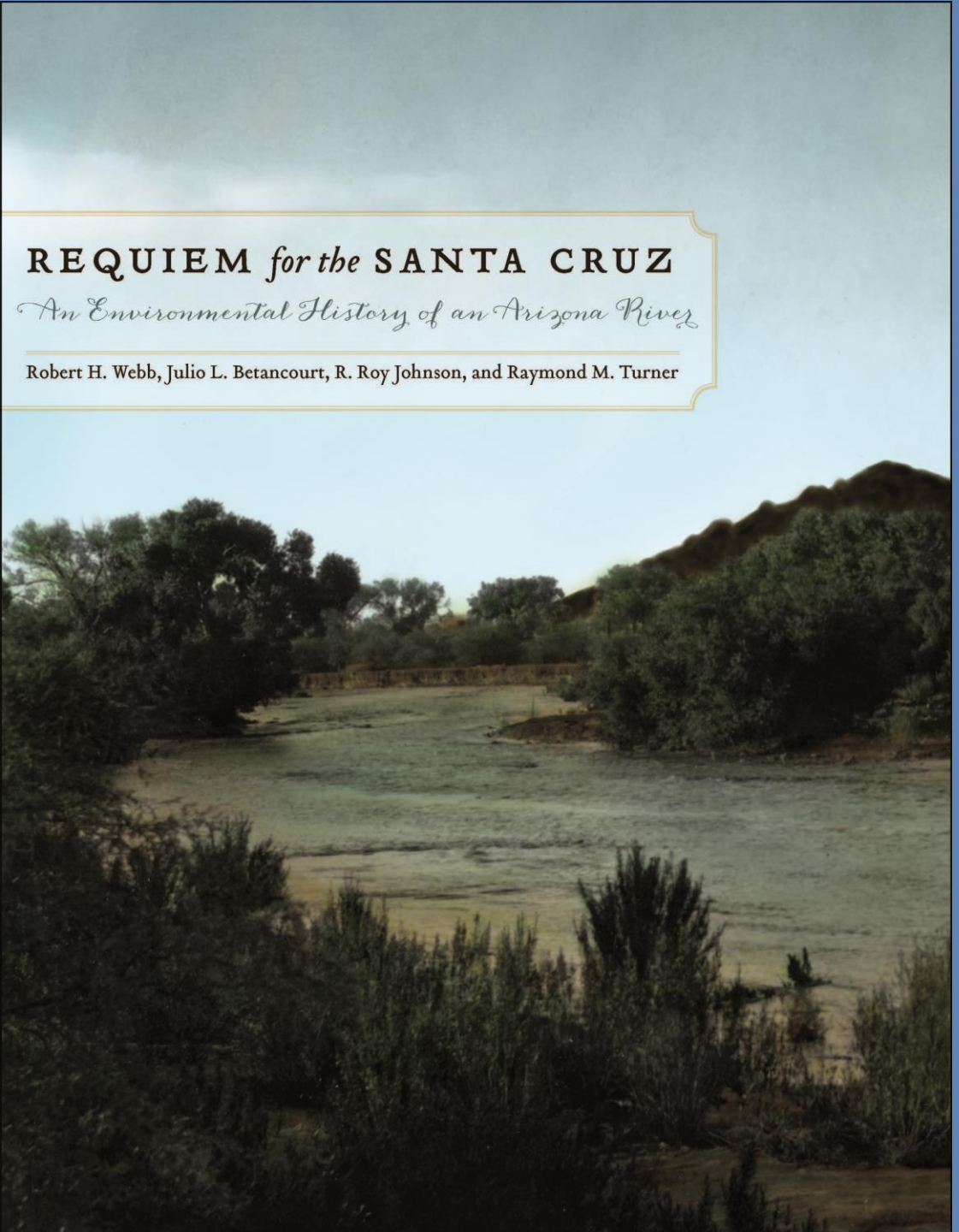


The Santa Cruz River through Tucson

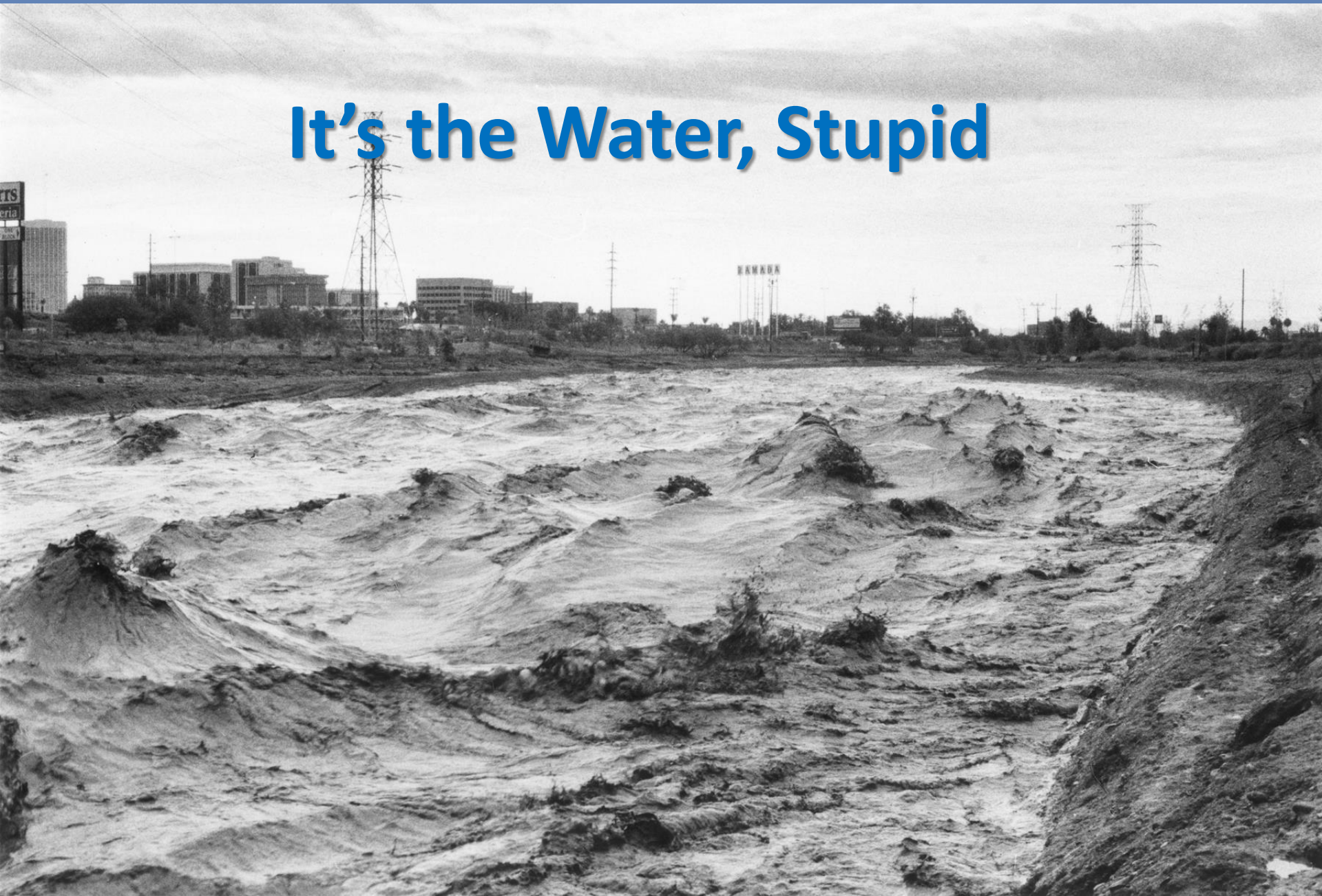
Robert H. Webb
Julio L. Betancourt
R. Roy Johnson
Raymond M. Turner

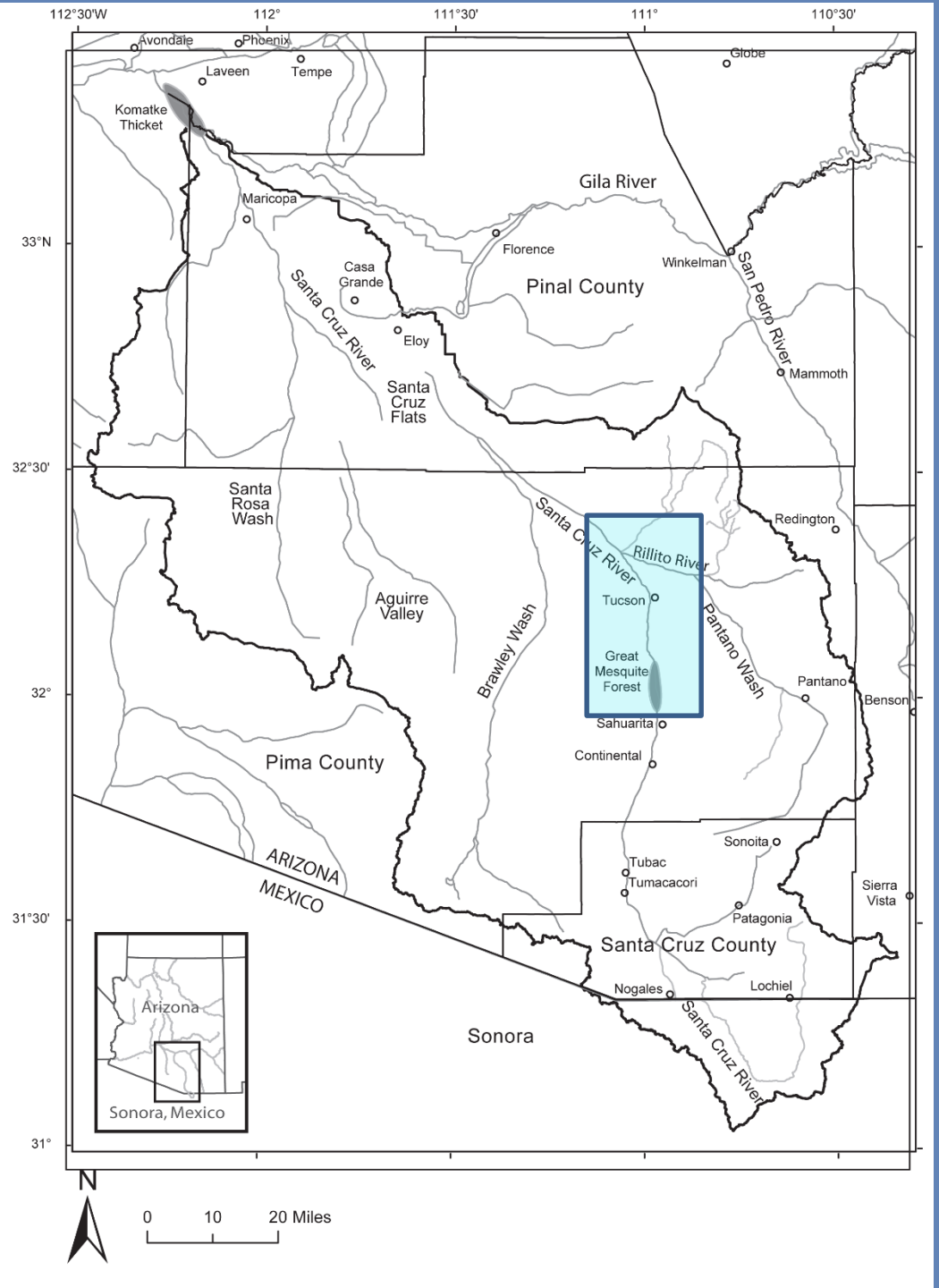
About the Authors

- Robert H. Webb
- Julio L. Betancourt
- R. Roy Johnson
- Raymond M. Turner
- Bernard “Bunny” Fontana (Foreward)

This Codger Klatch has a combined 260 years of professional experience

The 1983 Flood





Santa Cruz River Watershed

EXPLANATION

Pre-1900 spring, now dry

Headcut

Pre-1900 marsh, now dry

Present mainstem channel of the Santa Cruz River

A- Perennial reaches in 1890, now dry

B- Intermittent reaches in 1890

Modern Tucson urbanized area

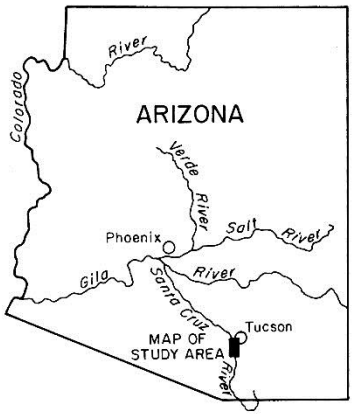
North

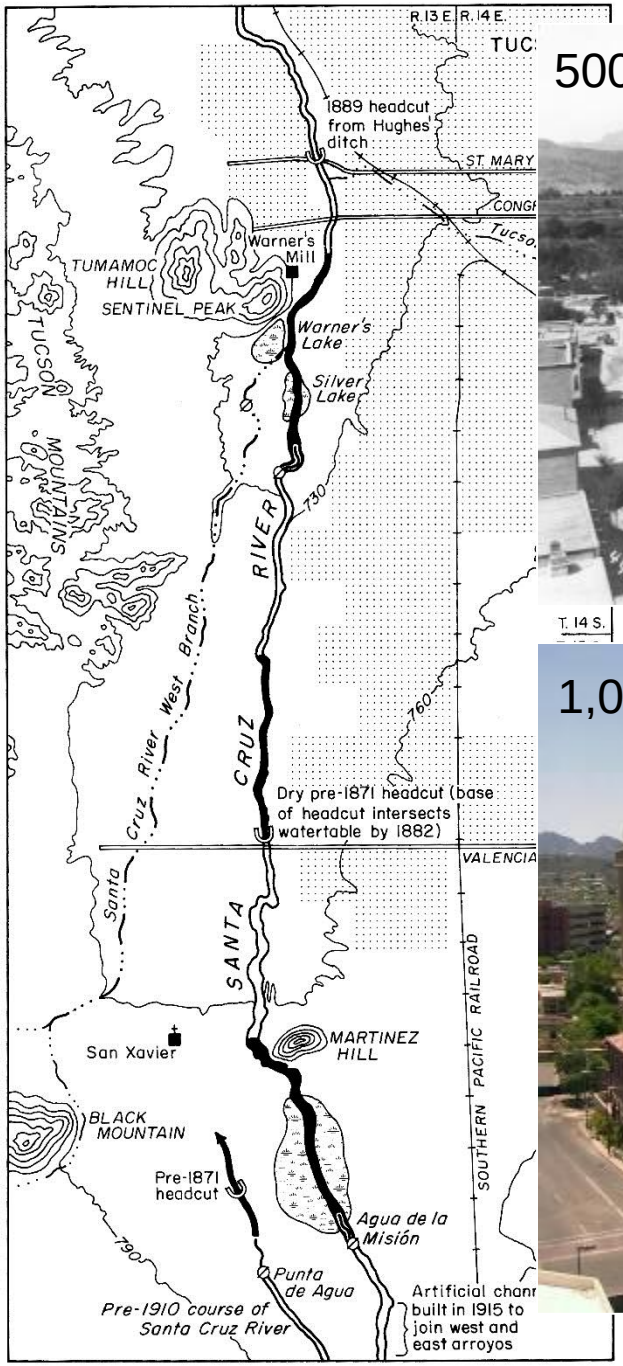
Kilometers 0 1 2 3 4 5

Miles 0 1 2 3

Contour interval 30 meters

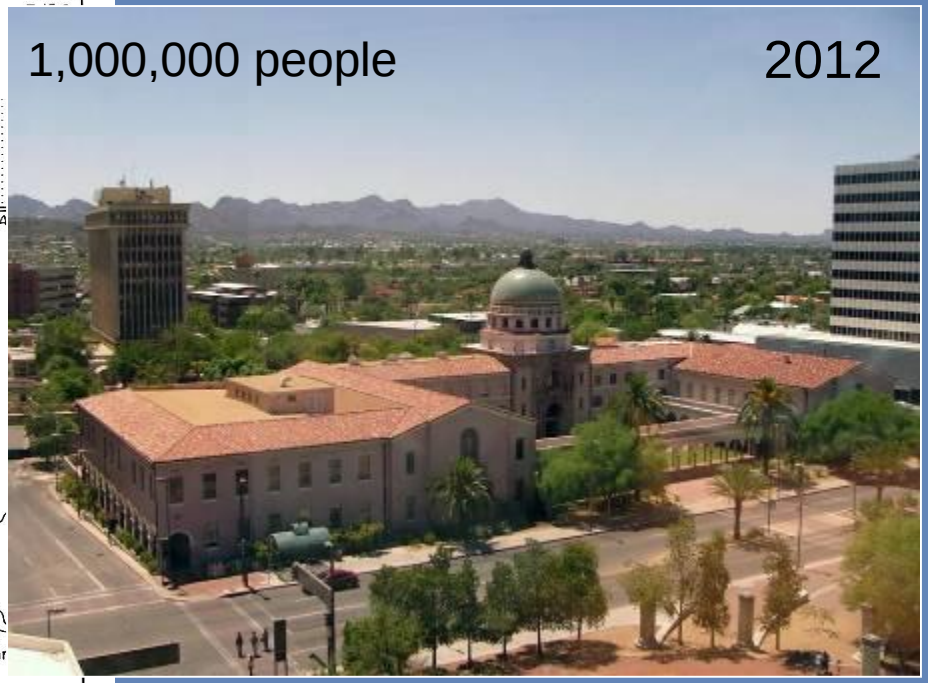
Compiled from U.S.G.S. base map 1:62,500





