

Improving flood-frequency analyses with a 4,000-year record of flooding on the Tennessee River near Chattanooga, Tennessee

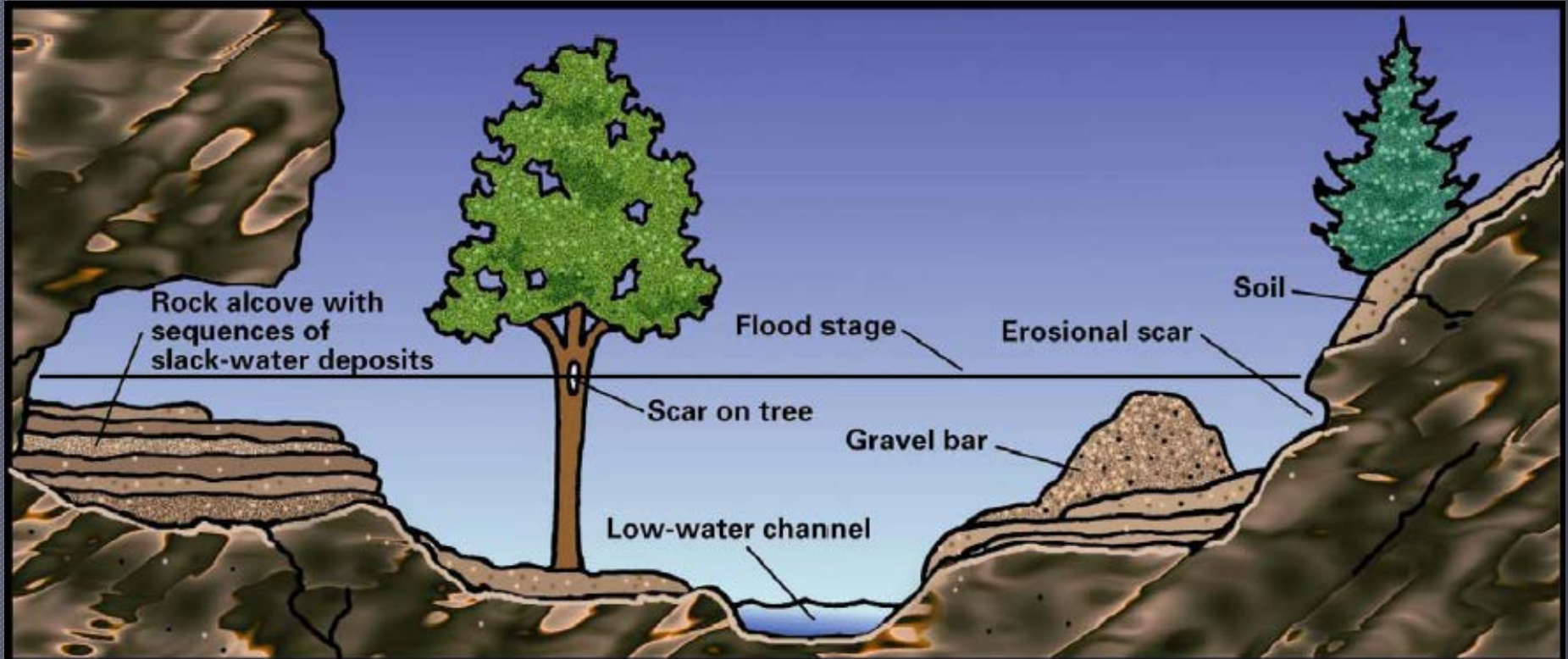


Tess Harden – USGS Oregon Water Science Center

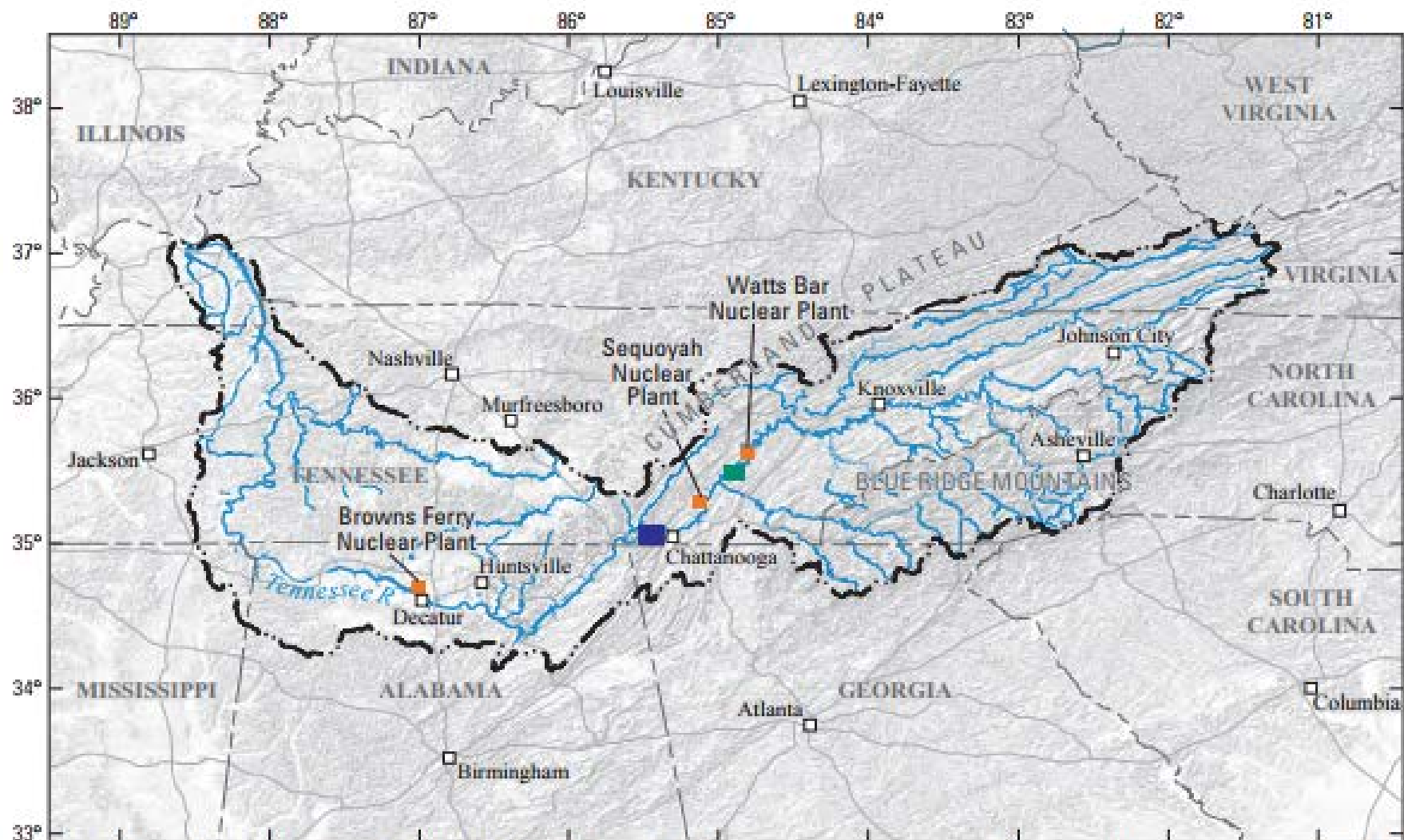
Jim O'Connor – USGS Geology, Mineral, Energy and Geophysics

Meredith Carr – Nuclear Regulatory Commission

What is “Paleoflood” Hydrology



....using geologic evidence to understand flood history...



Basemap modified from U.S. Geological Survey and other digital data, various scales and dates. Coordinate reference system: GCS_North_American_1927.
 WKID: 4267 Authority: EPSG. Horizontal datum is North American Datum of 1927.

