Habitat Characteristics that Made Delta Landscapes Unique:

Perspectives for Ecosystem Restoration

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Historical Ecology Program
Aquatic Science Center/San Francisco Estuary Institute

Delta Science Program Brown Bag Series
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"The goal must be clear at the start: a **functional ecosystem** that is **connected and productive and supports native biodiversity**…Restoration strategies must be designed from **a systems perspective** that the Delta is considered as an interconnected **watershed-river-marsh-estuary-ocean landscape**"

- Teal et al. 2010 *(Ecosystem Restoration Workshop Panel Report)*

"Restore large areas of interconnected habitats"

- *Delta Vision Strategic Plan*

"Develop and adopt criteria for prioritization and integration of large-scale ecosystem restoration in the Delta"

- *Second Draft Delta Plan*

"The expected outcome is restored large, interconnected patches of tidal freshwater emergent wetland natural community"

- *Bay Delta Conservation Plan draft*


ROA Restoration Opportunity Area
N
0 5
Scale in Miles
West Sacramento
Sacramento
Davis
Dixon
Yolo Bypass ROA
Clarksburg
Elk Grove
Hood
Courtland
Fairfield
Cache Slough ROA
Cosumnes/ Mokelumne ROA
Walnut Grove
Galt
Suisun Marsh ROA
Rio Vista
East Delta ROA
Isleton
West Delta ROA
Lodi
Pittsburg
Antioch
Concord
Stockton
South Delta ROA
Lathrop
Tracy
Banks Pumping Plant
Jones Pumping Plant
Delta Habitat Conservation & Conveyance Program
Advancing the Bay Delta Conservation Plan
Proposed Habitat Restoration Opportunity Areas
Preliminary - Subject to Change
This map provides locations of current alignment options; actual locations may be subject to change per environmental screening and site access considerations.
Rev. 08.10.10

"… the first step in a river restoration program should be to develop a solid understanding of what the targeted rivers were actually like before the changes that restorationists seek to undo or mitigate."

- Montgomery 2008 (*Science 319*:292)

"Landscapes that do not agree with the enduring context of a place may be riskier or more costly to build and maintain."

- Spirn 2000 (*Language of Landscape*)

why historical ecology?

Research the **past** to understand the **present** and envision the **future**

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- Provides information about historical landscape patterns, function and change
- Describes the conditions within which species evolved
- Challenges assumptions about past landscapes

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why historical ecology?

Research the **past** to understand the **present** and envision the **future**

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- Challenges assumptions about past landscapes
- Helps us understand the contemporary landscape
- Identifies opportunities and constraints
- Reveals a full palette of restoration potential

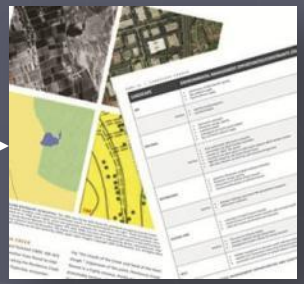
historical ecology methdology

Collection

Compilation

Synthesis

Analysis



Reporting

Archaeology Reports, Tribal Representatives

Explorer Journals

Travelogues/Memoirs

Diseños, Mexican Land Grant testimony

Maps/Surveys

Landscape photos and paintings

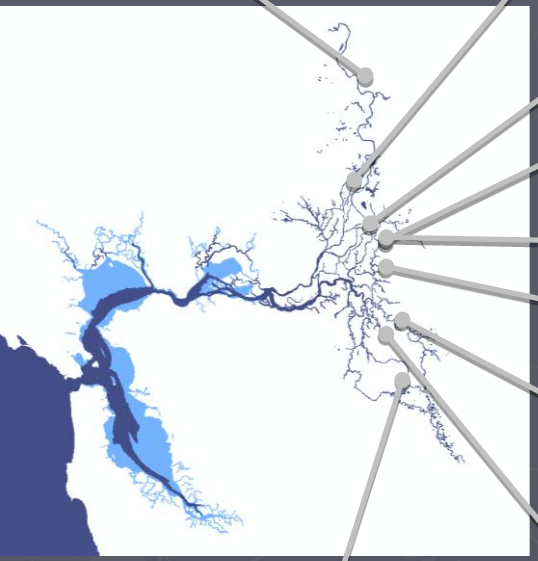
Aerial photography

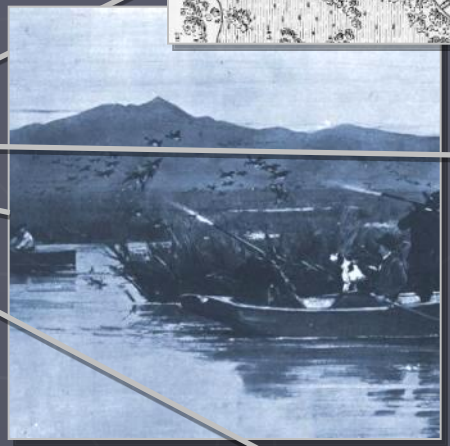
Interviews with long-time residents

Scholarly & professional reports & records

"The lake was situated far out in an impenetrable tule swamp of immense extent…it was a sort of "sanctuary" to which birds came…"

"lagoons…whose waters flowed back swiftly into the Sacramento with the ebbing tides"





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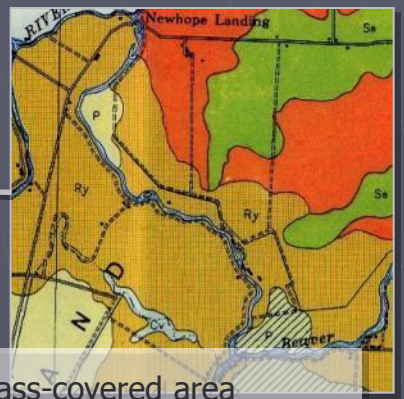

"In a grass-covered area between the forest and swamp"

"the river was filled with drift wood, forming a raft"

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"nothing but tule, without a tree under which the navigator may find shade"

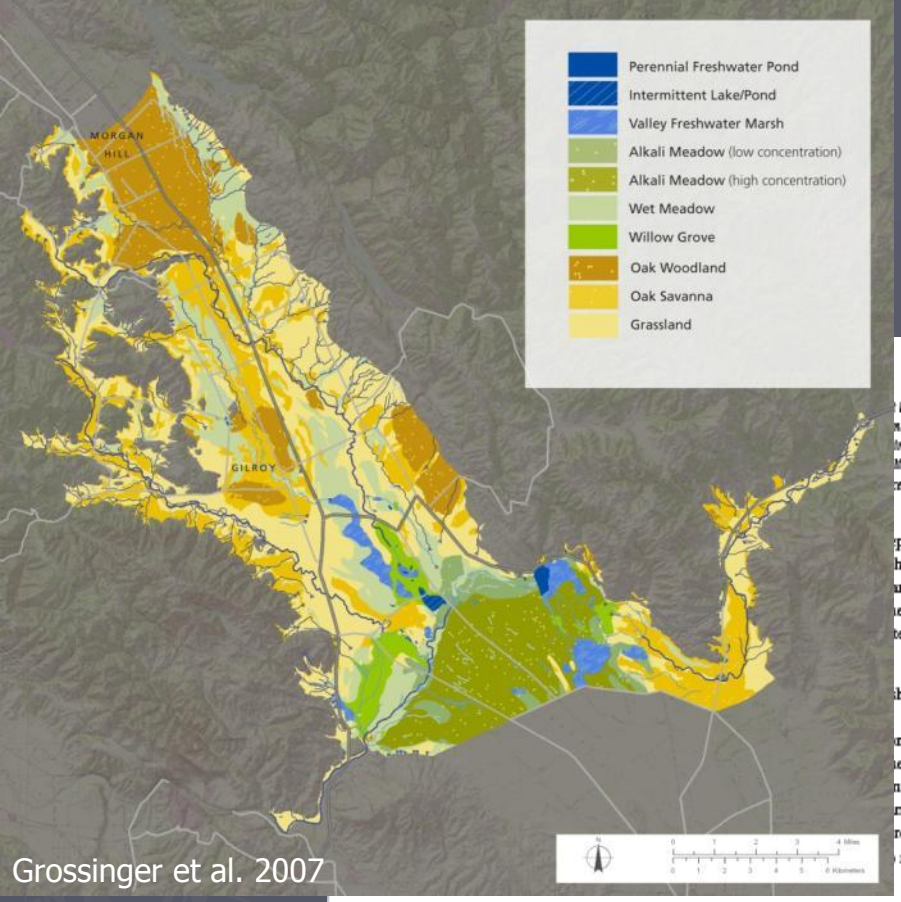
1800

1850

1900

1950

2000

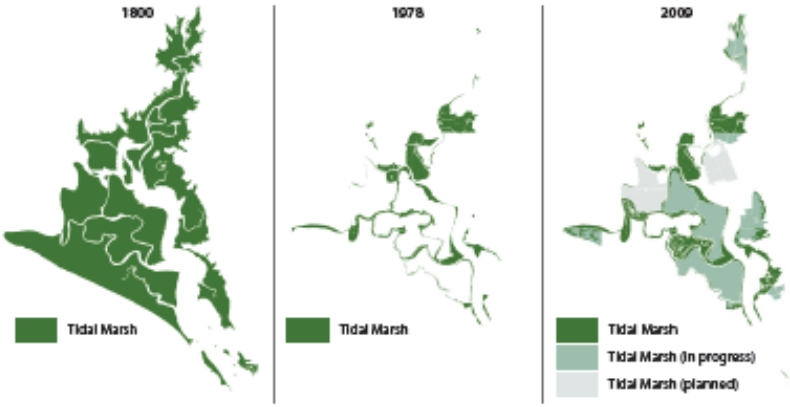


Grossinger et al. 2007

Years ago bass were so numerous in the lower reaches of Napa's sloughs that a man rowing a boat would strike a fish every few minutes with his oars. In recent years bass fishing in these sloughs has been largely abandoned because almost every slough that formerly afforded good fishing has been leveed off.

—NAPA RIVER ANGLER WP WEST, IN 1928.[37]

Tidal marsh trajectory, 1858-2009. Tidal marshlands along Napa River were almost completely eliminated during the first few decades of the 20th century. For over a half century, few marshes existed but recently their area has increased by 50%.[31]



Grossinger (in press)

RECLAMATION AND RESTORATION

Napa River's marshlands have always co-existed with people. When they formed, as the rate of sea level rise slowed several thousand years ago, native peoples already inhabited the margins of the expanding Bay. For countless generations, native tribes used the marshes for catching fish, hunting waterfowl, collecting salt, and transportation; 19th century Mexican and American cultures used the marshes similarly. Priorities shifted in the 1870s as farmers began to alter tidal hydrology to favor agriculture. Local chronicler Campbell Augustus Menefee proclaimed "the reclamation of a large body of tule land" taking place at Thompson's farm near Suscol in 1873. Five years later, the successful site was described as "meadow land reclaimed from… the overflowed tidelands of the Napa River."[32]

Yet it took time for reclamation to take hold. Many early levees failed. An 1885 article reported that "there have been attempts to levee or dike nearly all the marsh land … but the levees were not built strong enough to resist the pressure of the tide."[33] By 1914, however, the USGS showed levees constructed around the majority of Napa River's marshlands.[34] Robert Byrns, leading the resurvey of the Napa River marshlands for the US Coast and Geodetic Survey in 1922,[35] summarized both the transformation and its ordinariness, as similar changes were taking place throughout San Francisco Bay:

project goals

- Describe historical habitat characteristics
- Develop landscape-level understanding of historical ecological patterns
- Document former ecological, hydrologic, and geomorphic processes

TRANSLATING LANDSCAPE TO SPECIES SUPPORT FUNCTION

Physical Drivers

FLUVIAL PROCESSES

TIDAL PROCESSES

Habitats

Channels

Marshland

Ponds and lakes

Floodplain basins

Riparian forest

Upland ecotone

Function

Resting

Foraging

Breeding

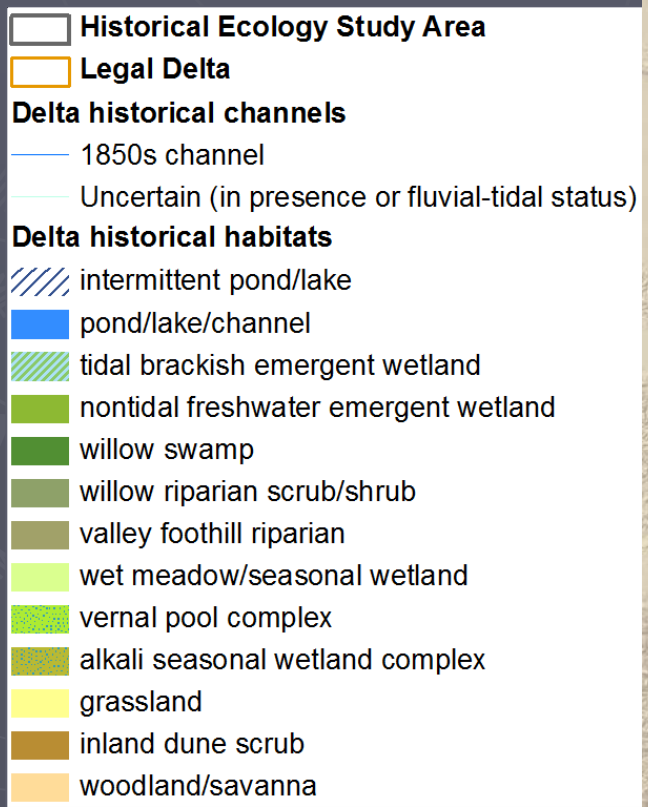
Migration

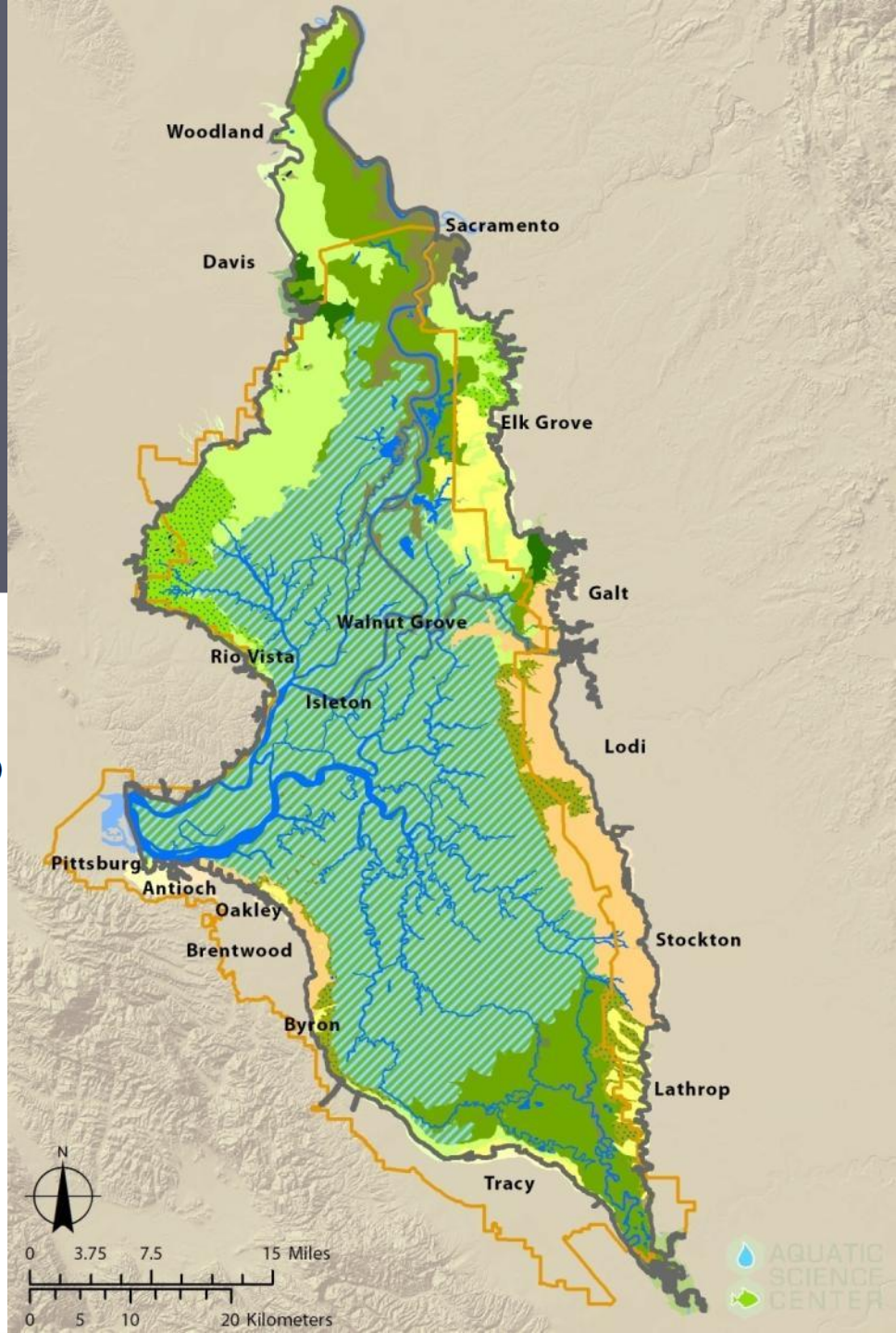
More than a vast expanse of tules

Font 1777

STUDY AREA

Historical Habitat Map (DRAFT)





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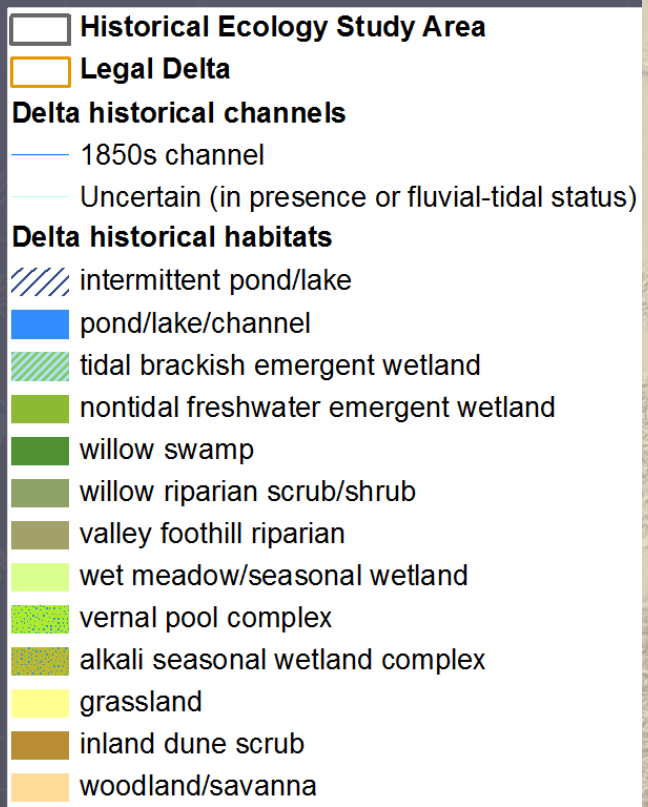