5000 people 1890

1,000,000 people 2012

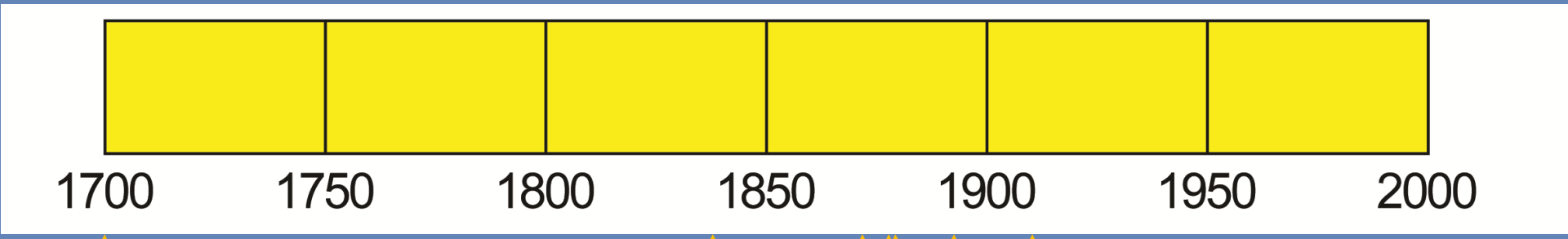


Tucson, View East on Congress Street from Powderhouse Hill

1981

2007

A Timeline



1700: Father Eusebio Kino in Tucson Basin

Mormon Battalion

Rainfall records begin

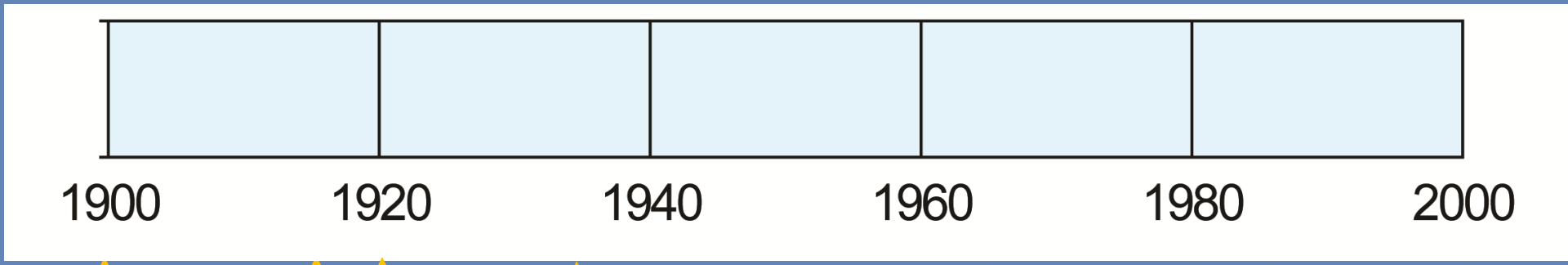
First ornithologist

First photographs

Arroyo downcutting begins

Streamflow gaging begins

A Timeline



Ornithologists flock to Tucson

Arroyo widening

Turbine pumps

First aerial photo

Mid-century drought

Satellites

Ground water use peaks

Soil cement insalled

1983 flood

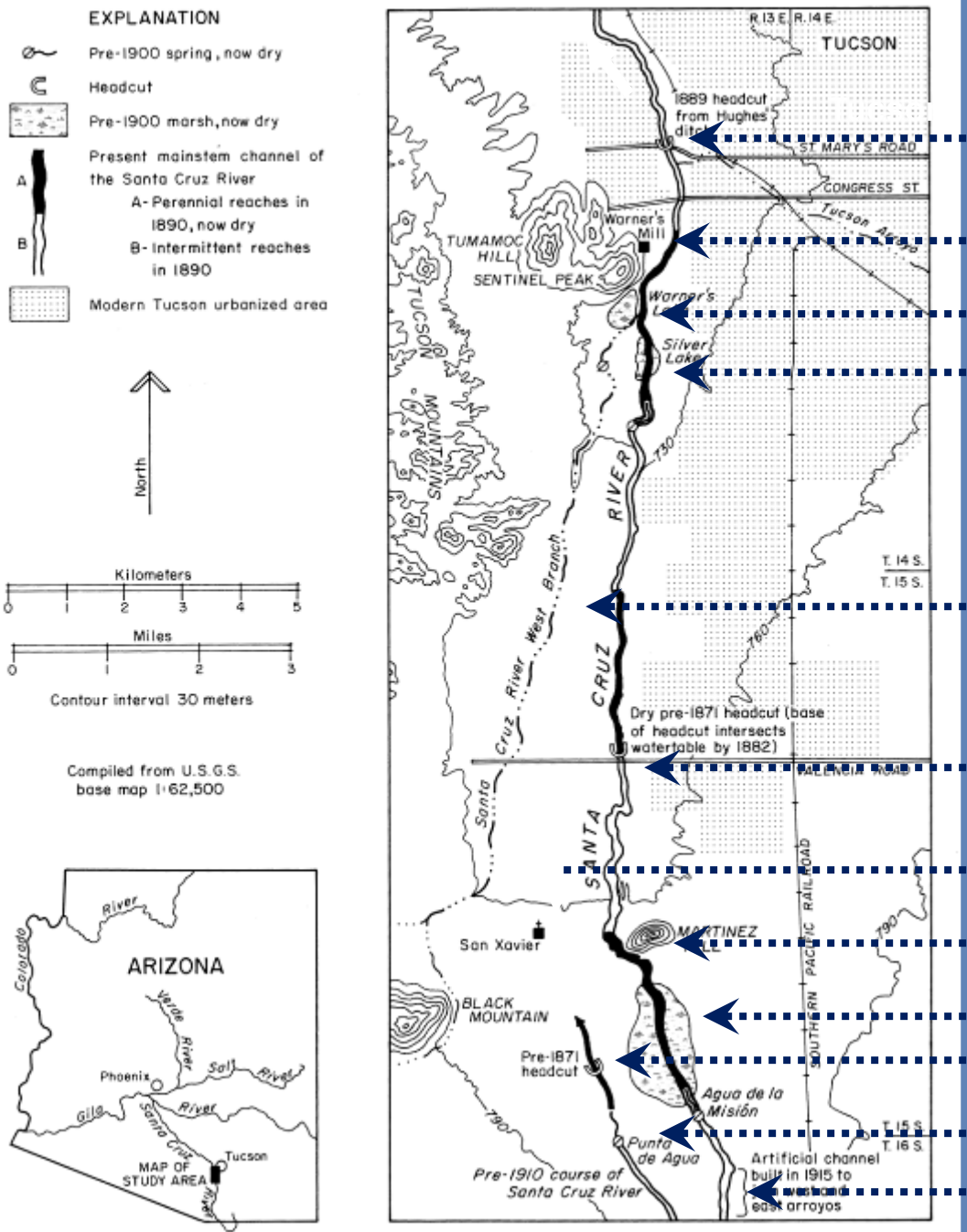
1993 flood

Drought

Environmental History

- The Santa Cruz River is one large uncontrolled experiment
- Cause – effect: equifinality in landform development?
- An array of evidence, ranging from anecdotal (descriptions) to visual (photographs) to quantitative (measurements)
- Putting the pieces together is always a difficult task

Santa Cruz River Before 1880



1889 headcut starts at Sam Hughes Intercept Ditch

Solomon Warner's Mill

Solomon Warner's Lake

Silver Lake

West Branch of Santa Cruz River

Dry pre-1871 headcut intersects water table by 1882

San Xavier Mission

Martinez Hill

Agua de Mision cienega

Pre-1871 headcut

Punta de Agua Spring

1915 Olberg & Schenck channel

- Discontinuous channel incision
- Alternating perennial – ephemeral reaches
- Generally high ground water levels in basin
- Large cienega south of Martinez Hill

The Santa Cruz River Was Not Perennial Its Entire Length

- Before 1878, the river had alternating perennial – ephemeral reaches related to groundwater discharge points where riparian vegetation established.
- The river was ephemeral, Continental to Pima Mine Road, and downstream from Marana.
- Headcuts were present, indicating a discontinuous arroyo.
- The reach through Tucson was unincised with high groundwater levels.

Santa Cruz River at 22nd Street

The Santa Cruz River in the Tucson Basin Had Perennial Reaches in the 1800s

- The river flowed at Mission San Xavier and A Mountain from springs arising from high groundwater tables.
- The river supported discrete, discontinuous riparian forests.
- The river had a clam, fish, and extensive waterbird populations.
- The riparian zones had Wild Turkey and numerous other, now rare birds.
- Beaver were not in the Tucson Basin, but muskrat may have been.

1904 **Santa Cruz River between 22nd and Congress Streets**

1981

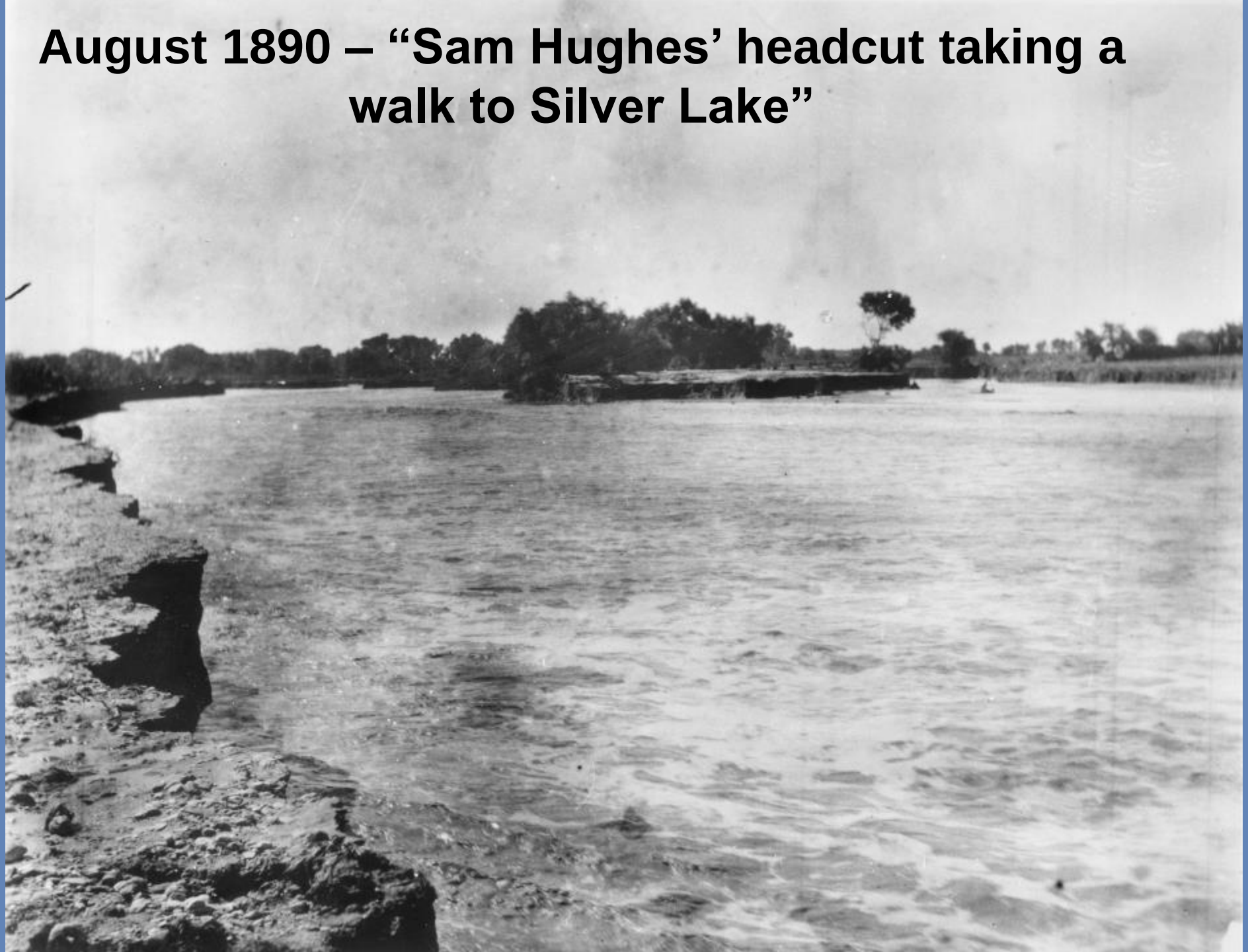
2000

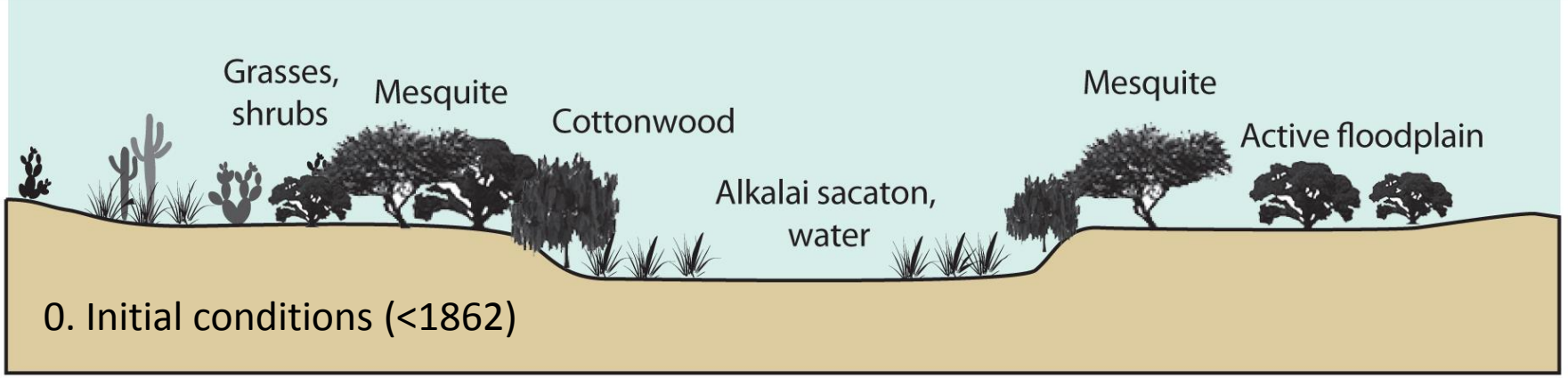
It's the Water, Stupid

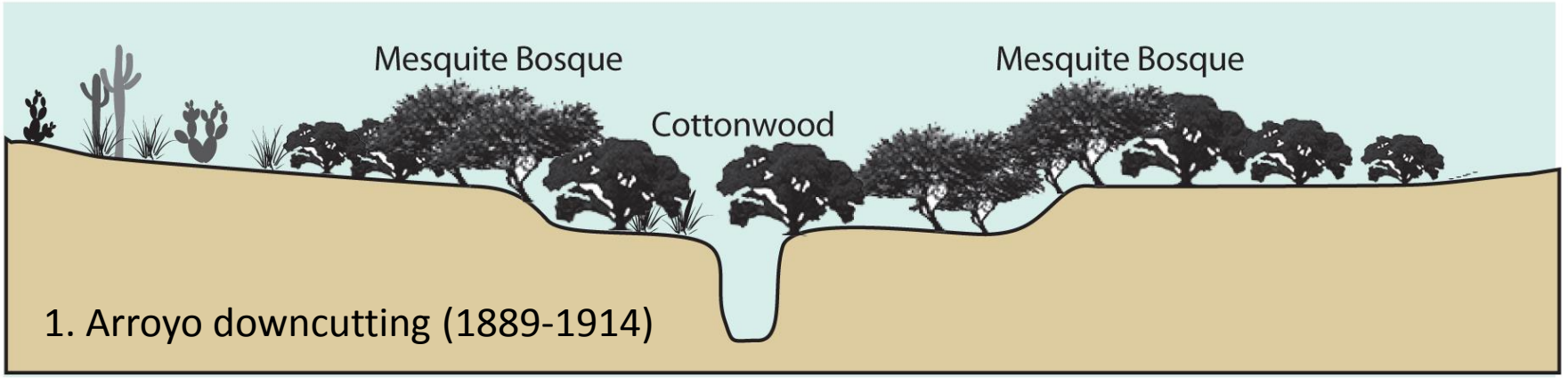
- The Santa Cruz River began downcutting and coalescing in the 1880s.
- Channel downcutting and widening was associated with large and(or) frequent floods.
- Paleoarroyos developed many times in the past, most recently during the height of Hohokam/Sobaipuri settlement
- In 1890, downcutting was focused on Sam Hughes Ditch, designed to erode during floods and create an irrigation canal
- Abundant evidence remains of Hohokam canals in the Tucson Basin, indicating floodplain water diversions did not guarantee channel erosion.

