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

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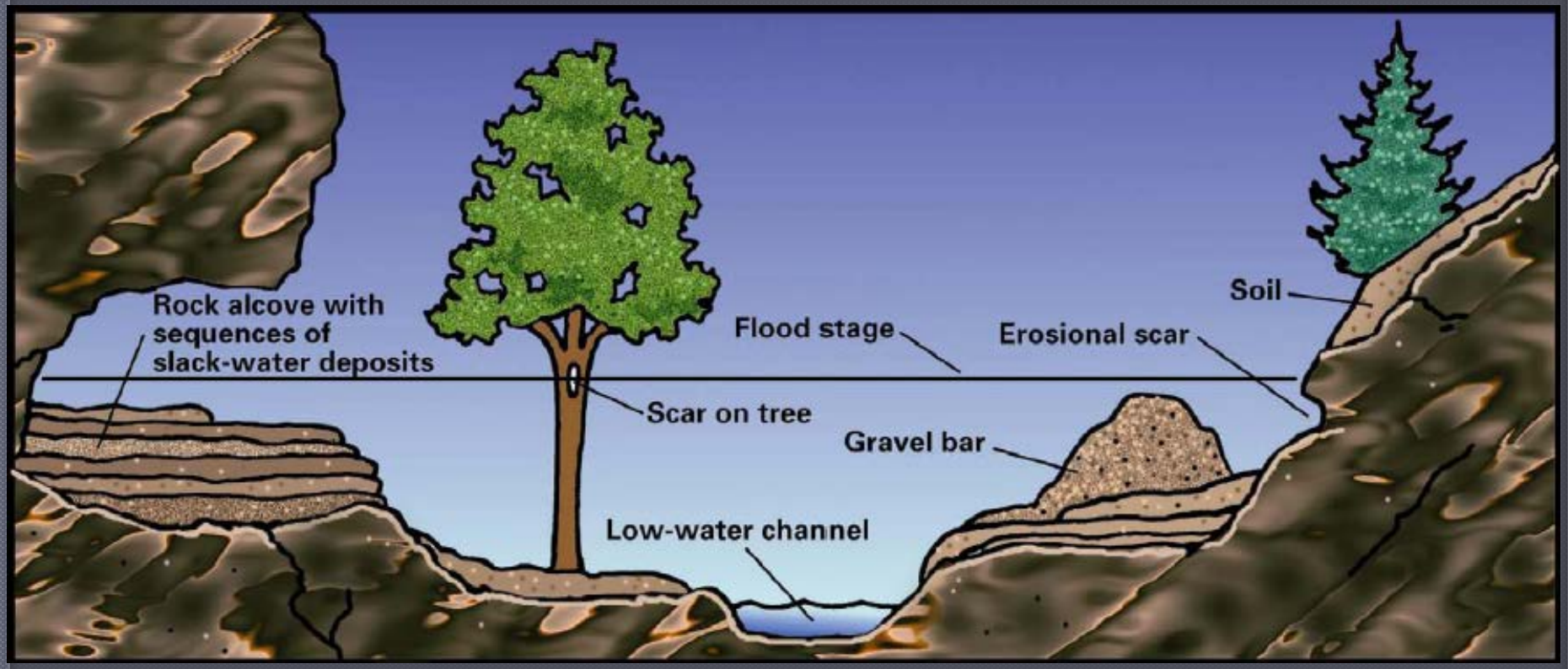
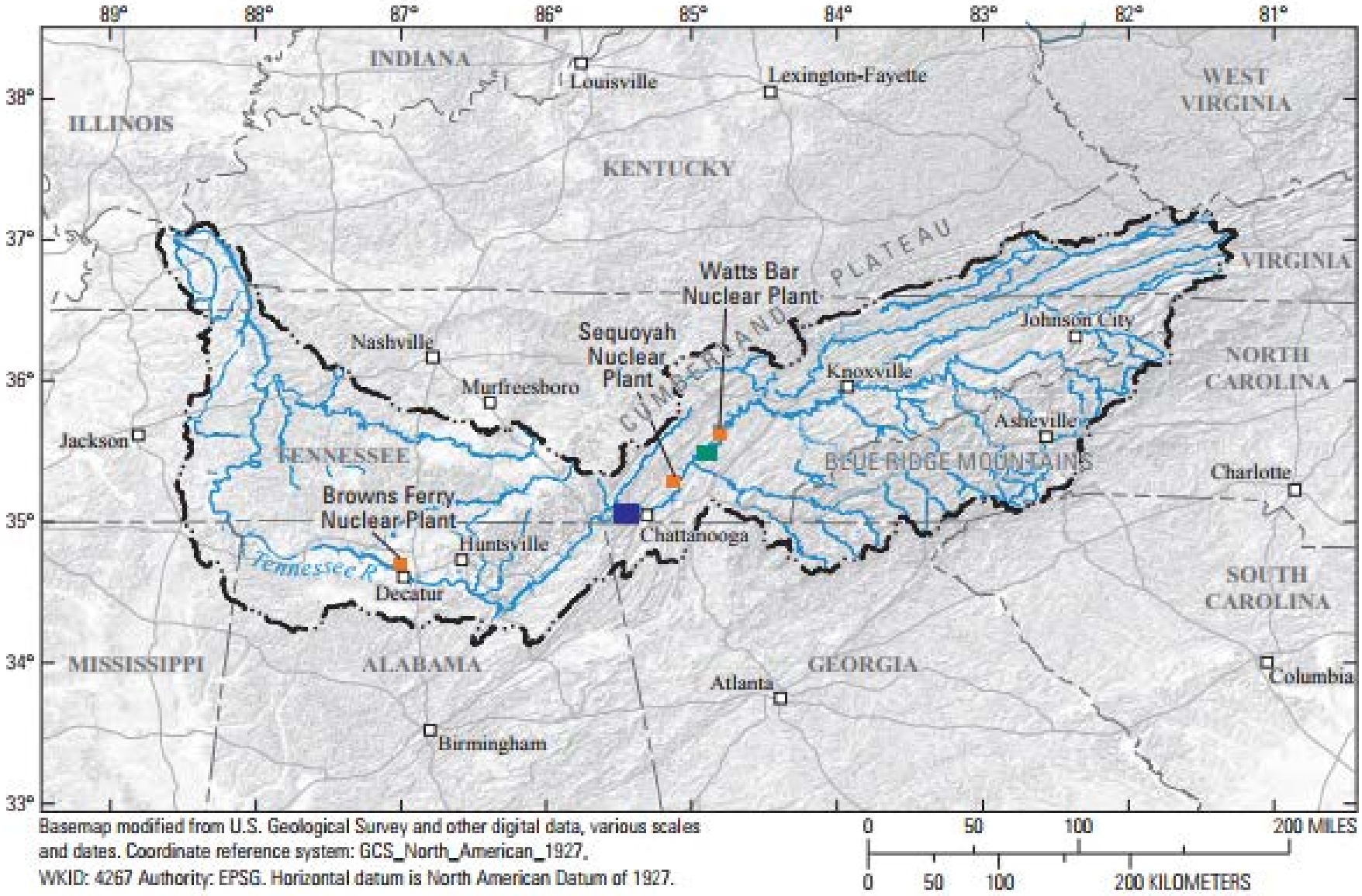
Jim O'Connor – USGS Geology, Mineral, Energy and Geophysics
Meredith Carr – Nuclear Regulatory Commission

