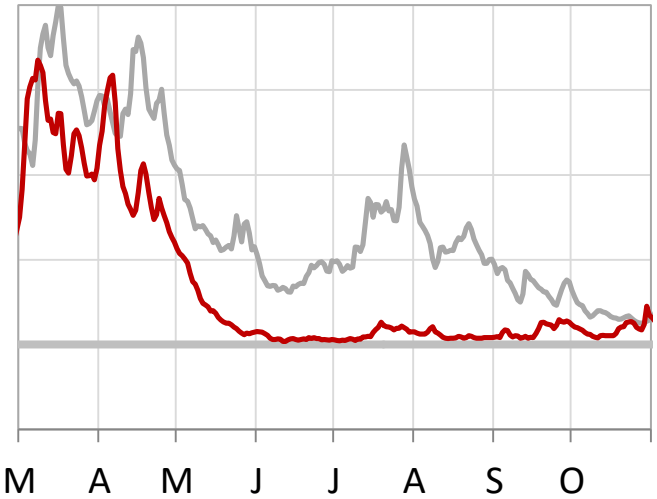
Long-term changes in channel morphology and flow regime of the Apalachicola River with an emphasis on mussel habitats

Helen Light
USGS retired

January 30, 2017

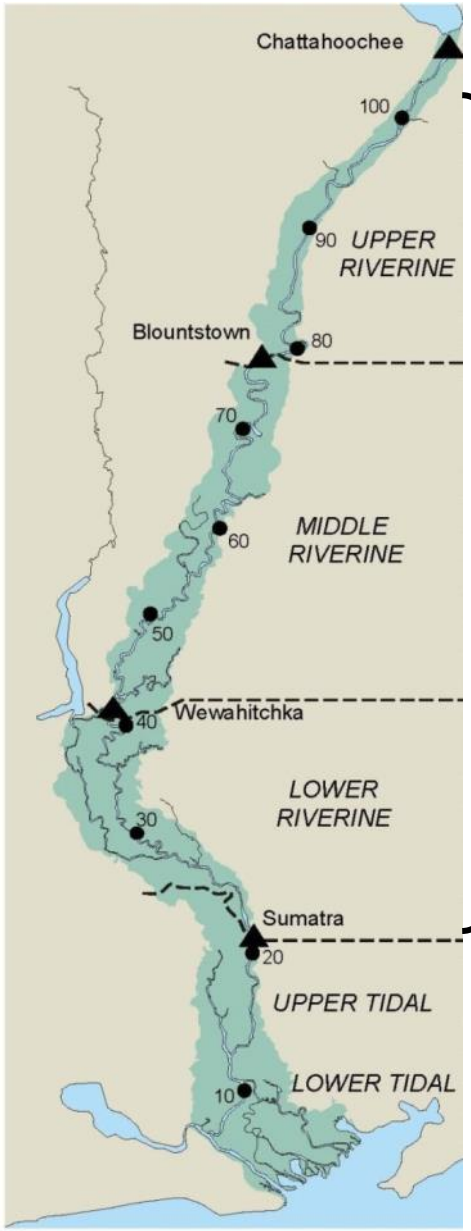
Channel alterations

Flow declines

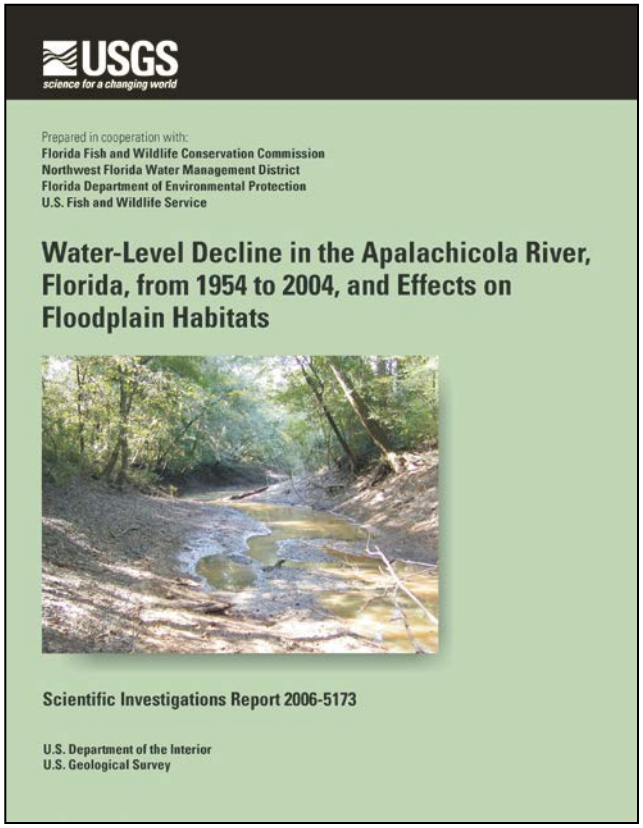


Habitat stabilization by willows

All flows in this presentation are discharges at *Chattahoochee gage*



Water levels at downstream locations were converted to Chattahoochee flow using nonstandard stage-discharge relations every 0.1 mile in Light et al. 2006.


USGS
science for a changing world

Prepared in cooperation with:
Florida Fish and Wildlife Conservation Commission
Northwest Florida Water Management District
Florida Department of Environmental Protection
U.S. Fish and Wildlife Service

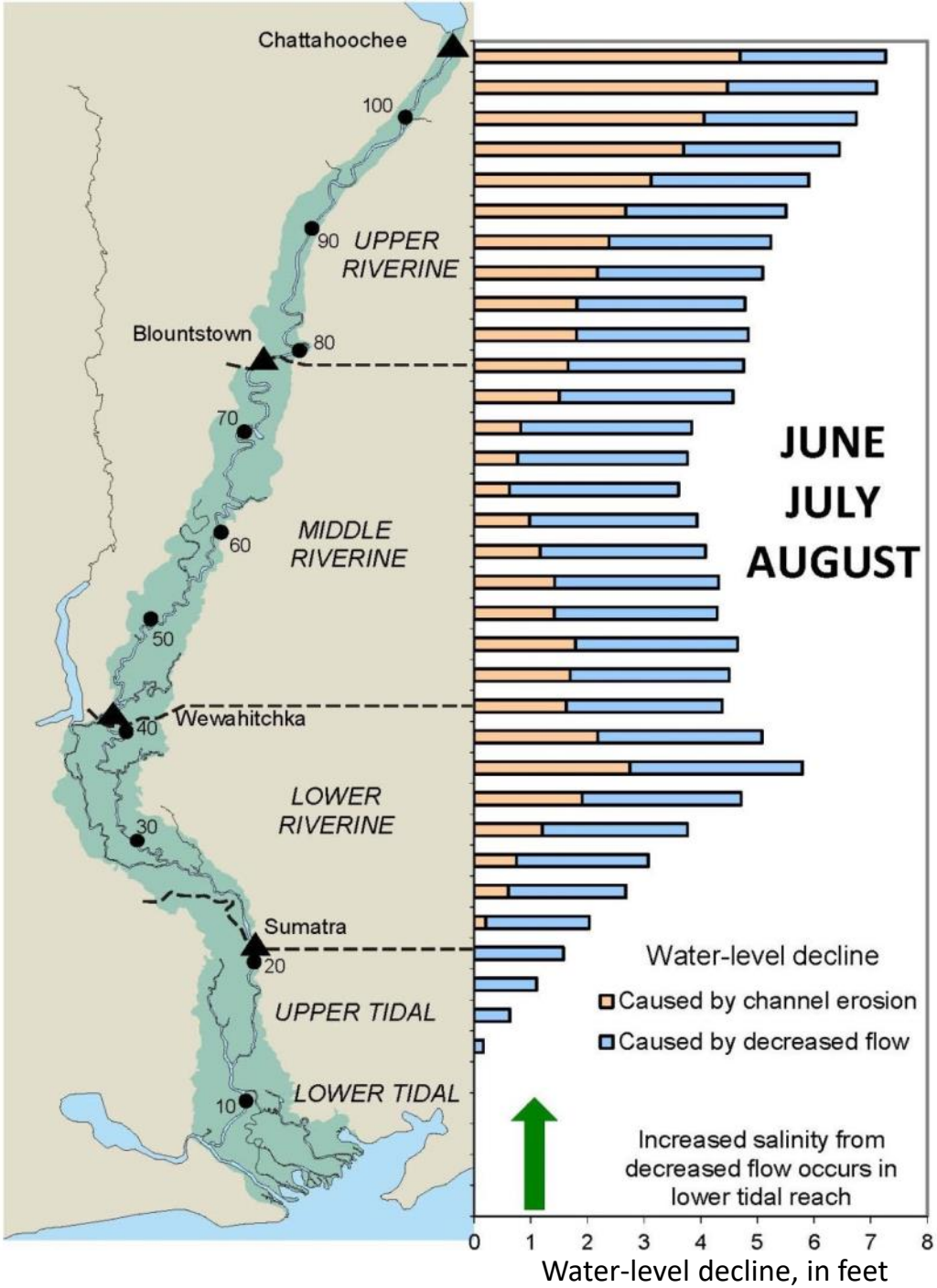
Water-Level Decline in the Apalachicola River, Florida, from 1954 to 2004, and Effects on Floodplain Habitats

Scientific Investigations Report 2006-5173

U.S. Department of the Interior
U.S. Geological Survey

Light et al. 2006
https://pubs.usgs.gov/sir/2006/5173/

Summer water-level decline in low-flow years from various causes



Decline in lowest 1/3 of years from:

- Channel erosion since 1954
- Decreased flow from early period (1923-1955) to recent period (1975-2012)

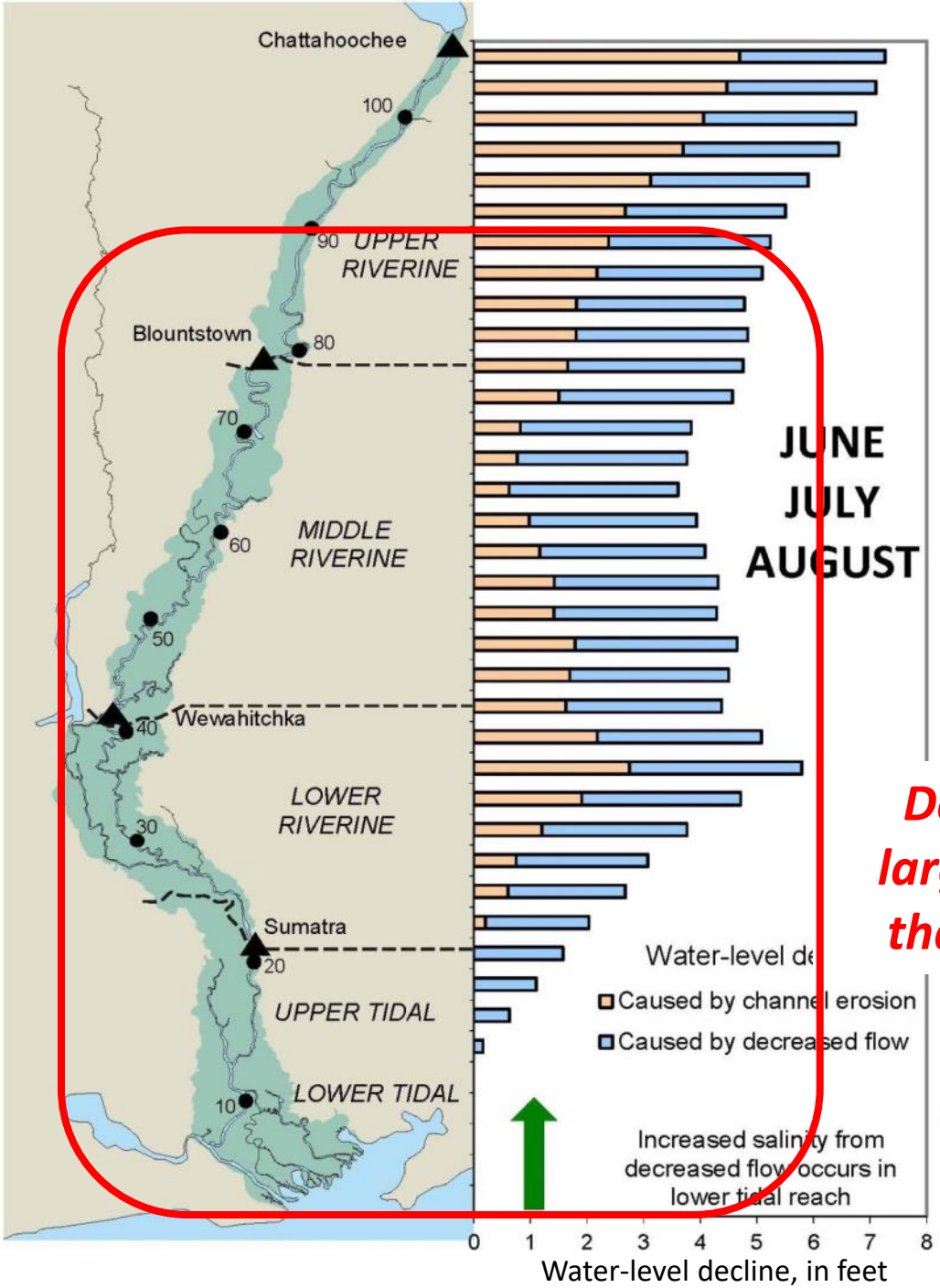
Water-level declines vary by flow. Declines were determined from a baseline flow of 12,700 cfs (mean June-Aug flow in low-flow years of early period, 1923-1955)

Sumatra ▲ STREAMFLOW GAGE -- with station name

70 ● RIVER MILE -- distance from mouth in miles

Modified from Fig. 5 in FDEP 2013

Summer water-level decline in low-flow years from various causes



Decline in lowest 1/3 of years from:

- Channel erosion since 1954
- Decreased flow from early period (1923-1955) to recent period (1975-2012)

