Modeling with Tree-ring Reconstructions

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CIRES
Tree-ring Workshop

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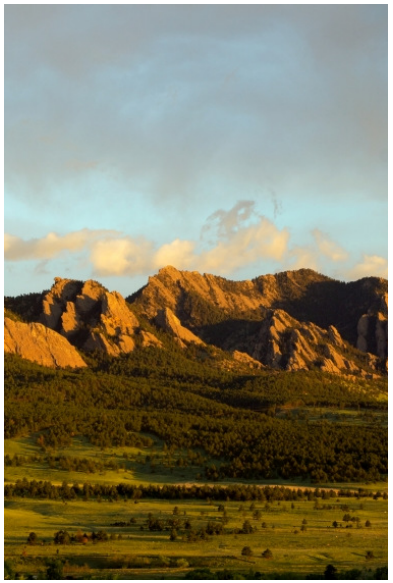


How Frequent is the Drought of Record?

- **The obvious inference:**
  - The drought of record in a 100-year record is the 100-year drought.
  - This falls afoul of Mencken's First Law[1].
- **The truth:**
  - There is about a 1 in 3 chance (37%) that a 100-year record **does not** contain a drought as severe as the true 100-year drought.
  - Said another way, there about a 1 in 3 chance that we have not yet experienced a drought as severe as the true 100-year drought.
  - There is a 95% probability that a 100-year record **does** contain a drought as severe as the true 30-year drought.
- **To have a 95% probability that you have a good estimate of the 100-year drought, you need a record 300 years long.**
- **So…we have to turn to paleo-hydrology.**

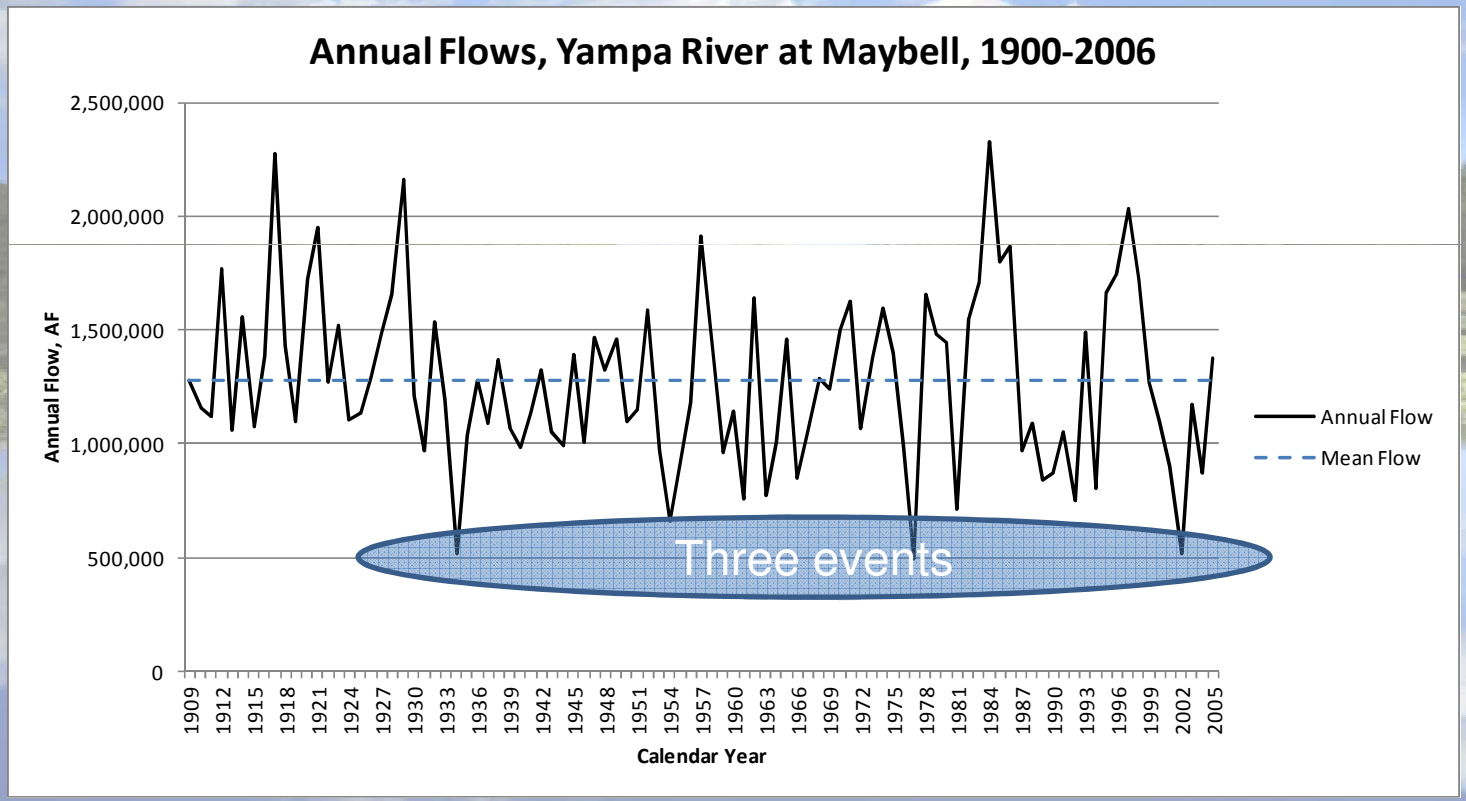
1. *"For every problem, there is a solution that is simple, neat, and wrong."*
   ~H. L. Mencken