0 50 100 200 MILES
 0 50 100 200 KILOMETERS

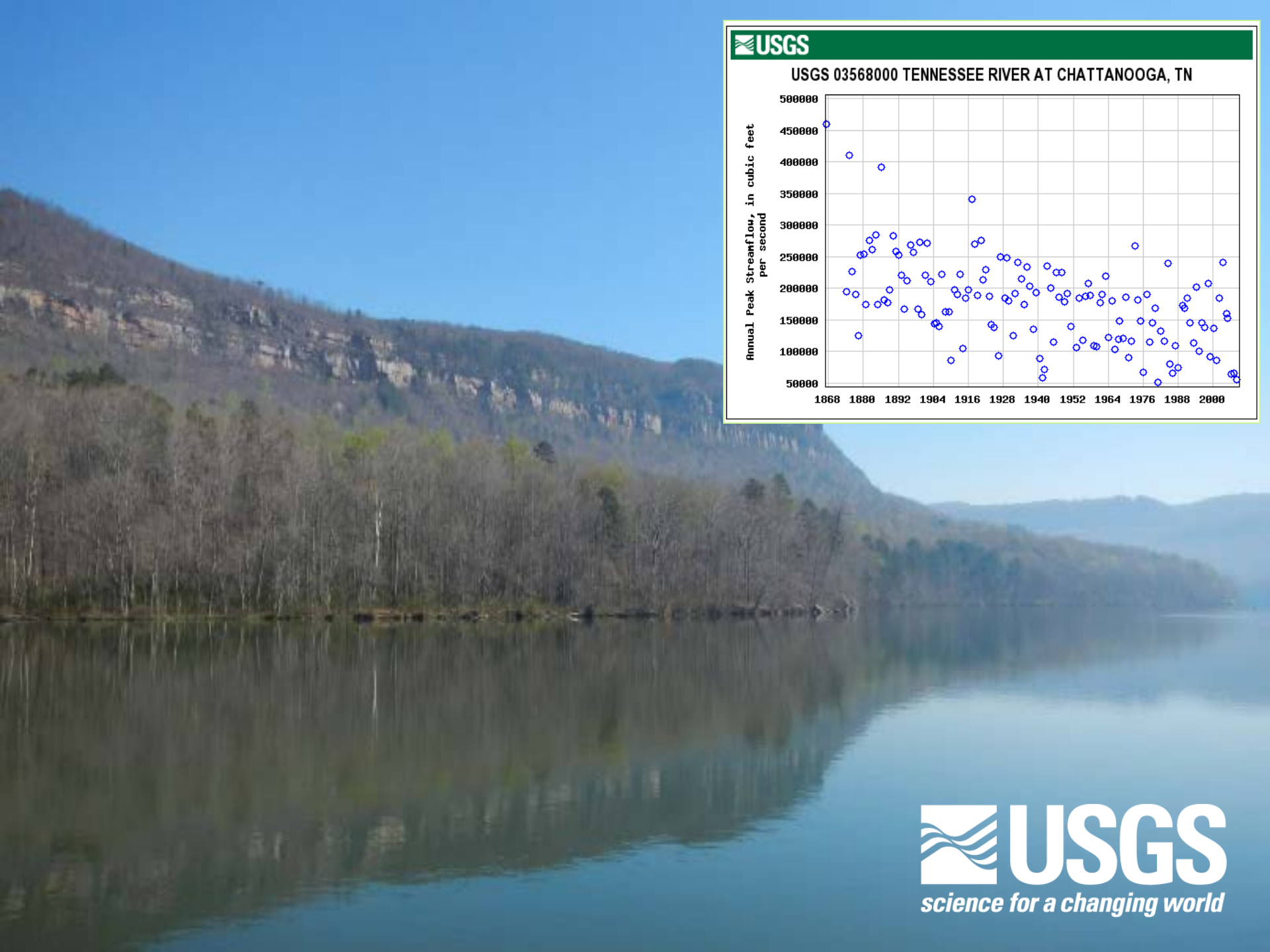
EXPLANATION

- Tennessee River Gorge, main study reach
- Eaves Ferry study reach
- Tennessee River Basin
- Nuclear power plant

