SOUTHERN ROCKIES
Landscape Conservation Cooperative

Reservoir Operation for Cottonwood Recruitment on the Provo River

Welcome/Housekeeping

- Thanks for participating!
- Please introduce yourself by typing your name/affiliation in the chat box
- Planning for a 1 hour presentation and 30 minutes for questions at the end (finish at 4:00)
  - * Type questions into chat box as we go; send to host
  - * And/or use audio to ask questions during question period

John Rice

Shortly After Construction

2004

2006

2008

Presenters

- **John Rice**, Science Coordinator, Southern Rockies LCC, Bureau of Reclamation
- **Mark Holden**, Executive Director, Utah Reclamation Mitigation and Conservation Commission
- **Melissa Stamp**, Project Coordinator, Utah Reclamation Mitigation and Conservation Commission
- **Daryl Devey**, Bonneville Unit O&M Manager, Central Utah Water Conservancy District
- **Darren Olsen**, Principal/Sr. Hydrologist, BIO-WEST, Inc.

Outline

- **Mark Holden**: Background about Central Utah Project Bonneville Unit and Provo River Restoration Project
- **Melissa Stamp**: Importance of riparian cottonwood forests; recruitment modeling tool
- **Daryl Devey/Mark Holden**: Reservoir release decision-making; 10-year update
- **All**: Wrap-up and questions

Mark Holden

Utah Reclamation Mitigation and Conservation Commission

- A presidential Commission established in July 1994 under the Central Utah Project Completion Act of 1992 (CUPCA)
- Primary authority for CUP Bonneville Unit mitigation

Colorado River Basin Water Development

- Colorado River Compact of 1948 allotted Utah 23% of Colorado River water in the Upper Basin (up to 1,715,000 AF)
- Colorado River Storage Project Act (CRSPA) of 1956 authorized numerous "participating projects", of which CUP is the largest

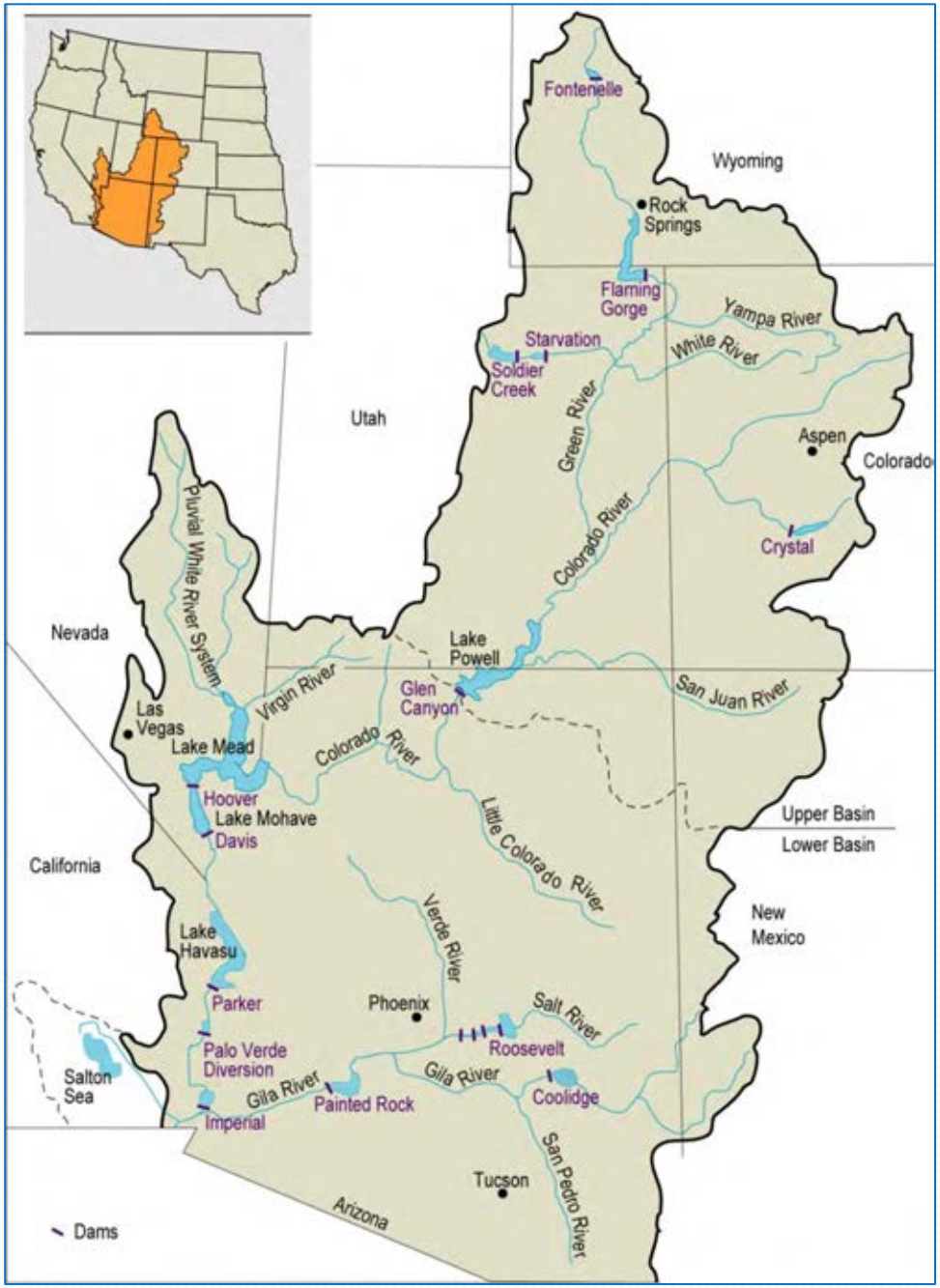
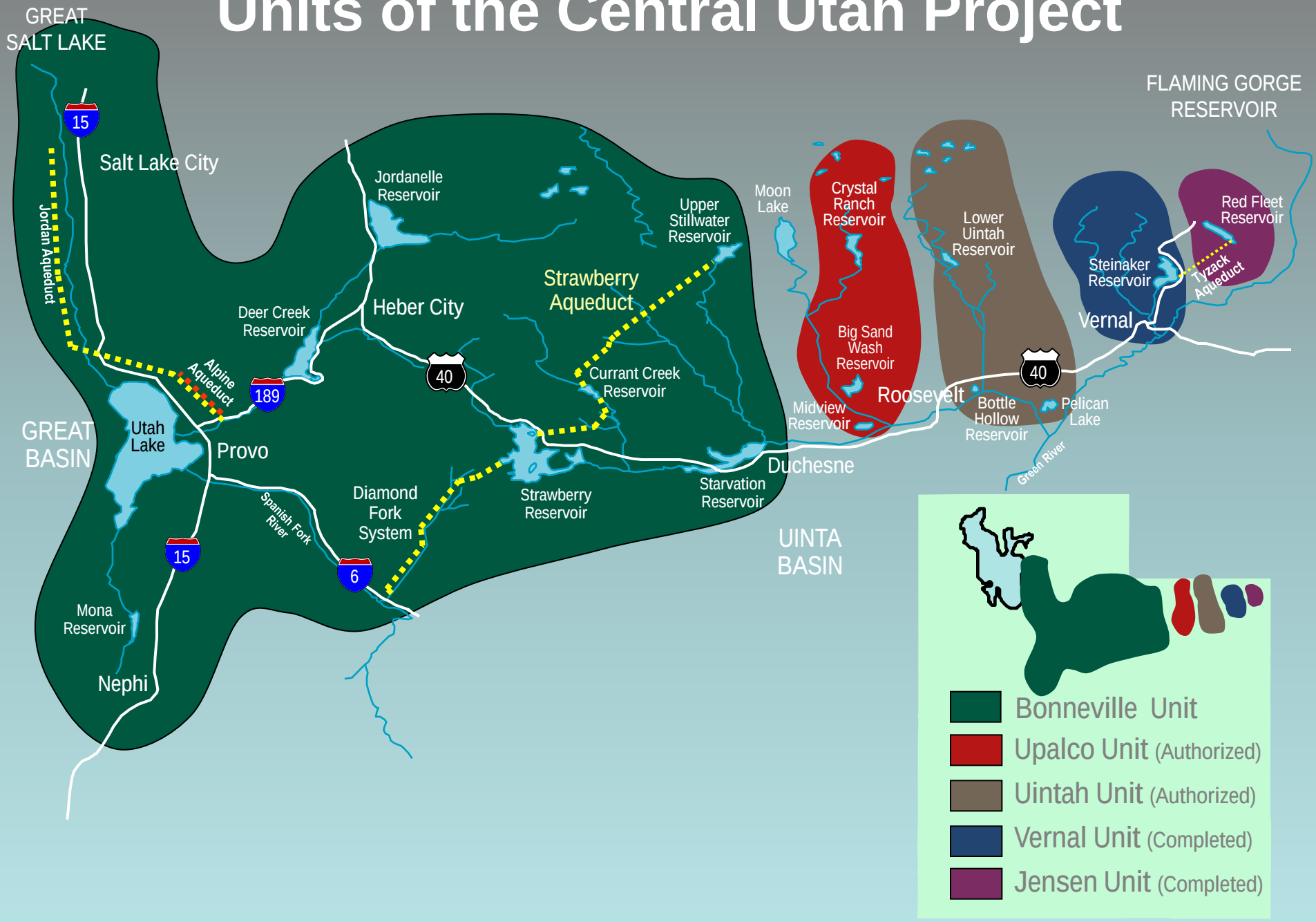
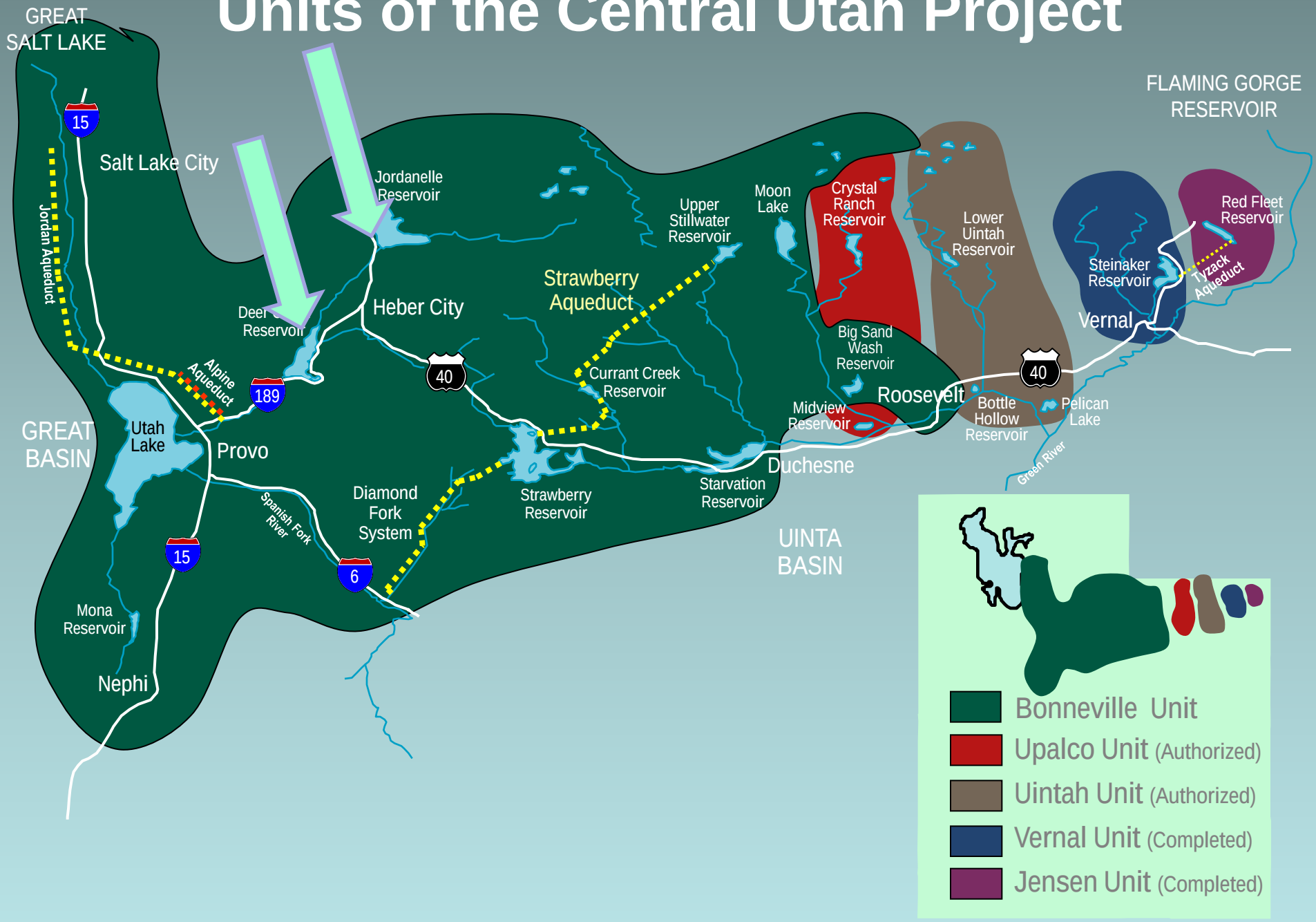


