Hydro-ecology and Poudre River Futures

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Civil and Environmental Engineering

Graduate Degree Program in Ecology

The Nature Conservancy

Outline

Address three questions:

- How does river function related to the things we care about?
- What kind of river do we have today, and what might we be most concerned about in the future?
- What can we do?

Geographic Focus

- Canyon mouth to Greeley
  - integrates the 1000+ square miles upstream
  - hardest working segment of the river
  - most vulnerable segment of the river
  - a focal point of the relationship between people and the river

Why do we care?

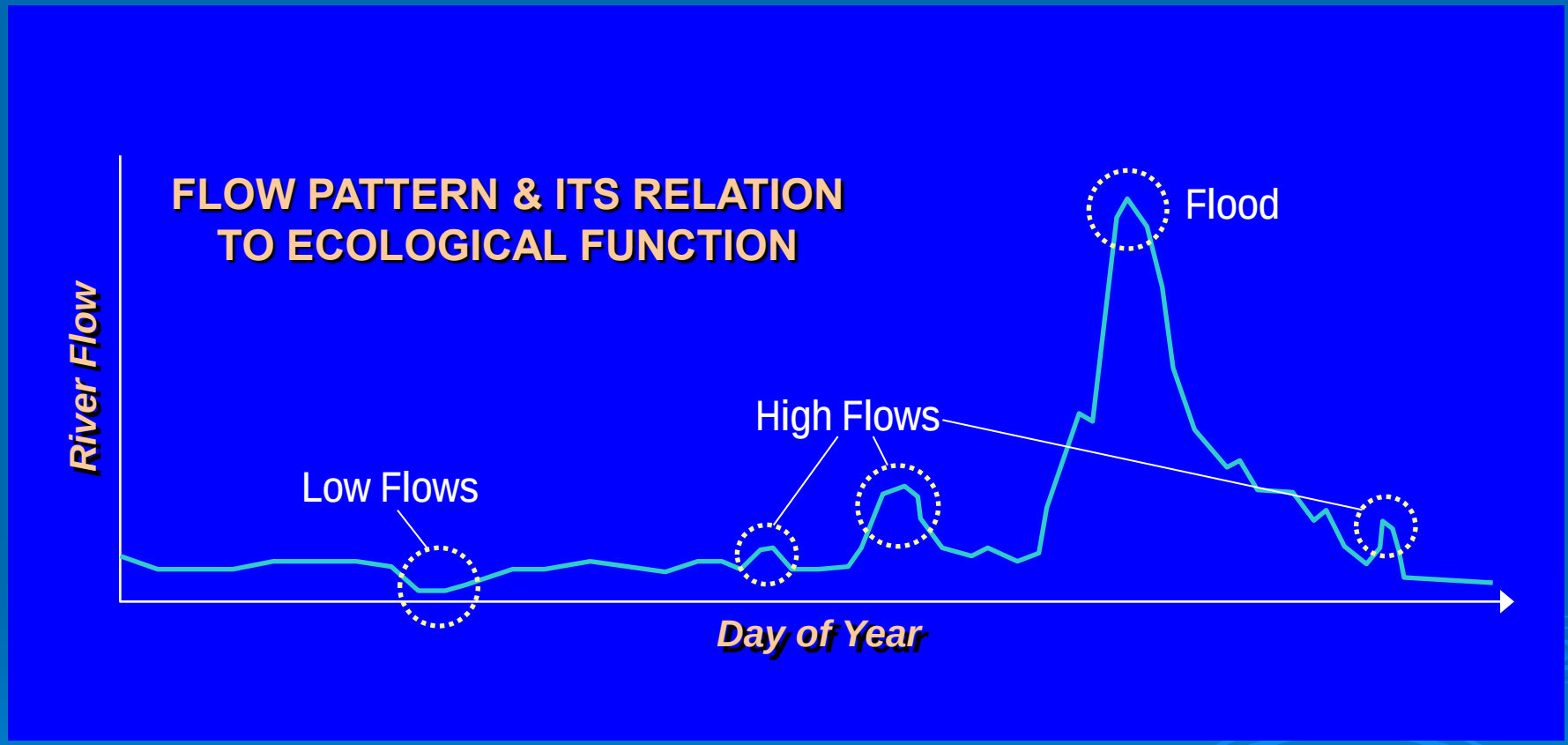
- Economic
  - Clean water
  - Cost of wastewater treatment
  - Tourism
  - Maintaining flood conveyance
- Biodiversity
  - Inherent value of native plants and animals
  - Need to meet regulatory requirements
- Aesthetics
  - Water clarity
  - Gravel and cobble versus silt and mud
  - Growth of algae
- Recreation
  - Trout fishing
  - Walking, biking, birding, tubing, playing,…

River Flow Patterns

- The “conductor” or master variable of the river ecosystem

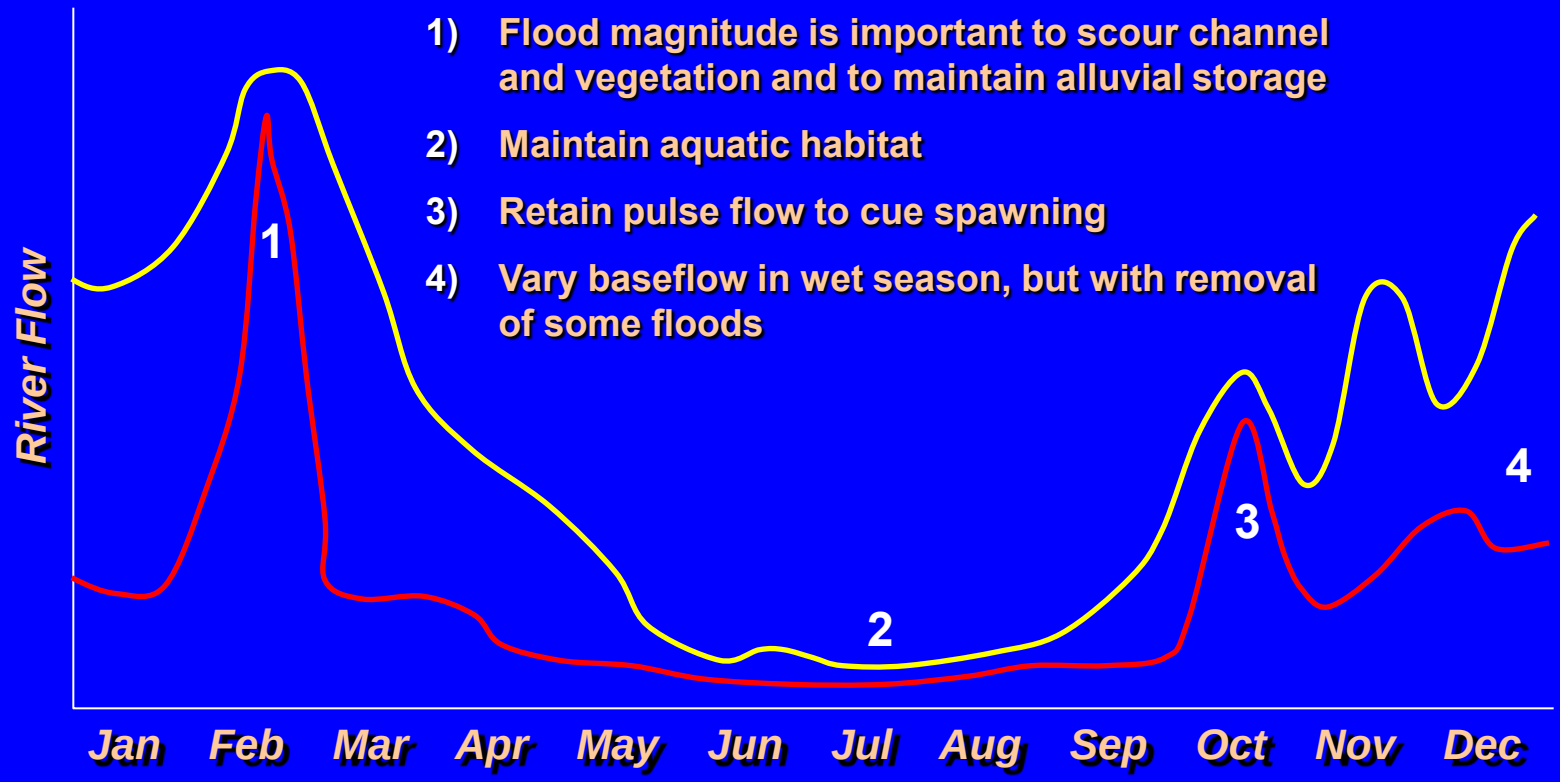
- 5 key characteristics:
  - Magnitude
  - Frequency
  - Duration
  - Timing
  - Rate of Change

Environmental Flow Concepts



Modified from Richter, Rivers at Life

Environmental Flow Concepts



Modified from Postel and Richter, 2003

A Brief Tour of a Poudre River Hydrograph

Maintain river channel size

Sediment size is a major determinant of river bed biological communities

Gravels and cobbles – transport common

Floodplain

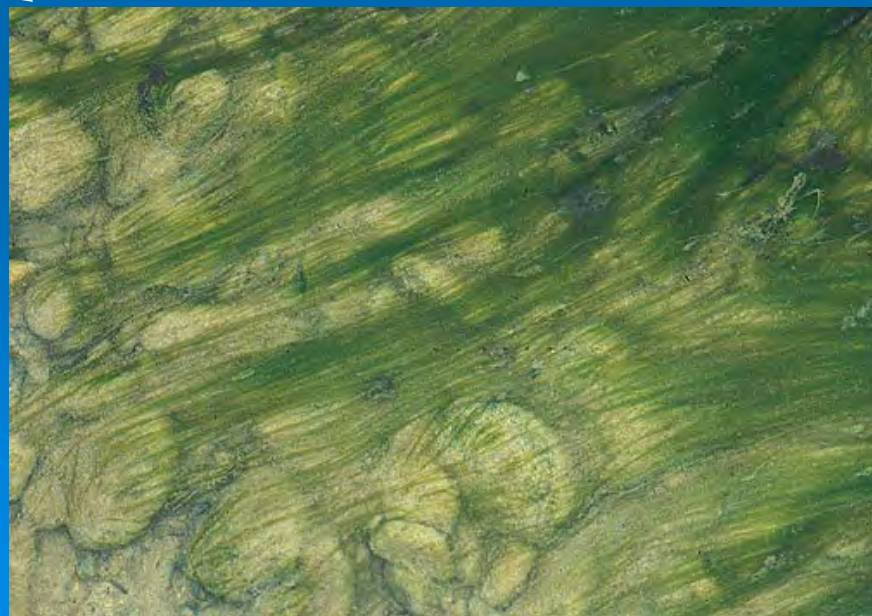
Channel maintenance

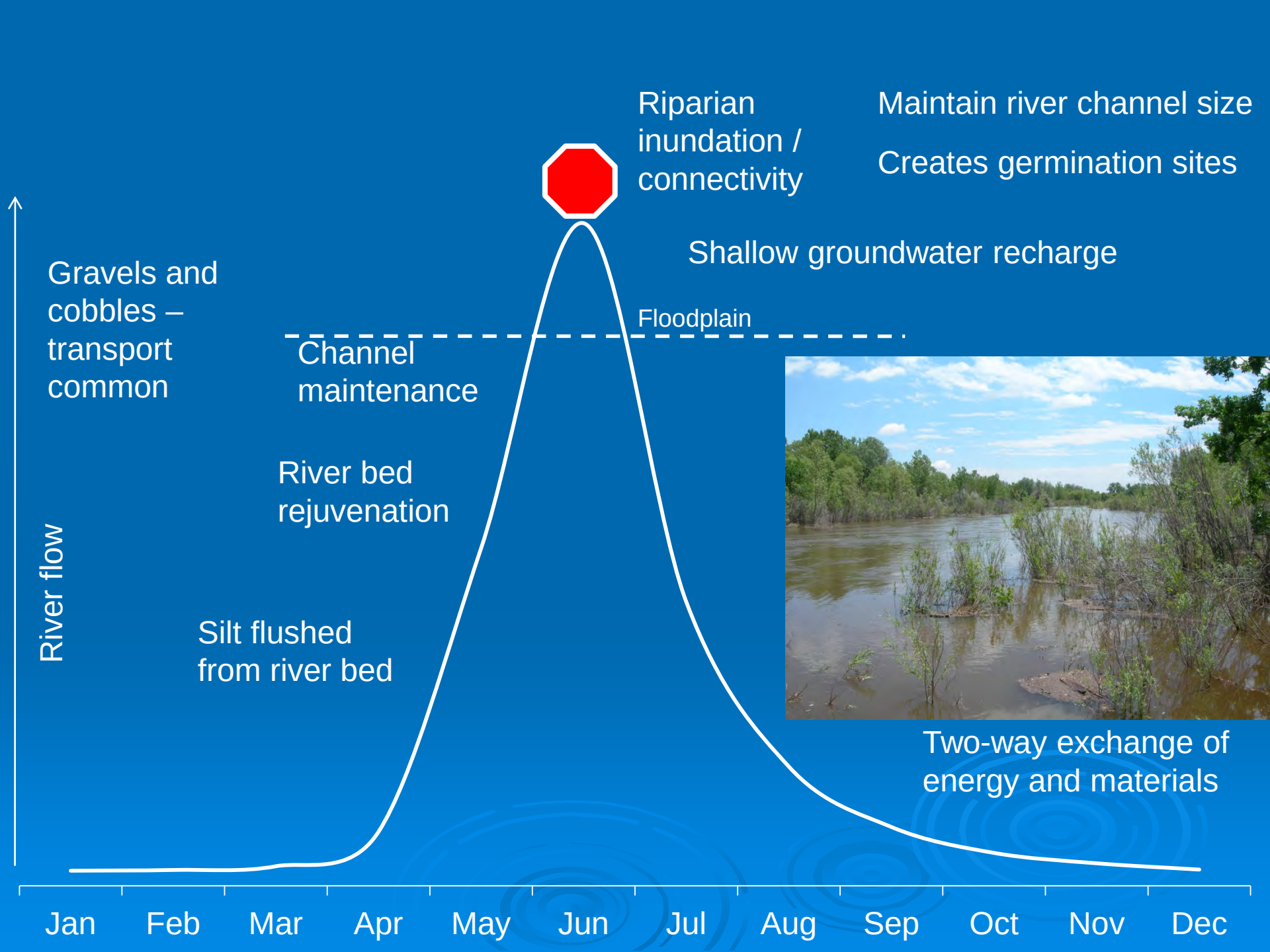
River bed rejuvenation

Silt flushed from river bed

River flow

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec




Riparian inundation / connectivity
Maintain river channel size
Creates germination sites
Shallow groundwater recharge
Gravels and cobbles – transport common
Floodplain
Channel maintenance
River bed rejuvenation
River flow
Silt flushed from river bed
Two-way exchange of energy and materials
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Riparian inundation / connectivity

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Creates germination sites

Shallow groundwater recharge

Gravels and cobbles – transport common

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Channel maintenance

Duration of bed rejuvenation?

Plains cottonwood seed dispersal

River bed rejuvenation

Silt flushed from river bed

River flow

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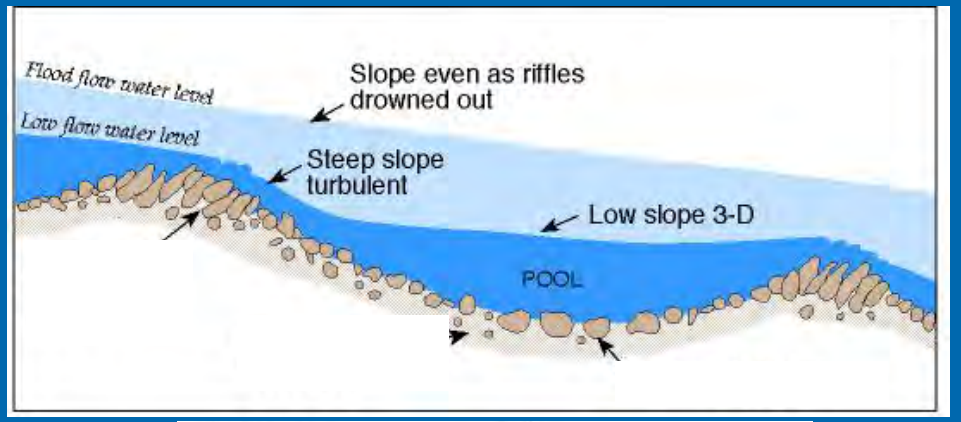
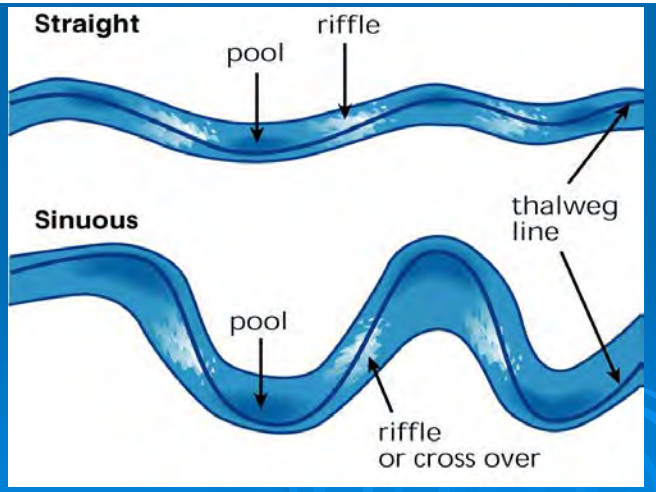
Cinderella's castle - Disneyland

A meandering river…

But does it have diverse habitat for fishes?