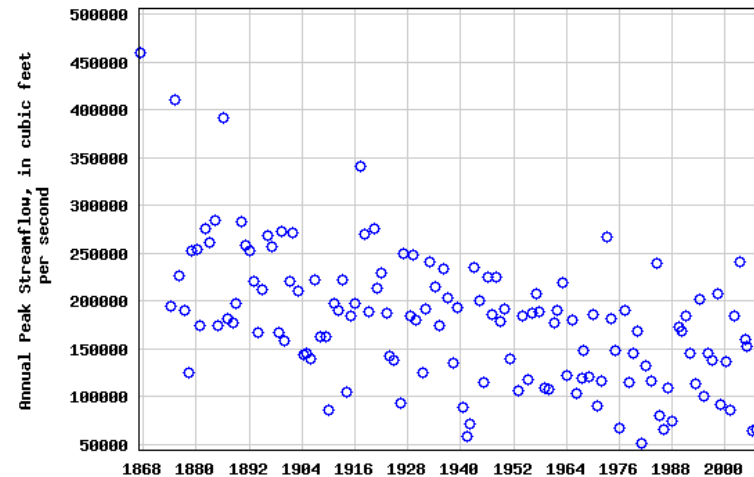
Tennessee River Gorge



Chattanooga



USGS 03568000 TENNESSEE RIVER AT CHATTANOOGA, TN

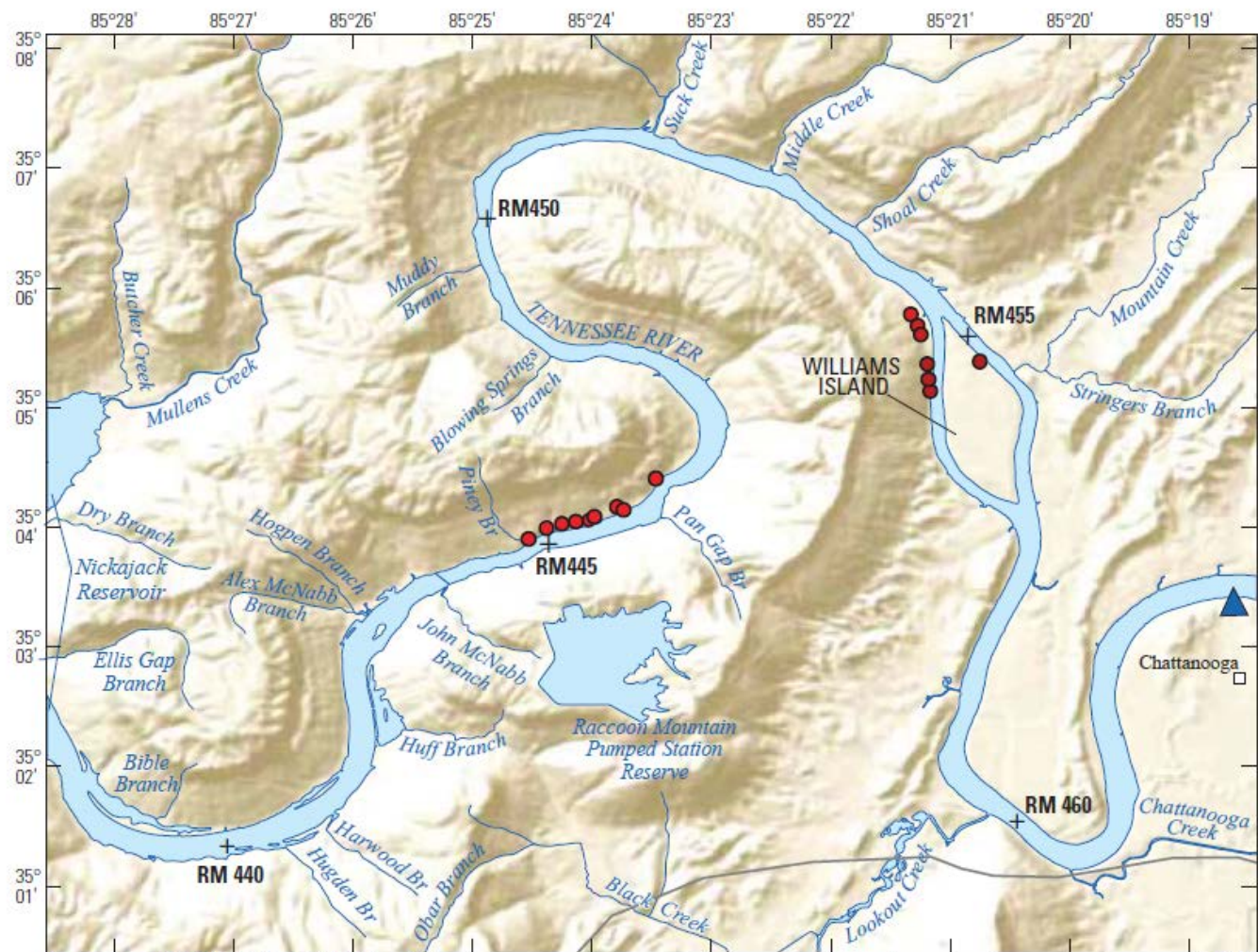






Areas of higher potential flood
sediment preservation





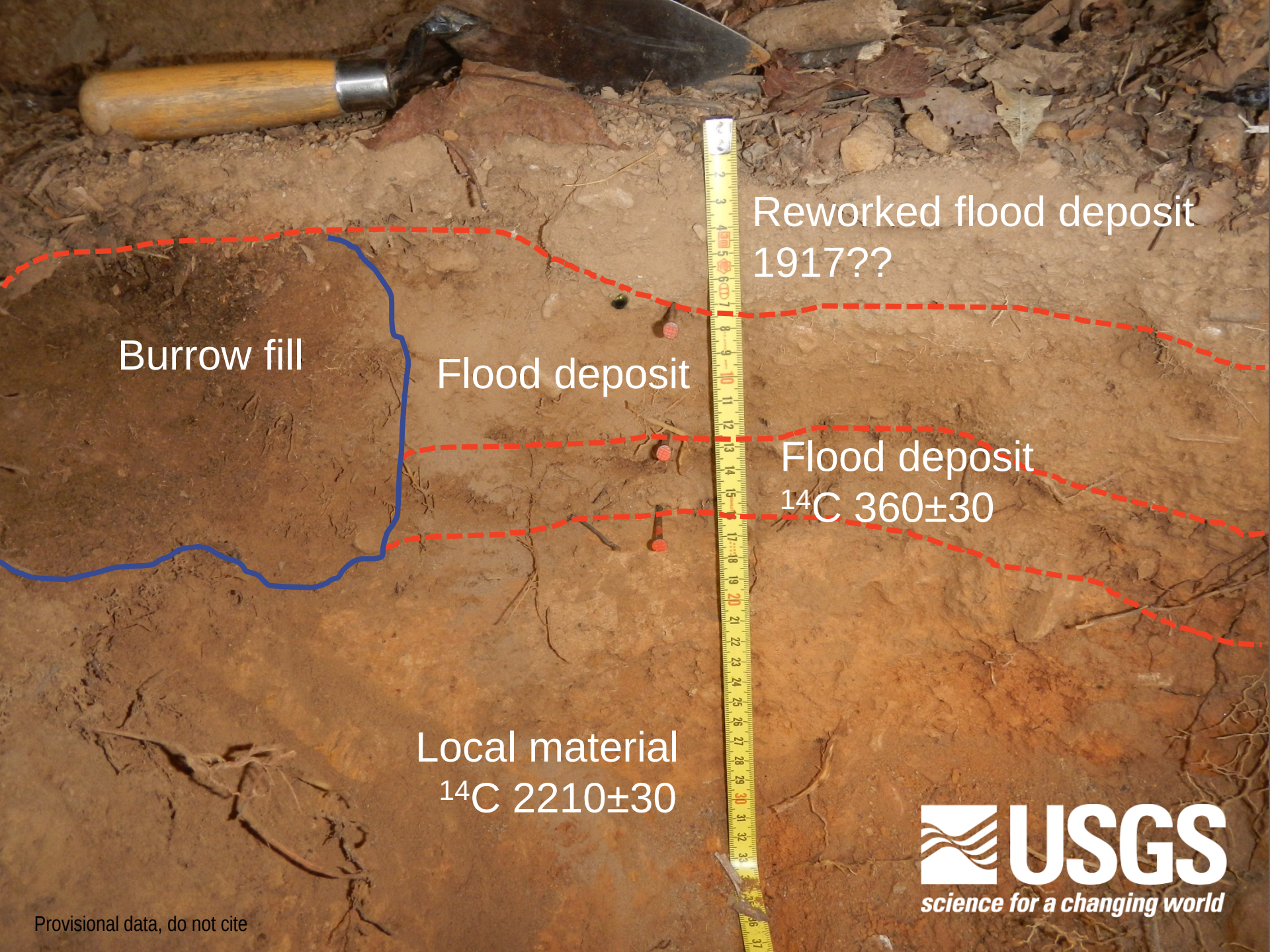
Base map from The National Map, digital edition, 2017.

EXPLANATION

- Detailed sites
- ▲ U.S. Geological Survey streamgaging station 03568000

RM 440+ River Mile





Reworked flood deposit
1917??

Burrow fill

Flood deposit

Flood deposit
 ^{14}C 360±30

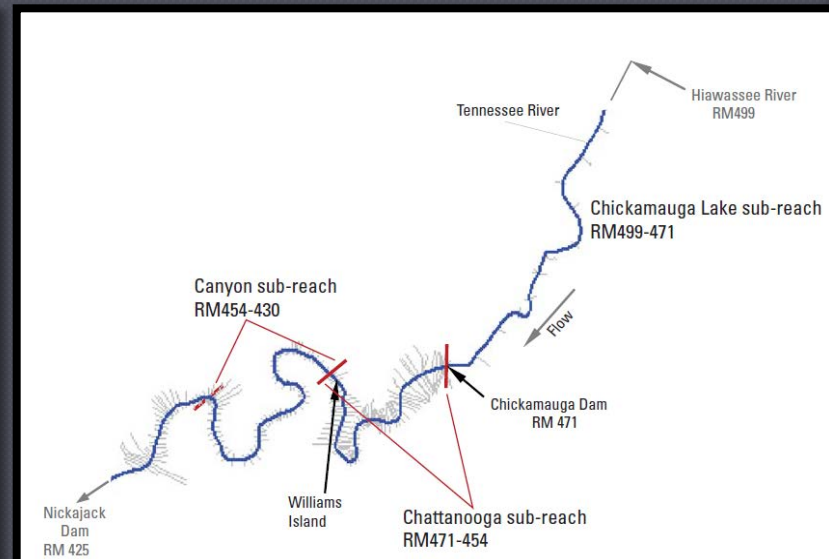
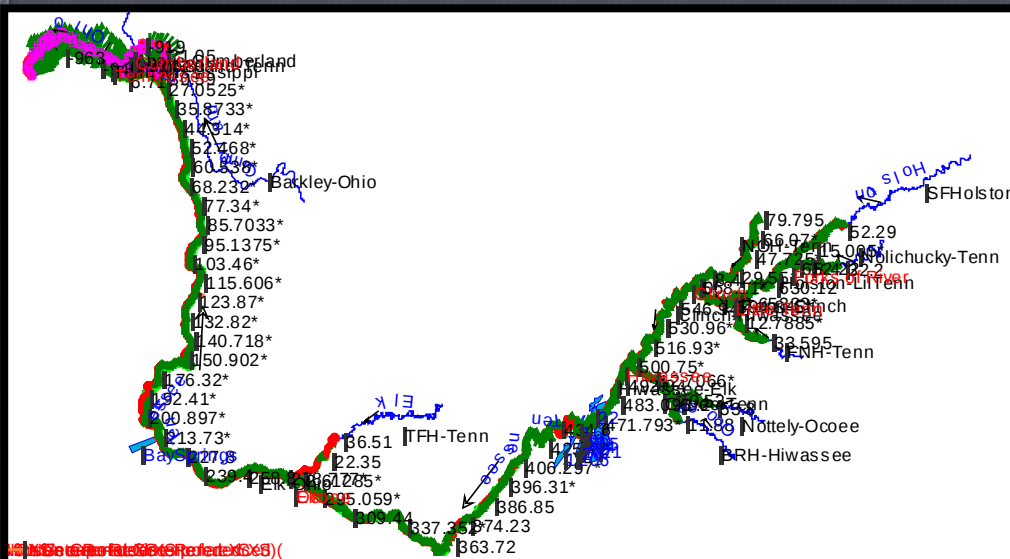
Local material
 ^{14}C 2210±30

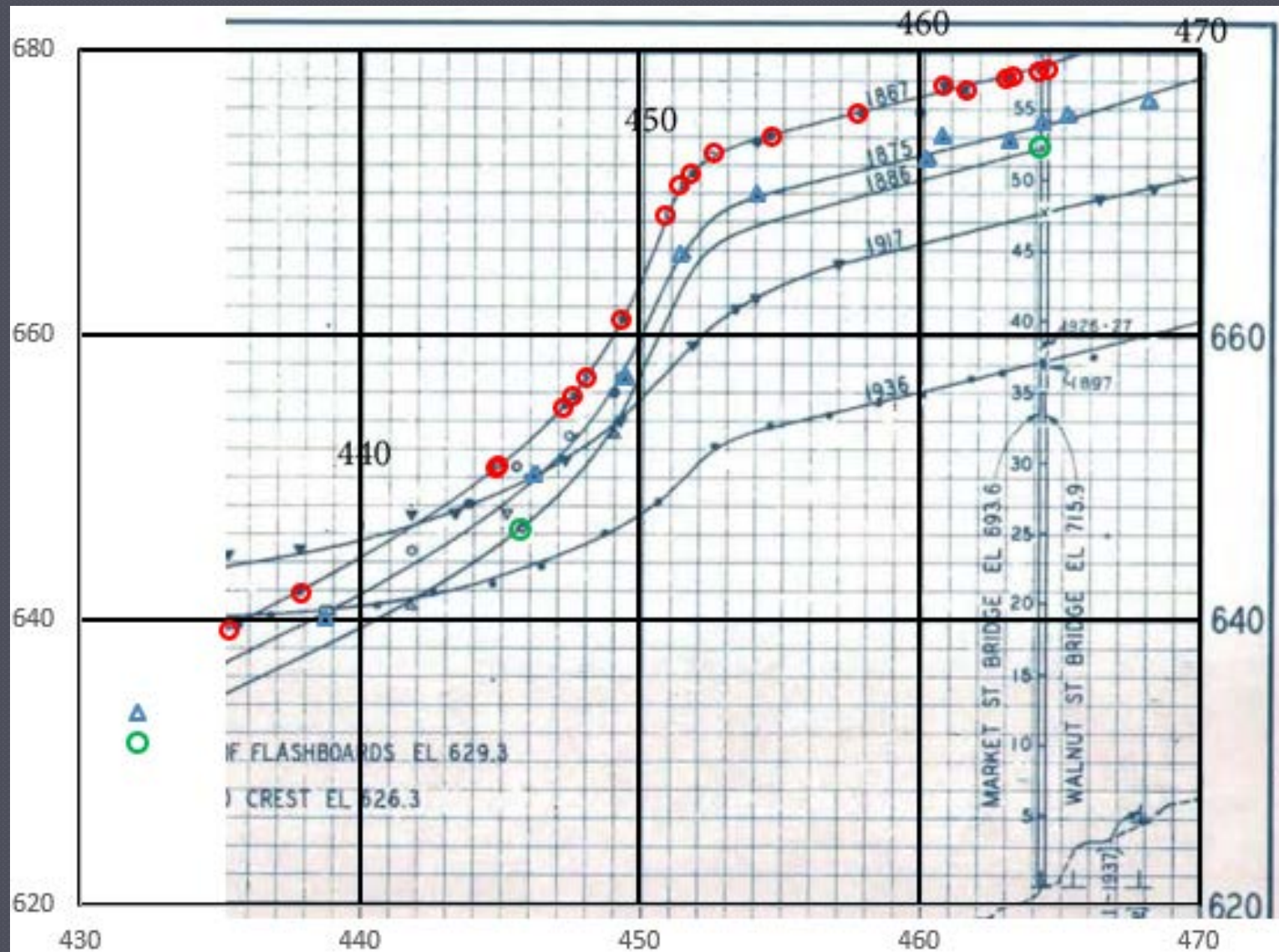
-
- ◉ Identified ~30 sites, fully described 17
 - ◉ Focused on sites where preservation of sediment was most ideal
 - ◉ Also targeted a full range of site elevations
 - ◉ Radiocarbon dating and optically stimulated luminescence (OSL)

Hydraulic Model

Tennessee Valley Authority “Naturals” model in HEC-RAS shortened to provide sufficient length for boundary conditions.