Decreased flow is the largest impact for more than 90% of floodplain

Sumatra ▲ STREAMFLOW GAGE -- with station name

70 ● RIVER MILE -- distance from mouth in miles

Modified from Fig. 5 in FDEP 2013

Water-level decline caused by *channel changes*

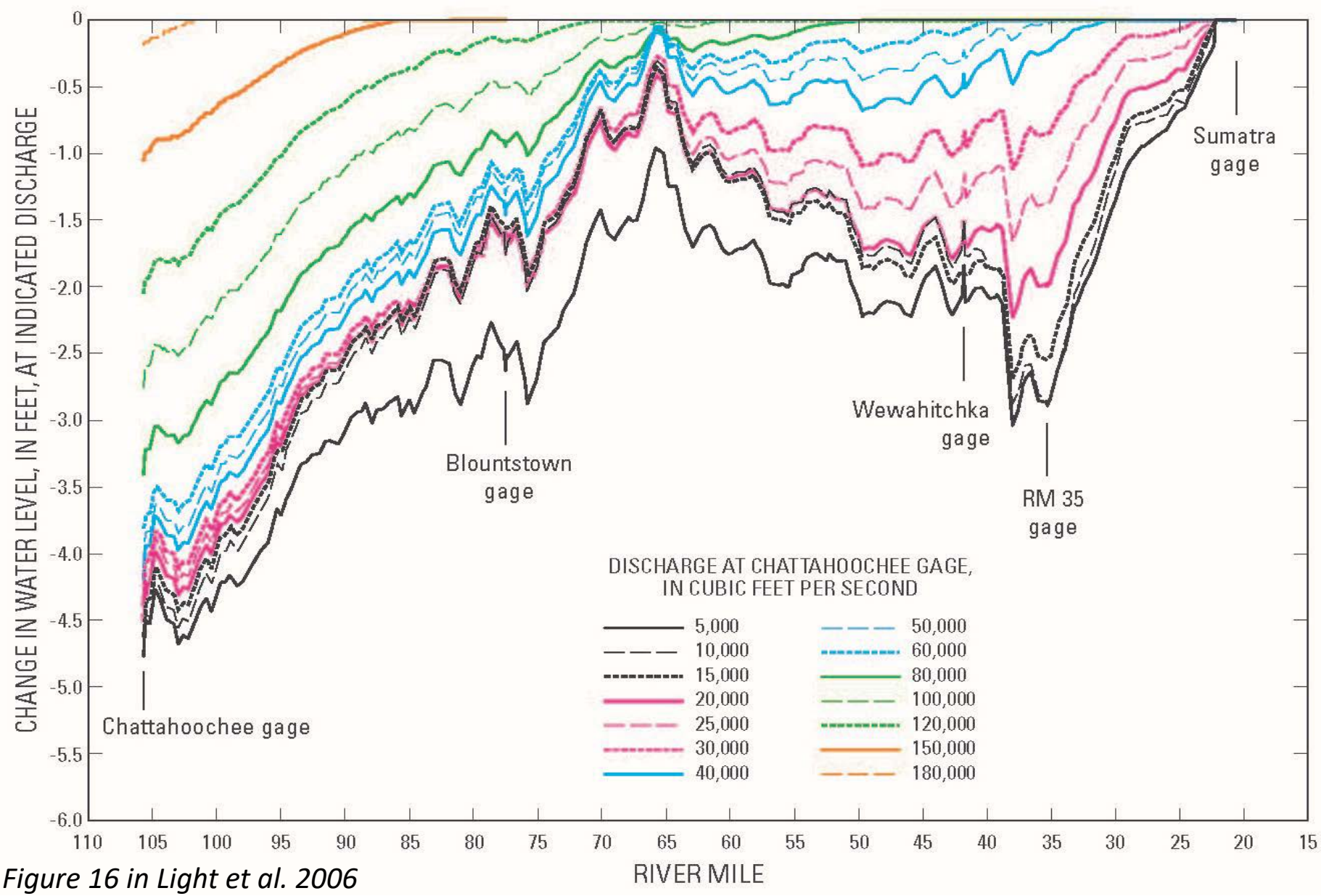


Figure 16 in Light et al. 2006

Water-level decline caused by *channel changes*

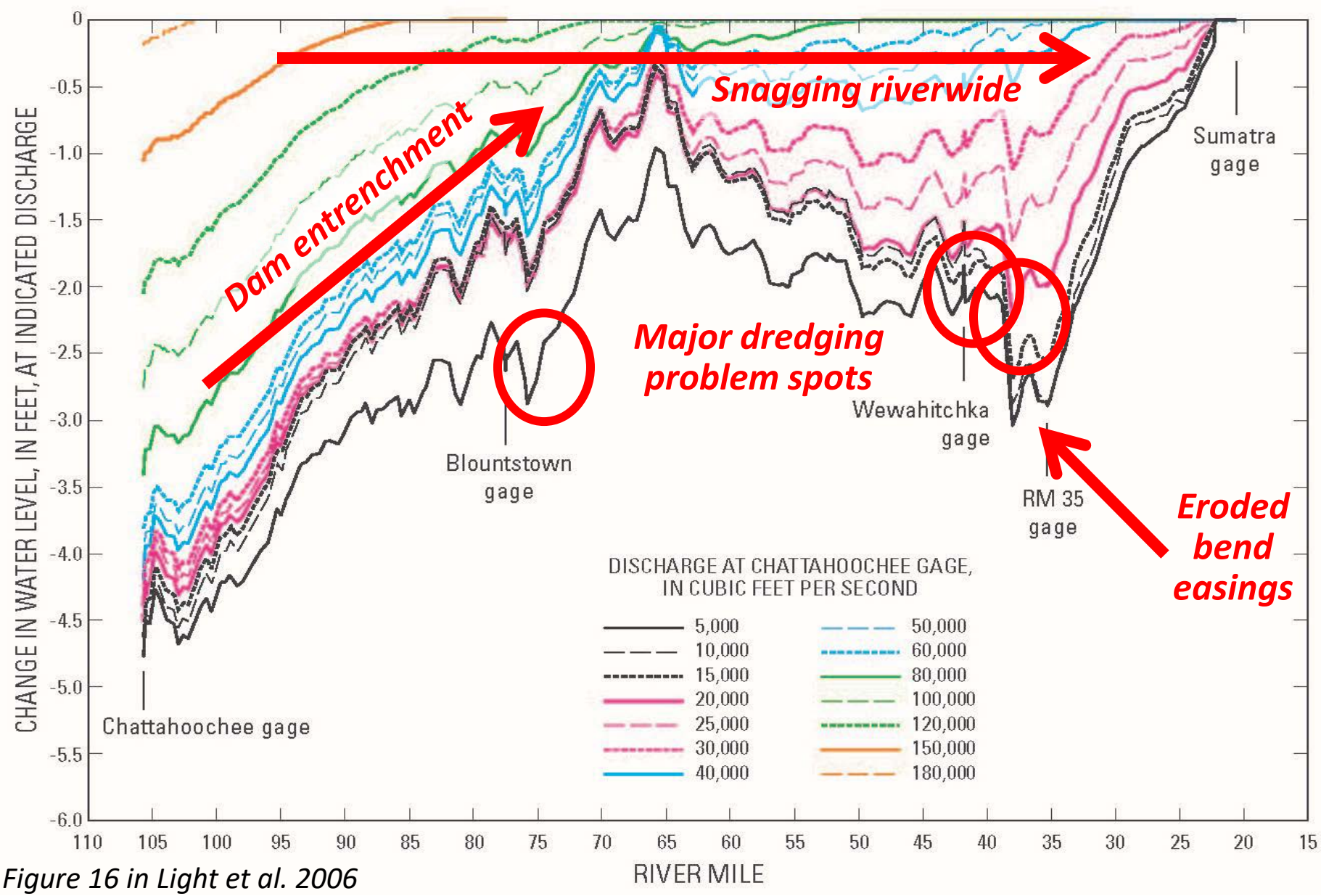


Figure 16 in Light et al. 2006

Channel widening

Treeline width by river mile in 1941 and 2004

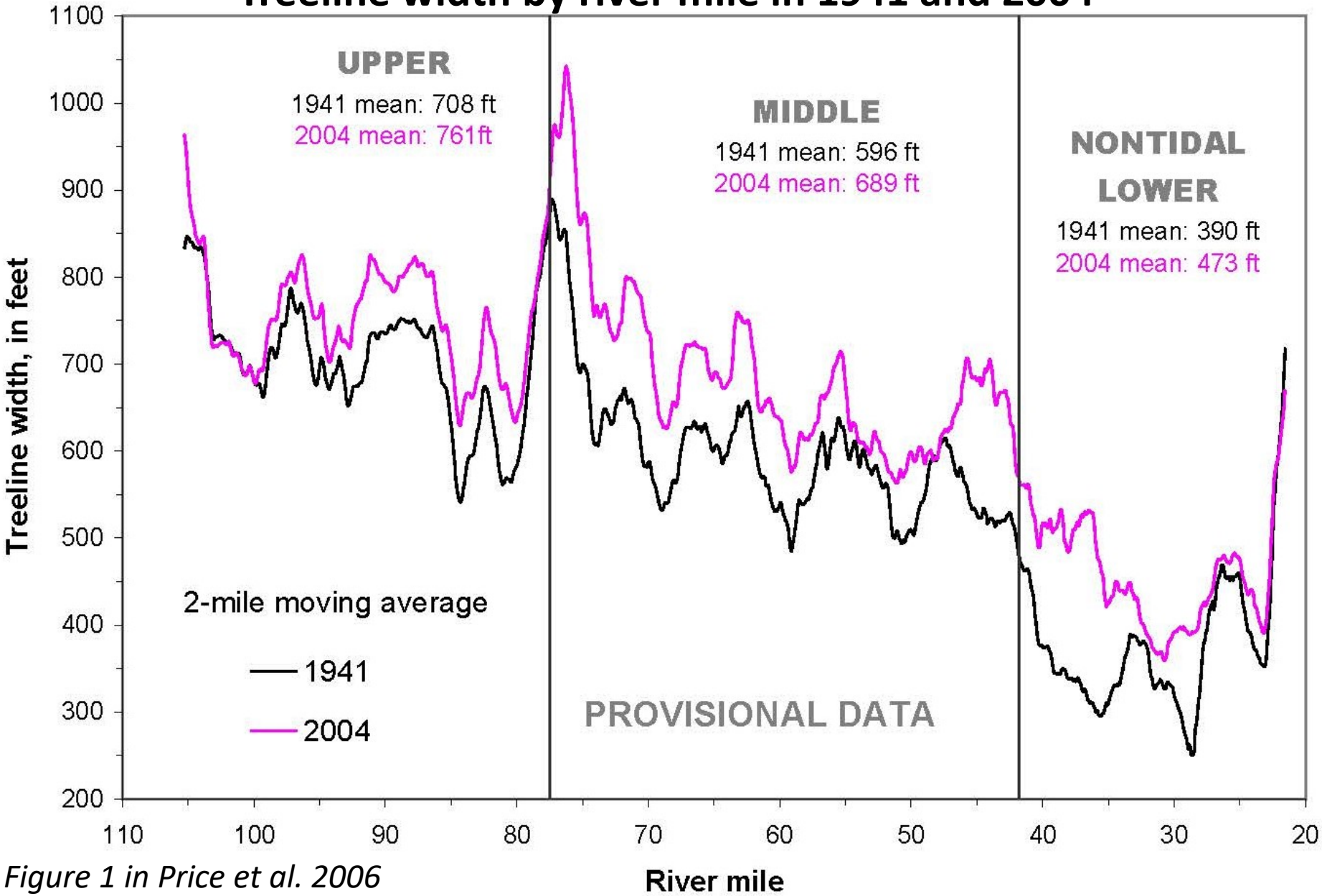


Figure 1 in Price et al. 2006

Channel widening

Change in treeline width by river mile from 1941 to 2004

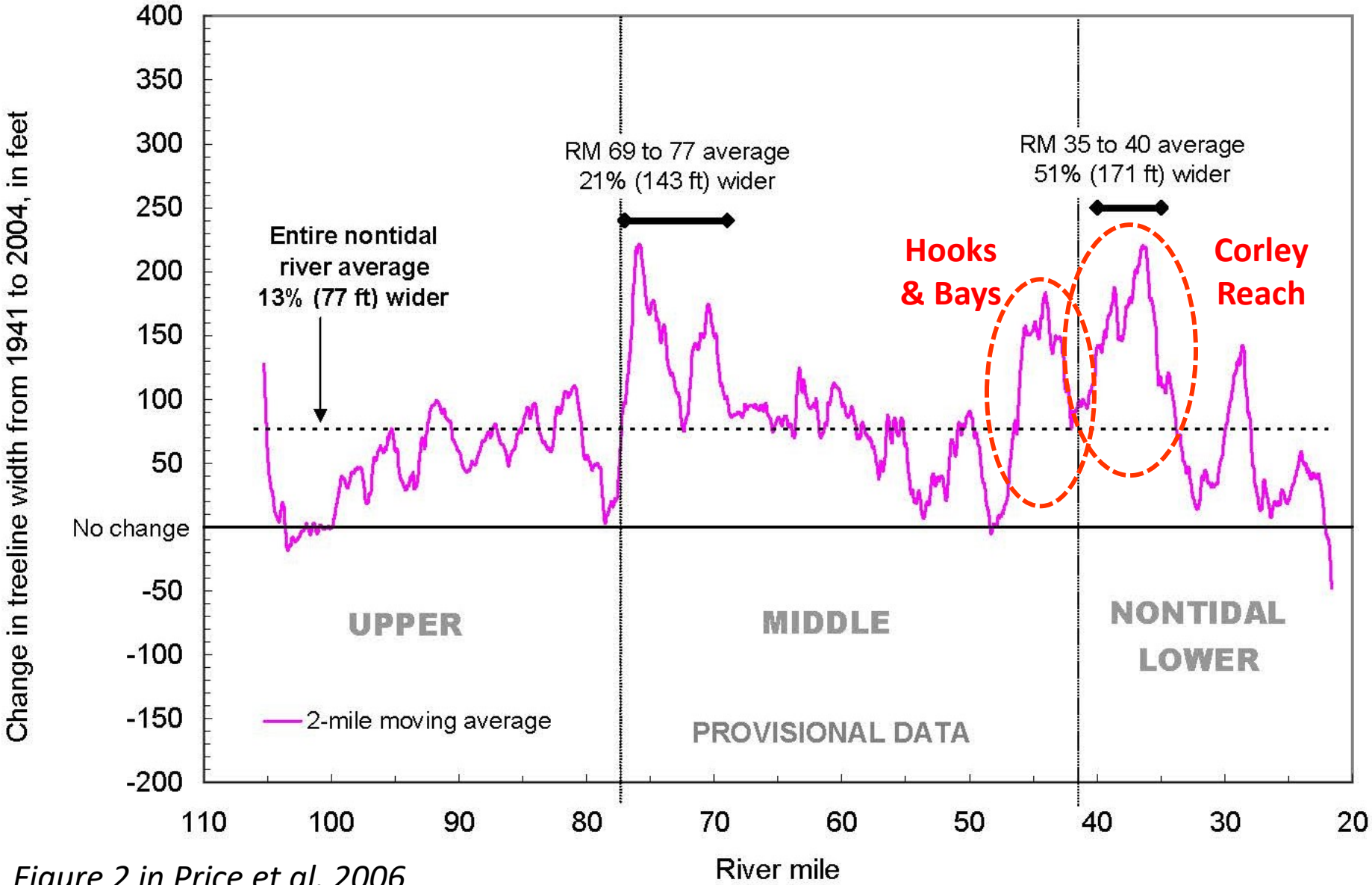
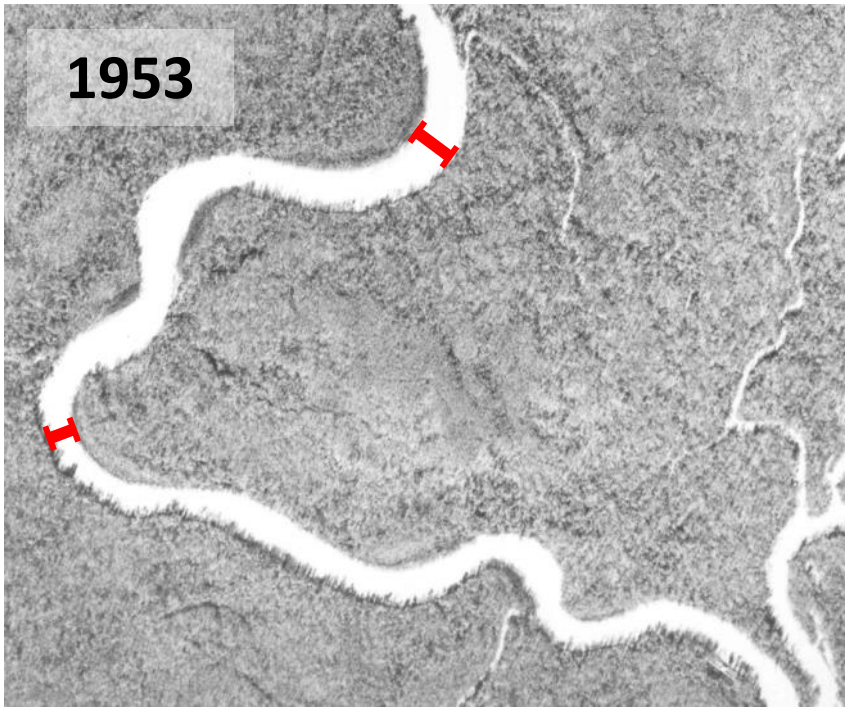


Figure 2 in Price et al. 2006

Channel width was measured at treeline
(not at outer edge of sandbar)

Treeline width is independent of flow at time of photo because tree tops are always visible regardless of flow, whereas sand pointbars are much larger at low flow than high flows.



Mile 35.2 – 37.3

Heavily engineered reach had greatest widening (reach average 61% wider)

1. Mechanical redistribution 1990-1999
Spoil pushed into river with bulldozers caused large expansion of point bar and opposite bank erosion; channel doubled in width.

2. Corley Slough bend easing 1969
Channel width more than doubled from subsequent erosion of “Sand Mountain”.

3. Virginia Cut bend easing 1969
Erosion at upper end caused widening.

Treeline width by reach in relation to time

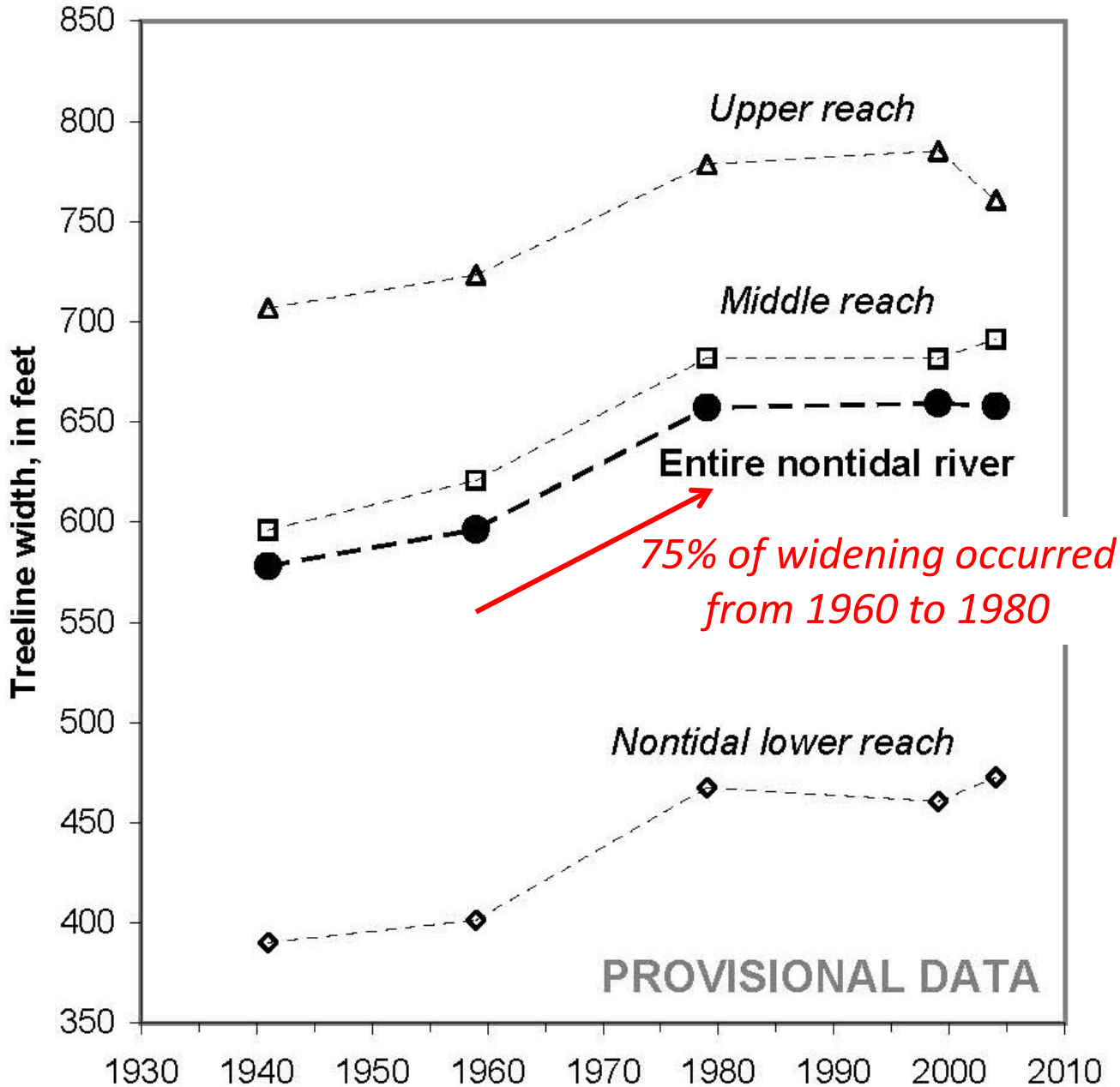
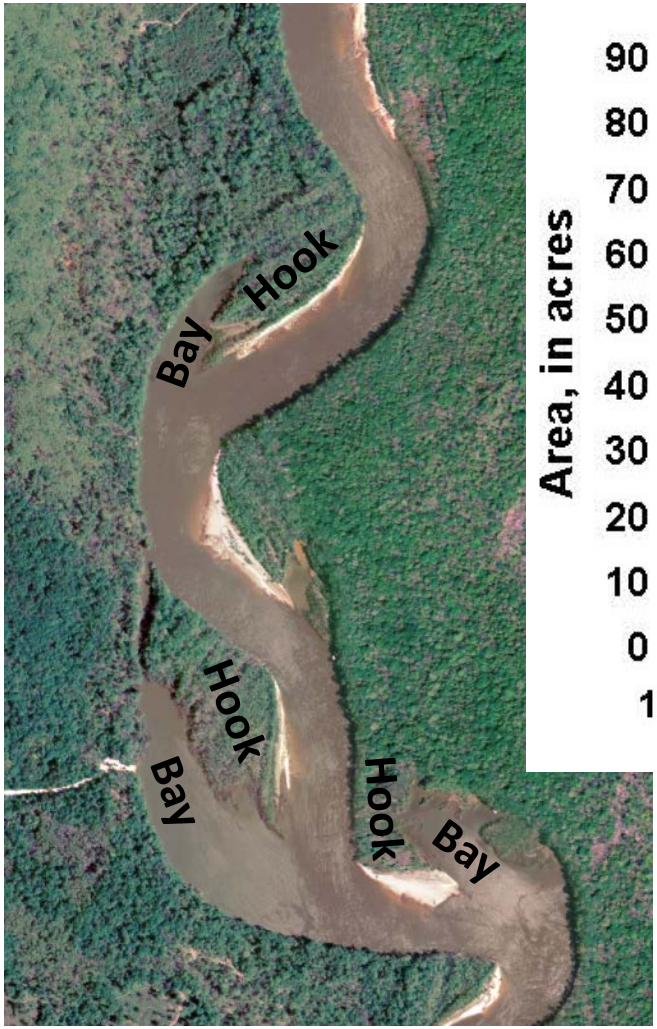