Figure Source: David L. Alles
Western Washington University

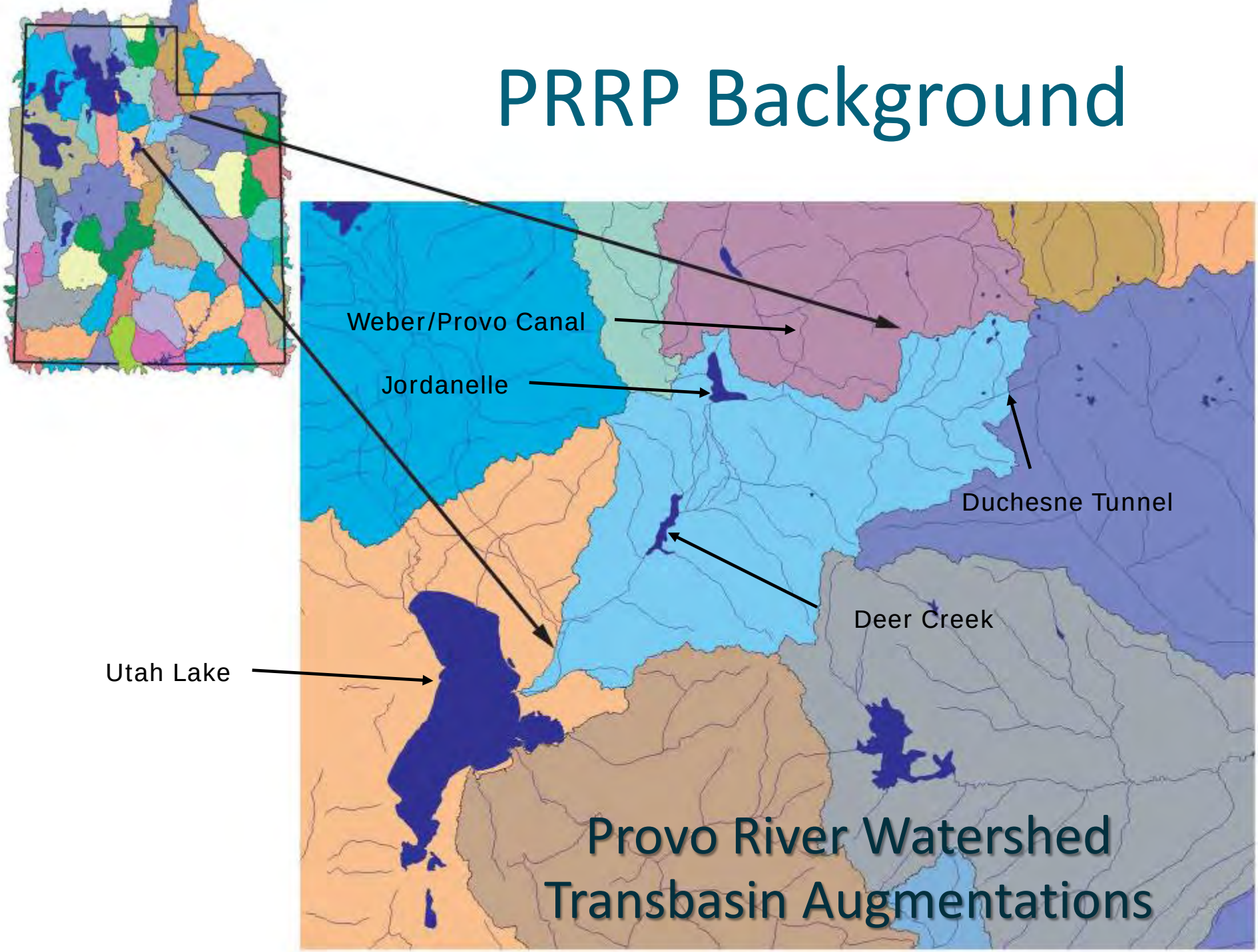
Units of the Central Utah Project



Units of the Central Utah Project

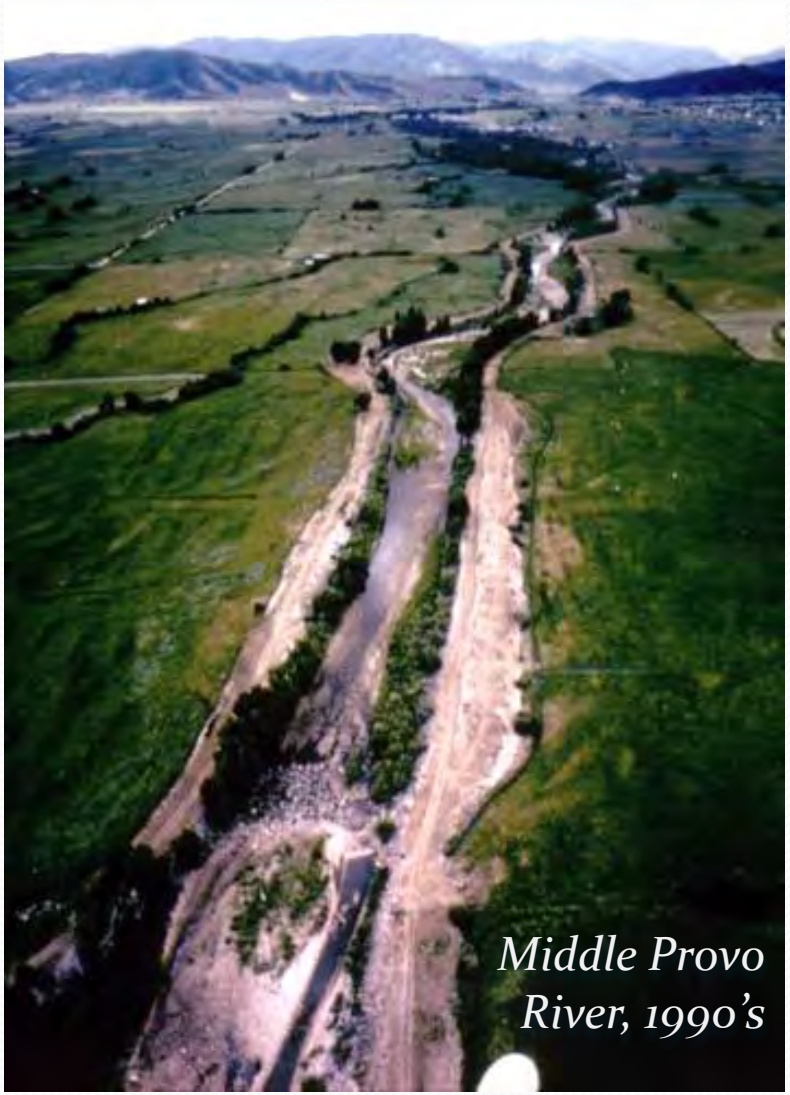


PRRP Background



PRRP Background

- Transbasin flow augmentations contributed to flooding problems
- Channel was channelized and diked in 1950's-1960's



Jordanelle Dam, Bonneville Unit of the CUP

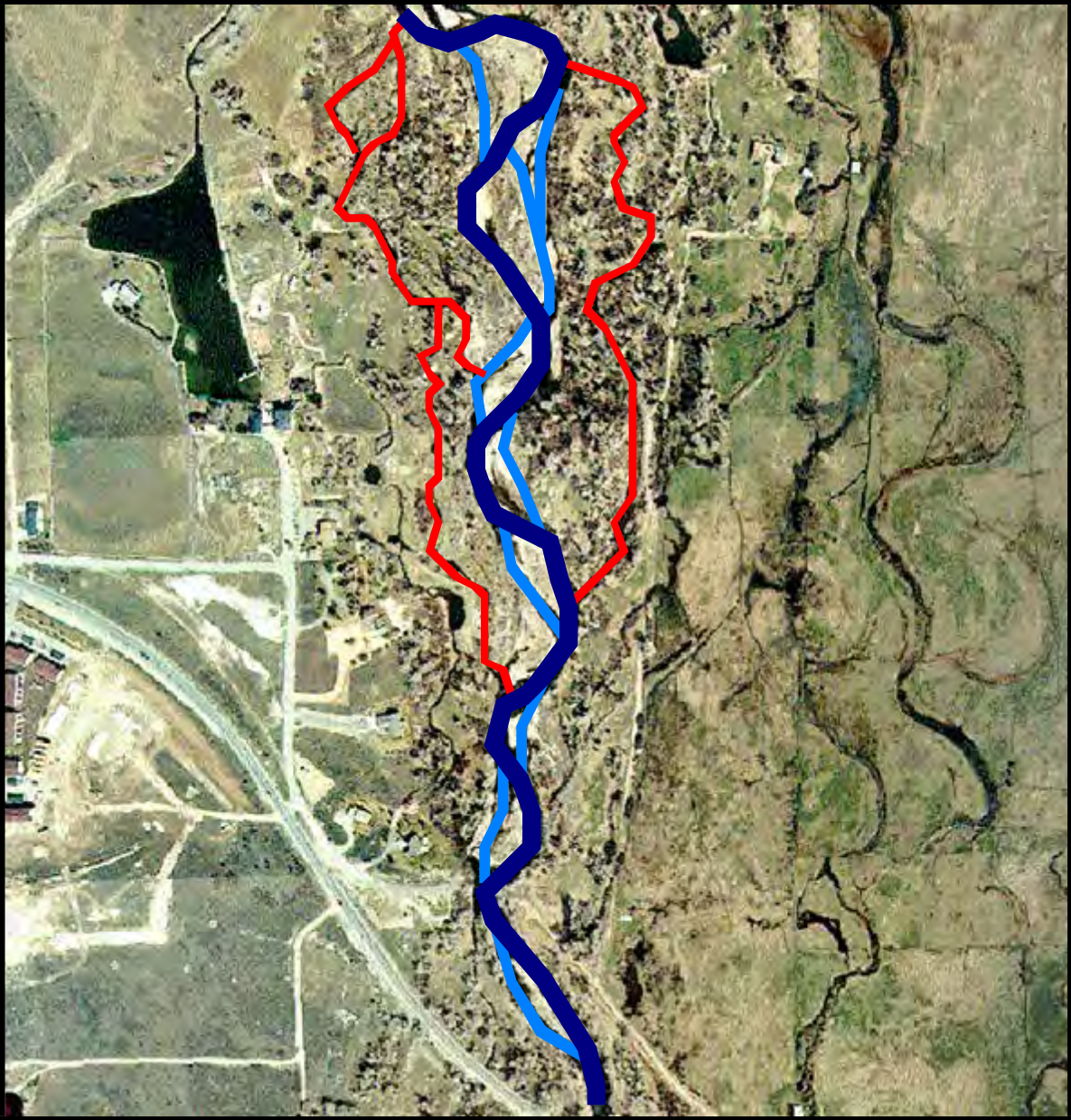
- Completed in 1992
- Provides some degree of flood control previously only provided by dikes
- Helped make restoration possible

PRRP Implementation

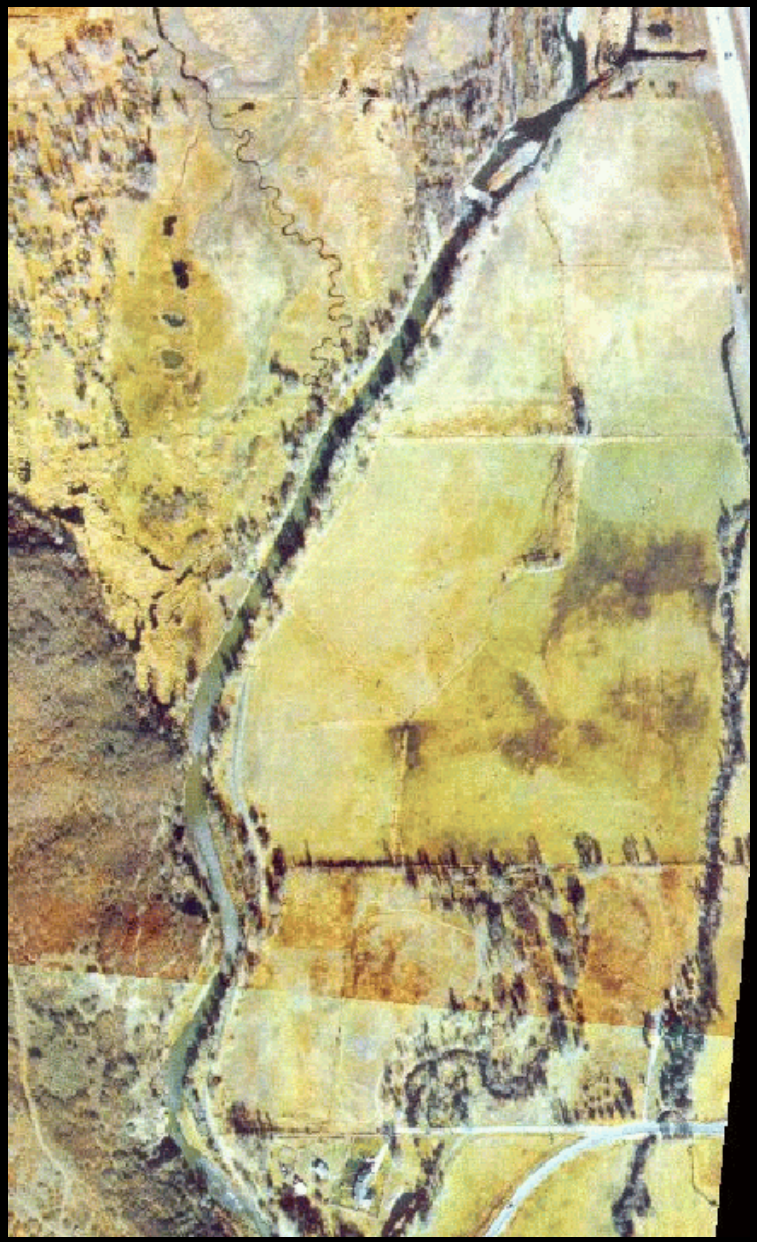
- 1988 – 1992 Pre-planning and studies
- 1992 – 1997 Planning & NEPA
- 1998 – 2008 Project implementation

Low Hydraulic Diversity; Low Biomass

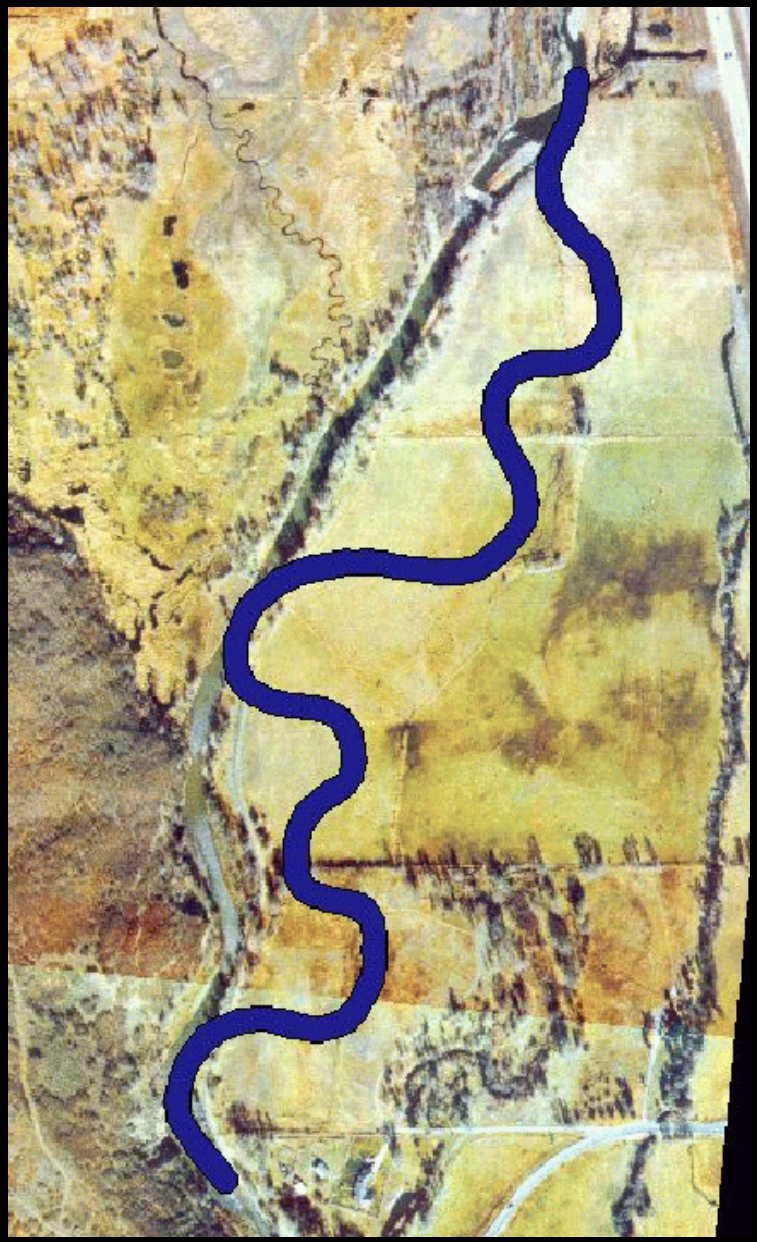
High Hydraulic Diversity; High Biomass

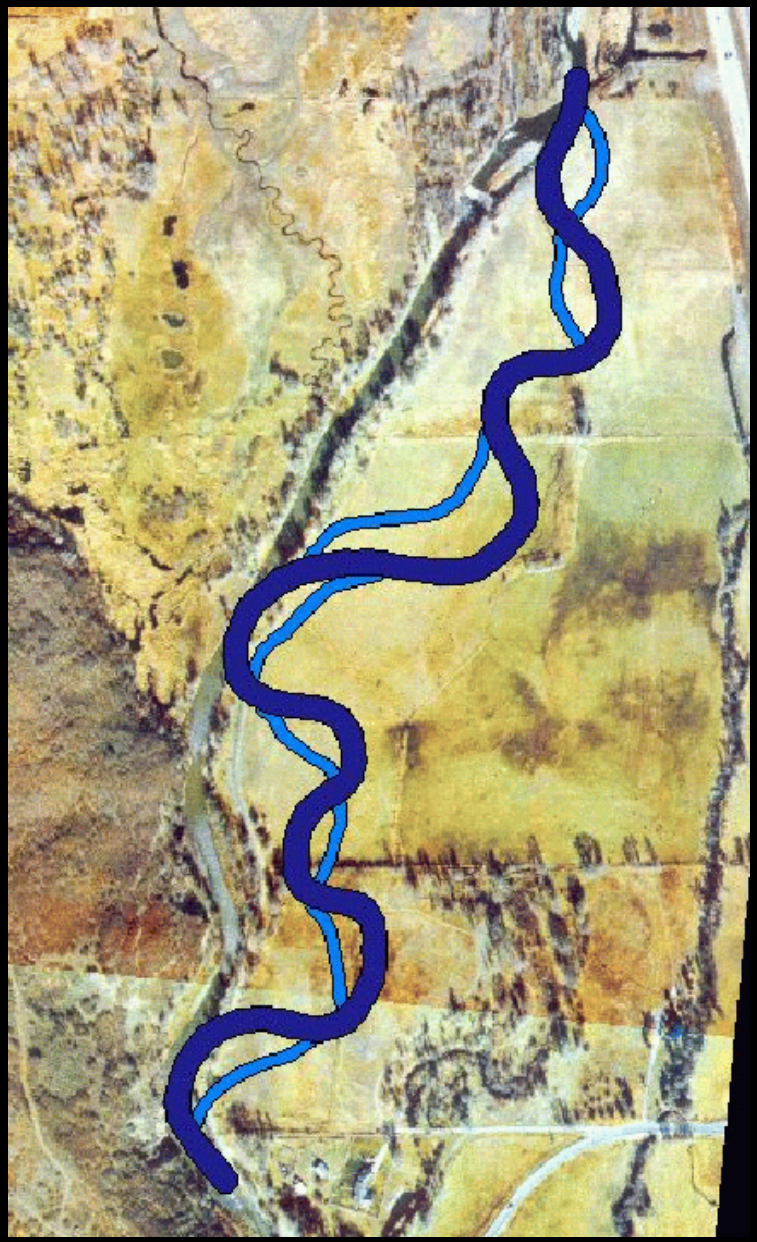


Reach 7 Design



October, 1999





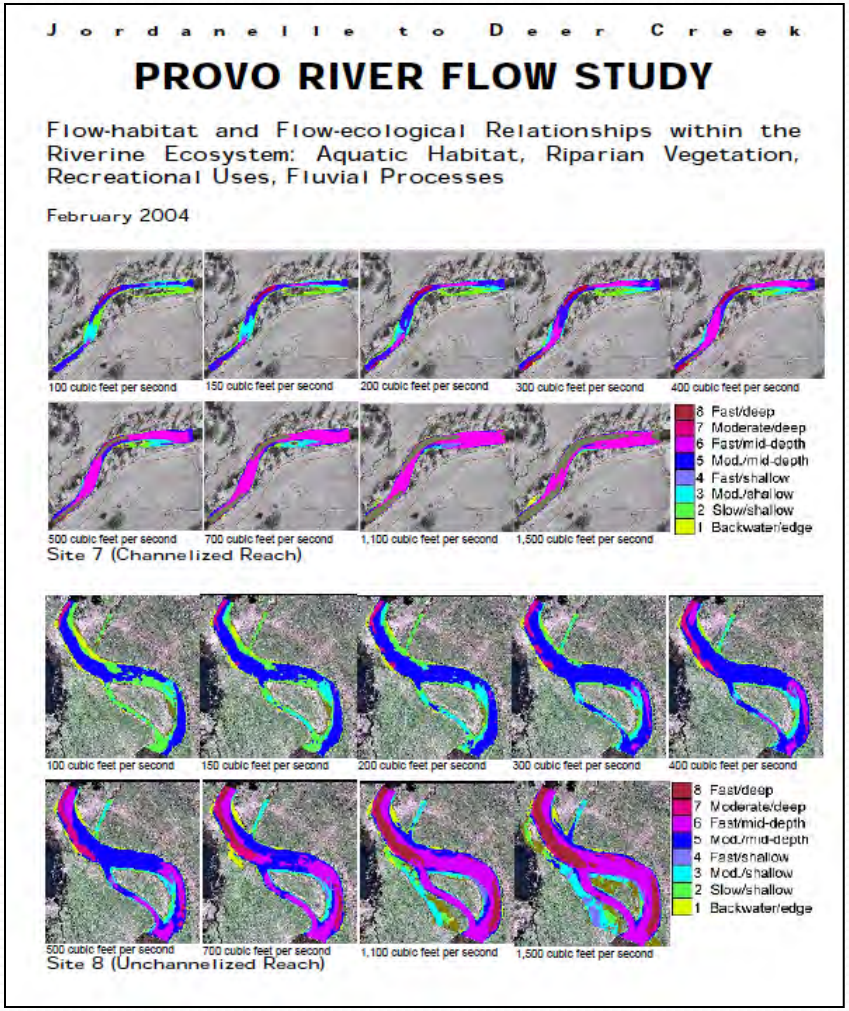
November, 2001

June, 2013

Melissa Stamp

Cottonwood Recruitment Model

- Work done in 2002-2004 as part of **Provo River Flow Study**
  - Evaluate effects of alternative flow regimes on ecological components of Provo River system