What is “Paleoflood” Hydrology

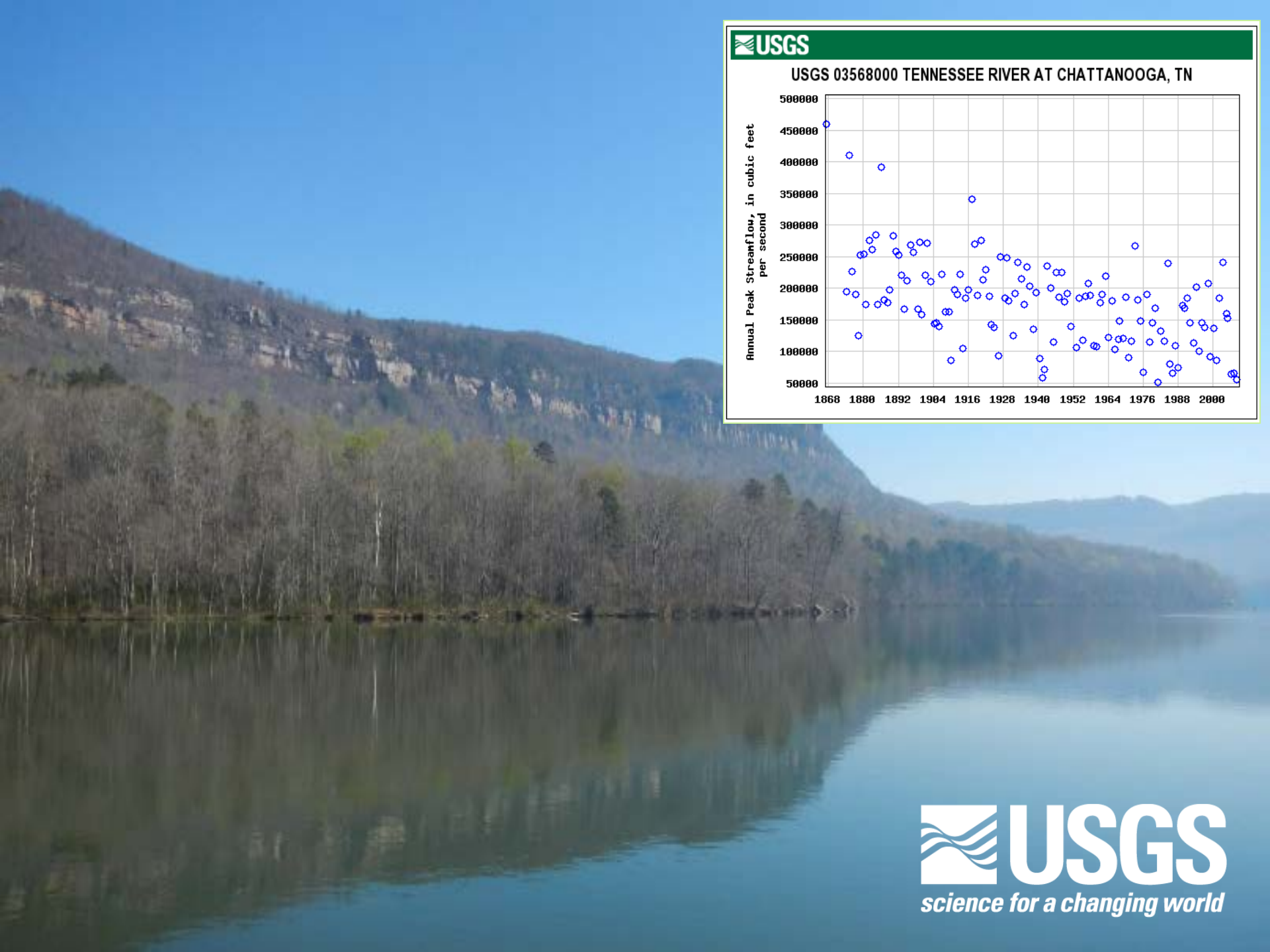


….using geologic evidence to understand flood history…



Harden and O'Connor, 2017

Tennessee River Gorge


USGS
USGS 03568000 TENNESSEE RIVER AT CHATTANOOGA, TN
Annual Peak Streamflow, in cubic feet per second
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
1868
1880
1892
1904
1916
1928
1940
1952
1964
1976
1988
2000
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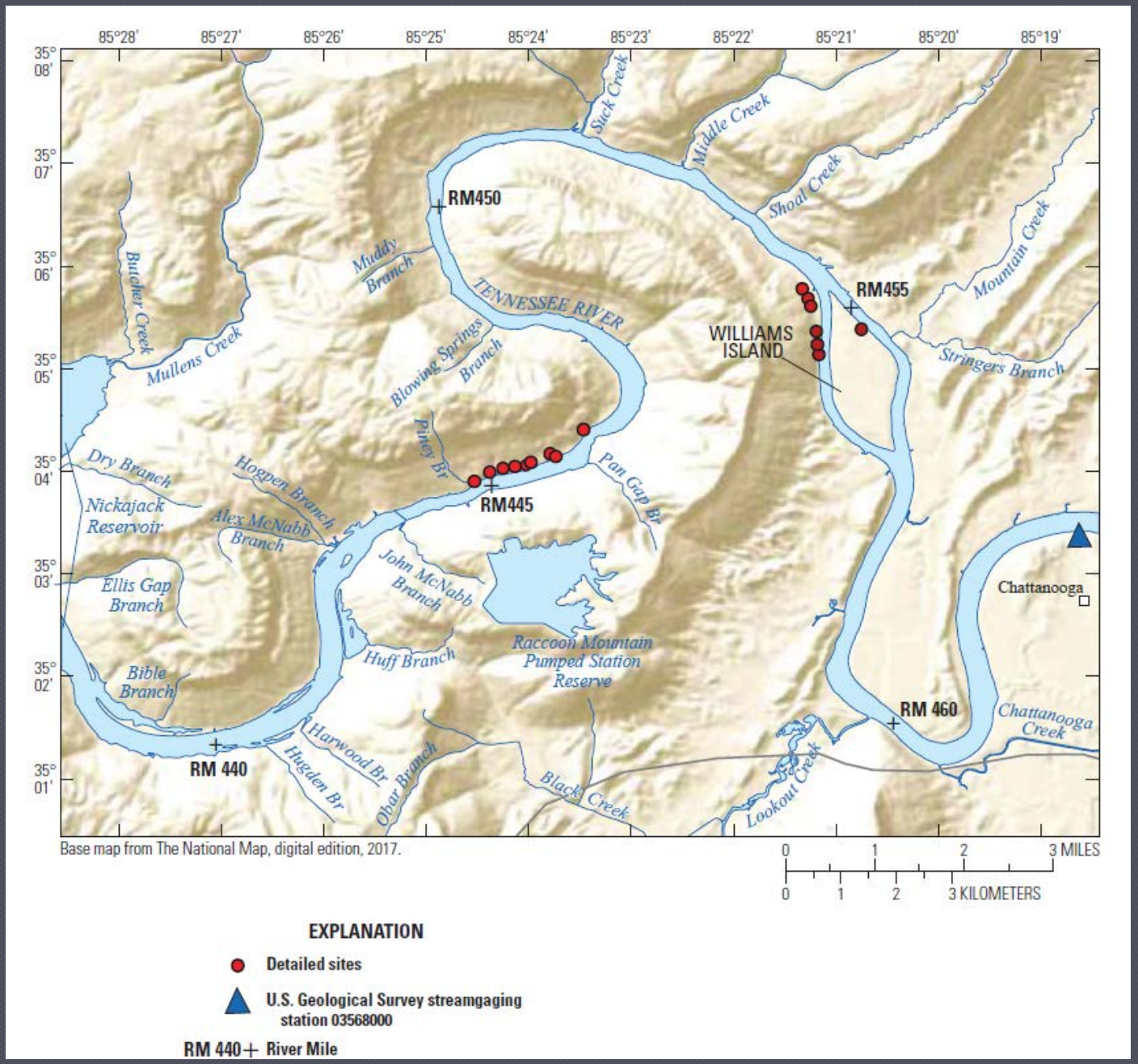
Areas of higher potential flood sediment preservation


85°28'
85°27'
85°26'
85°25'
85°24'
85°23'
85°22'
85°21'
85°20'
85°19'
35° 08'
35° 07'
35° 06'
35° 05'
35° 04'
35° 03'
35° 02'
35° 01'
Stuck Creek
Middle Creek
Shoal Creek
Mountain Creek
RM450
Muddy Branch
TENNESSEE RIVER
RM455
WILLIAMS ISLAND
Butcher Creek
Mullens Creek
Blowing Springs Branch
Stringers Branch
Piney Br
Dry Branch
Hoggen Branch
Pan Gap Br
RM445
Nickajack Reservoir
Alex McNabb Branch
John McNabb Branch
Chattanooga
Ellis Gap Branch
Raccoon Mountain Pumped Station Reserve
Huff Branch
Bible Branch
RM 460
Chattanooga Creek
Harwood Br
Hugden Br
Ohar Branch
RM 440
Black Creek
Lookout Creek
Base map from The National Map, digital edition, 2017.
0 1 2 3 MILES
0 1 2 3 KILOMETERS
EXPLANATION
Detailed sites
U.S. Geological Survey streamgaging station 03568000
RM 440+ River Mile