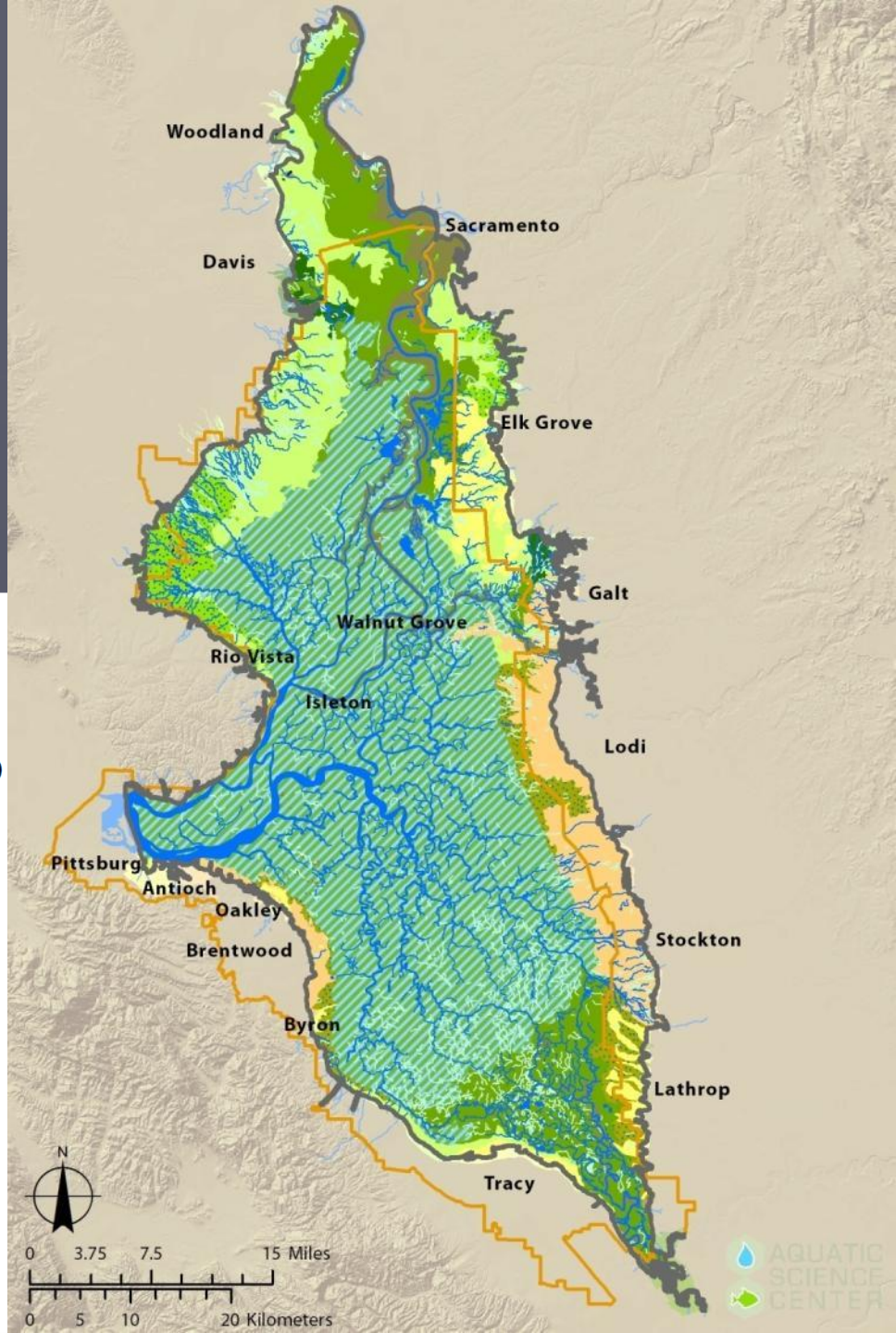

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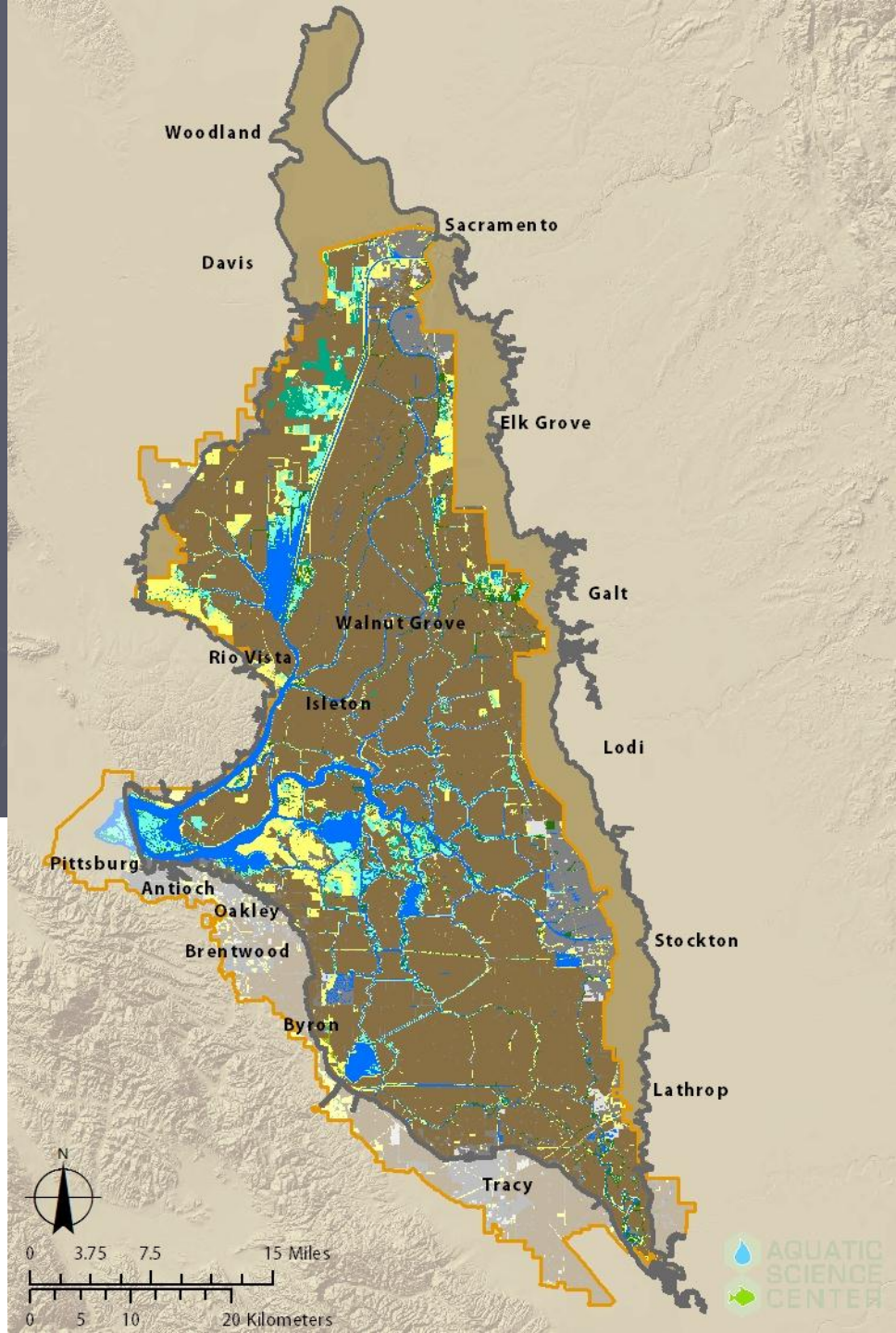
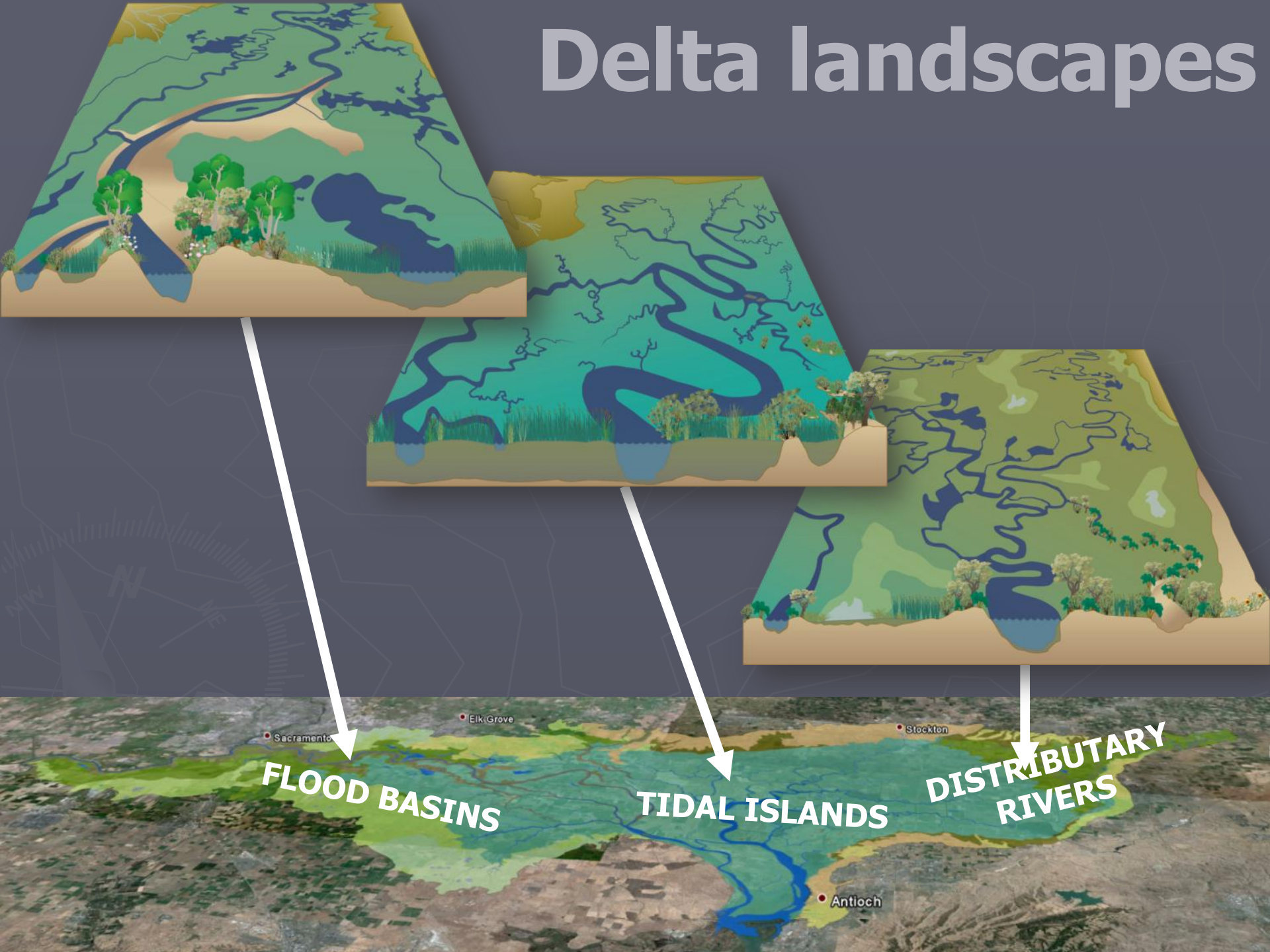


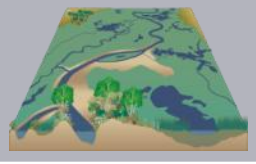
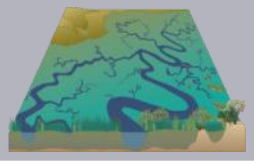
Keeler-Wolf 1997

- Riverine
- Valley Foothill Riparian
- Fresh Emergent Wetland
- Saline Emergent Wetland
- Annual Grassland
- Alkali Desert Scrub
- Coastal Scrub
- Coastal Oak Woodland
- Barren
- Agriculture
- Urban

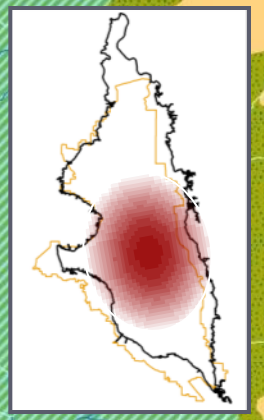
Delta landscapes



SELECTED LANDSCAPE CHARACTERISTICS – IN DEVELOPMENT

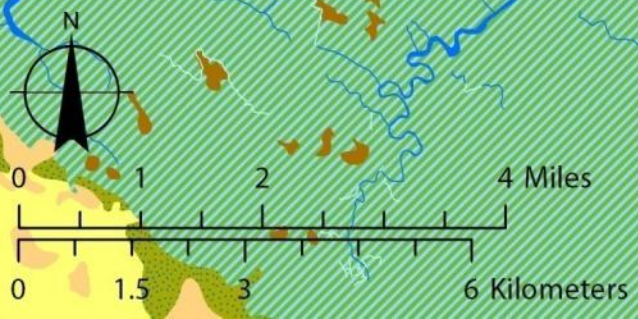
	Flood Basins	Tidal Islands	Distributary Rivers
			
Relative tidal influence	limited by natural levees and flood basin formation	inundated at least by spring tides	limited by channel complexity and topography
Relative fluvial influence	high flood events, lots of sediment	muted by tides	flooding linked to snowmelt
Channel characteristics	dendritic with density dependent on proximity to tidal source	large, sinuous, patterns repeating at island scales	greatly affected by fluvial processes
Ponds and lakes	large in size, located in flood basins away from tidal and sediment sources	small, apparently uncommon	moderate in size, located in floodplains, created by riverine dynamics
Natural levees	high, stable	low to none	moderate, more dynamic
Riparian vegetation	dense with oaks, sycamores, ash, walnut, vines, rose, etc.	tule, willow and other brush	moderately dense with oaks and willow

TIDAL ISLANDS LANDSCAPE: Central Delta



General Summary (GIS not finalized)

- Mapped freshwater emergent wetland: 300,000 acres
- Mapped riparian forest: 4,000 acres
- Mapped channel: 23,000 acres
- ~900 miles of tidal channel
- Channel densities generally between 20 and 40 ft/ac



TIDAL ISLANDS: relative tidal influence

On Sherman Island:

"Although the **high tide rises about half a foot** above the surface level of the soil..."

Tide lands overall:

"The surface of the land is perfectly level, being about **six inches below high and from three to six feet above low tide**..."

- Daily Herald, July 10, 1869

"There are no 'salt marshes' within these limits...**The ordinary tides wet the lands when not leveed, but do not overflow them except at the spring tides,** and then only a foot or so on the lower portions, in hollows, and along the bayous..."

- Day 1869

TIDAL ISLANDS: channel characteristics

CAUSED BY "CUTS".

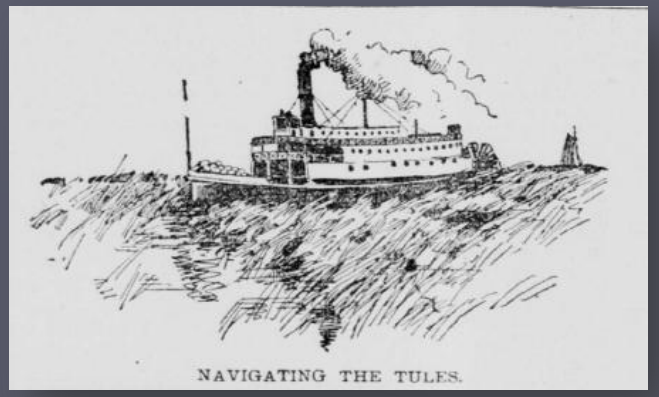
The San Joaquin Almost Unnavigable.

EXCEPT AT HIGH TIDE.

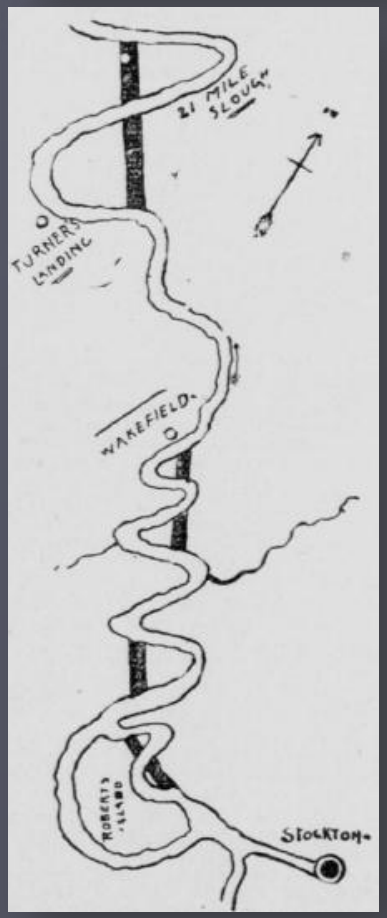
Unexpected Result of Shortening the River.

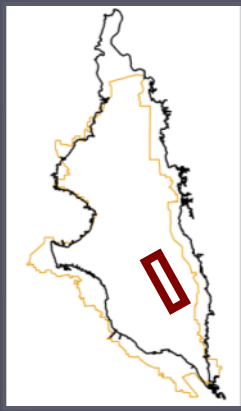
In the old days, when the river twisted like a snake, the rise and fall of the tide in the bay did not make a difference in the San Joaquin between Stockton and Twenty-one Mile Slough of more than two feet. The reason of this was that the many curves in the stream prevented the water running out as fast as the tide fell. By the time the tide had fallen six feet in the bay the water fell only two feet in the river, and when the tide rose in the bay it caught the flood and the river commenced to rise again. By this natural phenomenon the river was navigable at all hours.