Upper Yampa Water Conservancy District

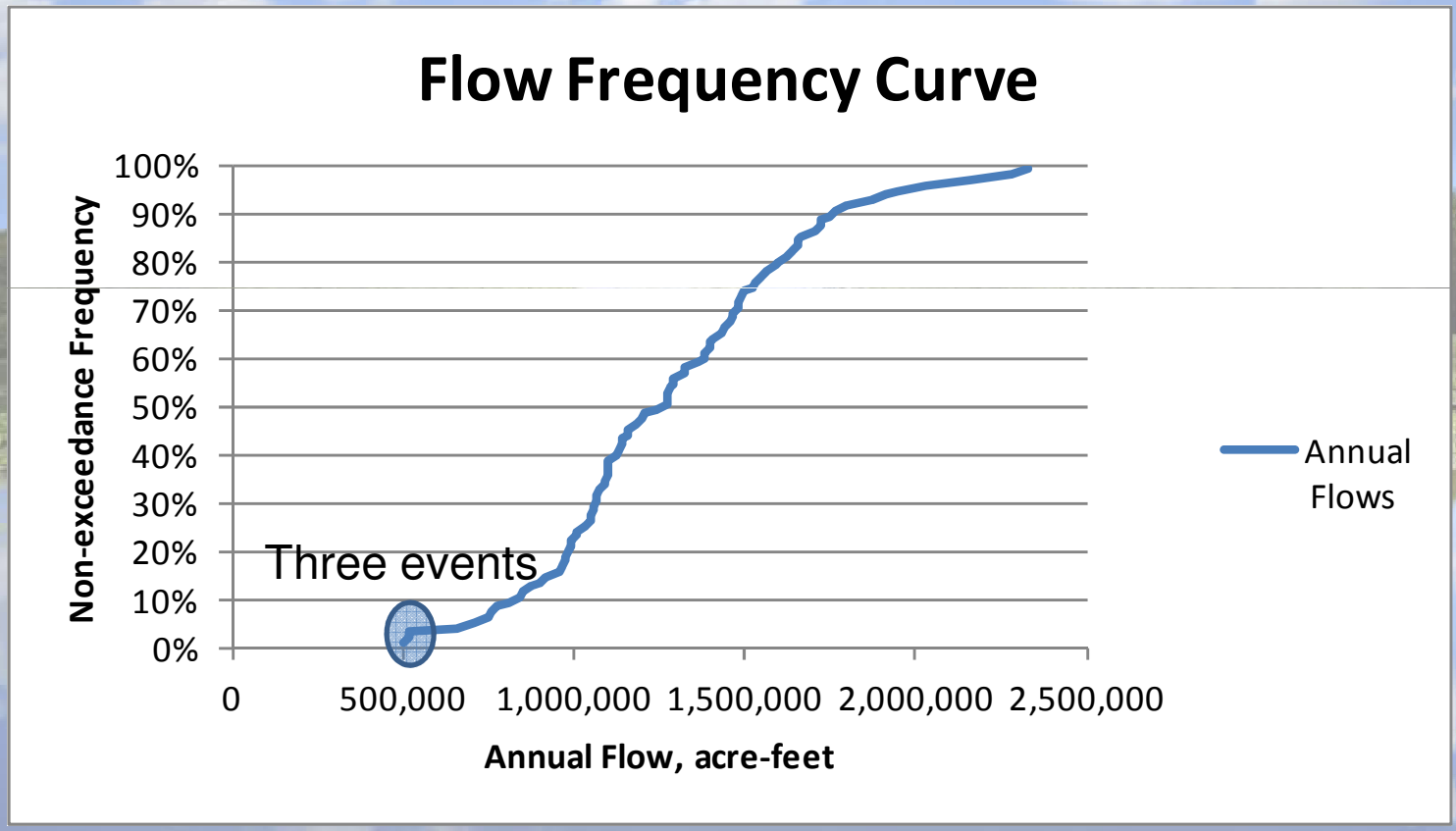
- **Domain**
  - Yampa River Basin
- **Objectives**
  - Evaluate water availability and the adequacy of District infrastructure and water rights.
  - Serve as the basis for possible water rights filings in the future.