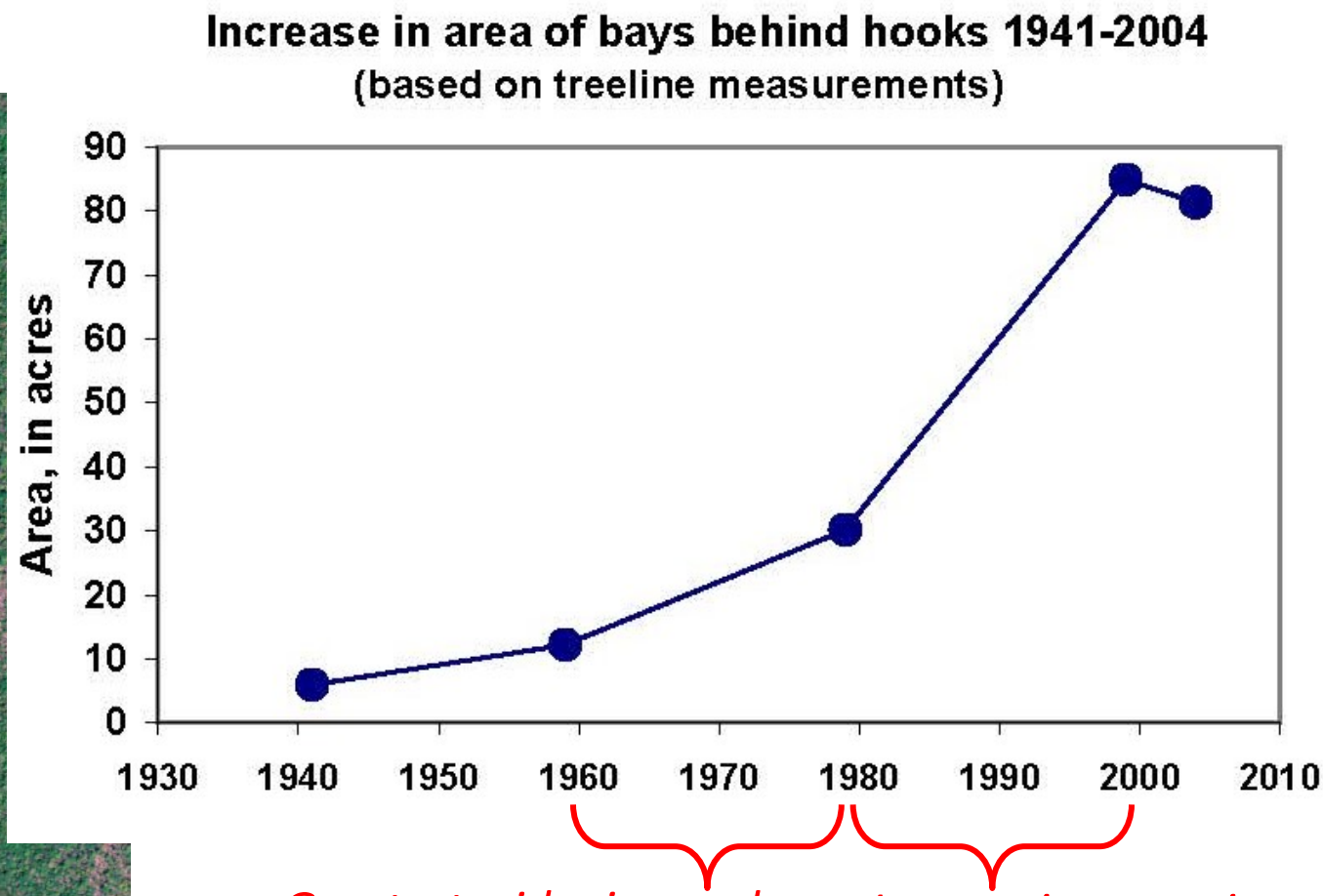
Figure 3 in Price et al. 2006

Development of "hooks and bays" in relation to time

Mile 44.5 - 46.7 2004



Florida DEP



Greatest widening and water-level decline occurred 1960-1980

Largest increase in hooks and bays occurred later

Unpublished USGS data, 2005

Largest concentration (in size and number) of hooks and bays are in 4.5-mile reach immediately upstream of Wewa gage

Mile 44.5 - 46.7 2004

Florida DEP

Mile 41.4 - 43.7 2004

Florida DEP

Wewahitchka gage at Gaskin Park

Changes in water level over time at a constant flow (~10,000 cfs) caused by channel changes at Wewahitchka gage

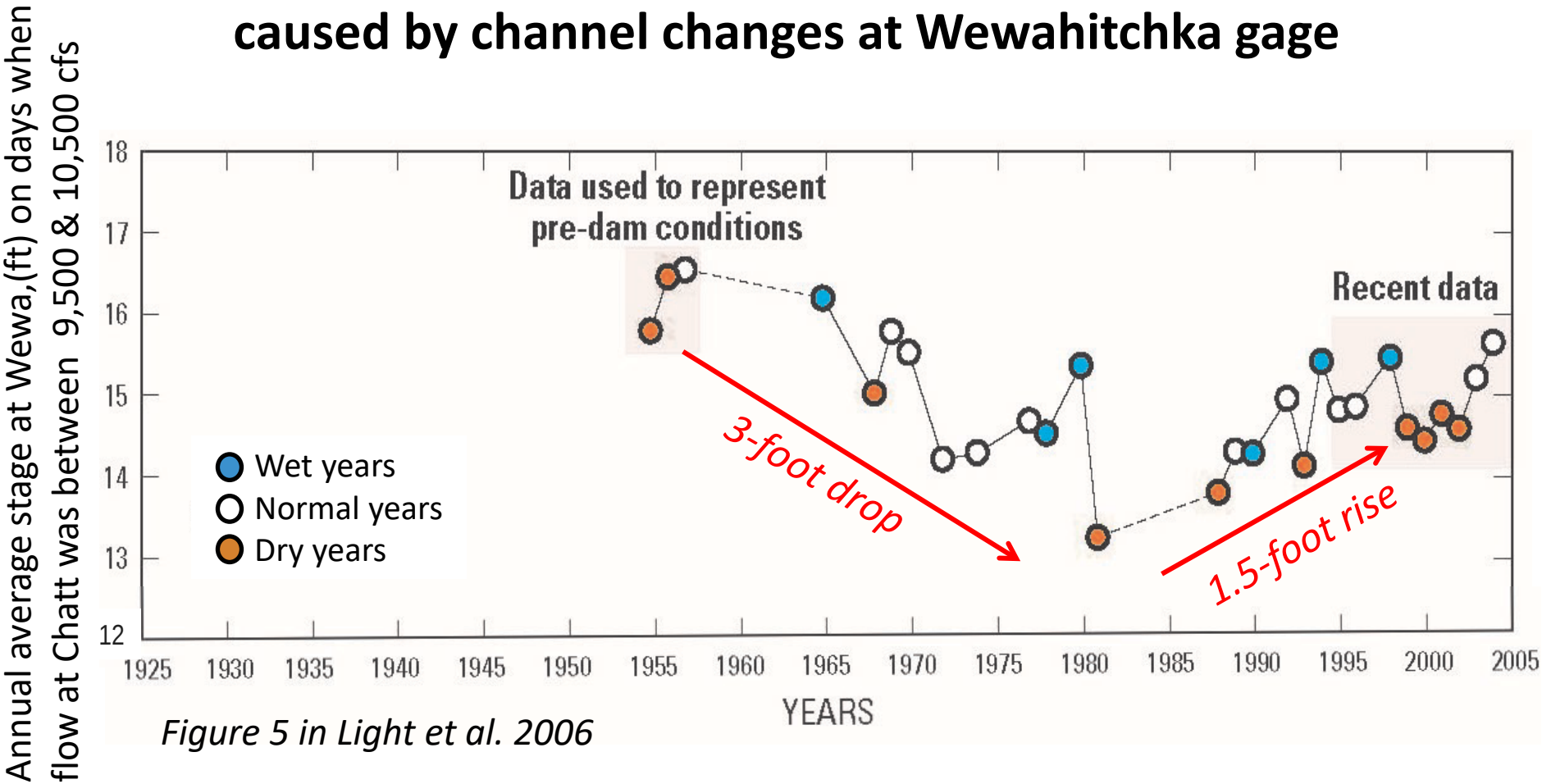


Figure 5 in Light et al. 2006

Changes in water level over time at a constant flow (~10,000 cfs) caused by channel changes at Wewahitchka gage

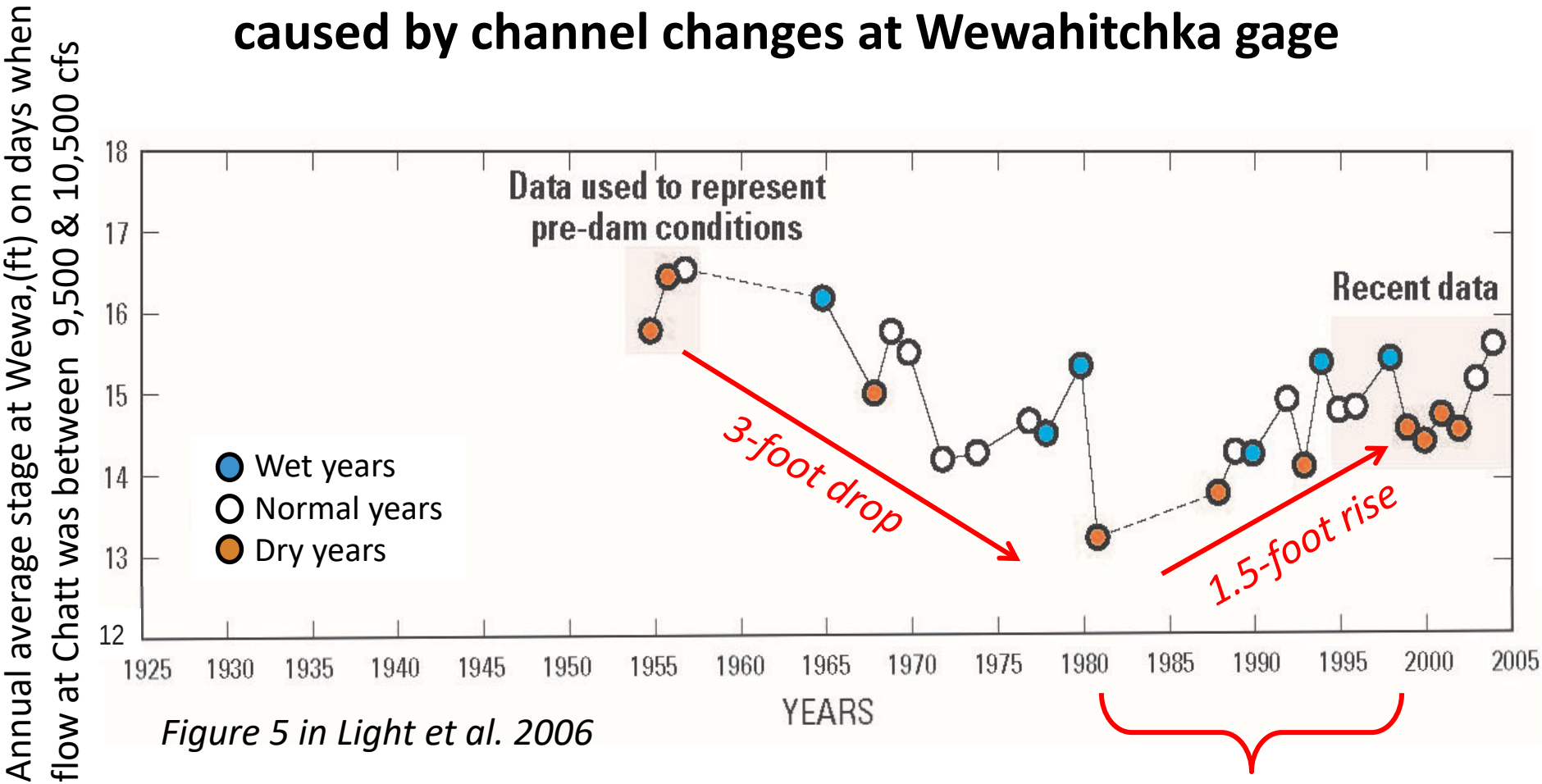


Figure 5 in Light et al. 2006

Increase in hooks and bays 4.5 miles upstream of Wewa gage may be related to post-1980 increase in water levels from channel changes at gage, which likely caused a decrease in slope and velocity immediately upstream.

Lower slope & velocity can increase deposition.