"But now things have changed," said Pilot Arthur Robinson yesterday, "and the water runs through those cuts at low tide as it would out of a tin pan. The tide



NAVIGATING THE TULES.





"In the old days, when the river twisted like a snake, the rise and fall…did not make a difference…of more than two feet."

"…the many curves…prevented the water running out as fast as the tide fell."

"…the river was navigable at all hours."

"…now things have changed…the water runs through those cuts…as it would out of a tin pan."

The Morning Call, September 19, 1894


N
0
0.125
0.25
0.5 Miles
0
0.25
0.5
1 Kilometers


N
0
0.125
0.25
0.5 Miles
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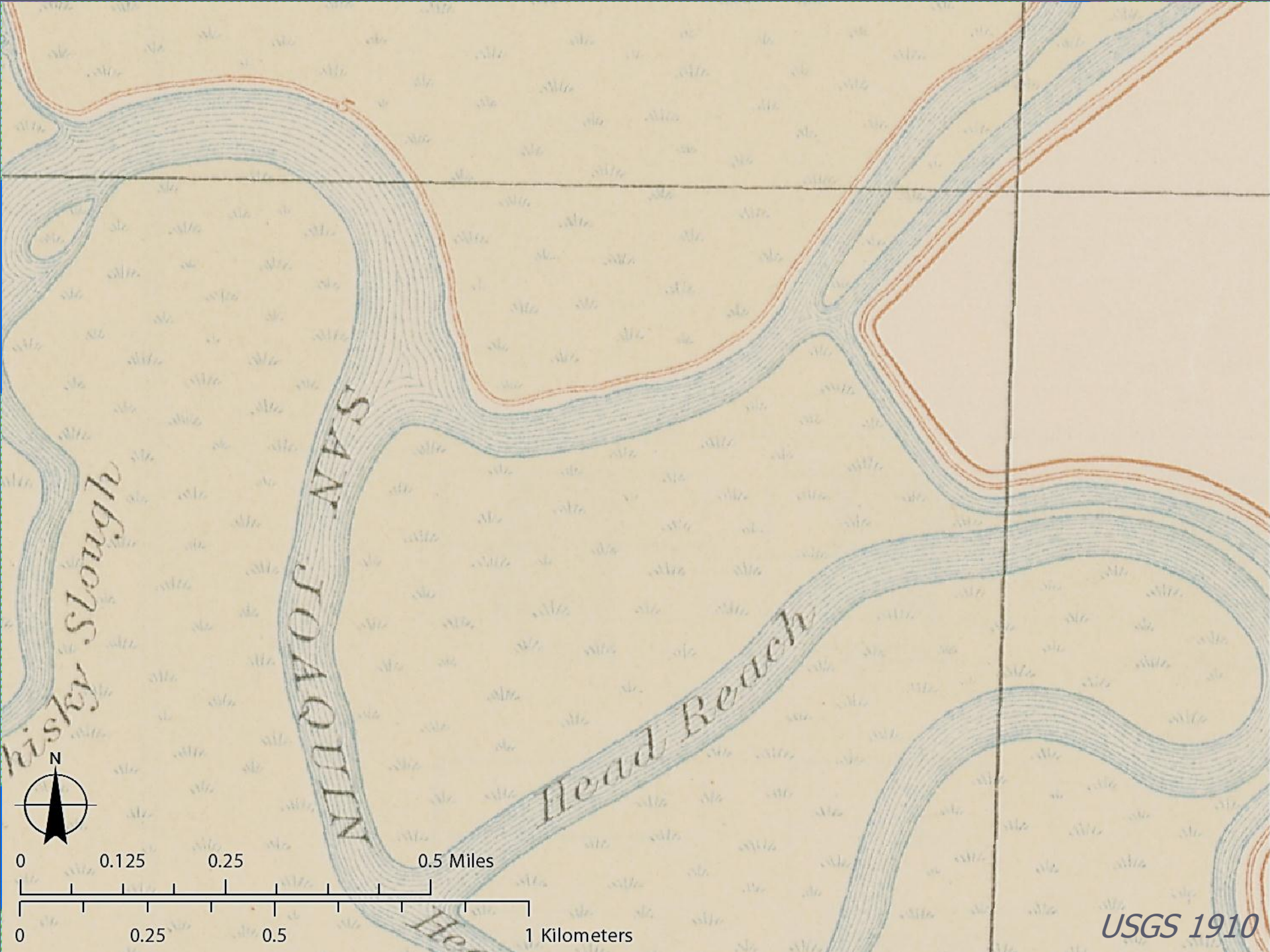
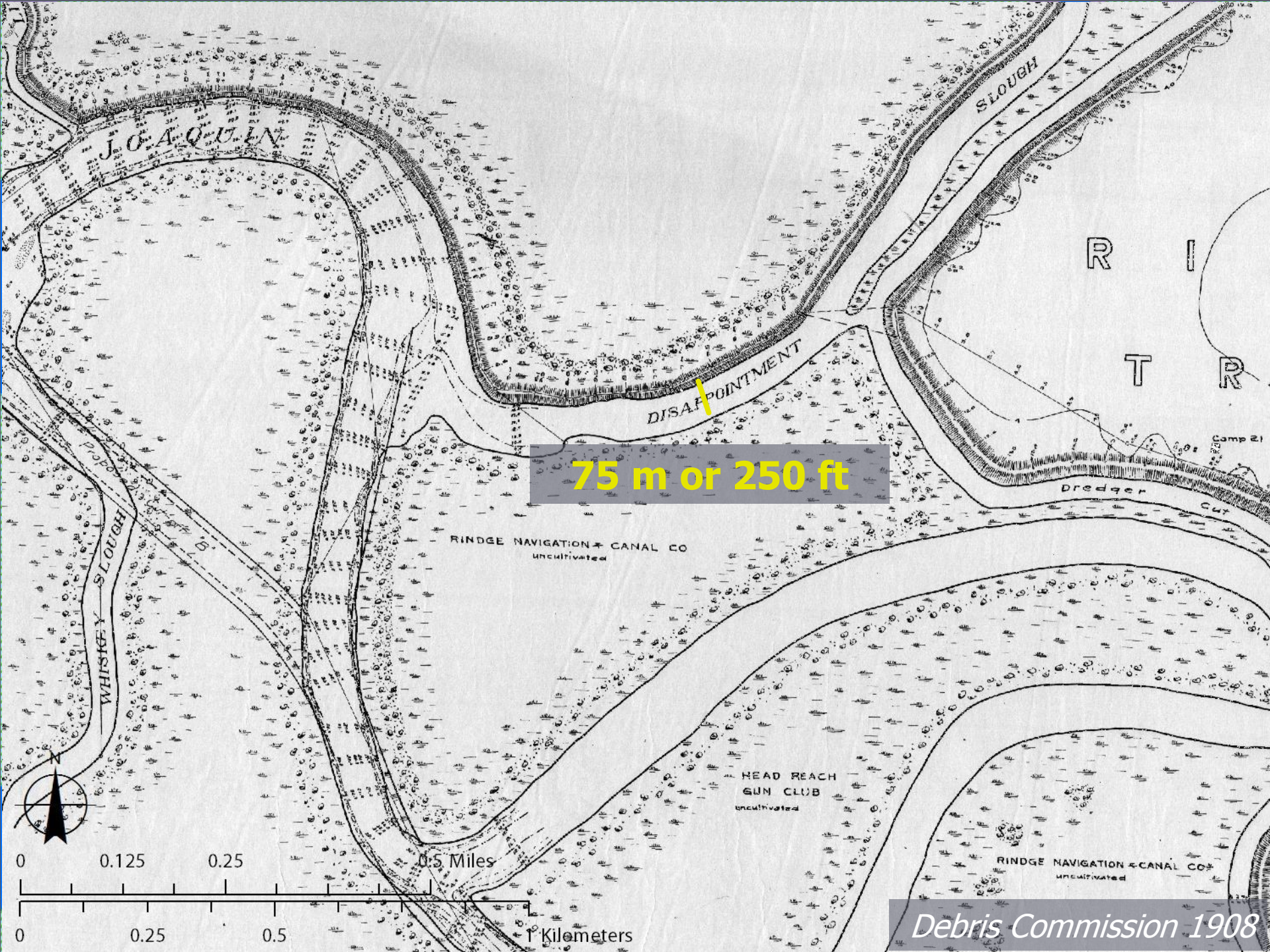
1 Kilometers


Whisky Slough
SAN JOAQUIN
Head Reach
N
0
0.125
0.25
0.5 Miles
0
0.25
0.5
1 Kilometers
USGS 1910


SLOUGH
J O A Q U I N
DISAPPOINTMENT
75 m or 250 ft
Dredger Cut
RINDGE NAVIGATION & CANAL CO
uncultivated
WHISKEY SLOUGH
HEAD REACH
GUN CLUB
uncultivated
RINDGE NAVIGATION & CANAL CO
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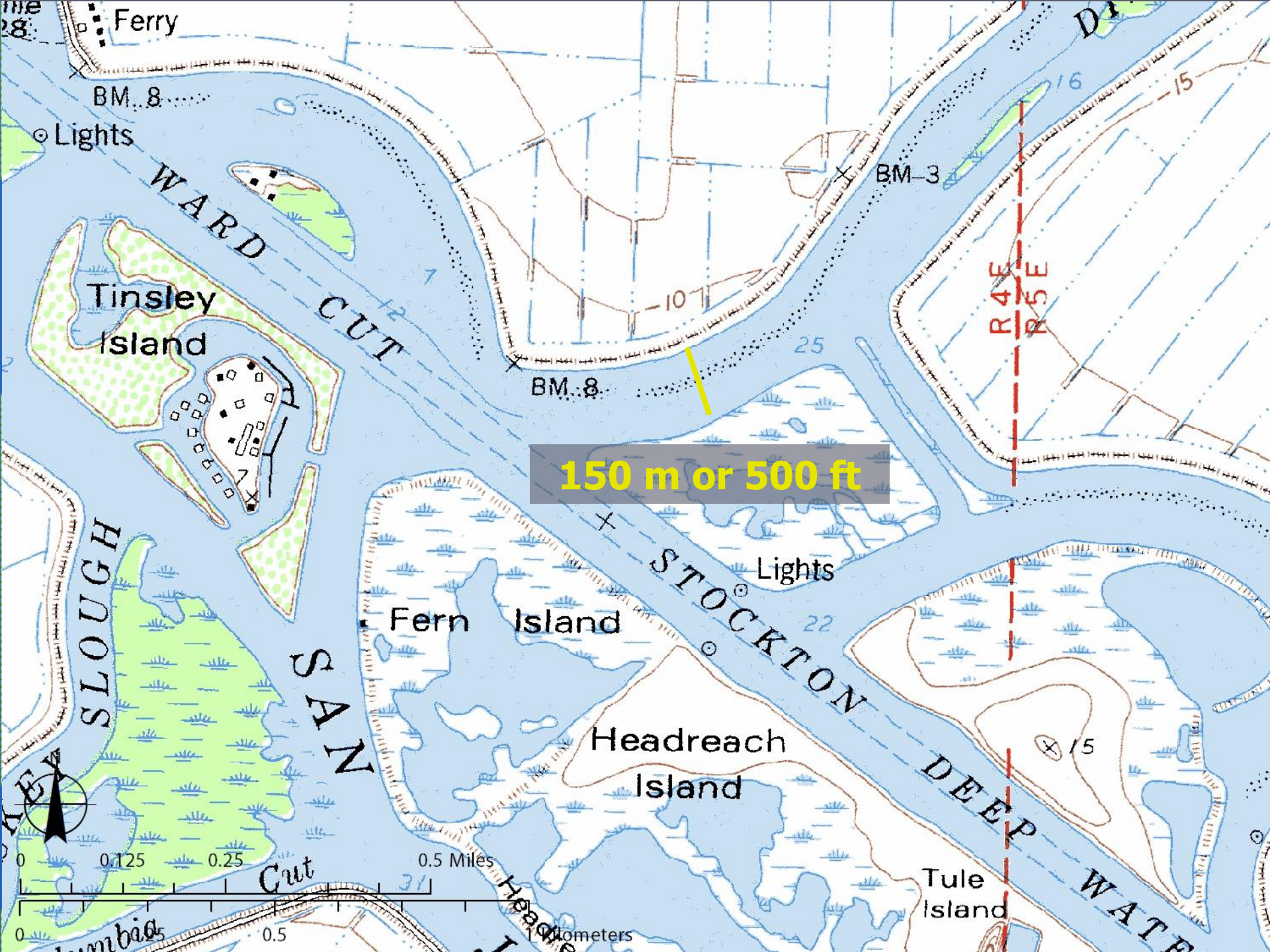
1 Kilometers
Debris Commission 1908


Ferry
BM 8
Lights
WARD CUT
Tinsley Island
BM 8
BM 3
R4E
R5E
150 m or 500 ft
Lights
STOCKTON DEEP
Fern Island
SAN
SLOUGH
Headreach Island
Tule Island
0 0.125 0.25 0.5 Miles
0 0.25 0.5 1 Kilometers


N
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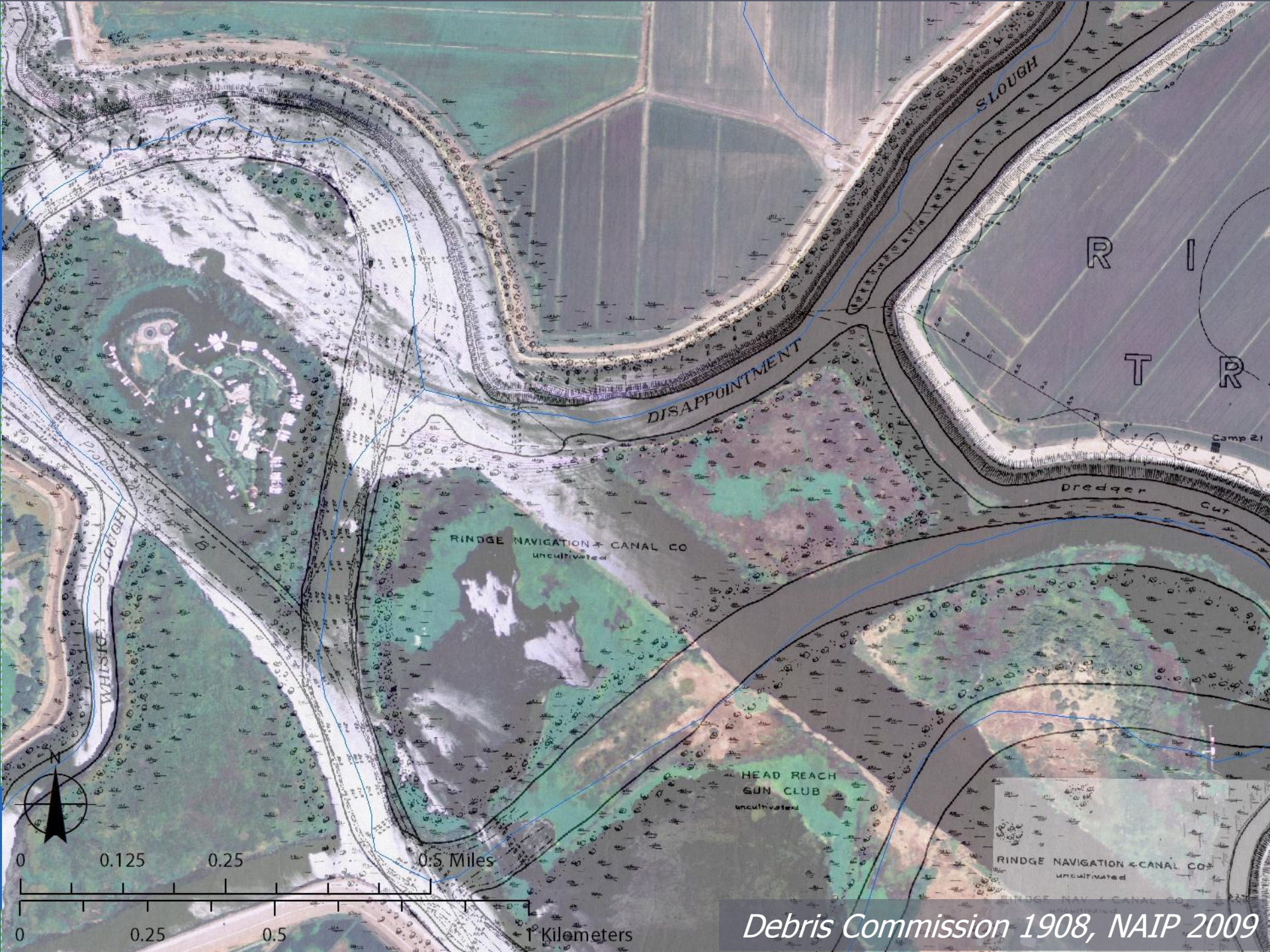
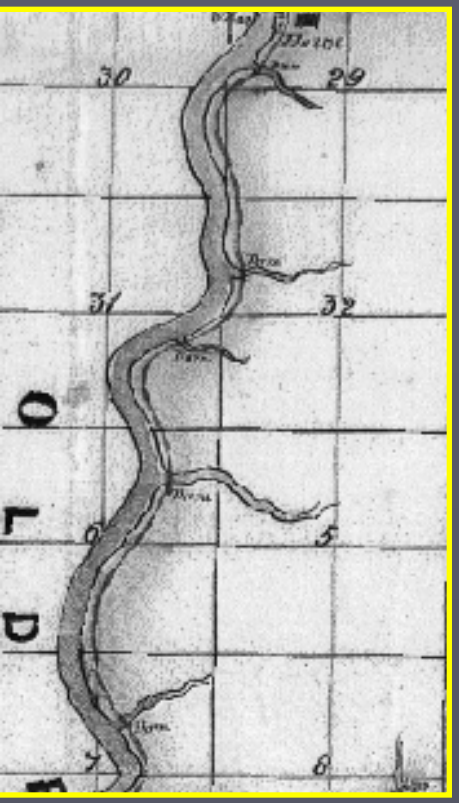
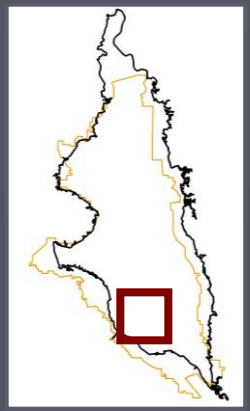
NAIP 2009