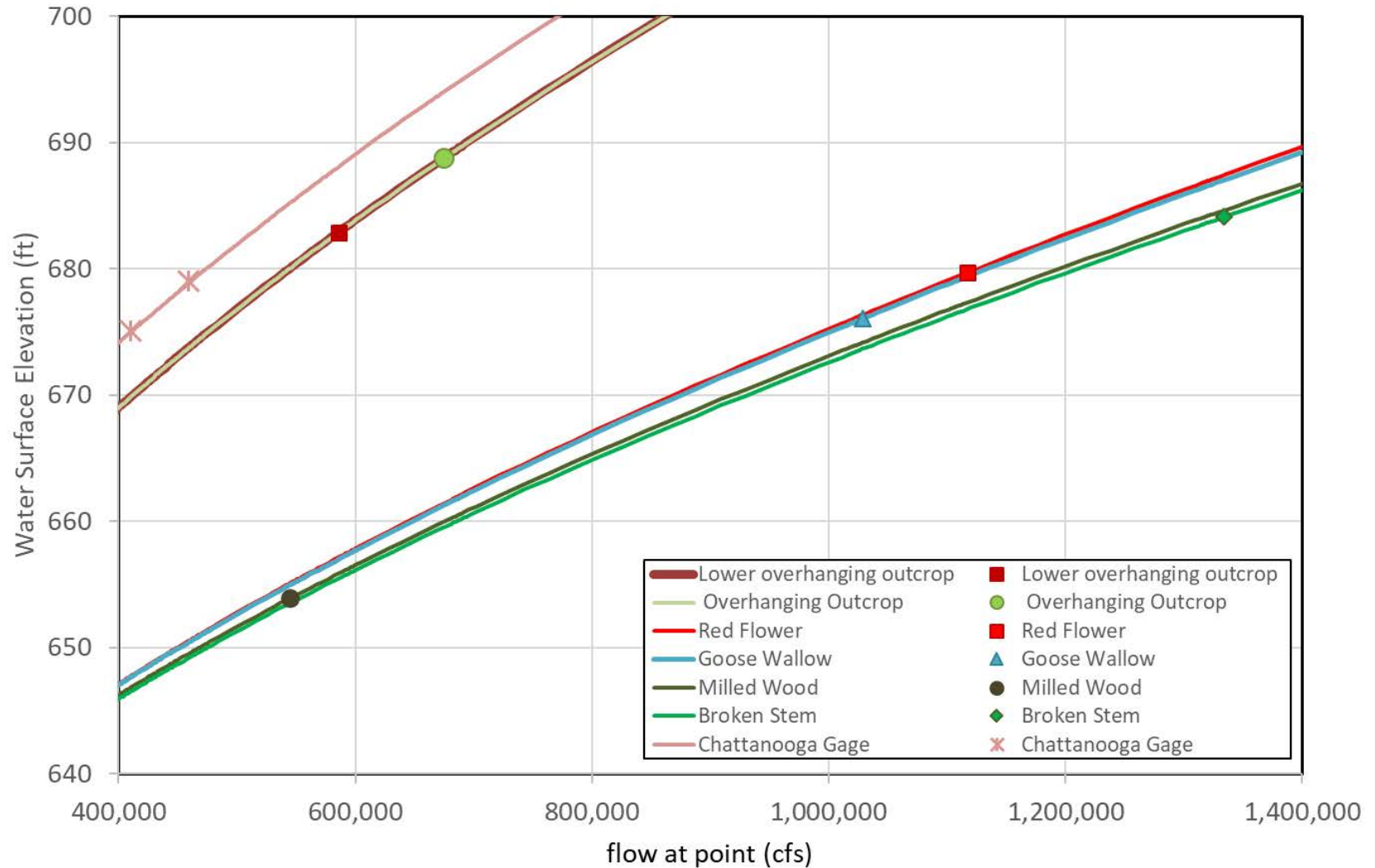
Calibrated to historical high water marks.

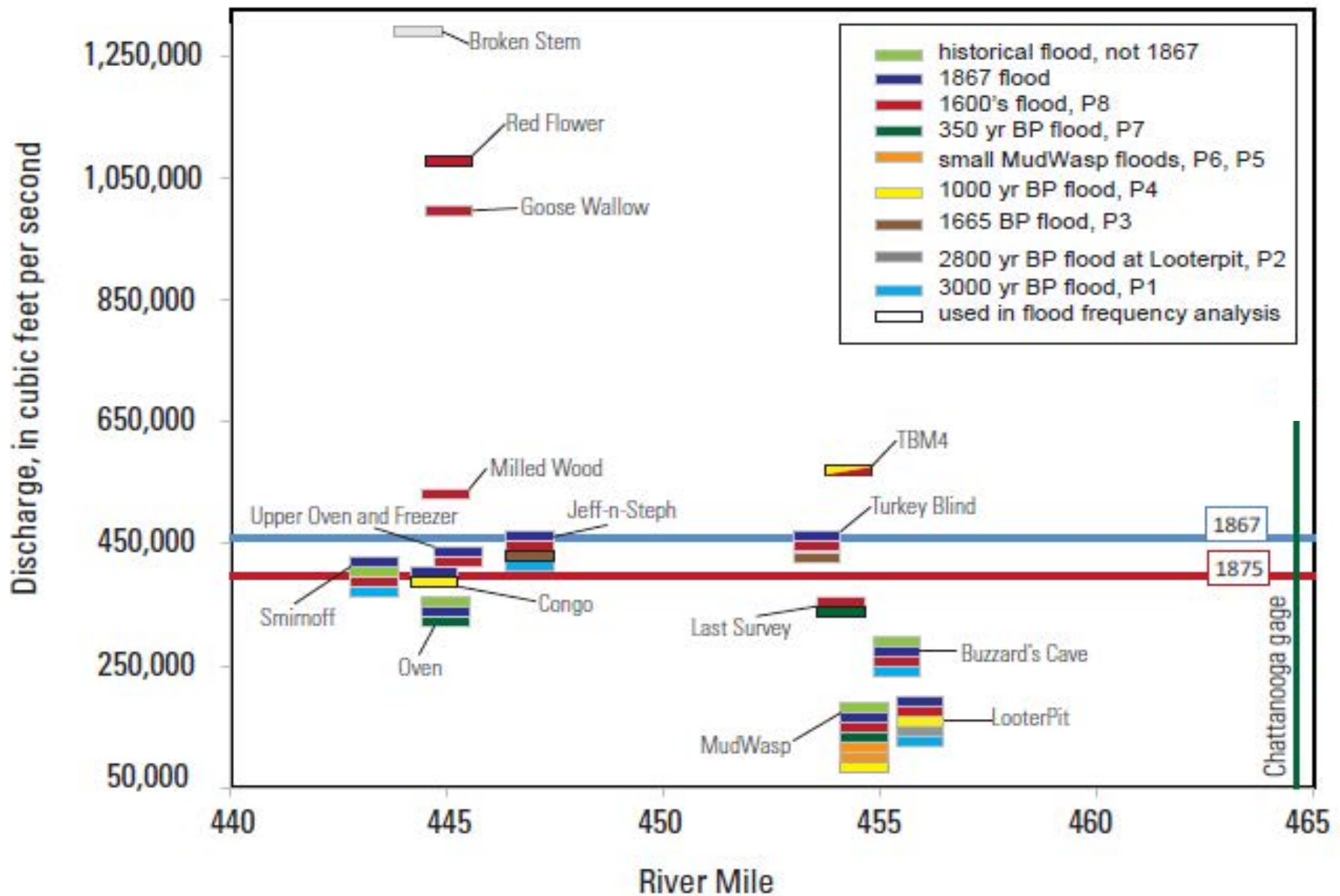




▲ 1875 Observed, uncertainties ● 1867 Observed, uncertainties ● 1886 Observed, uncertainties

Stage-Discharge Curves 550K cfs and larger





8 unique paleofloods in ~4,000 years

Flood-Frequency Analysis

- Bulletin 17C
- EMA
- LP3 distribution
- Discharge uncertainty and perception thresholds
- USGS PeakFQ



Estimating Magnitude and Frequency of Floods Using the PeakFQ 7.0 Program



Guidelines for Determining Flood Flow Frequency Bulletin 17C

Chapter 5 of
Section B, Surface Water
Book 4, Hydrologic Analysis and Interpretation