Many combinations of depth, flow velocity, and gravel sizes?

Riparian inundation / connectivity

Maintain river channel size

Creates germination sites

Shallow groundwater recharge

Gravels and cobbles – transport common

Floodplain

Channel maintenance

Duration of bed rejuvenation?

Plains cottonwood seed dispersal

River bed rejuvenation

Water table decline → seedling establishment
aquatic insects emerging → food

Silt flushed from river bed

River flow

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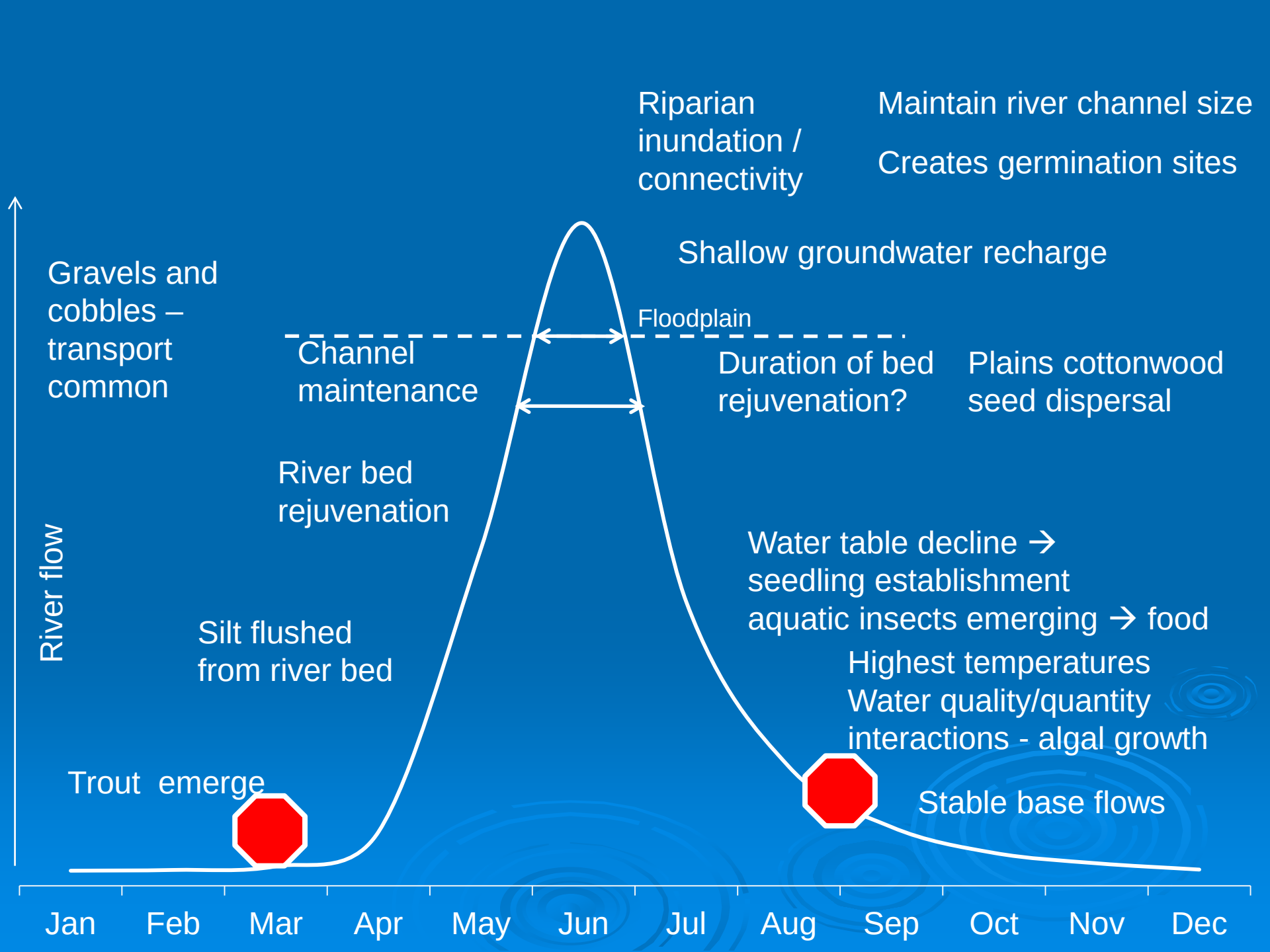
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Duration of bed rejuvenation?
Plains cottonwood seed dispersal
River bed rejuvenation
Water table decline → seedling establishment
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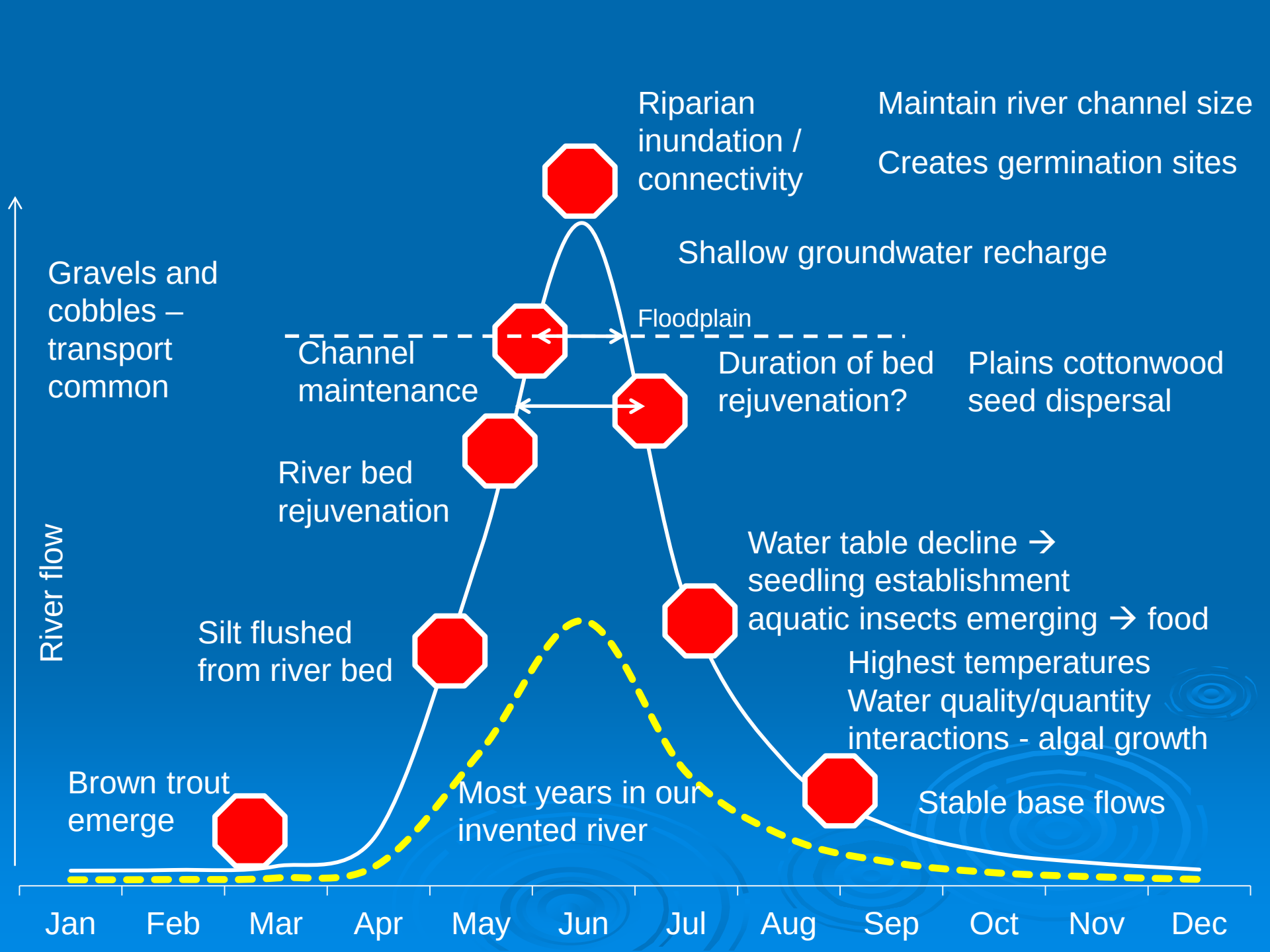
Highest temperatures
Water quality/quantity interactions - algal growth
Silt flushed from river bed
Trout emerge
Stable base flows
River flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Brown trout

Late summer / fall temps < ~74 ^{o}F
Fall spawning

Spring emergence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Highest temperatures
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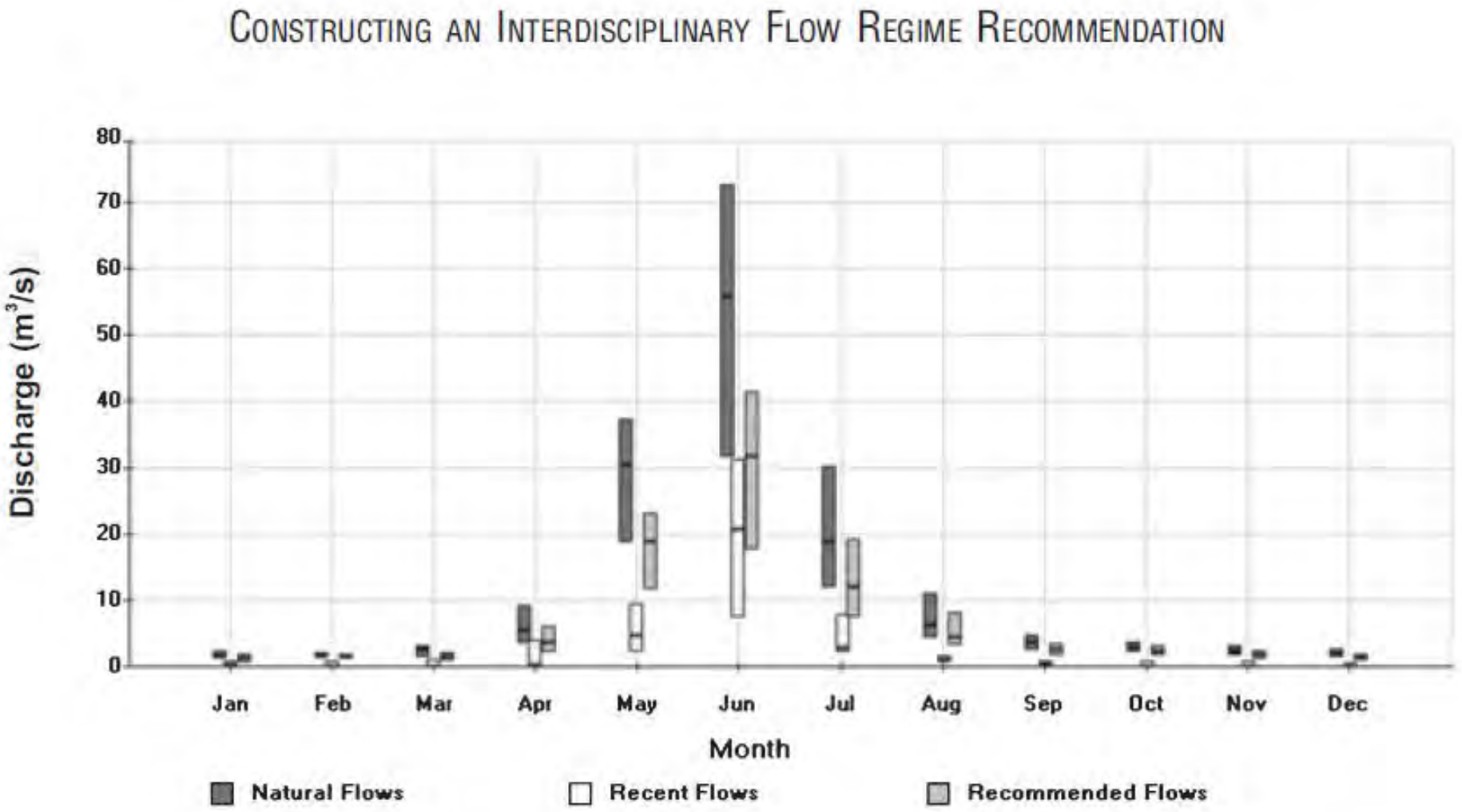
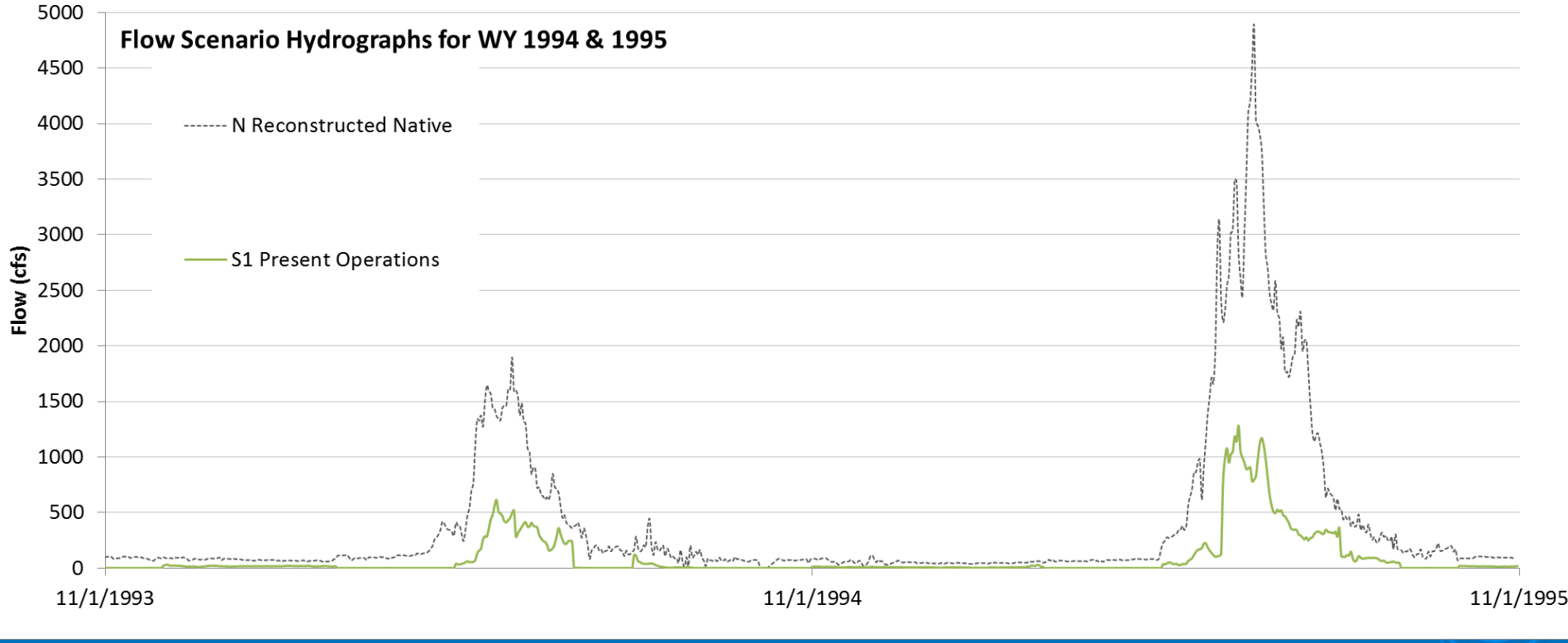
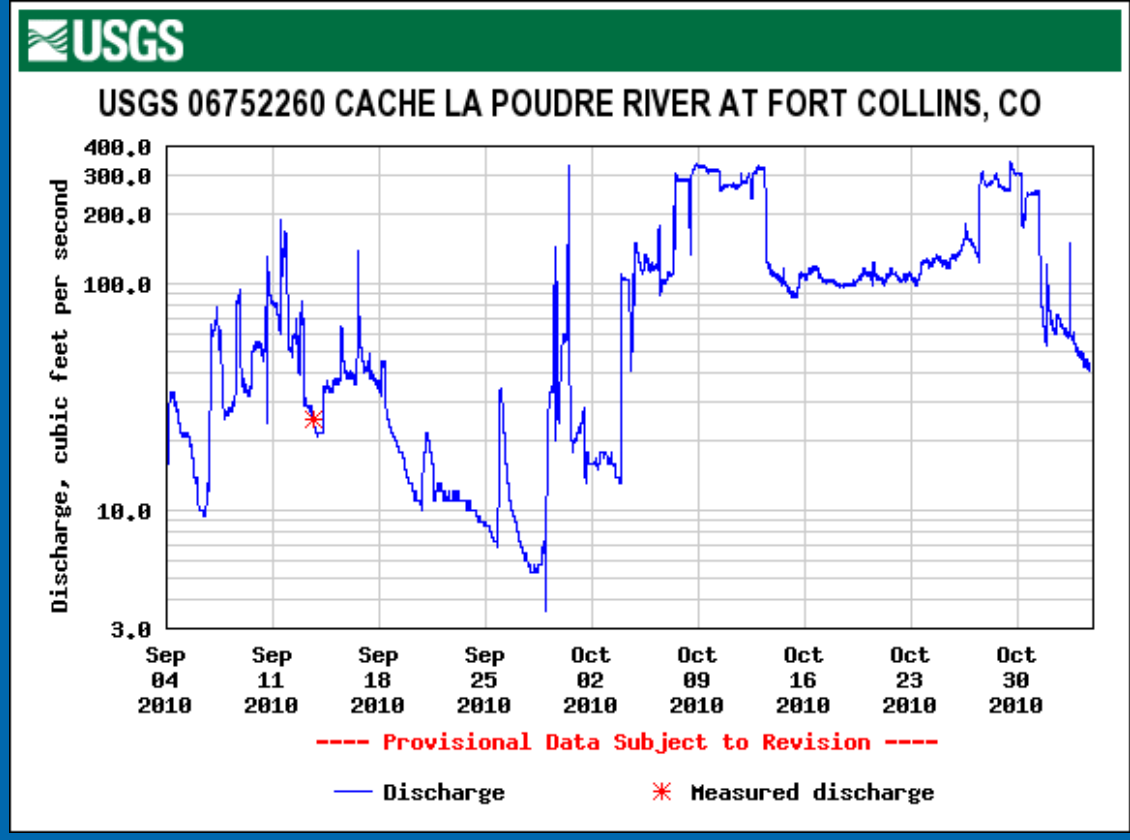
Brown trout emerge
Most years in our invented river
Stable base flows
River flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Estimated Natural and Recent Historic Flows at the Lincoln gauge