What Do We Know About the Past: The Observed Record

Source: CDSS Natural Flows

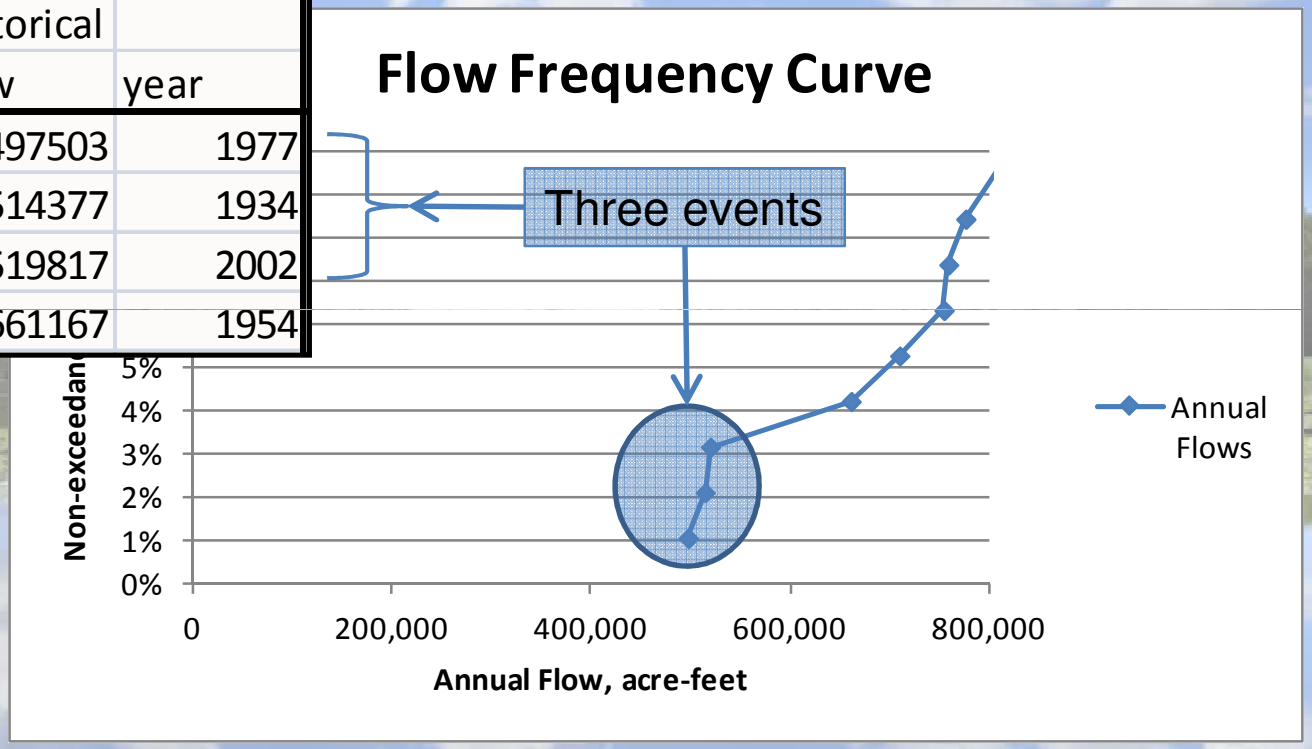


The Curve


Flow Frequency Curve
Non-exceedance Frequency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Three events
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Annual Flow, acre-feet
Annual Flows

The Dry End (the Fs)

	Historical flow	year
0.011	497503	1977
0.021	514377	1934
0.032	519817	2002
0.042	661167	1954



More objectives

- **District needs to know the effect of low-frequency events on their *system***
  - E.g. with return intervals longer than c. 30 years
  - Effects on many water rights and reservoirs
- **Analysis may serve as the basis for a water rights filing**
  - The use of paleo hydrology may have no precedent in Colorado water rights
  - The method needs to be concrete and as simple as possible
- **Approach**
  - Direct reconstruction of prehistoric flows
  - Forcing a water resources model

Statistics of reconstruction vs. observed

Gray, S. T., J. J. Lukas, and C. A. Woodhouse, 2011. Millennial-Length Records of Streamflow From Three Major Upper Colorado River Tributaries. Journal of the American Water Resources Association (JAWRA) 47(4):702-712. DOI: 10.1111/j.1752-1688.2011.00535.x