Importance of Woody Riparian Vegetation to Aquatic Habitat

- Instream cover
  - Woody debris
  - Roots/overhanging banks
- Habitat complexity
  - Velocity refuges
  - Scour holes at log jams

Importance of Woody Riparian Vegetation to Aquatic Habitat

- Water Quality
  - Temperature
  - Dissolved oxygen
  - Nutrients
- Channel morphology
  - Bar deposits
  - Bank strength

Cottonwood Recruitment Modeling

- Why cottonwoods?
  - Dominant native riparian tree in western U.S.
  - Recruitment success dependent upon fluvial surfaces, flows
    - Indicator of ecosystem health
    - Indicator of restoration success

Cottonwoods in Decline

- Susceptible to effects of dams and diversions
  - Require flooding and disturbance
  - Require fresh sediment deposits
- Limited to old-growth stands on many western rivers

River Systems Affected

- Lower Colorado River
- Missouri River
- Truckee River
- Rio Grande
- Yampa River
- Green River
- San Joaquin River
- San Pedro River
- *and more….*

Cottonwood Recruitment Modeling

- Why cottonwoods?
  - Body of research exists outlining recruitment criteria
  - Cottonwoods can serve as a surrogate for other native woody riparian plant species (willow, dogwood etc.)

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

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

The Importance and Extent of Cottonwood Forest Decline Downstream from Dams

CONFERENCE PAPER · JANUARY 1991

Development of a spatially-distributed hydroecological model to simulate cottonwood seedling recruitment along rivers

ARTICLE in [illegible]

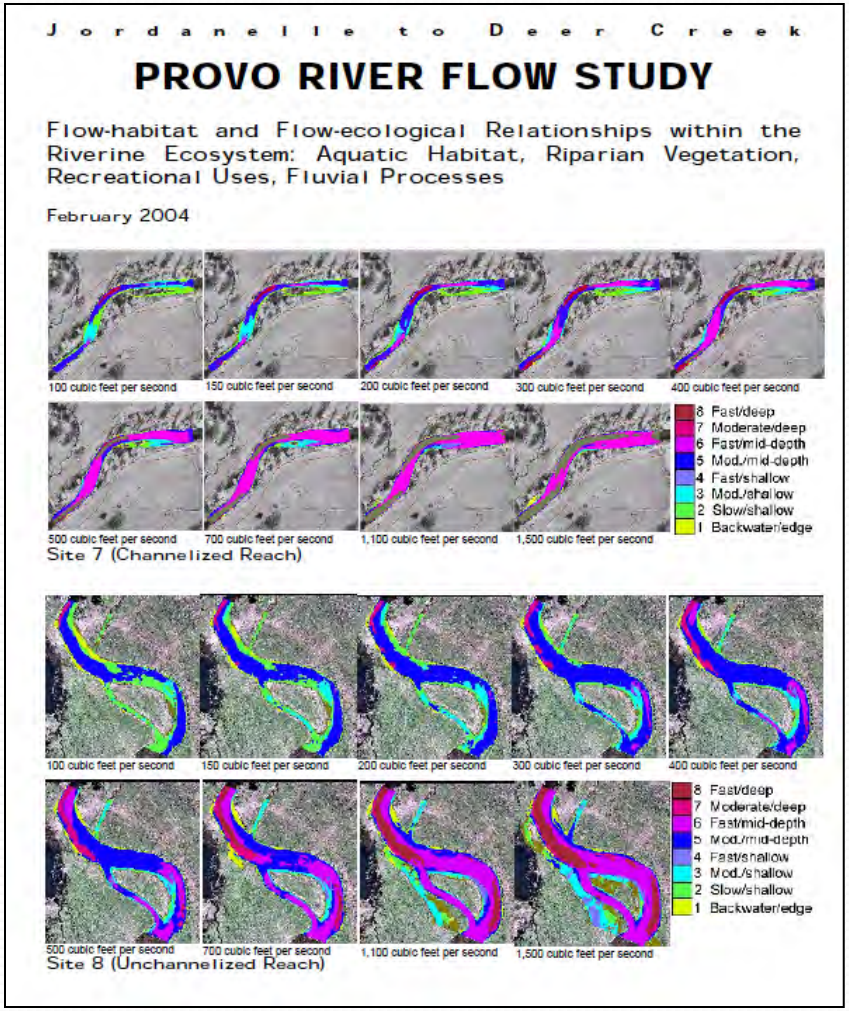
[illegible]MENTAL MANAGEMENT · JULY 2014

WETLANDS, Vol. 18, No. 4, December 1998, pp. 546–556
© 1998, The Society of Wetland Scientists

FLUVIAL DISTURBANCE PATCHES AND COTTONWOOD RECRUITMENT ALONG THE UPPER MISSOURI RIVER, MONTANA

Cottonwood Recruitment Model

- Study funded by Mitigation Commission
  - BIO-WEST, Inc.
    - Institute for Natural Systems Engineering (INSE)/Utah State University (*Craig Addley*)
    - GEO/Graphics, Inc.
  - Central Utah Water Conservancy District



Model Objectives

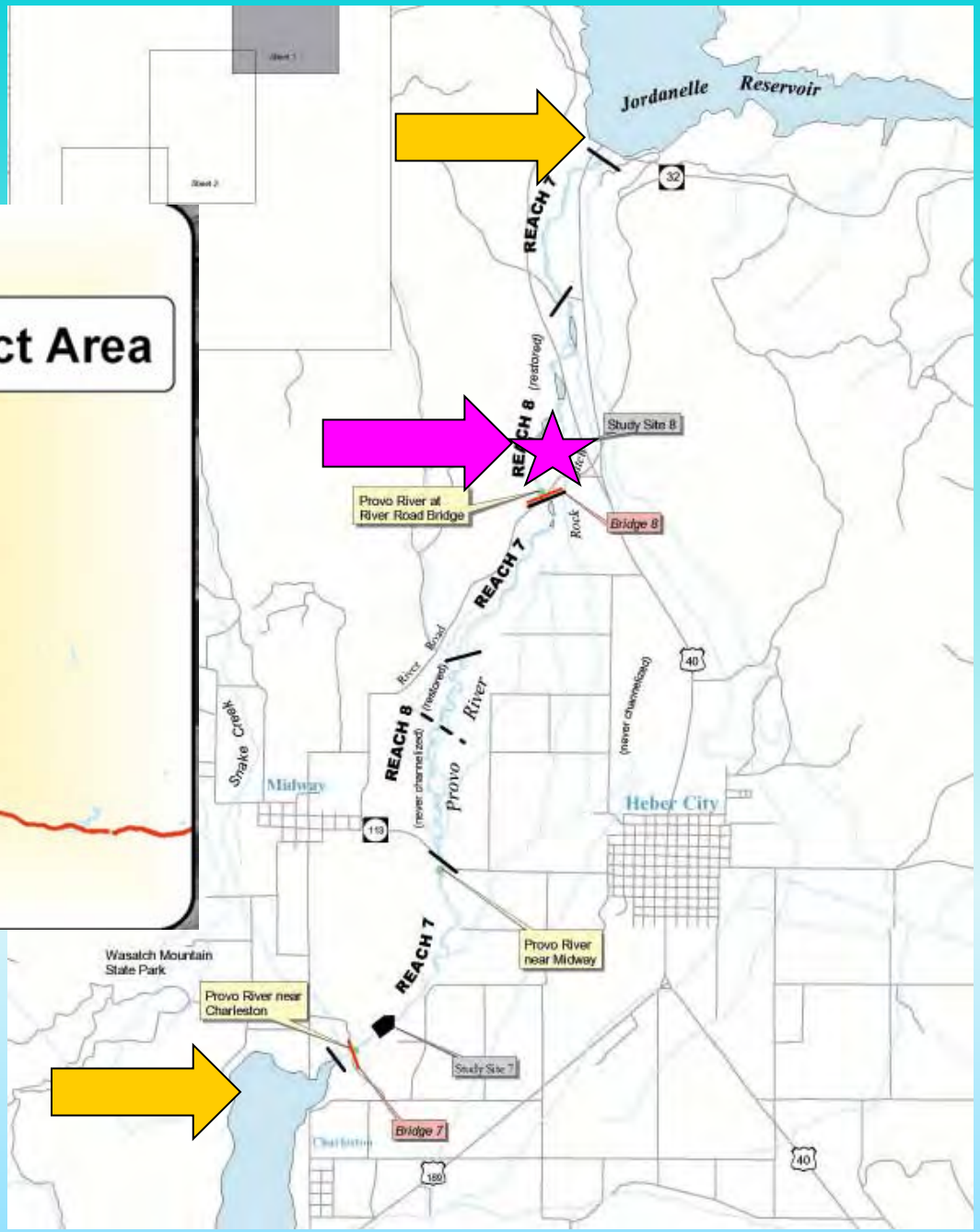
- Assess alternative flow regimes
- Evaluate effects of restoration designs
- Develop flow recommendations to maximize riparian recruitment in restored reaches

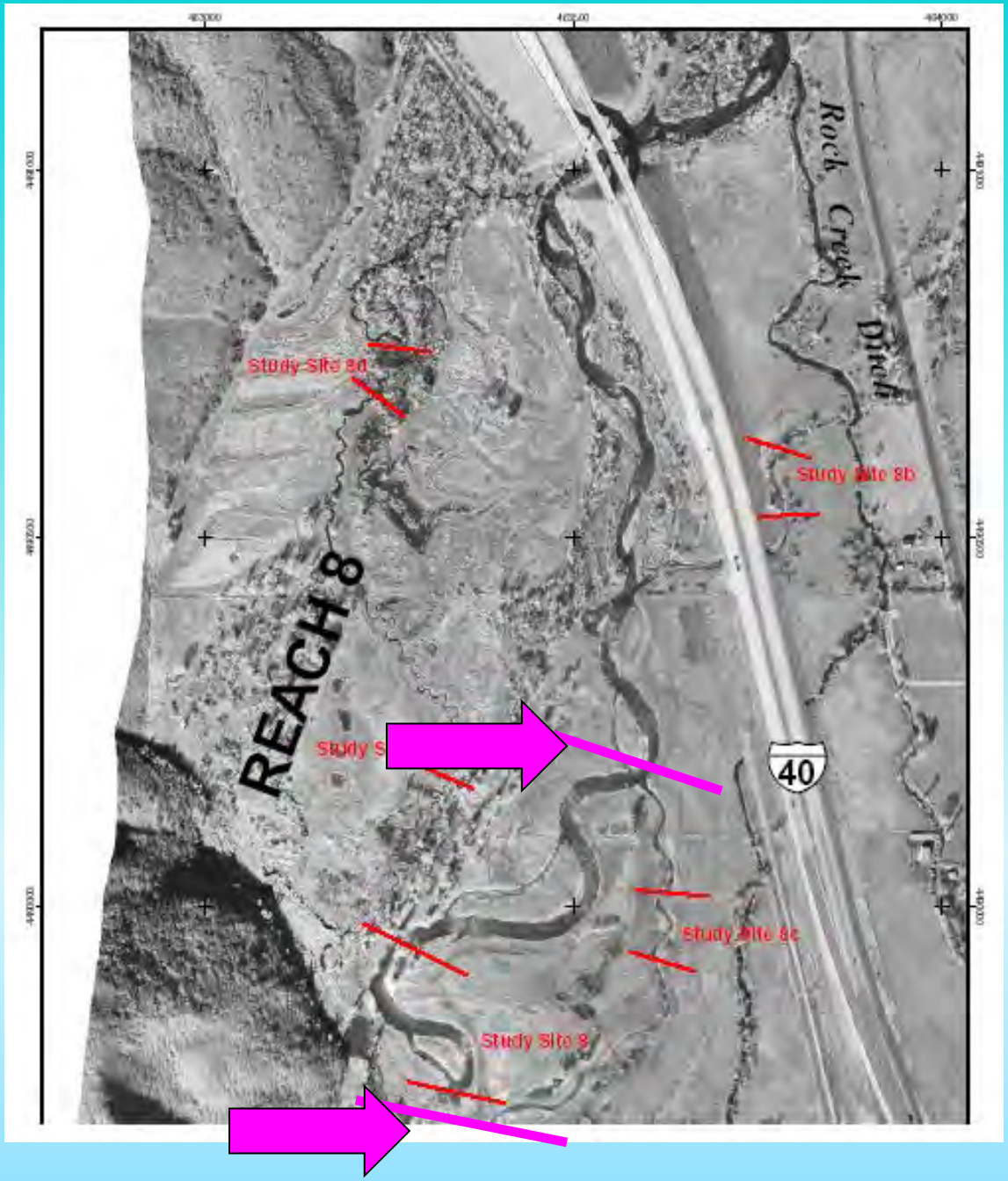
"All models are wrong, but some are useful"

- George Box, Statistician, 1978

Study Area

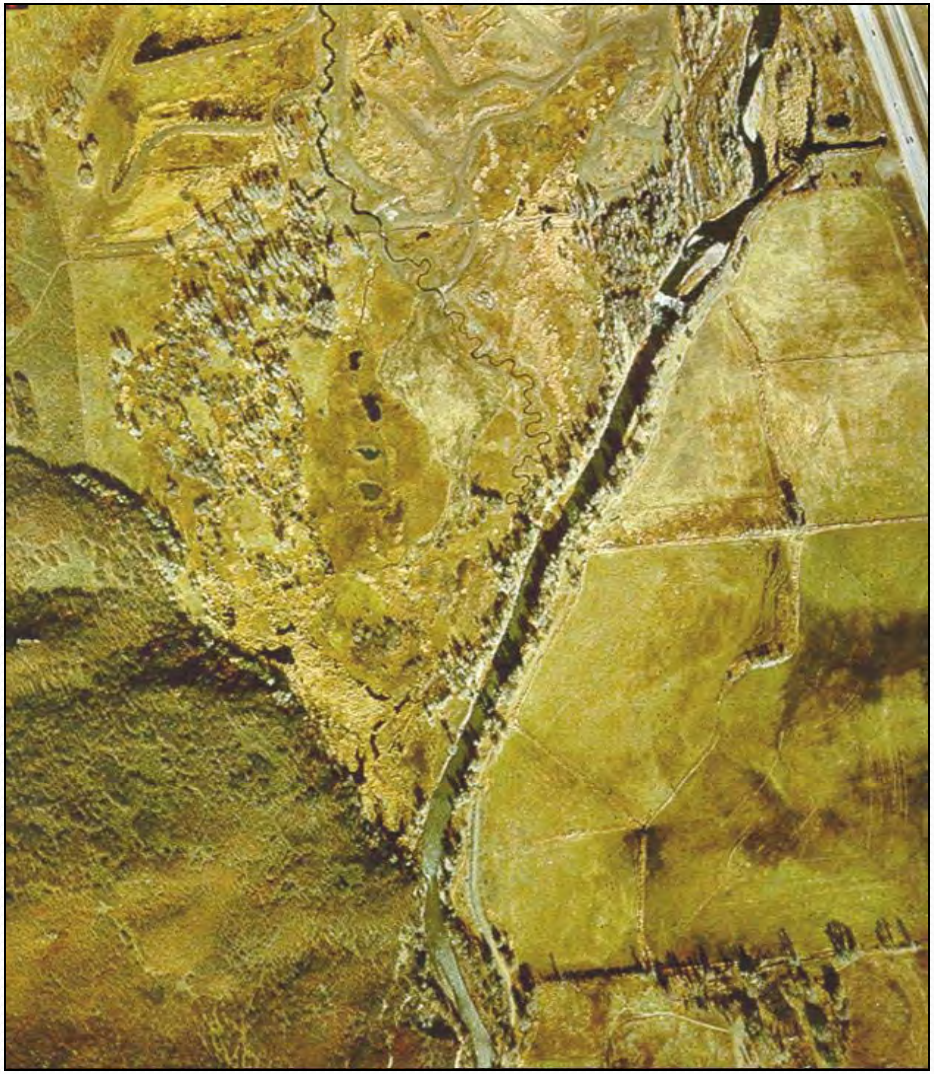
15
Project Area
Salt Lake City
Heber City
40
Provo
N