Lufkin
RUGGED
RED
END
mm
USGS
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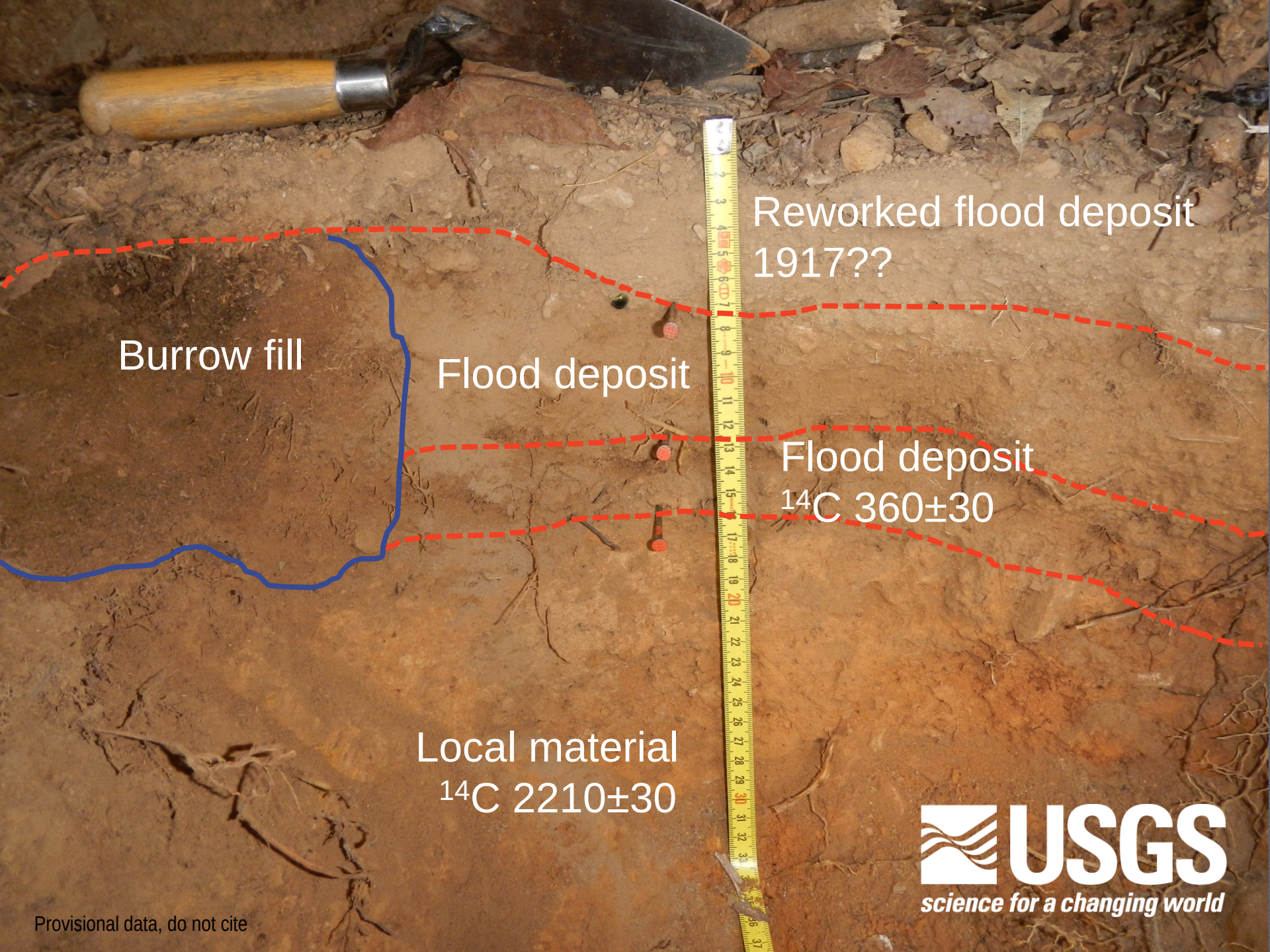

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Provisional data, do not cite

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

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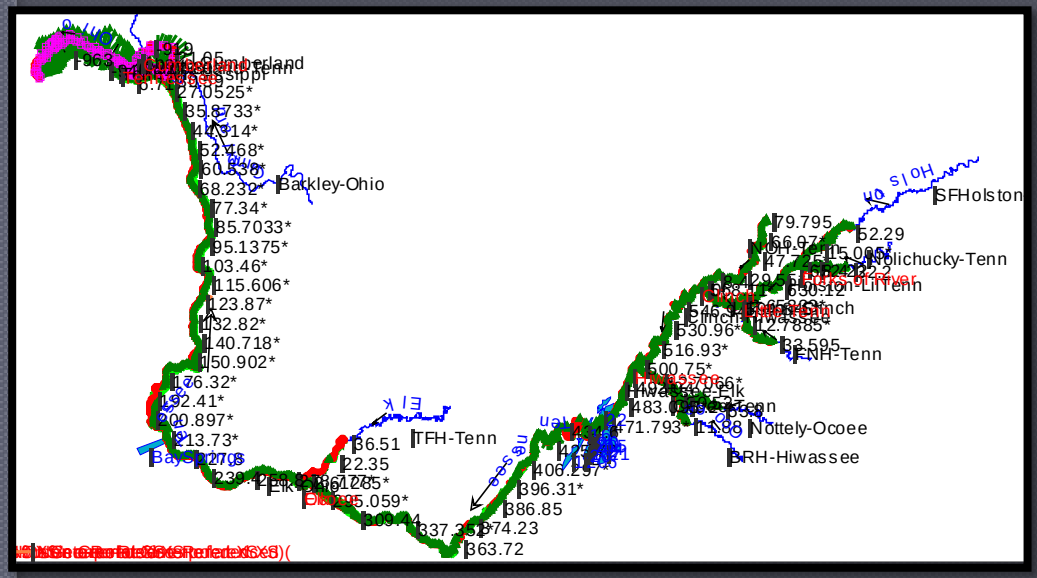
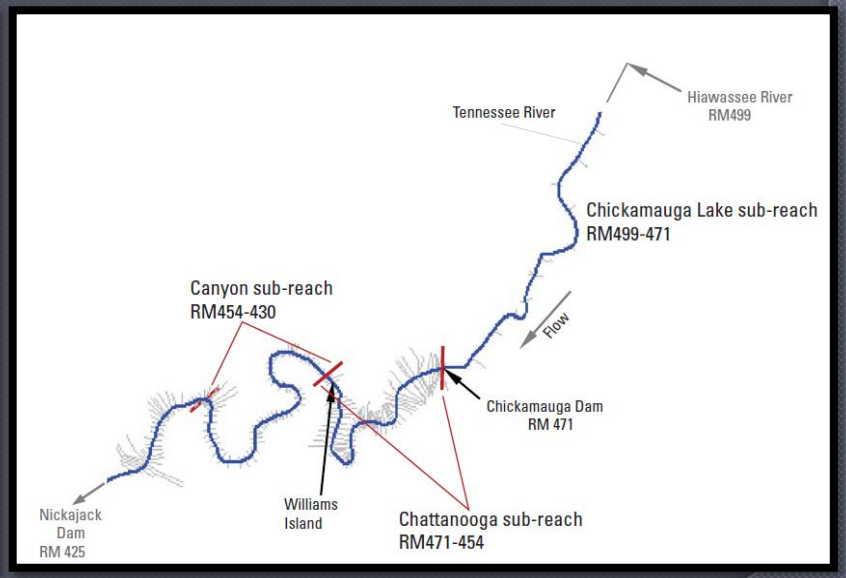
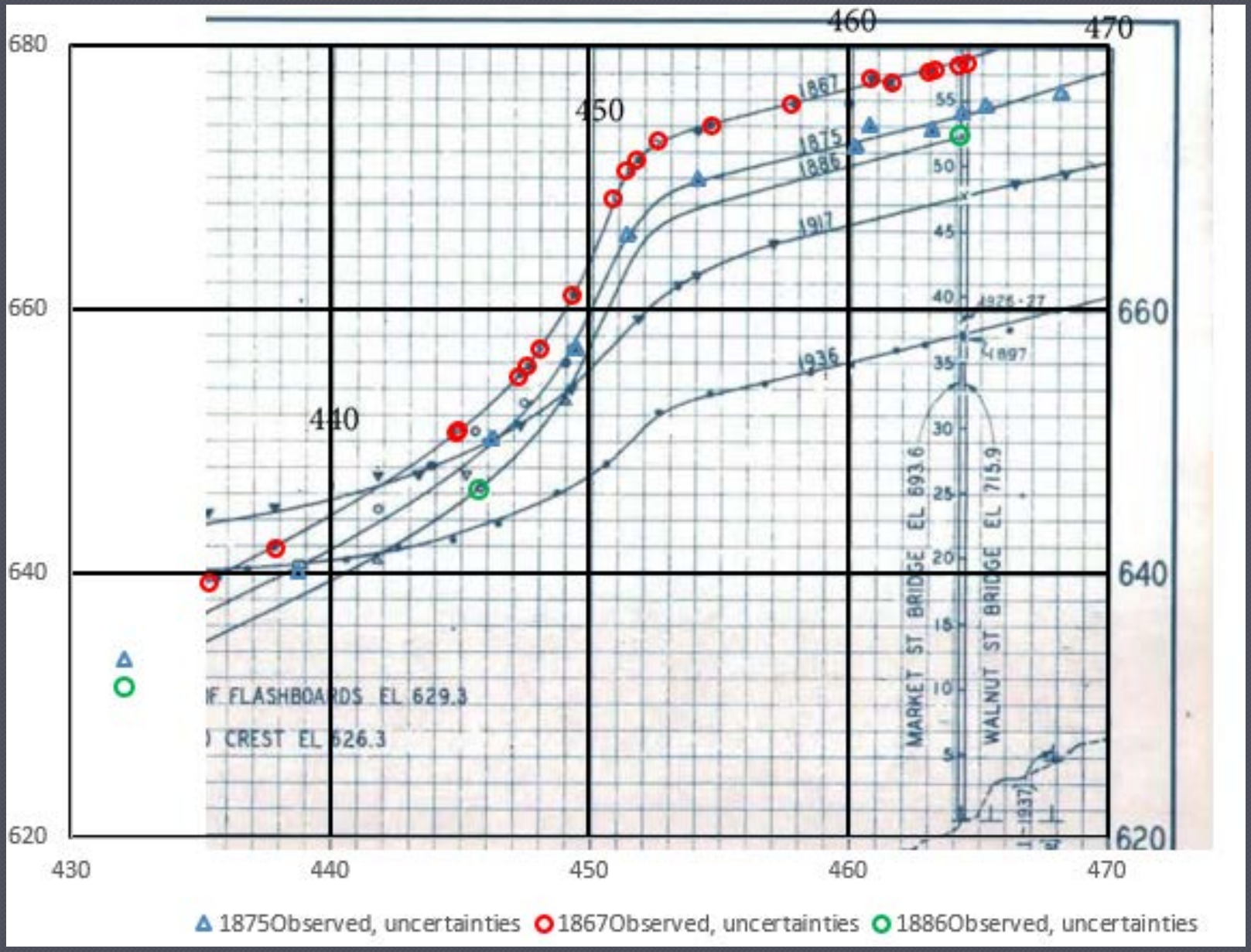
Hydraulic Model