Channel deepening

Mean bed elevation by river mile in 1960 and 2001

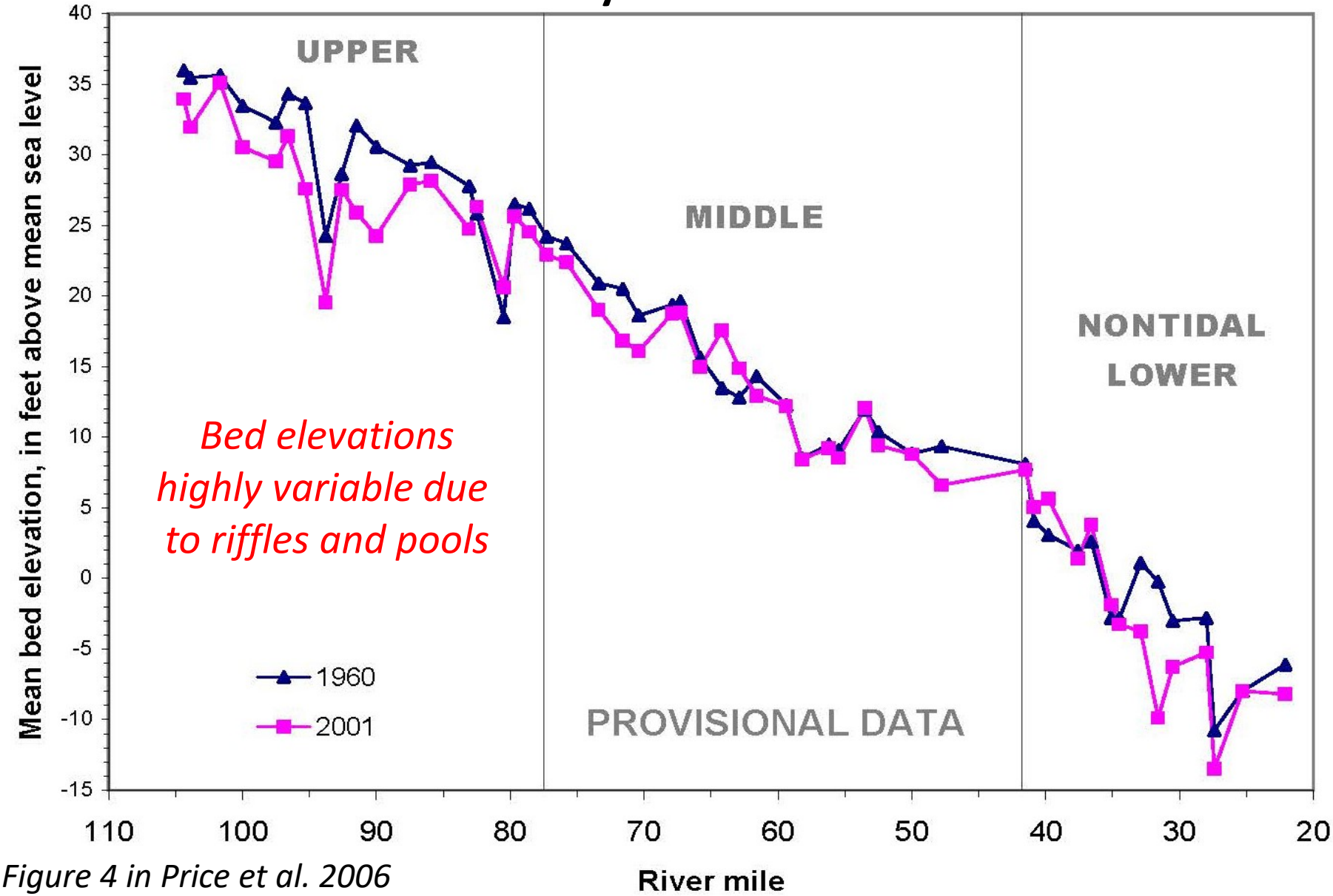


Figure 4 in Price et al. 2006

Channel deepening

Change in bed elevation by river mile from 1960 to 2004

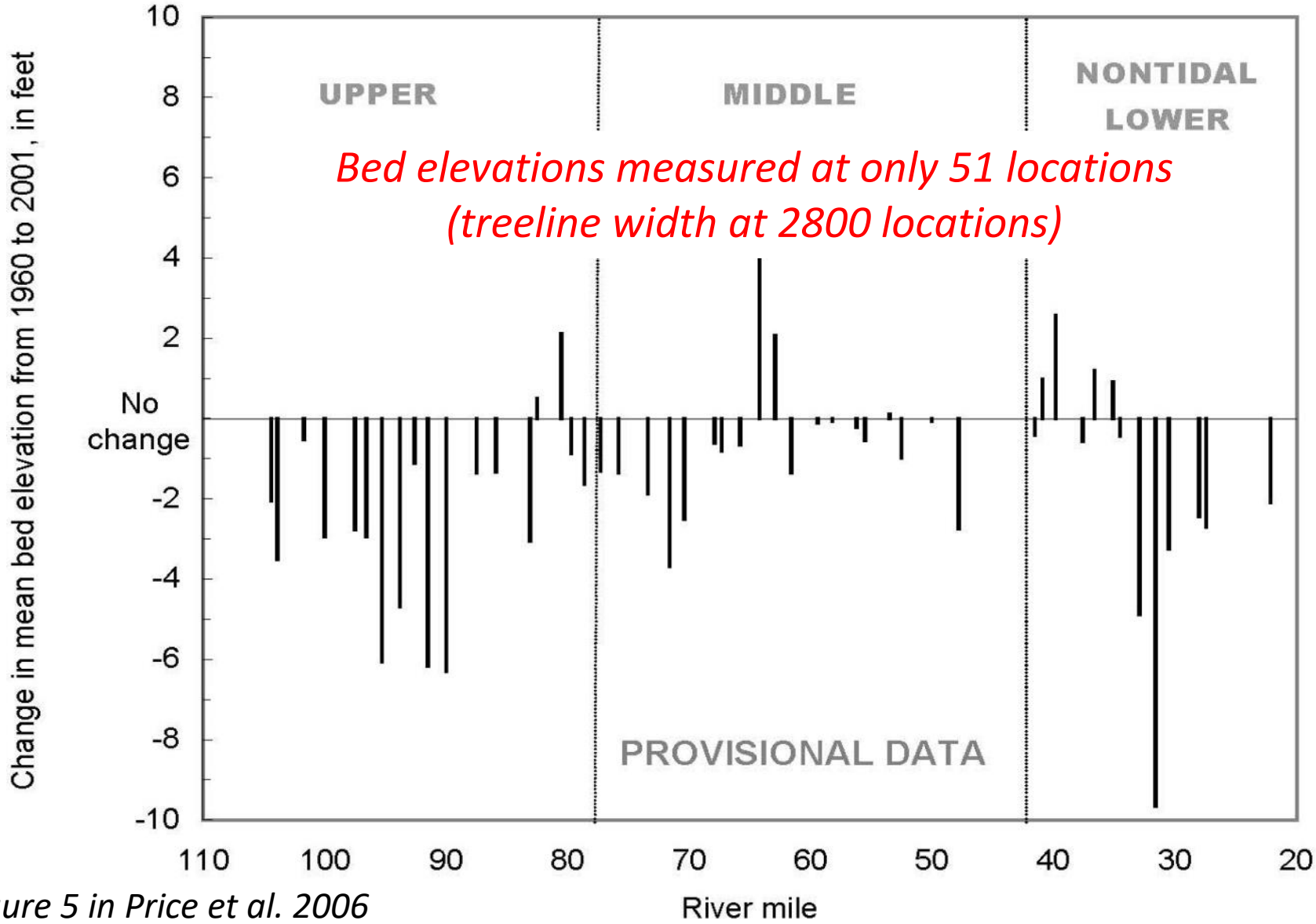
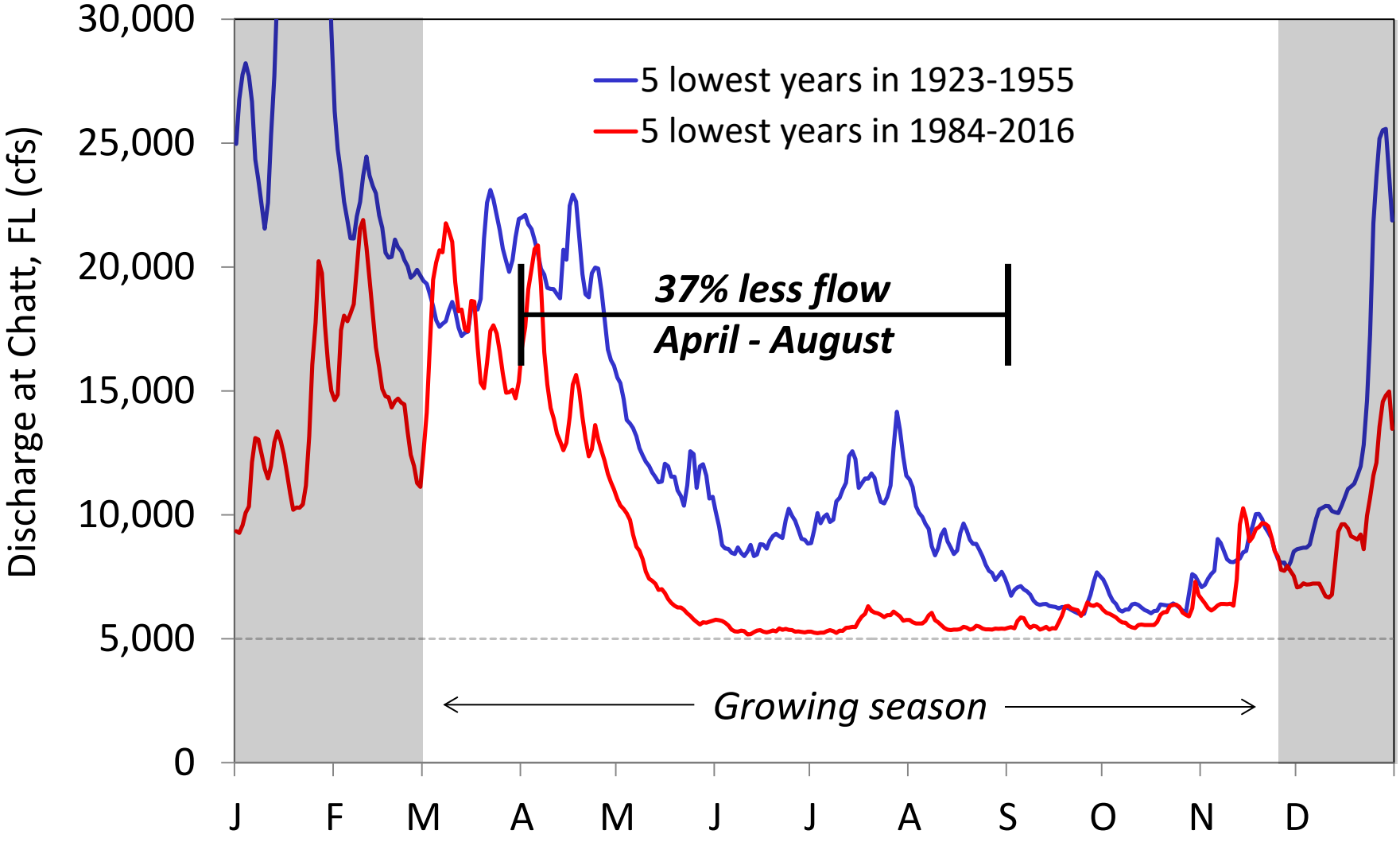


Figure 5 in Price et al. 2006

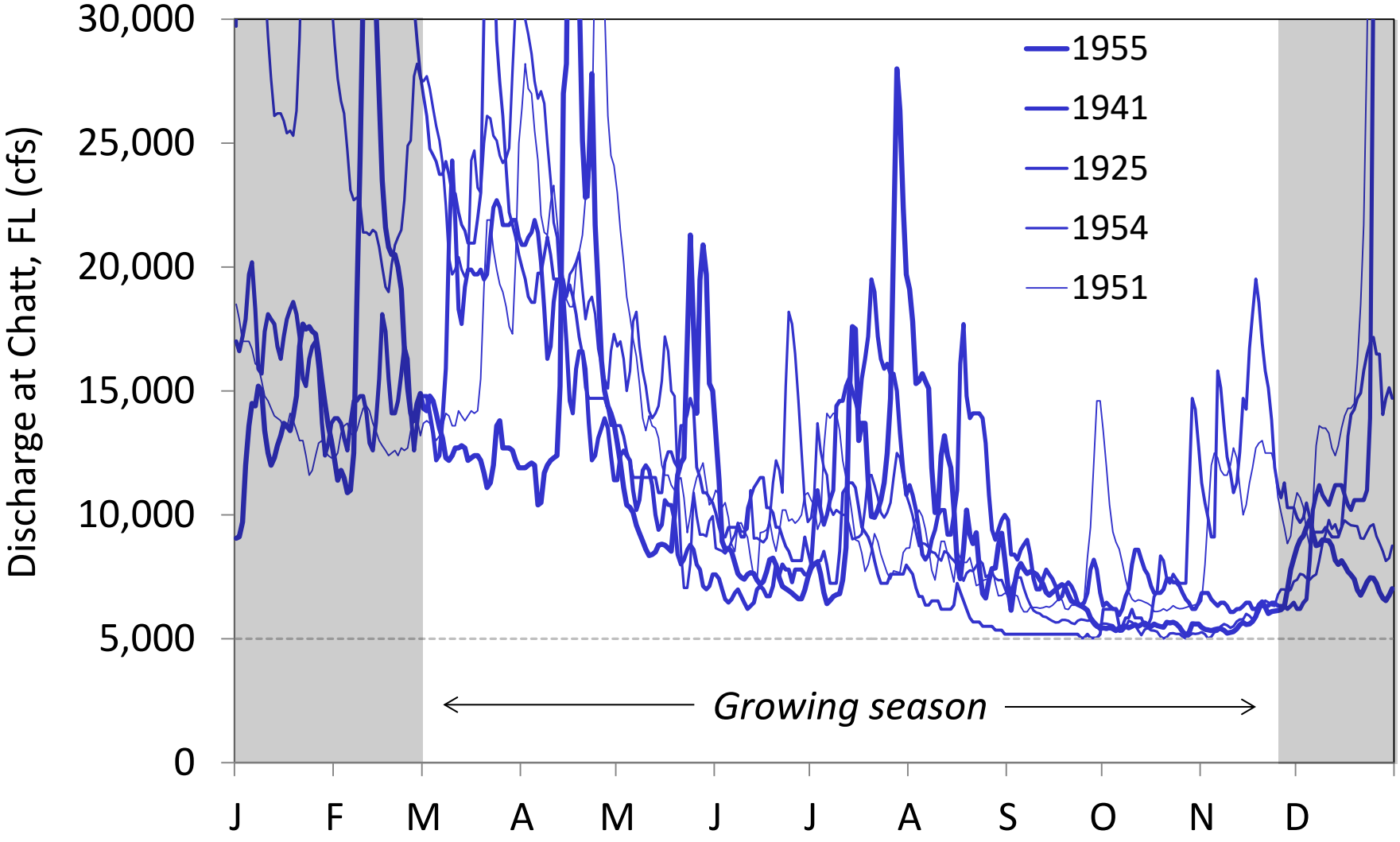
Long-term changes in flow regime in low-flow years

Average of five lowest years in earliest and latest 33 years
Ranked by mean annual *growing season* flow



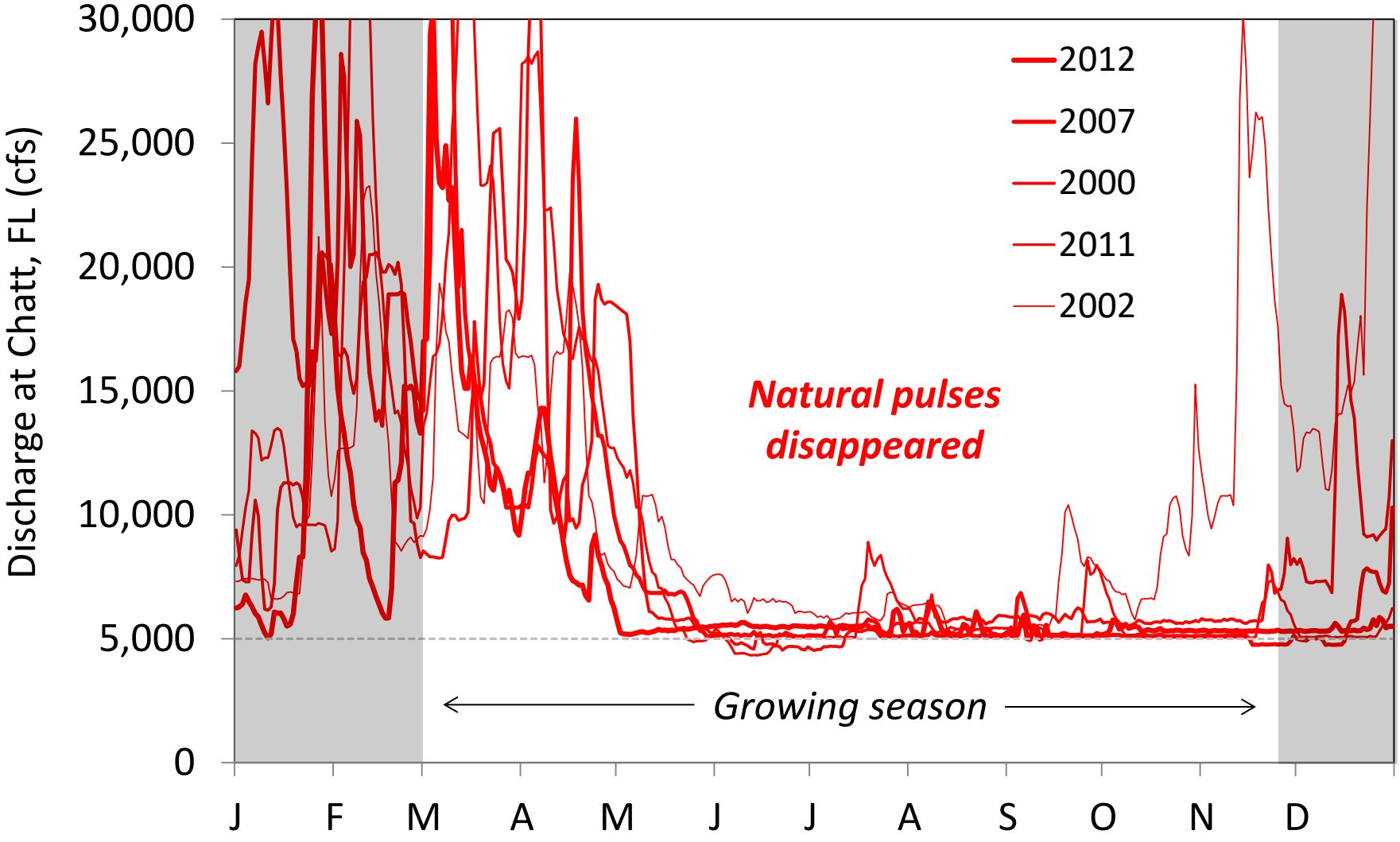
Individual hydrographs for 5 lowest years in <u>earliest</u> period

Ranked by mean annual *growing season* flow in earliest 33 years (1923-1955)