	Observed	Reconstructed
Maximum	2,326,651	2,003,748
90th Percentile	1,738,702	1,605,933
10th Percentile	843,832	888,686
Minimum	497,503	491,935
Mean	1,280,922	1,267,405
Standard Deviation	378,649	302,230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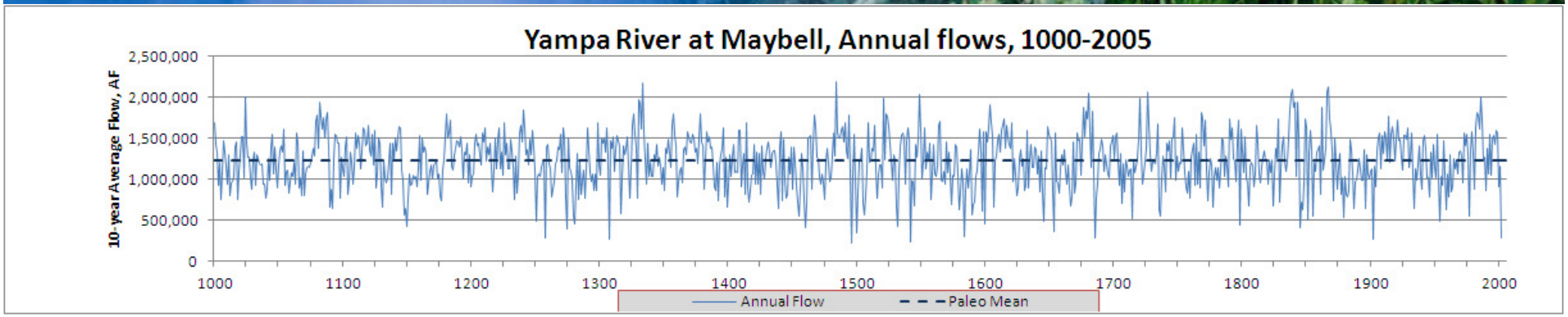
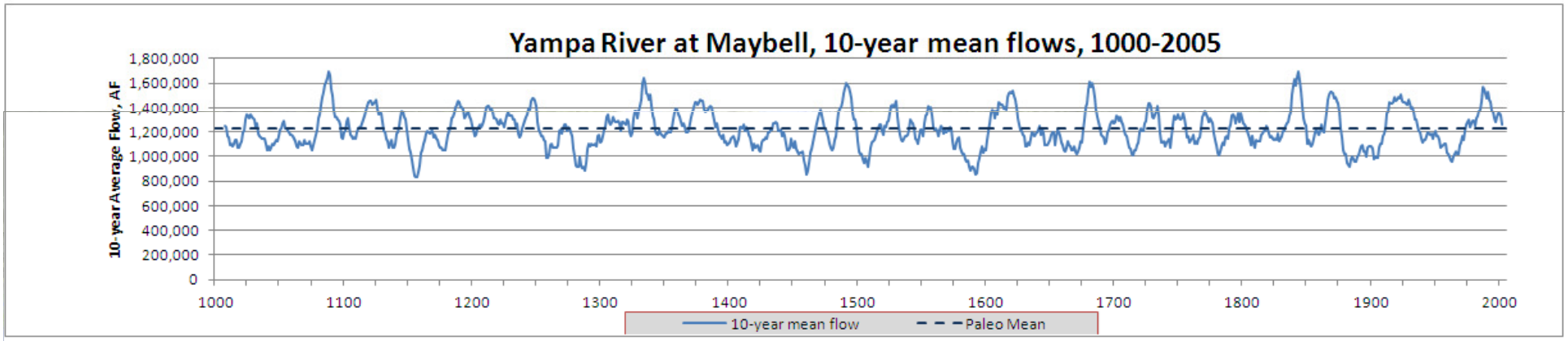
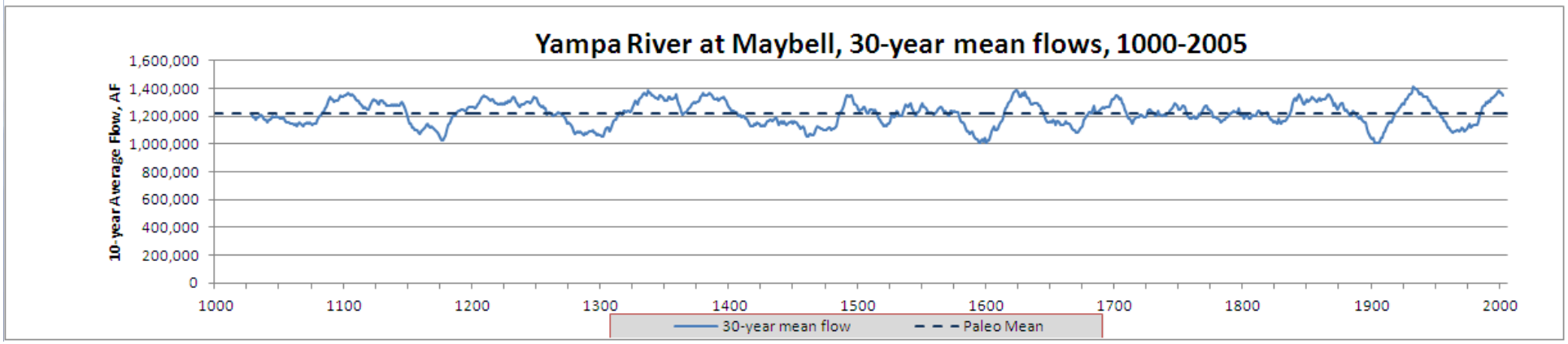
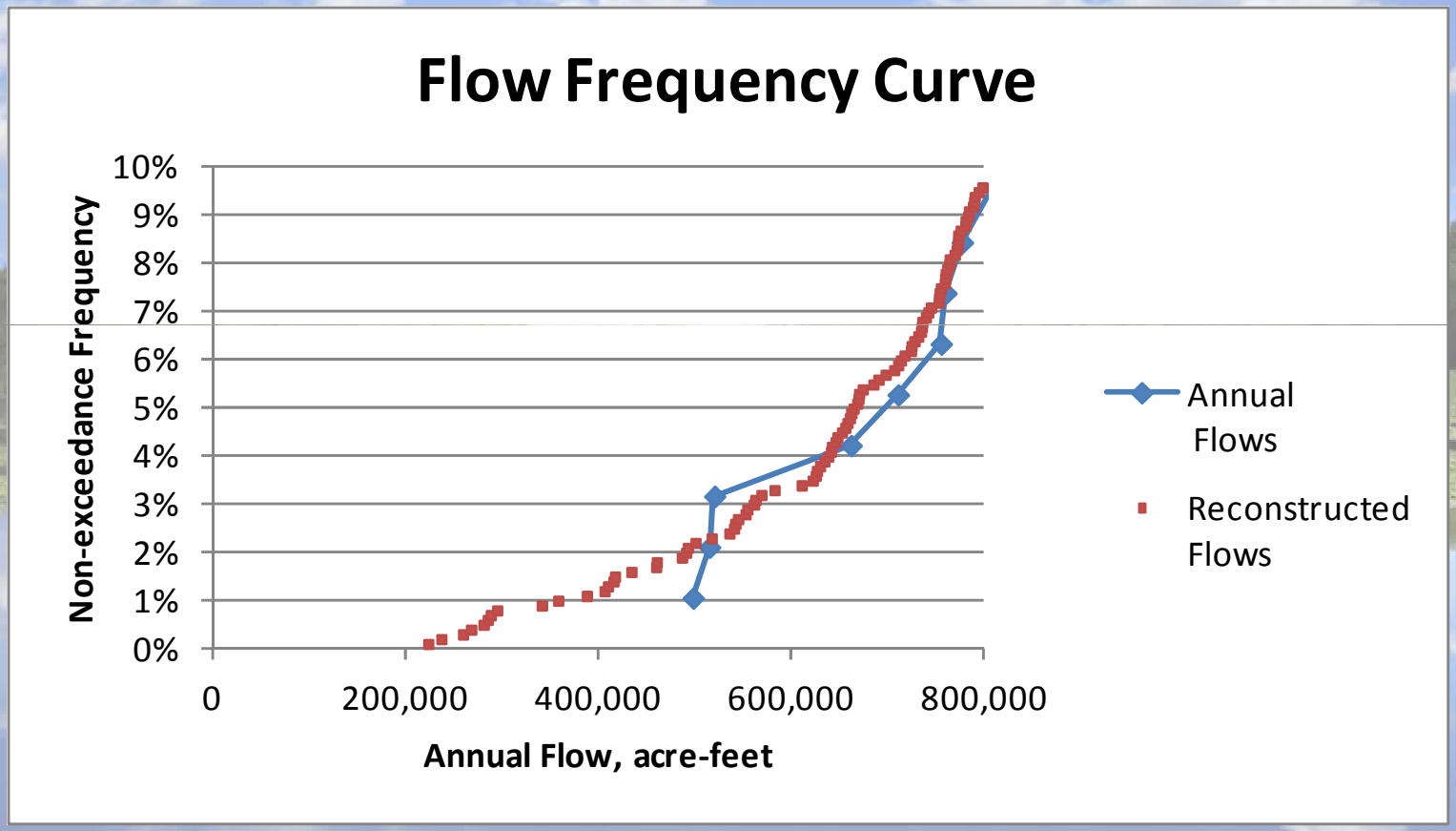