Hydrologic Scenarios→	Present Operations	Pre-Settlement
Period of record (WY)	1950-2005	1970-1995
Average daily flow (cfs)	99	425
Average Summer (Jul-Sep) baseflow (cfs)	81	74
Average winter baseflow (cfs)	12	77
Average peak daily flow (cfs)	1094	3213
Wetland flow (cfs)[1]	1007	2841
One-year floodplain flow (cfs)[2]	2006	4373


Flow Scenario Hydrographs for WY 1994 & 1995
N Reconstructed Native
S1 Present Operations
Flow (cfs)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
11/1/1993
11/1/1994
11/1/1995



Unstable base flows

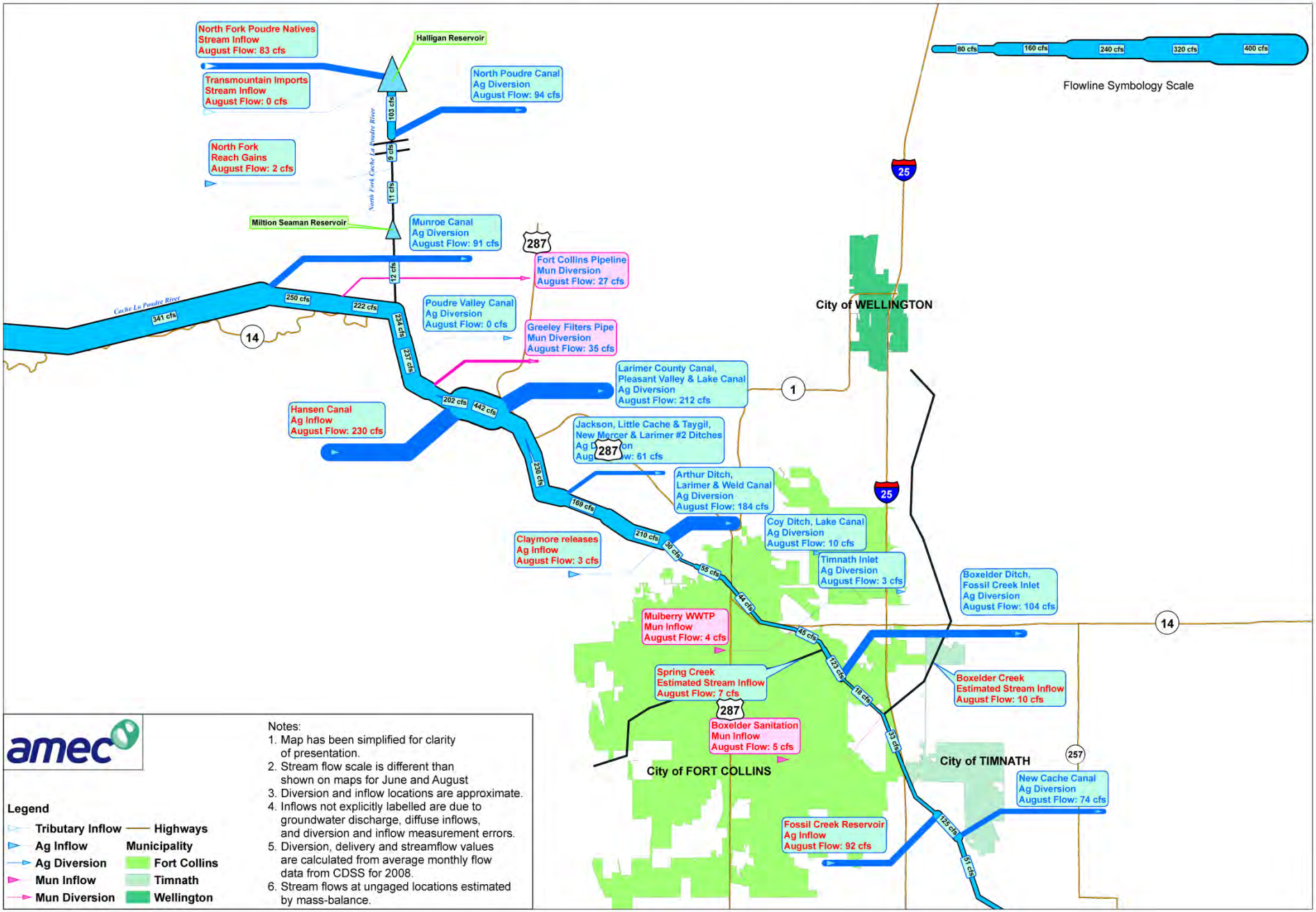
Too warm for trout survival

Jul

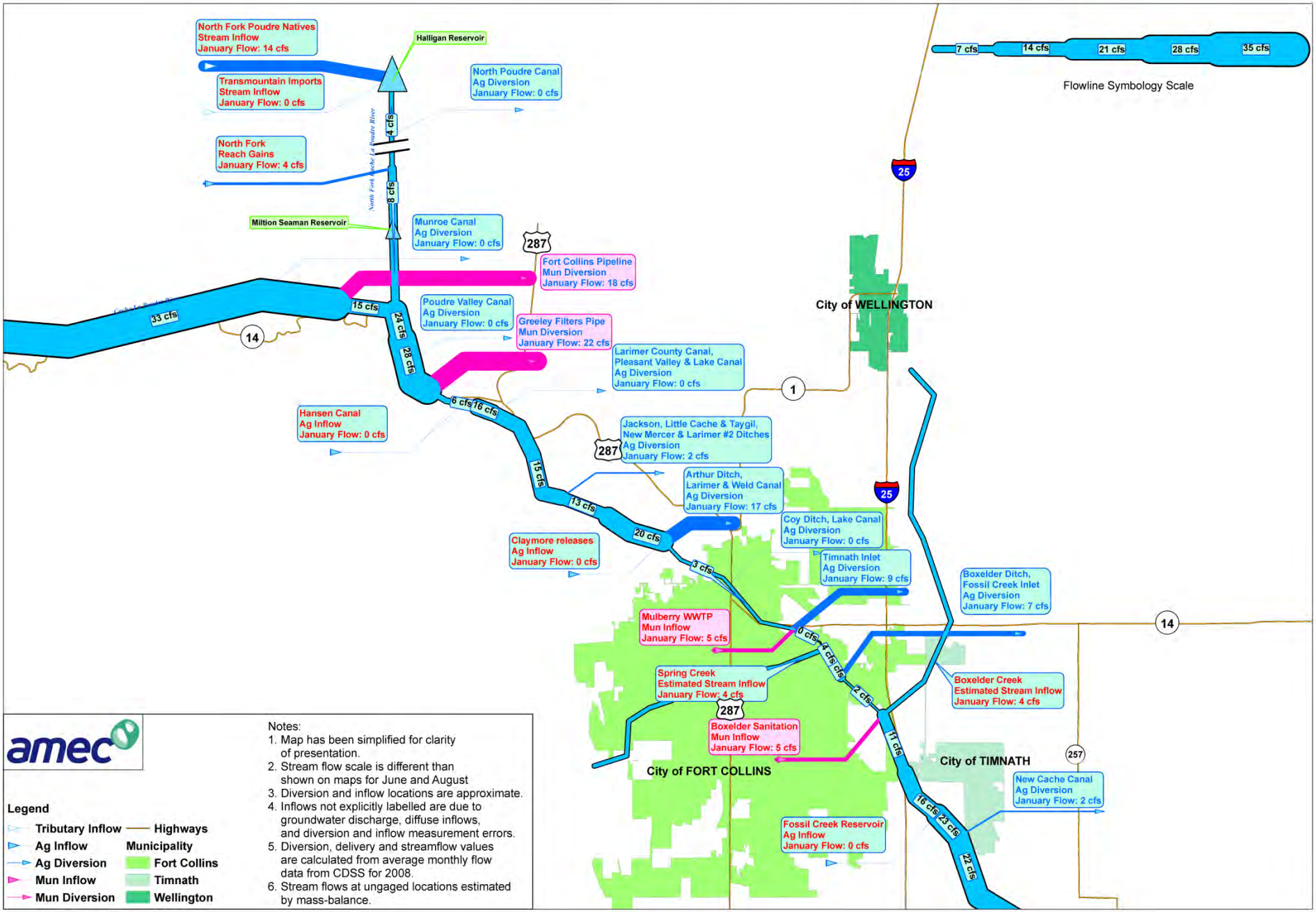
Aug

Sep

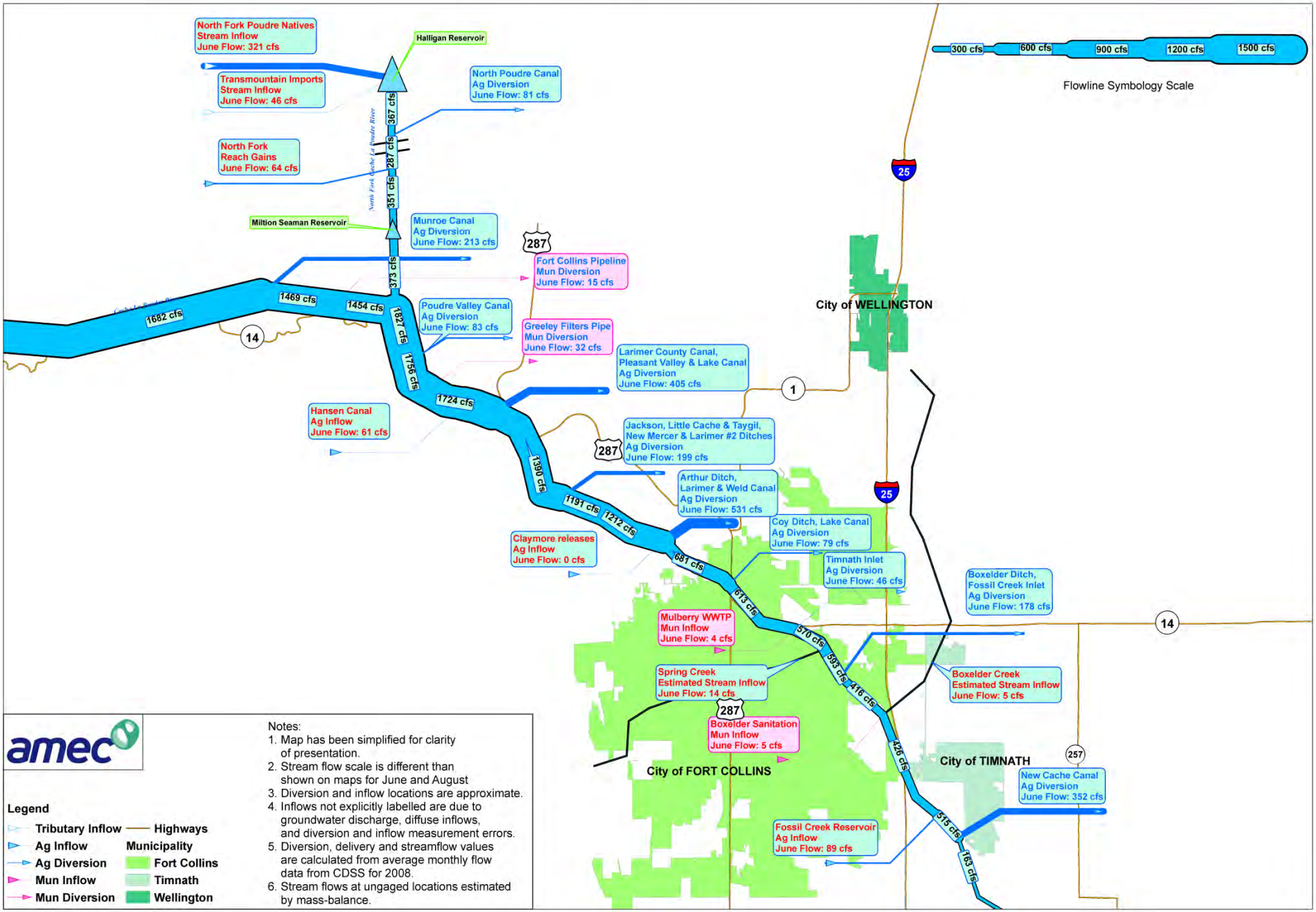
Conceptual Flow Diagram of the Cache La Poudre River in August



Conceptual Flow Diagram of the Cache La Poudre River in January



Conceptual Flow Diagram of the Cache La Poudre River in June



amec

Legend

- Tributary Inflow
- Ag Inflow
- Ag Diversion
- Mun Inflow
- Mun Diversion
- Highways

Municipality

- Fort Collins
- Timnath
- Wellington

Notes:

1. Map has been simplified for clarity of presentation.
2. Stream flow scale is different than shown on maps for June and August
3. Diversion and inflow locations are approximate.
4. Inflows not explicitly labelled are due to groundwater discharge, diffuse inflows, and diversion and inflow measurement errors.
5. Diversion, delivery and streamflow values are calculated from average monthly flow data from CDSS for 2008.
6. Stream flows at ungaged locations estimated by mass-balance.

What kind of river do we have today (ecologically)?

Algae

Invertebrates

Trout

Native Fish

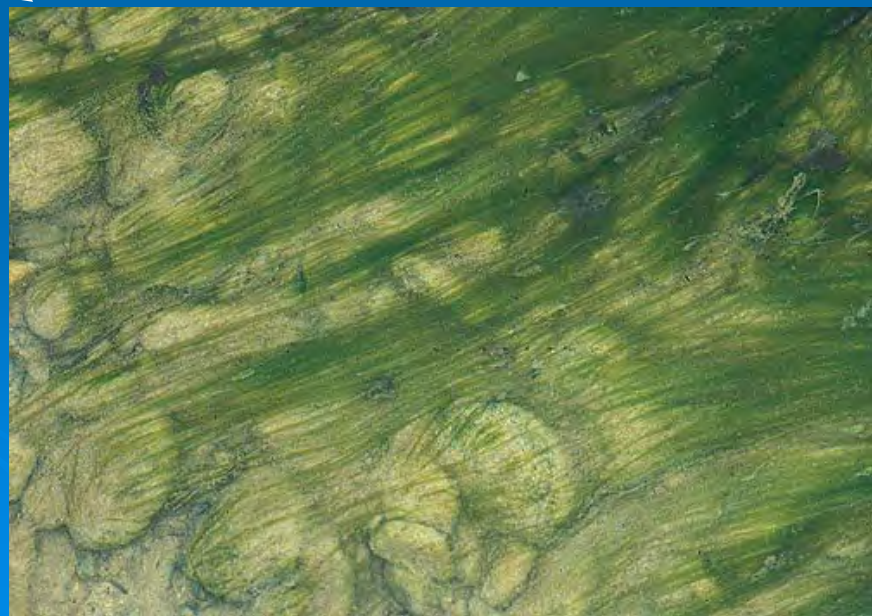
Streamside vegetation

Reduced Summer Low Flows

- Loads of N and P result in higher concentrations in less water
- Higher temperatures
- Water quality / quantity interactions

MORE PRODUCTION OF ALGAE

WITH SHIFTS TO FILAMENTOUS FORMS – reduced aesthetic appeal for fishing and recreation, also food web effects

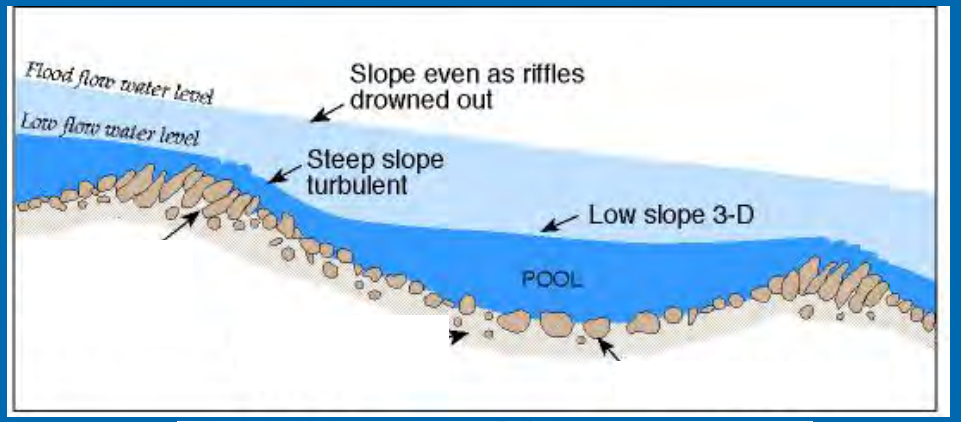


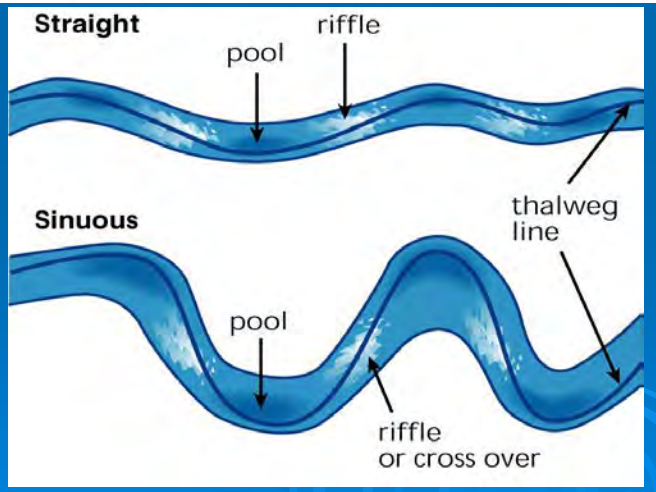
NABS (www.benthos.org)