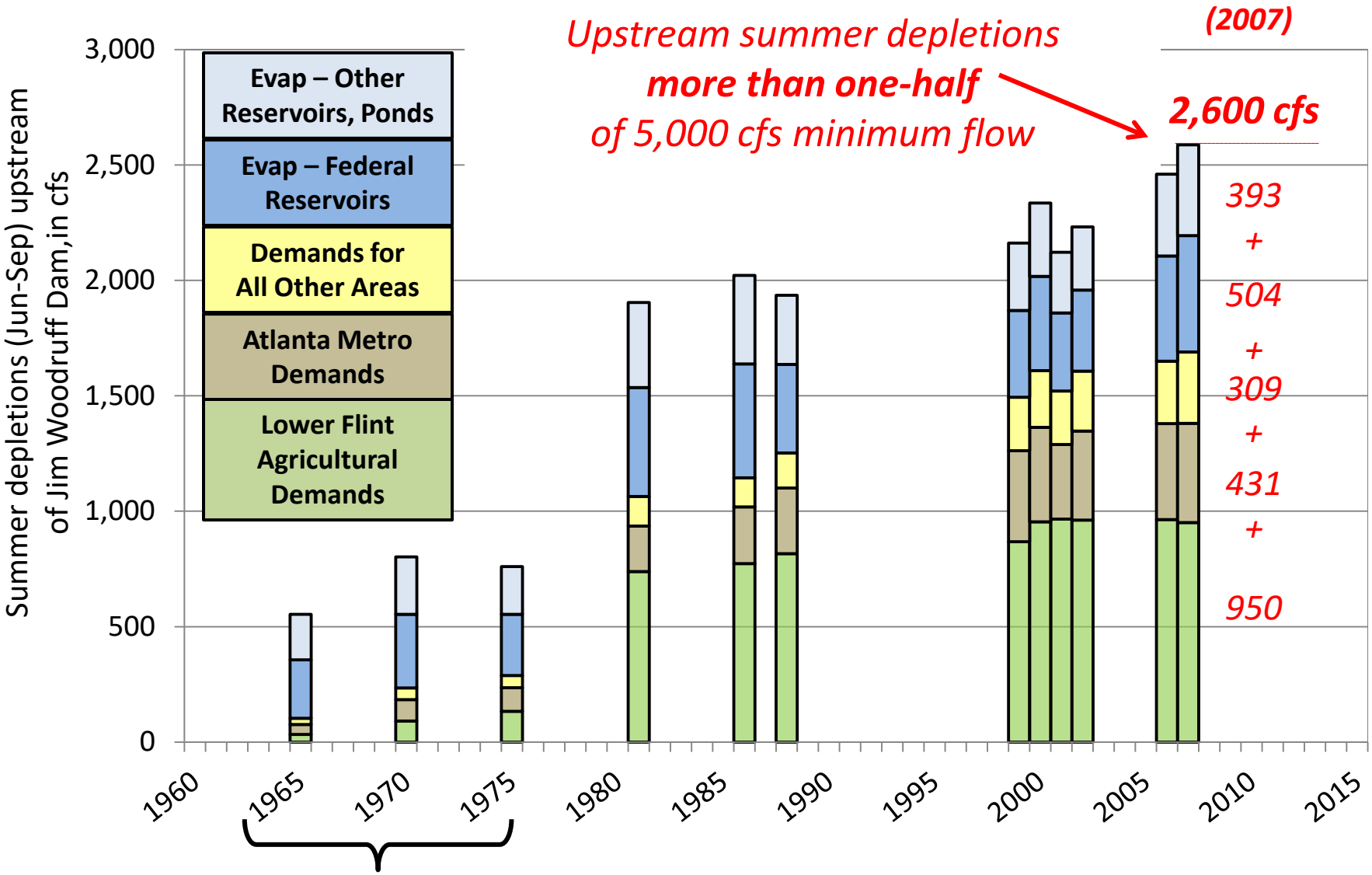


Individual hydrographs for 5 lowest years in latest period

Ranked by mean annual *growing season* flow in latest 33 years (1984-2016)



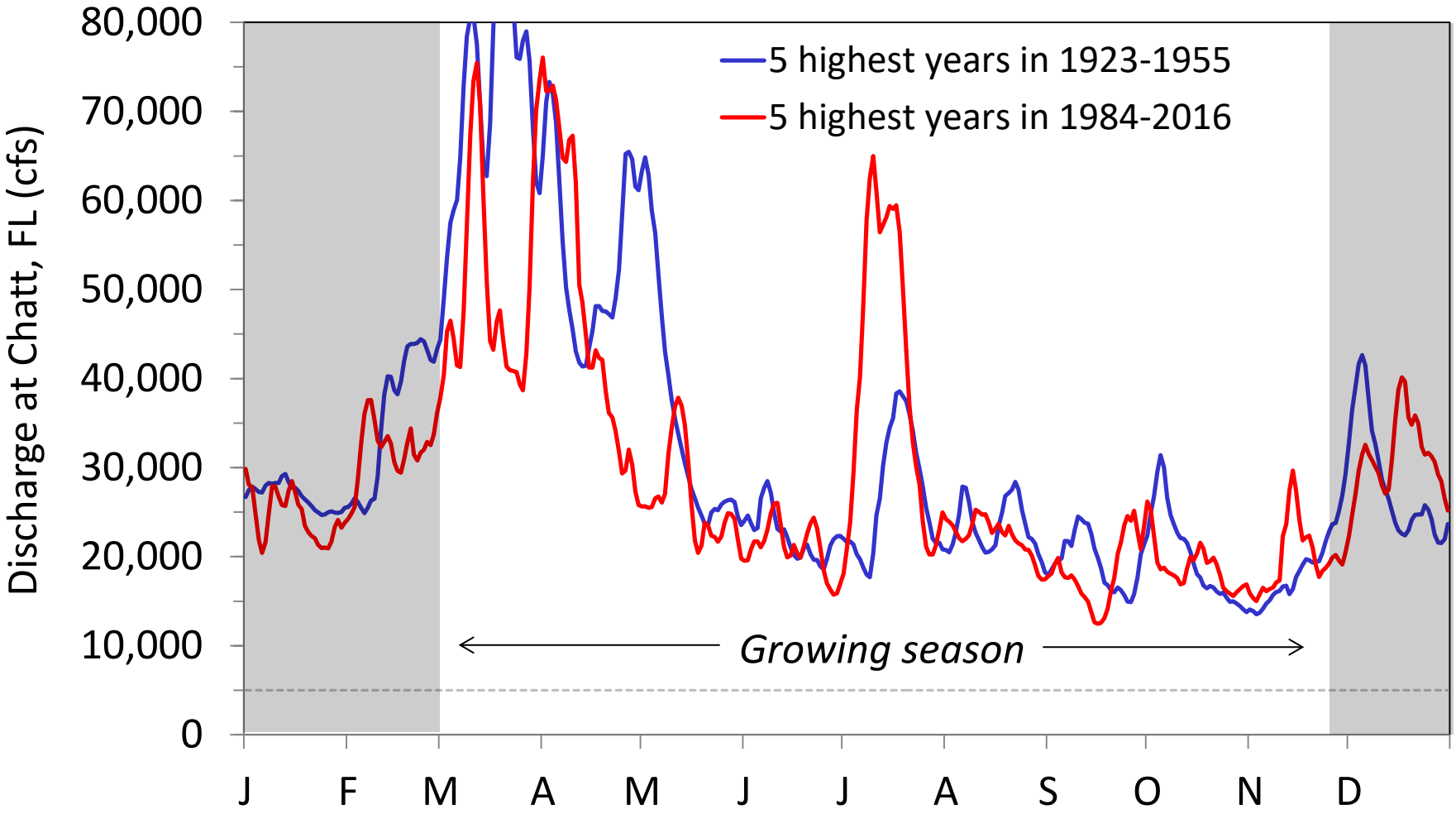
Summer Depletions (June-Sept) in Drought Years



Note: 1965, 1970, and 1975 were not drought years; however, dry- and normal-year demand data prior to 1980 were similar.

No obvious change in flow regime in high-flow years

Average of 5 highest years in earliest and latest 33 years, ranked by mean annual *growing season* flow



Lower low years and no change in high years means biota is subjected to more extremes

Willow growth stabilizes sand on point bars

Helen Light 1979

"Stream geomorphic and substrate stability is especially crucial for the maintenance of diverse, viable mussel beds." *USFWS Recovery Plan (7 mussels)*

Willow recruitment and growth

Germination is best in wet sandy soil *not* covered by water.

Seedlings and cuttings must have high soil moisture but cannot survive deep inundation.

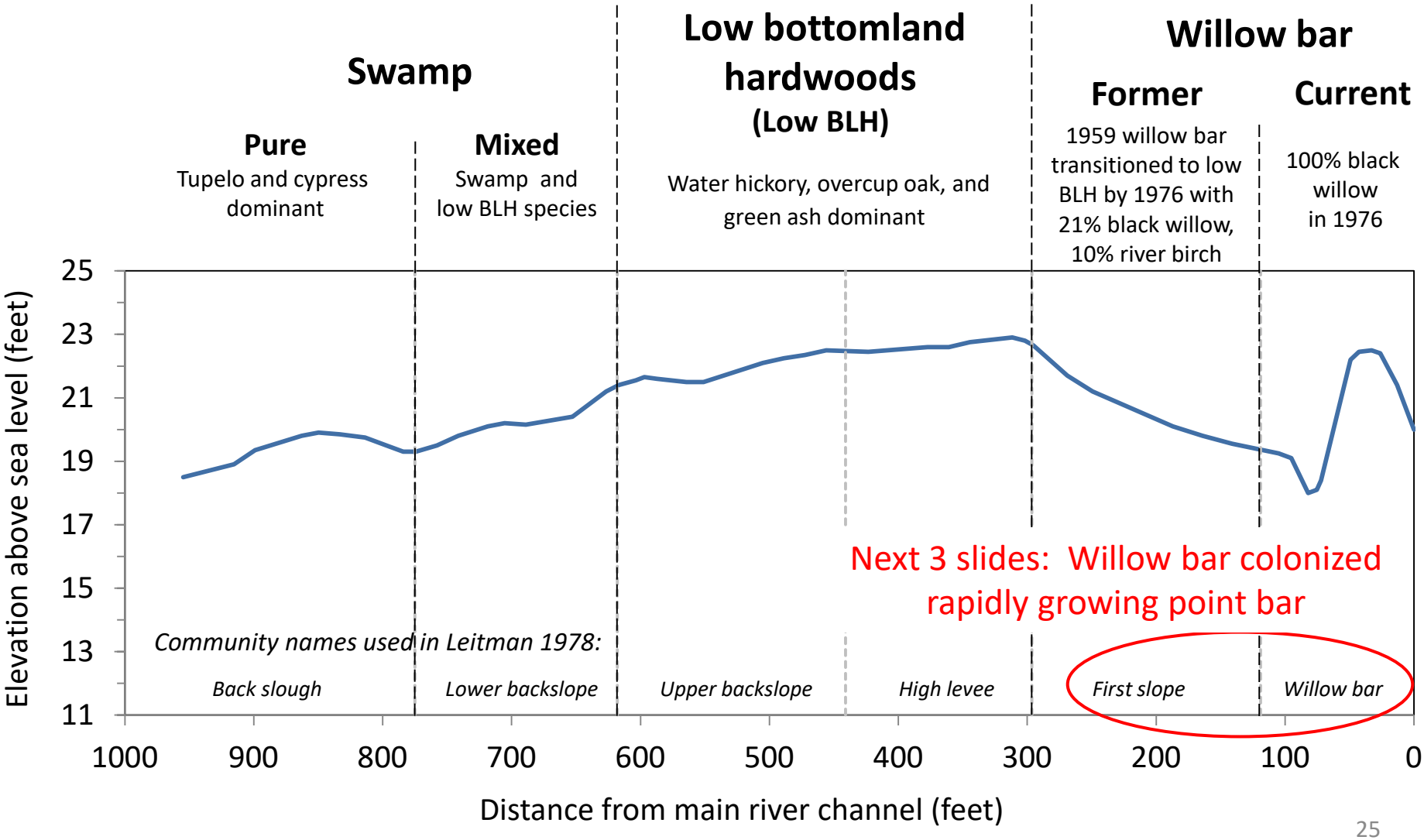
Rapid height growth is essential -- seedlings and saplings can't be overtopped by floods for too long in growing season.

Adult trees do *not* need wet soils; they are highly tolerant of both wet and dry extremes.

Helen Light 2001

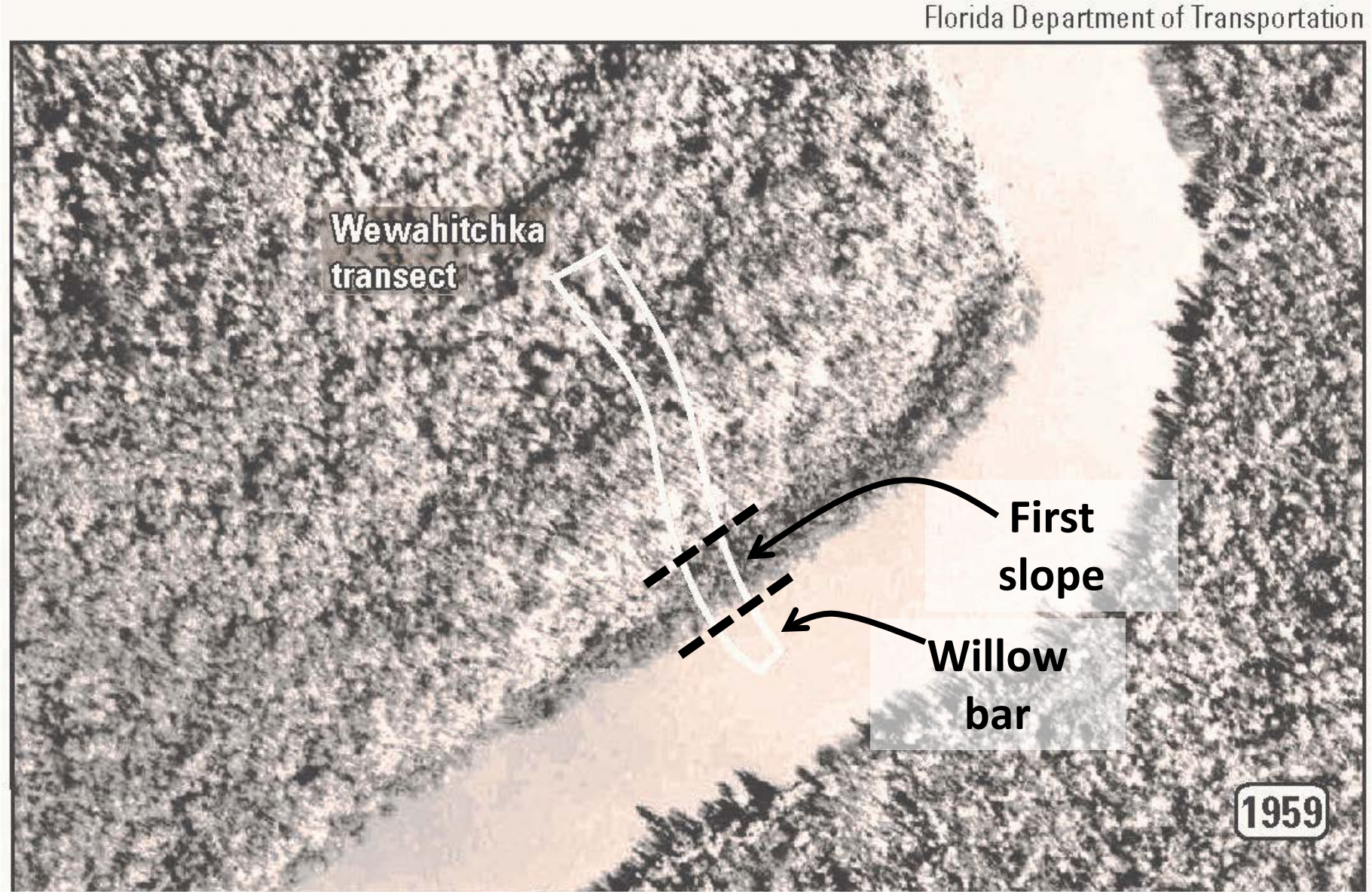
Floodplain trees, elevations, and soils mapped at Mile 41.9 in 1976

From Figure 7 and Table 3 of Leitman 1978 master's thesis, except forest type names above graph which were revised for this presentation. "First slope" was formerly a willow bar 17 years earlier based on 1959 aerial photo (see next slide).