Jordanelle Reservoir
32
REACH 7
REACH 8 (restored)
Study Site 8
Provo River at River Road Bridge
Bridge 8
REACH 7
River Road
REACH 8 (restored)
(never channelized)
Provo River
(never channelized)
40
Snake Creek
Midway
Heber City
119
REACH 7
Provo River near Midway
Wasatch Mountain State Park
Provo River near Charleston
Study Site 7
Bridge 7
Charleston
189
40

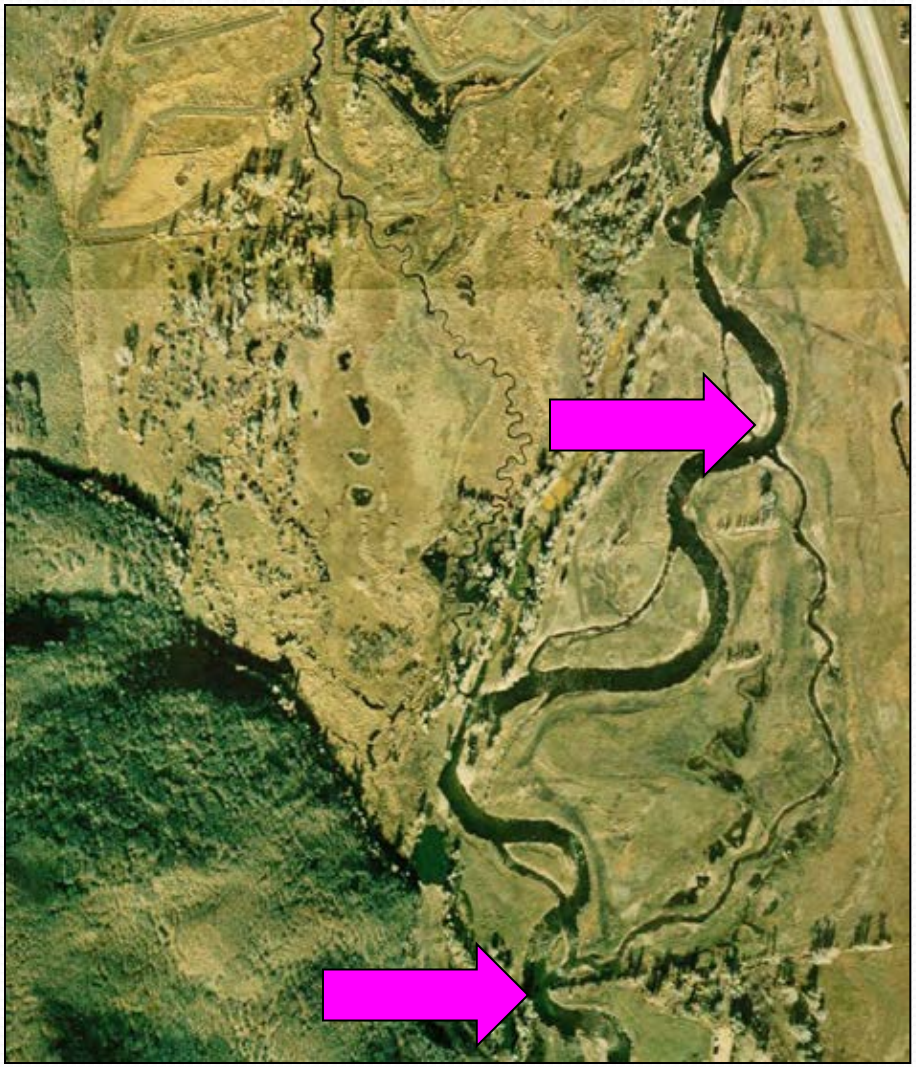


Study Area

- Approx. 3 miles below Jordanelle Dam
- 3000-foot long reach
- Restoration of channel and floodplain completed in fall 2001



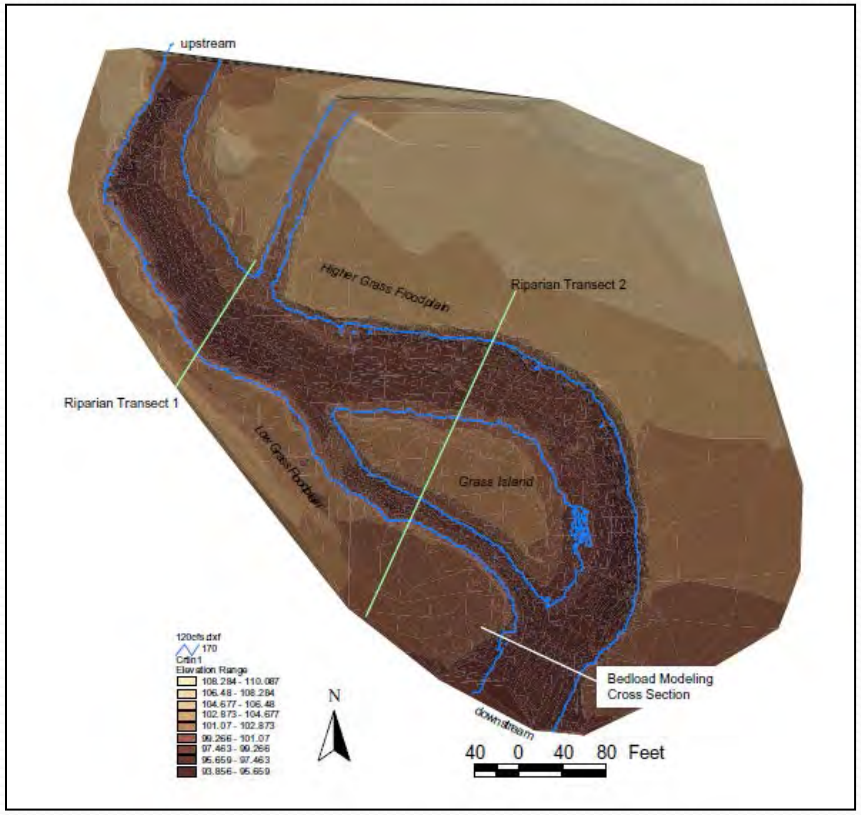
Before



After

Methods

- Digital Terrain Model (DTM)
  - Detailed topographic surveying (total station)
  - 3D orthophoto interpretation (May 2003 photography)
  - Result is topographic "mesh" with 250,000 nodes (1 sq. m each)



Methods

- Hydrodynamics Model
  - Substrate and riparian mapping for roughness parameters
  - Field-surveys of water surface profiles at different discharges to calibrate roughness
  - 2-D hydrodynamics & ground water model (River2D)
    - Water depth (positive value = inundated; negative value = below ground surface)
    - Velocity
  - Outputs for each node in mesh for given flow

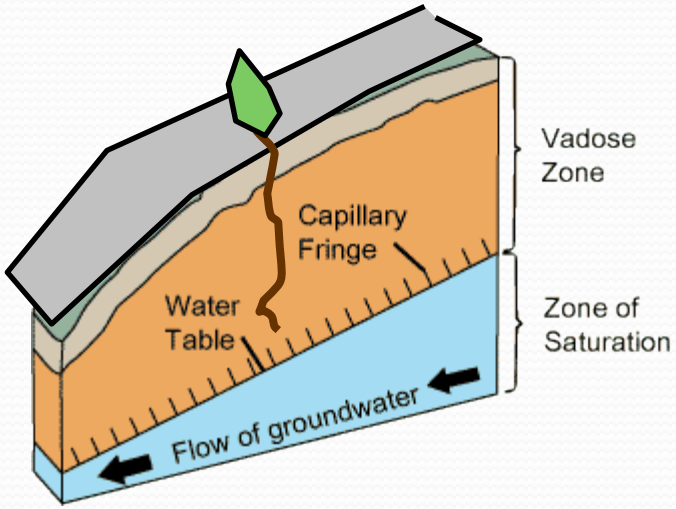
Recruitment Criteria

Recruitment Criteria

- General requirements for seed-based reproduction (Scott et al., 1993)
  - Presence of moist, bare surface with fresh sediment at time of seed dispersal
  - Transport and deposition of seeds onto the surface

Recruitment Criteria

- General requirements for seed-based reproduction (Scott et al., 1993)
  - Post-germination decline in water levels at a rate slow enough that seedlings do not desiccate
  - Absence of post-germination floods that would scour seedlings



Requirements for Seed-Based Reproduction

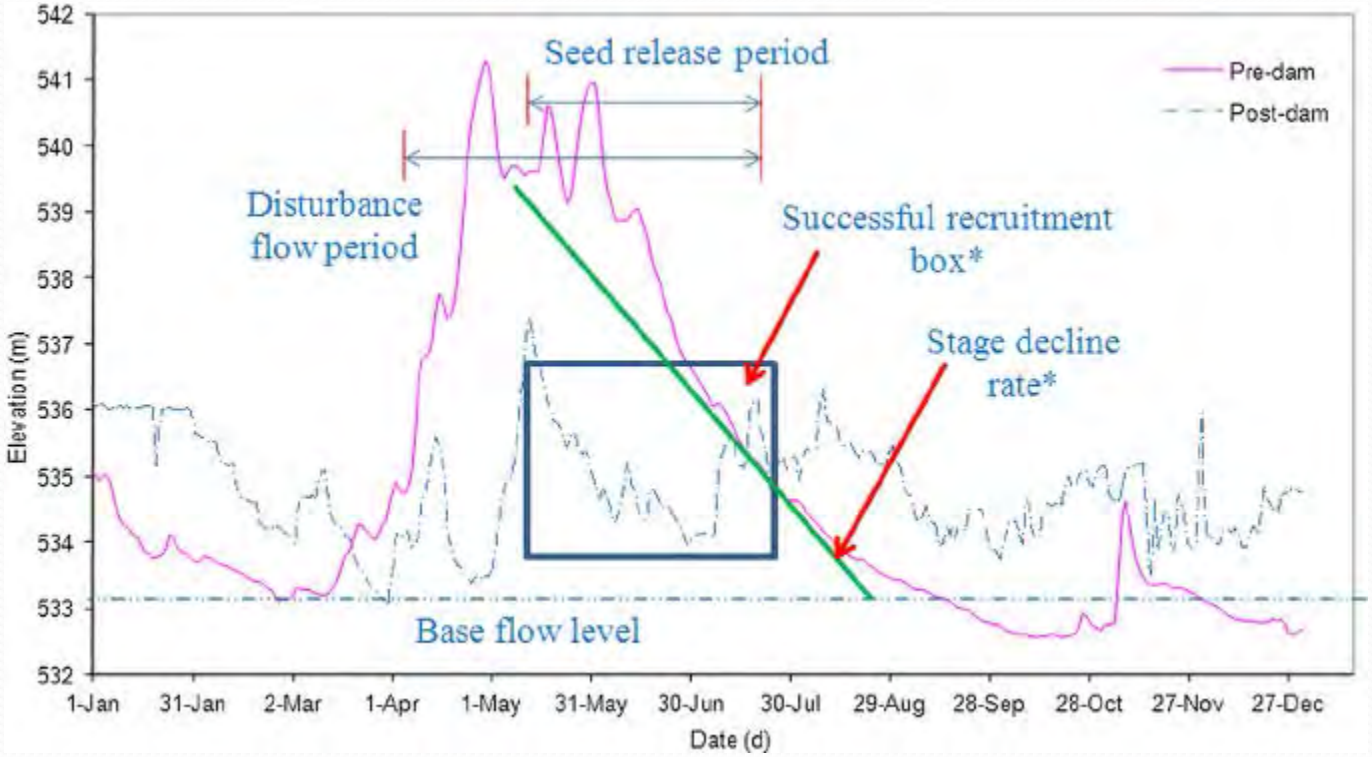


Figure from Bejankar et al., 2014; recruitment box concept based on Mahoney and Rood 1998

Recruitment Model Criteria

- Node must be wetted and then exposed within seed dispersal window
  - May 30 to July 19
- Within 10 days of being wetted, soil surface at node remains moist and viable for germination
  - Groundwater level has not dropped below capillary fringe (20 cm)

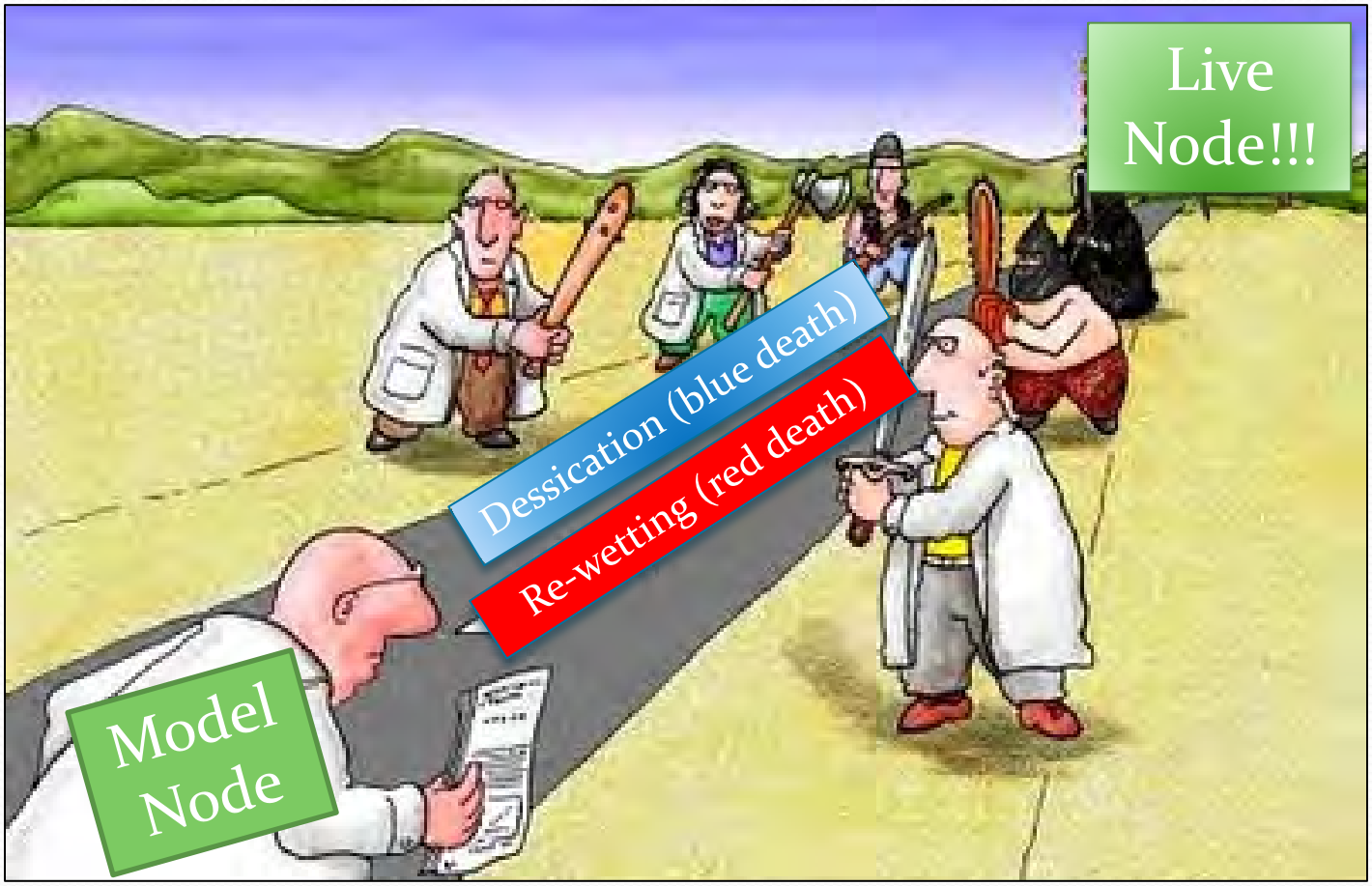
Recruitment Model Criteria

- Recession rate not greater than 2.5 cm (1 inch) per day (5-day moving avg)
- Final groundwater elevation at end of run (July 31) not more than 1 meter below ground surface
- Node is not re-wetted after seed dispersal window

Model Input/Output

- Input is May 1- July 31 hydrograph (92 daily flows)
- For each node, model tracks recruitment success
  - node becomes "**live**" if meets initial criteria
  - node "dies" if all criteria are not met (**recession rate**, etc.)
  - node "**resets**" if re-inundated during seeding window
- Final output is total number of "live" nodes at end of model run
- Also can output video (*.avi file)