Yampa River at Maybell, Annual flows, 1000-2005
10-year Average Flow, AF
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Annual Flow
Paleo Mean

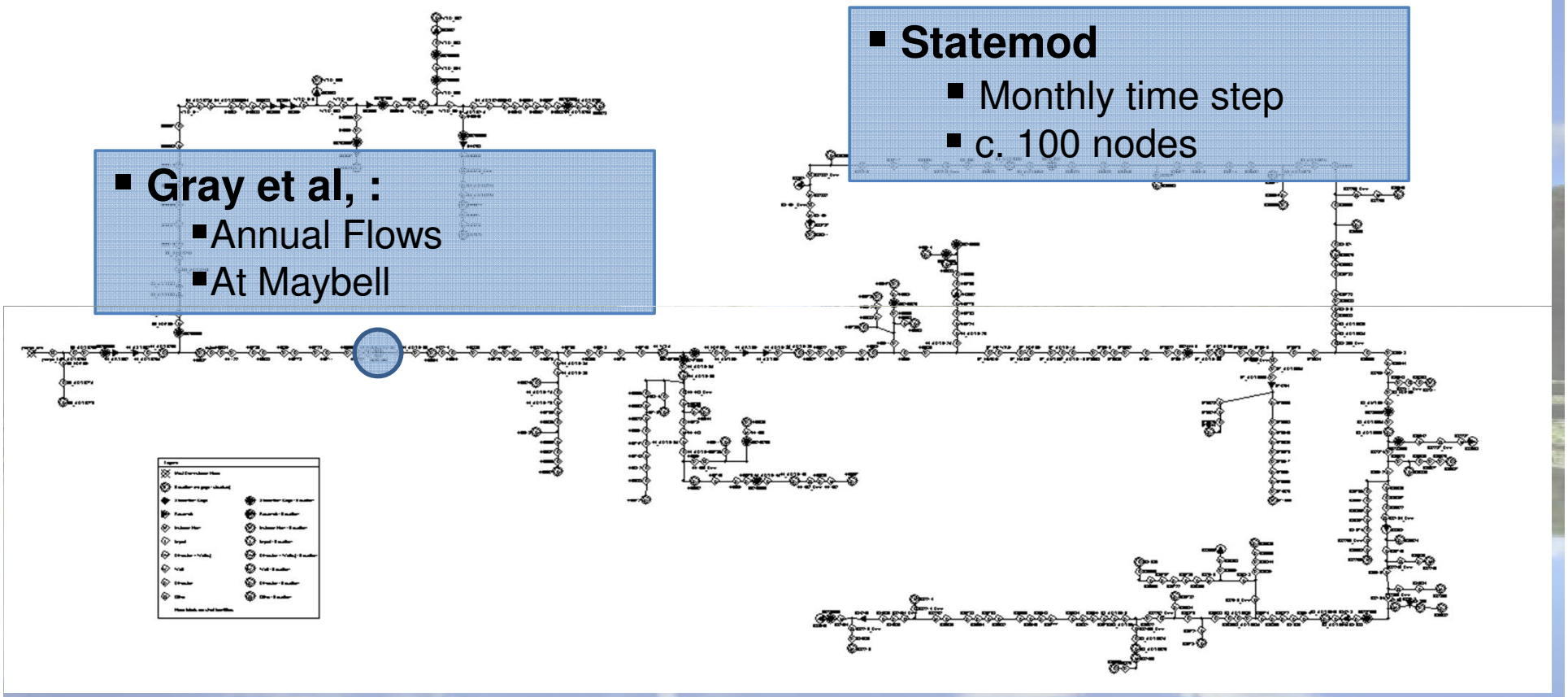

Yampa River at Maybell, 10-year mean flows, 1000-2005
10-year Average Flow, AF
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
10-year mean flow
Paleo Mean


Yampa River at Maybell, 30-year mean flows, 1000-2005
10-year Average Flow, AF
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
30-year mean flow
Paleo Mean