Cinderella's castle - Disneyland

A meandering river…

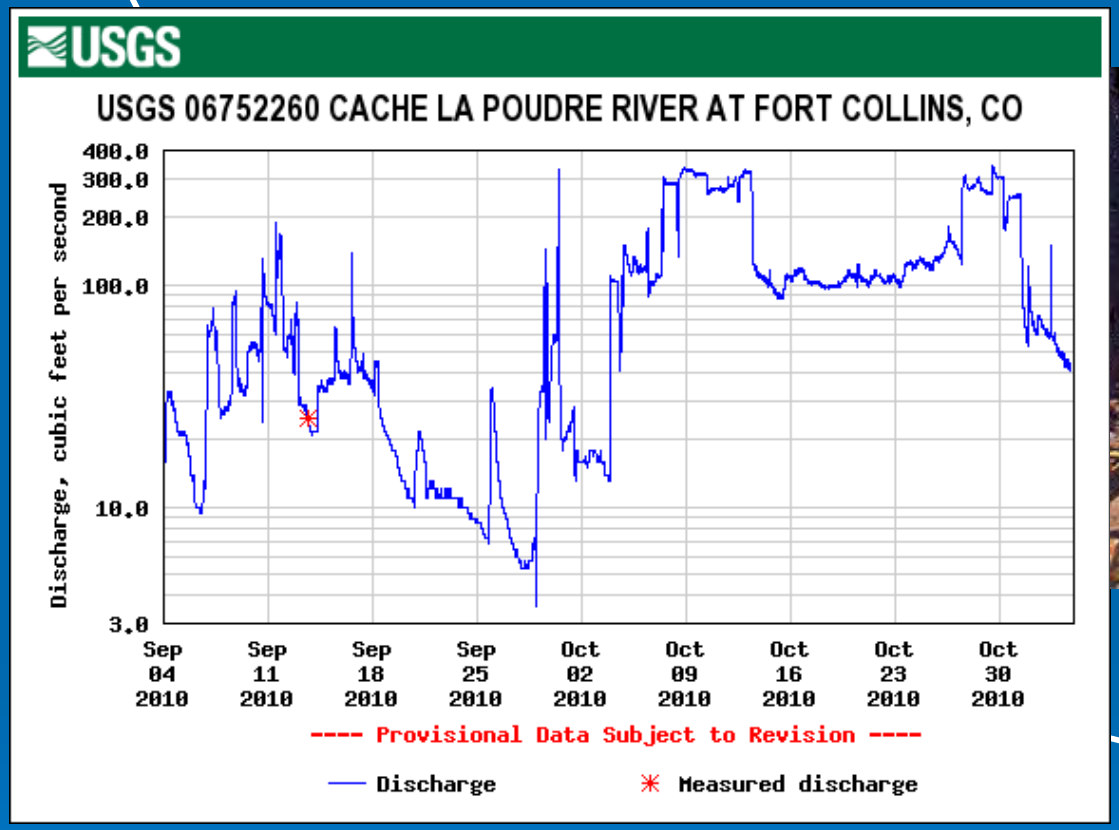
But does it have diverse habitat for fishes?





Many combinations of depth, flow velocity, and gravel sizes?

Fish: Summer / Fall Base Flows

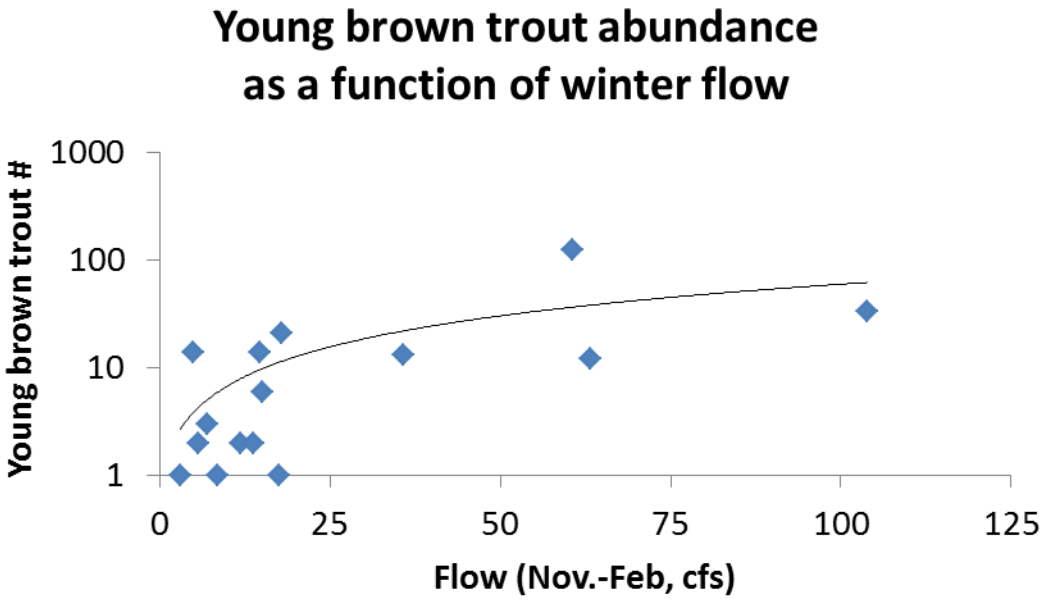


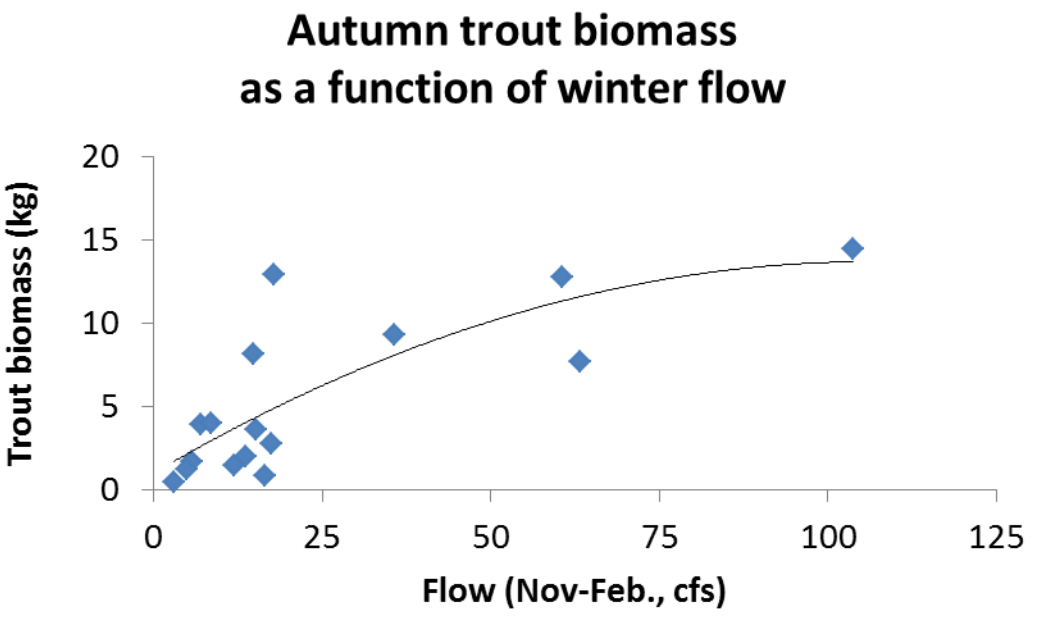
Stable base flows

Temperatures cool enough to maintain trout

Jul | Aug | Sep

What if very low flows extend into winter?





X
ESA
State
Concern
X
ESA
State
Concern
X
ESA
State
Concern
X
ESA
State
Concern
X
ESA
State
Concern
X
State
State
Concern
X
State
Concern
Concern
X
State
Concern

Common shiner

Brassy minnow

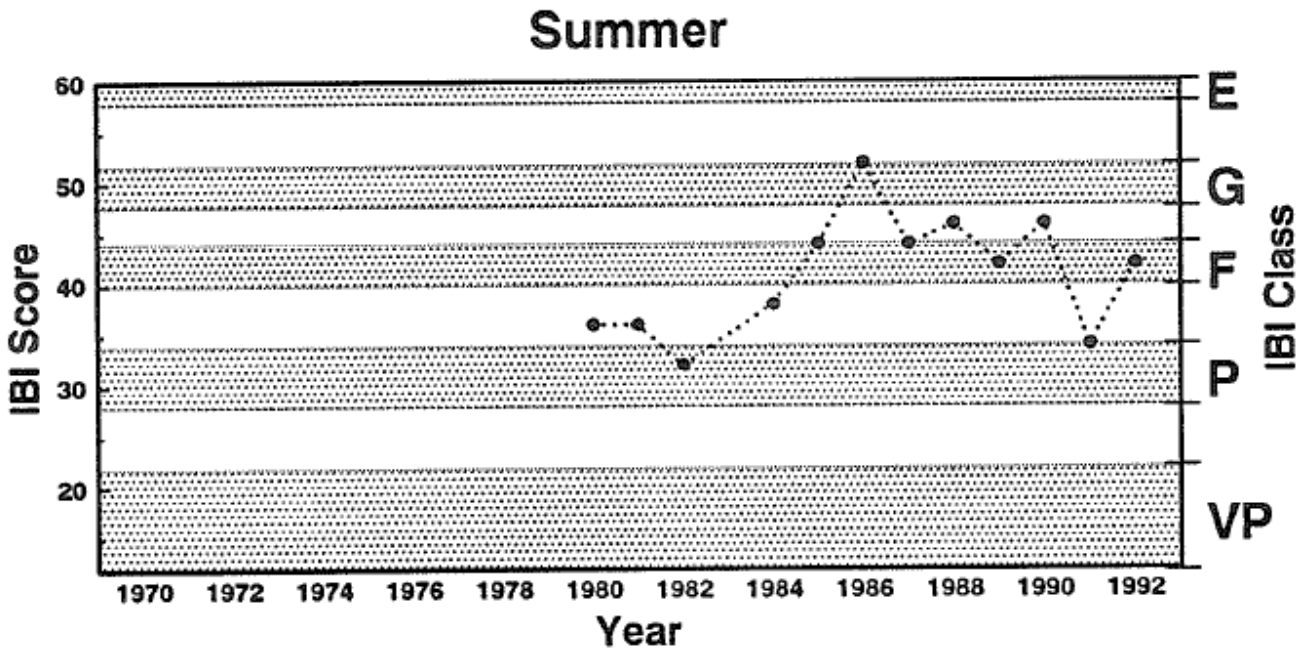
Creek chub

“Decline of these species is probably related to increased siltation, as these species require clean sand or gravel substrate for spawning.”

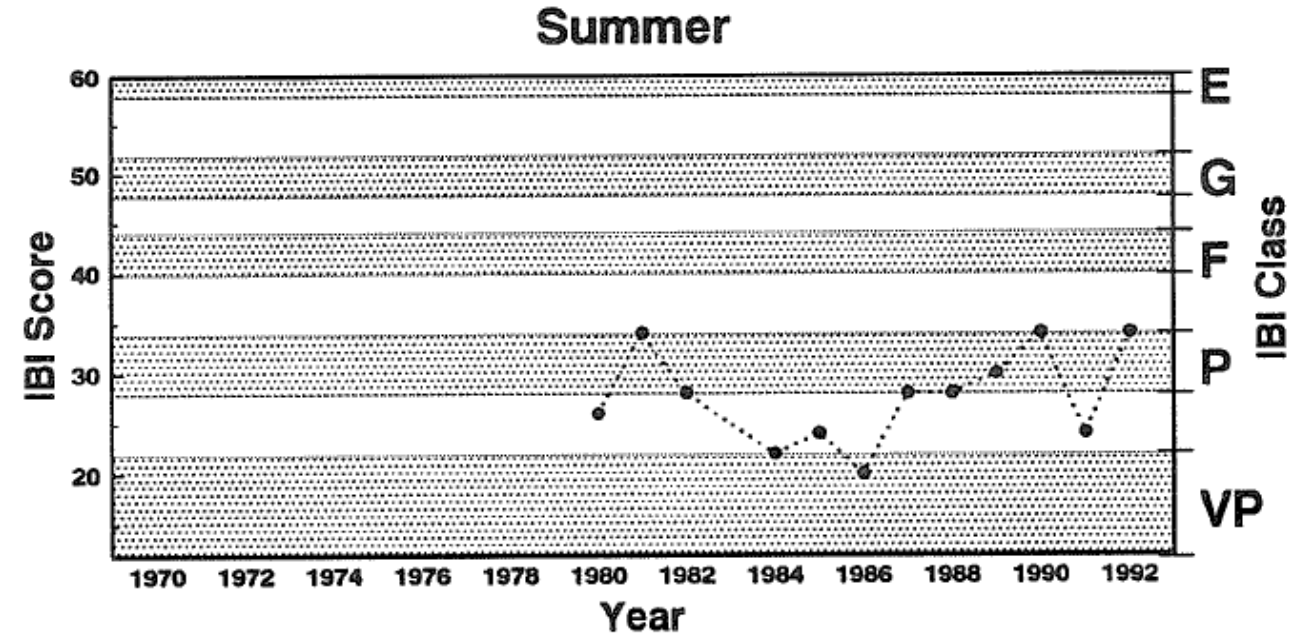
Bestgen and Fausch 1993

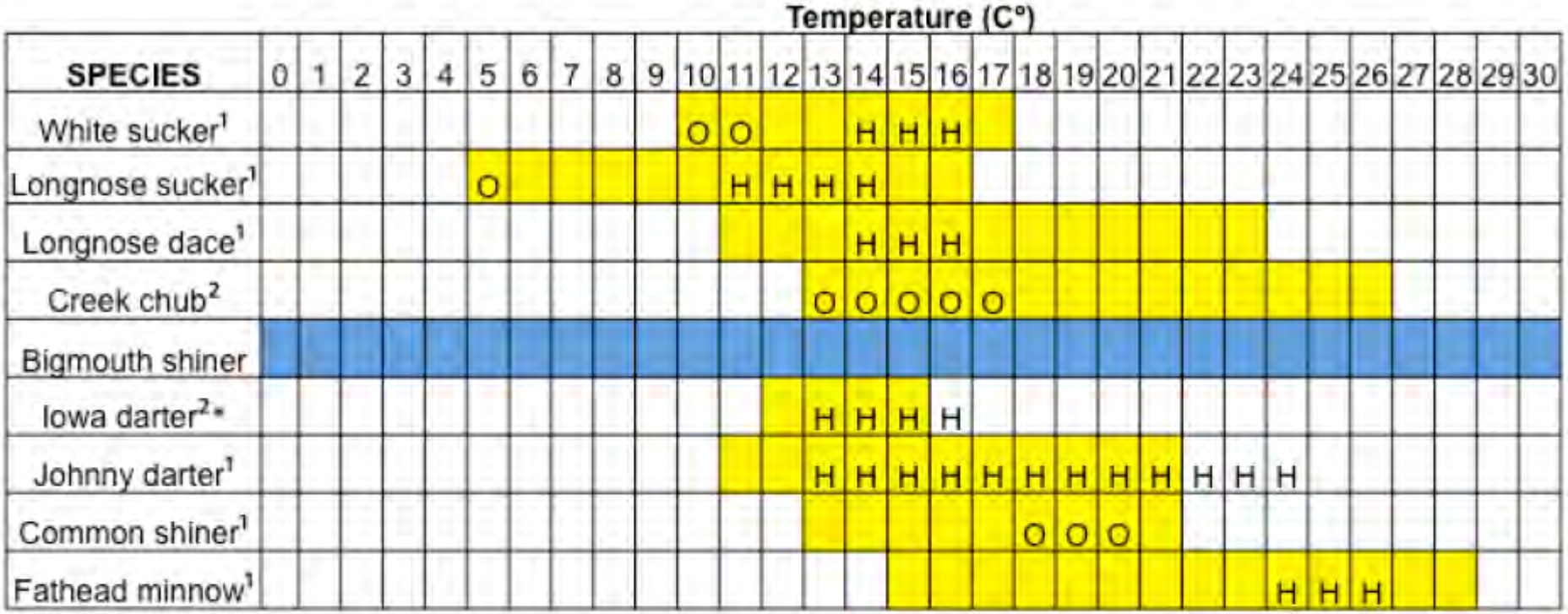
Index of Biological Integrity

Site 1
In Fort Collins



Site 10
Above Greeley





H=Hatching

O=Optimum Spawning

Within Tolerable Range of Spawning

Lacks Data

[1]Wismer and Christie 1987
[2]Becker 1983
*Simon and Faber 1987

Plains cottonwood

Cottonwood on Meandering Rivers

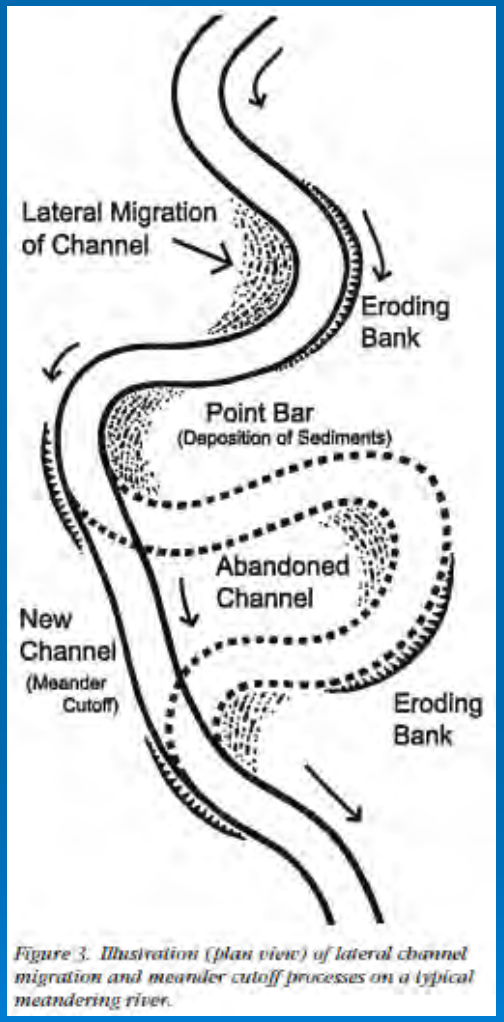


Figure 3. Illustration (plan view) of lateral channel migration and meander cutoff processes on a typical meandering river.