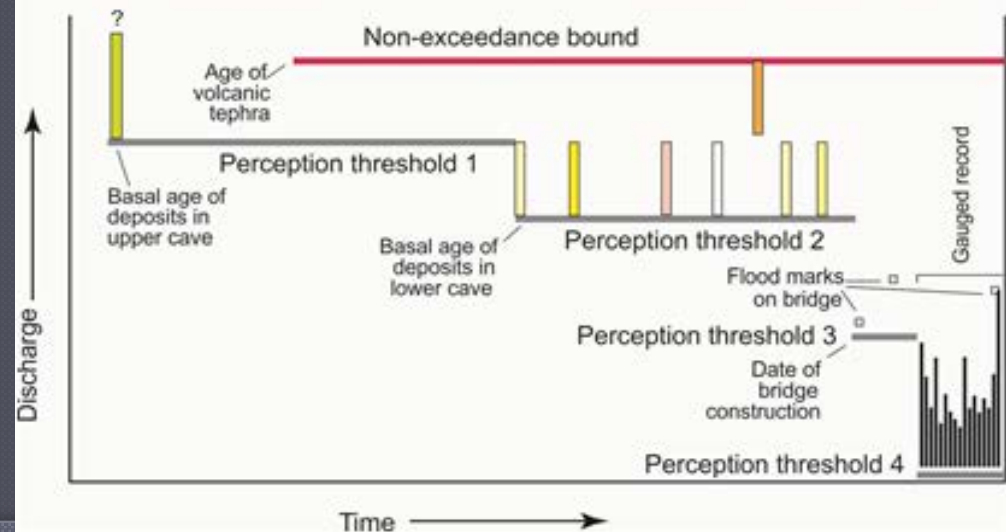
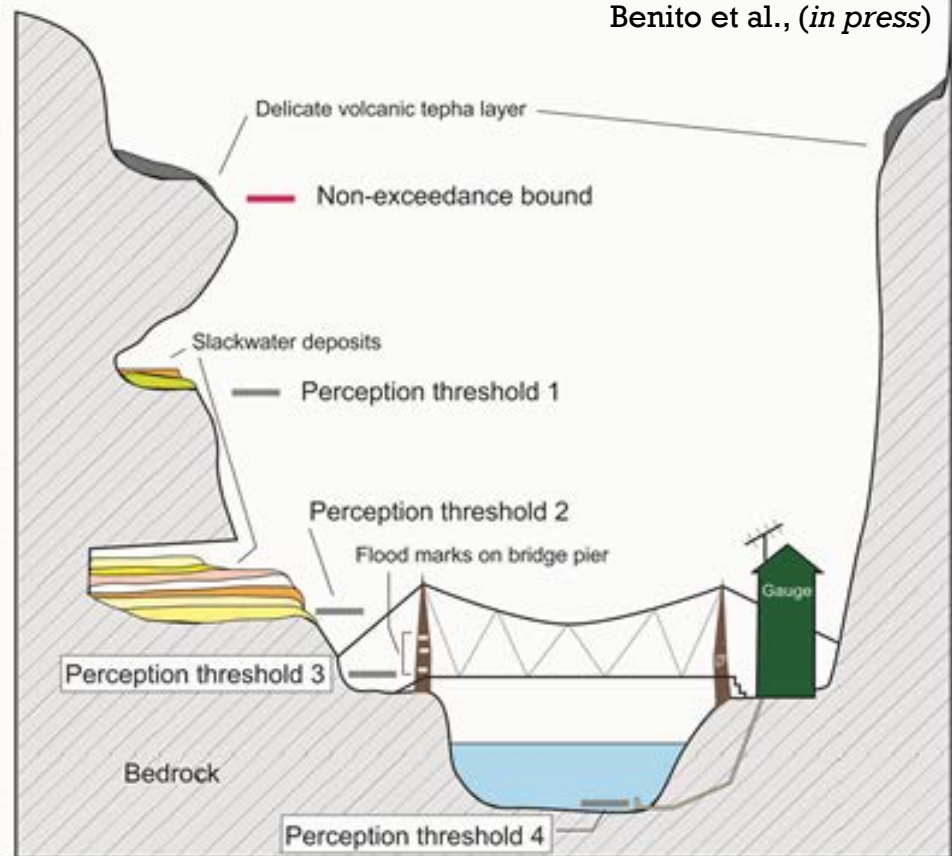
Techniques and Methods 4-B5

England and others, 2019

Perception thresholds

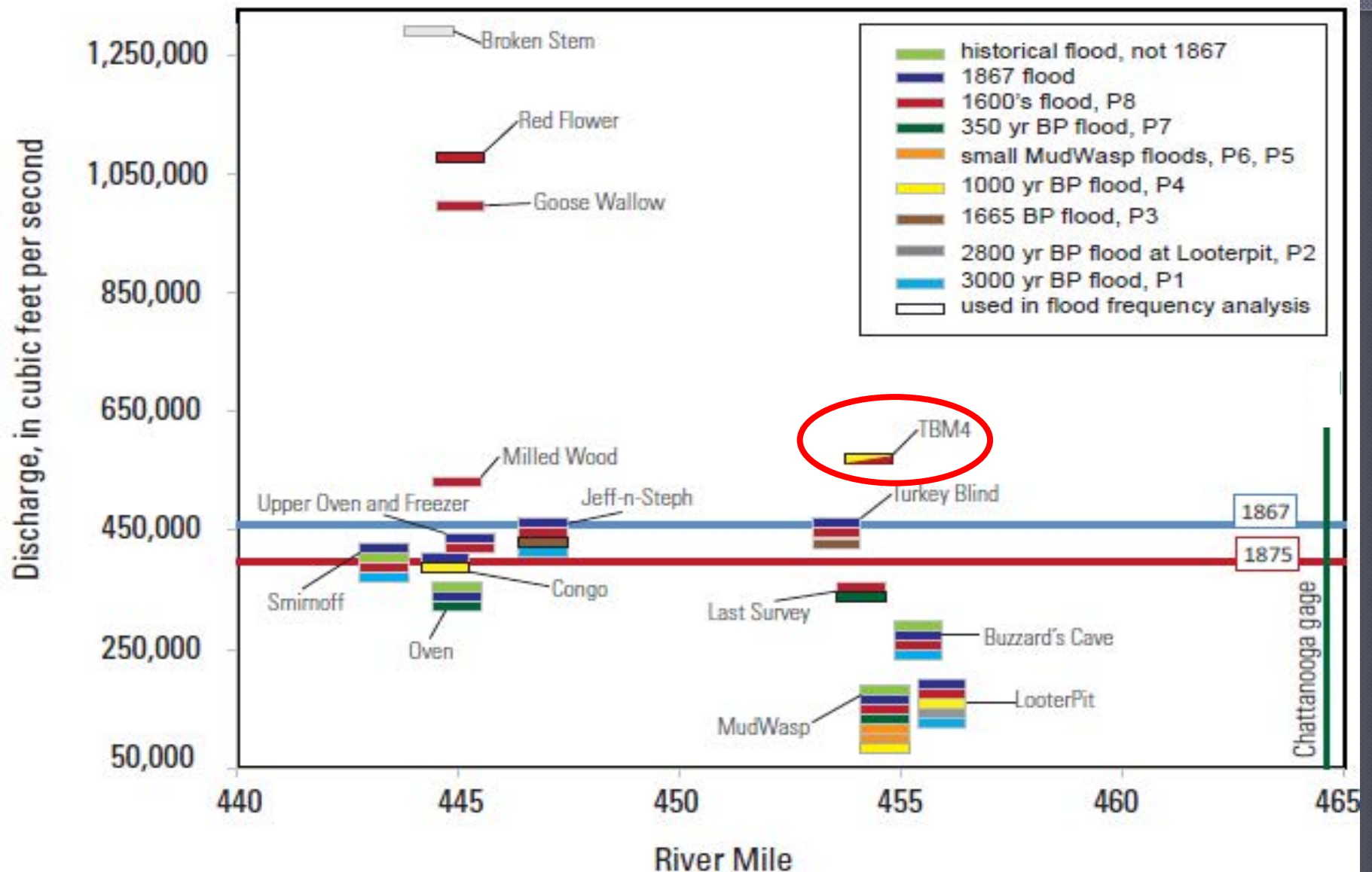
(17C; England et al., 2019):

- The stage or flow above which a source would provide information on the flood peak in any given year.
- Reflect the range of flows that would have been measured had they occurred



Flood-frequency analyses for 7 different scenarios:

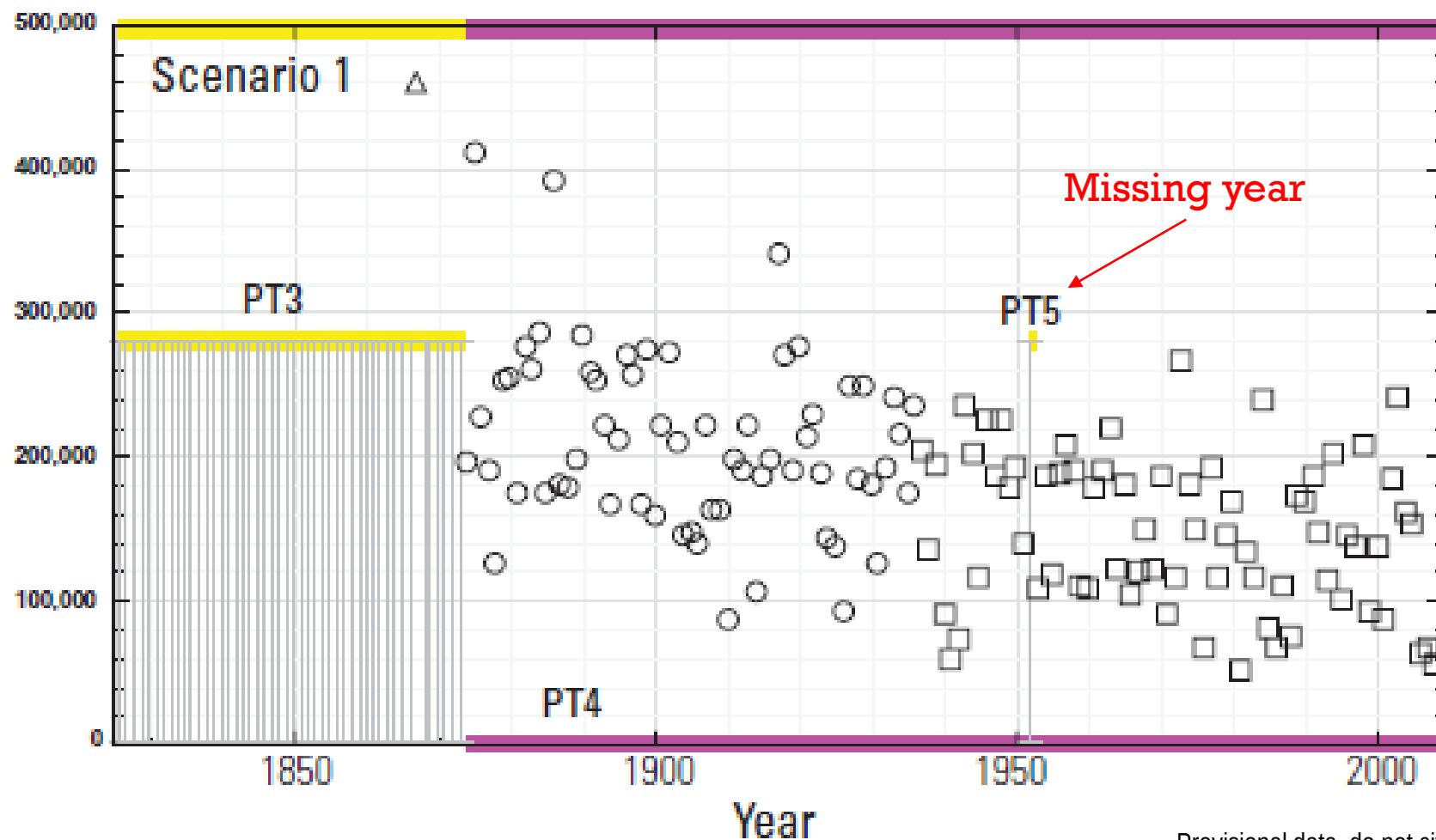
- **Scenario 1:** Gaged plus historical record (1826-2008), 3 perception thresholds
- **Scenario 2-4:** 4 paleofloods (350, 1000, 1500, 1650); 5 perception thresholds (variation to 1 paleo perception threshold)
- **Scenario 5-7:** 4 paleofloods (variation in age and magnitude); 5 perception thresholds



4 paleofloods used in the flood frequency analysis.

Age and magnitude was varied in some scenarios to account geochronologic and stratigraphic uncertainty.

Annual Peak Discharge, in Cubic Feet per Second

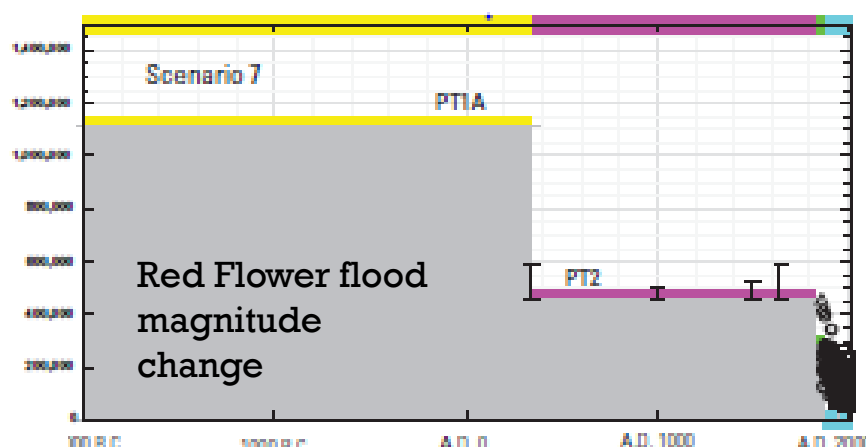
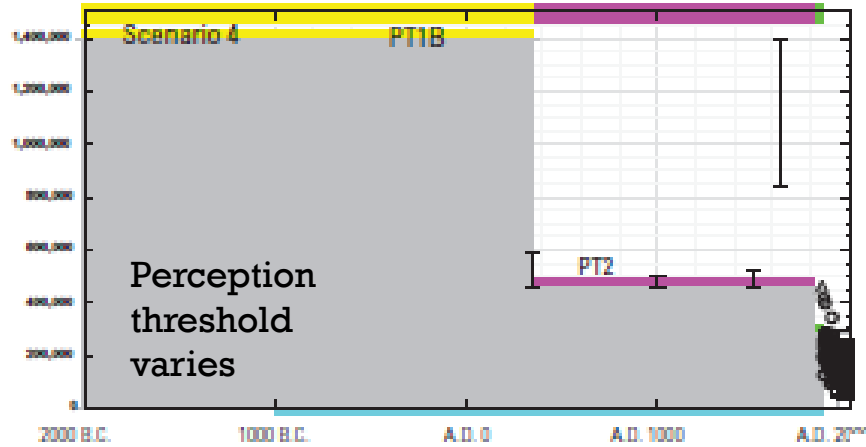
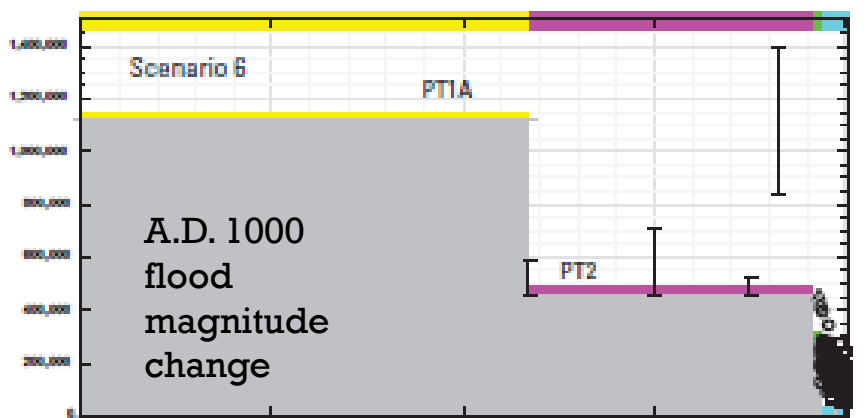
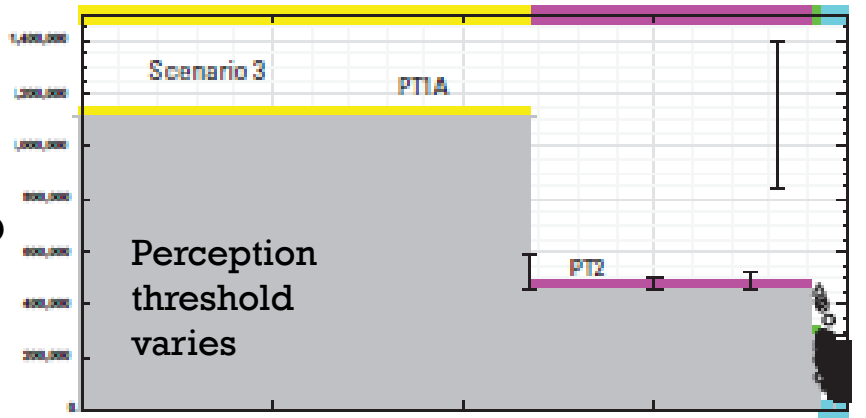
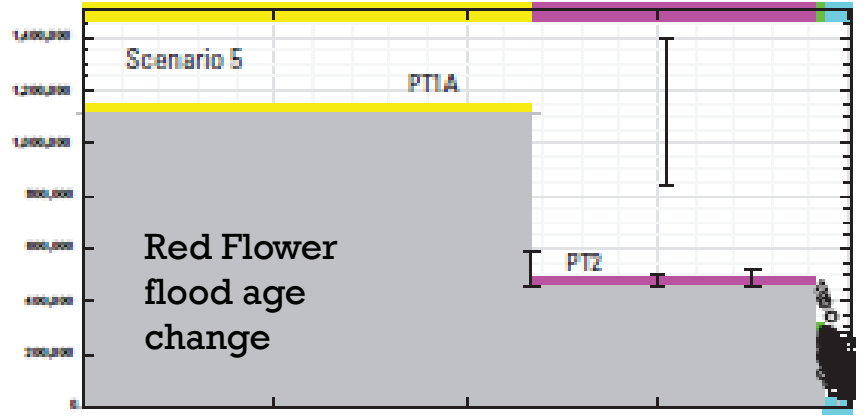
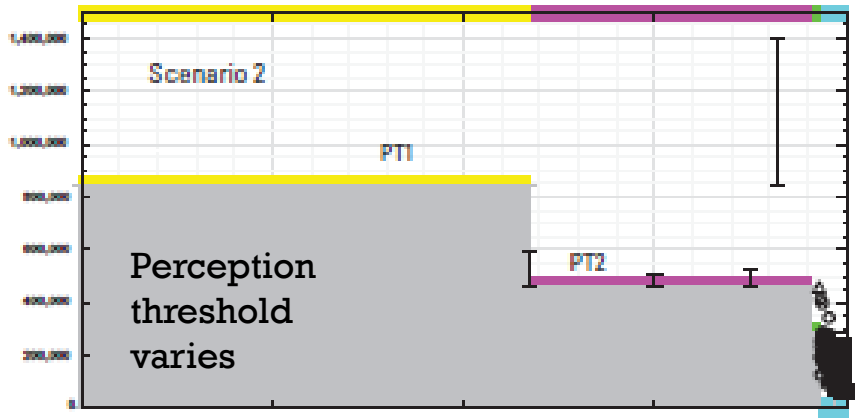