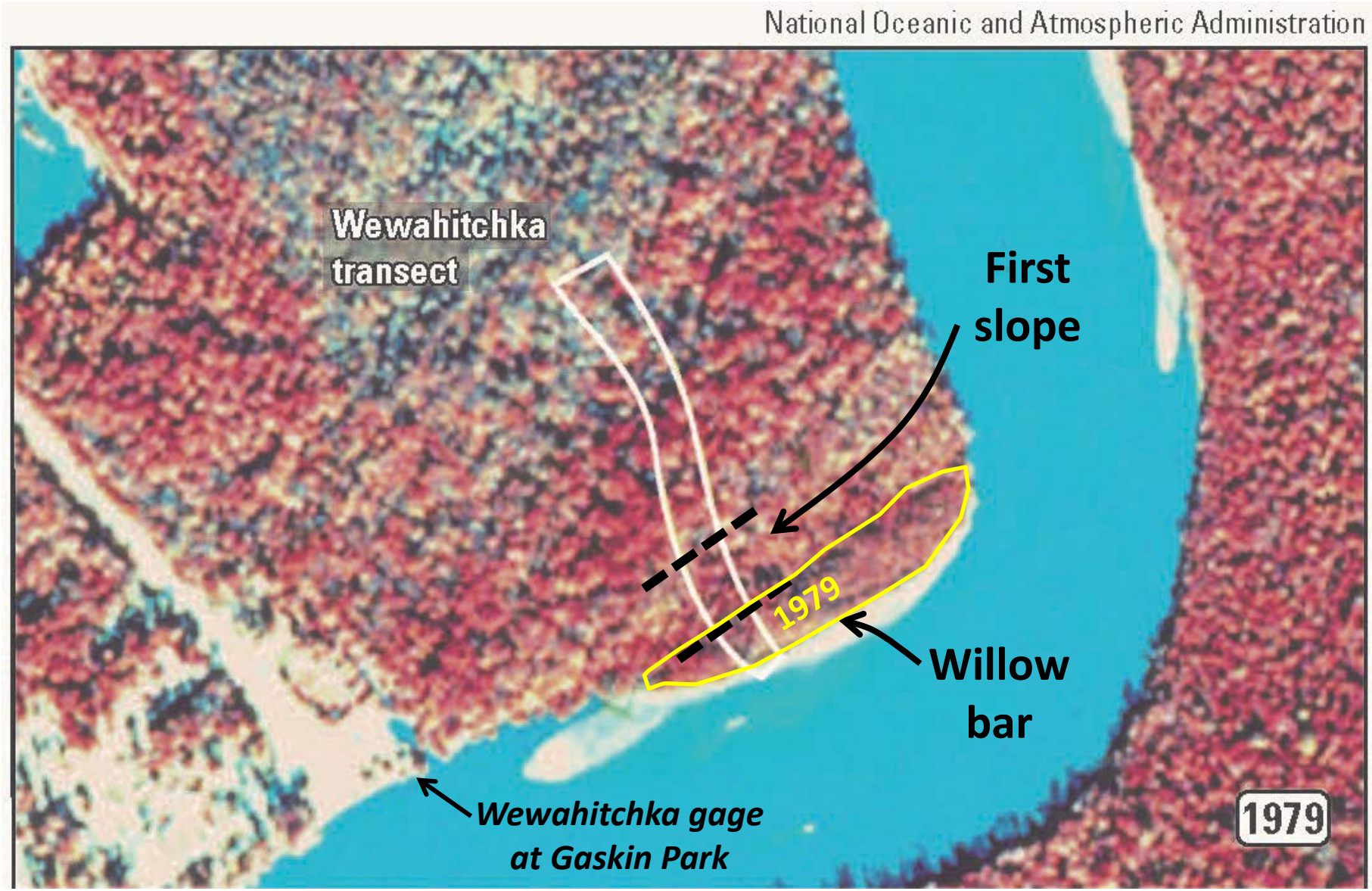
Willow bar and first slope on 1959 aerial photo (17 yrs *before* study)

Boundary of Leitman thesis transect (in white) digitized and projected on aerial photos in Fig 5 of Darst and Light 2008.

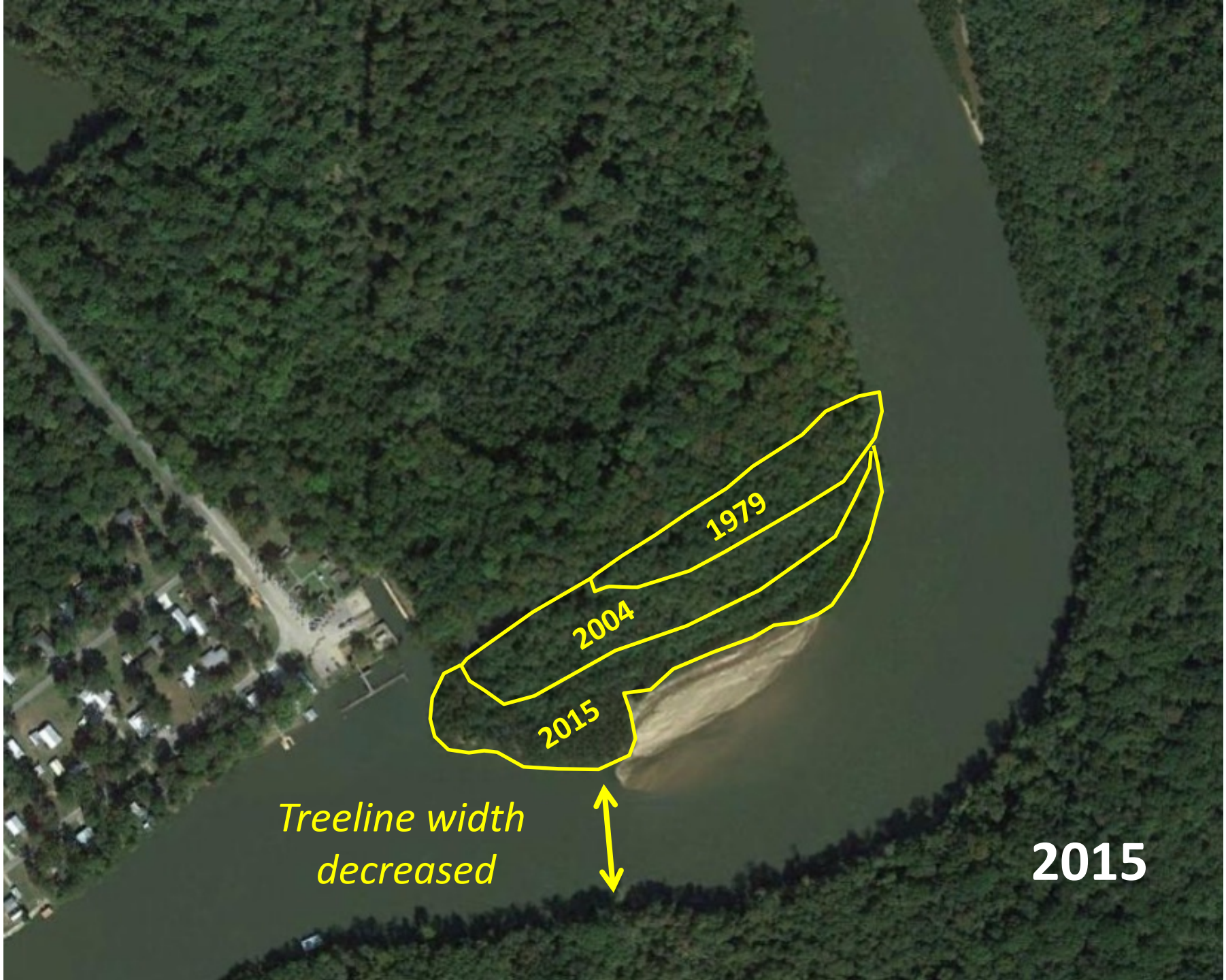


Willow bar and first slope on 1979 aerial photo (3 yrs after study)

Boundary of Leitman thesis transect (in white) digitized and projected on aerial photos in Fig 5 of Darst and Light 2008.



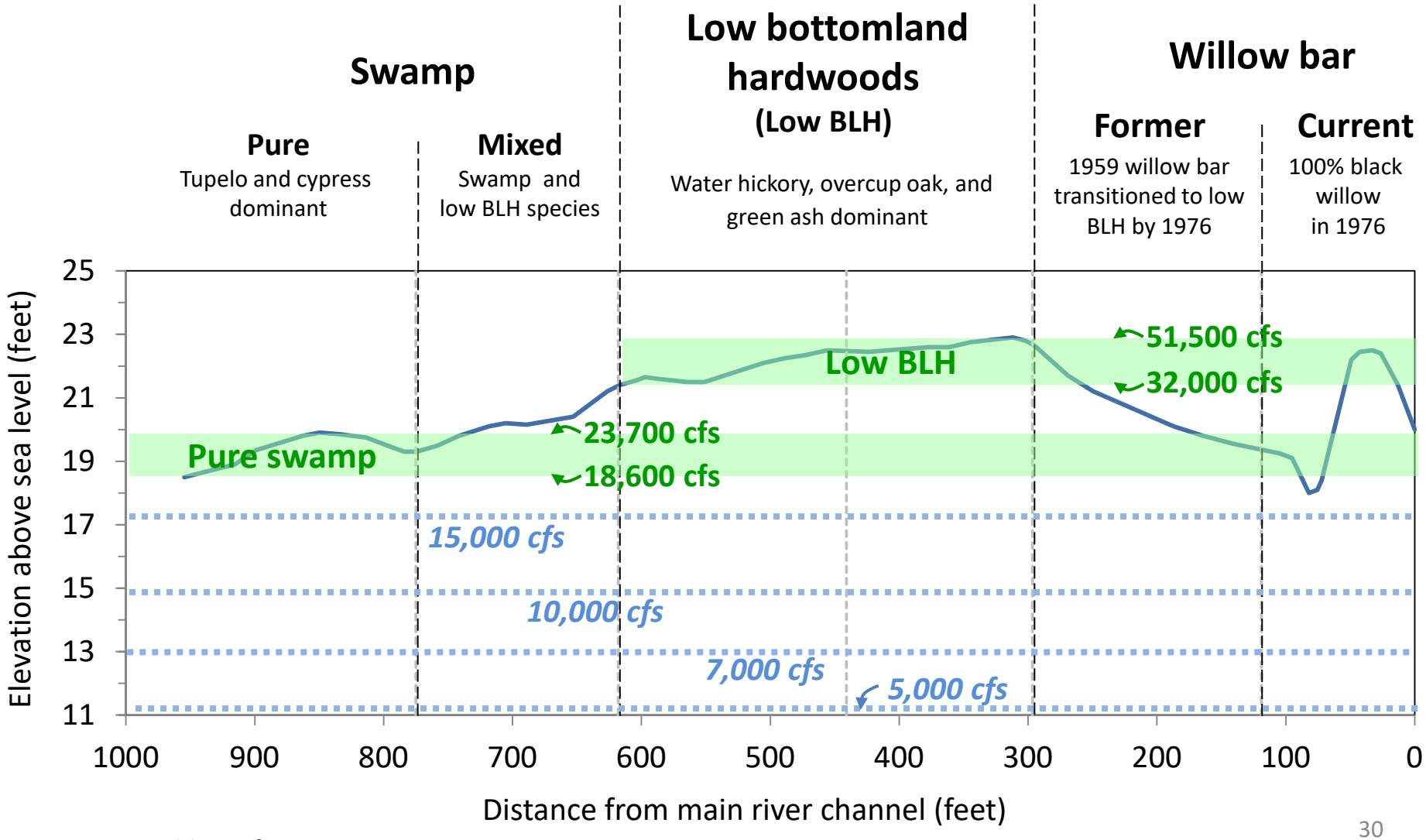
Florida Department of Environmental Protection



Google Earth

Forest types, elevations, and flows

"Recent" stage-discharge relations (as opposed to "pre-dam") were used to determine flows because 1976 water levels at Wewa were very similar to those in recent period.



From Fig. 7, Table 3 of Leitman 1978

Particle size distribution, in percent:

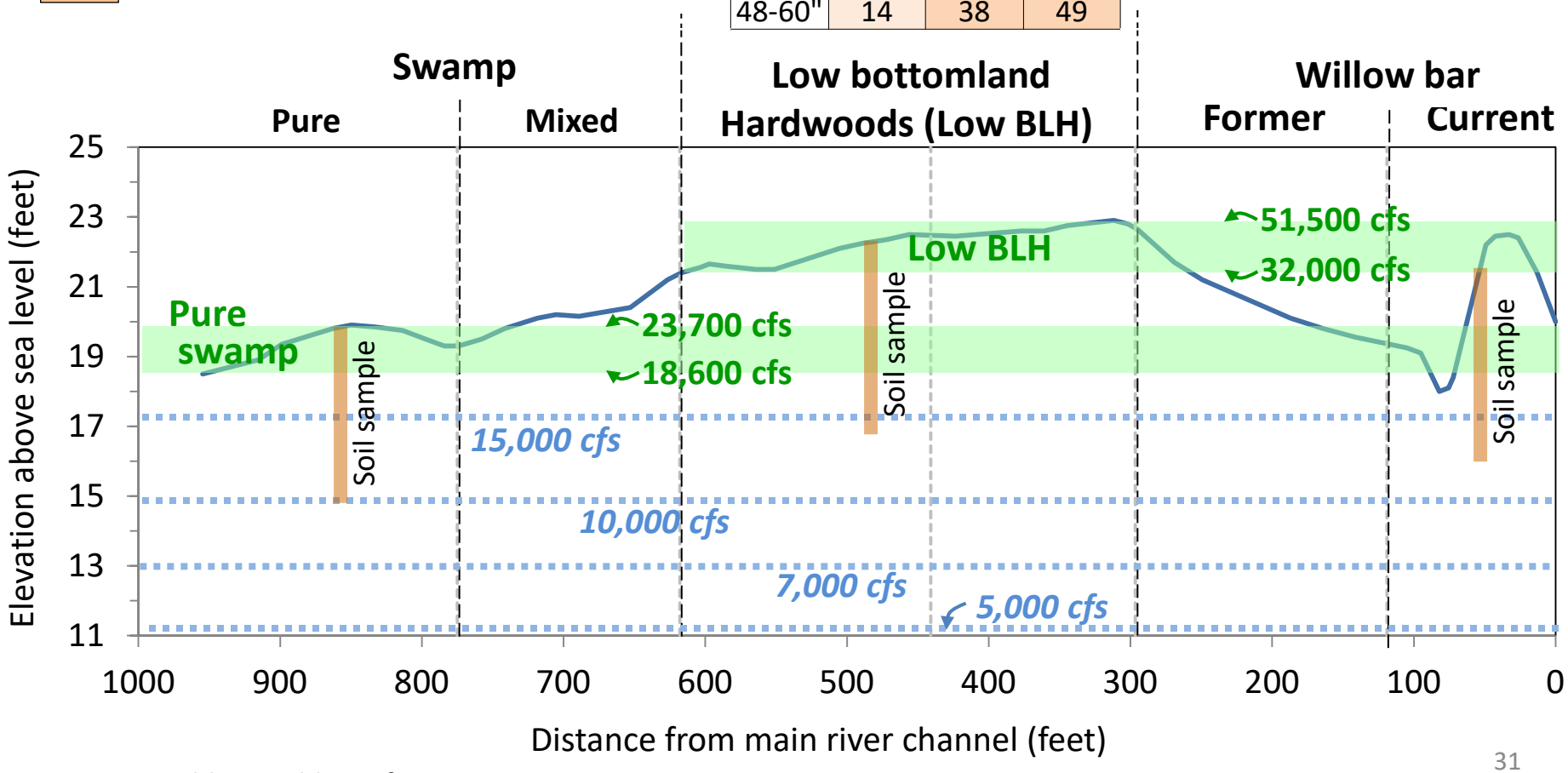
- 10-30%
- 30-50%
- >50%

Pure swamp			
	Sand	Silt	Clay
0-6"	4	19	76
6-18"	2	21	77
18-24"	2	23	76
24-36"	1	22	77
36-60"	1	26	73

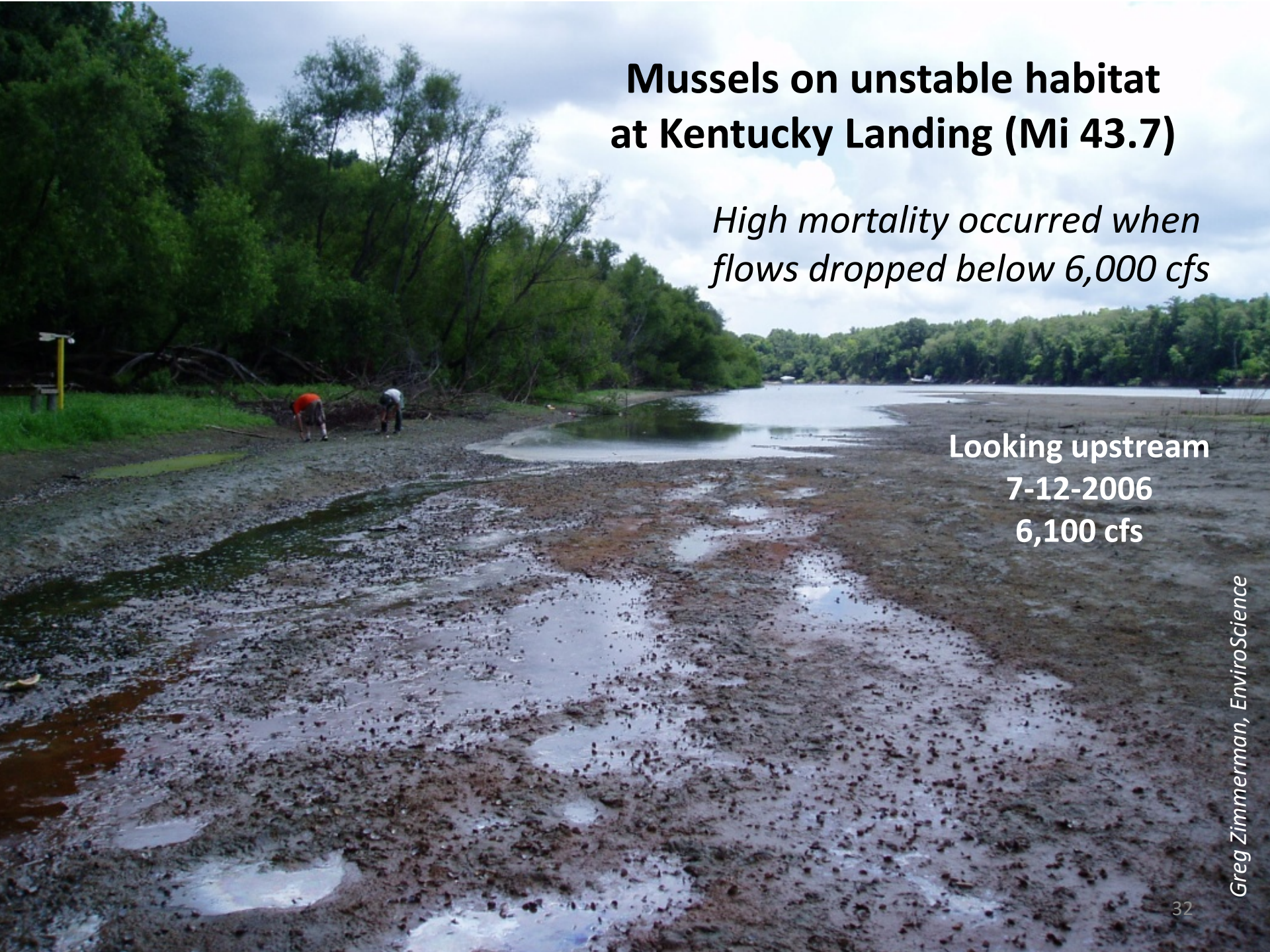
Low BLH			
	Sand	Silt	Clay
0-2"	5	30	64
2-11"	3	32	65
11-20"	7	41	52
20-32"	16	39	45
32-48"	4	33	63
48-60"	14	38	49