Model Input/Output



Model is like running the gauntlet…

Model Verification

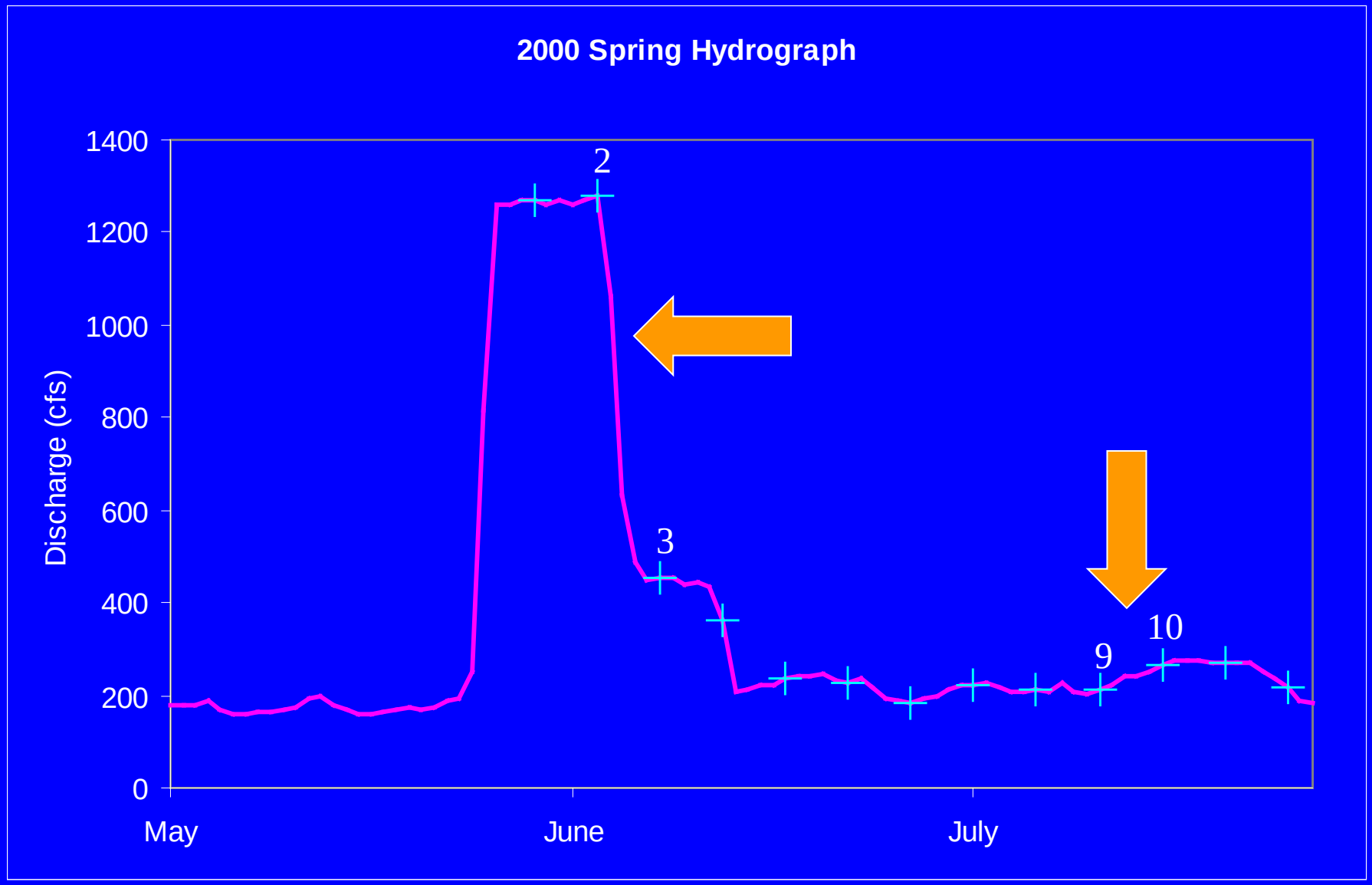
- Field-mapped inundated areas during June, 2003 flood (1,400 cfs)
- Field visit in August 2003 to identify areas with live seedlings
- Adjusted model parameters (capillary fringe, recession rate, etc.) to match observations

Disclaimers

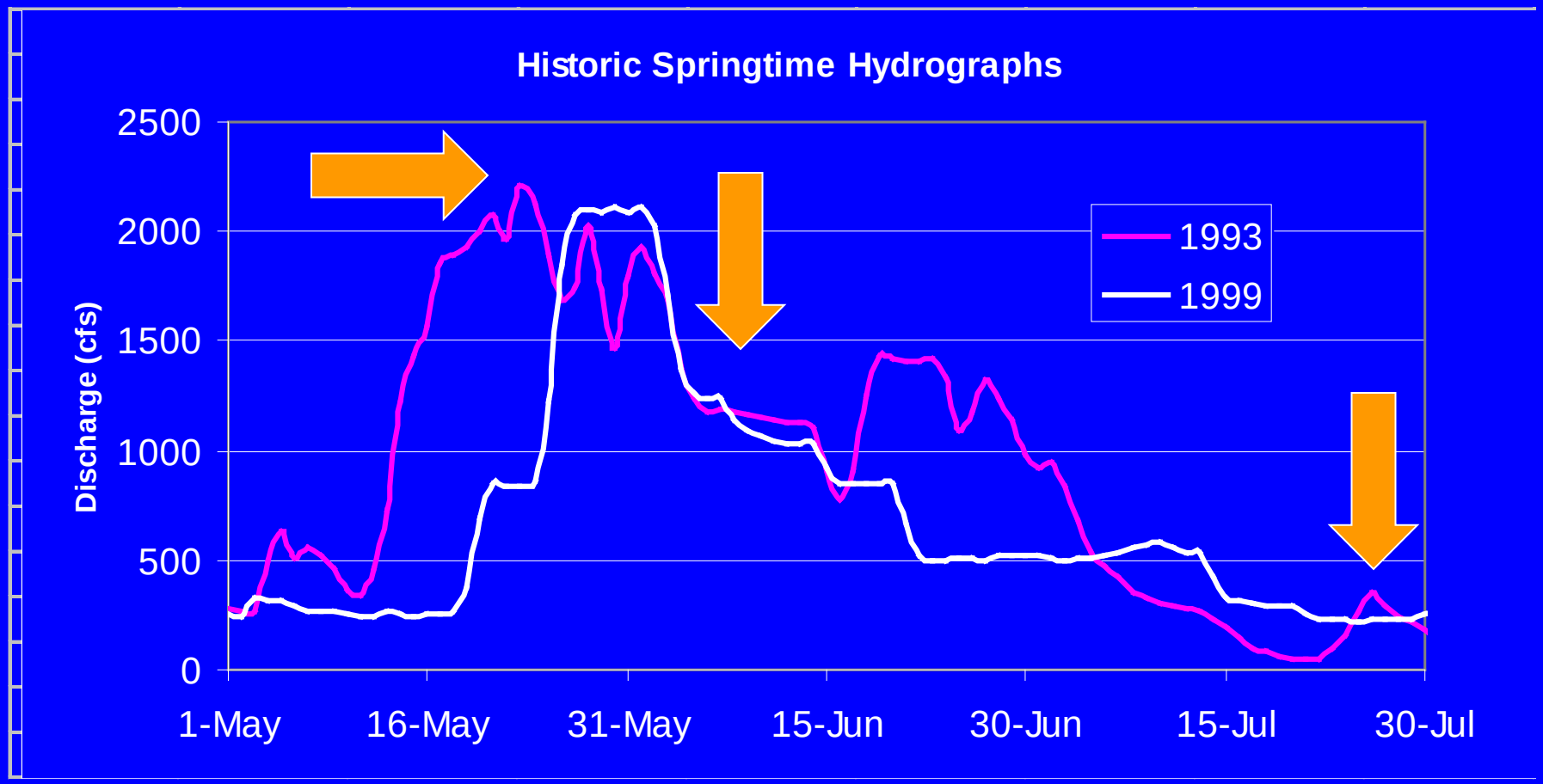
- Model only relevant for seed-based reproduction
  - Cottonwoods also reproduce vegetatively
- Model only runs for one growing season
  - Nodes that are “live” could be scoured by next year’s flood
- Model does not account for all criteria
  - Antecedent moisture conditions
  - Alternative water sources (rainfall, groundwater seeps)
  - Variability in soil types
  - Variability in seed supply
  - Existing plant cover
- Model is a tool only

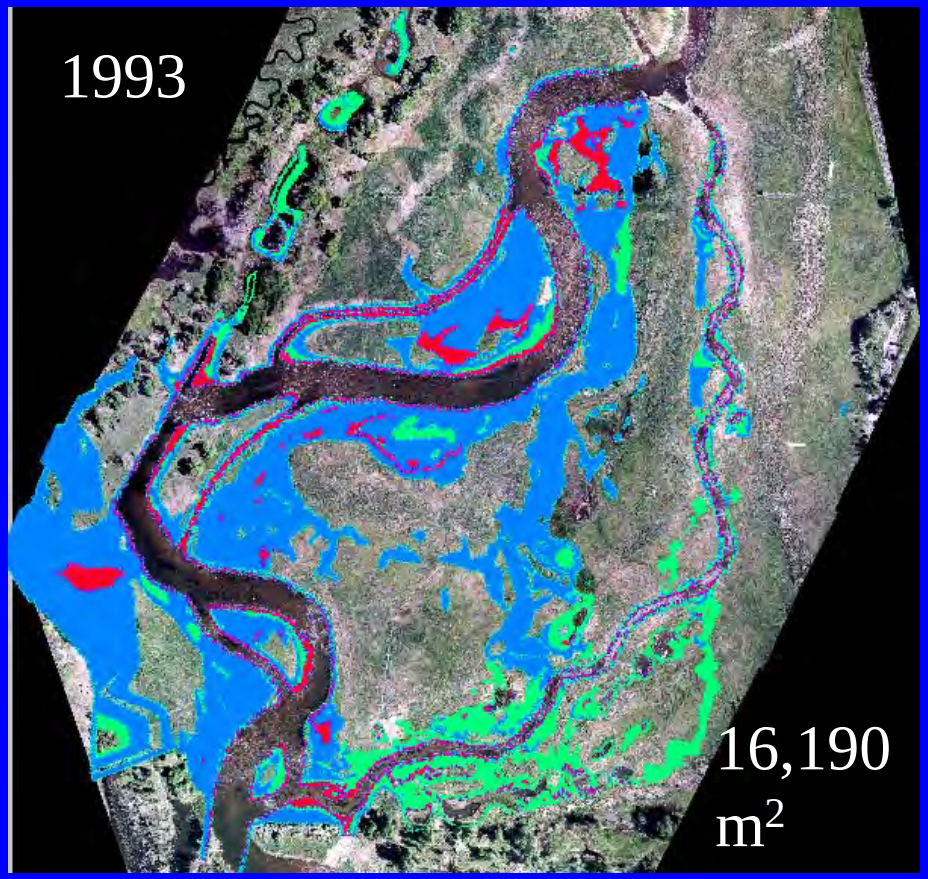
Disclaimers cont'd

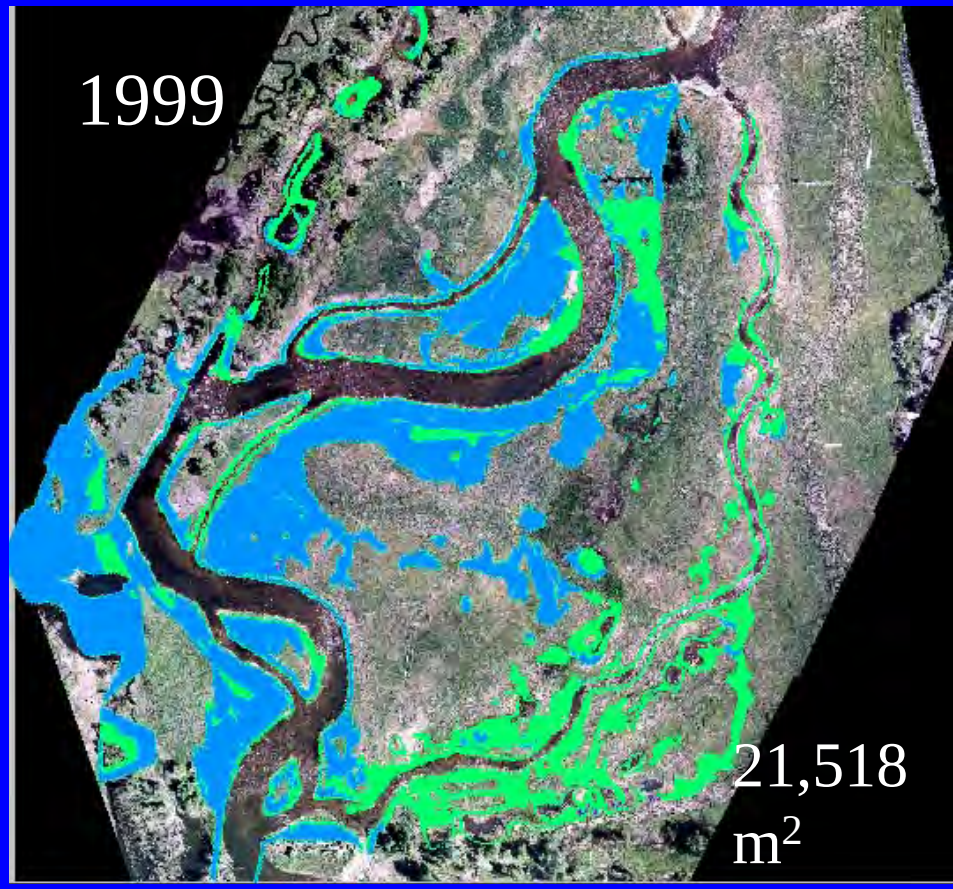
- Modeled only 3,000 feet out of ~12 miles
- Restoration design and construction included a lot of reach-to-reach variability
  - Overbank flooding occurs at various flow levels
  - Channel slope differs from reach to reach; therefore channel dimensions vary also
  - "Less than ideal" water delivery for cottonwood recruitment in this Reach may be more "ideal" in another Reach
- **Repeat:** model is a tool only


2000 Spring Hydrograph
Discharge (cfs)
1400
1200
1000
800
600
400
200
0
May
June
July
2
3
9
10

2000
4.00
3.69
3.38
3.07
2.76
2.45
2.14
1.83
1.52
1.21
0.90

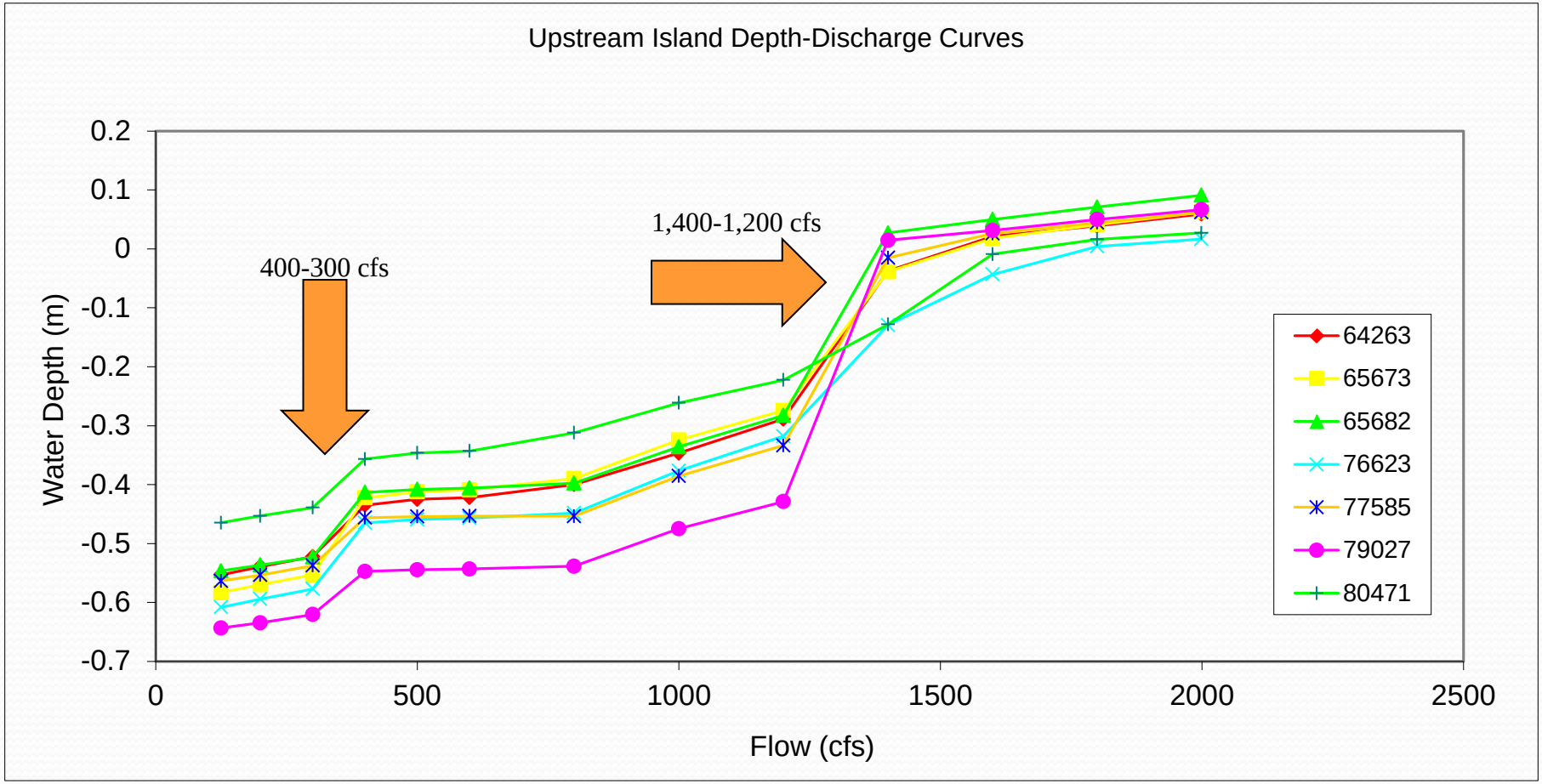

Historic Springtime Hydrographs
Discharge (cfs)
2500
2000
1500
1000
500
0
1-May
16-May
31-May
15-Jun
30-Jun
15-Jul
30-Jul
1993
1999