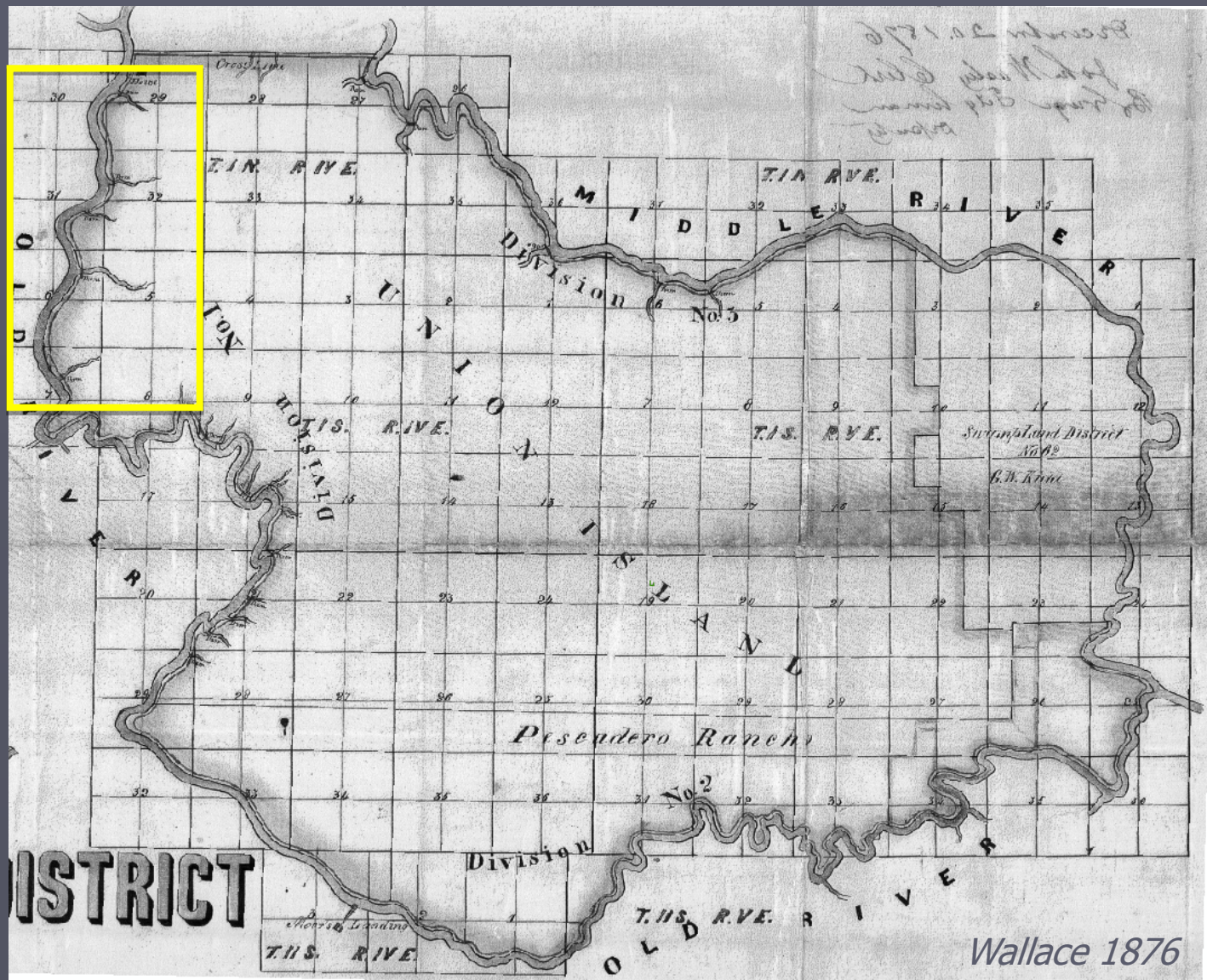

SLOUGH
DISAPPOINTMENT
R I
T R
Camp 21
Dredger Cut
RINDGE NAVIGATION & CANAL CO
uncultivated
HEAD REACH
GUN CLUB
uncultivated
RINDGE NAVIGATION & CANAL CO
uncultivated
WHISKEY SLOUGH
N
0
0.125
0.25
0.5 Miles
0
0.25
0.5
1 Kilometers
Debris Commission 1908, NAIP 2009

TIDAL ISLANDS: channel characteristics

How many sloughs and where?







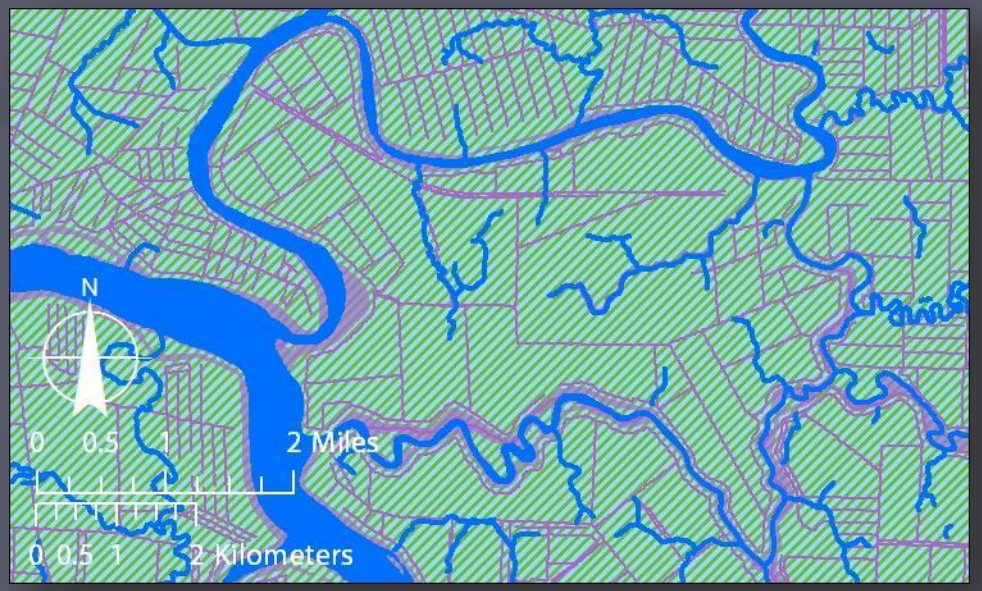
Wallace 1876

TIDAL ISLANDS: channel characteristics

Bouldin Island:

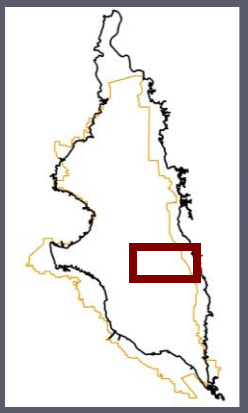
"In making the circumference of the island the line crosses **3 Beaver cuts and 3 sloughs.** The Beaver cuts being from **4 to 7 feet deep** and the sloughs from **10 to 20 feet [deep]**...The sloughs keep their width and depth for some distance inland and the surface being low at their heads..."

- Beaumont 1861



TIDAL ISLANDS: channel characteristics

How wide were the sloughs?



General Land Office Survey

W. F. Benson 1878

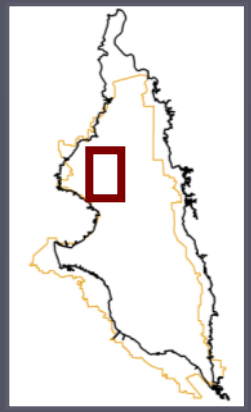
TIDAL ISLANDS: channel characteristics

NAIP 2009

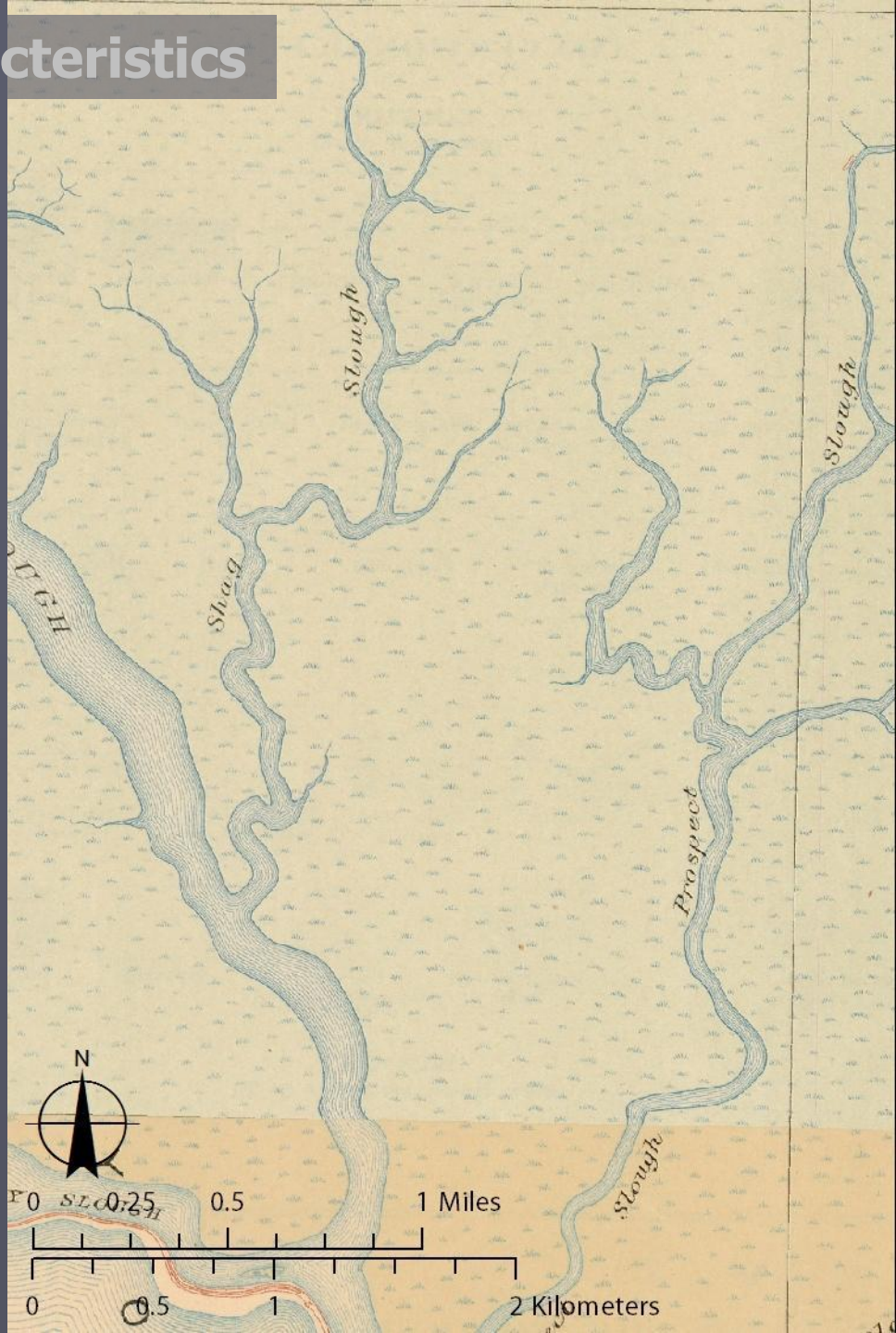
TIDAL ISLANDS: channel characteristics

Historical USGS topographic quads

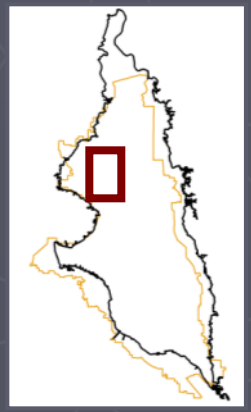
3rd or 4th order channels



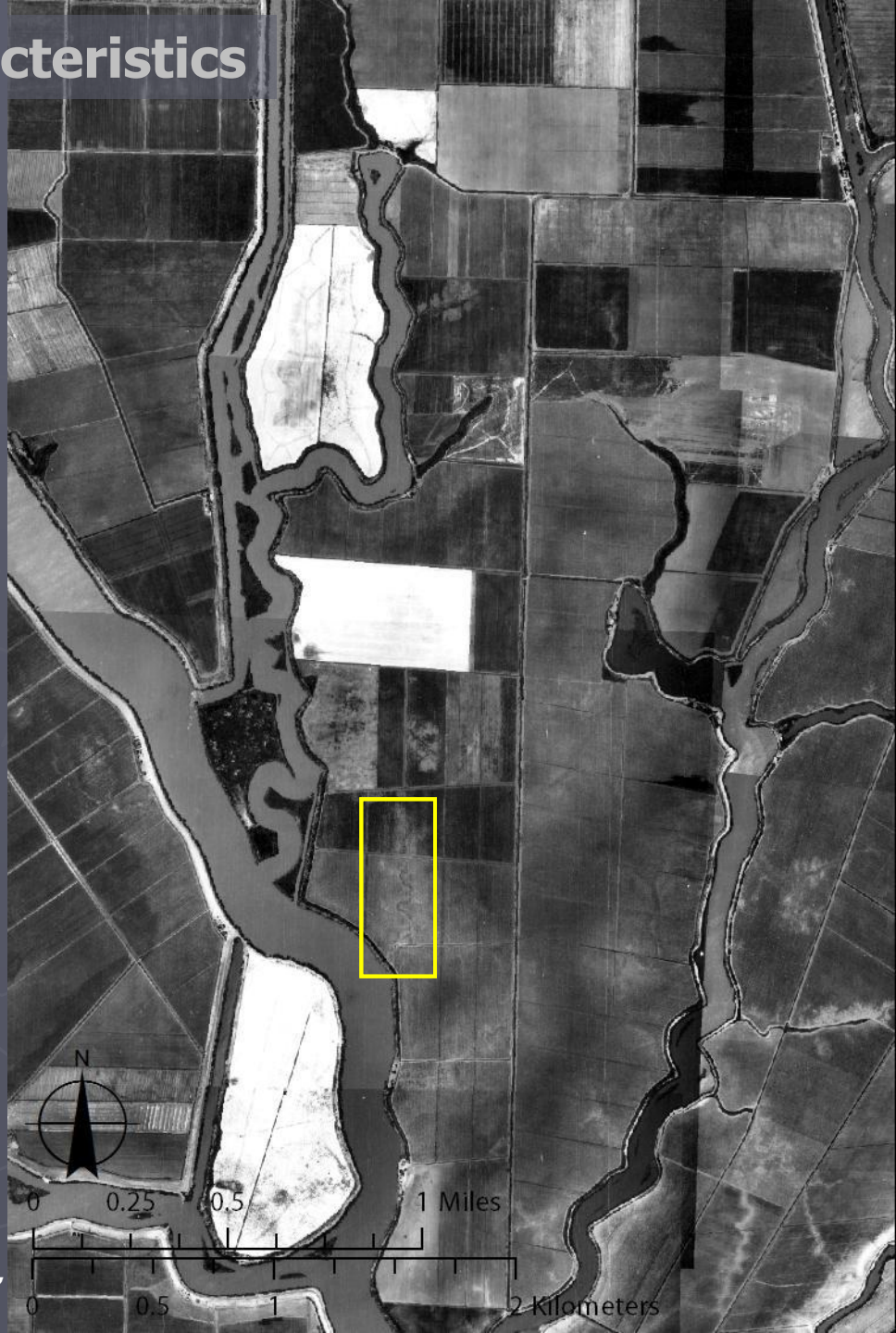
USGS 1916



TIDAL ISLANDS: channel characteristics



USDA 1937



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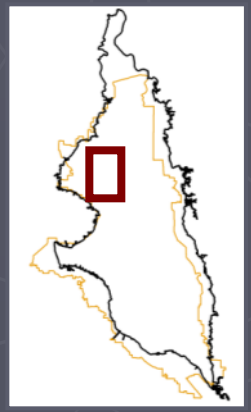


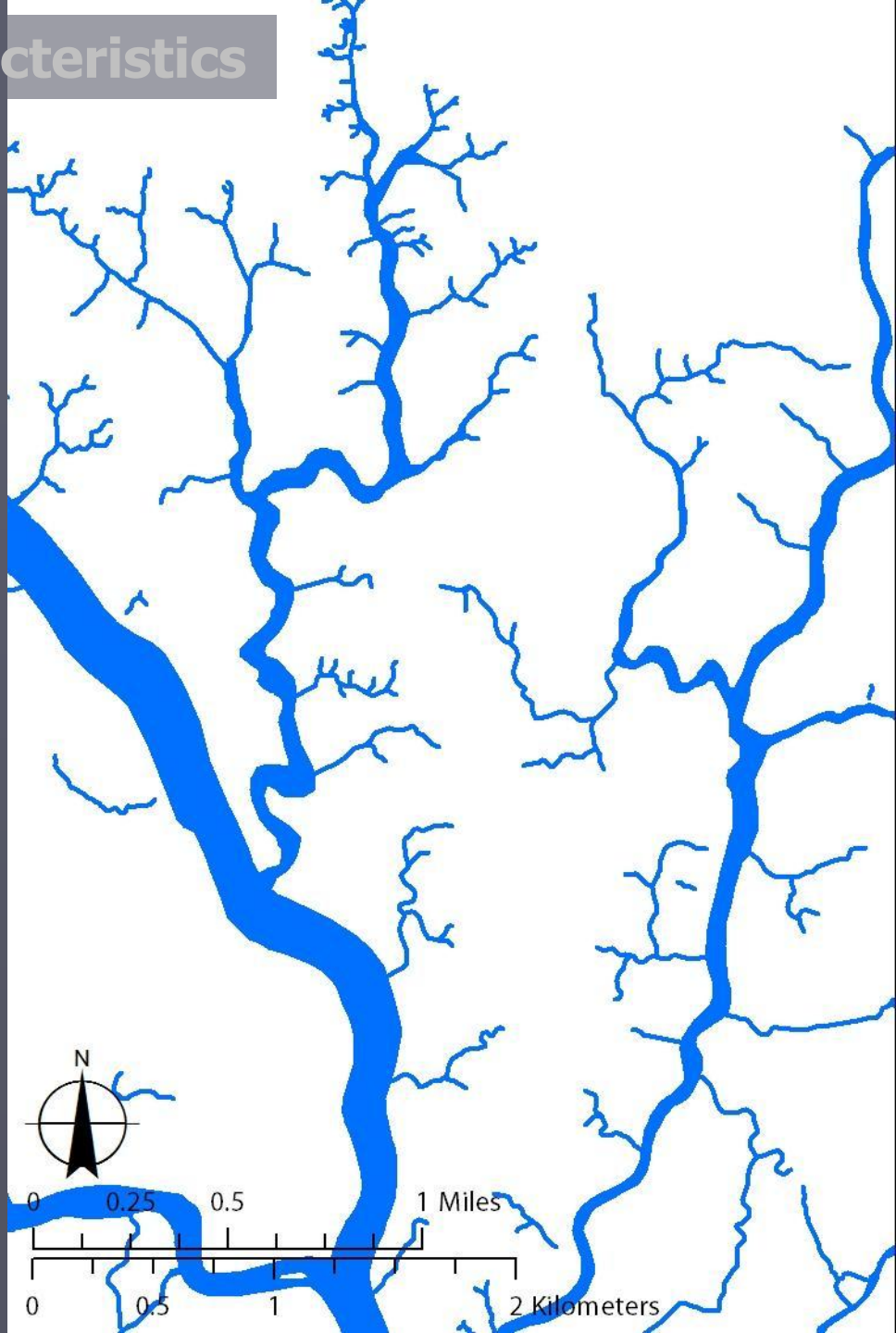
Wheeler 1920

TIDAL ISLANDS: channel characteristics

Pre-reclamation

Using the 1937 historical aerial photography and other maps…

Liberty Island approximate density: 3.3 km/km^2 or 44 ft/ac



TIDAL ISLANDS: vegetation patterns

Comparing the Sacramento and San Joaquin:

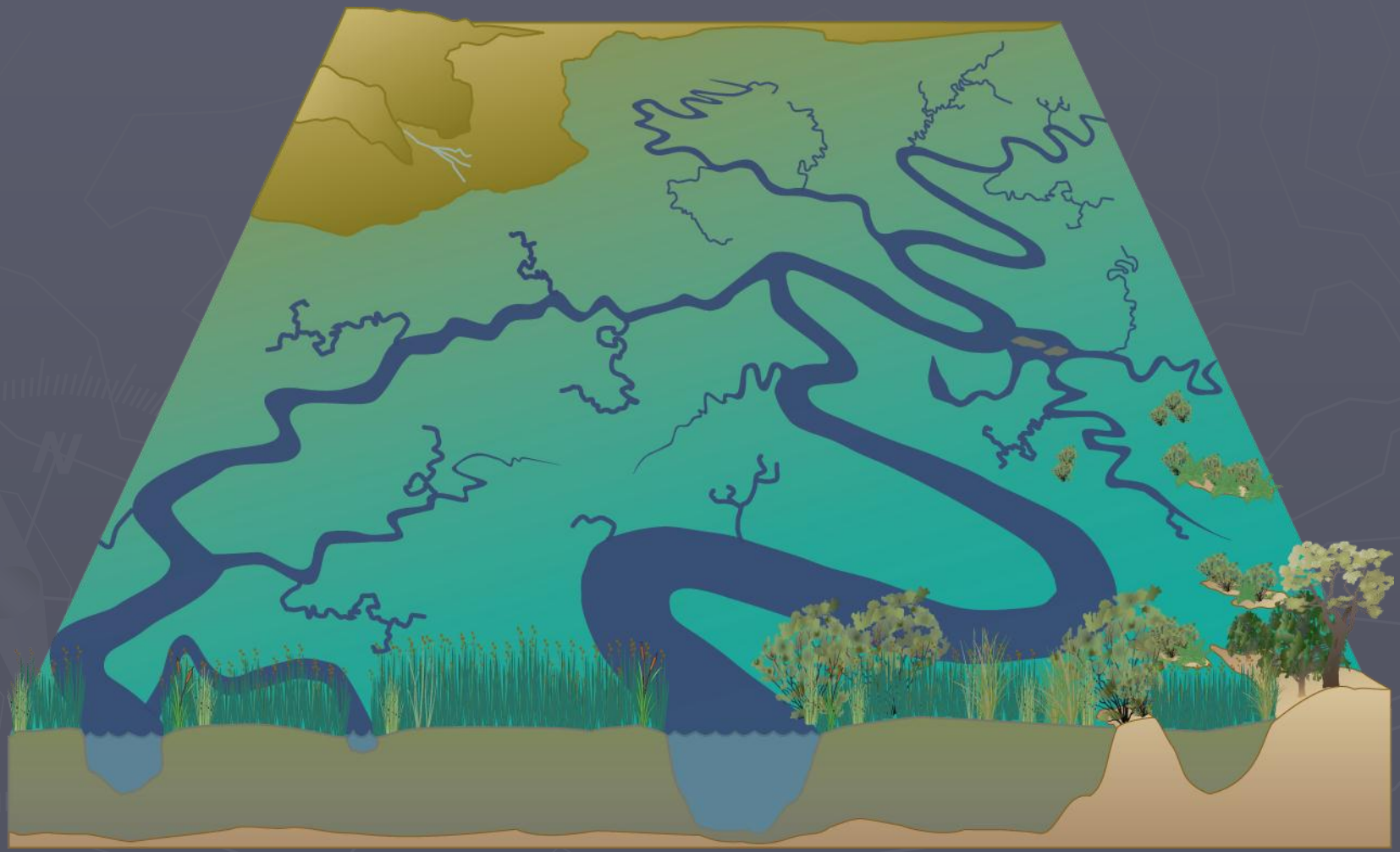
"The islands of the San Joaquin do not exhibit so decided a tendency to this basin-like formation. Their edges are not so elevated, nor are they so covered with vegetation, while their **interior parts the tule is thinner and shorter. Willows here grow in bunches , and different kinds of coarse grass are found successfully maintaining themselves against the aggressive tule**." (USDA 1874)

TIDAL ISLANDS: vegetation patterns

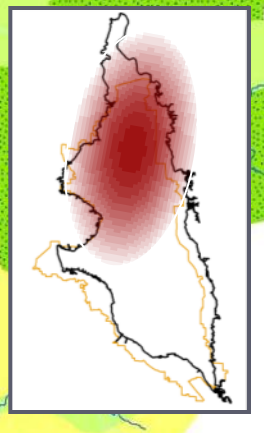
"There were extensive willow swamps with a dense understory of Ladyfern."

- botanist Anson Blake in Mason's "Floristics of the Sacramento-San Joaquin Delta"

tidal islands landscape (Central Delta)

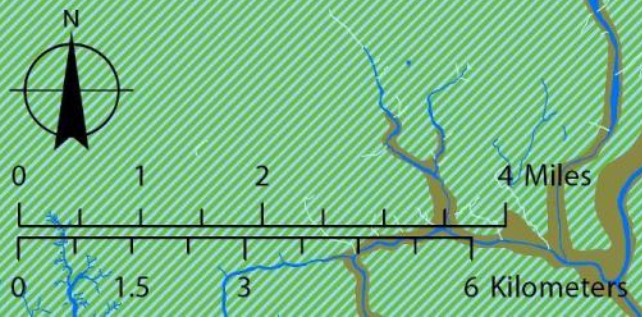


FLOOD BASINS LANDSCAPE: North Delta



General Summary (GIS not finalized)

- Mapped freshwater emergent wetland: 150,000 acres
- Mapped riparian forest: 35,000 acres
- Mapped ponds/lakes: 4,500 acres
- The eight largest lakes are >100 acres, largest >1,000 acres



FLOOD BASINS: hydrologic regime

Interactions between flow, sediment supply, and vegetation govern the temporal conditions of habitat

"Putu [sic] and Cache creeks…form in the rainy season **a lake some 40 miles long, and from 5 to 10 miles wide**. In some years this lake is increased by the overflowing of the Sacramento…"

- Californian, 26 April 1848

"…the water pours down Cache slough from the tule on the west in such volume and with such force as **completely to neutralize the current** in Steamboat slough."

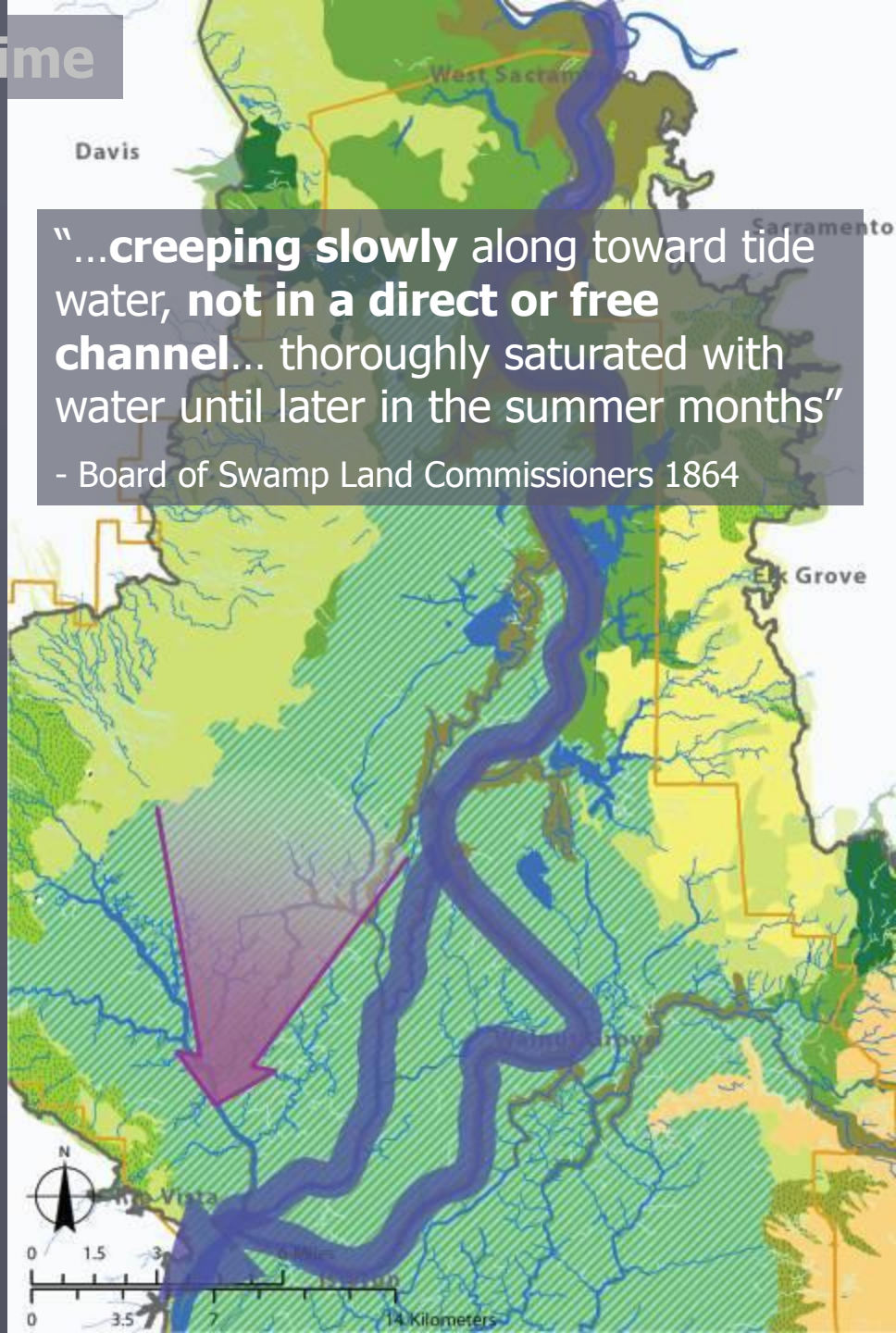
- Sacramento Daily Union, 24 March 1862

FLOOD BASINS: hydrologic regime

Character of hydrologic connectivity

In-stream flows: inorganic sediment, short residence time

Tidal marsh discharge: organic material, zooplankton, longer residence time, capacity for nutrient exchange, warmer termperatures



"…**creeping slowly** along toward tide water, **not in a direct or free channel**… thoroughly saturated with water until later in the summer months"

- Board of Swamp Land Commissioners 1864

FLOOD BASINS: ponds and lakes

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"...seem to be **filled at high water**, but become **stagnant during the dry season**"
- Wilkes 1845

"many **coves and slough-like branches**" - Wright ca. 1850

"Though the lake was a large one it was very shallow - **could be waded in all parts**, except a small streak in the middle..." - Wright ca. 1850

~500 acres

USGS 1906-1916

Swampland Dist No. 2 1864

FLOOD BASINS: ponds and lakes

"edge of the lake for a distance of one hundred yards out thickly covered with **lily pads**." (Wright ca. 1850)

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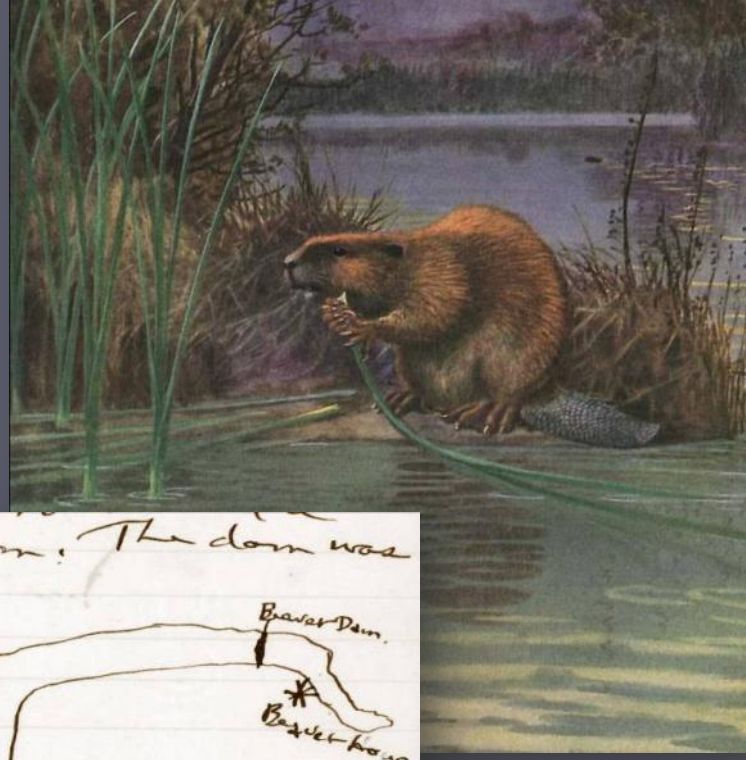
Tule marsh water was "so thoroughly impregnated with decaying vegetable matter that **it looked more like sherry than water**…In order to see the strange creatures in the water no microscope was required; they were visible to the naked eye…In lying down to drink from the edge of a pool we had before us for study **a whole universe of animalcules**." (Wright ca. 1850)

USGS 1907, Courtesy Center for Sacramento History

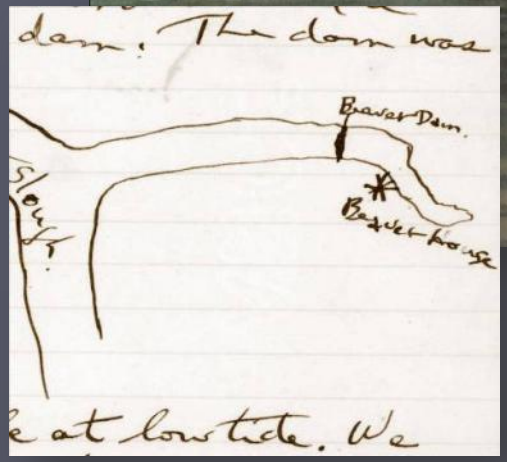
FLOOD BASINS: ponds and lakes



They were used:

"…into the tule to open spaces which were covered with water **where ducks and geese would light**." (Thornton 1859)

"The **small fish run into the sloughs and lakes** as soon as the water gets sufficiently high, and **return to the river when it begins to get low**." (Sacramento Daily Union, 6 June 1854)

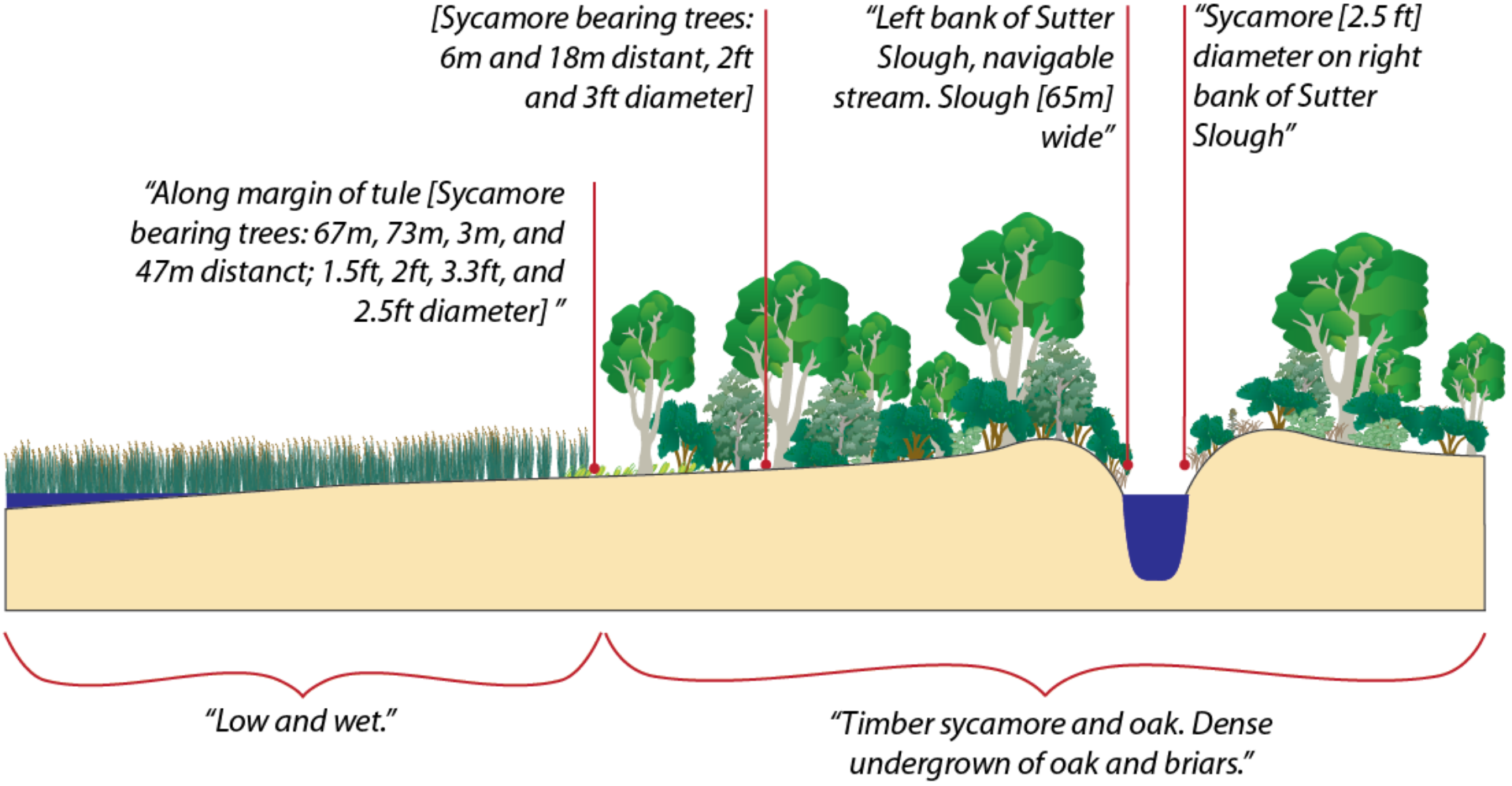


And modified:

"**subterranean excavations of the beaver** always gave us a perpendicular drop of about two feet " (Wright ca. 1850)

"The geese eat the roots and **clean out areas of 5, 10 and 20 acres** or even more… Sometimes these '**geese wallows**' become 4 or 5 ft deep, as the waters recede the geese work down. " (Jepson 1904)

FLOOD BASINS: riparian vegetation



General Land Office Survey by William J. Lewis on November 27, 1859

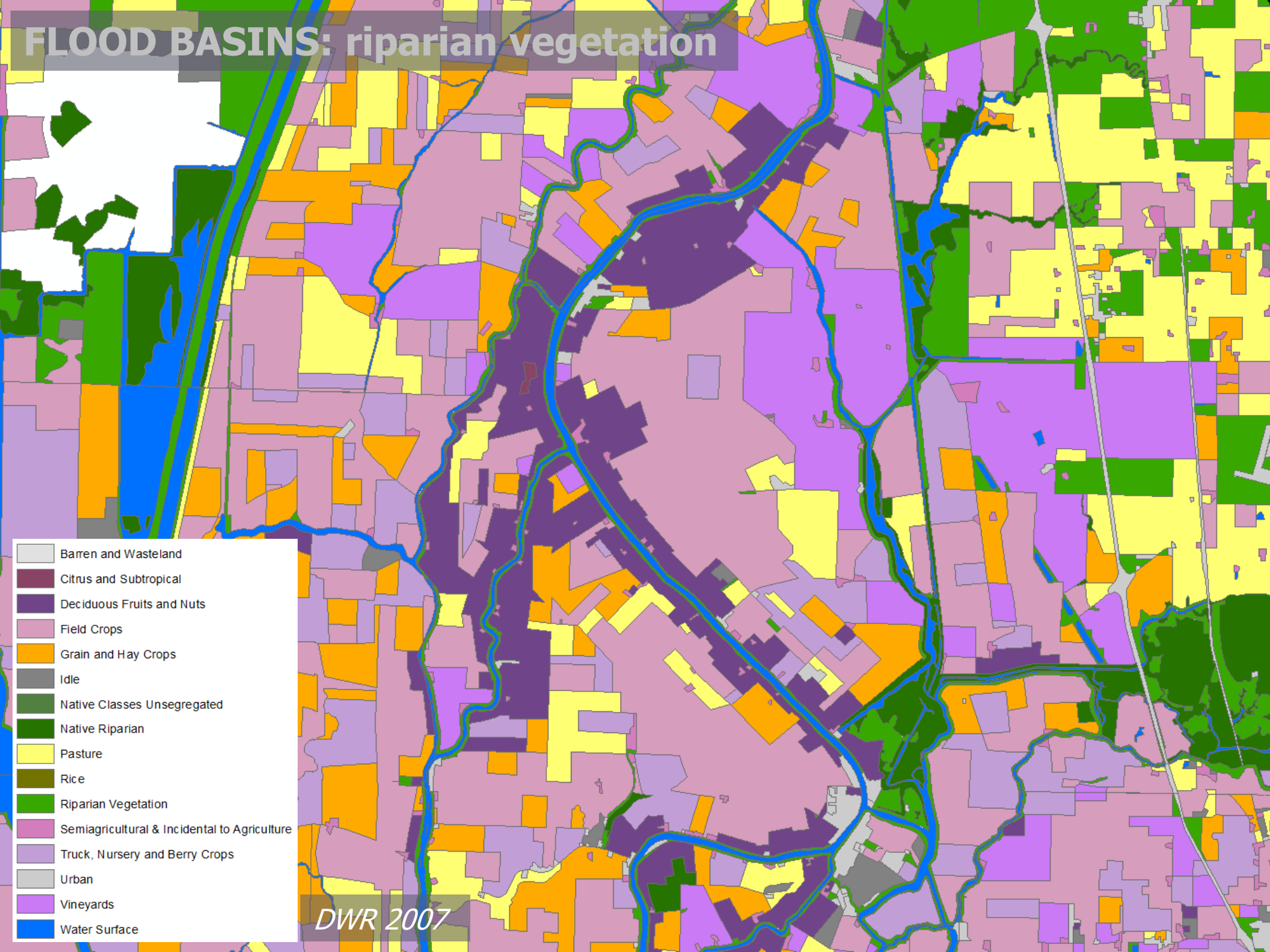
FLOOD BASINS: riparian vegetation

"Between this body of water and the river was a **narrow ridge of land mostly covered with a growth of oak, cottonwood, willow and sycamore trees, amidst which was a matted jungle** of grape and blackberry vines which, with other shrubbery…

This slightly elevated ridge seemed to be exempt from overflow…"

- Fairchild 1934

FLOOD BASINS: riparian vegetation



FLOOD BASINS: riparian vegetation

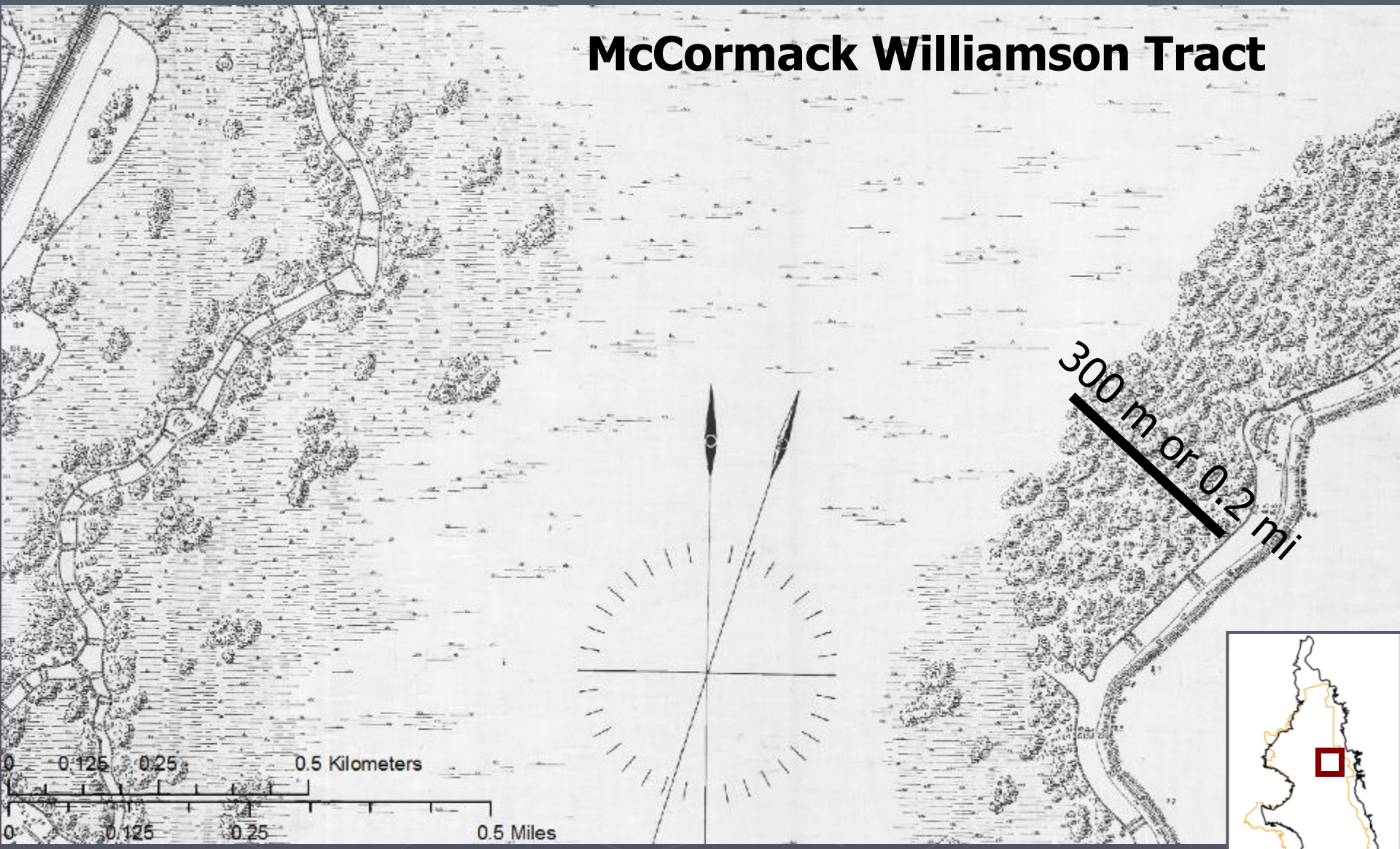
How wide was the forest?

1.1 km or 0.7 mi

"There being a large tuly [tule] or rush swamp about **half a mile** from the river"
- Clyman and Camp 1960[1845]

Boyd 1895

FLOOD BASINS: riparian vegetation

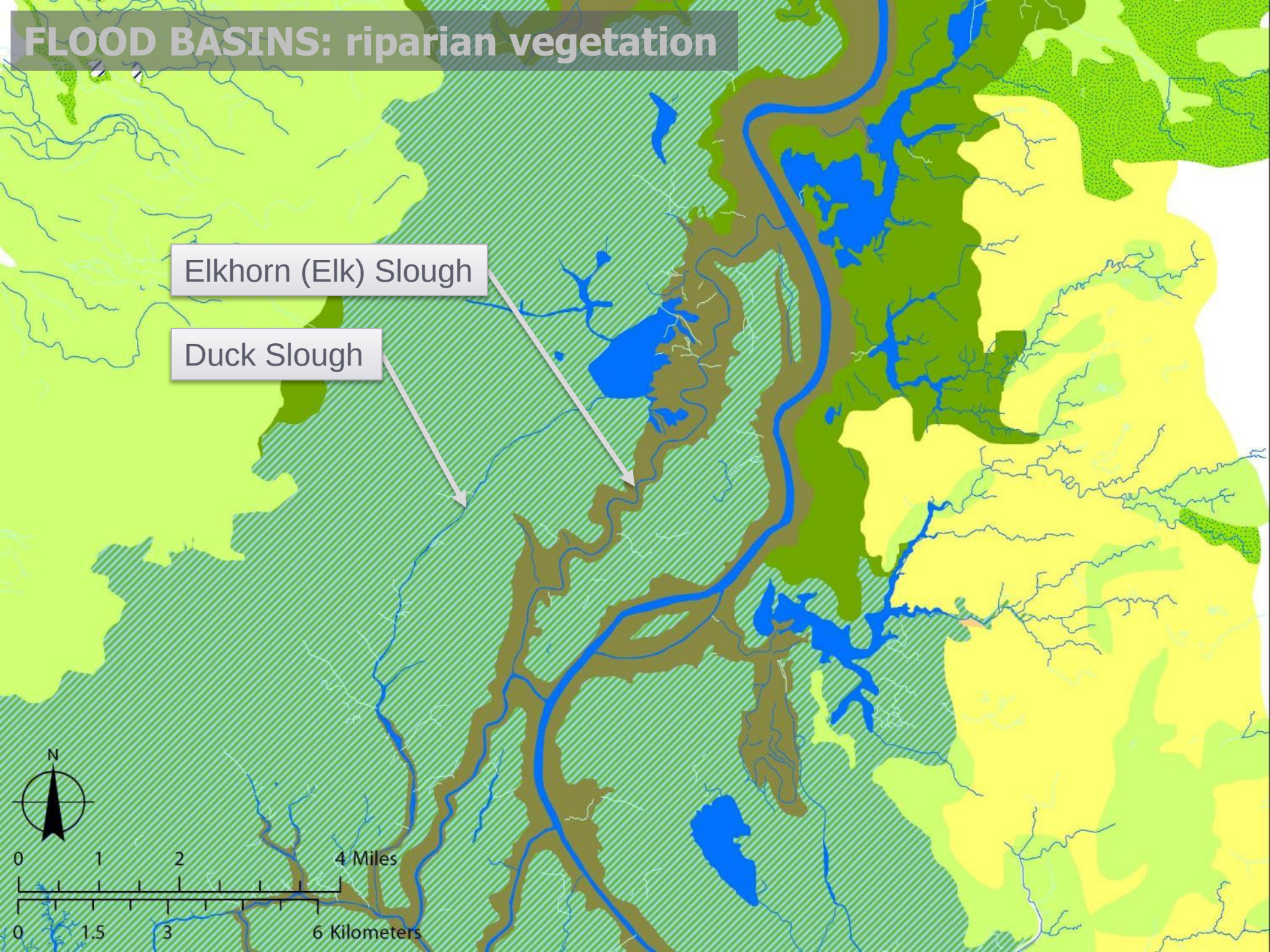


Debris Commission 1914

FLOOD BASINS: riparian vegetation

NAIP 2005

FLOOD BASINS: riparian vegetation



FLOOD BASINS: riparian vegetation

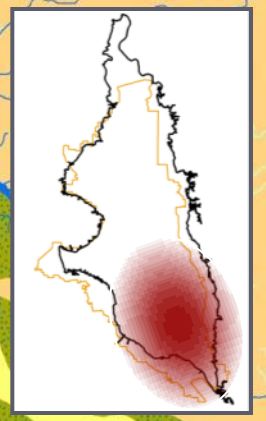
ELKHORN SLOUGH

FLOOD BASINS: riparian vegetation

DUCK SLOUGH

flood basins landscape (North Delta)

DISTRIBUTARY RIVERS LANDSCAPE: South Delta



General Summary (GIS not finalized)

- Mapped freshwater emergent wetland: 78,000 acres
- Mapped riparian forest: 6,000 acres
- Mapped ponds/lakes: 740 acres
- Most ponds/lakes <100 acres

N

0 1 2 4 Miles

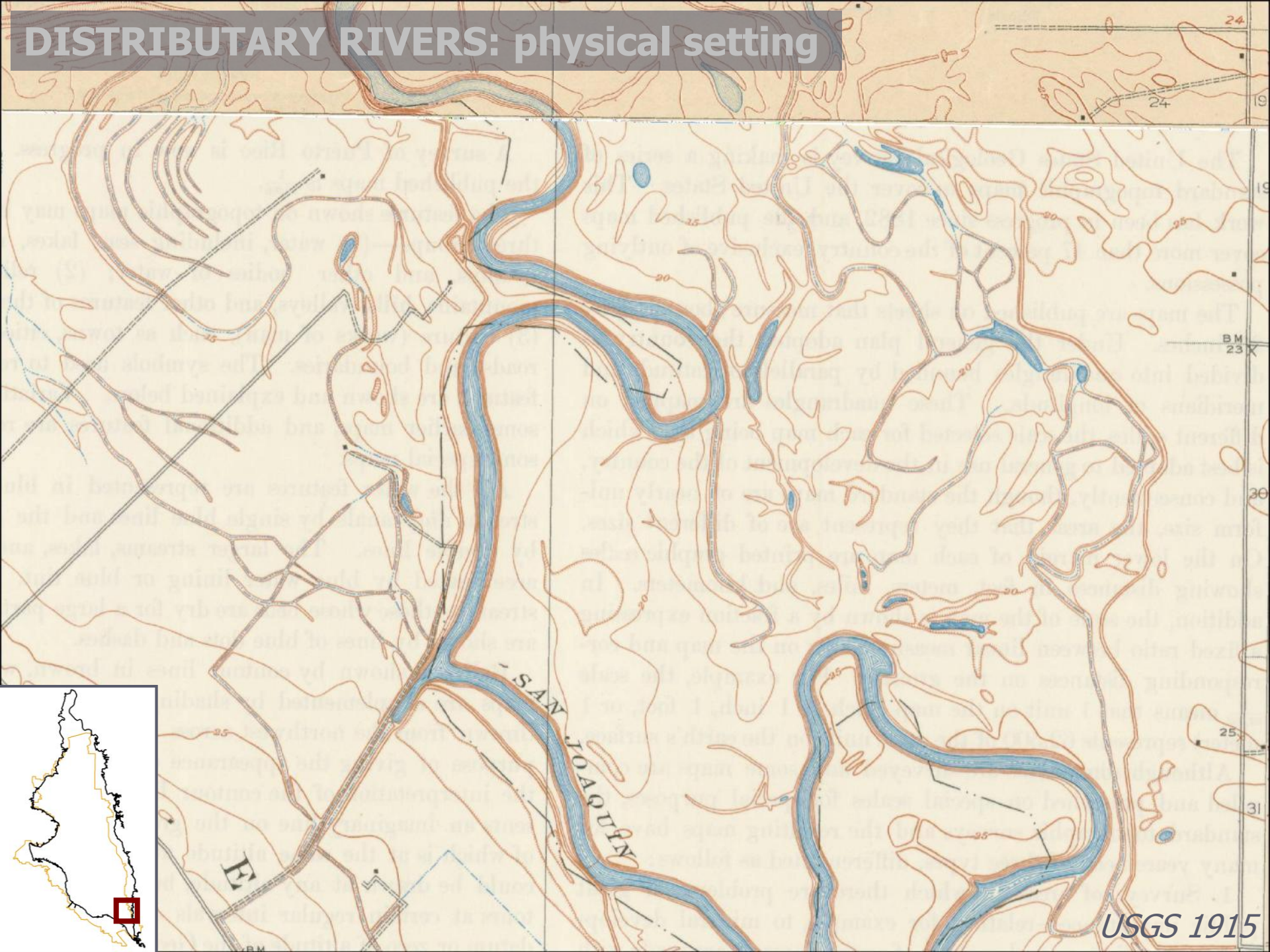
0 1.5 3 6 Kilometers

DISTRIBUTARY RIVERS: habitat complexity

June 10: "passed 2 or 3 sloughs – water 4 ft deep…after much trouble reached the river at night having spent the day in making 1 ½ miles. Bridged one of the sloughs with brush."