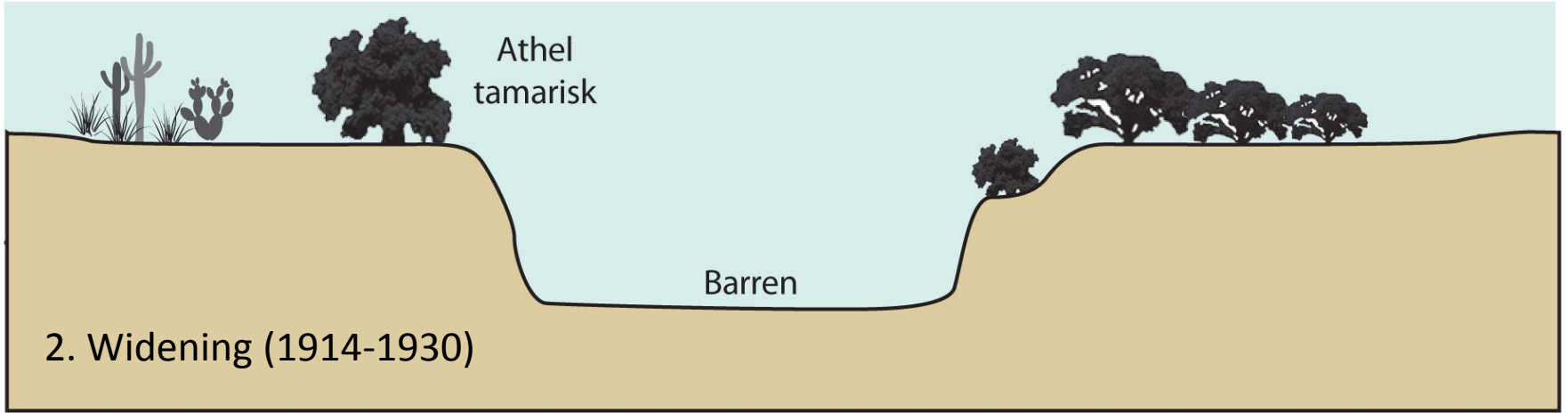
October 1889 - Sam Hughes' Headcut

August 1890 – “Sam Hughes’ headcut taking a walk to Silver Lake”




Grasses,
shrubs
Mesquite
Cottonwood
Alkalai sacaton,
water
Mesquite
Active floodplain
0. Initial conditions (<1862)


Mesquite Bosque
Cottonwood
Mesquite Bosque
1. Arroyo downcutting (1889-1914)

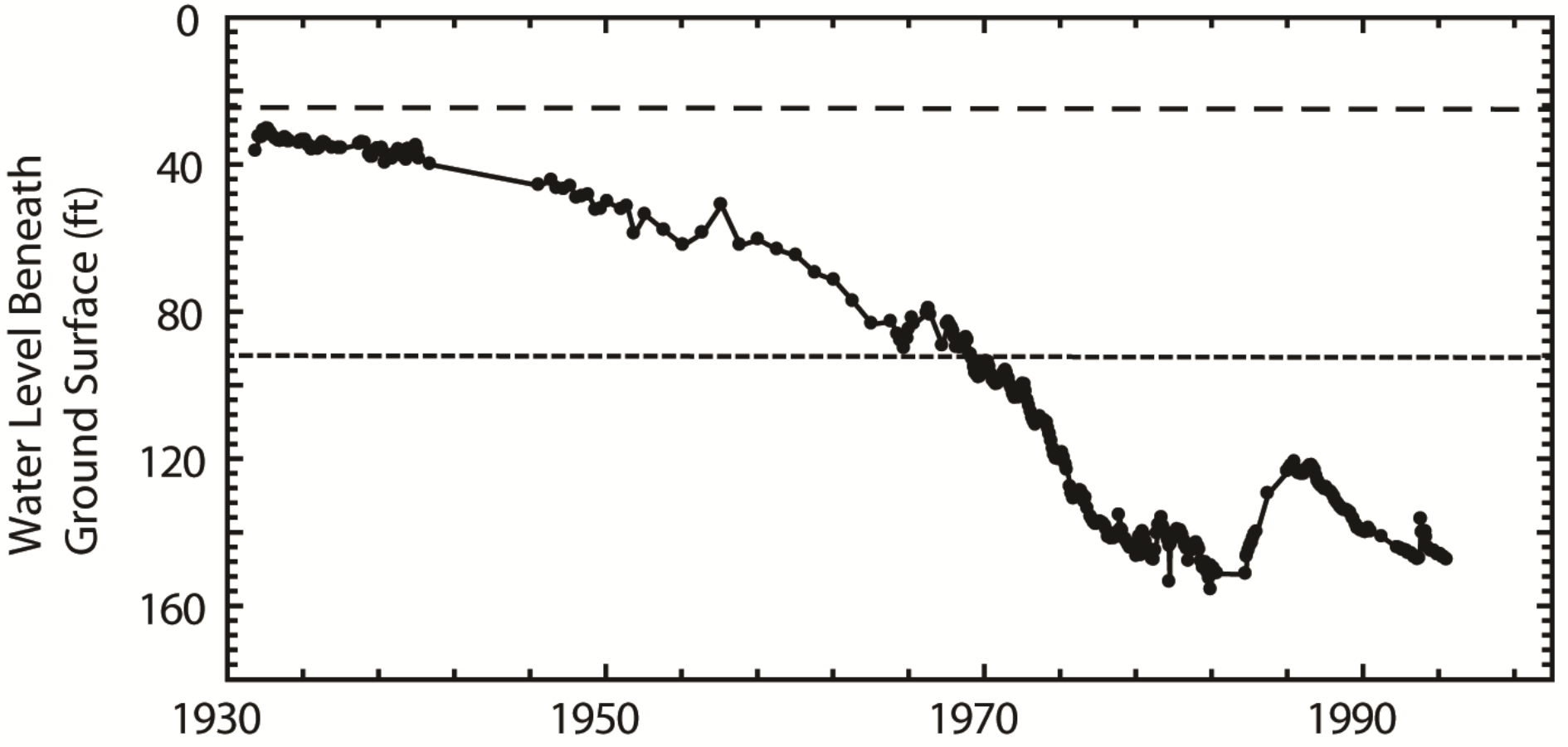

Athel
tamarisk
Barren
2. Widening (1914-1930)

Cause of Arroyo Downcutting

- **Climatic variability**
- **Livestock grazing**
- **Groundwater declines due to drought**

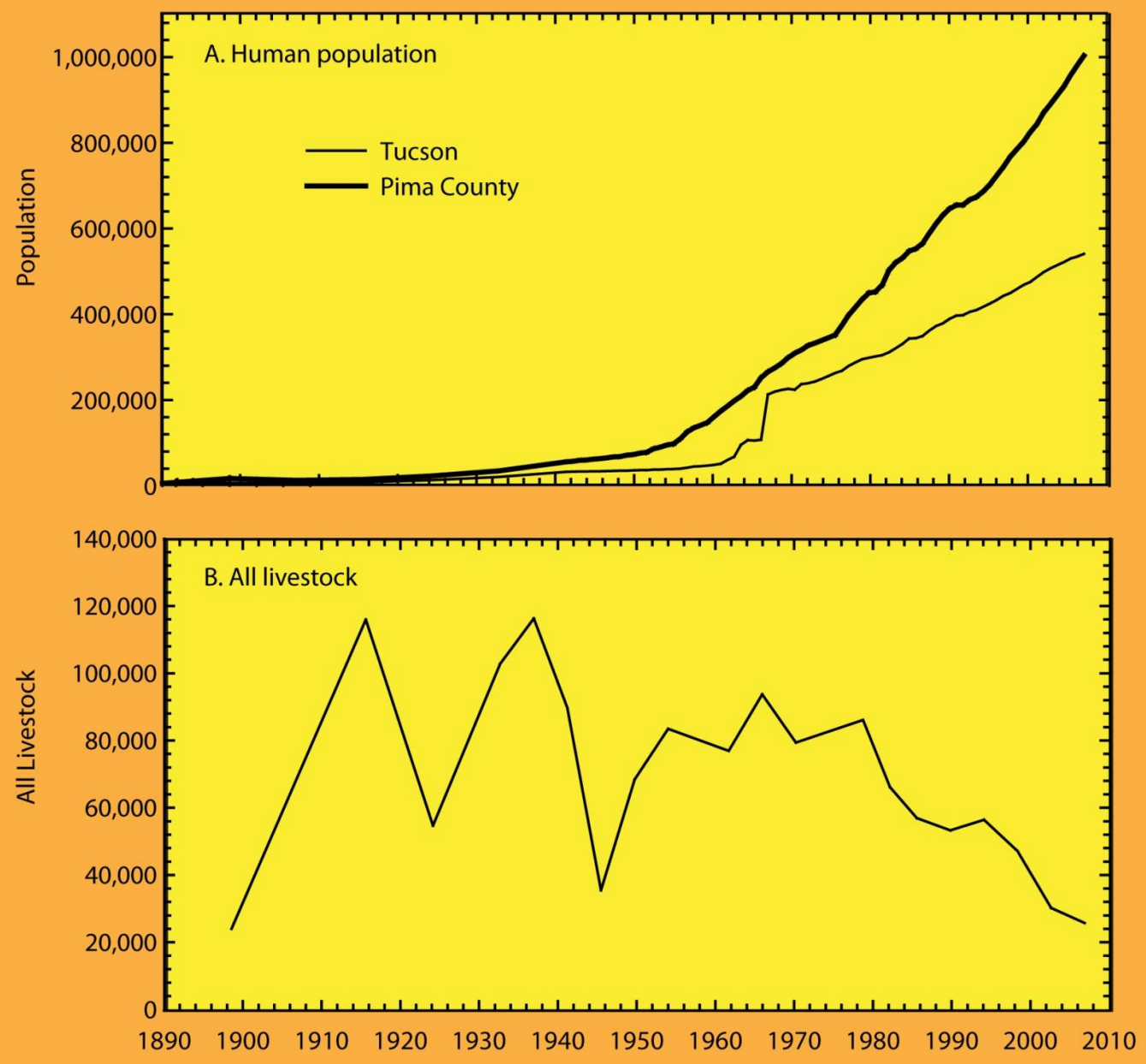
It takes water to transport sediment

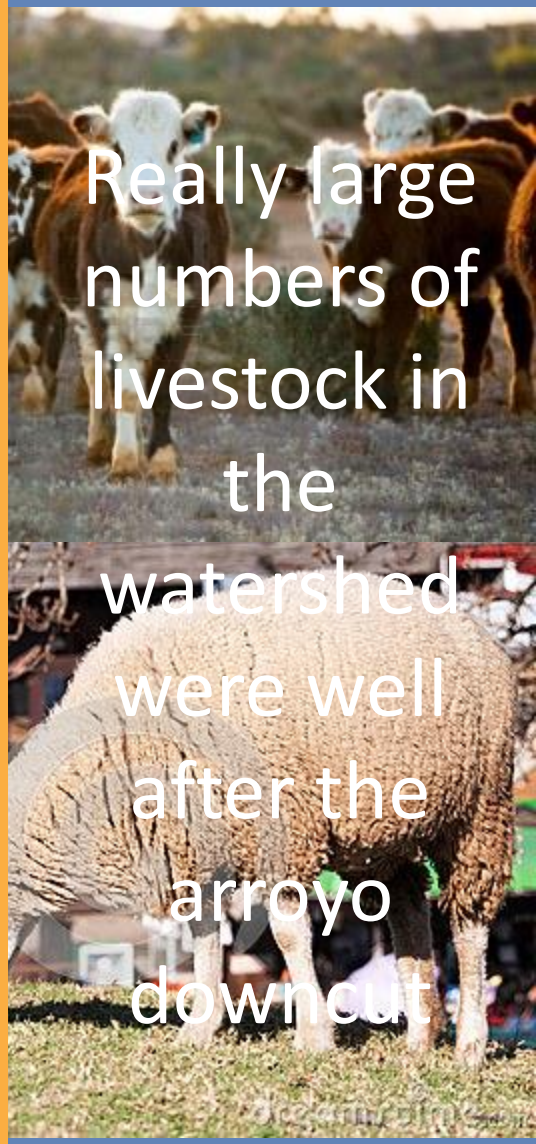
The Groundwater – Drought Hypothesis



Plant-killing groundwater lowering (ca 1920s) occurred well after arroyo downcutting began (1878)