- peak flow = 2,210 cfs (1,930 cfs)
- peaks before seeding window
- August re-wetting (red death)
- total AF =237,818

- peak flow = 2,110 cfs
- faster receding limb rate
- higher baseflow
- total AF =248,747
- 25% more recruitment with 4% more water

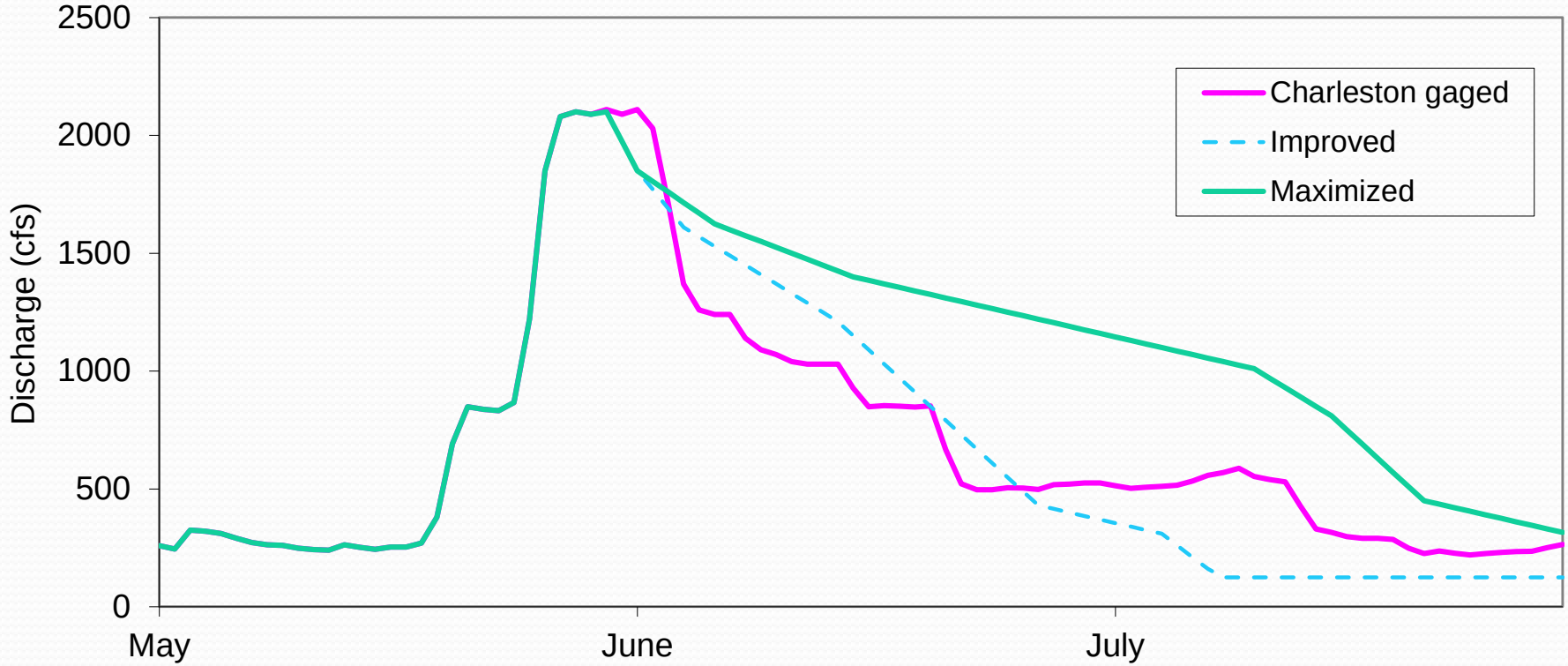


Lines aren't smooth. Two flow ranges have steep drops.

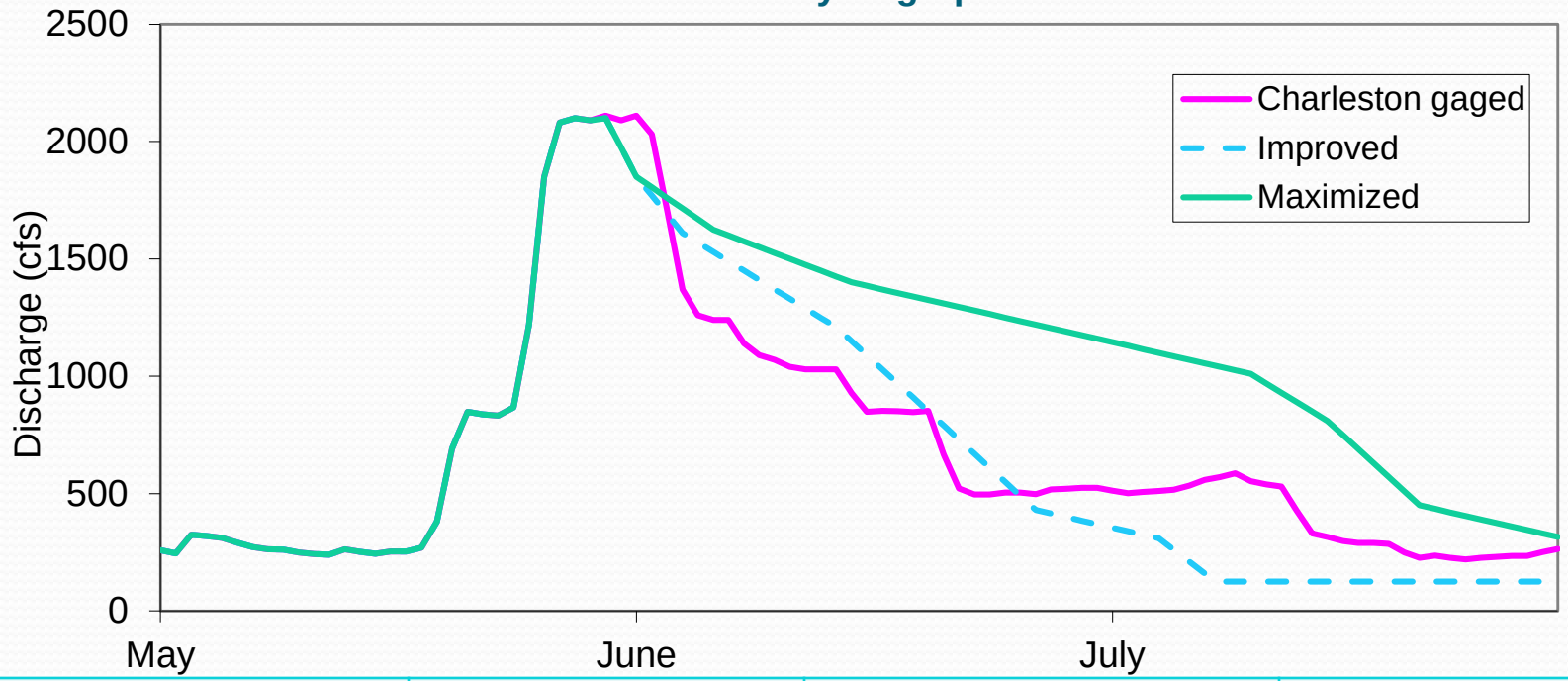
Recommended Rates of Decline for Successful Riparian Recruitment

- 125 cfs/day between 2300 and 1800
- 45-80 cfs/day between 1800 and 1600
- 25-40 cfs/day between 1600 and 1400
- 15-40 cfs/day between 1400 and 1200
- 15-60 cfs/day between 1200 and 1000
- 40-60 cfs/day between 1000 and 800
- 60 cfs/day between 800 and 400
- 15 cfs/day between 400 and 300
- 50 cfs/day between 300 and 125

Cottonwood Recruitment Flow Recommendations
1999 Hydrographs



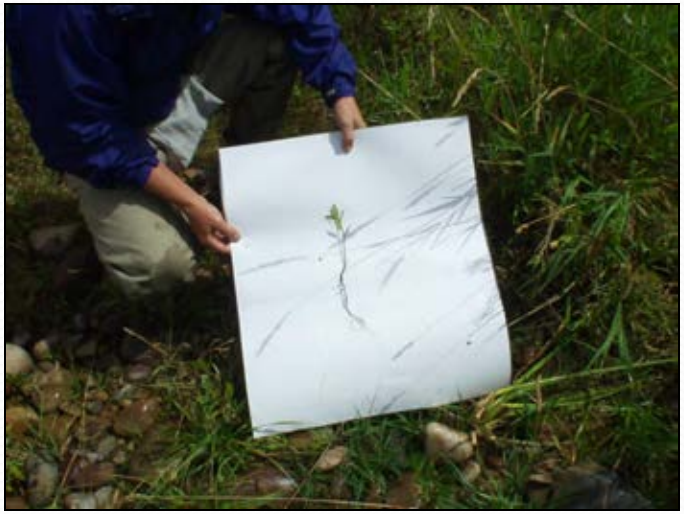
Cottonwood Recruitment Flow Recommendations
1999 Hydrographs



1999 Hydrograph	Charleston Gaged	"Improved Flows"	"Maximized Flows"
Annual ac-ft	248,747	242,336 (-3%)	299,837 (+21%)
May 1 - July 31 ac-ft	125,780	119,369	176,870
Recruitment Success	21,518 m^2	26,495 m^2 (+23%)	26,628 m^2 (+24%)

How Often is Recruitment Possible?

- Recruitment requires about 220,000 to 235,000 AF annually
- Over the modeled 50-year POR, 220,000 AF is delivered to Deer Creek from Jordanelle in 12 years (about 1 in 4 years); 235,000 AF occurred 7 years (about 1 in 7 years)
- Natural recruitment frequency about 1 in 7 years



Is Model Useful?

- Provides quantitative starting point for coordination with reservoir operators
- Not all flow ranges/recruitment surfaces are created equal
  - Slower ramp-down rates only needed for certain ranges
- Increased cottonwood recruitment success does not necessarily mean more water

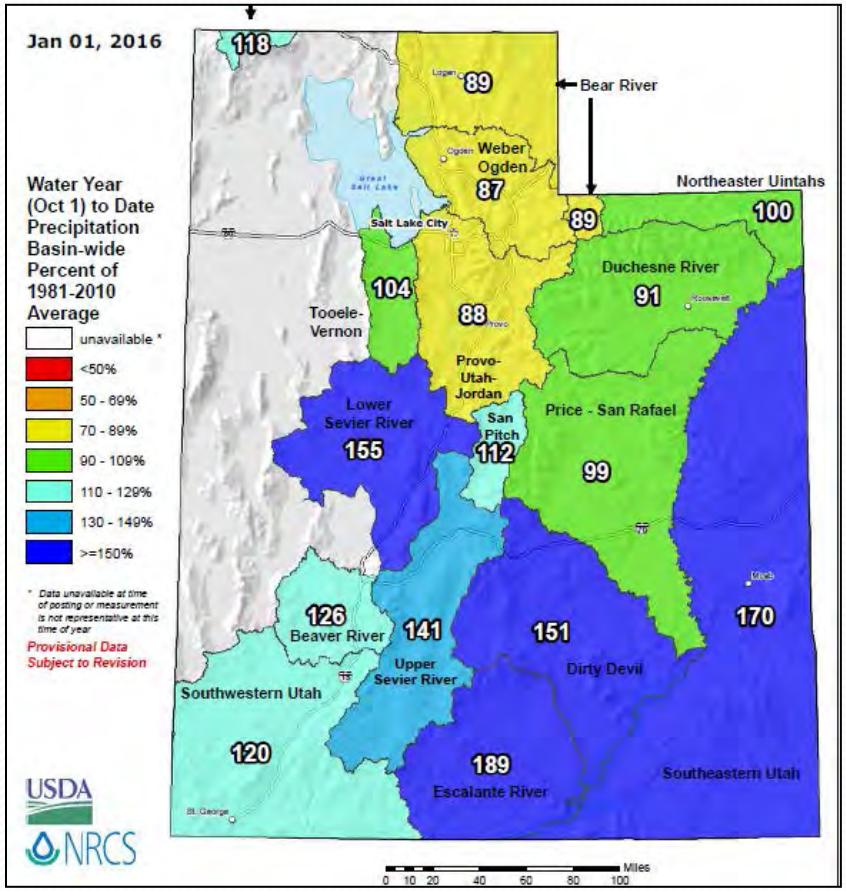
"All models are wrong, but some are useful"

- George Box, Statistician, 1978

Daryl Devey

Implementation

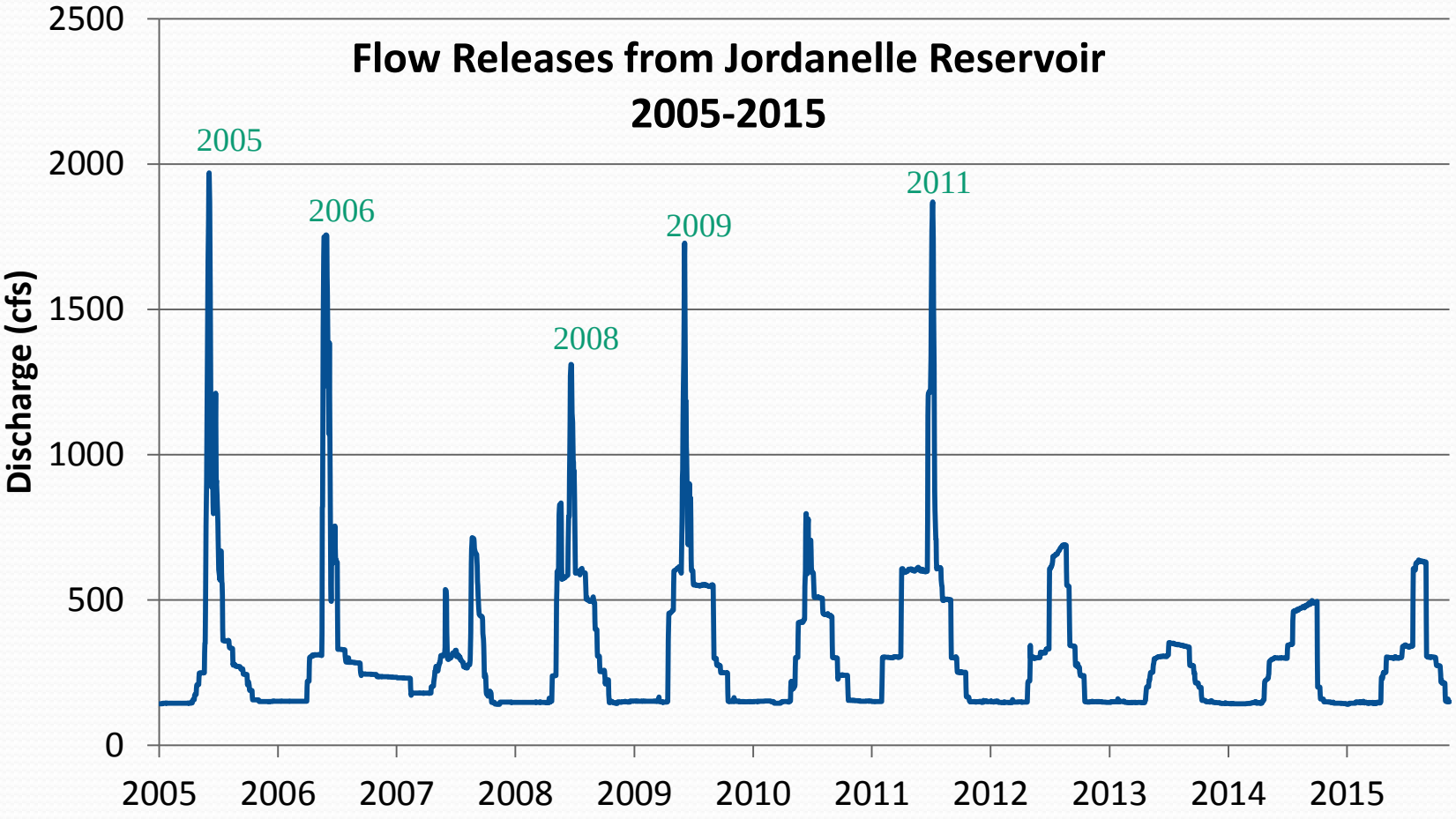
- How are these flow recommendations implemented?
  - Flow workgroup meets each spring to assess snowpack levels, flow predictions
  - Main focus of workgroup is lower Provo River, where there is an endangered species