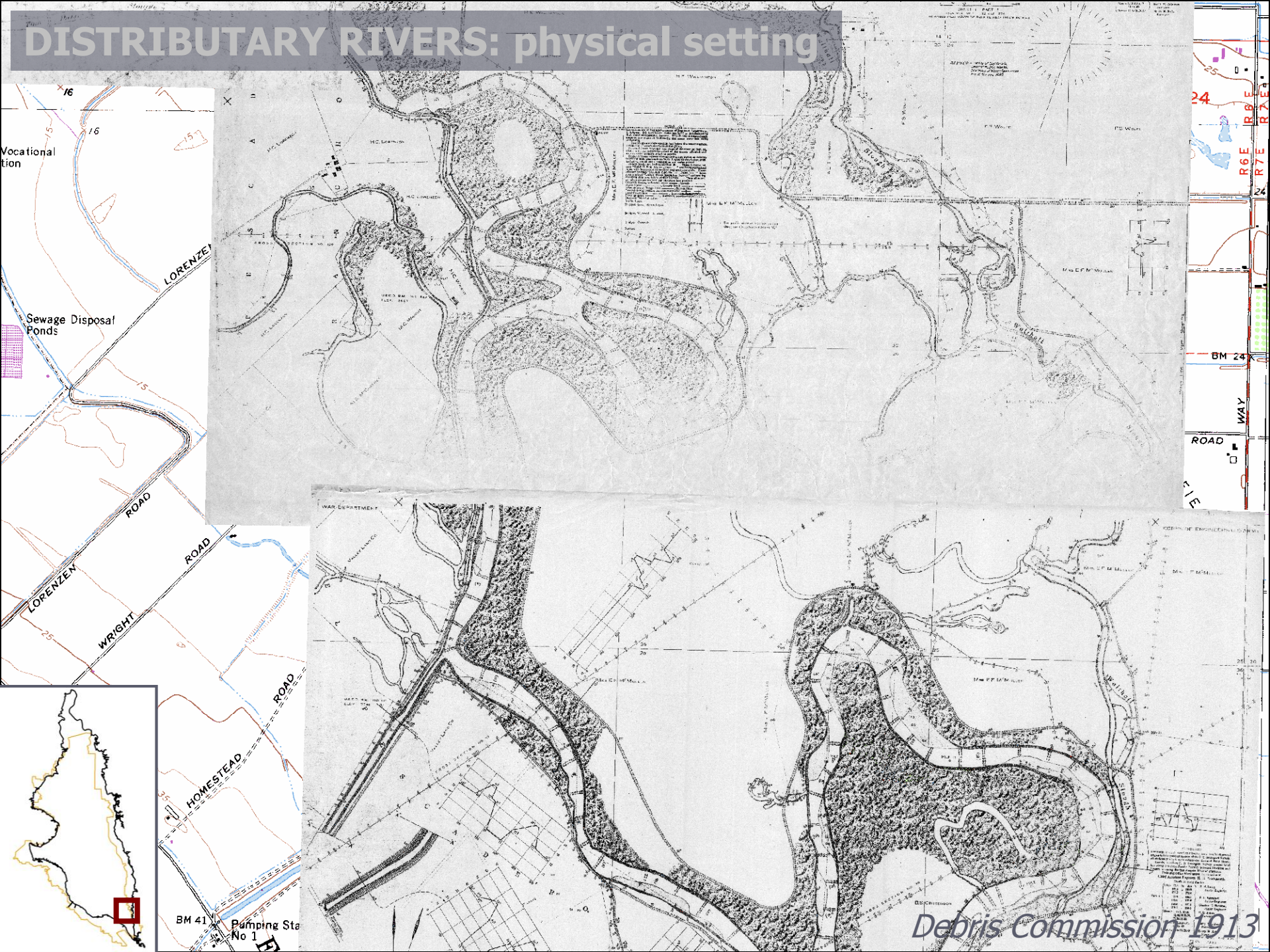
- Lyman 1848

DISTRIBUTARY RIVERS: physical setting



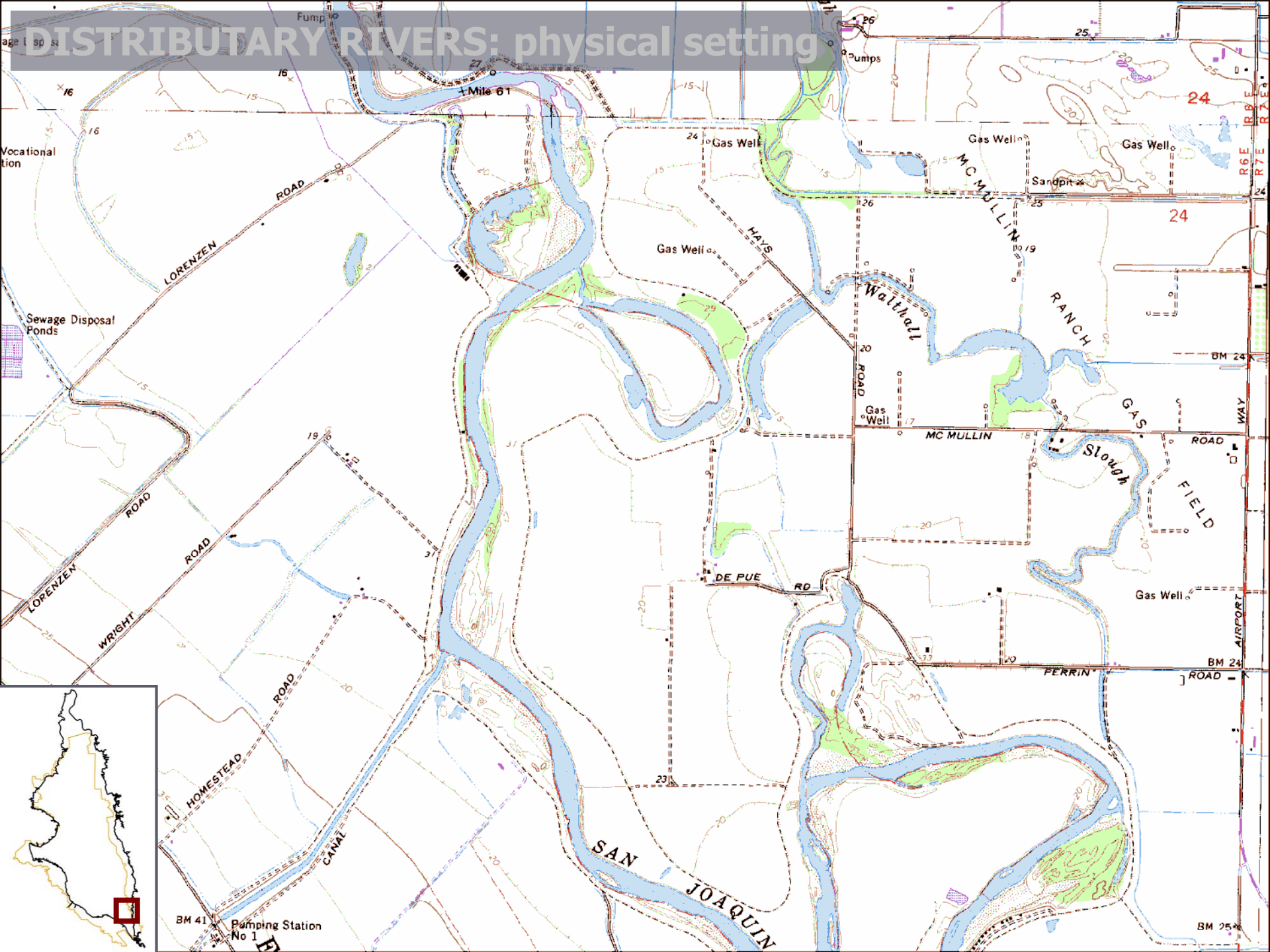
USGS 1915

DISTRIBUTARY RIVERS: physical setting



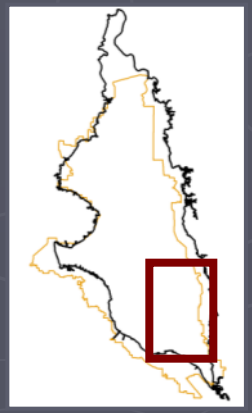
Debris Commission 1913

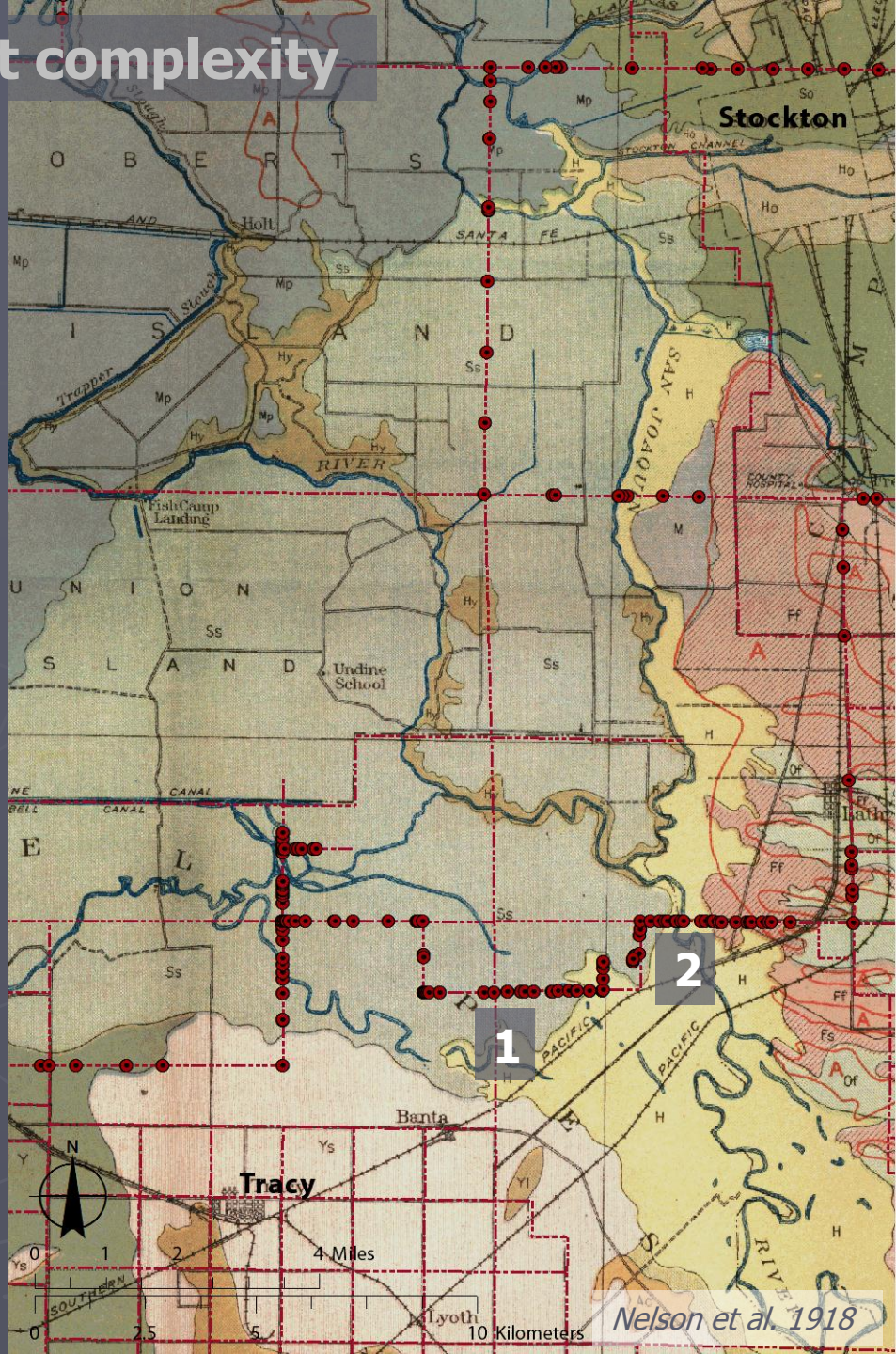
DISTRIBUTARY RIVERS: physical setting



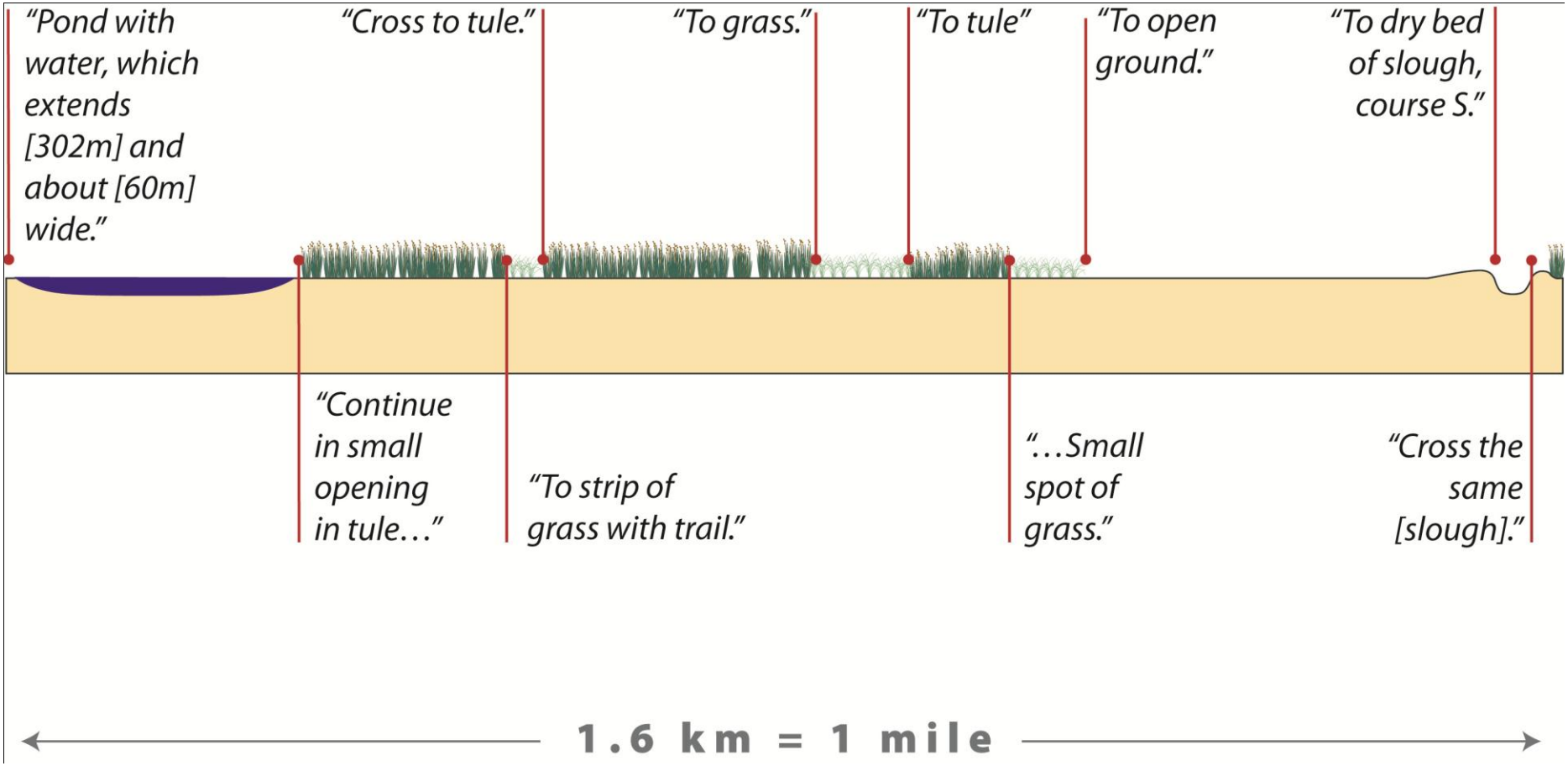
DISTRIBUTARY RIVERS: habitat complexity

Transition zone from tidal marsh to riverine floodplain



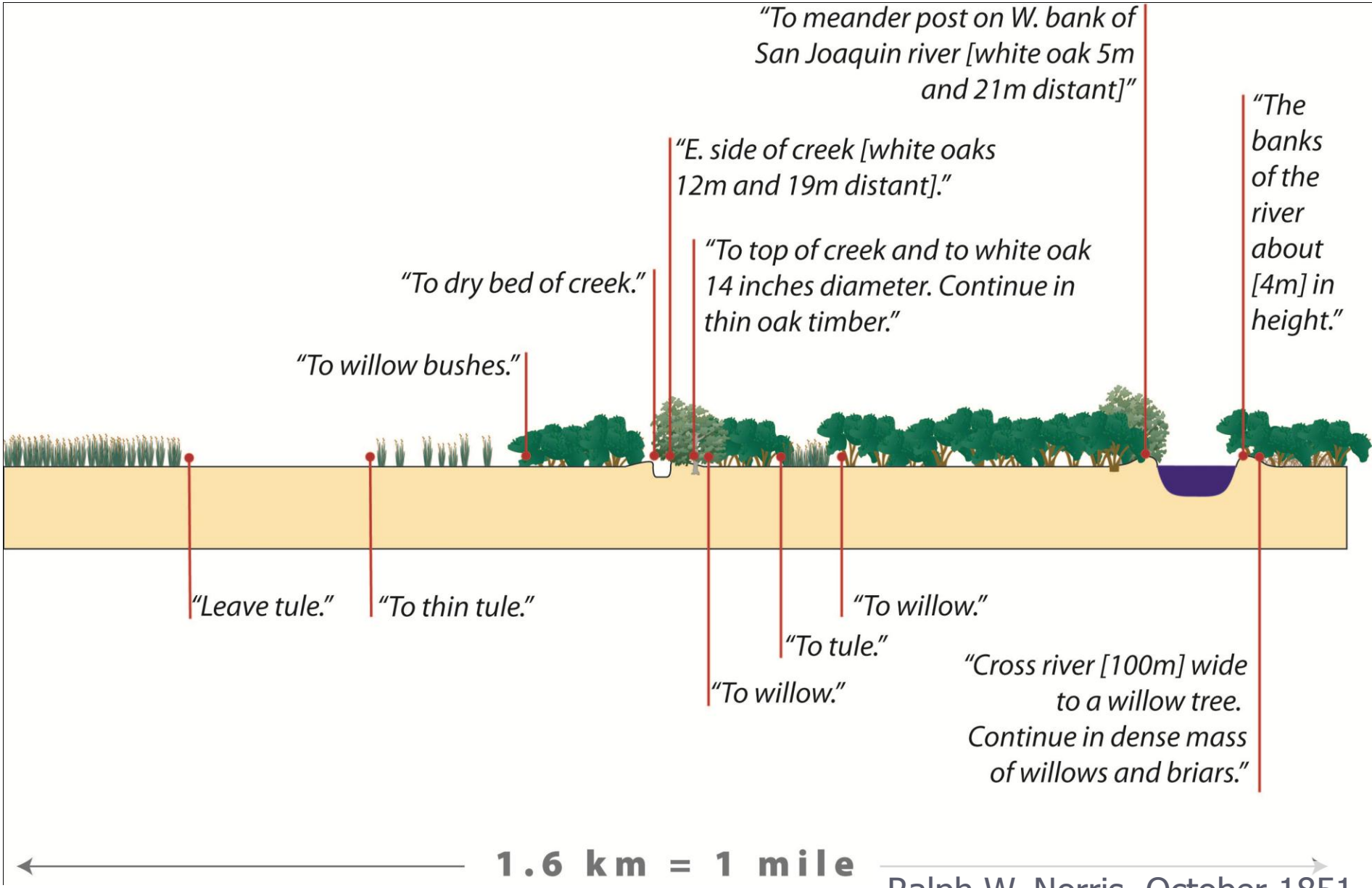


DISTRIBUTARY RIVERS: habitat complexity



Ralph W. Norris, October 1851

DISTRIBUTARY RIVERS: habitat complexity

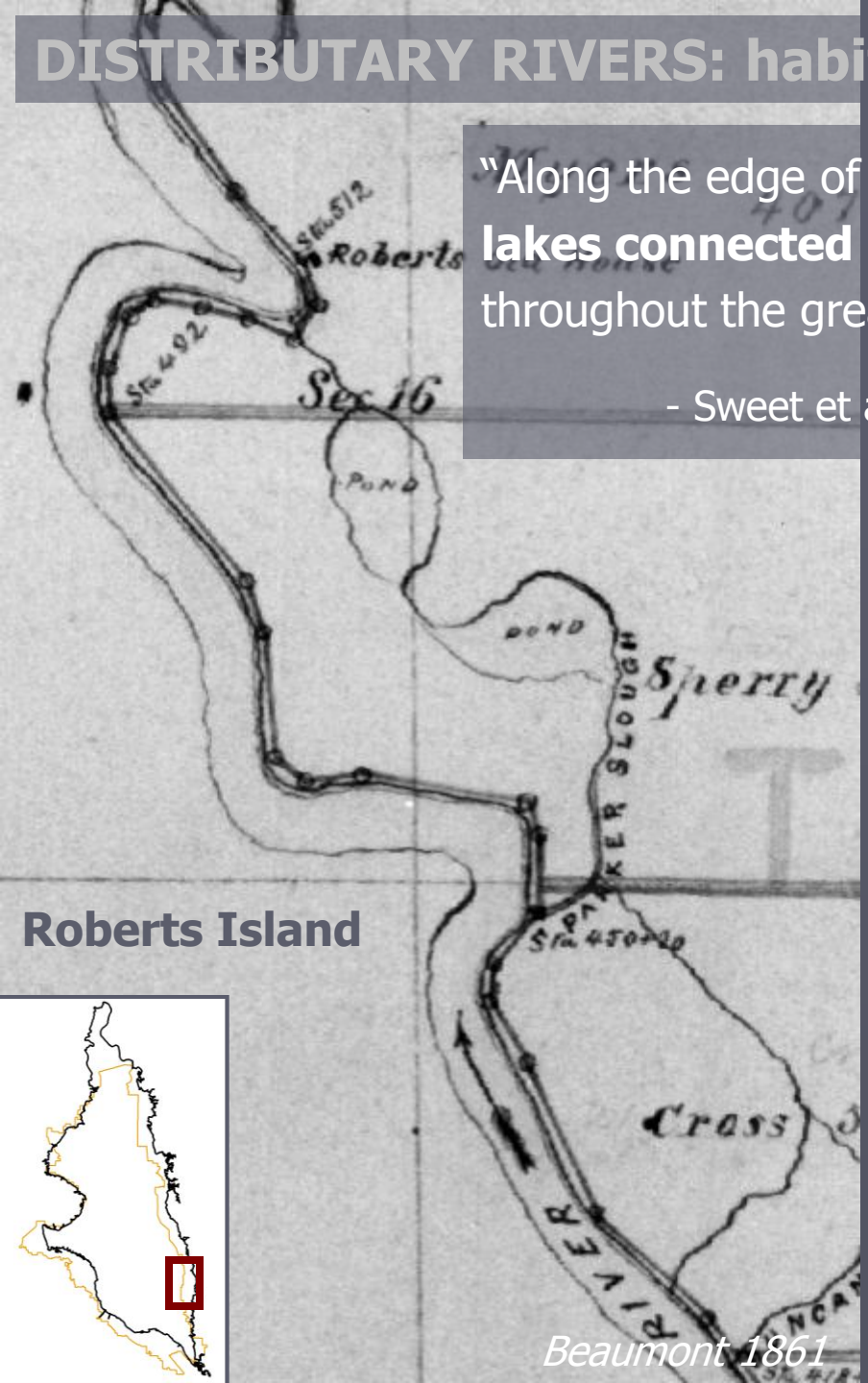


Ralph W. Norris, October 1851

DISTRIBUTARY RIVERS: habitat complexity

"Along the edge of the lowland…a **string of lakes connected by sloughs** extend throughout the greater part of the area."

- Sweet et al. 1908

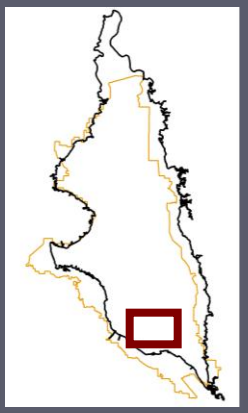


Roberts Island

Beaumont 1861

NAIP 2005

DISTRIBUTARY RIVERS: habitat complexity



ITEMS REMOVED DUE TO COPYRIGHT STATUS

Depth: 1 ½ fathoms = 9 ft

Area: 150-200 acres

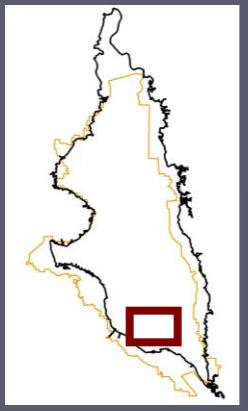
Gibbes 1850

DISTRIBUTARY RIVERS: habitat complexity

Salmon Slough: "The stream bed is **full of logs** and the boats grounded two or three times." (Abella 1811)

"The current of that river being thus destroyed, the river was **filled with drift wood, forming a raft**…" (Naglee 1879)

"…great many **old logs and an immense amount of driftwood** and rubbish in Old River" (Tucker Field Notes 1879)



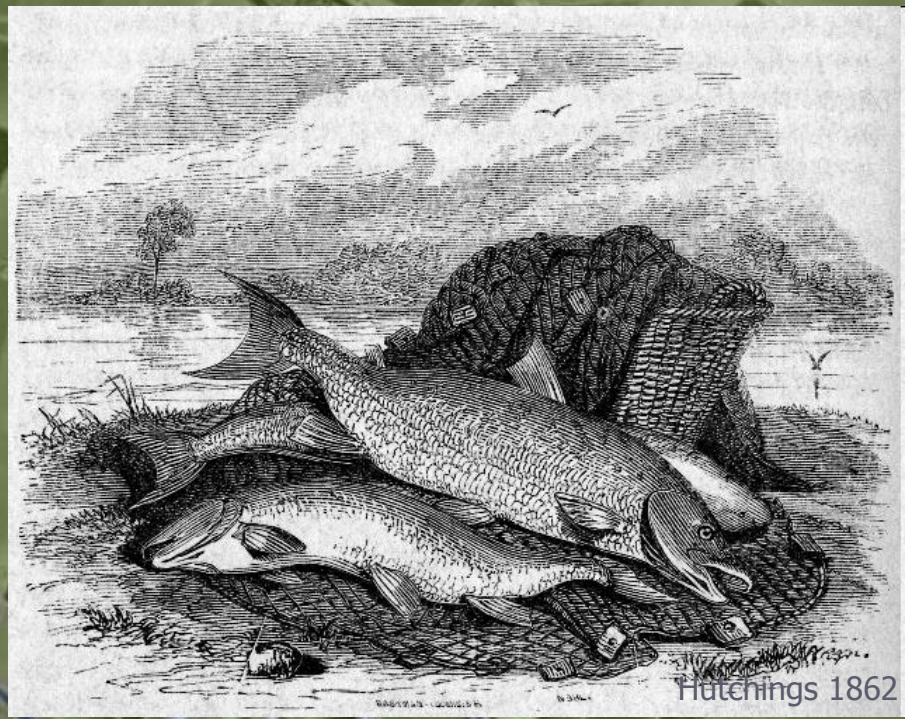
ITEM REMOVED DUE TO COPYRIGHT STATUS

DISTRIBUTARY RIVERS: habitat complexity

"Río del Pescadero [Old River]…**fishing is done in it for salmon**."
(Cook 1960, "Report of Hermenegildo Sal," January 31, 1796)

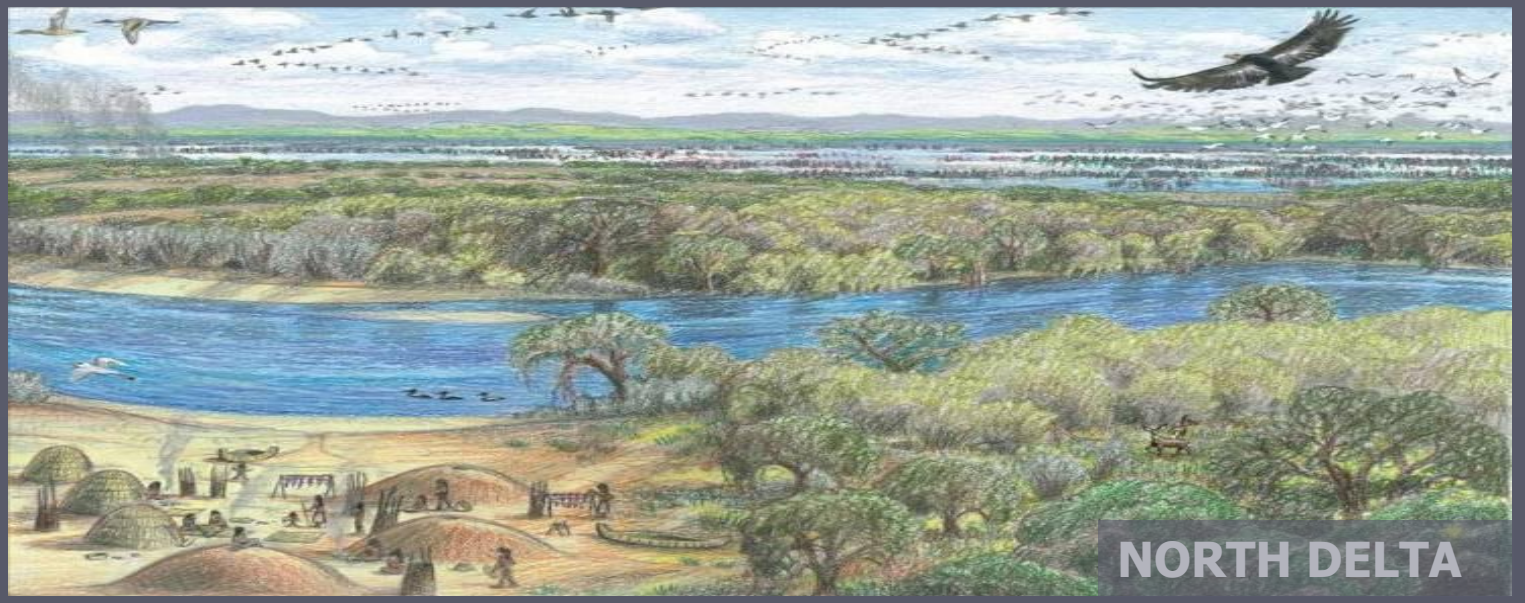
"…it was **salmon, tenderer, fatter, and more savory**…for perhaps because there is so much fresh water here it grows larger, fatter, and better flavored."
(Bolton [ed] 1927, "Anza's California Expeditions" 1776)

"…we rested here [El Pescadero] and passed the time well with **fresh salmon** and wild grapes" (Cook 1960, "Father Vaider's Second Trip," October 29, 1810)



