHAVES
SIERRA
GRANT
OTERO
LEA
EDDY
LUNA
HIDALGO

Middle Rio Grande Basin Reconstructed PDSI

(plotted as 10-year moving average; Grissino-Mayer et al., 2002)



Key Findings

Wet Periods:

- Recurrence interval of 42 years
- Average duration of 11 years
- 1978-1992 is one of the wettest periods in this record

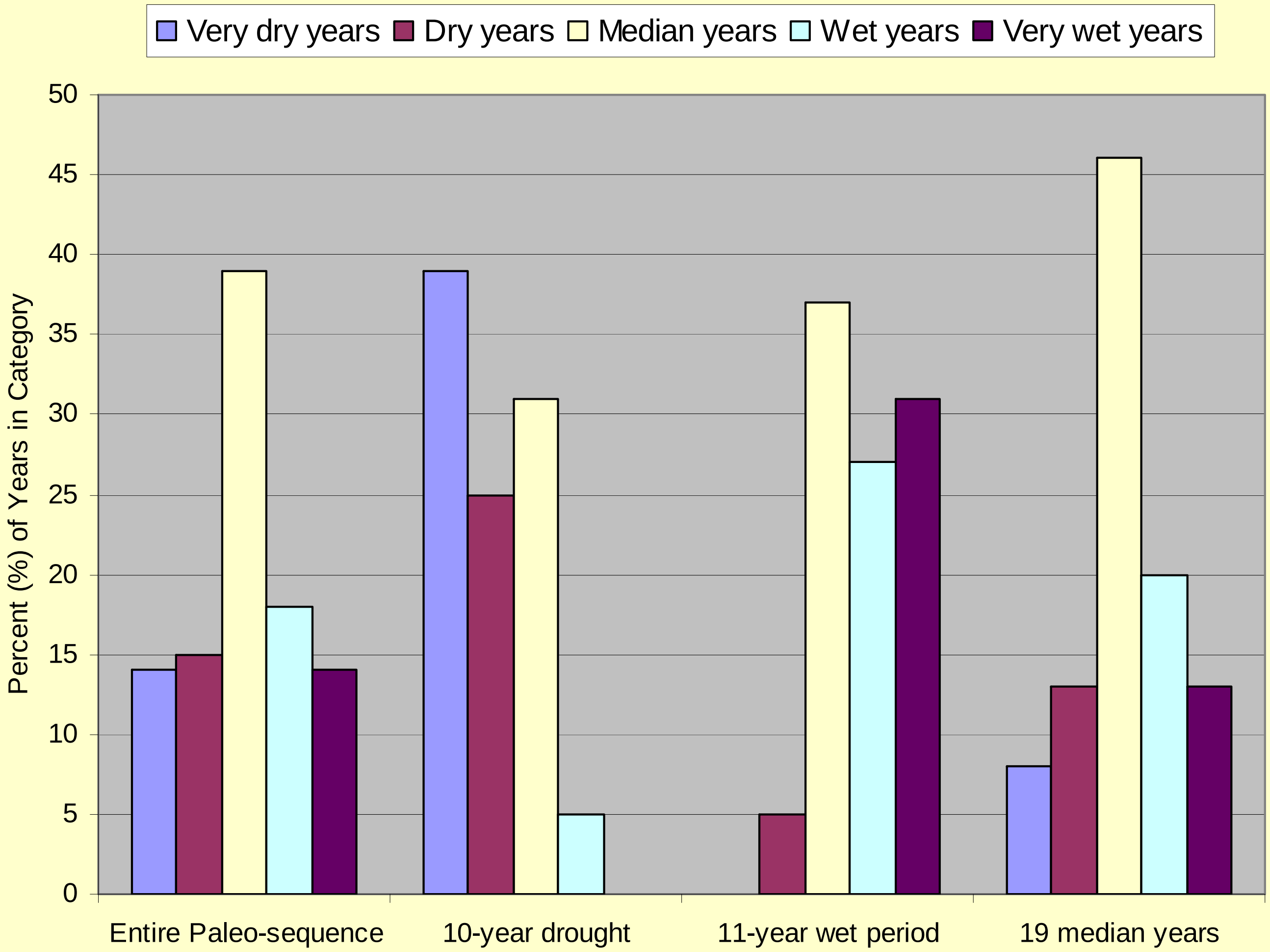
Droughts:

- Recurrence interval of 40 years
- Average duration of 10.4 years
- 1945-1963 is one of the worst droughts on record in the past 1400 years

General:

- 1950-2002 representative of long-term average conditions

Percentage Distribution of Conditions



Very dry conditions: PDSI<-2

Dry conditions: –2<PDSI<-1

Wet conditions: 1<PDSI< 2

Very wet: 2<PDSI

Implications for Management

- 1975-2000 is not a particularly good period to use for water budgets unless you want a very optimistic picture of available supply
- The period from 1950-2000 is a fair representation of “average” historical conditions
- The 1950s and 1960s drought was one of the more significant droughts on record (though not the most severe)
- The 1980s and 1990s were unusually wet

URGWOM: Generating a 40-year synthetic sequence

Problem:

To be useful for water management, the 40-year synthetic climatic sequence needs to reflect the broad range of climatic conditions that may be encountered in 40 years of water management including both drought and wet period recurrence interval, length, and severity.

The sequence needs to "normalize" the recent record to the long-term record as reflected in the paleo-climate data.

The "pool" of available data for construction of this sequence is from 1975 to 1999. This period is wetter than the long-term average; consequently, a simple random sampling will not generate a sequence representative of long-term conditions.

URGWOM: Generating a 40-year synthetic sequence

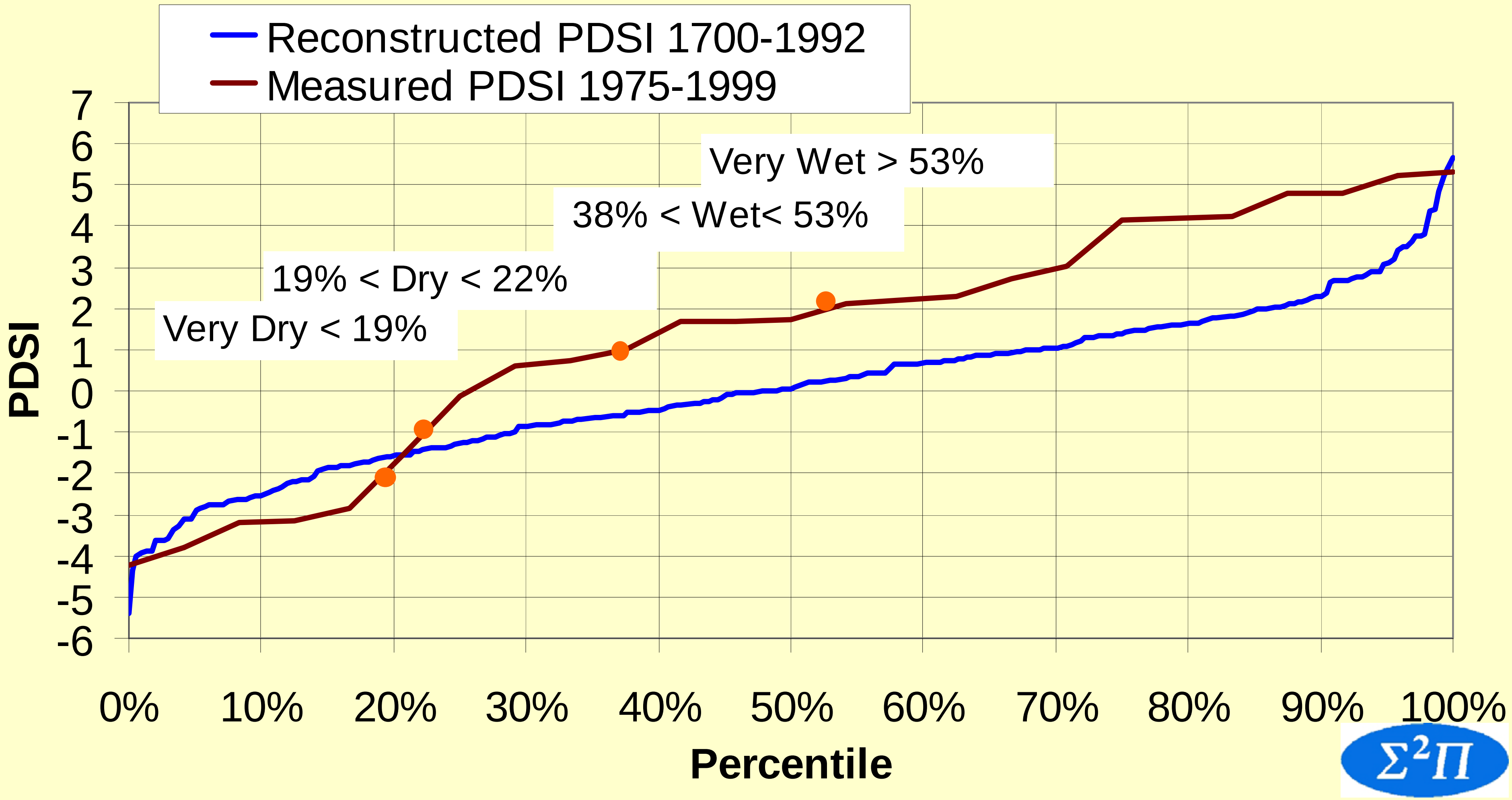
Approach:

Based on a good correlation between flows and measured PDSI for the climate division, SSPA:

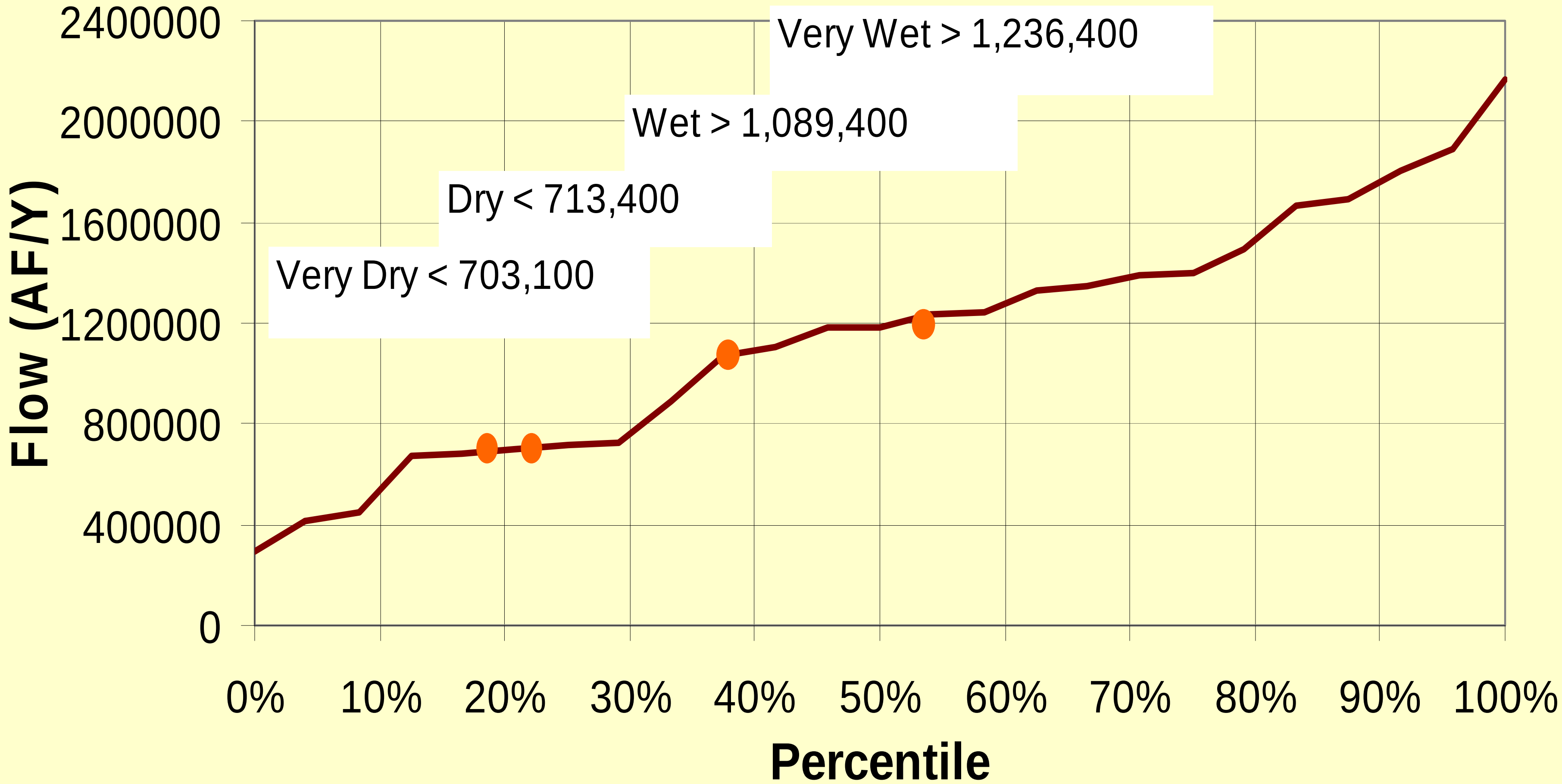
- "Normalized" the recent record to the long-term record
- Ranked the 1975-1999 PDSI values based on how they reflected the long-term average as obtained from the reconstructed PDSI values
- Used the ranked PDSI values to rank flow values
- Selected very dry, dry, average, wet and very wet flows based on these rankings
- Generated a sequence of hydrologic years representative of long-term historical conditions