Provisional data, do not cite

- △ Historic peak discharge
- Gaged peak discharge
- Urban or Regulated Peaks
- Censored peak discharge
- Note: horizontal bars represent perception thresholds

Historical: 1826-1873
Gage: 1874-2008

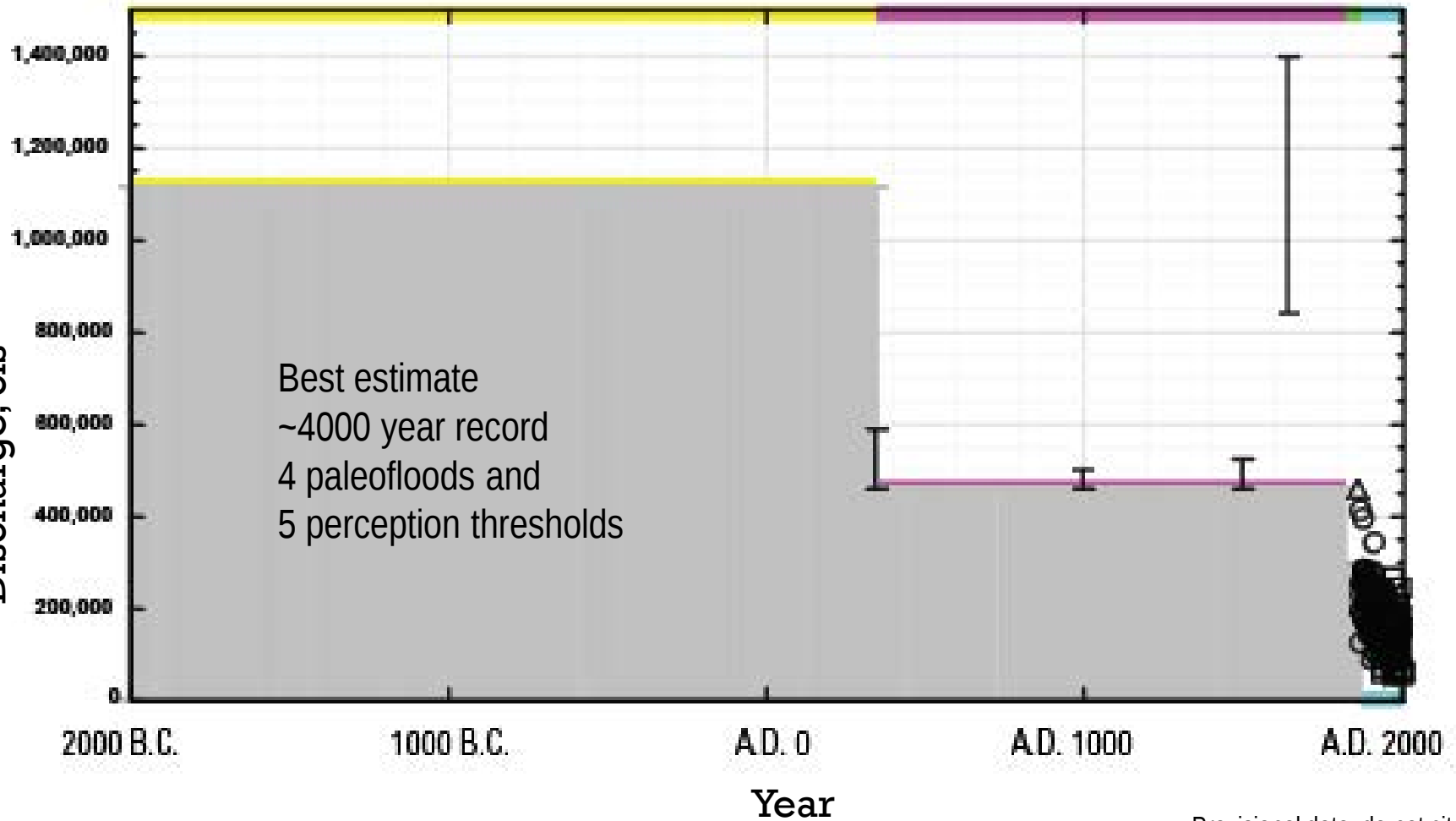
Discharge, cfs



Year

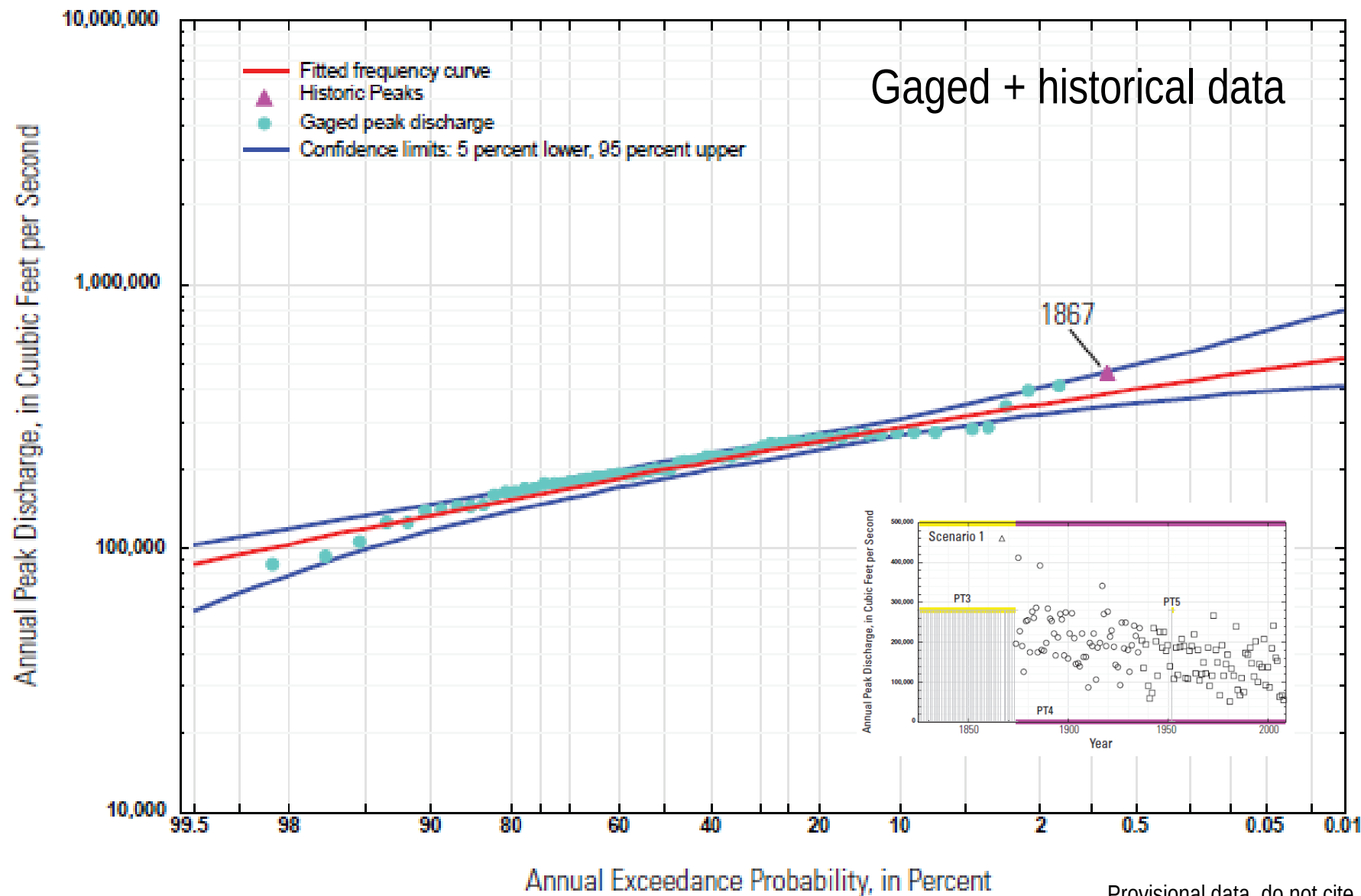
Provisional data, do not cite

Discharge, cfs

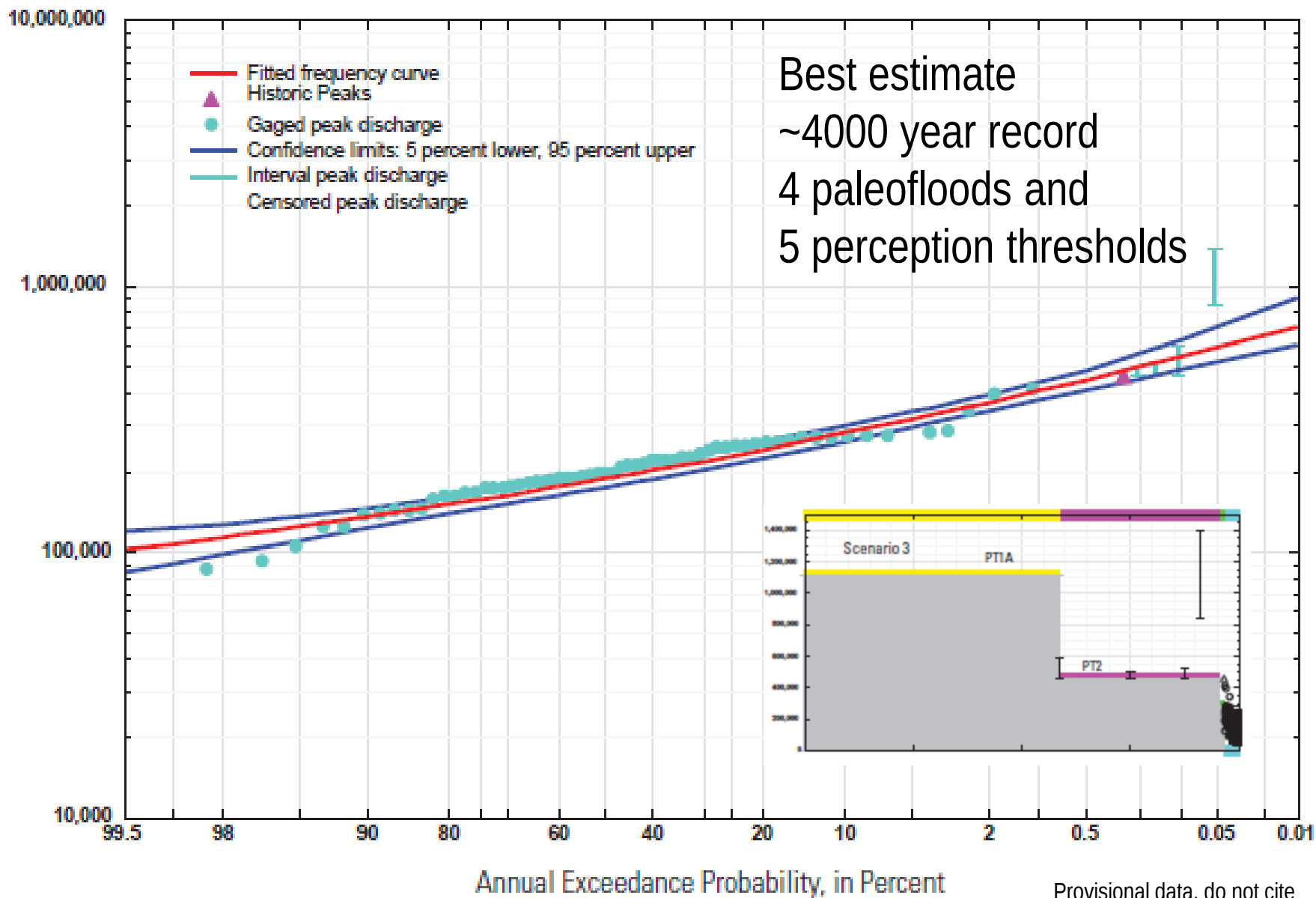


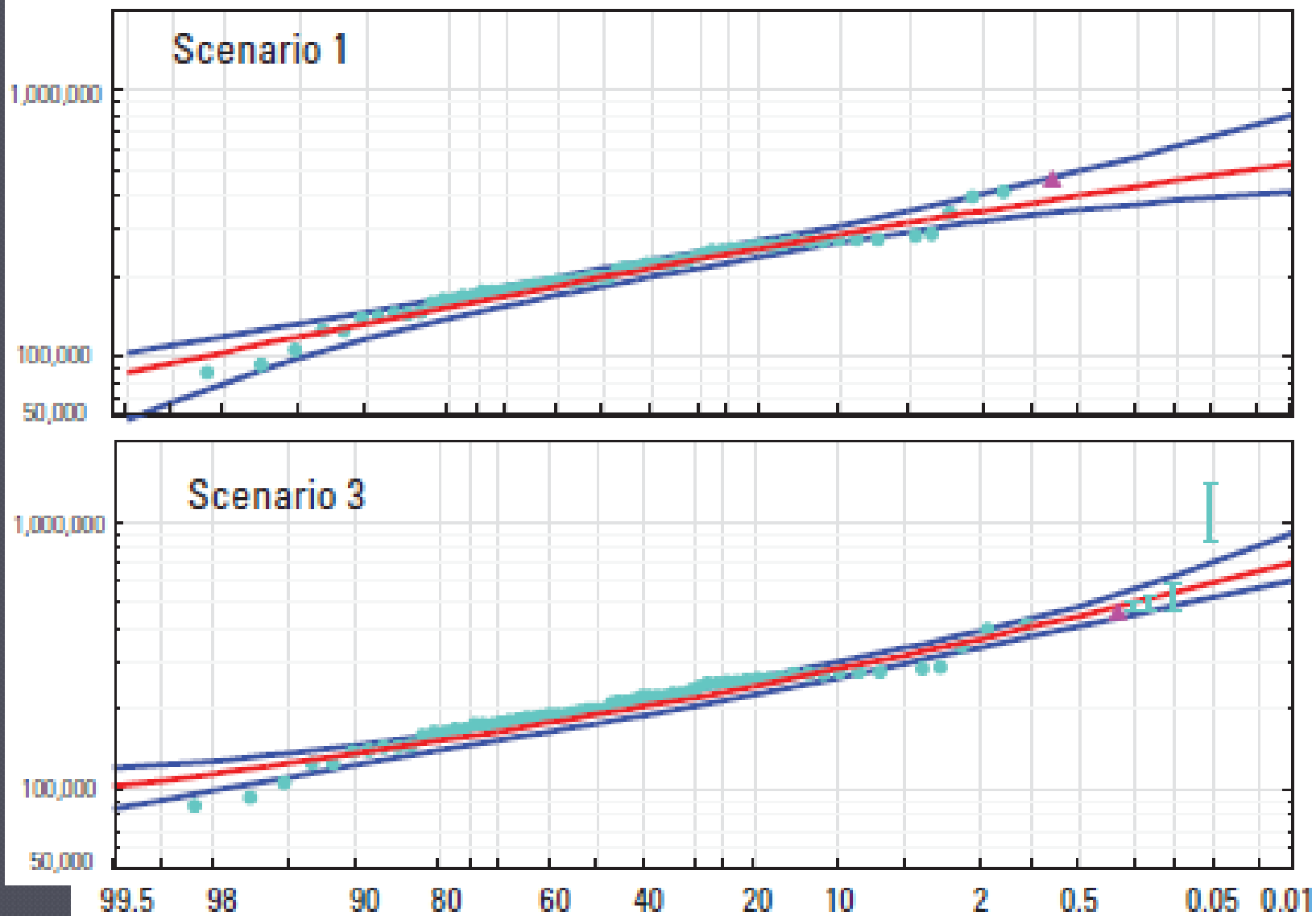
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Provisional data, do not cite





Annual Exceedance Probability, in Percent

Provisional data, do not cite

Gaged + historical record

Scenario 1: Gaged and Historical Record

Return Period	AEP	EMA Estimate	Confidence Limits	
			Lower	Upper
100	0.01	370000	340000	450000
200	0.005	390000	350000	490000
500	0.002	430000	370000	560000
1,000	0.001	460000	380000	610000
10,000	0.0001	520000	410000	800000

Scenario 5: 4 Paleofloods (Red Flower A.D. 1050), PT1A-PT5

Return Period	AEP	EMA Estimate	Confidence Limits	
			Lower	Upper
100	0.01	400000	370000	440000
200	0.005	440000	400000	480000
500	0.002	490000	450000	560000
1,000	0.001	540300	480000	620000
10,000	0.0001	700900	600000	900000

Scenario 3: 4 Paleofloods, PT1A-PT5, Best Estimate

Return Period	AEP	EMA Estimate	Confidence Limits	
			Lower	Upper