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

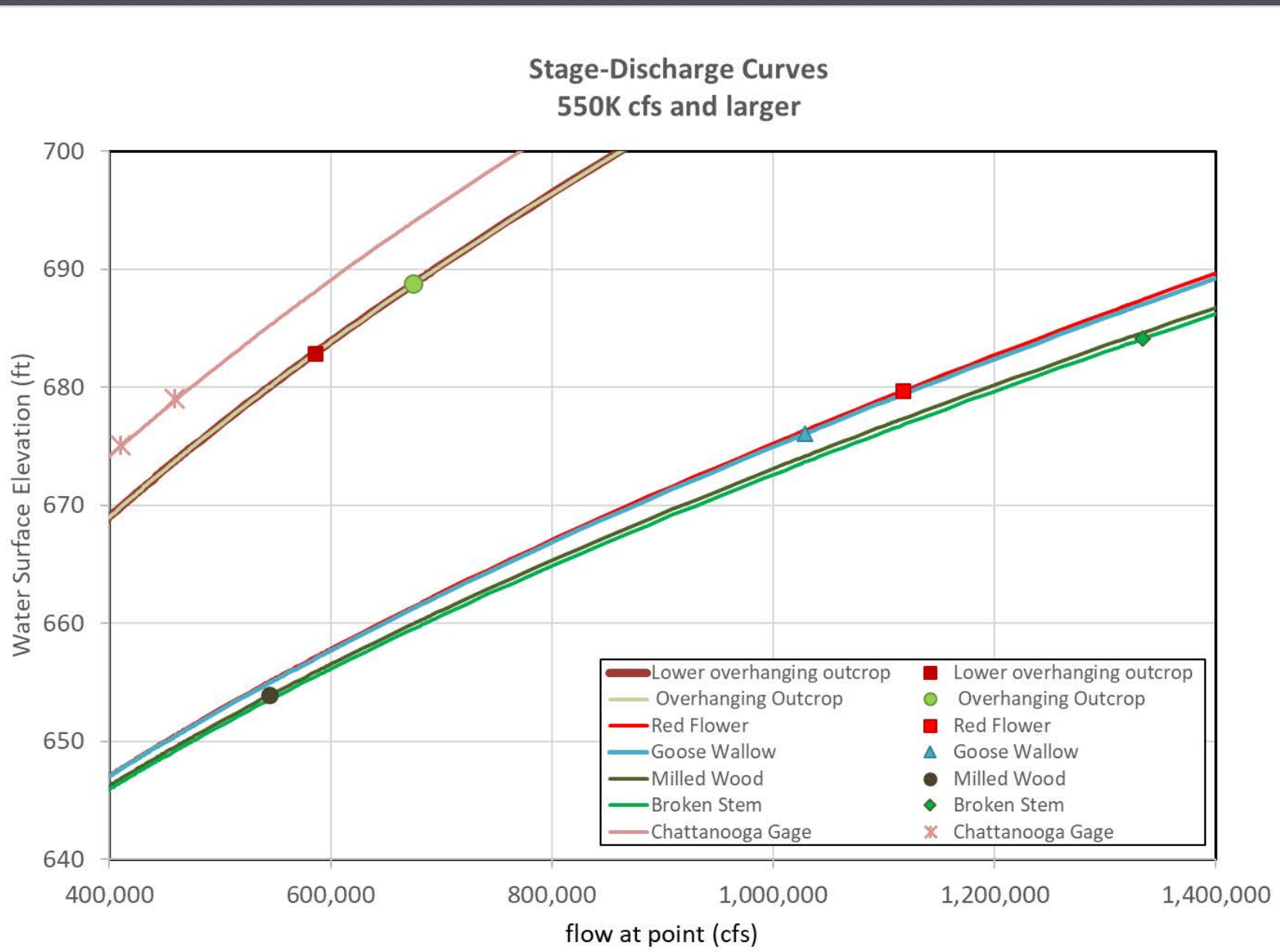
Calibrated to historical high water marks.

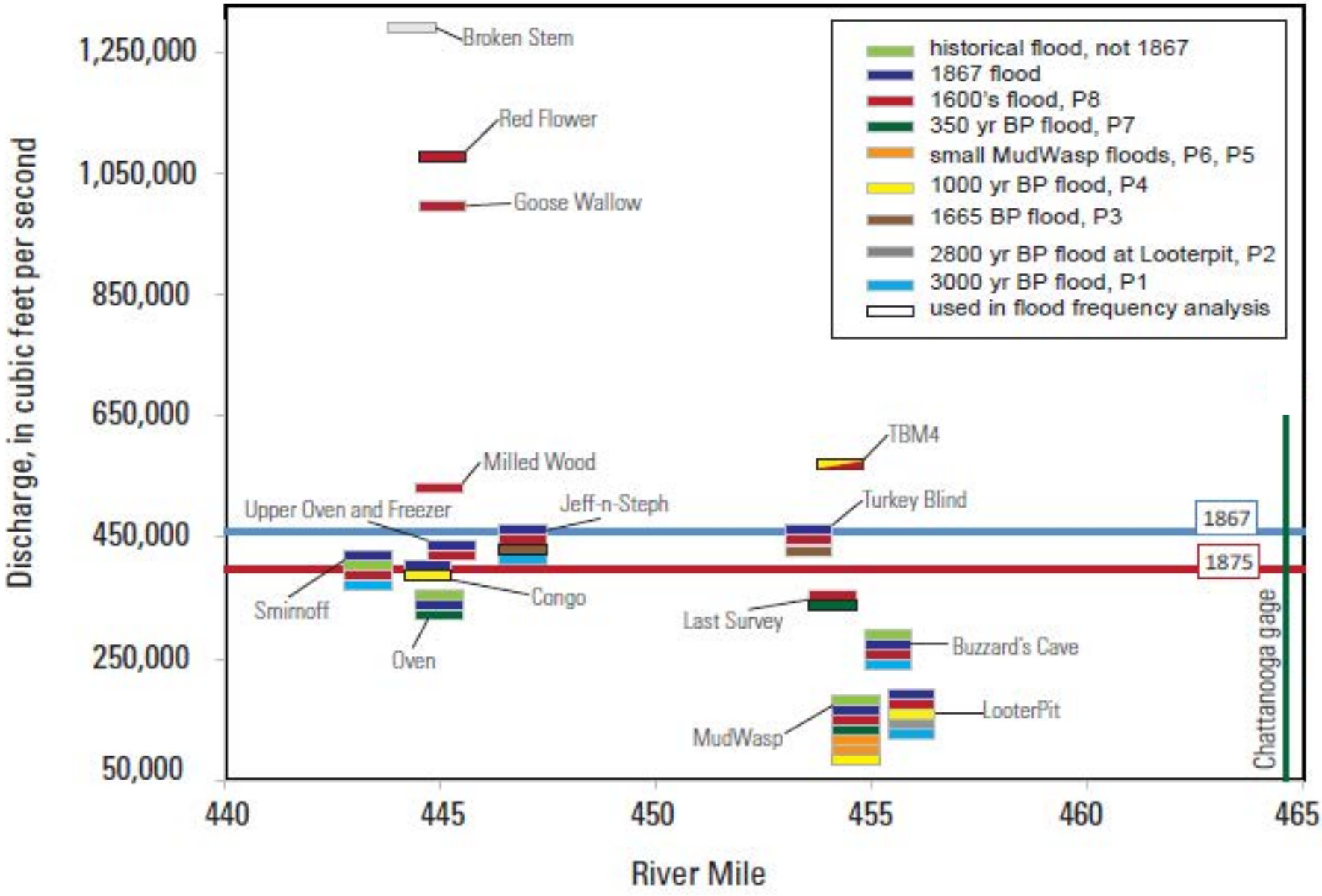





460
470
680
660
640
620
450
440
1867
1875
1886
1917
1936
1926-27
1897
55
50
45
40
35
30
25
20
15
10
5
MARKET ST BRIDGE EL 693.6
WALNUT ST BRIDGE EL 715.9
1937
IF FLASHBOARDS EL 629.3
CREST EL 626.3
430
440
450
460
470
1875Observed, uncertainties
1867Observed, uncertainties
1886Observed, uncertainties