Ranked PDSI and associated cutoffs for very dry, dry, average, wet and very wet conditions

Note: 1700-1992 curve included to demonstrate that 1975 to 1992 values are skewed toward higher PDSI values



Otowi Index flow cutoffs for very dry, dry, wet, and very wet years, 1975-1999



Creating 40-year sequence

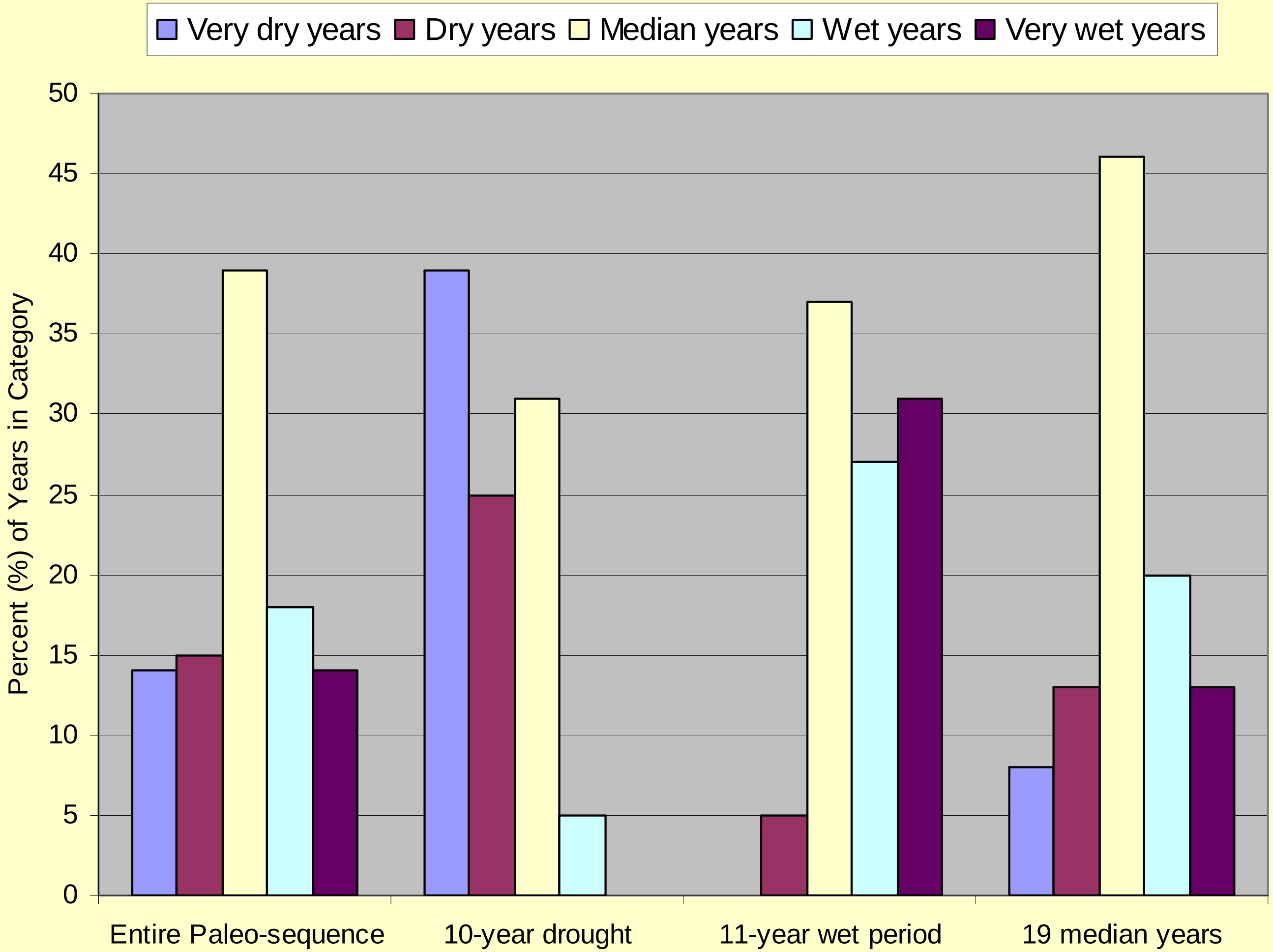
"Representative" drought and wet period events over the past 300 years occur roughly every 40 years, with a duration of roughly 10 years.

These patterns were incorporated into a 40-year synthetic hydrograph to represent hydrologic input for the planning model.

Through this mechanism, alternate water operations scenarios simulated with the planning model could be evaluated under a wide range of climatic conditions.