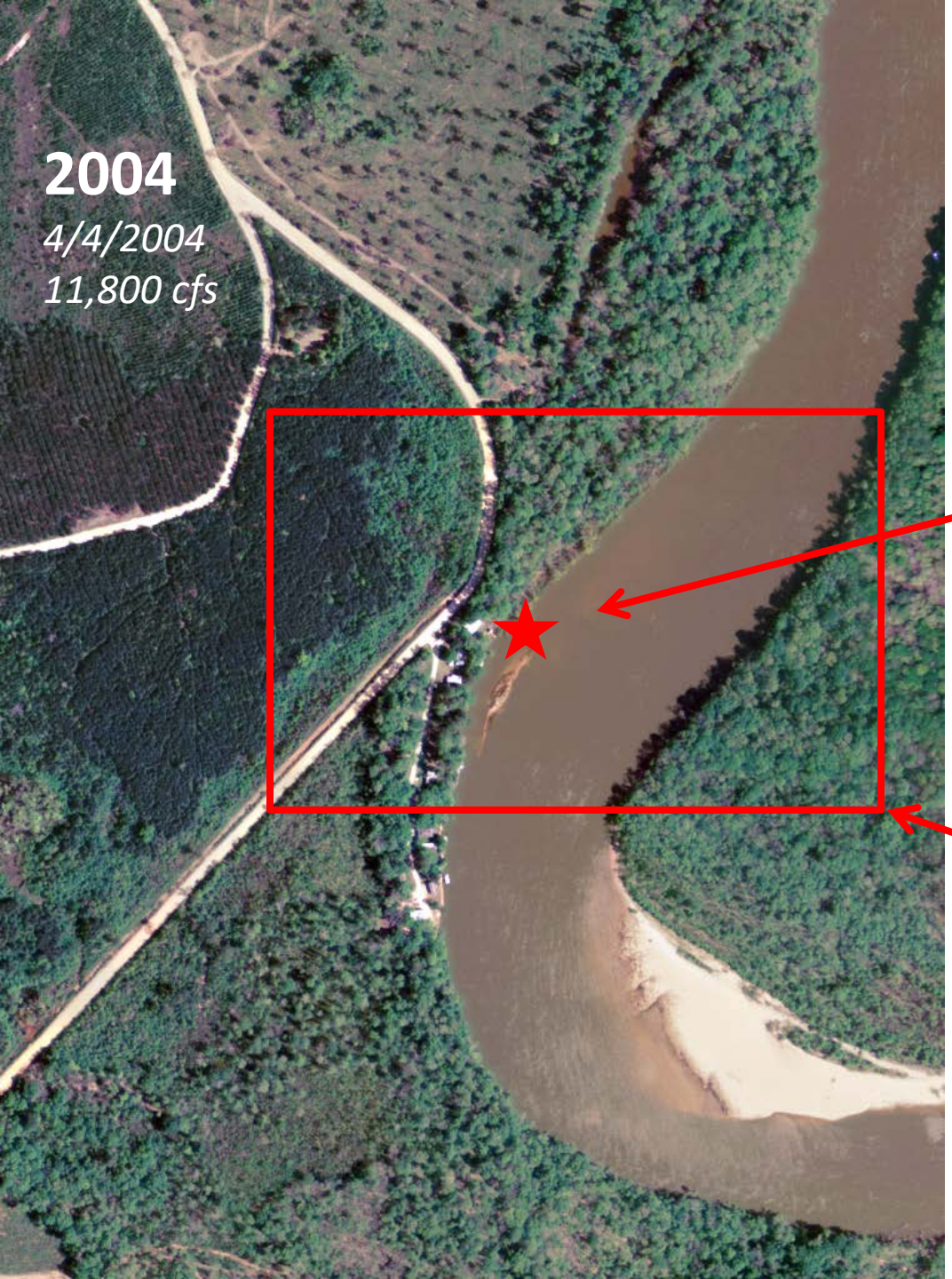
Willow bar			
	Sand*	Silt	Clay
0-12"	86	0	18
15-50"	68	16	17
50-60"	69	16	16

**99% of sand in willow bar is fine and very fine*



From Fig. 7, Table 3, Table 7 of Leitman 1978

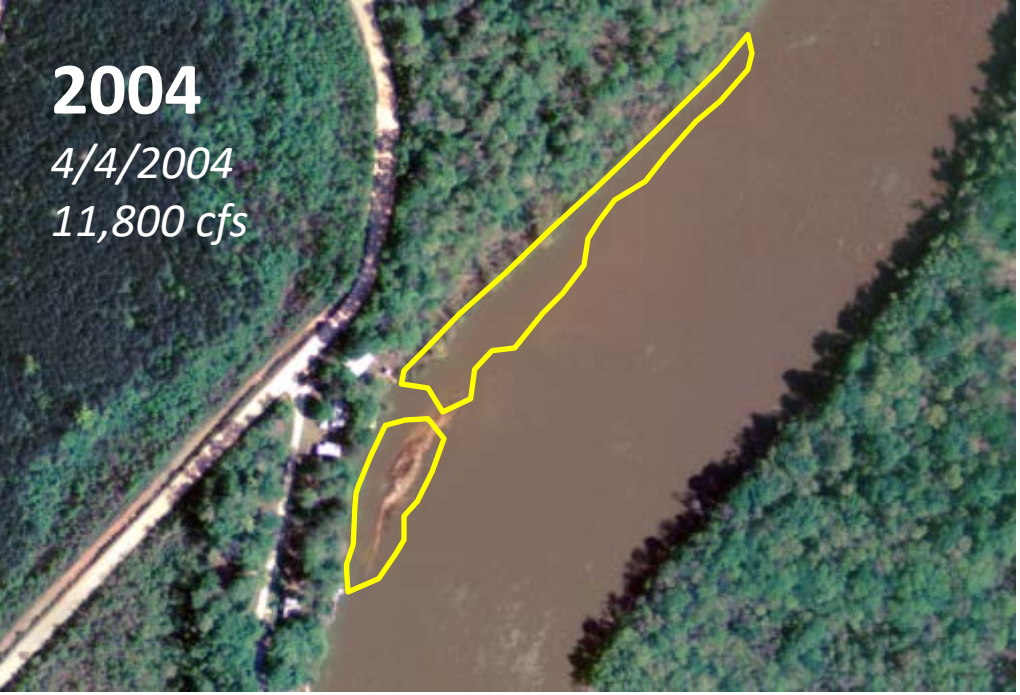

Mussels on unstable habitat
at Kentucky Landing (Mi 43.7)
High mortality occurred when
flows dropped below 6,000 cfs
Looking upstream
7-12-2006
6,100 cfs
Greg Zimmerman, EnviroScience

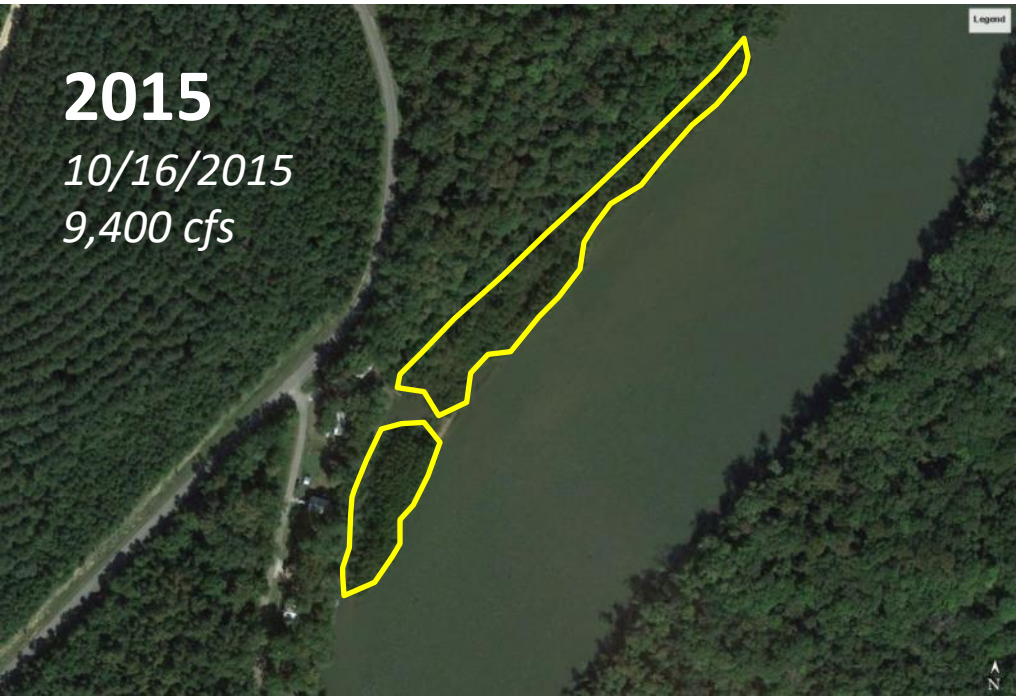


Mussel beds at Kentucky Landing on outside of bend

Photo location of previous slide

Scenes on next slide

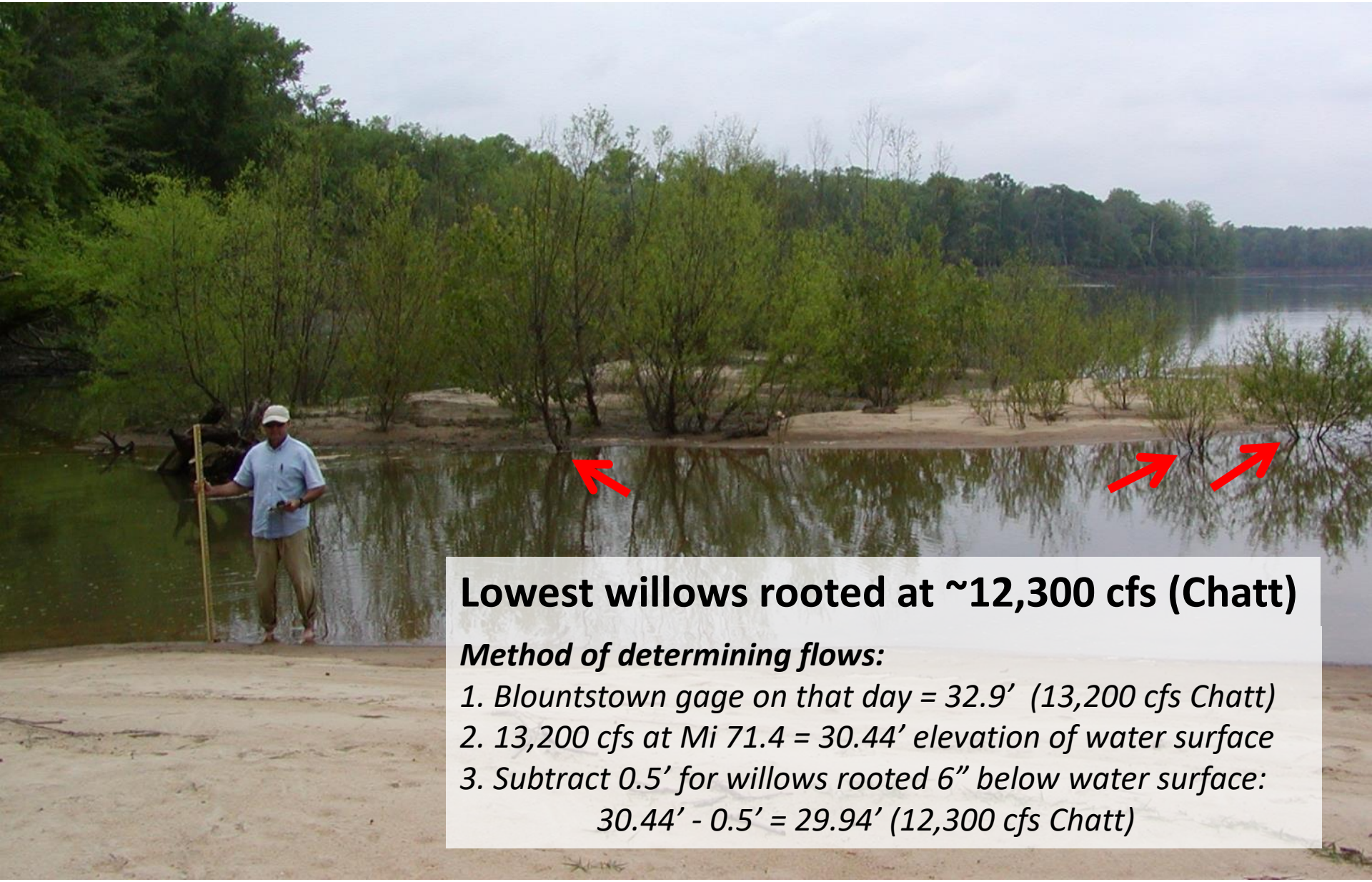




Dense willow growth in 10 years at Kentucky Landing, Mi 43.7

Outlined areas had no trees in 2004; thick growth of willows in 2015

Young willows at Mile 71.4 (Poloway Cutoff) April 11, 2002



Lowest willows rooted at ~12,300 cfs (Chatt)

Method of determining flows:

1. Blountstown gage on that day = 32.9' (13,200 cfs Chatt)

2. 13,200 cfs at Mi 71.4 = 30.44' elevation of water surface

3. Subtract 0.5' for willows rooted 6" below water surface:

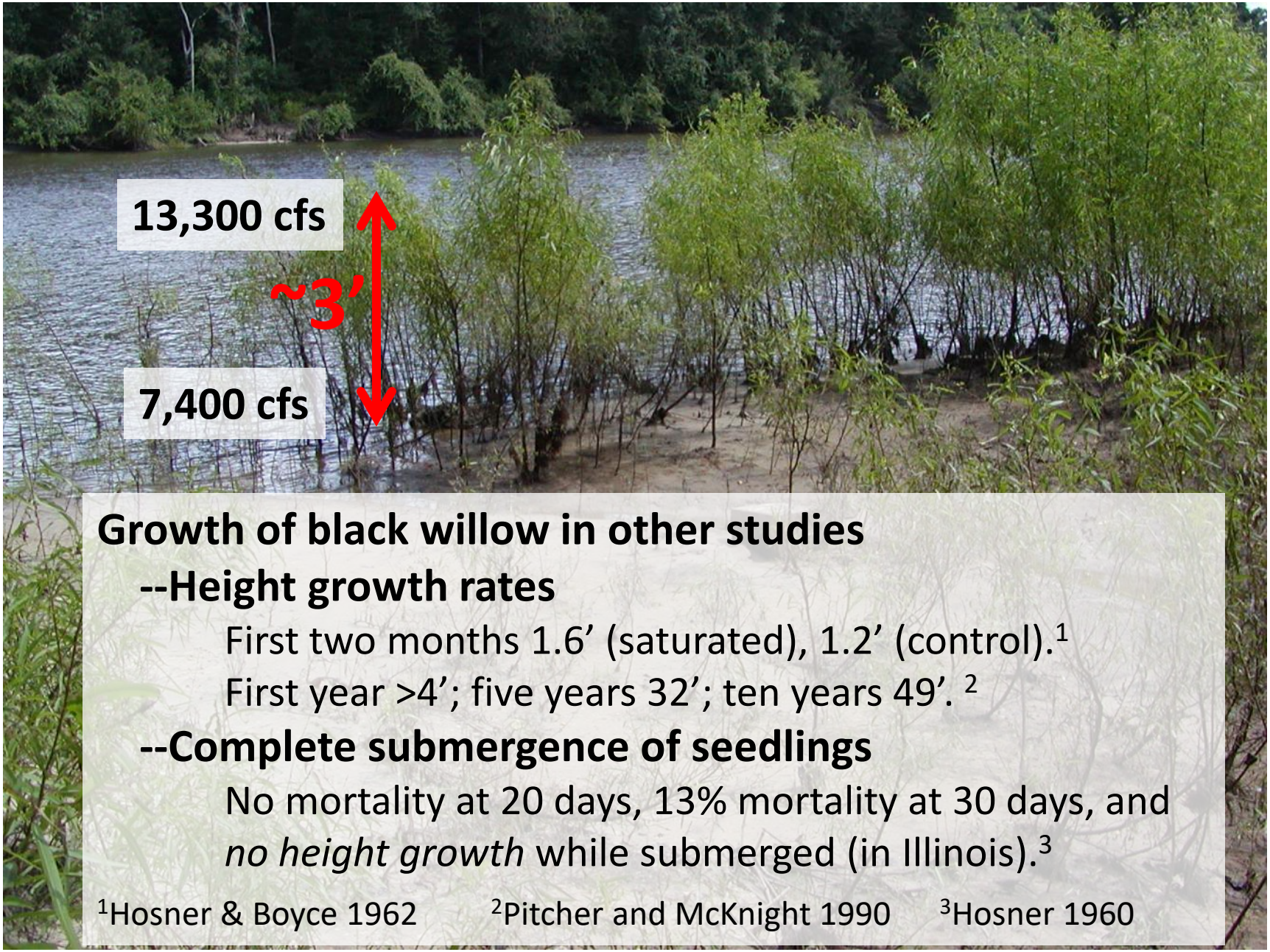
30.44' - 0.5' = 29.94' (12,300 cfs Chatt)