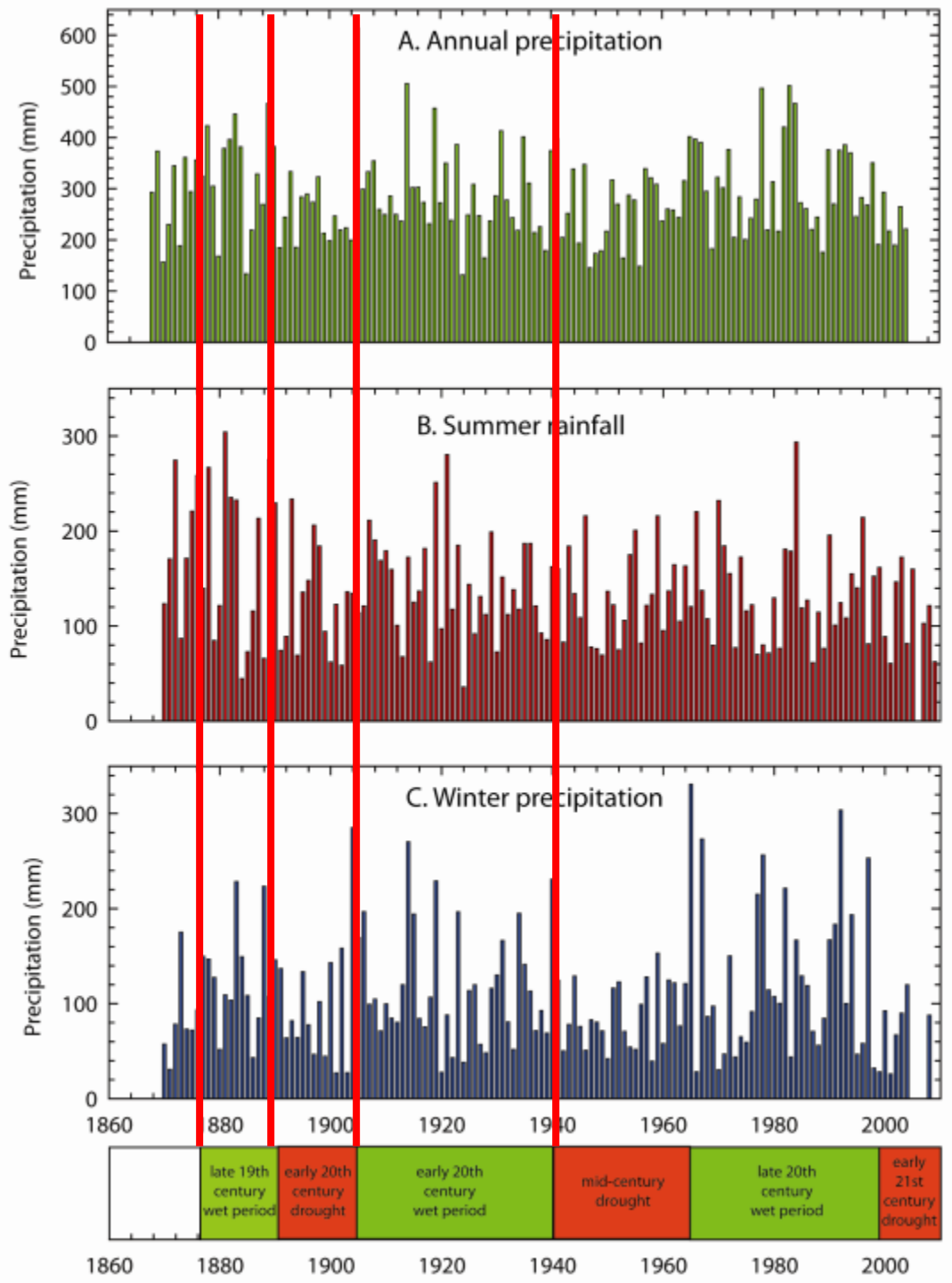
Land Use and Livestock





Channel Erosion

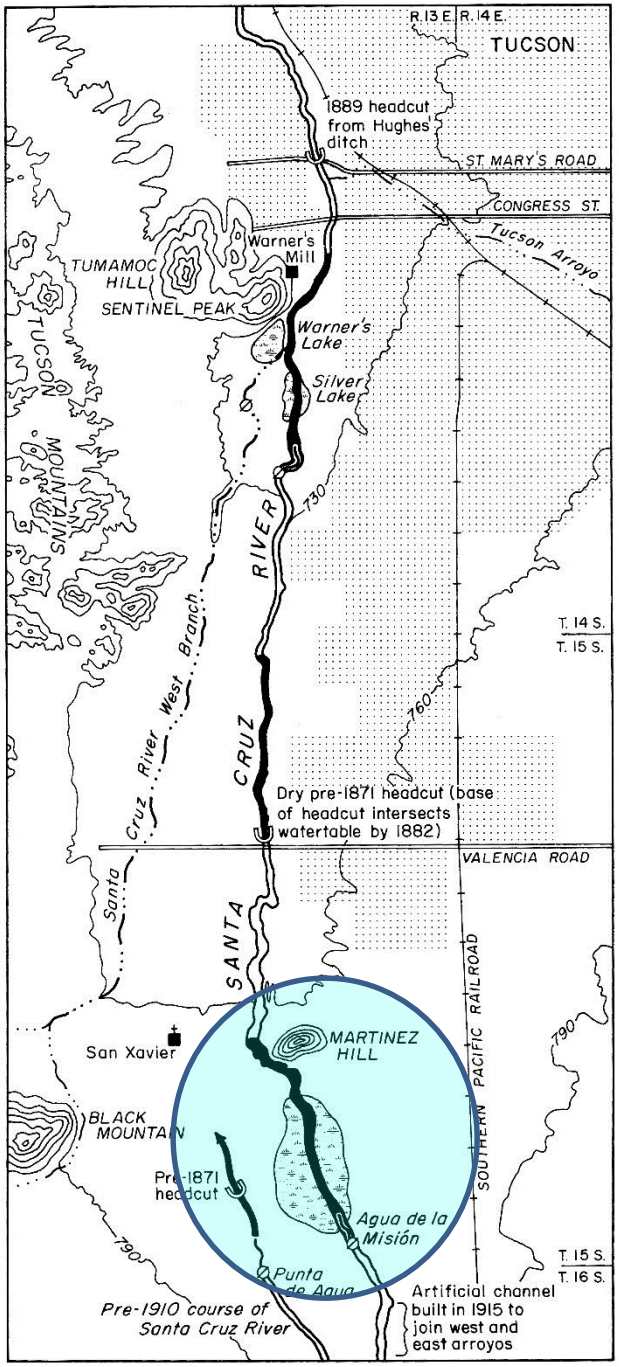
red during a time of



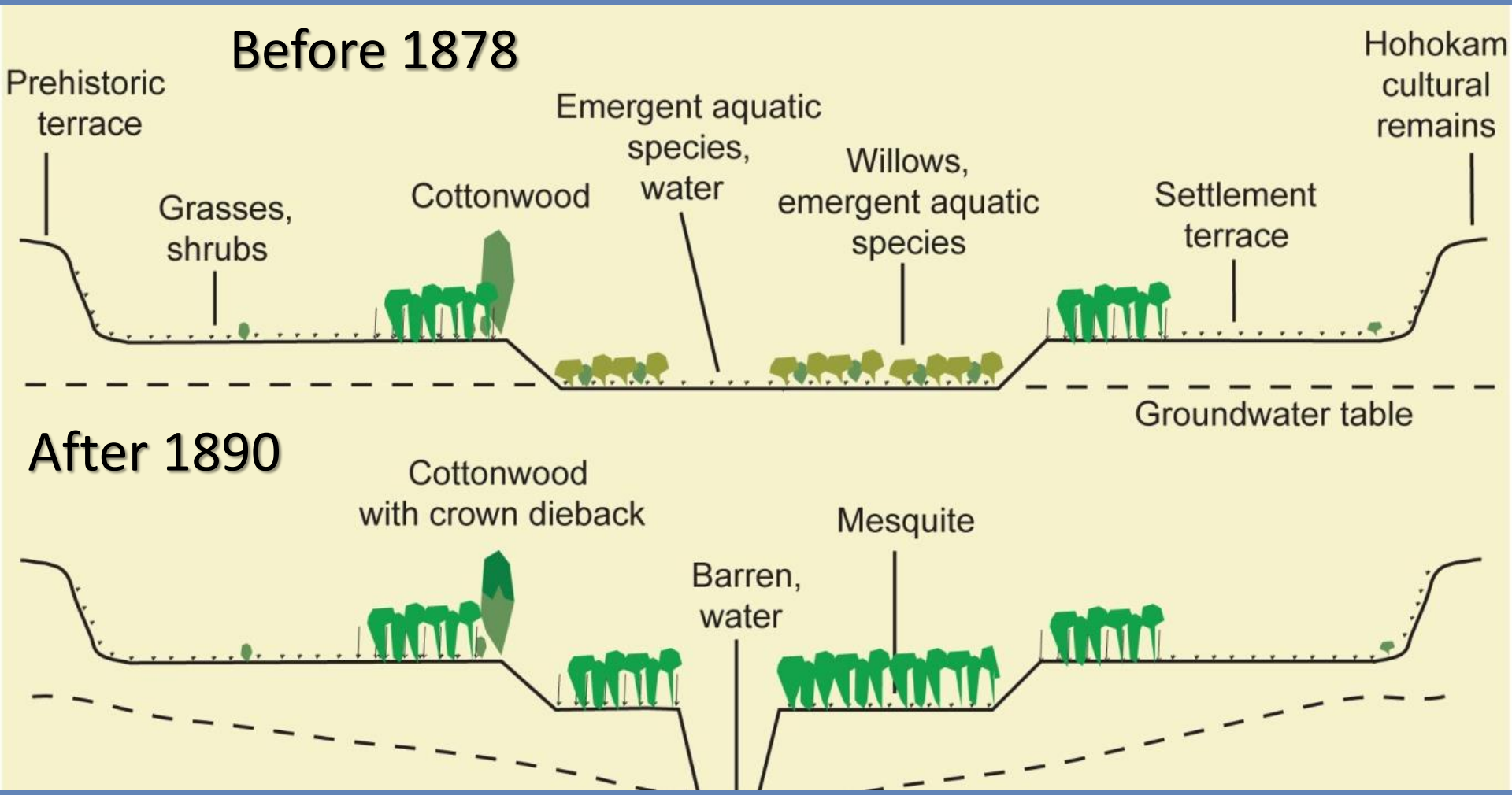
Precipitation Tucson University of Arizona, 1868-2008

The Great Mesquite Forest

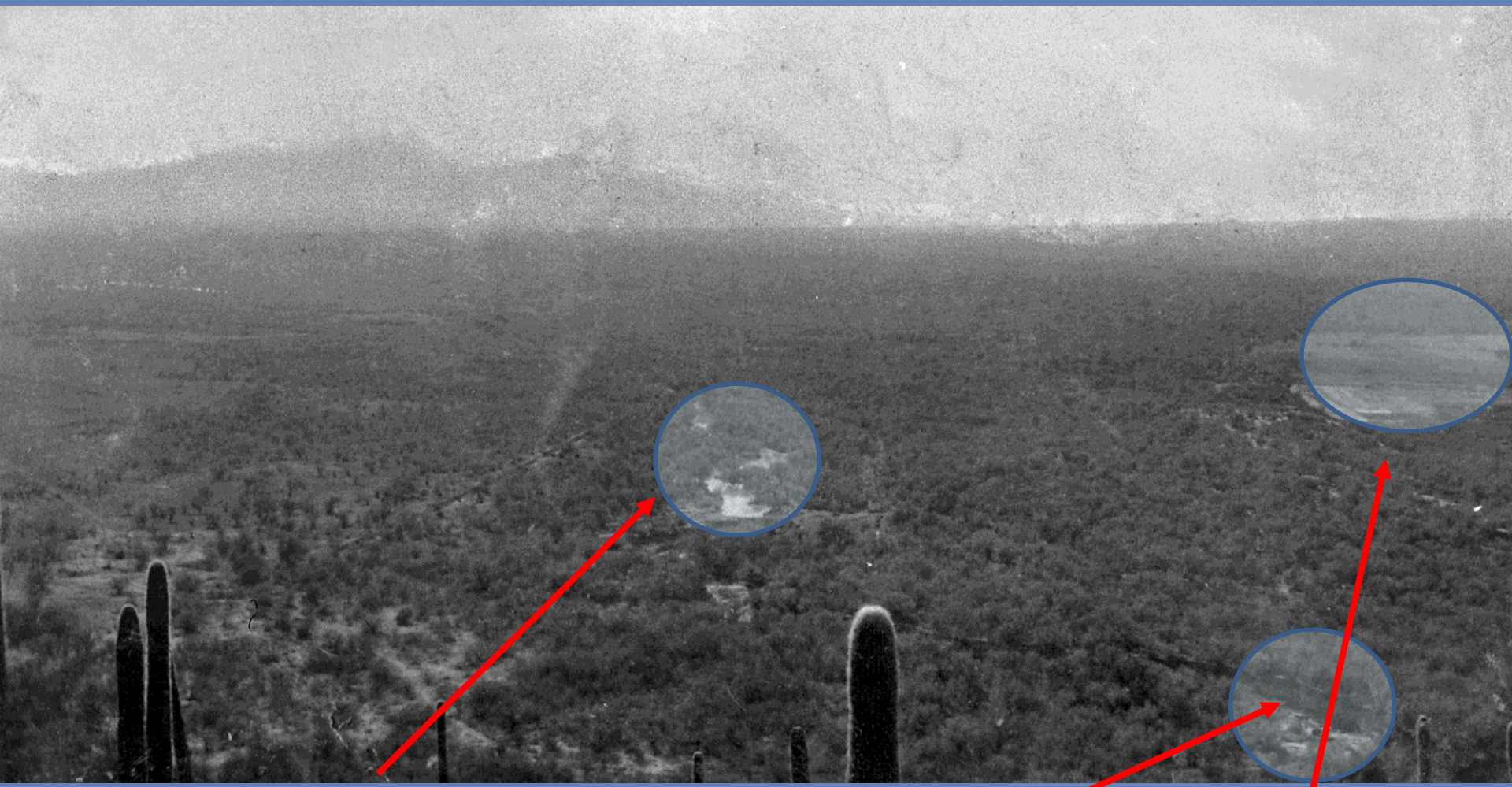
- A major riparian area we call the Great Mesquite Forest occurred upstream from Martinez Hill and Mission San Xavier.
- First observations indicate an open cienega with alkali sacaton grasslands rimmed with a mesquite bosque and trees of enormous size (4-foot diameter, 65-75 feet tall).
- The arroyo downcut and drained the cienega, encouraging mesquite growth in the now unsaturated soils.
- Massive mesquites supported a world-class avian ecosystem, attracting the top ornithologists in the US, 1900-1940.

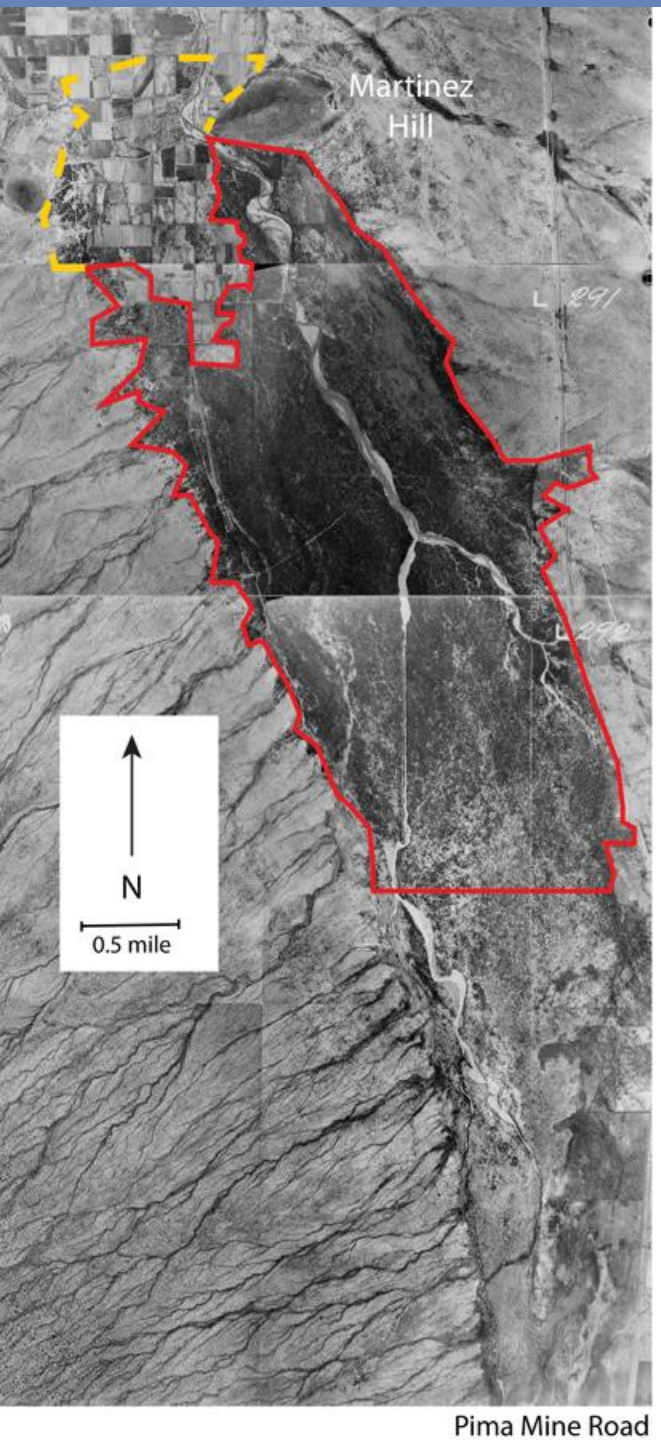


Drain the Cienega, Grow Trees



The Great Mesquite Forest (1912)

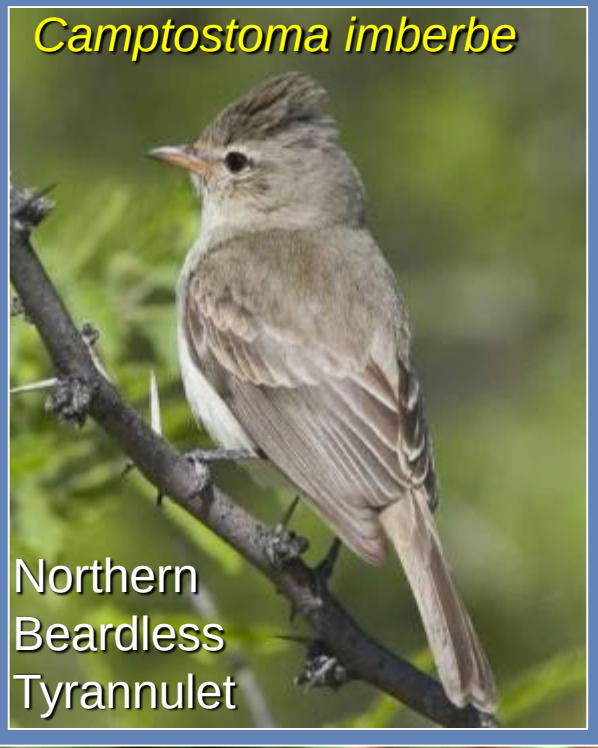




The Great Mesquite Forest (1936)

- This mesquite bosque was famous among ornithologists at the turn of the 20th century.
- More than a hundred species of neotropical migrant birds, waterbirds, and residents.
- Many of these birds no longer occur in the United States or are threatened or endangered species.