Richter, B. D. and H. E. Richter. 2000. Prescribing flood regimes to sustain riparian ecosystems along meandering rivers. Conservation Biology **14:1467-1478.**

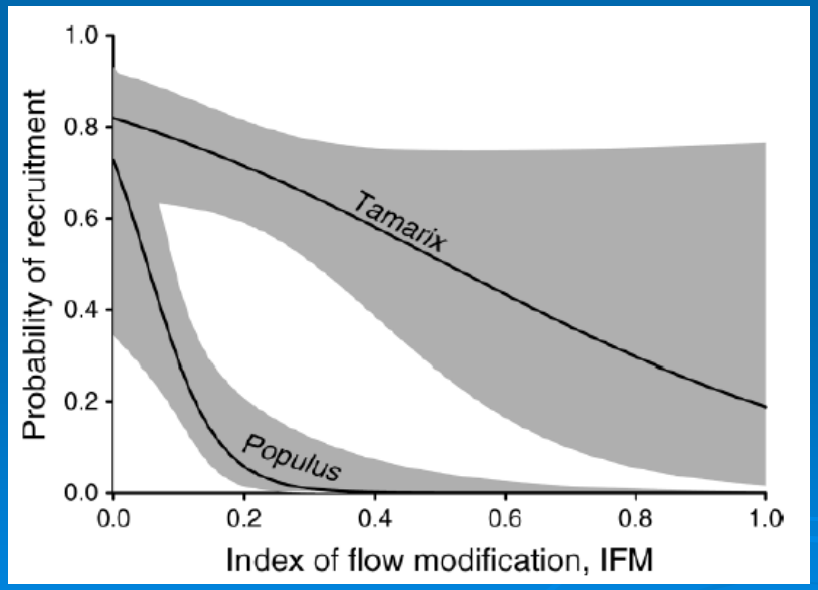
Cottonwood establish in bands on point bars

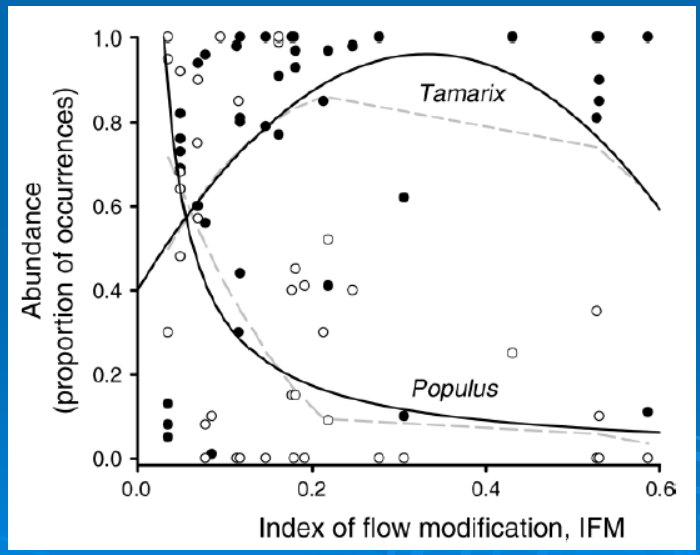
Rood, S. B., L. A. Goater, J. M. Mahoney, C. M. Pearce, and D. G. Smith. 2007. Floods, fire, and ice: disturbance ecology of riparian cottonwoods. Canadian Journal of Botany 85:1019–1032(Belly River)

Ecological Applications, 20(1), 2010, pp. 135–152
© 2010 by the Ecological Society of America

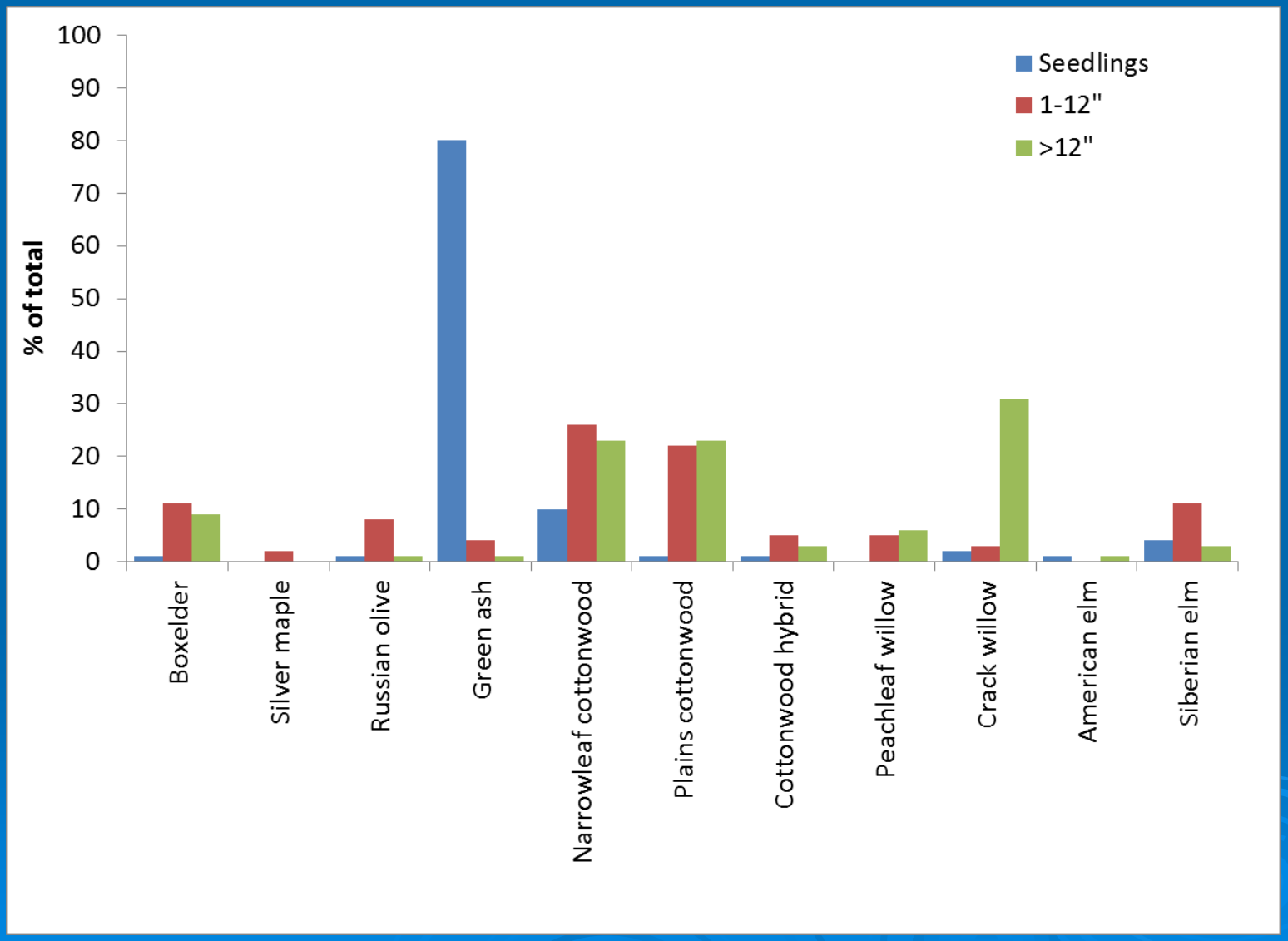
Shifting dominance of riparian *Populus* and *Tamarix* along gradients of flow alteration in western North American rivers

DAVID M. MERRITT[1,2,5] AND N. LEROY POFF[3,4]





1937
Timberline Road
2005
Prospect Road
Boxelder Ditch
Diversion
Fossil Creek Reservoir
Inlet Ditch Diversion
CSU
ELC
Drake Road


% of total
100
90
80
70
60
50
40
30
20
10
0
Seedlings
1-12"
>12"
Boxelder
Silver maple
Russian olive
Green ash
Narrowleaf cottonwood
Plains cottonwood
Cottonwood hybrid
Peachleaf willow
Crack willow
American elm
Siberian elm

Flood Conveyance

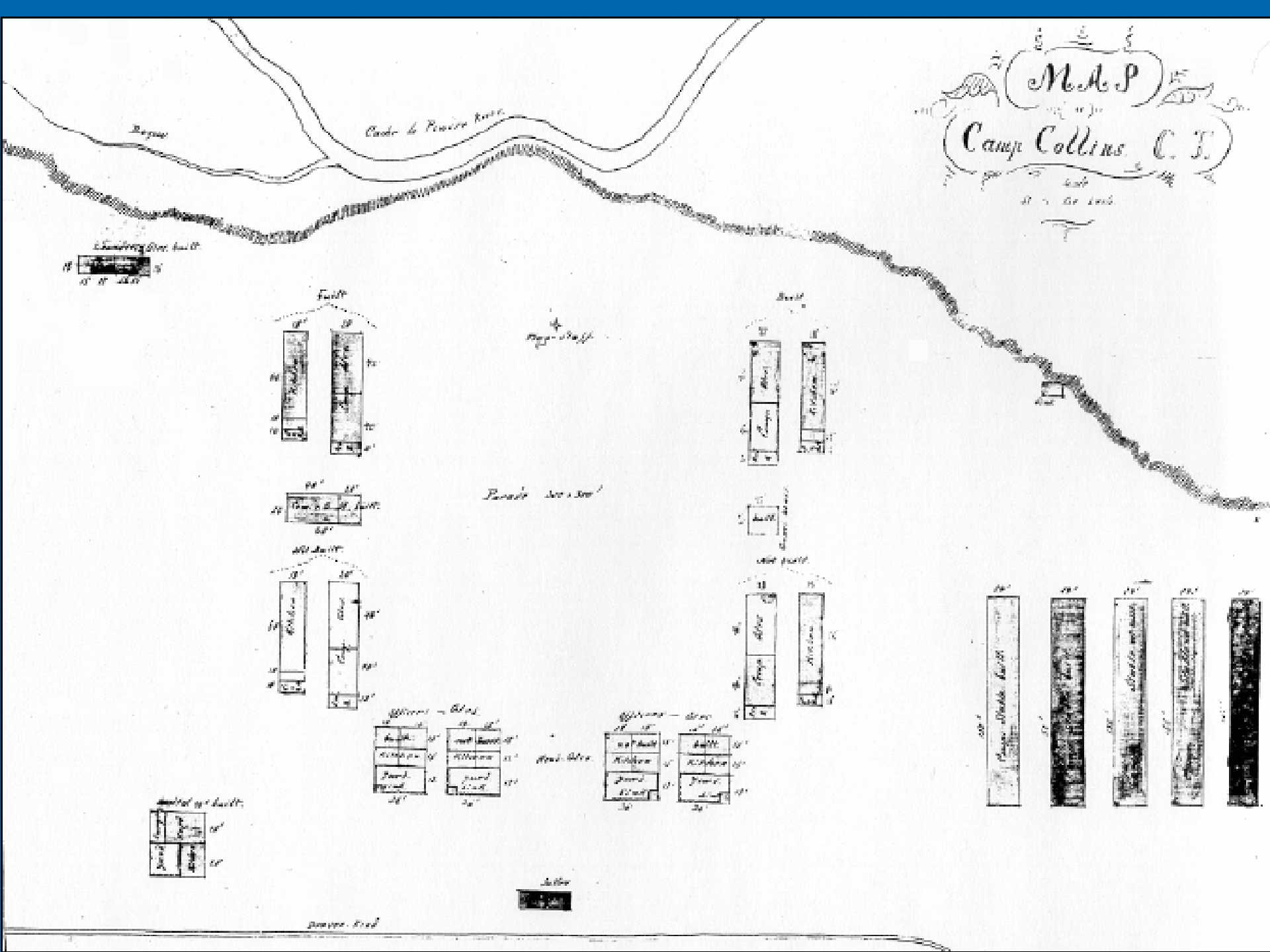
Looking upstream from Shields Ave. in Fort Collins - 2004