Helen Light

Young willows at Mile 30 (Douglas feeder slough) Sept. 12, 2001

Helen Light

Young willows at Mile 30 (Douglas feeder slough) Sept. 12, 2001



Growth of black willow in other studies

--Height growth rates

First two months 1.6' (saturated), 1.2' (control).[1]

First year >4'; five years 32'; ten years 49'. [2]

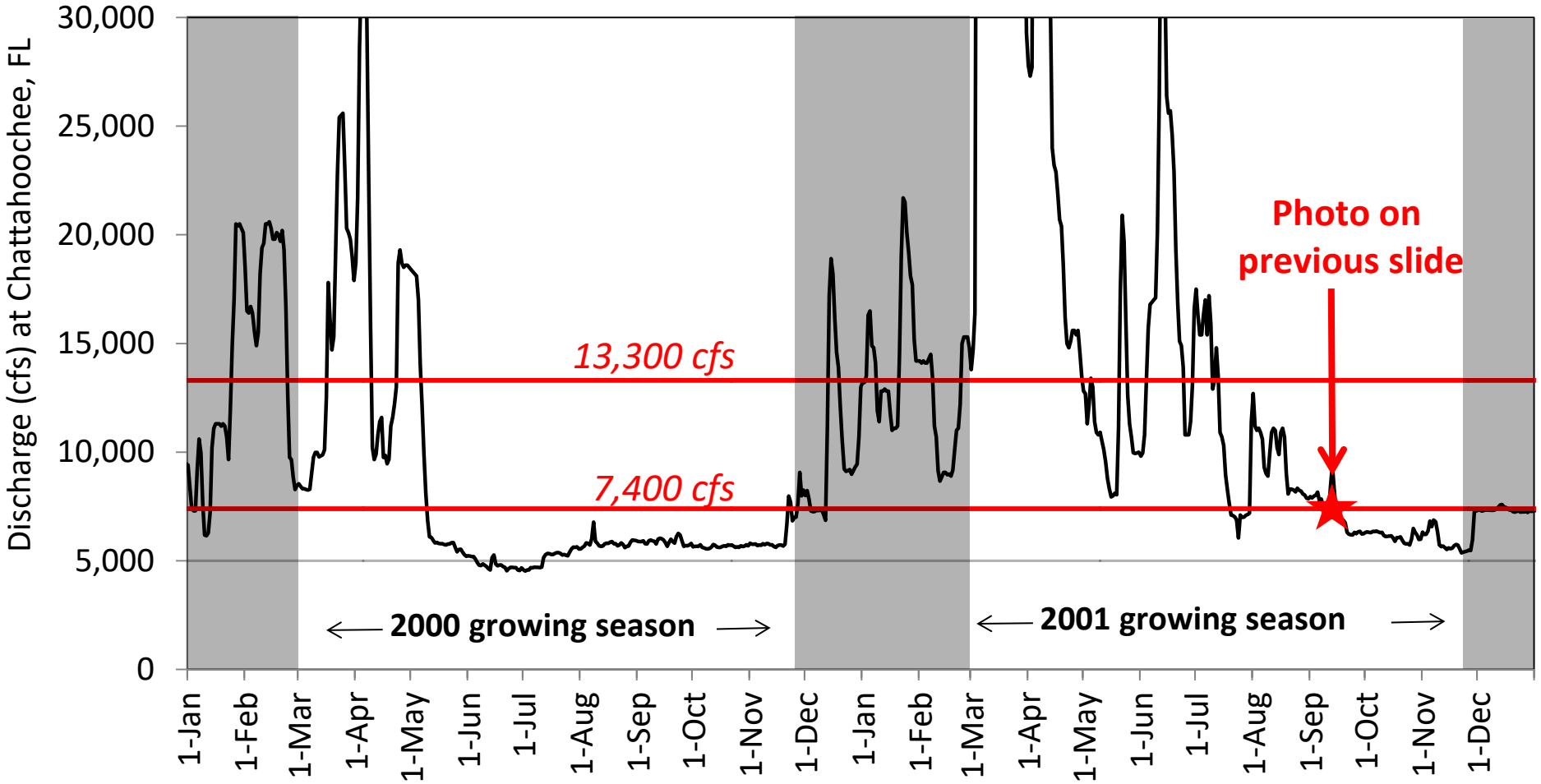
--Complete submergence of seedlings

No mortality at 20 days, 13% mortality at 30 days, and *no height growth* while submerged (in Illinois).[3]

[1]Hosner & Boyce 1962 [2]Pitcher and McKnight 1990 [3]Hosner 1960

Helen Light

Chattahoochee flows in relation to photo date



Seedlings likely germinated May 2000, and survived 2 months of complete submergence in March-April 2001 when temperatures were still low. Remaining floods in summer 2001 were less than 3 weeks, and 2002 had little flooding.

Some point bars have been resistant to willow recruitment

Example: Louisa Bend at Mile 38.7

↑ ***Before 1999***

No spoil disposal for at least 22 years or longer (no records prior to 1977).

After 1999 →

Spoil disposal only once in 2001.

Isolated willows finally taking hold. Because dredging stopped in 2002? Or antecedent flows and soil characteristics right for recruitment?

Copies of this presentation and the following sources are available upon request

helenmlight@gmail.com

Darst, M.R., and Light, H.M. 2008. Drier forest composition associated with hydrologic change in the Apalachicola River floodplain, Florida: U.S. Geological Survey Scientific Investigations Report 2008-5062, 81 p. *http://pubs.usgs.gov/sir/2008/5062/*

FDEP. 2013. Addendum to February 2011 Fish and Wildlife Coordination Act (FWCA) report. Attachment to January 14, 2013 letter from Thomas Beason (DEP) to Tetra Tech (USACE contractor) RE: Comments on ACF Master Water Control Manual. 26 p. plus digital appendix with species lists (Appendix III).

Hosner, J.F., 1960, Relative tolerance to complete inundation of fourteen bottomland tree species: Forest Science, v. 6, no. 3, p. 246-251.

Hosner, J.F., and Boyce, S.G., 1962, Tolerance to water saturated soil of various bottomland hardwoods: Forest Science, v. 8, no. 2, p. 180–186.

Leitman, H.M., 1978, Correlation of Apalachicola floodplain tree communities with water levels, elevation, and soils: Master's thesis, Tallahassee, Florida State University. 57 p.

Light, H.M., Vincent, K.R., Darst, M.R., and Price, F.D. 2006. Water-Level Decline in the Apalachicola River, Florida, from 1954 to 2004, and Effects on Floodplain Habitats: U.S. Geological Survey Scientific Investigations Report 2006-5173, 83 pp., plus CD. *http://pubs.usgs.gov/sir/2006/5173/*

McCluskey, D.C., Brown, J., Bornholdt, D., Duff, D.A., and Winward, A.H. 1983. Willow planting for riparian habitat improvement. USDI-BLM, Tech Note 363. 21 pages.

McLeod, K.W., and McPherson, J.K. 1973 Factors limiting the distribution of *Salix nigra*. Bulletin of the Torrey Botanical Club 100(2):102-110.

Price, F.D., Light, H.M., Darst, M.R., Griffin, E.R., Vincent, K.R., and Ziewitz, J.W. 2006.Change in channel width from 1941 to 2004, and change in mean bed elevation from 1960 to 2001, in the nontidal Apalachicola River, Florida: U.S. Government Printing Office. *http://permanent.access.gpo.gov/lps89667/*

Pitcher, J.A., and McKnight, J.S. 1990. Black willow (*Salix nigra* Marsh.). *In* Silvics of North America: Vol. 2. Hardwoods. p. 768-772. Burns, R.M., and Honkala, B.H., tech. coords. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, D.C.

U.S. Fish and Wildlife Service. 2003. Recovery Plan for Endangered Fat Threeridge, Shinyrayed Pocketbook, Gulf Moccasinshell, Ochlockonee Moccasinshell, Oval Pigtoe, and Threatened Chipola Slabshell, Purple Bankclimber. 149 p. *https://www.fws.gov/panamacity/resources/7_Mussel_Recovery_Plan_Sep_2003.pdf*

Zonge, L., Davison, J .and Swanson, S. 1997. Tips for successfully planting willows in riparian areas. University of Nevada Reno Cooperative Extension Unit, Fact sheet 97-09.

Example Instructions

How to use nonstandard stage-discharge relations in Light et al. 2006 to estimate Chattahoochee flows for different elevations at downstream locations.

Nonstandard stage-discharge relations for every 0.1 mile can be obtained from the following site:
https://pubs.usgs.gov/sir/2006/5173/

Click on:
Digital files of stage-discharge relations at streamgages and between-gage sites

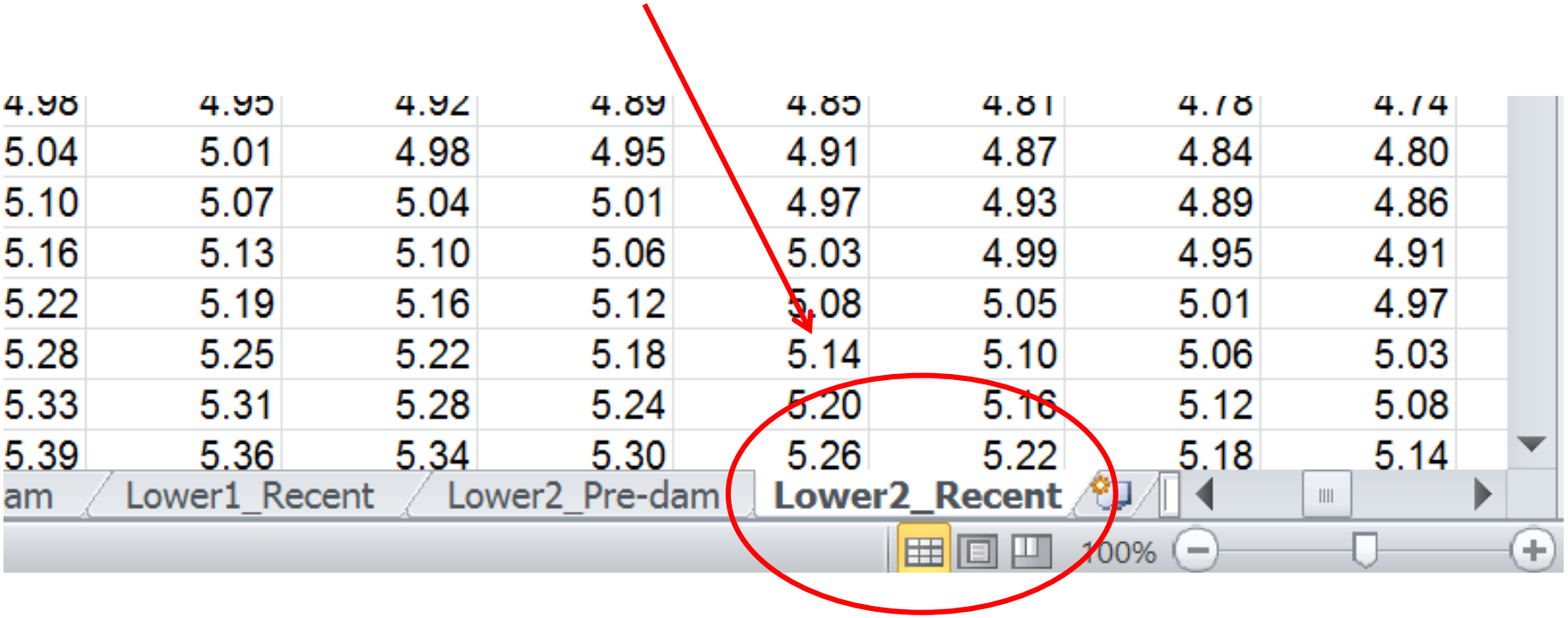
Then click on:
Excel formatted files.xls

Estimating flows for base and top of willows in Mi 30 photo:

1) Get mean daily stage at closest gage on date of photo (9-12-2001).

Closest gage at the time was Mile 35 gage, which was <u>6.48 ft</u> on that day.

2). Select tab for "Recent" stage for lowest reach (Lower2).



4.98	4.95	4.92	4.89	4.85	4.81	4.78	4.74
5.04	5.01	4.98	4.95	4.91	4.87	4.84	4.80
5.10	5.07	5.04	5.01	4.97	4.93	4.89	4.86
5.16	5.13	5.10	5.06	5.03	4.99	4.95	4.91
5.22	5.19	5.16	5.12	5.08	5.05	5.01	4.97
5.28	5.25	5.22	5.18	5.14	5.10	5.06	5.03
5.33	5.31	5.28	5.24	5.20	5.16	5.12	5.08
5.39	5.36	5.34	5.30	5.26	5.22	5.18	5.14

Estimating flows for base and top of willows in Mi 30 photo:

3) Click on cell B5 and freeze panes, then scroll over to the Mile 35.3 column.

This is the river mile location of the former Corps "Mile 35" gage, which is now discontinued.

4). Read off flow corresponding to a stage of 6.48 ft.

7,400 cfs is the flow associated with the water surface on day of photo.

	A	B	C	D	E
1	RECENT	lower2 reach - RM 35.3 to 20.6 (RM			
2					
3	ChattQ	RM 35 gage			
4	105.7	35.3	35.2	35.1	35
23	6300	5.58	5.56	5.51	5.49
24	6400	5.67	5.65	5.59	5.58
25	6500	5.75	5.73	5.68	5.66
26	6600	5.84	5.82	5.76	5.74
27	6700	5.92	5.90	5.85	5.83
28	6800	6.00	5.98	5.93	5.91
29	6900	6.09	6.07	6.01	5.99
30	7000	6.17	6.15	6.09	6.07
31	7100	6.25	6.23	6.17	6.15
32	7200	6.33	6.31	6.25	6.23
33	7300	6.41	6.39	6.32	6.30
34	7400	6.49	6.46	6.40	6.38
35	7500	6.56	6.54	6.48	6.46
36	7600	6.64	6.62	6.55	6.53
37	7700	6.71	6.69	6.63	6.61
38	7800	6.79	6.77	6.70	6.68
39	7900	6.86	6.84	6.78	6.75
40	8000	6.94	6.92	6.85	6.83
41	8100	7.01	6.99	6.92	6.90
42	8200	7.08	7.06	6.99	6.97
43	8300	7.16	7.13	7.06	7.04
44	8400	7.23	7.20	7.13	7.11

Estimating flows for base and top of willows in Mi 30 photo:

5). Scroll over to column for photo location at Mile 30.

6). Read off stage corresponding to a flow of 7,400 cfs.

5.25 ft is the elevation where willows are rooted at the water surface.

	A	BC	BD	BE	BF
1	RECENT				
2					
3	ChattQ				
4	105.7	30	29.9	29.8	29.
17	5700	4.11	4.10	4.09	4.0
18	5800	4.18	4.17	4.16	4.1
19	5900	4.25	4.24	4.23	4.2
20	6000	4.32	4.31	4.30	4.2
21	6100	4.39	4.38	4.37	4.3
22	6200	4.46	4.45	4.44	4.4
23	6300	4.53	4.52	4.51	4.5
24	6400	4.60	4.59	4.58	4.5
25	6500	4.67	4.66	4.64	4.6
26	6600	4.74	4.72	4.71	4.7
27	6700	4.80	4.79	4.78	4.7
28	6800	4.87	4.85	4.84	4.8
29	6900	4.93	4.92	4.91	4.8
30	7000	5.00	4.98	4.97	4.9
31	7100	5.06	5.05	5.03	5.0
32	7200	5.12	5.11	5.10	5.0
33	7300	5.19	5.17	5.16	5.1
34	7400	5.25	5.24	5.22	5.2
35	7500	5.31	5.30	5.28	5.2
36	7600	5.37	5.36	5.34	5.3
37	7700	5.43	5.42	5.40	5.3
38	7800	5.49	5.48	5.46	5.4

Estimating flows for base and top of willows in Mi 30 photo:

7). Add 3 ft for the height of the willow seedlings.

5.25 ft at water surface plus 3 ft to top of willow seedlings equals 8.25 ft.

8). Read off flow in the Mi 30 column that corresponds to 8.25 ft stage.

13,300 cfs is the flow associated with top of willow seedlings. They would be overtopped above this flow.

	A	BC	BD	BE	BF
1	RECENT				
2					
3	ChattQ				
4	105.7	30	29.9	29.8	29.
83	12300	7.83	7.80	7.78	7.7
84	12400	7.87	7.85	7.82	7.8
85	12500	7.92	7.89	7.87	7.8
86	12600	7.96	7.94	7.91	7.8
87	12700	8.00	7.98	7.95	7.9
88	12800	8.05	8.02	8.00	7.9
89	12900	8.09	8.07	8.04	8.0
90	13000	8.13	8.11	8.08	8.0
91	13100	8.18	8.15	8.13	8.1
92	13200	8.22	8.20	8.17	8.1
93	13300	8.26	8.24	8.21	8.1
94	13400	8.31	8.28	8.25	8.2
95	13500	8.35	8.32	8.30	8.2
96	13600	8.39	8.36	8.34	8.3
97	13700	8.43	8.40	8.38	8.3
98	13800	8.47	8.45	8.42	8.3
99	13900	8.51	8.49	8.46	8.4
100	14000	8.55	8.53	8.50	8.4
101	14100	8.59	8.57	8.54	8.5
102	14200	8.63	8.61	8.58	8.5
103	14300	8.67	8.65	8.62	8.5
104	14400	8.71	8.69	8.66	8.6