Common
black
hawk
Buteogallus anthracinus


Camptostoma imberbe
Northern
Beardless
Tyrannulet


Gray hawk
Buteo nitidis


Rose-throated
Becard
Pachyramphus validus

White-winged Dove

- White-winged Dove was perhaps the most common species of the Great Mesquite Forest
- In 1922, A.C. Bent wrote: “White-winged doves fairly swarmed through the thickets, and their tiresome notes were the dominant sounds…”
- Now, Arizona Game and Fish maintains tamarisk reserves on the Gila River for this species

The Developing Bosque

- 1700-1850: cienega rimmed with mesquite, large trees in this outer halo
- 1860s: a herd of 500 cattle in the cienega, no changes
- 1880s-1890s: arroyo downcut, lowering water table to bottom of the channel. Mesquite encroaches on former marsh
- 1880s-1920s: intensive woodcutting in bosque supplies Tucson fuelwood, secondary growth of mesquites occurs
- 1900-1940: Great Mesquite Forest may have been at its zenith

It's the Water Stupid

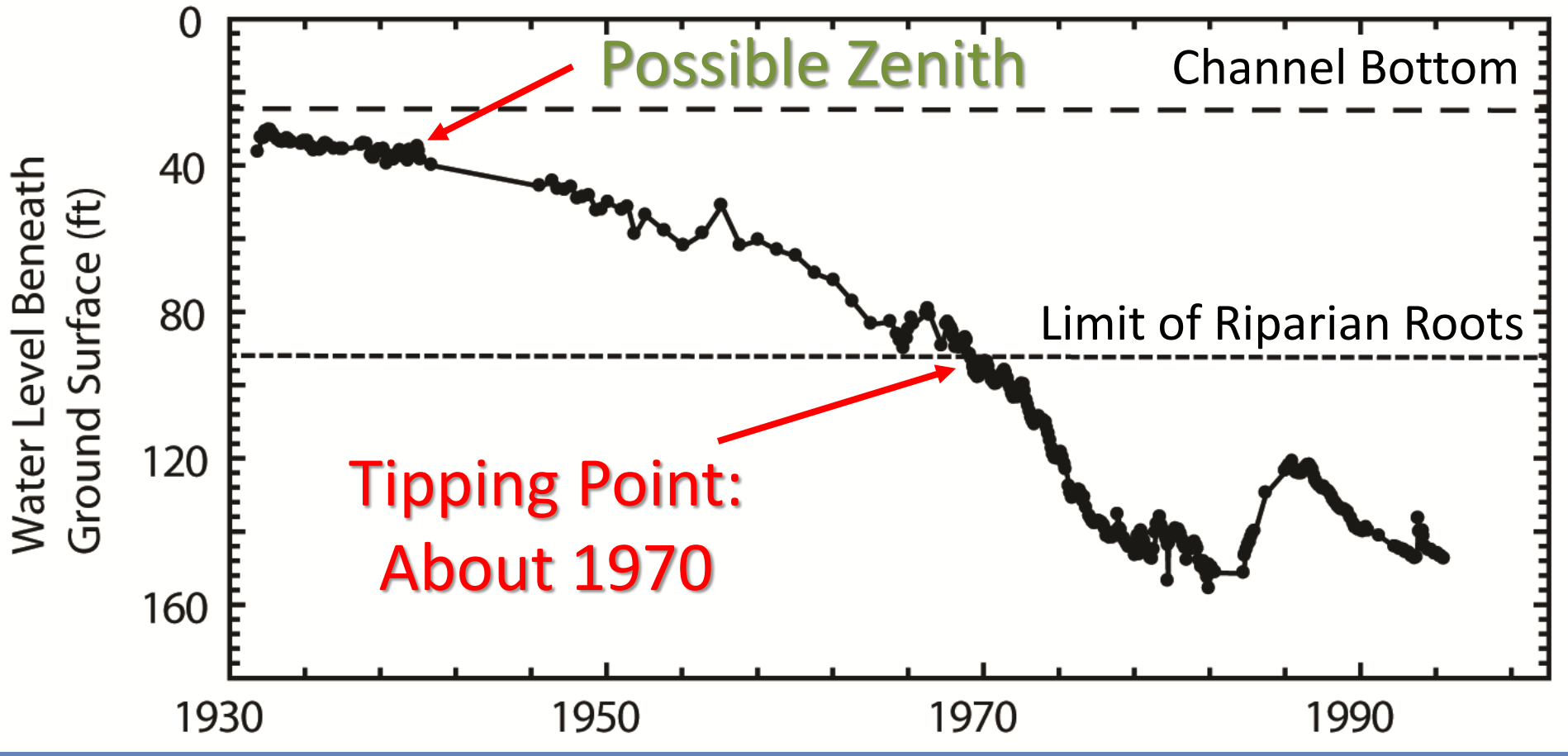
Before the US Senate in 1931, C. K. Smith, mayor of Tucson, testified:

"The city of Tucson has been scouting for some time to get a larger and more available water supply for the city. Our engineer employed for the purpose of finding what the available sources of water were came to the conclusion that the Santa Cruz Valley carries from its watershed the largest and most valuable source of water for Tucson. We are a growing community. We have an adequate supply for the present but we must look forward to the future. Eight or nine miles up the river is the Indian Reservation. . . . It is the most available place for water in the entire river course. Now, I want to offer a tentative plan that might be of benefit to the Indian Service and also to Tucson. Our engineers have investigated the claim that there is more water than the Indians can ever use and more than Tucson can use for 50 years to come."

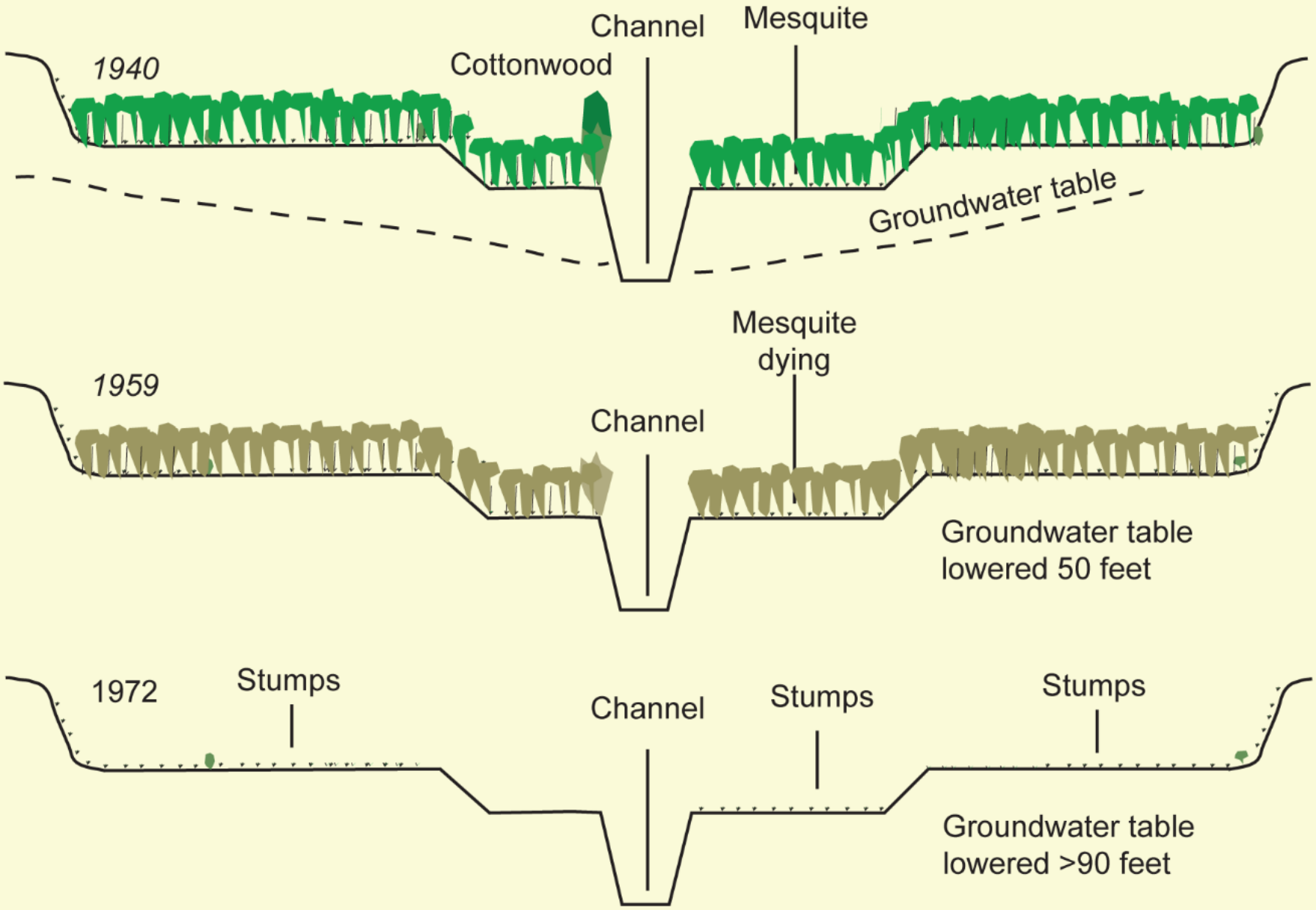
From *Requiem for the Santa Cruz*

"The bosque withstood arroyo downcutting, clearing, and woodcutting, but this unique ecosystem could not withstand those stresses combined with the lowering of the underlying water tables." (p. 172)

It's the Groundwater, Stupid



Lower Groundwater, Kill Trees



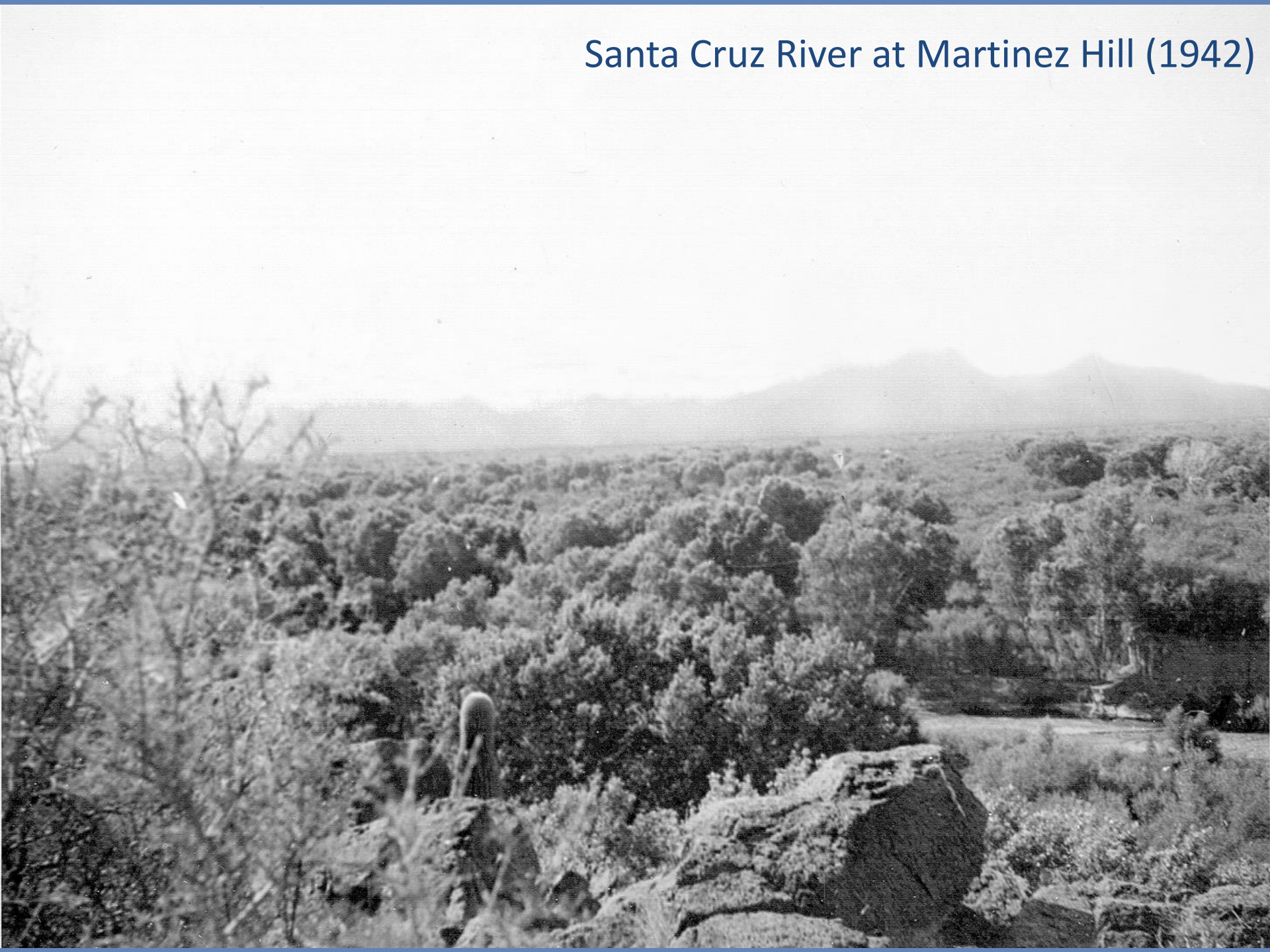
Who Dunnit: Who Killed the Great Mesquite Forest?

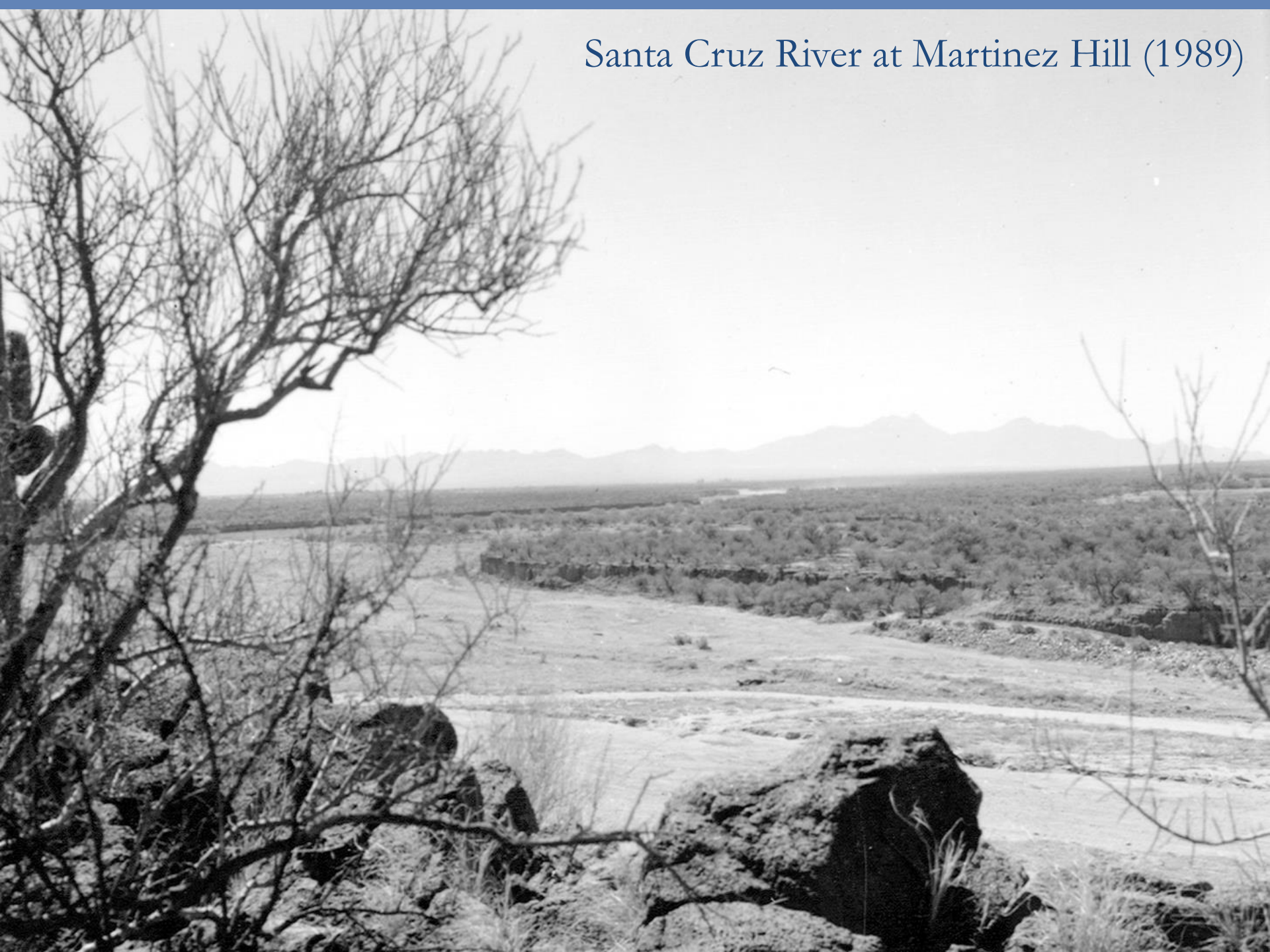
- Was it Mahlon E. Layne, who invented the vertical turbine pump in the 1902, allowing aquifers to be pumped from below instead of from the surface?
- Was it Tucson Mayor C.K. Smith, who proposed to pump water out of the San Xavier District in 1931?
- Or was it our predecessors, the citizenry of Tucson, who thirsted for more and more water without understanding the consequences to a priceless ecosystem?