TVA, 1940

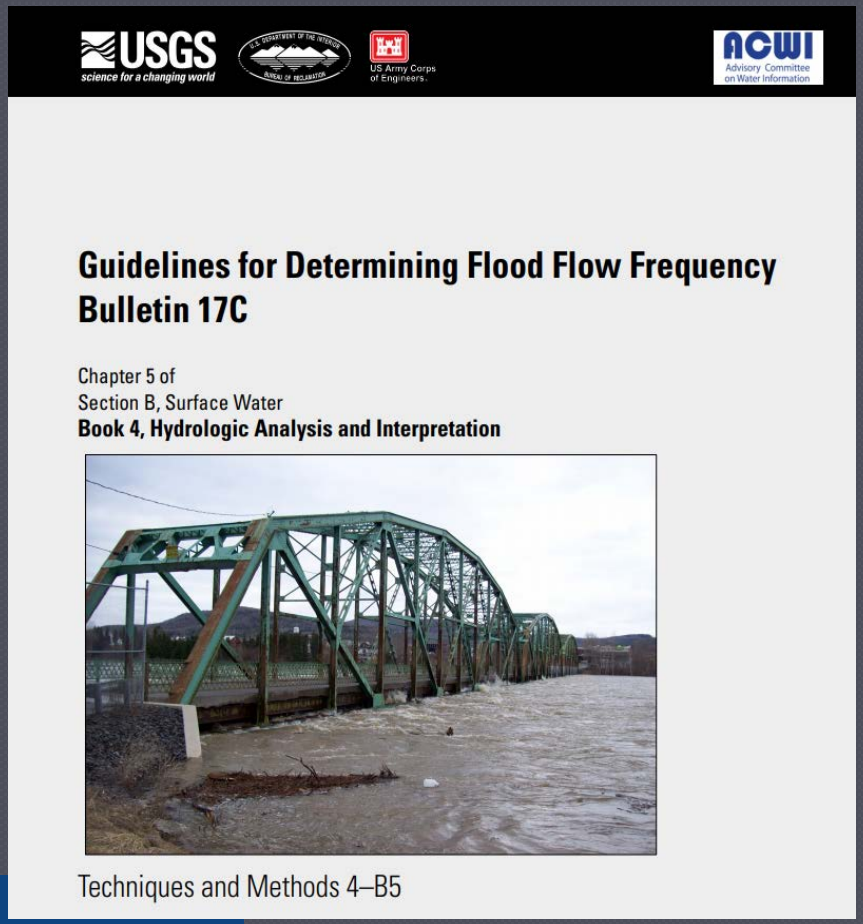

Stage-Discharge Curves
550K cfs and larger
Water Surface Elevation (ft)
700
690
680
670
660
650
640
400,000
600,000
800,000
1,000,000
1,200,000
1,400,000
flow at point (cfs)
Lower overhanging outcrop
Overhanging Outcrop
Red Flower
Goose Wallow
Milled Wood
Broken Stem
Chattanooga Gage
Lower overhanging outcrop
Overhanging Outcrop
Red Flower
Goose Wallow
Milled Wood
Broken Stem
Chattanooga Gage