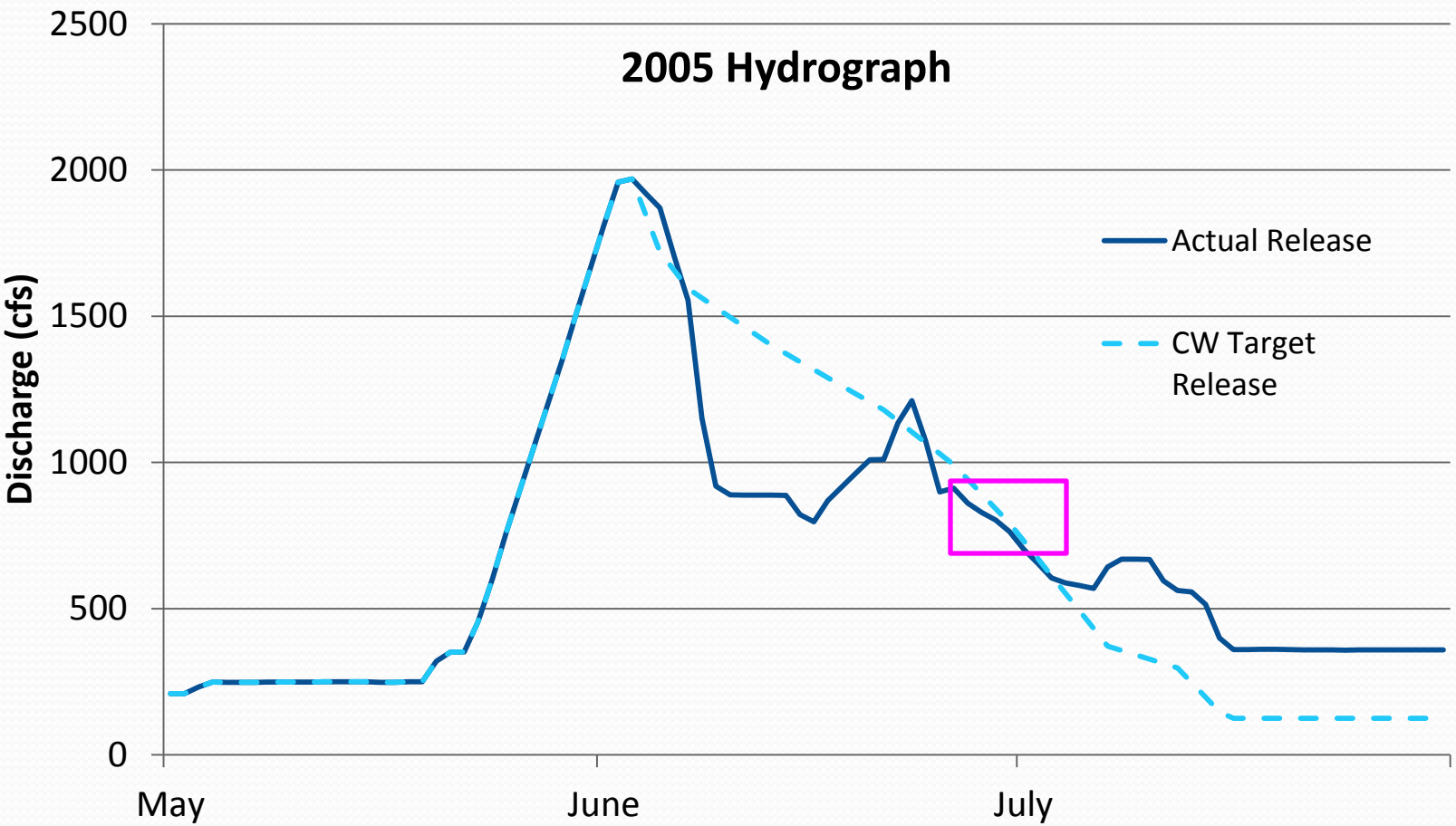


Implementation

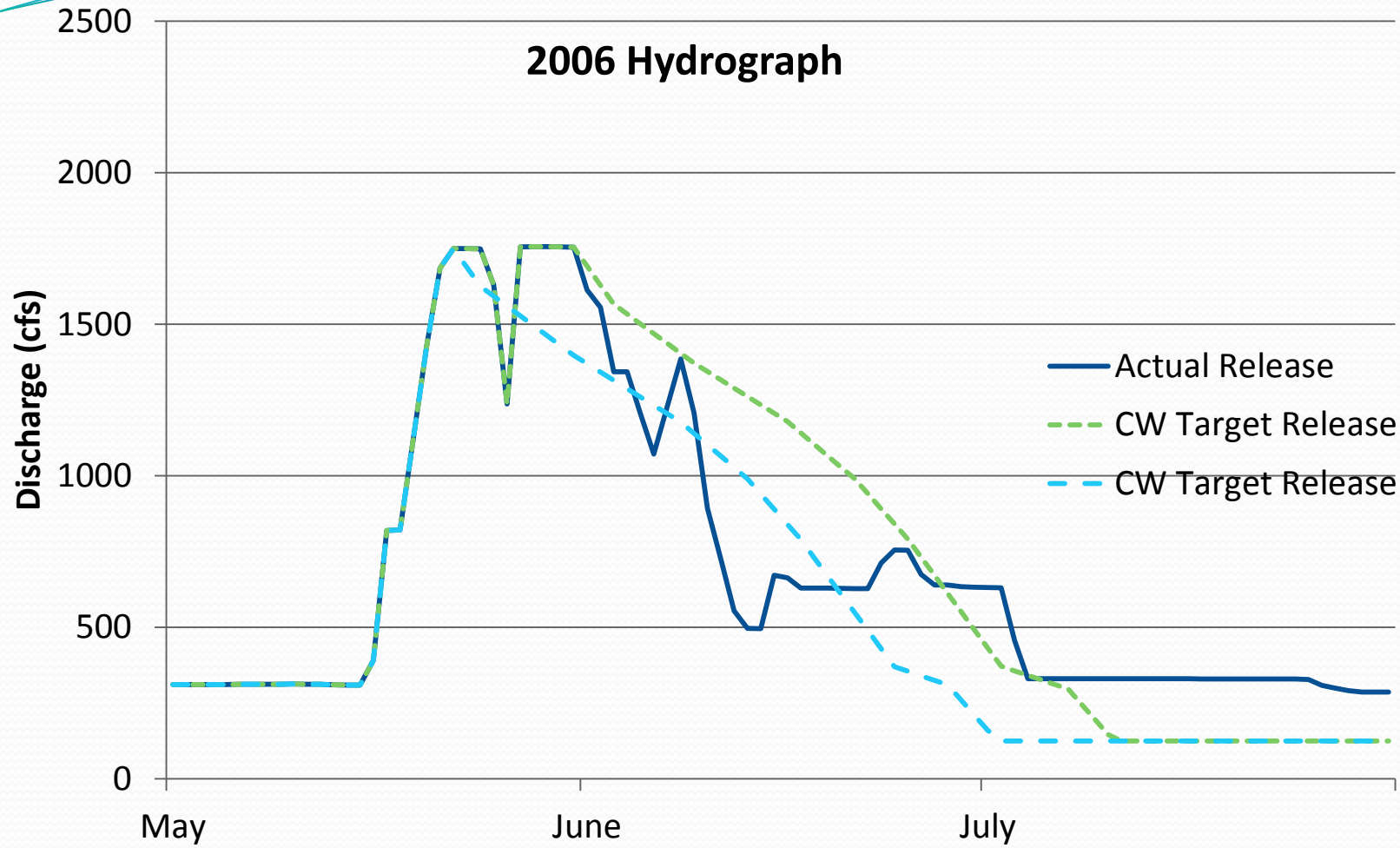
- Factors considered when planning springtime reservoir releases:
  - Snowpack, and runoff forecasts
  - Downstream water demand
  - Flooding risk
  - June sucker needs
  - Cottonwood recruitment
  - Downstream reservoir levels
  - Upstream reservoir levels
  - Institutional agreements/water rights

Eleven-Year Update

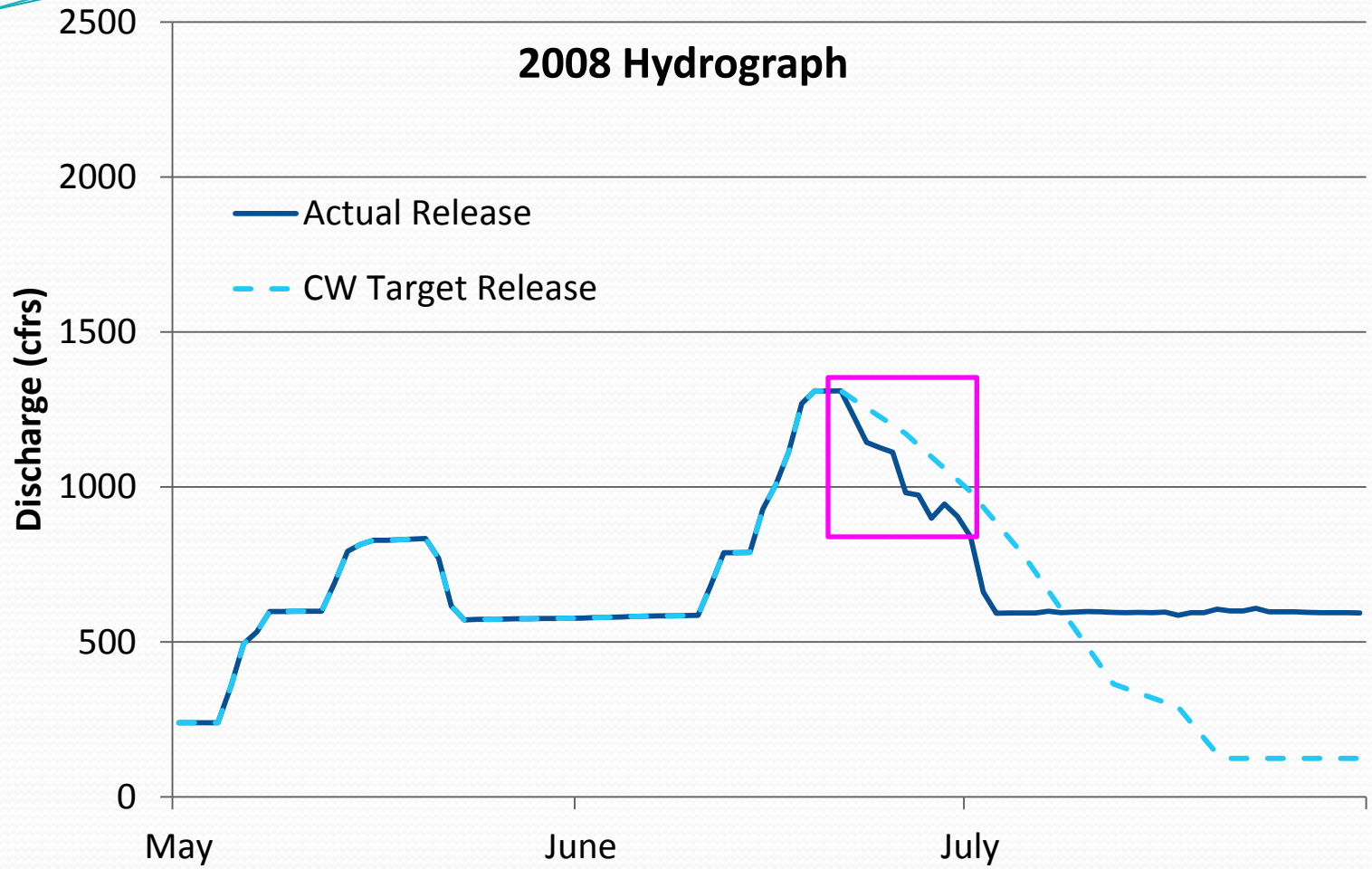




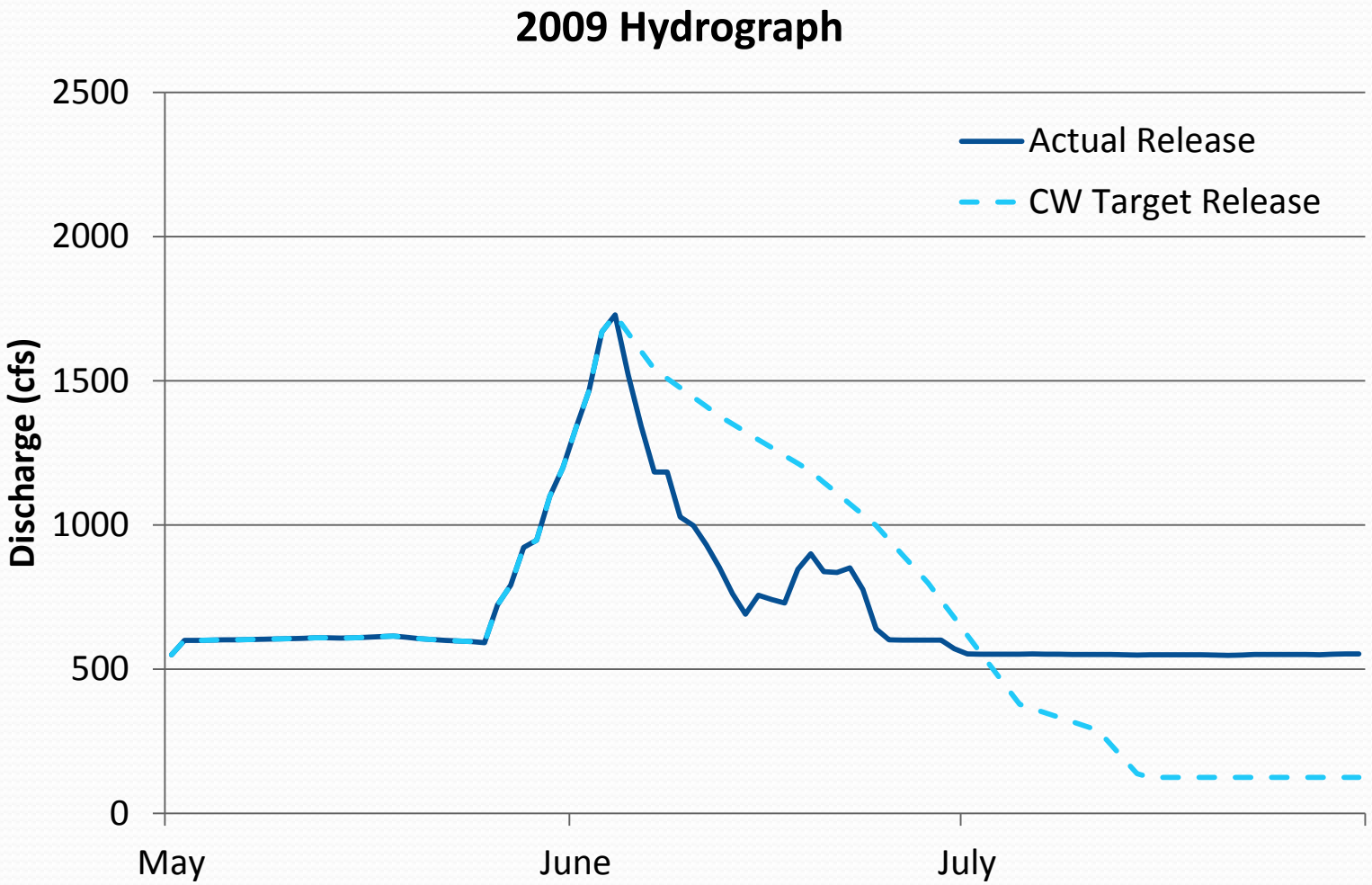
One small “recruitment box” in 2005…



Recession rates generally too rapid in 2006



- Almost matched target release
- Flows stayed high (600 cfs) throughout July



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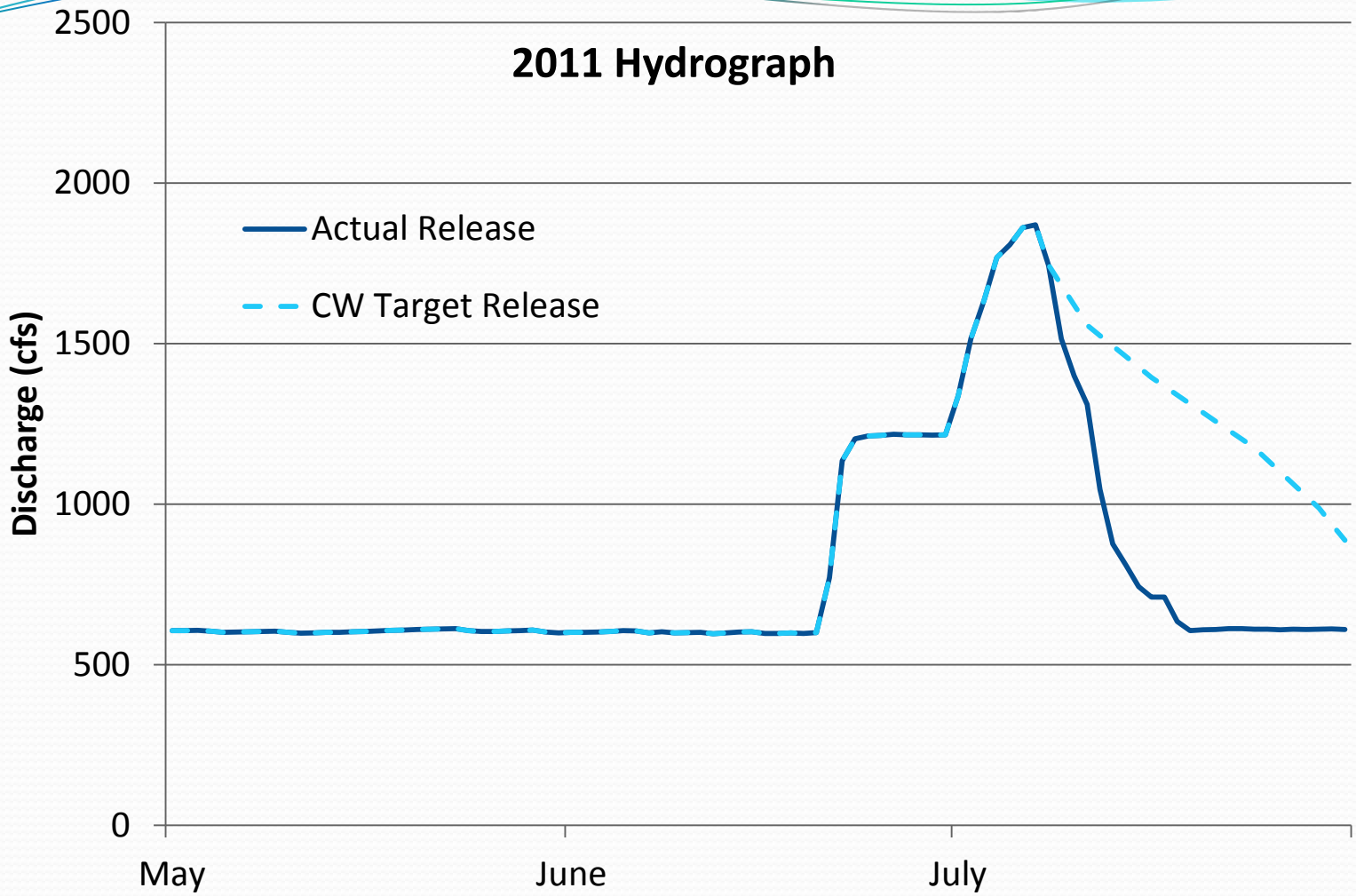