Santa Cruz River at Martinez Hill

1902

Santa Cruz River at Martinez Hill (1942)





Santa Cruz River at Martinez Hill (1989)

Requiem for the Great Mesquite Forest

- ±85 species of summer birds, ±73 species nesting (early 20th century). No estimates of density.
- Now ±75 species, ±66 nesting at Sweetwater Wetlands, density has to be far lower.
- In 1940, 31 species of amphibians and reptiles. Now, 21 have been recorded, including different species.
- In 1940, 39 species of mammals, present number is unknown.

Other Equivalent Bosques?

- Bosque del Apache (Rio Grande, NM) – cottonwood-willow
- Komatke Thicket (Santa Cruz River at Gila confluence) – mesquite, unknown size
- Gila River at San Carlos River confluence (now under San Carlos Reservoir)
- Gila River at Colorado River confluence (now a tamarisk thicket)
- Colorado River delta

Riparian Vegetation in the Colorado River Delta (Mexico)

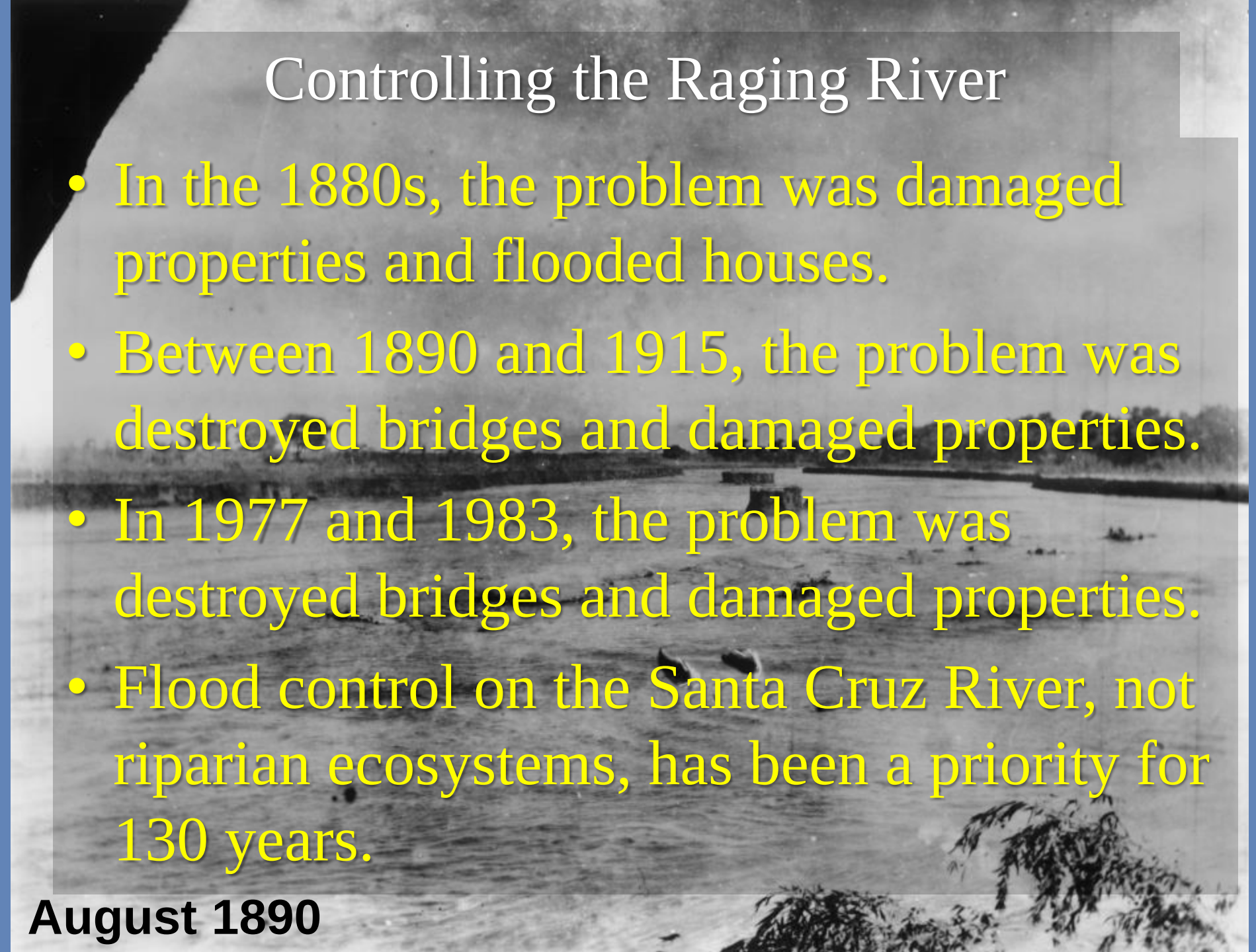
	1904	2004
Class	Area (ha)	Area (ha)
Cottonwood and willow	1404	1122
Heavy mesquite timber	10,554	0
Medium mesquite timber	896	157
Scattering mesquite timber	9875	0
All Mesquite	**21,325**	**157**
Saltcedar	0	4928
ALL TREES	22,729	6364
Saltbush		185
Seepwilllow		682
Arrowweed		1591
Emergent vegetation		639
SHRUBS AND HERBS	57,536	3097
TOTAL	**80,265**	**9461**

Great Mesquite Forest

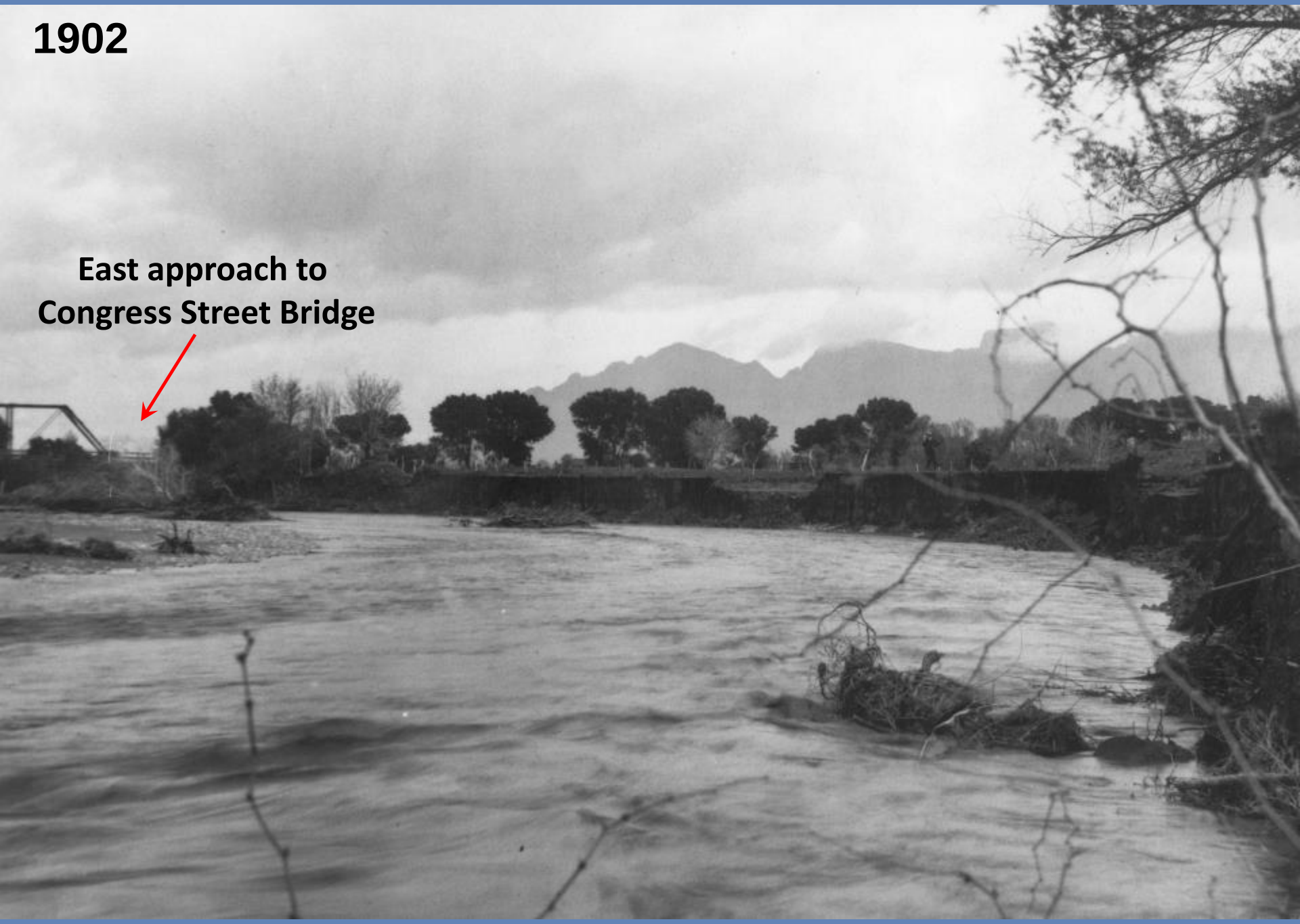
2,071 ha

Controlling the Raging River

- In the 1880s, the problem was damaged properties and flooded houses.
- Between 1890 and 1915, the problem was destroyed bridges and damaged properties.
- In 1977 and 1983, the problem was destroyed bridges and damaged properties.
- Flood control on the Santa Cruz River, not riparian ecosystems, has been a priority for 130 years.



August 1890


1902
East approach to
Congress Street Bridge

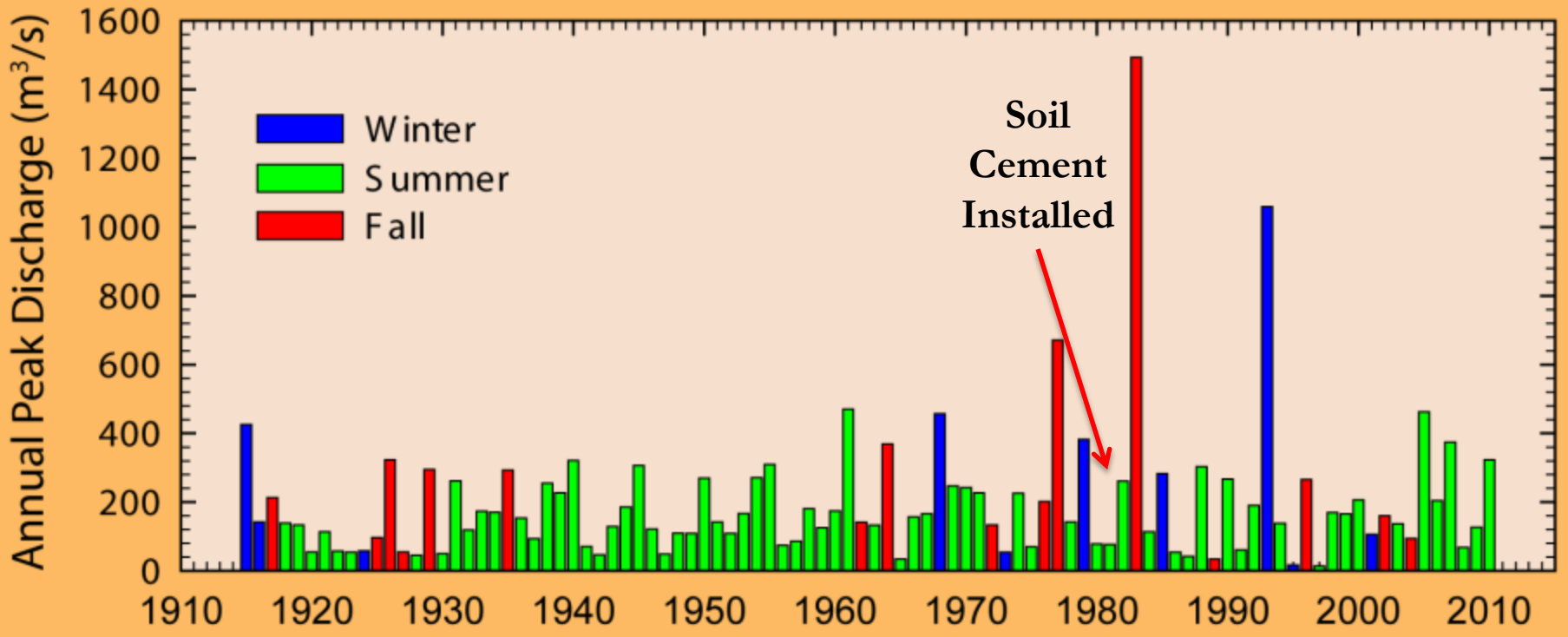

December 1914

February 1915

20th Century Floods and Channel Change

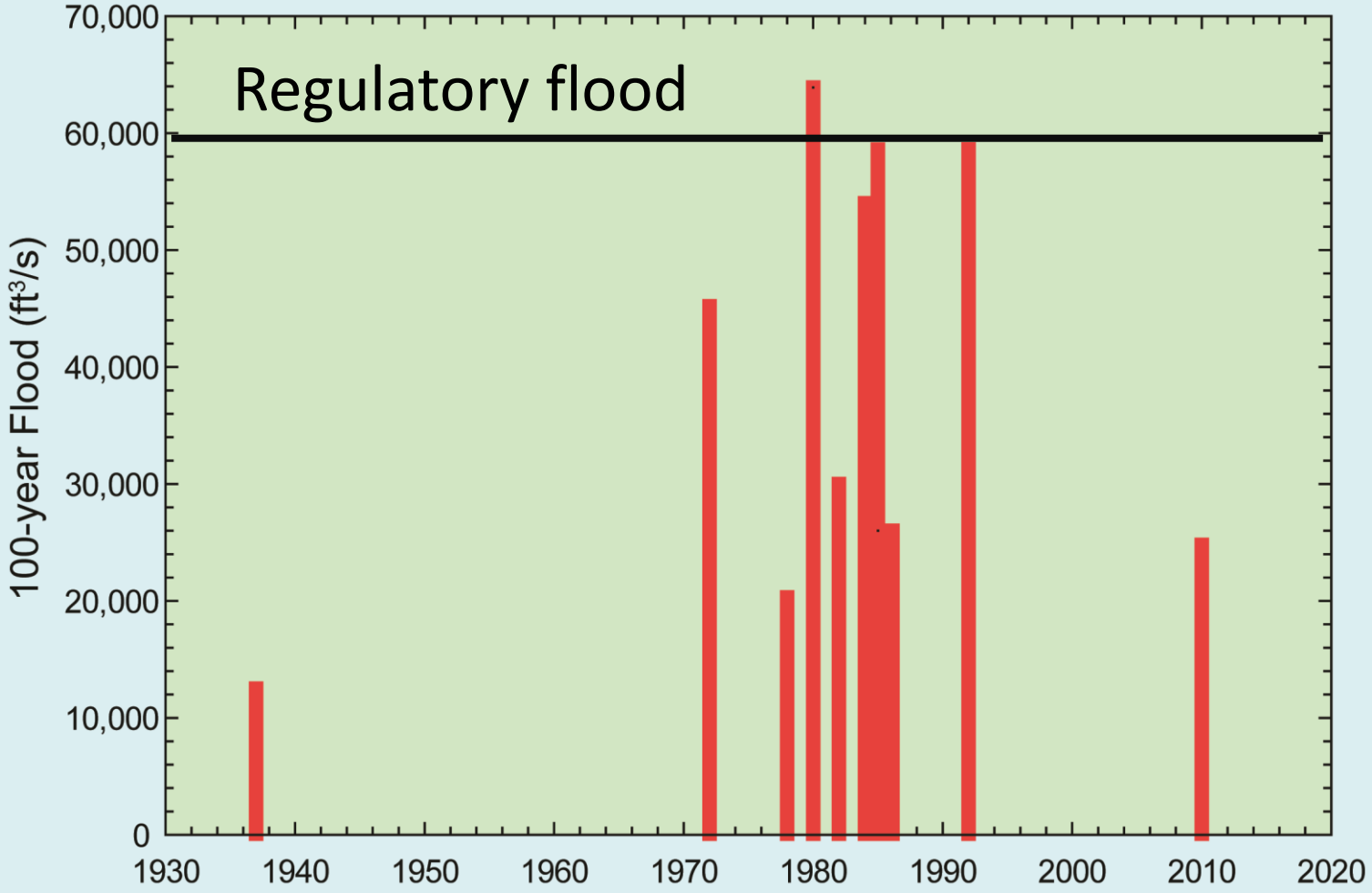
- Channel widening occurred in the first third of the 20th century.
- Channel did not change much in the mid-20th century, mostly narrowed through reduced flow and trash dumping.
- Renewed widening/downcutting beginning in 1977 with Hurricane Heather, leading to installation of bank protection (soil cement).
- Large floods in 1983 and 1993 continued the widening in reaches without soil cement.