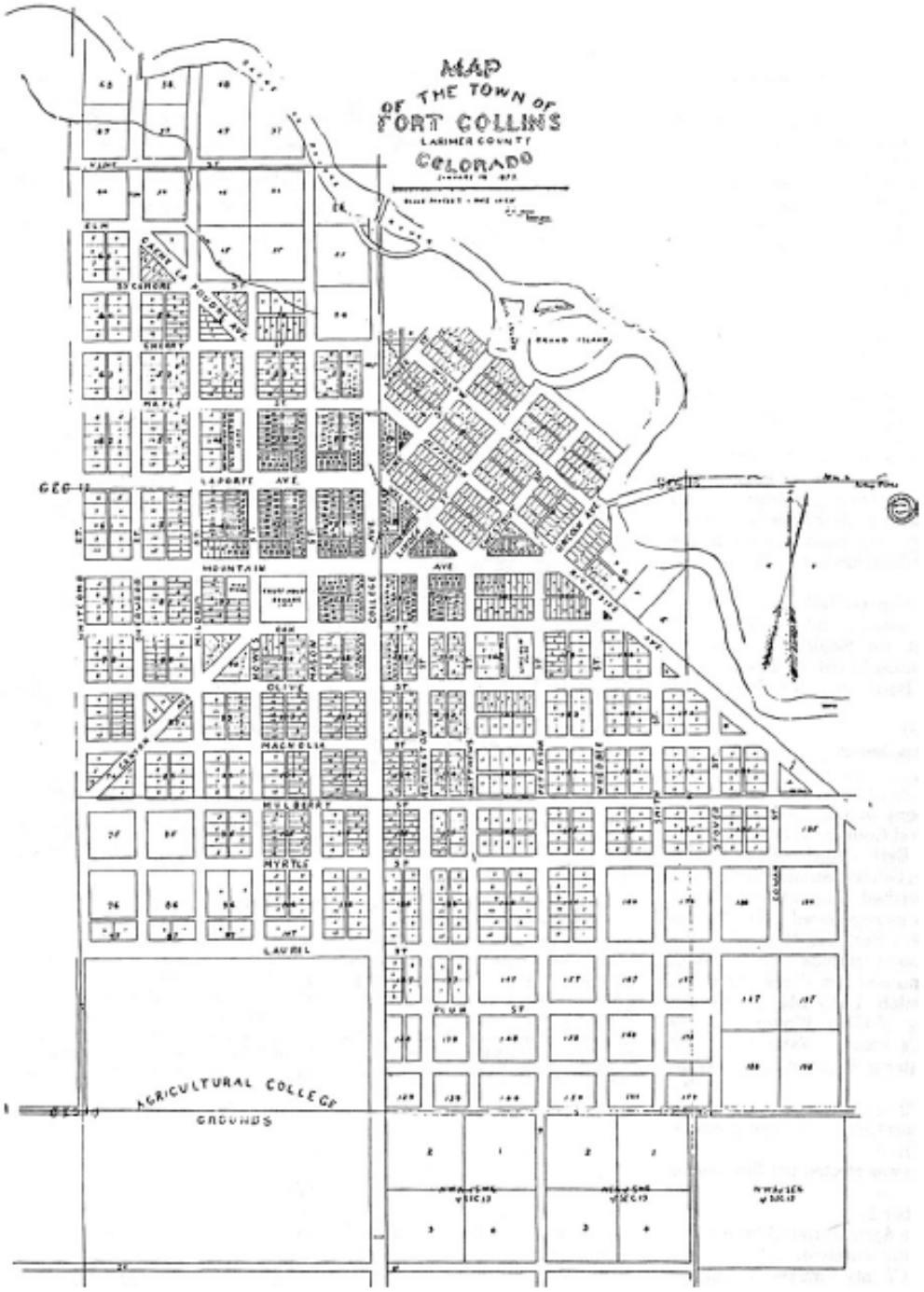
Same location 2010

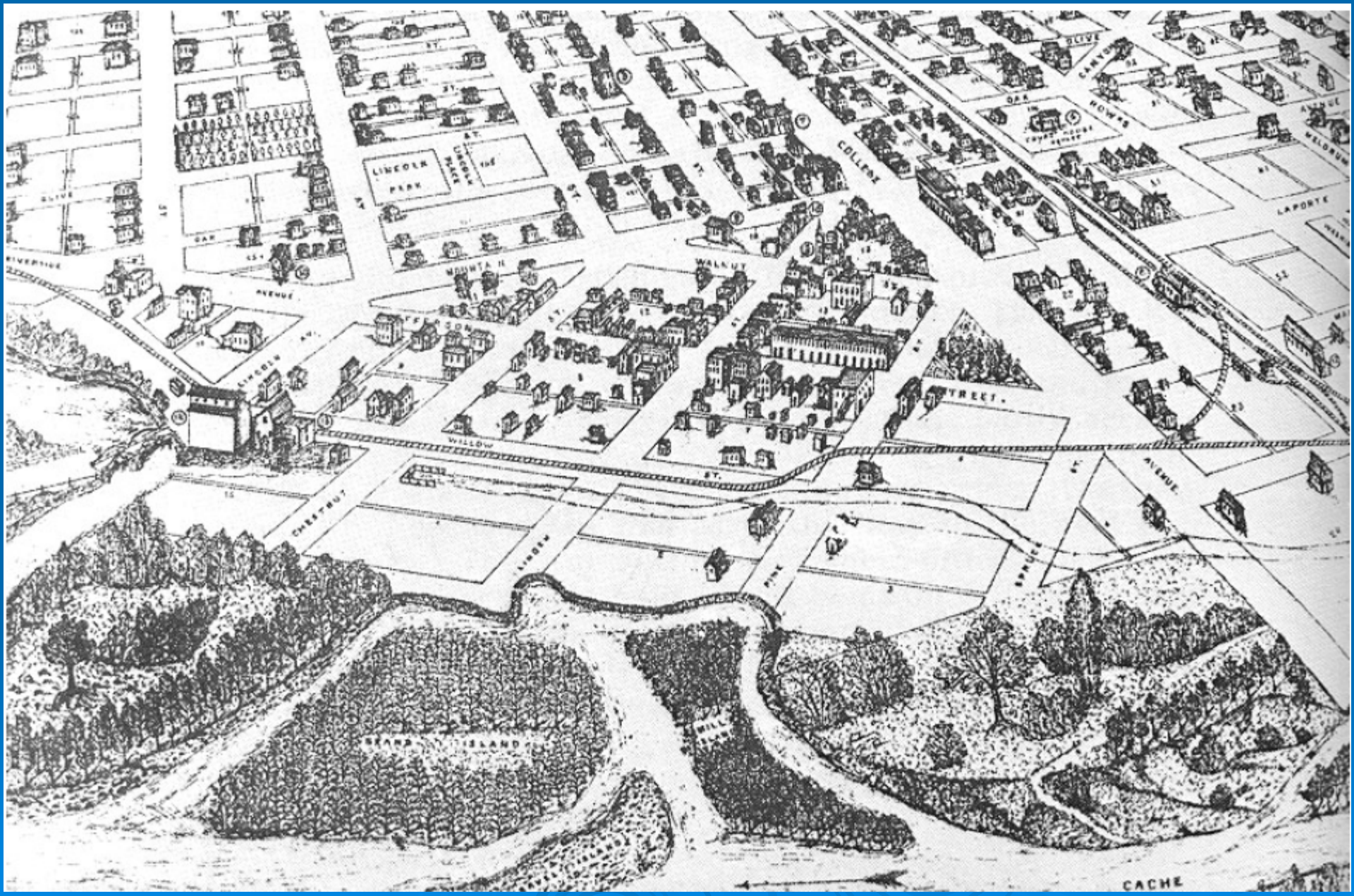
1937
Timberline Road
2005
Prospect Road
Boxelder Ditch
Diversion
Fossil Creek Reservoir
Inlet Ditch Diversion
CSU
ELC
Drake Road

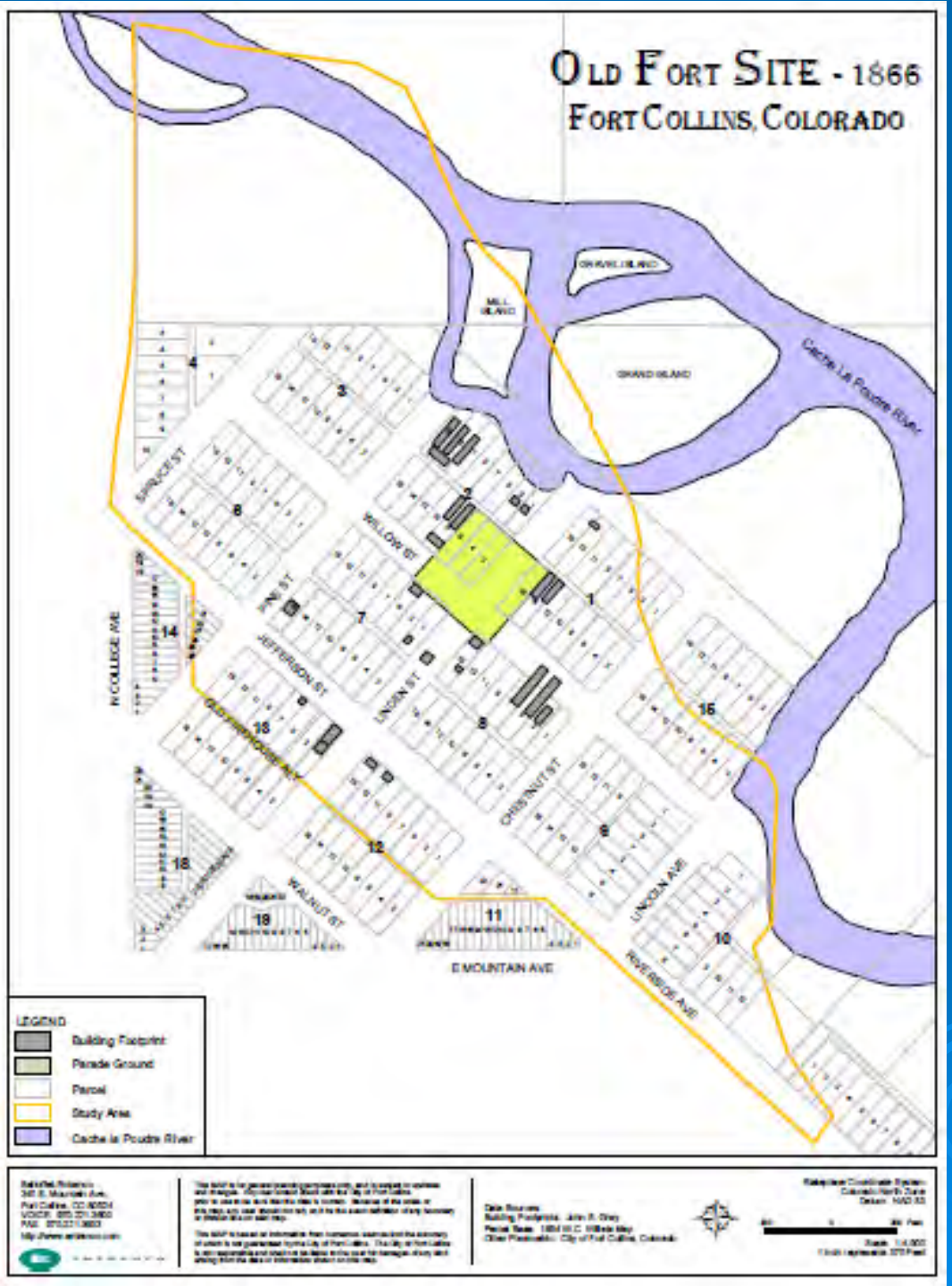
Fort Collins 1904

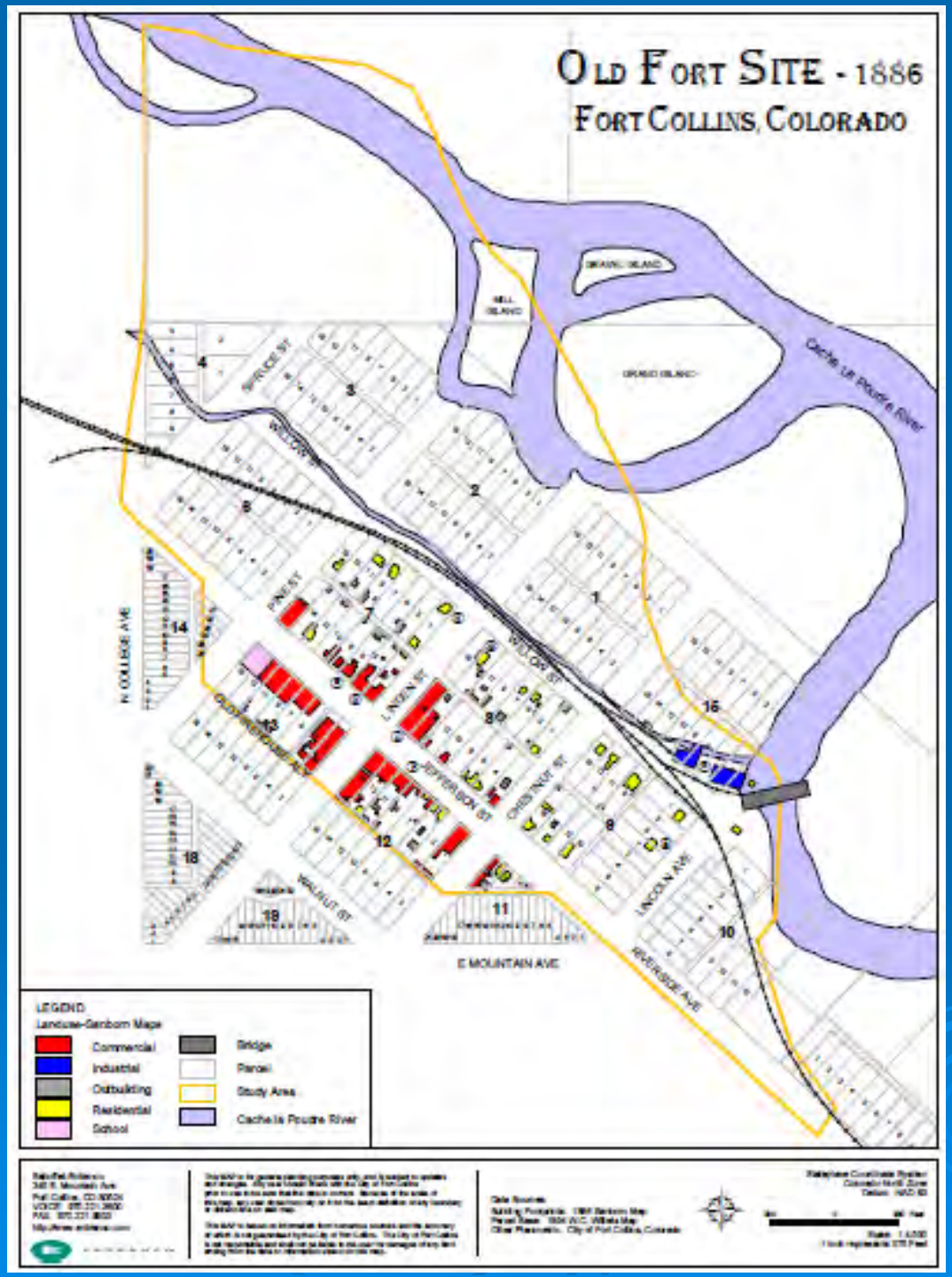
1999

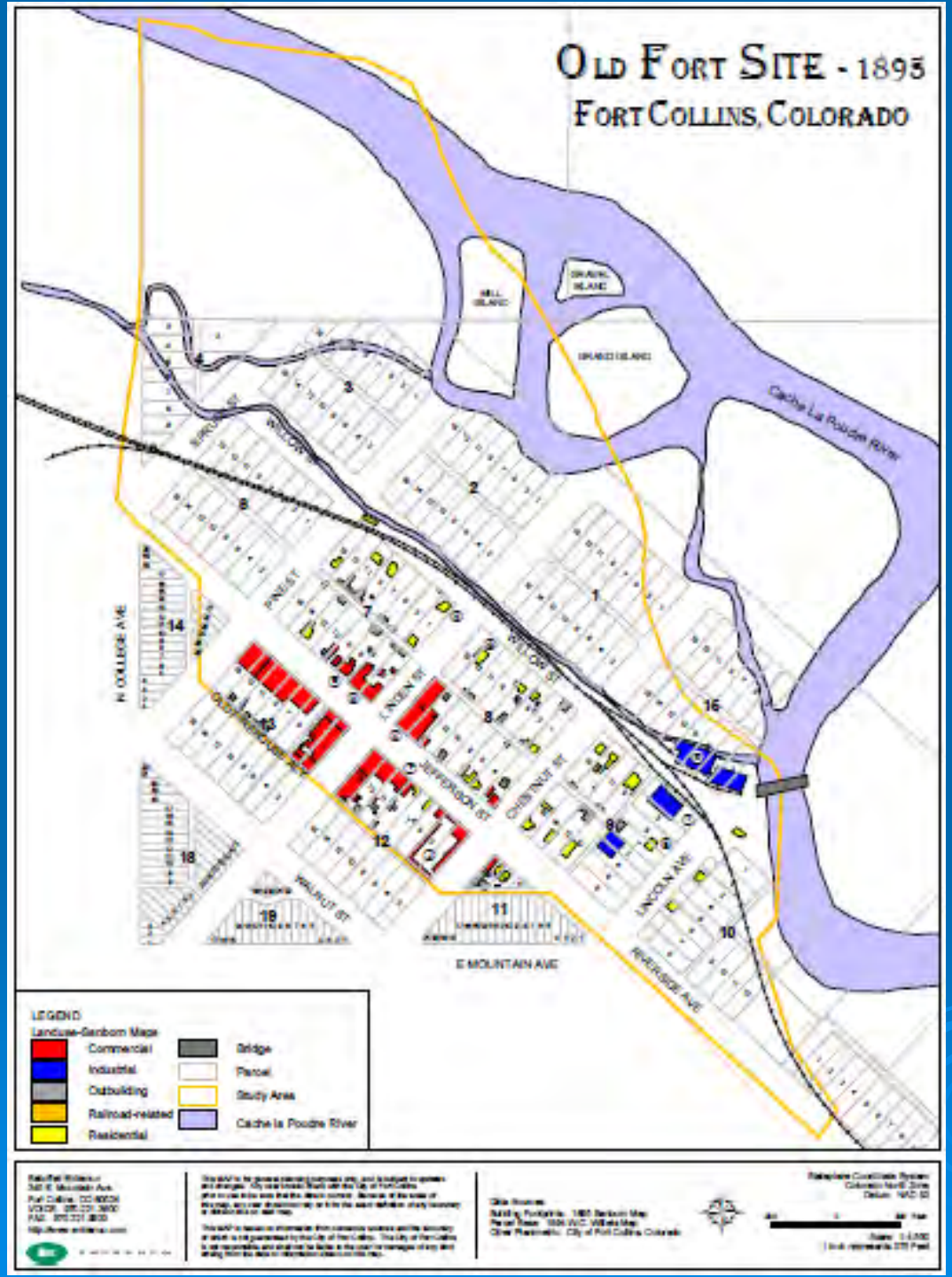

M.M.P
Camp Collins C. T.