100	0.01	400000	370000	430000
200	0.005	440000	400000	480000
500	0.002	500000	450000	560000
1,000	0.001	540000	480000	620000
10,000	0.0001	700000	600000	900000

Scenario 7: 4 Paleofloods (Red Flower flood discharge equal to that of Jeff-n-Steph flood), PT1A-PT5

Return Period	AEP	EMA Estimate	Confidence Limits	
			Lower	Upper
100	0.01	400000	360000	420000
200	0.005	420000	390000	450000
500	0.002	460000	420000	500000
1,000	0.001	490000	440000	540000
10,000	0.0001	580000	510000	690000

Best Estimate Paleoflood Scenario

Provisional data, do not cite

Change date of large Red Flower flood

Scenario 1: Gaged and Historical Record

Return Period	AEP	EMA Estimate	Confidence Limits	
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100	0.01	370000	340000	450000
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Best Estimate Paleoflood Scenario

Provisional data, do not cite

Gaged plus historical record

Provisional data, do not cite

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Best Estimate Paleoflood Scenario

Change magnitude of large Red Flower flood

Summary

- Adding 4000 years of paleoflood data reduces uncertainty of the very small AEP's by 22-44%
- Adding 4000 years of paleoflood data increases the magnitude of the very small AEP's.
- Record length has a strong influence on the curve.