Santa Cruz River Flood Frequency

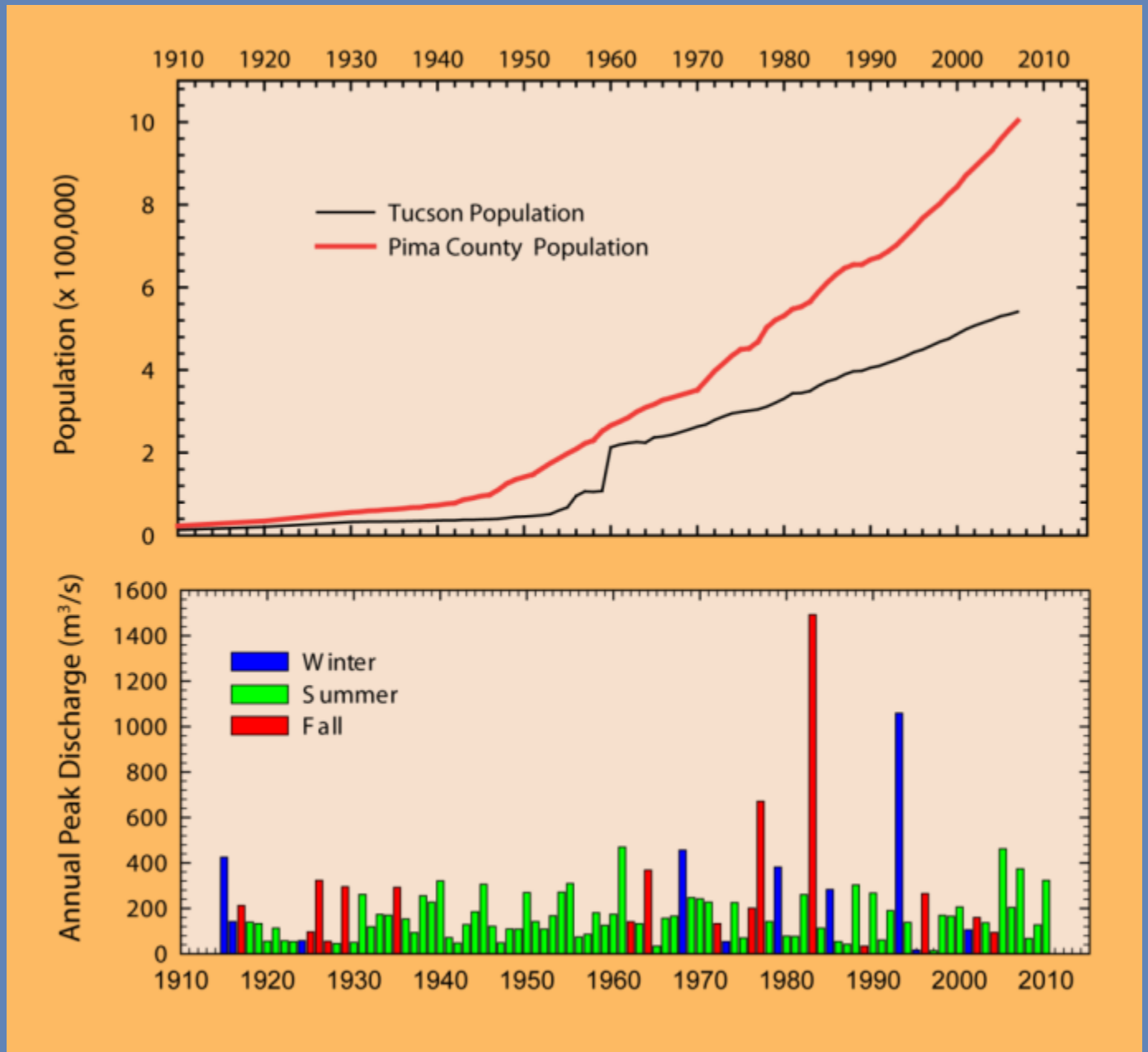


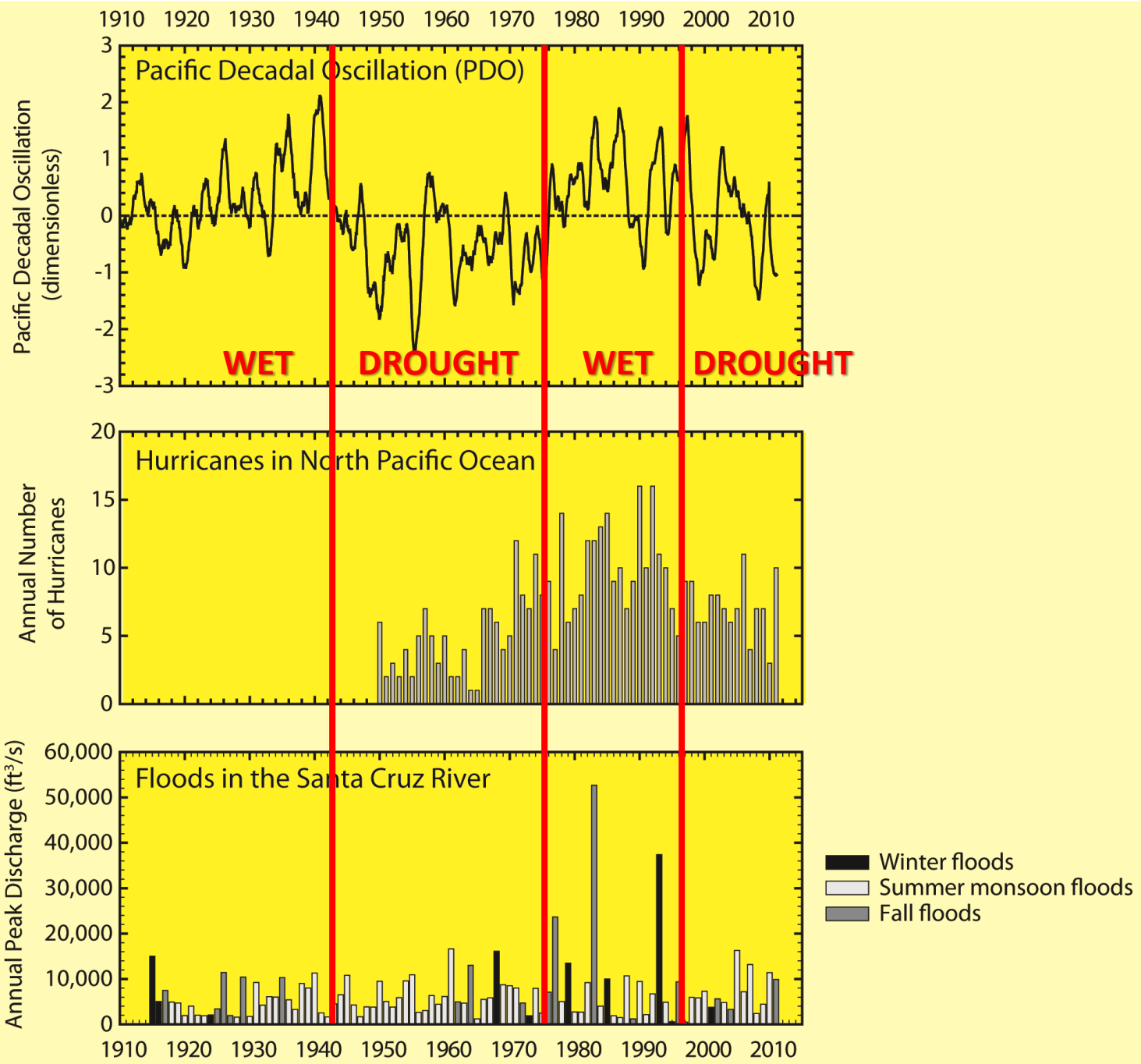
Santa Cruz River at Congress Street

100-year Flood Estimates



Are Floods Related to Land Use?

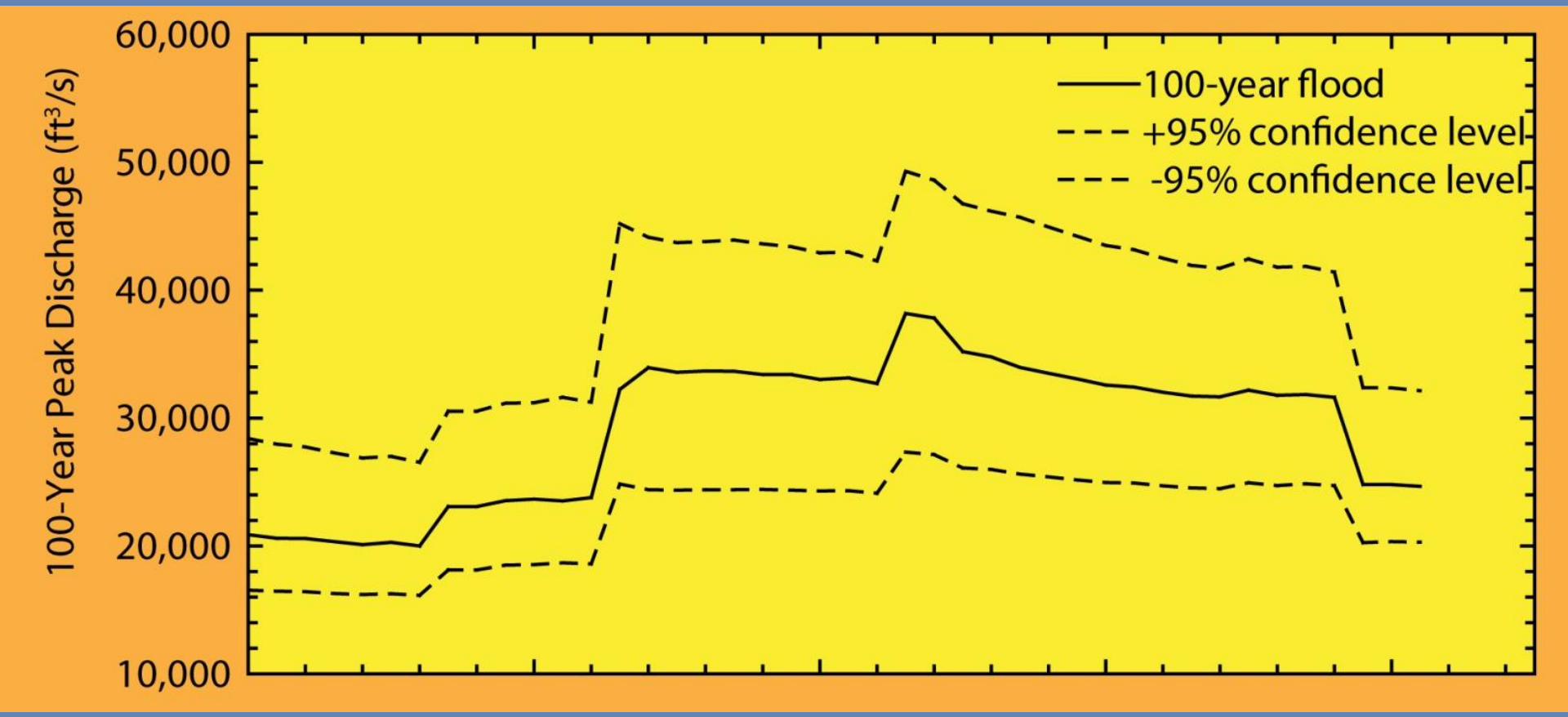



1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Pacific Decadal Oscillation (PDO)
Pacific Decadal Oscillation (dimensionless)
3
2
1
0
-1
-2
-3
WET
DROUGHT
WET
DROUGHT
Hurricanes in North Pacific Ocean
Annual Number of Hurricanes
20
15
10
5
0
Floods in the Santa Cruz River
Annual Peak Discharge (ft³/s)
60,000
50,000
40,000
30,000
20,000
10,000
0
1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010
Winter floods
Summer monsoon floods
Fall floods

The Concept of Nonstationarity

- In time-series analysis, statistics in the time domain (e.g., flood-frequency analysis) require the assumption of stationarity
- Type 1 stationarity: time invariant mean and variance
- When the mean and variance change with time, the assumptions of flood-frequency analysis are violated – and the results wildly vary based on data used

Floods and Flood Frequency

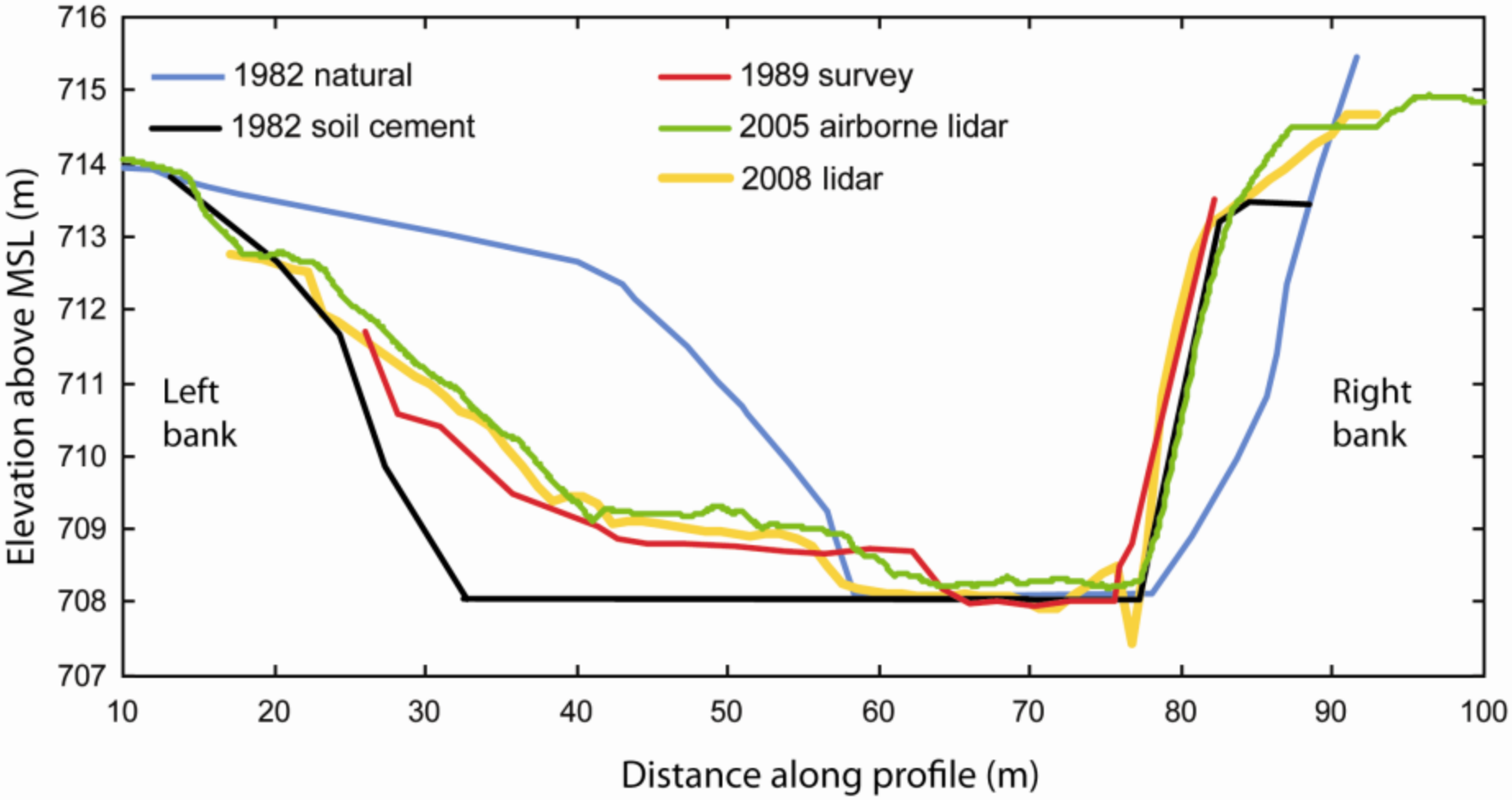


Is the Arroyo Filling?