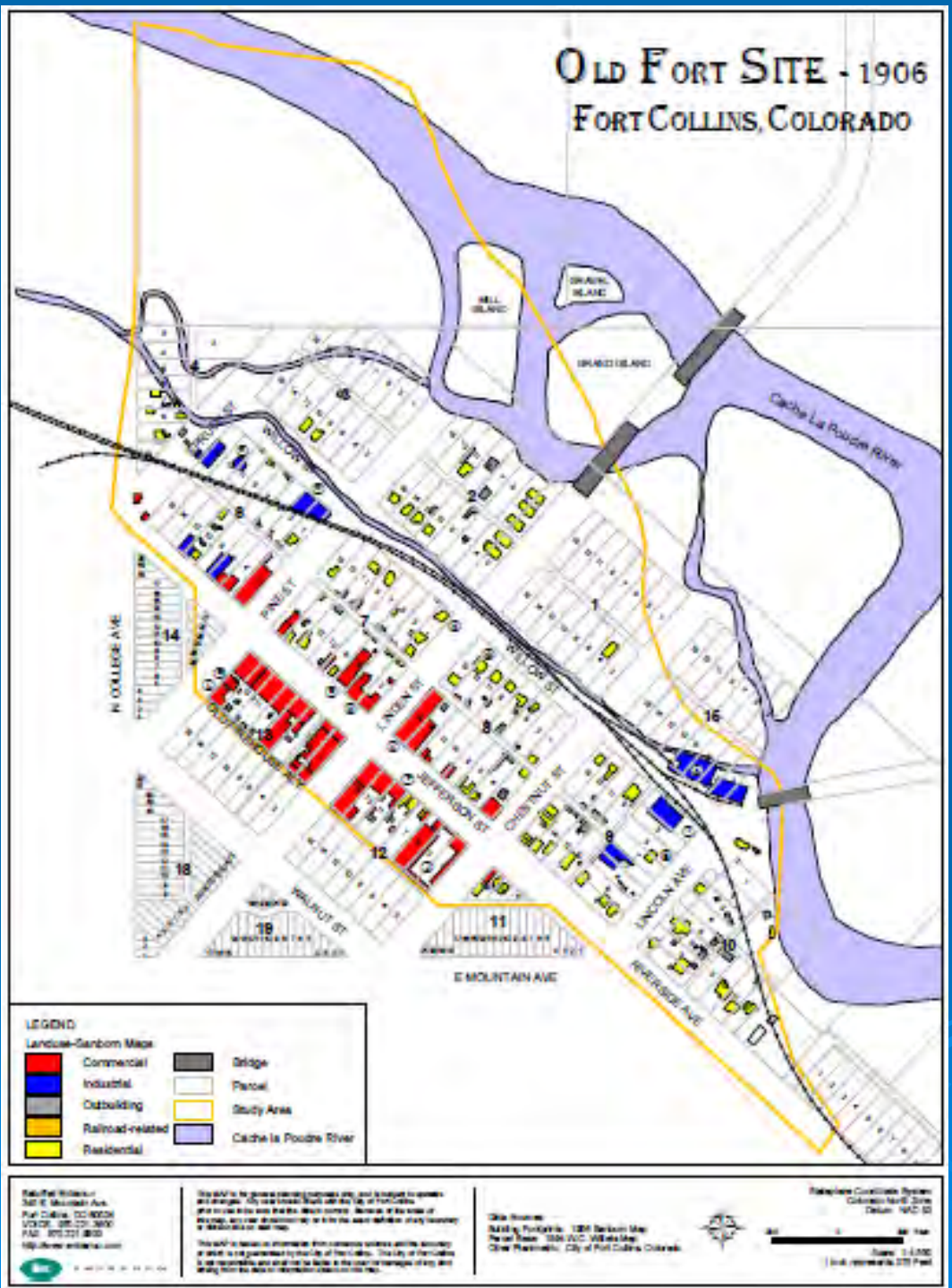

MAP
OF THE TOWN OF
FORT COLLINS
LARIMER COUNTY
COLORADO
ELM
SYCAMORE
CHERRY
MAPLE
LAPORTE AVE
MOUNTAIN
OAK
OLIVE
MAGNOLIA
MULBERRY
MYRTLE
LAUREL
PLUM
AGRICULTURAL COLLEGE
GROUNDS

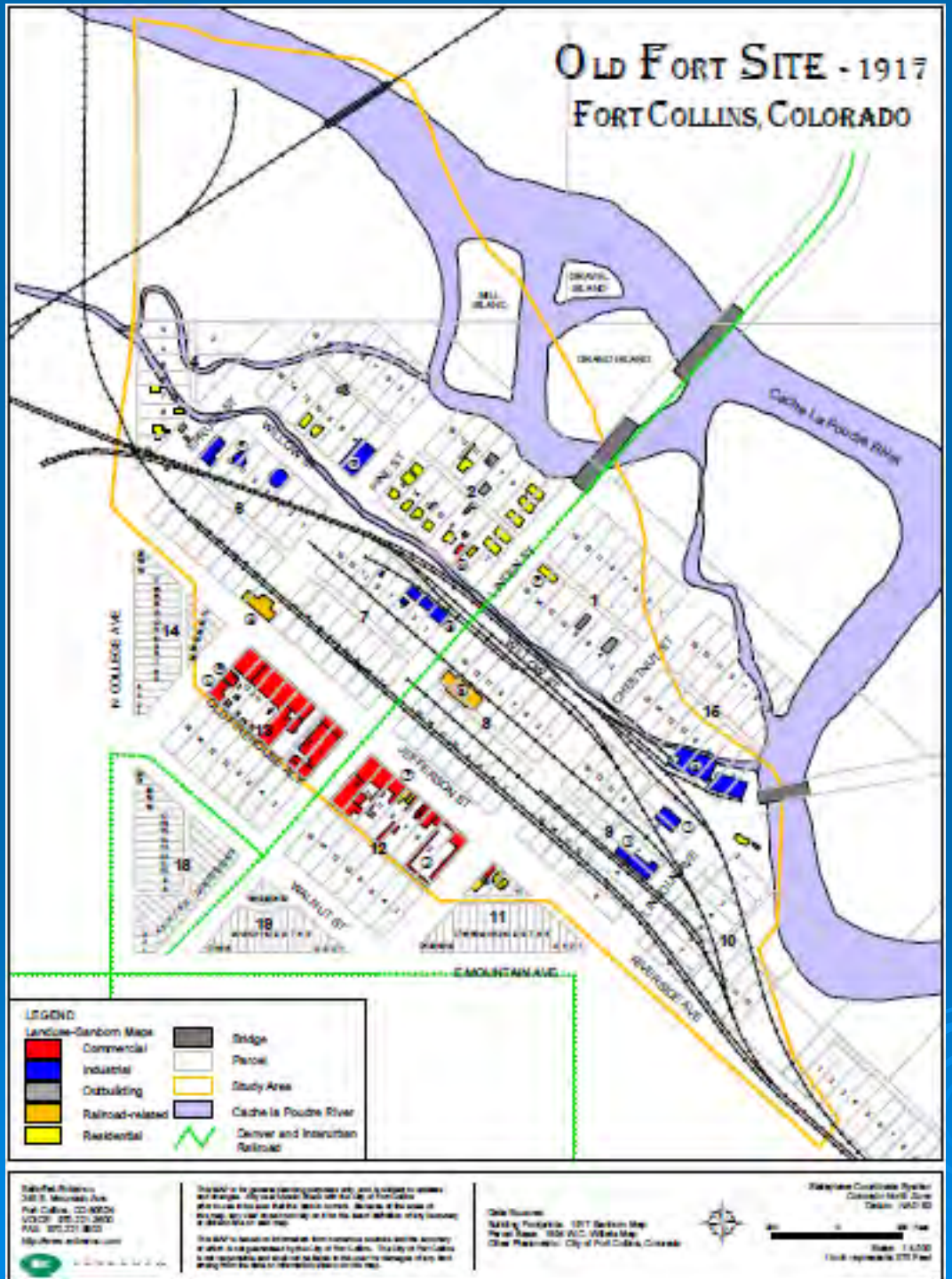

LINCOLN PARK
COLLEGE
STREET
WILLOW ST.
CHESTNUT
AVENUE
BEARD ISLAND
CACHE

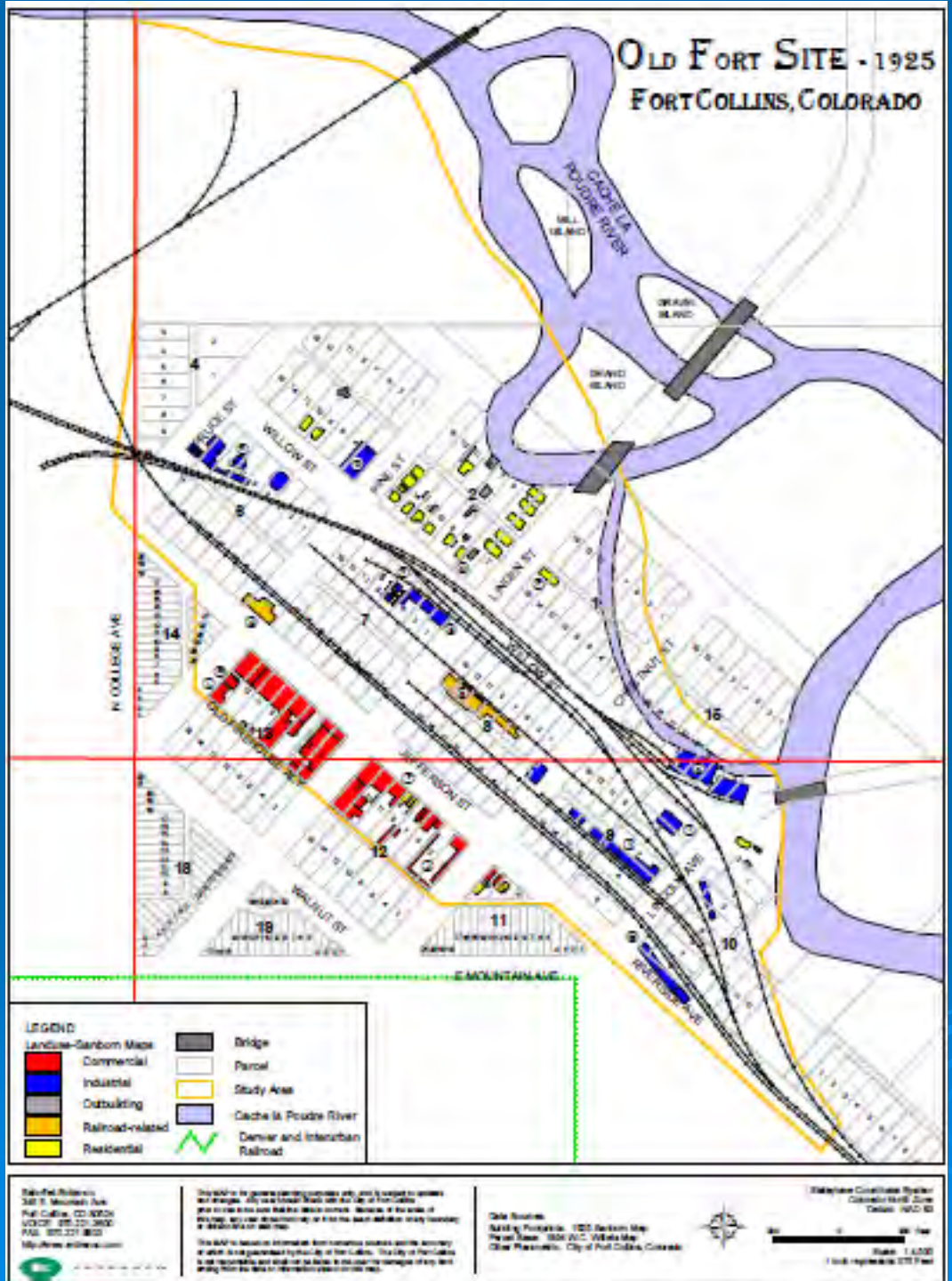

OLD FORT SITE - 1866
FORT COLLINS, COLORADO
MILL ISLAND
GRAND ISLAND
Cache La Poudre River
SPRUCE ST
WILLOW ST
JEFFERSON ST
OLDTOWNE ALY
LINCOLN ST
CHESTNUT ST
WALNUT ST
N COLLEGE AVE
E MOUNTAIN AVE
LINCOLN AVE
RIVERSIDE AVE
LEGEND
Building Footprint
Parade Ground
Parcel
Study Area
Cache la Poudre River

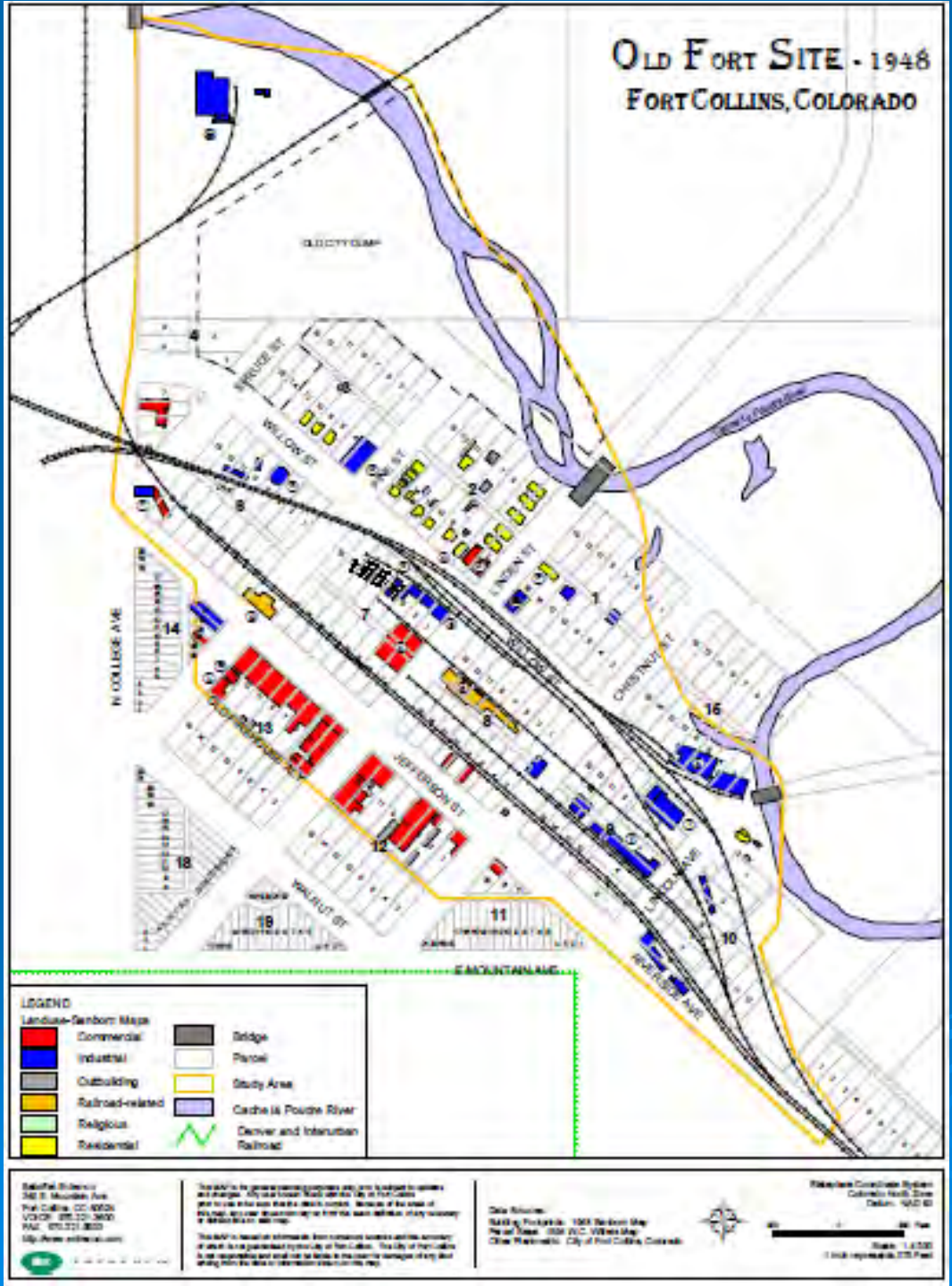

OLD FORT SITE - 1886
FORT COLLINS, COLORADO
Cache La Poudre River
GRAND ISLAND
MILL ISLAND
SPRUCE ST
WILLOW ST
LINDEN ST
WALNUT ST
CHESTNUT ST
JEFFERSON ST
N COLLEGE AVE
E MOUNTAIN AVE
LINCOLN AVE
RIVERSIDE AVE
LEGEND
Landuse-Sanborn Maps
Commercial
Industrial
Outbuilding
Residential
School
Bridge
Parcel
Study Area
Cache la Poudre River

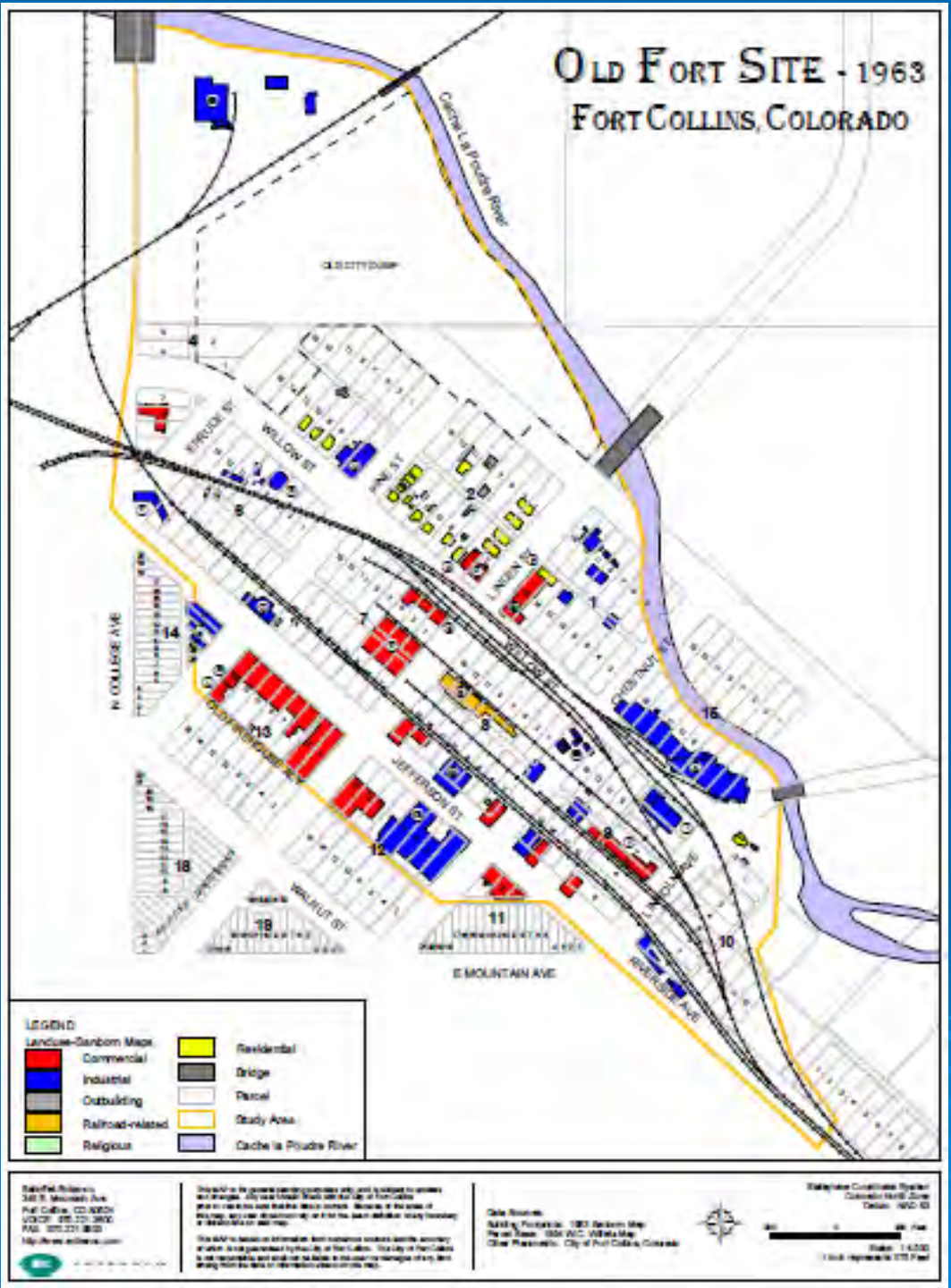

OLD FORT SITE - 1895
FORT COLLINS, COLORADO
Cache La Poudre River
N COLLEGE AVE
LINDEN ST
JEFFERSON ST
CHESTNUT ST
WALNUT ST
LINCOLN AVE
E MOUNTAIN AVE
RIVERSIDE AVE
LEGEND
Landuse-Sanborn Maps
Commercial
Industrial
Outbuilding
Railroad-related
Residential
Bridge
Parcel
Study Area
Cache la Poudre River