8 unique paleofloods in ~4,000 years

Flood-Frequency Analysis

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

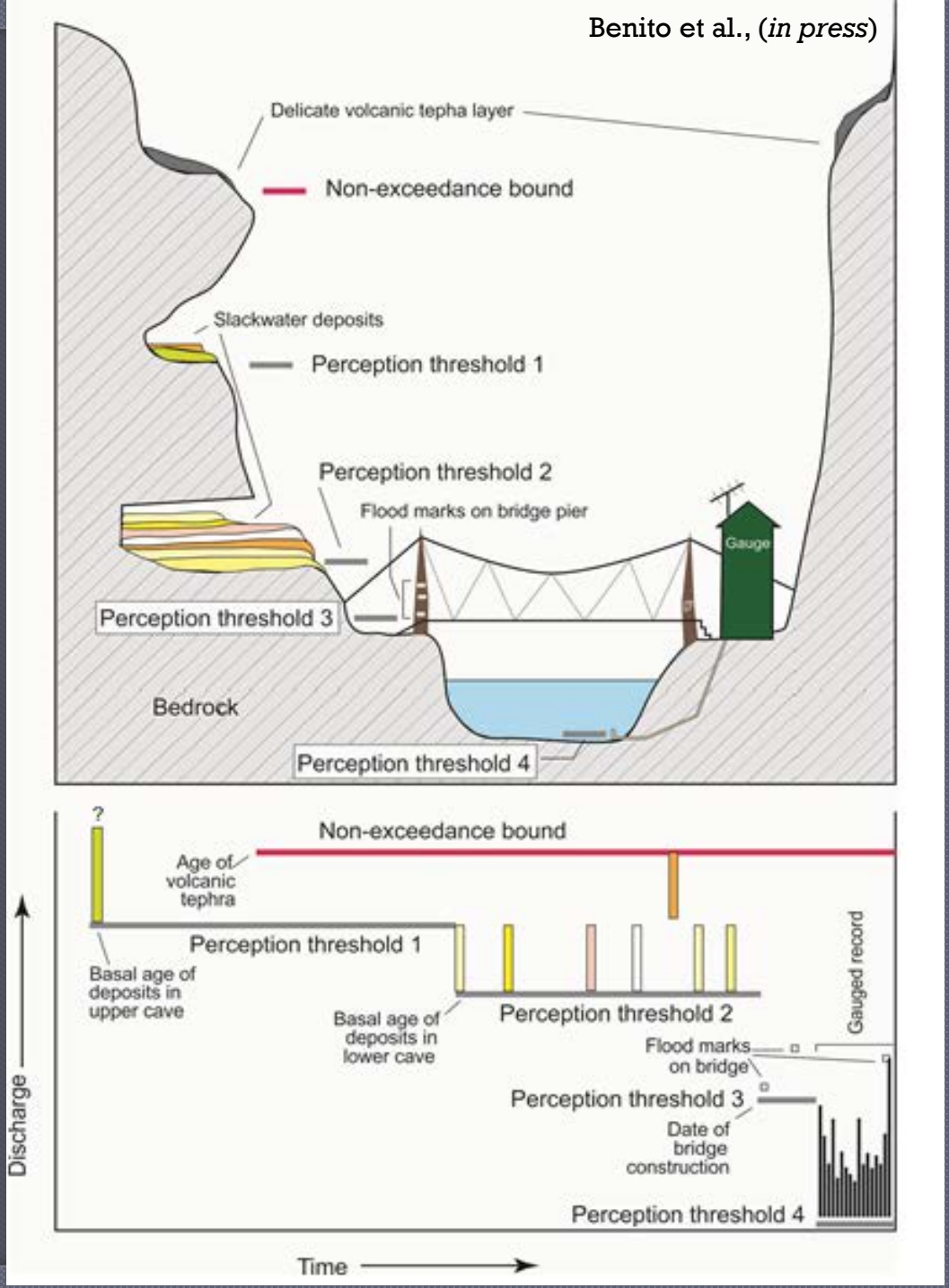


England and others, 2019

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



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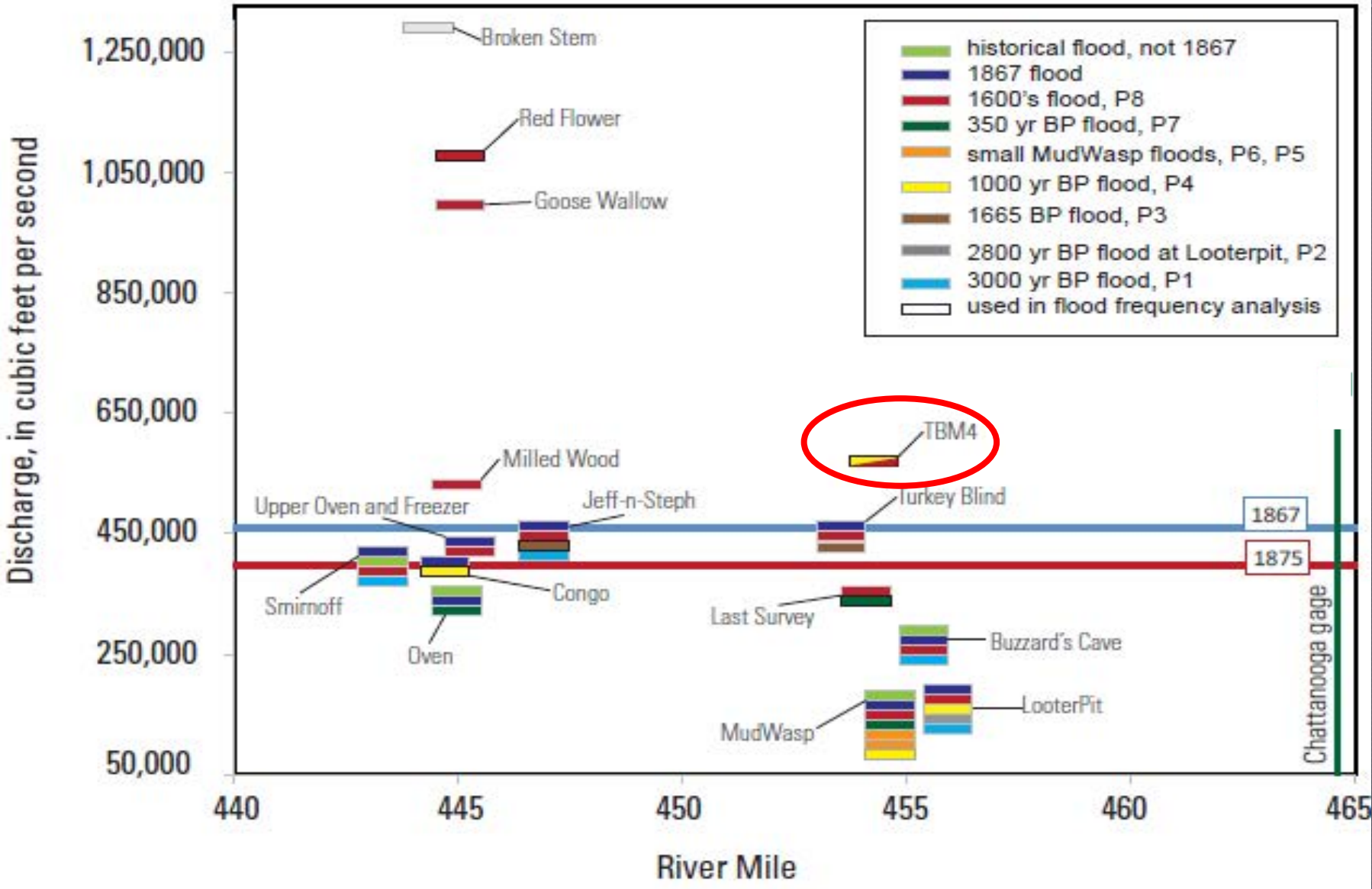
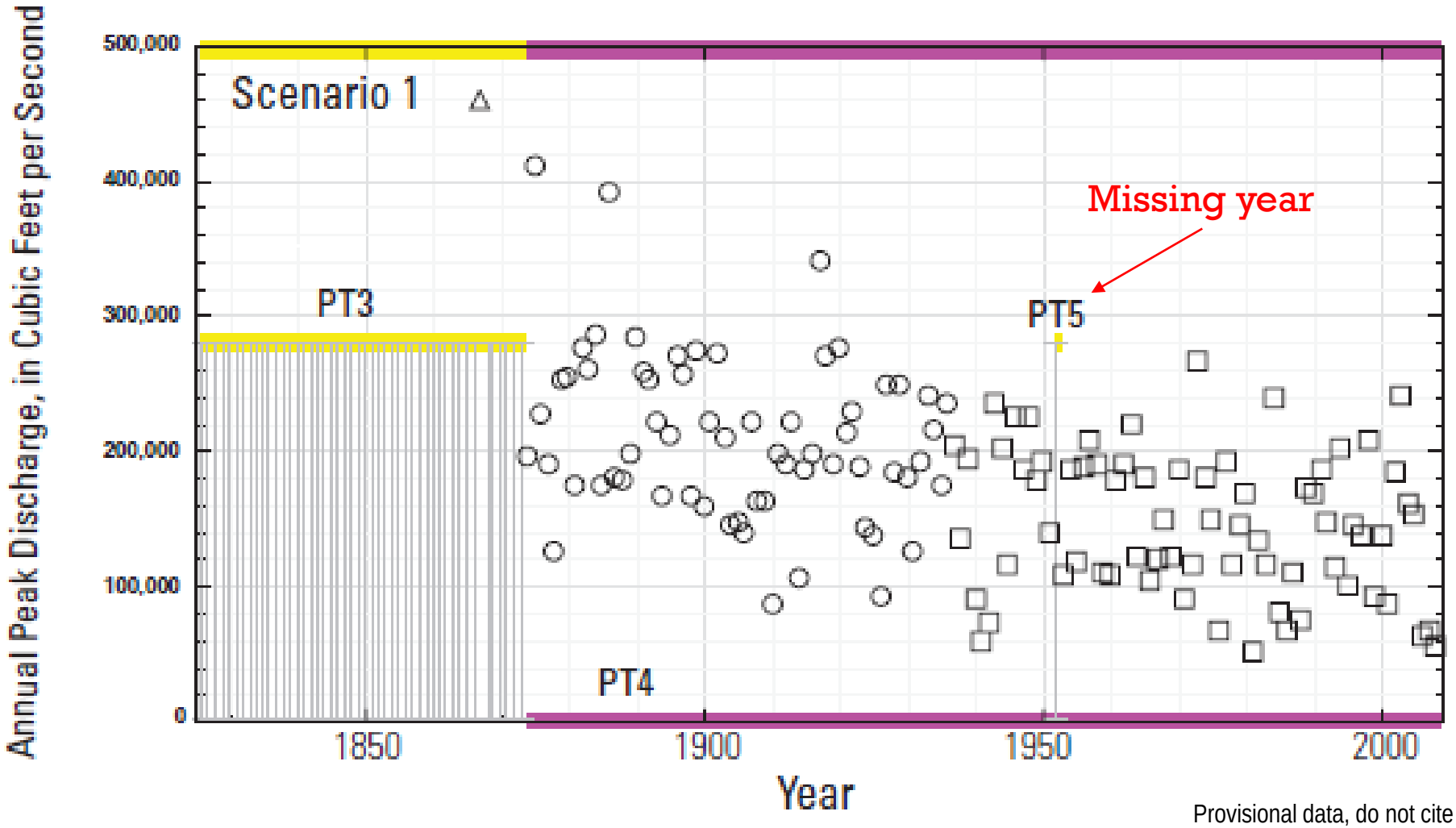
Flood-frequency analyses for 7 different scenarios:

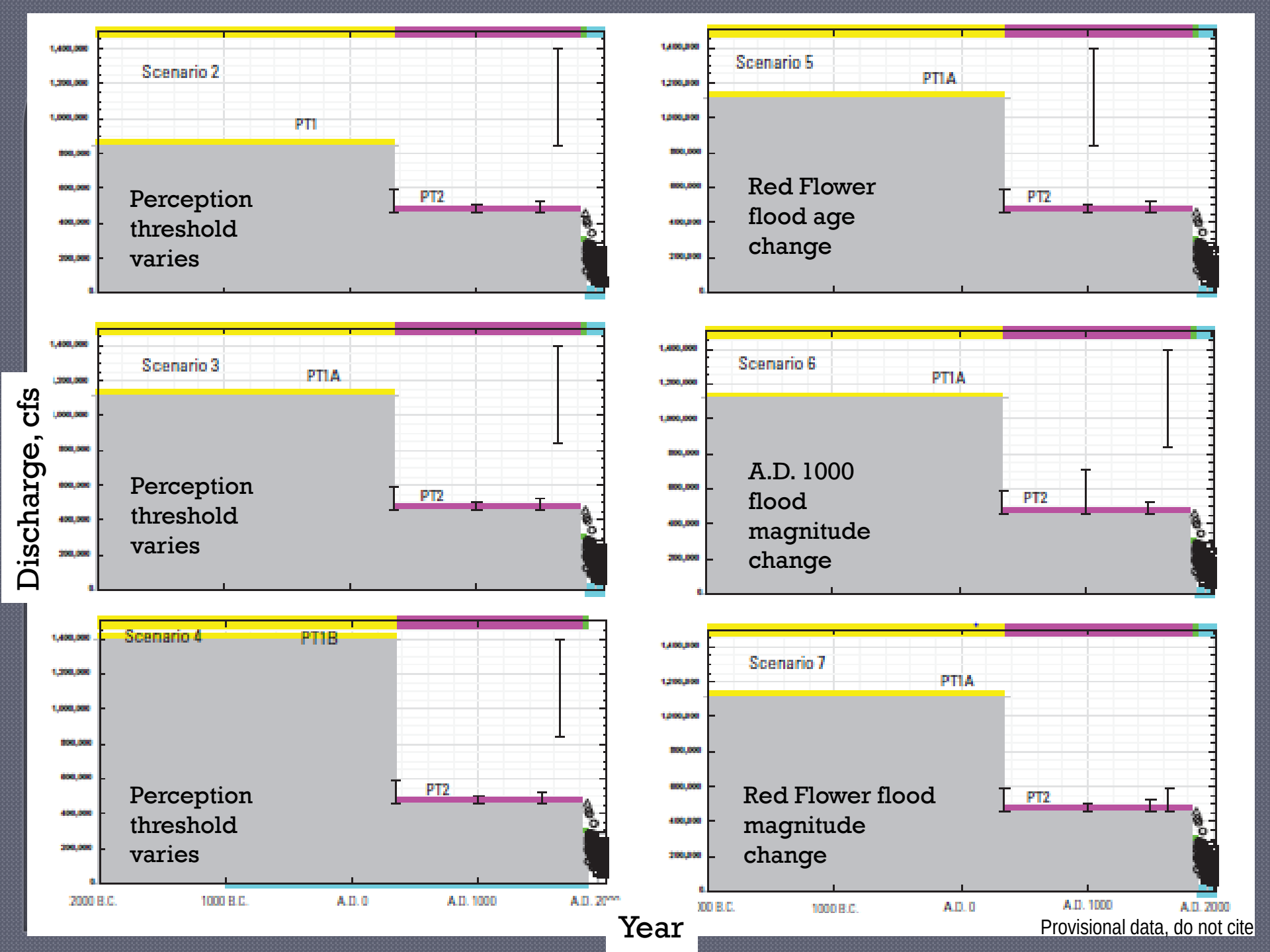
- **Scenario 1:** Gaged plus historical record (1826-2008), 3 perception thresholds
- **Scenario 2-4:** 4 paleofloods (350,1000, 1500, 1650); 5 perception thresholds (variation to 1 paleo perception threshold)
- **Scenario 5-7:** 4 paleofloods (variation in age and magnitude); 5 perception thresholds