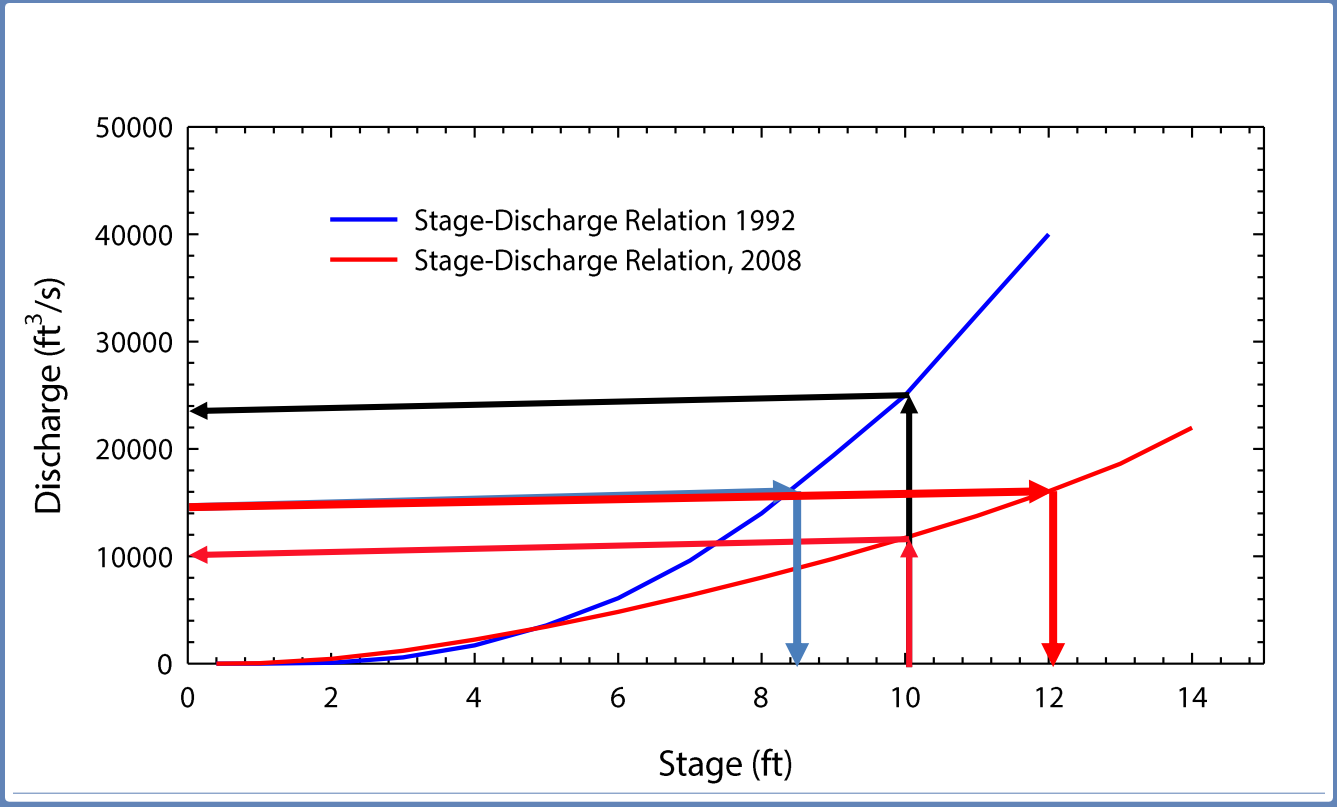
Change in Channel Cross Section

- The first data, other than the single cross section at the gaging station, was in 1982 (before soil cement)
- The 1982 soil cement installation was designed
- We established 12 cross sections and surveyed in 1989
- We used the 2005 aerial Lidar to obtain cross sections at the 1989 sites
- We used Terrestrial Lidar in 2008

Change in Cross Section 4

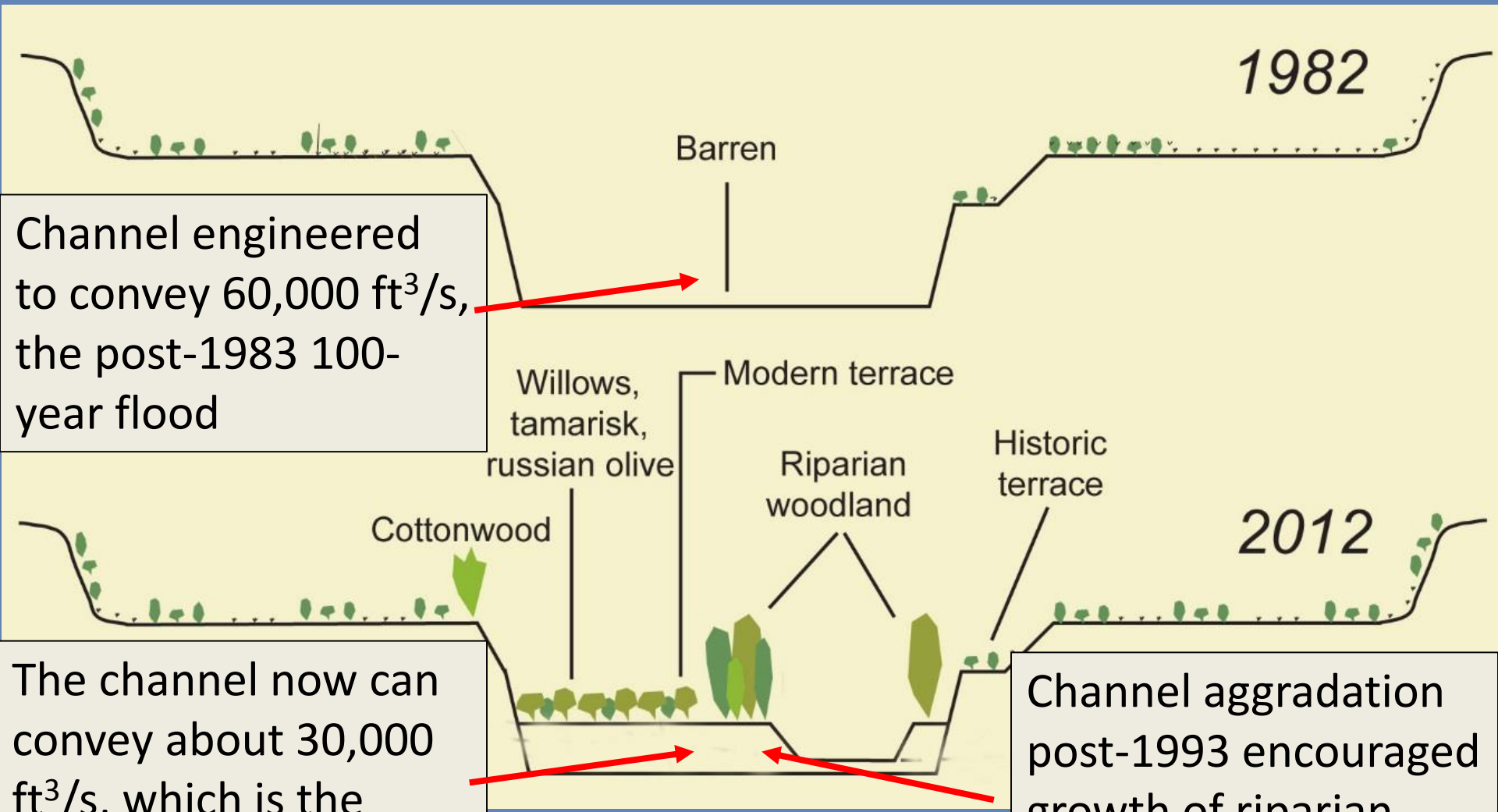


Evidence of Increased Flood Hazard in the Stage-Rating Curve



- 1992: channel contains 100-year flood
- 2008: channel contains 50-year flood

Oh The Irony of It All



Channel engineered to convey 60,000 ft^3/s, the post-1983 100-year flood

The channel now can convey about 30,000 ft^3/s, which is the drought-induced 100-year flood

Channel aggradation post-1993 encouraged growth of riparian vegetation, increasing channel roughness

Photo: Bureau of Land Management

WHAT DO WE WANT FROM OUR ARID-REGION RIVERS?

- Water for development
- Flood control for infrastructure
- Ecosystems for biodiversity

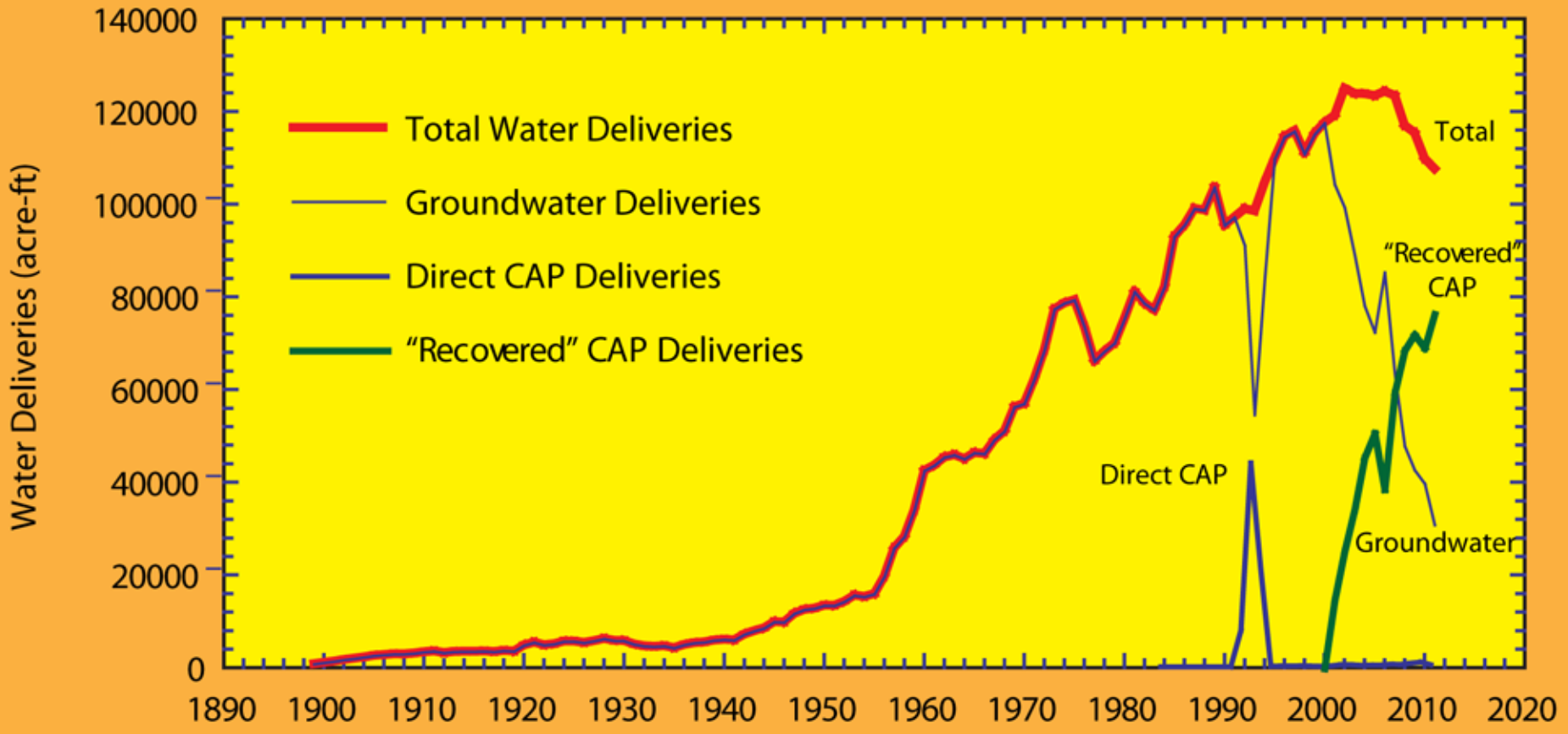
A Little Rant on Restoration

- “Restoration” is a euphemism for creation of designer ecosystems with little or no relation to what resources once were present
- “Restoration” typically has vaguely defined goals with little scientific basis
- If you hear the word “restoration” applied, immediately ask: “Restore to what and when?”

The Cottonwood Conundrum

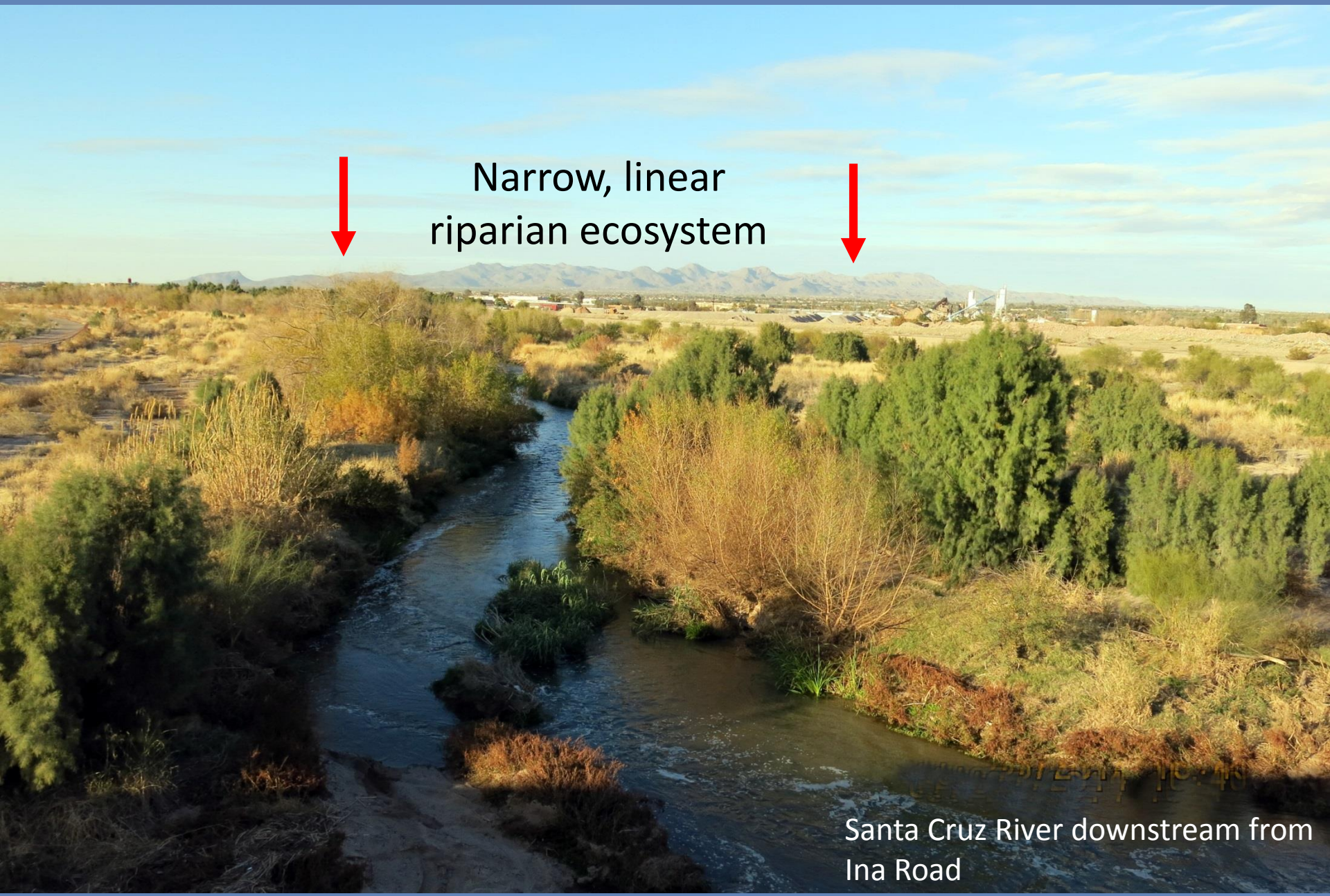
- The common perception is that the big loss in riparian vegetation was cottonwood-willow forests.
- Moreover, avian studies emphasize cottonwood-willow resources as most important, de-emphasizing mesquite bosques.
- Until very recently, “restoration” focused on planting cottonwood and willow, not mesquite.

It's the Groundwater, Stupid



Data Section, Tucson Water (2012)

It’s the Reclaimed Water Stupid



Santa Cruz River downstream from Ina Road

Santa Cruz River Upstream from Valencia Road

Santa Cruz River Downstream From Irvington Road

Santa Cruz River Upstream From Irvington Road