Yampa at Maybell—More information



Yampa River Basin Model



- **Gray et al, :**
  - Annual Flows
  - At Maybell

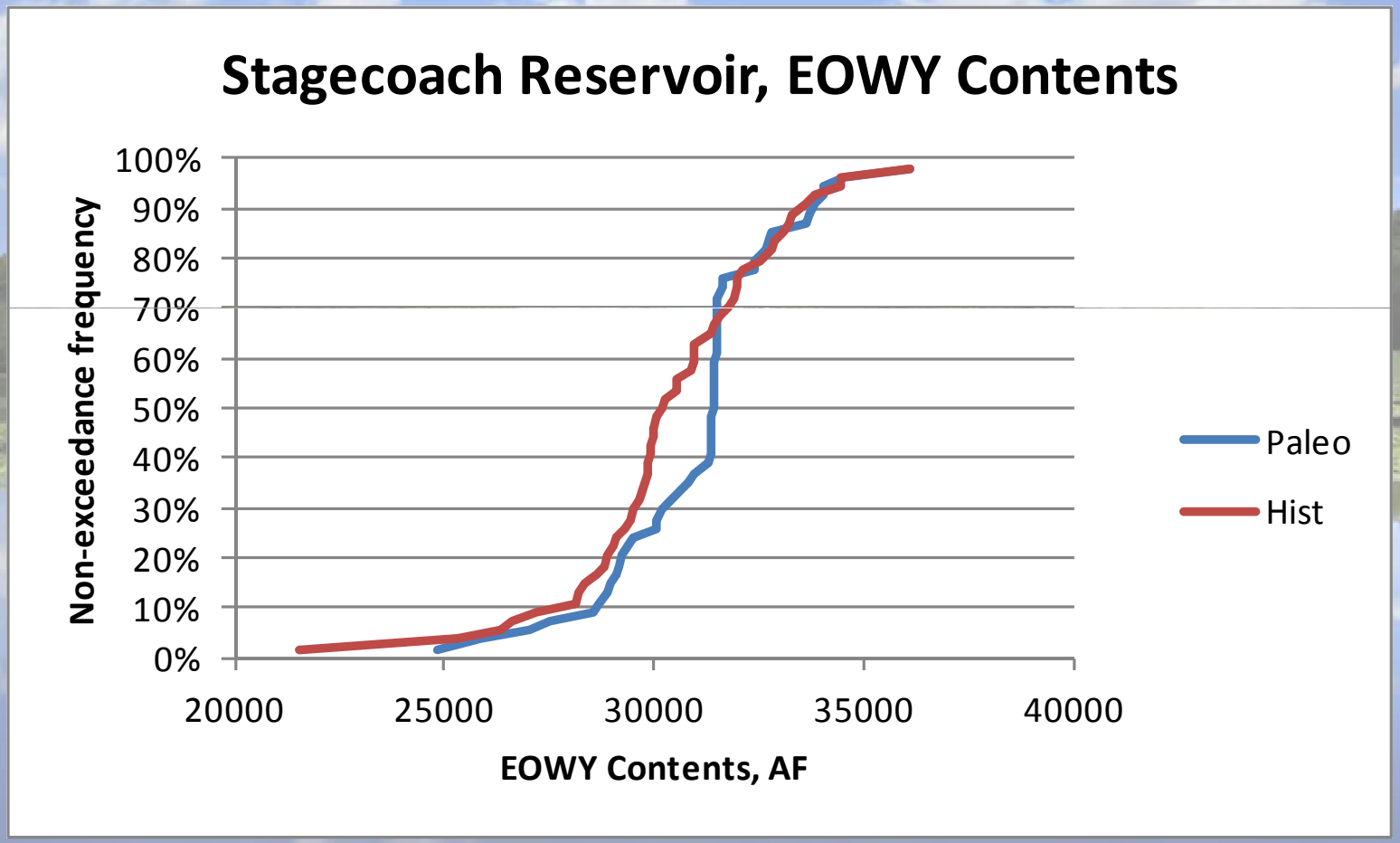
- **Statemod**
  - Monthly time step
  - c. 100 nodes

Nowak, K., J. Prairie, B. Rajagopalan, and U. Lall (2010), A nonparametric stochastic approach for multisite disaggregation of annual to daily streamflow, Water Resour. Res., 46, W08529, doi:10.1029/2009WR008530.

Limitations of Paleo-Hydrology

- **Based on models**
- **Only explain approximately 60%-80% of the variance of flows**
- **Different reconstructions will give different results**
  - Different data (trees or flow)
  - Different model structures
  - Different model parameters

Effect of reduced variability



Colorado River Water Availability Study

- **Domain**
  - Colorado River Basin
- **Objectives**
  - Evaluate water availability
  - Provide the basis for future analyses
  - Provide a probabilistic evaluation
  - Integrate with projected climate
- **Approach**
  - Stochastic re-sequencing of historic flows based on the statistics of reconstructed flows

Prairie, J., K. Nowak, B. Rajagopalan, U. Lall, and T. Fulp. (2008) "A stochastic nonparametric approach for streamflow generation combining observational and paleoreconstructed data." Water Resources Research 2008 Volume 44, W06423

Summary

- Estimates of drought frequen observations are biased low.
- Paleo hydrology allows for more reliable estimates of low-frequency annual events.
- Convenient, easy-to-apply disaggregation methods now exist.
- So, water resources modeling is now practical
- Variability is biased low in reconstructions
- Yield estimates for small reservoirs appear to contain error, but perhaps not a consistent bias.

Thanks!

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