4 paleofloods used in the flood frequency analysis.
Age and magnitude was varied in some scenarios to account geochronologic and stratigraphic uncertainty.



Historical: 1826-1873
Gage: 1874-2008



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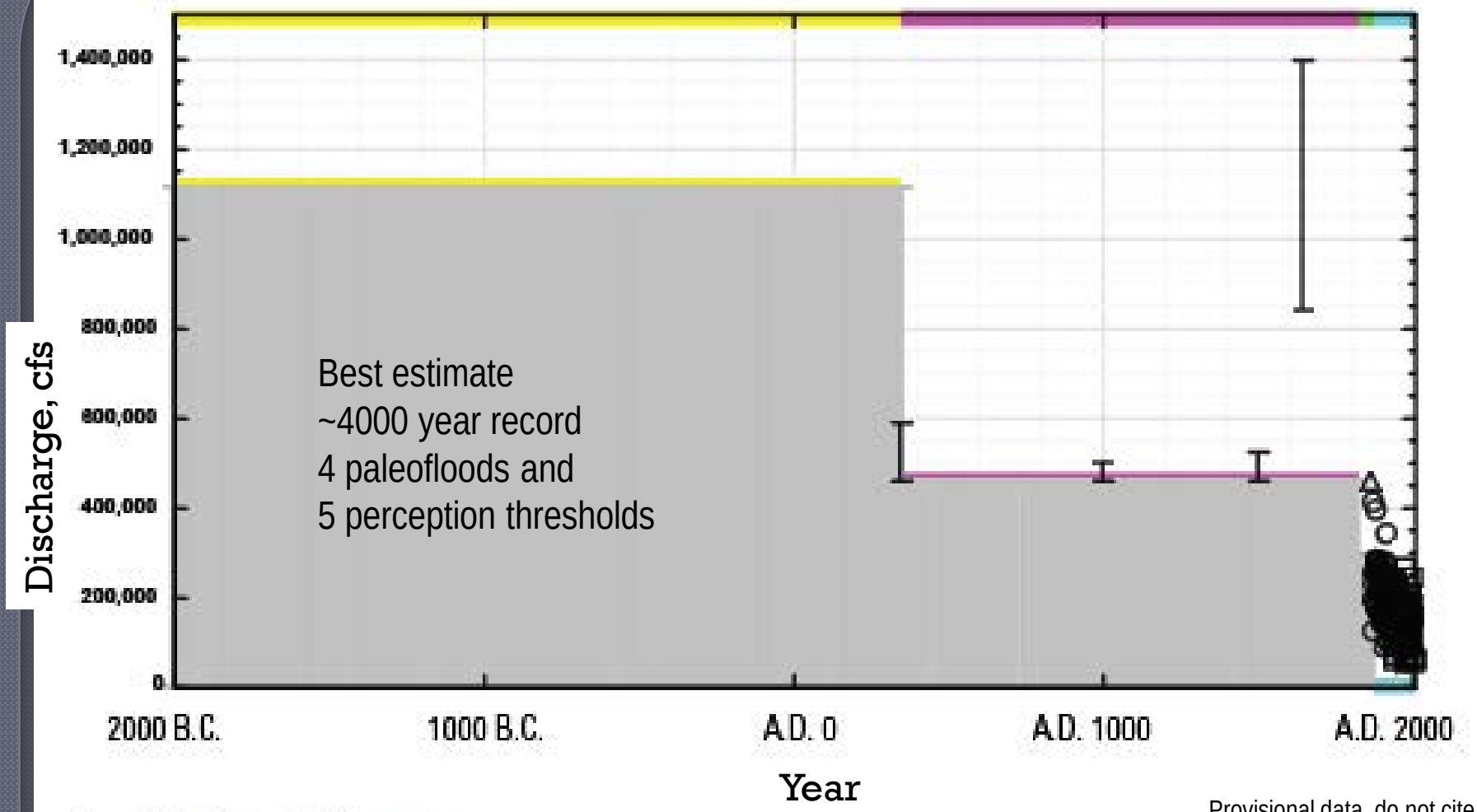