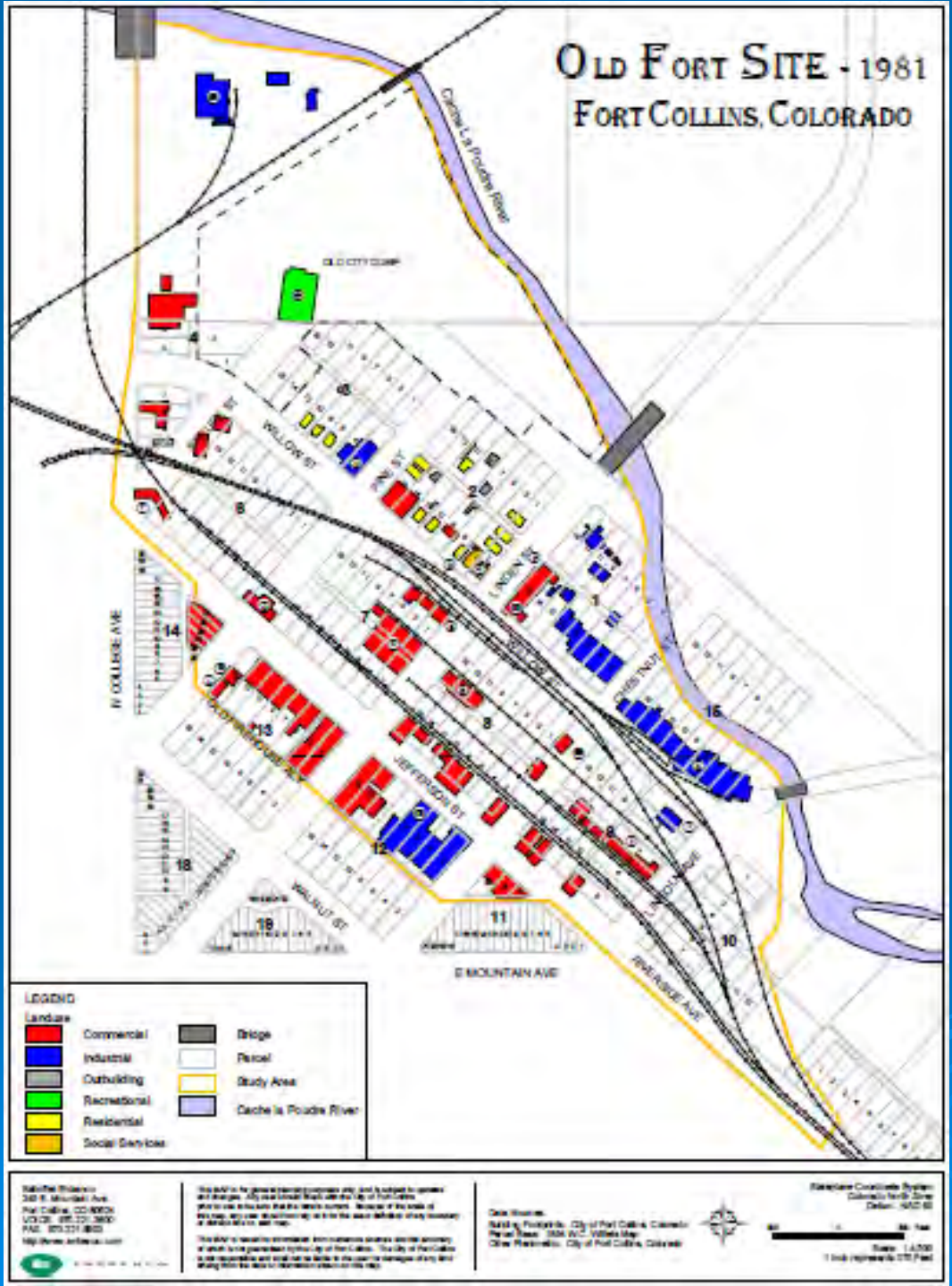

OLD FORT SITE - 1906
FORT COLLINS, COLORADO
Cache La Poudre River
N COLLEGE AVE
E MOUNTAIN AVE
LEGEND
Landuse-Sanborn Maps
Commercial
Industrial
Outbuilding
Railroad-related
Residential
Bridge
Parcel
Study Area
Cache la Poudre River

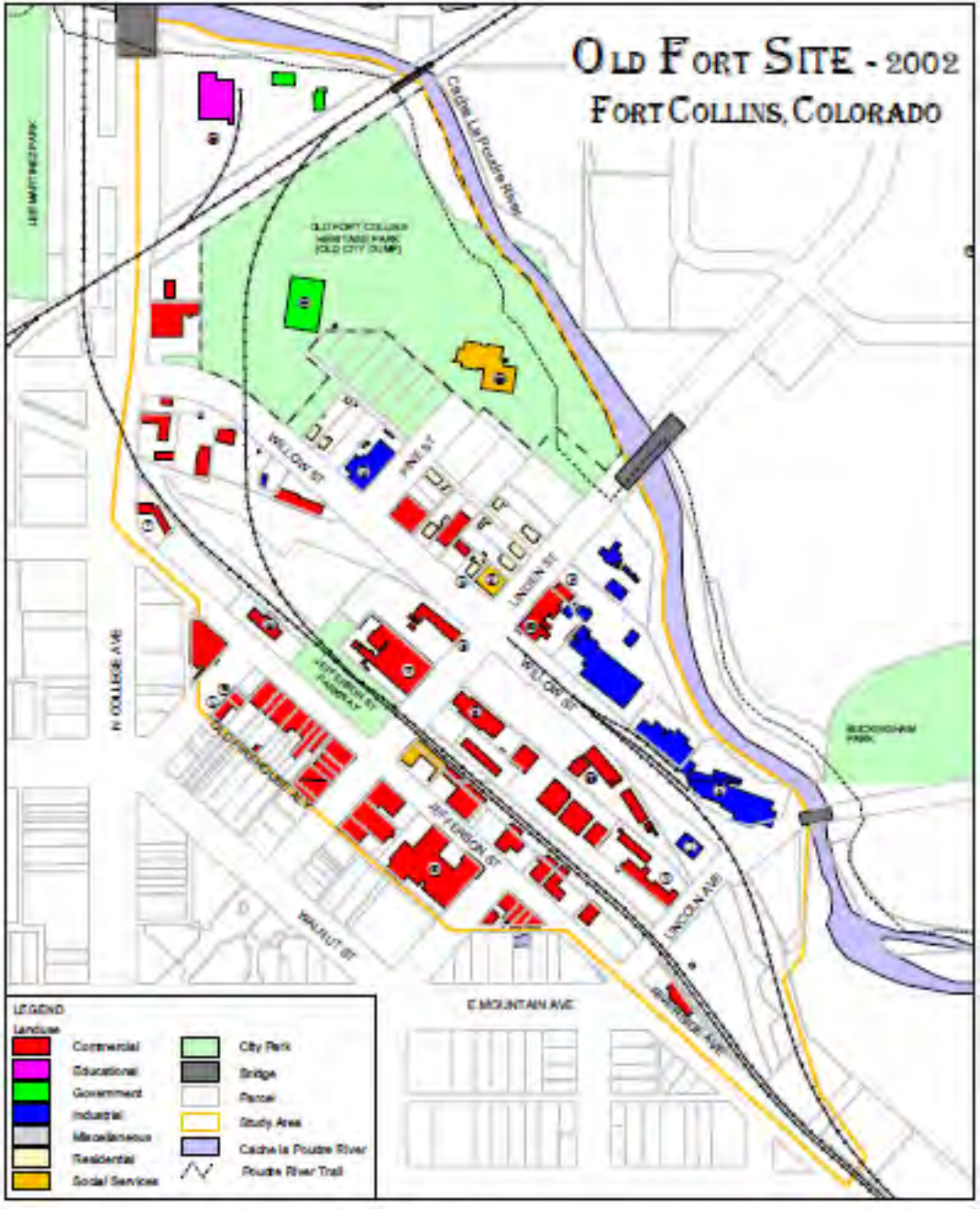

OLD FORT SITE - 1917
FORT COLLINS, COLORADO
Cache La Poudre River
N COLLEGE AVE
MOUNTAIN AVE
JEFFERSON ST
WALNUT ST
CHESTNUT ST
LEGEND:
Landuse-Sanborn Maps
Commercial
Industrial
Outbuilding
Railroad-related
Residential
Bridge
Parcel
Study Area
Cache la Poudre River
Denver and Interurban Railroad


OLD FORT SITE - 1925
FORT COLLINS, COLORADO
CACHE LA POUDRE RIVER
MILL ISLAND
BRAUN ISLAND
GRAND ISLAND
N COLLEGE AVE
E MOUNTAIN AVE
LEGEND
Landuse-Sanborn Maps
Commercial
Industrial
Outbuilding
Railroad-related
Residential
Bridge
Parcel
Study Area
Cache la Poudre River
Denver and Interurban Railroad

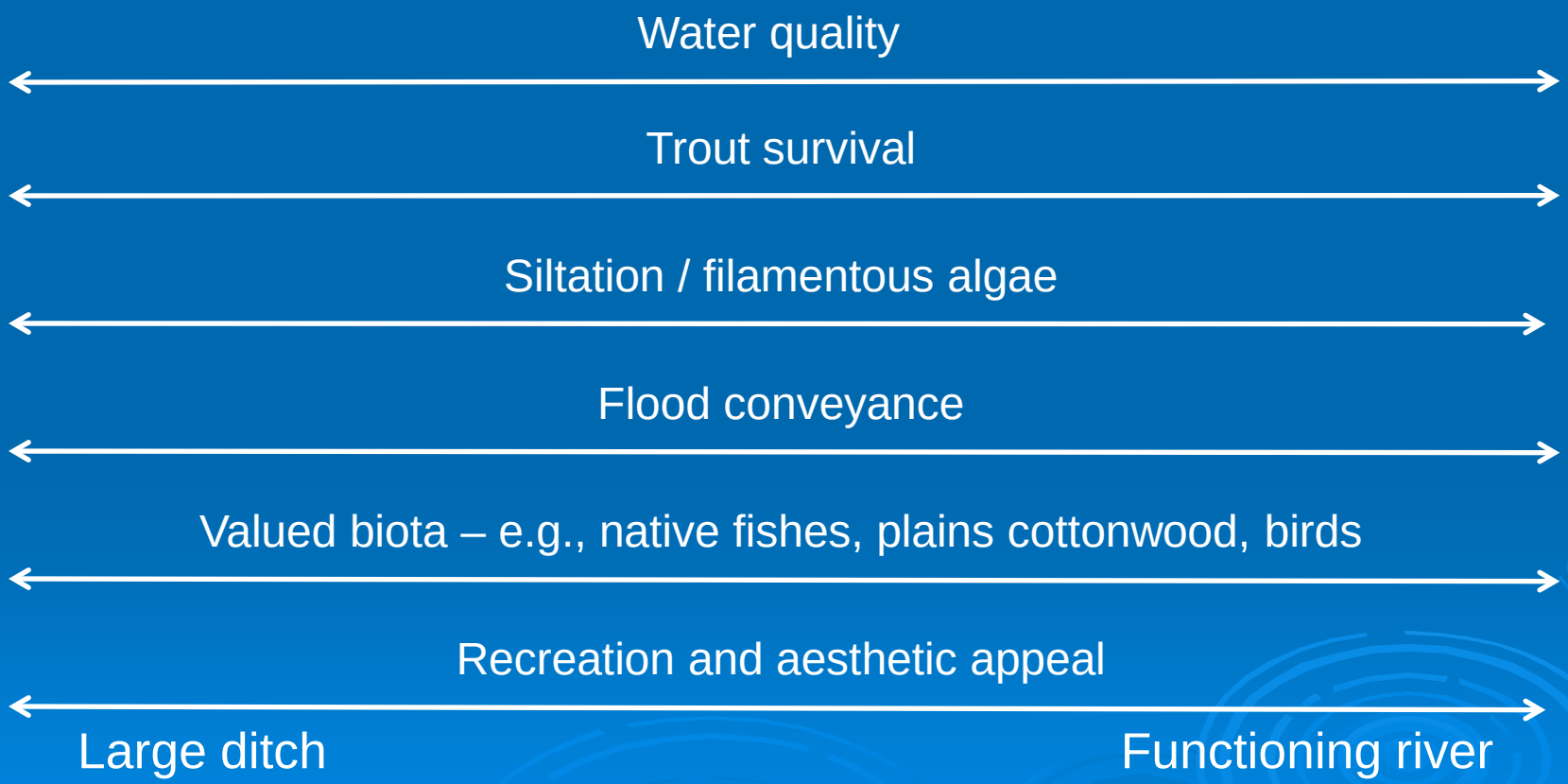

OLD FORT SITE - 1948
FORT COLLINS, COLORADO
LEGEND
Landuse-Sanborn Maps
Commercial
Industrial
Outbuilding
Railroad-related
Religious
Residential
Bridge
Parcel
Study Area
Cache la Poudre River
Denver and Interurban Railroad
N COLLEGE AVE
E MOUNTAIN AVE
WILLOW ST
CHESTNUT ST
JEFFERSON ST
WALNUT ST


OLD FORT SITE - 1963
FORT COLLINS, COLORADO
Cache La Poudre River
OLD CITY DUMP
WILLOW ST
N COLLEGE AVE
JEFFERSON ST
WALNUT ST
E MOUNTAIN AVE
LEGEND
Landuse-Sanborn Maps
Commercial
Industrial
Outbuilding
Railroad-related
Religious
Residential
Bridge
Parcel
Study Area
Cache la Poudre River


OLD FORT SITE - 1981
FORT COLLINS, COLORADO
Cache La Poudre River
OLD CITY CEMP
WILLOW ST
N COLLEGE AVE
JEFFERSON ST
WALNUT ST
E MOUNTAIN AVE
RIVERSIDE AVE
LEGEND
Landuse
Commercial
Industrial
Outbuilding
Recreational
Residential
Social Services
Bridge
Parcel
Study Area
Cache la Poudre River


OLD FORT SITE - 2002
FORT COLLINS, COLORADO
Cache La Poudre River
OLD FORT COLLINS HERITAGE PARK (OLD CITY DUMP)
WILLOW ST
PINE ST
LINDEN ST
WILSON ST
N COLLEGE AVE
E MOUNTAIN AVE
LINCOLN AVE
WALNUT ST
LEGEND
Landuse
Commercial
Educational
Government
Industrial
Miscellaneous
Residential
Social Services
City Park
Bridge
Parcel
Study Area
Cache la Poudre River
Poudre River Trail

A Spectrum of Poudre River Futures



More Risk

Less Risk

What can we do?

- Work towards environmental flows that conserve river amenities and functions
  - Some aspects easier than others
  - Engineers need numbers
  - Incremental approach based on measured successes
- Reduce waste and inefficiency
  - Cooperation, conservation, reuse
- Economic valuation of and payments for ecosystem services

Tangible policy decisions and management actions that could make a difference – few examples:

- Provide suitable minimum flow for trout and native fishes
- Ensure periodic high flow events
- Allow channel movement in some designated segments
- Physically restore habitat
- Manage riparian vegetation
- Remove, consolidate, or retrofit diversion structures
- Reduce point and non-point source pollution
- Manage aquatic and riparian non-native species

Restoration?

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.

Take Home Messages

- The Poudre River is not going back to pre-development conditions – irreversible change has occurred – now an invented river ecosystem

- Restoration is not returning the river to an undeveloped historical condition. It is assisting the recovery and sustainability of an ecosystem that has been damaged.

Take Home Messages

- The current trend of deteriorating river integrity and amenities can be reversed with environmental flows and sound long-term stewardship that balances human demands with ecosystem needs.
- A wide range of alternative river futures is still available to us (for now).
- Engineers need numbers – those numbers are mostly available.

Take Home Messages

- Focus on river services / amenities that we value the most:
  - Clean water
  - Trout and native fishes
  - Valued flora and fauna
  - Flood conveyance
  - Recreation and aesthetic appeal…
- Healthy farms and cities are compatible with sustaining these river amenities
- WE MUST HAVE A VISION!

Planning an alternative future for the river

What’s your vision?