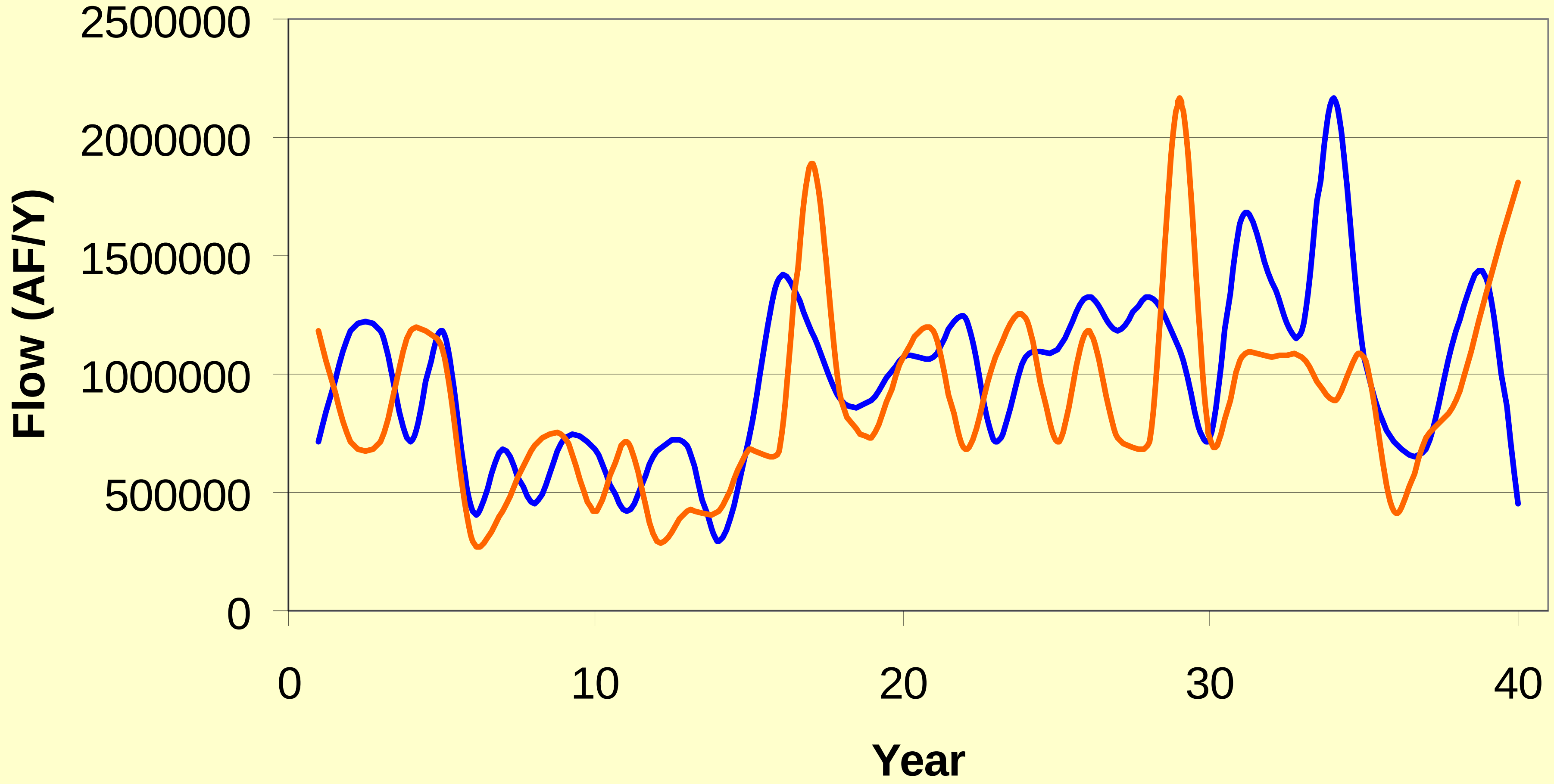
- 5 "average" years, 10 drought years, 10 average years, 10 wet years, 5 average years
- Random selection for each period from the distribution of conditions for that period

Percentage Distribution of Conditions



Very dry conditions:	PDSI<-2	Wet conditions:	1<PDSI< 2
Dry conditions:	–2<PDSI<-1	Very wet:	2<PDSI

Sample synthetic hydrographs



Using tree ring records has enabled us...

- ...to verify that the period of record used for modeling accurately reflects historical climate
- ...to calibrate the 1975-1999 record such that we could use it to generate synthetic hydrographs representative of long-term conditions

- ...to provide more accurate information to regional planners concerning hydrologic scenarios for the region

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Application to Climate-Change Scenarios

This approach allows generation of synthetic data sets representing particular climate scenarios, and the use of these data sets in forecast modeling and sensitivity analyses.

The approach can be adapted for generating potential future climate patterns under anticipated global warming scenarios. These adaptations may be based on paleo-climate reconstructions, recent data sets, and modeling or assumptions about future climate conditions.

Middle Rio Grande Reconstructions – Data Limitations

- The Grissino-Mayer reconstructions are of climatic parameters related to flow, not reconstructions of flow. SSPA has used these reconstructions as proxies for flow based on strong correlation with flow for period of available overlapping record.
- The Grissino-Mayer reconstructions end in 1992 – we have 15 years of good, high resolution hydrologic data and only limited ability to tie it to past conditions

Wish List

- Reconstructions of flow, rather than just Palmer Drought Severity Index or precipitation as a proxy for flow.
- New reconstructions reflecting the past 15 years (since 1992).