Hutchings 1862

distributary rivers landscape (South Delta)

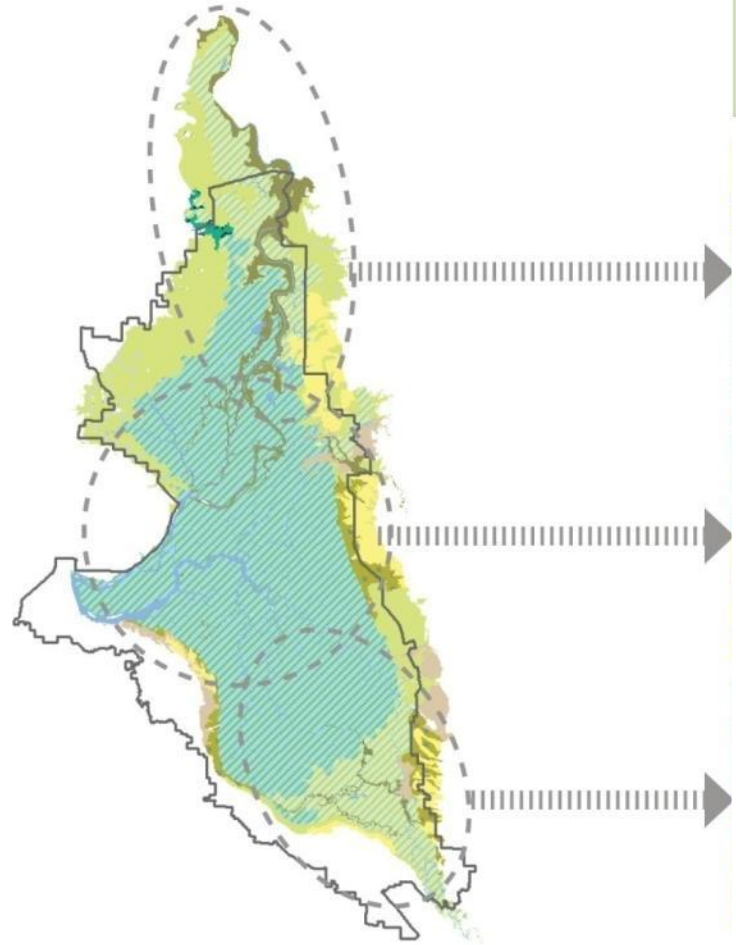


Cunningham 2010 *Bay Nature*

BENEFITS TO DELTA RESTORATION AND MANAGEMENT

- Improves understanding of the relationship between habitats and physical process
- Provides knowledge of the evolutionary template for species of concern and overall biological productivity
- Contributes to efforts to establish design principles and target metrics and recalibrates expectations
- Is useful to the process of establishing a unified vision for the future Delta
- Identifies opportunities (and constraints) within the contemporary landscape
- Helps individual restoration projects link into functional landscape units

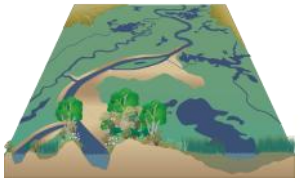
BENEFITS TO DELTA RESTORATION AND MANAGEMENT

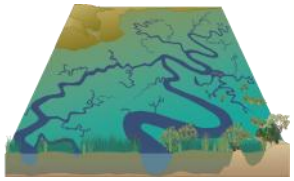


Delta historical ecology, including compiled datasets, GIS, and associated documentation

Landscape conceptual models and habitat metrics
e.g., channel plan form, edge to channel ratio, flood frequency and flows, pond/lake size and depth, residence time, patch size, riparian forest width

Contemporary data and research, ecological theory





Functions provided by habitats
e.g., flood protection, water storage, fish rearing, shading, turbidity, nutrient processing, healthy DO levels

Principles
e.g., fluvial-tidal connectivity in floodplain basin wetland, riparian forest >100 m width, room for river migration, overflow of natural levees in times of flood, adequate sediment supply

Habitat-related stressors
e.g., loss of flood basins, loss of marsh connectivity to tidal channels, decreased flood frequency, lower residence time, loss of riparian forest

Metrics, targets, and performance objectives

AQUATIC SCIENCE CENTER

THANKS TO

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RESEARCHERS:

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DFG collaborators: Carie Battistone, Daniel Burmester, Gena Glasko, Bronwyn Hogan, Amy Lyons, Daniel Rankin, Ciprian Simon, Carl Wilcox, Dave Zezulak

THANK YOU

QUESTIONS?

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