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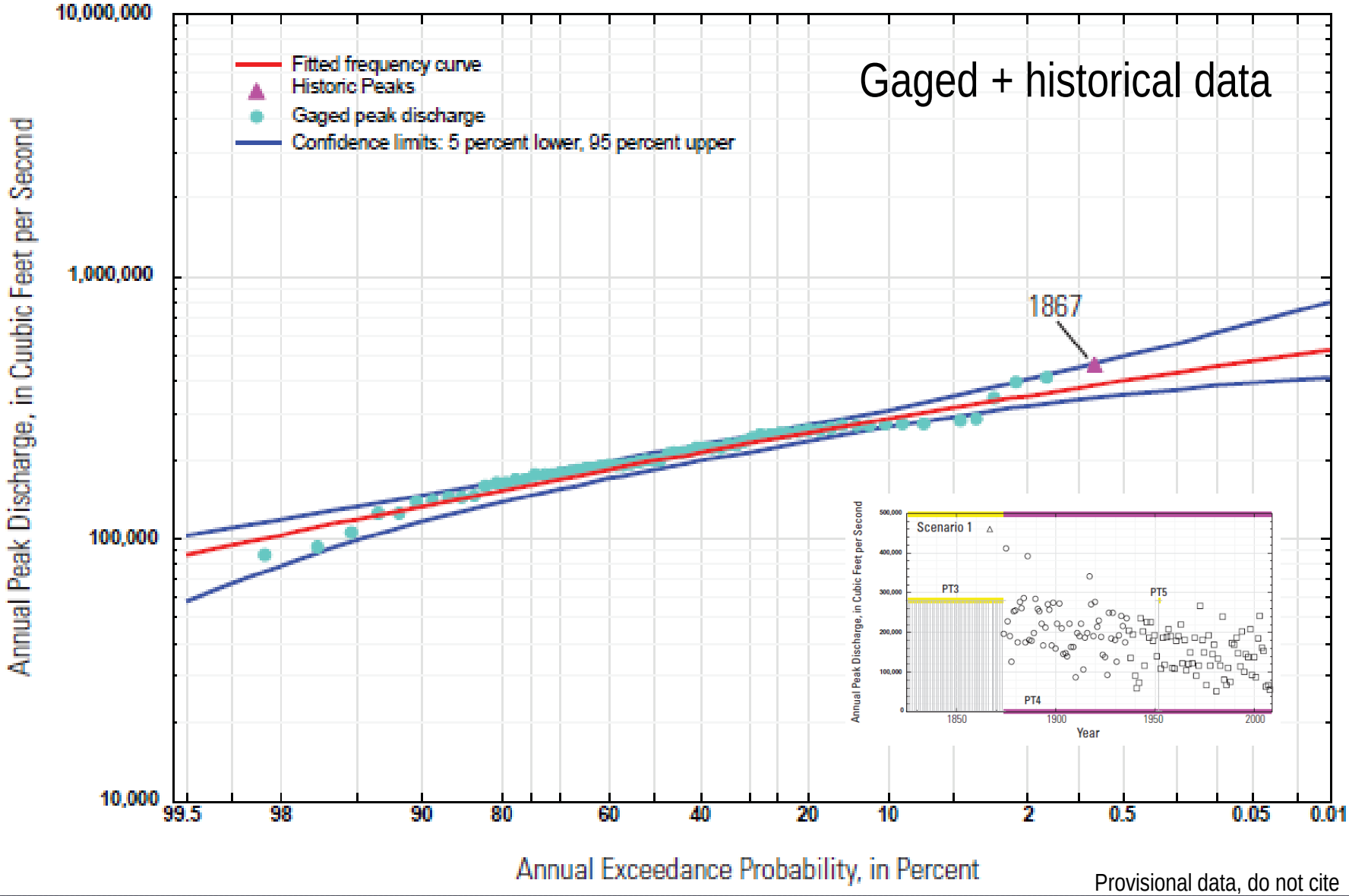
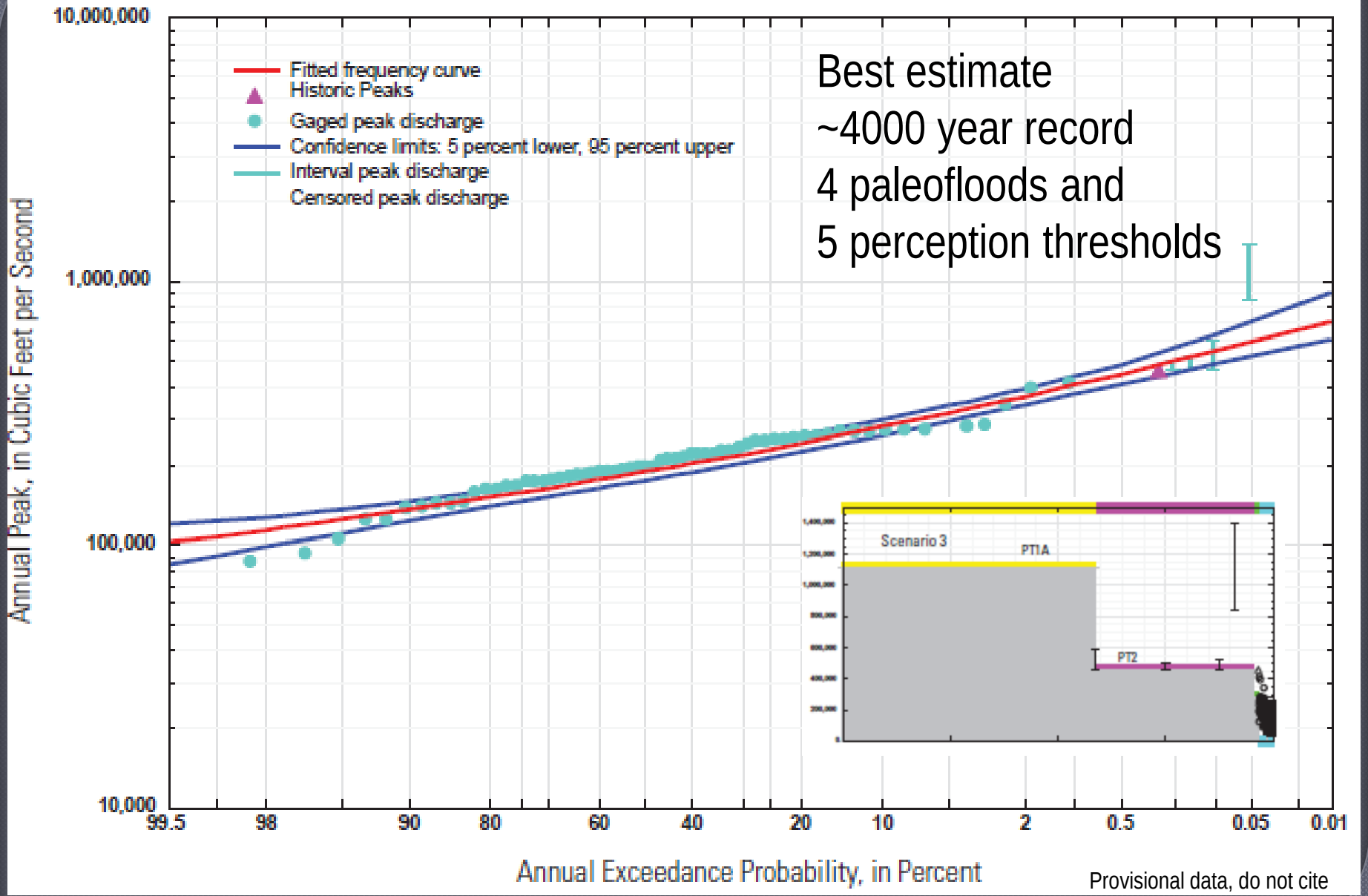
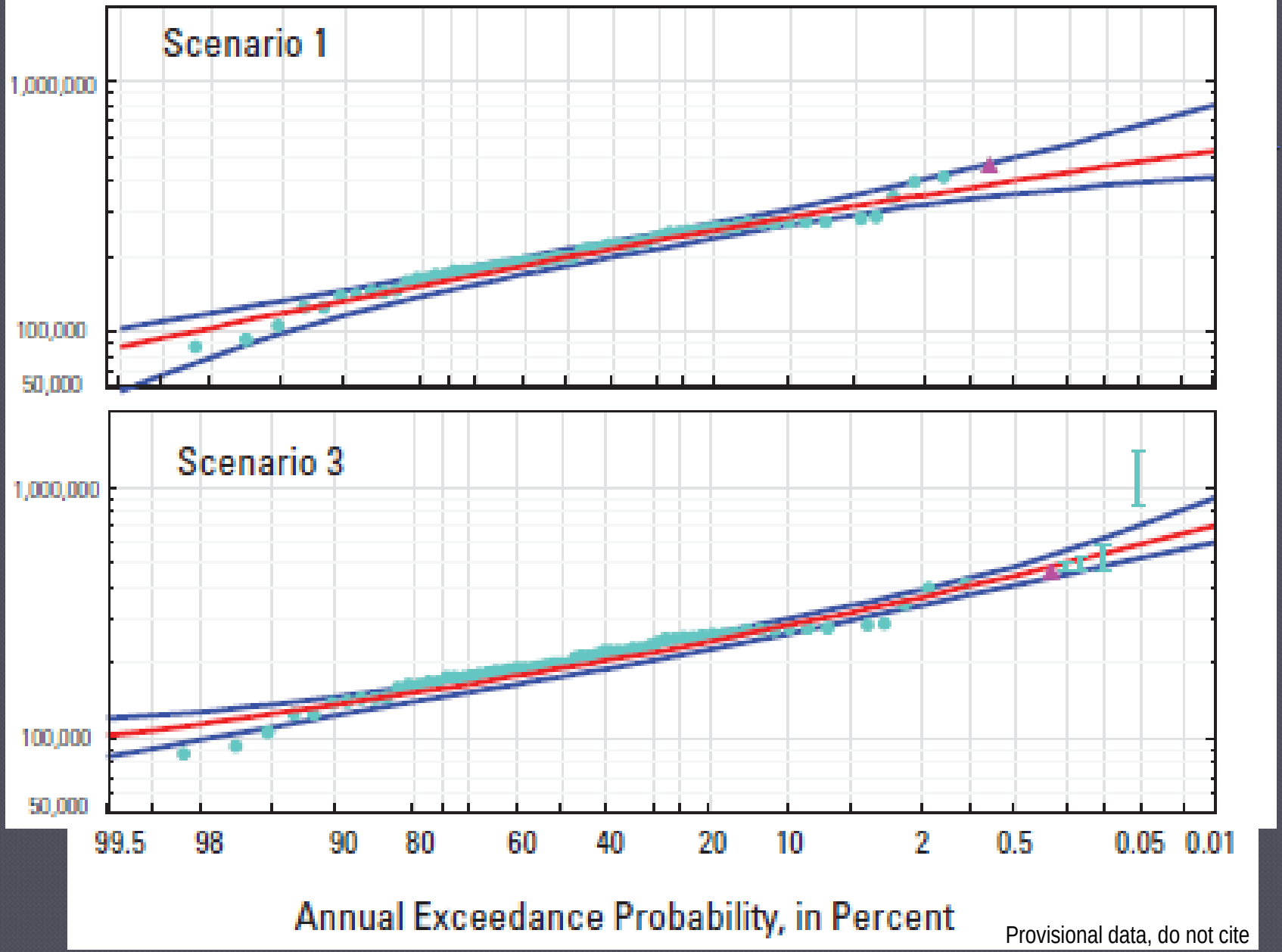
Gaged + historical data



Provisional data, do not cite



Provisional data, do not cite


Scenario 1
1,000,000
100,000
50,000
Scenario 3
1,000,000
100,000
50,000
99.5
98
90
80
60
40
20
10
2
0.5
0.05
0.01
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

Change date of large Red Flower flood

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
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			Lower	Upper
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500	0.002	460000	420000	500000
1,000	0.001	490000	440000	540000
10,000	0.0001	580000	510000	690000

Best Estimate Paleoflood Scenario

Gaged plus historical record

Provisional data, do not cite

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
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Return Period	AEP	EMA Estimate	Confidence Limits	
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Best Estimate Paleoflood Scenario

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Return Period	AEP	EMA Estimate	Confidence Limits	
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500	0.002	460000	420000	500000
1,000	0.001	490000	440000	540000
10,000	0.0001	580000	510000	690000

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.

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