- Late peak
- Recession rate too rapid

Eleven-Year Summary

- Since 2004, only two years (2005/2008) had much recruitment potential (based on model)
  - Recession rates are typically too rapid
- Reasons cottonwood target releases couldn't be met included:
  - No space to recover water downstream
  - Low customer demands
  - Too much "CUP water" downstream
  - Utah Lake above compromise
  - Late summer water quality issues at WTPs
  - ?
  - ?

Eleven-Year Summary – cont'd

- **HOWEVER**, PRRP saw substantial recruitment of native vegetation, especially willows, throughout that time period
- *Remember our model disclaimers…*

"All models are wrong, but some are useful"

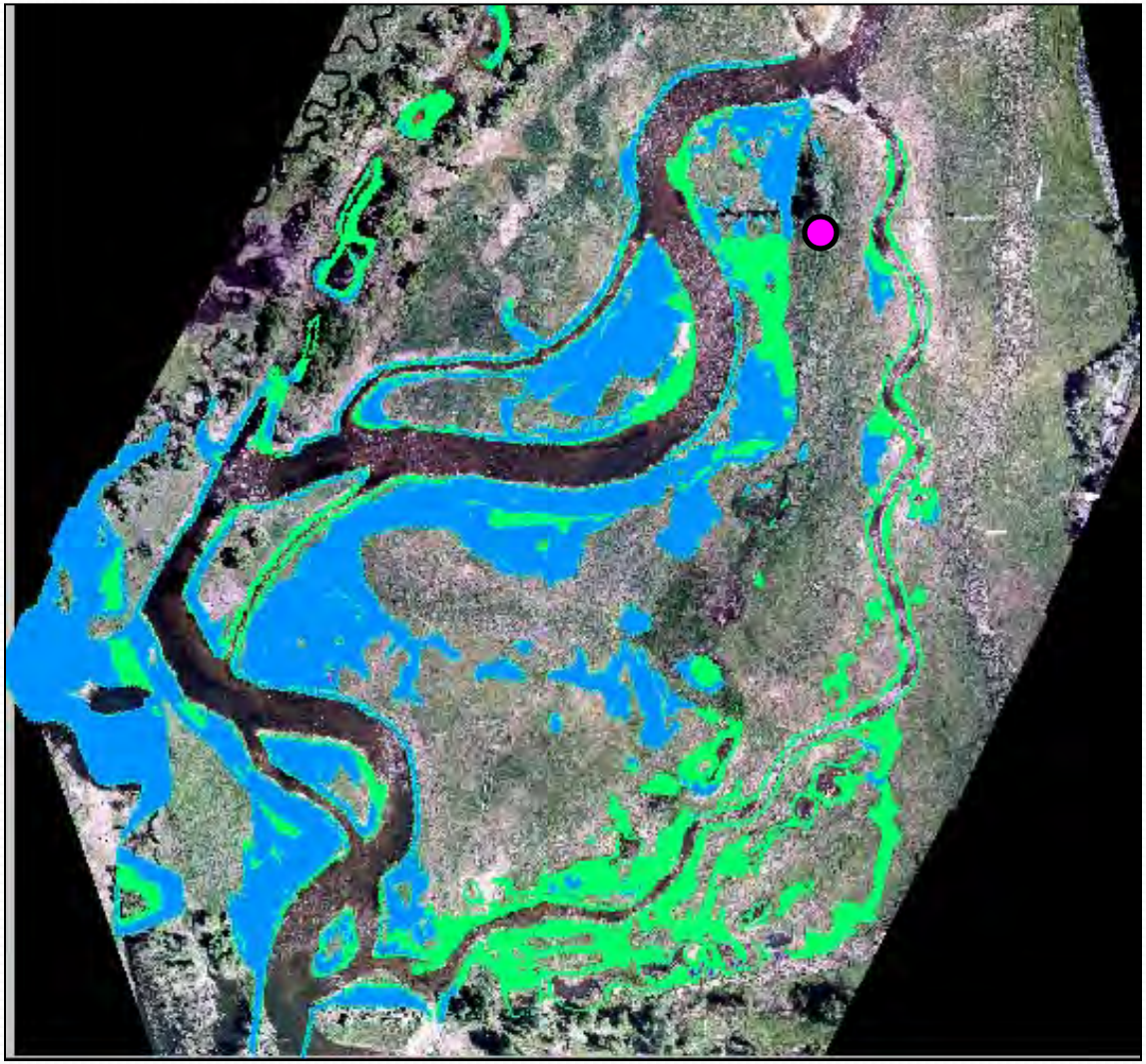
- George Box, Statistician, 1978

Real-world Recruitment Success

- No comprehensive mapping of cottonwood locations, age classes has been completed
- Photo point monitoring provides some information

Real-world results

- Photo Sequences
  - Old ditch/low point in restored floodplain (photo point in pink)



August 2001

August 2002

August 2005

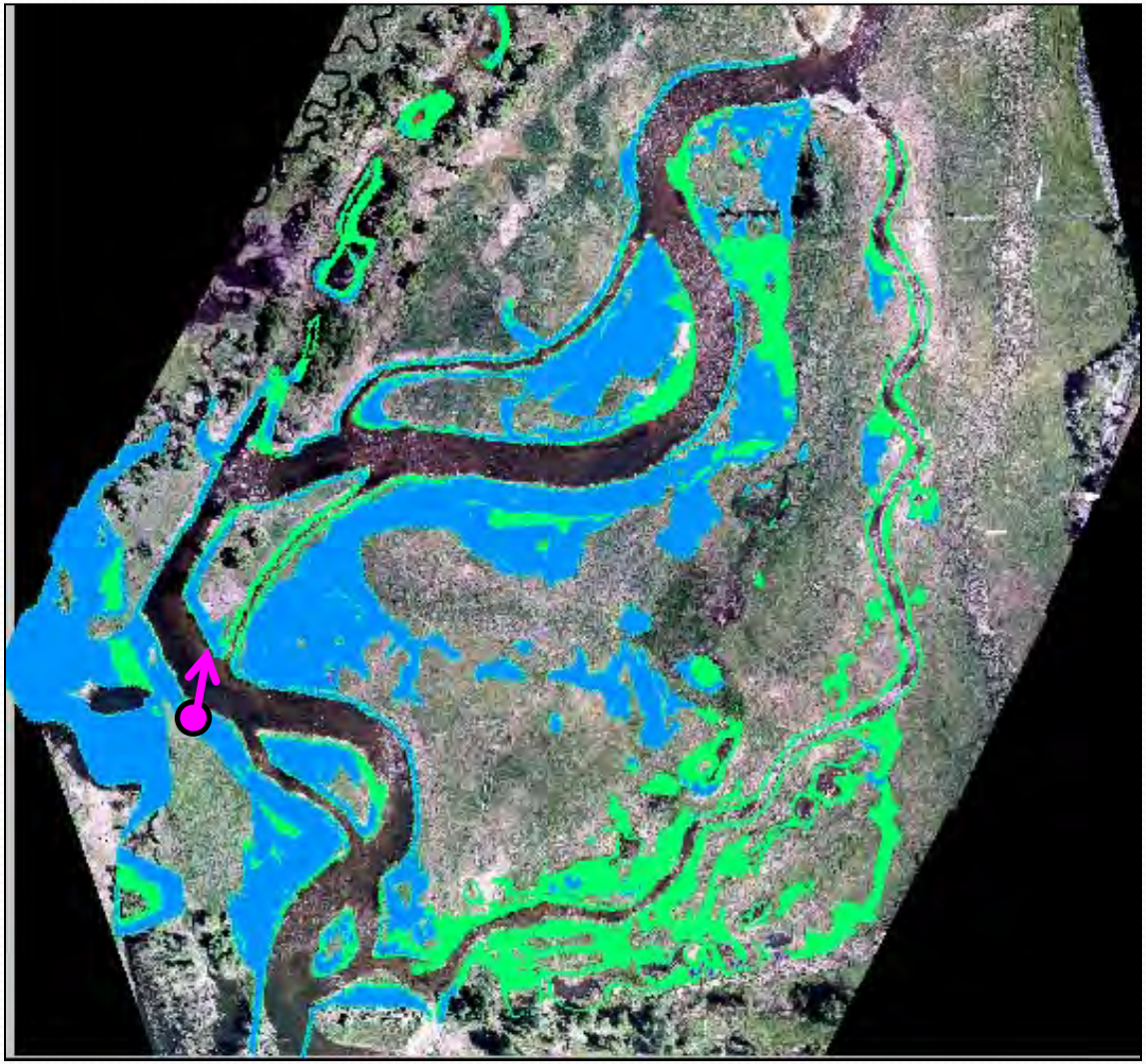
July 2010

August 2015

- Success in this area may be partly a function of groundwater

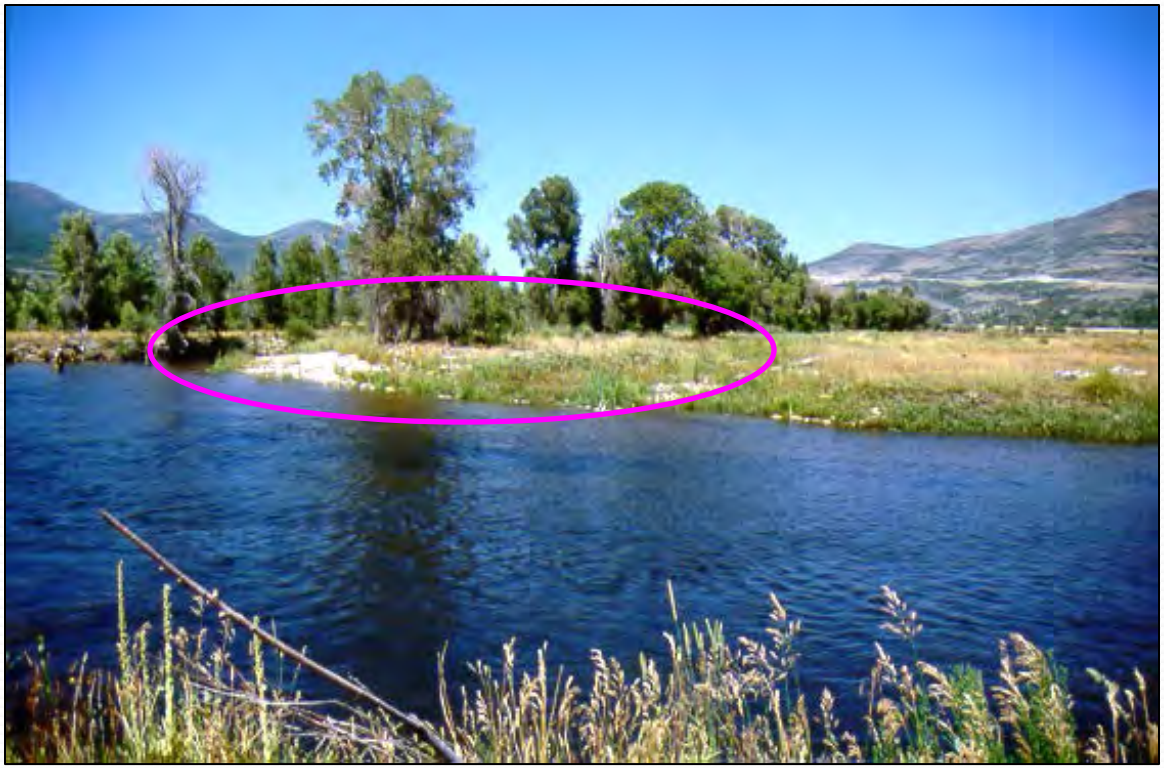
Real-world results

- Photo Sequences
  - Side channel

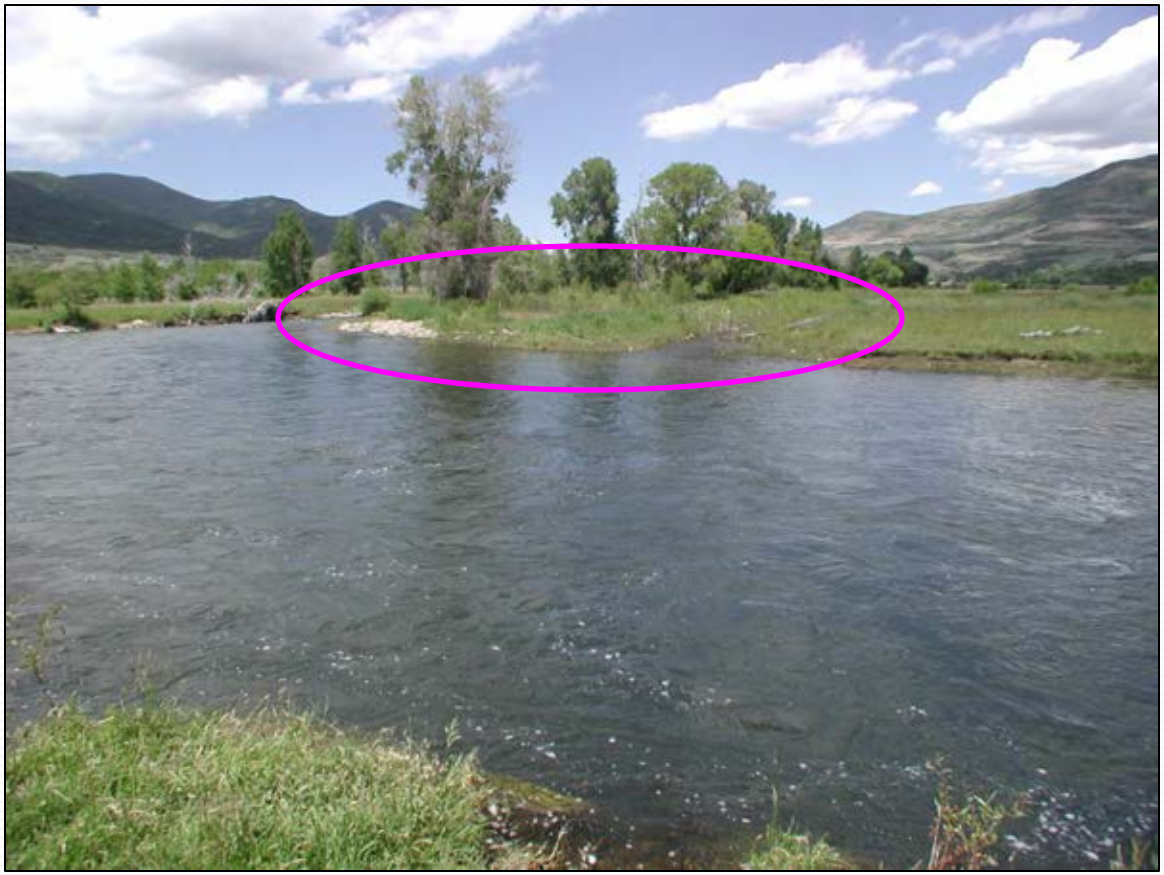


April 2001

August 2002



June 2005

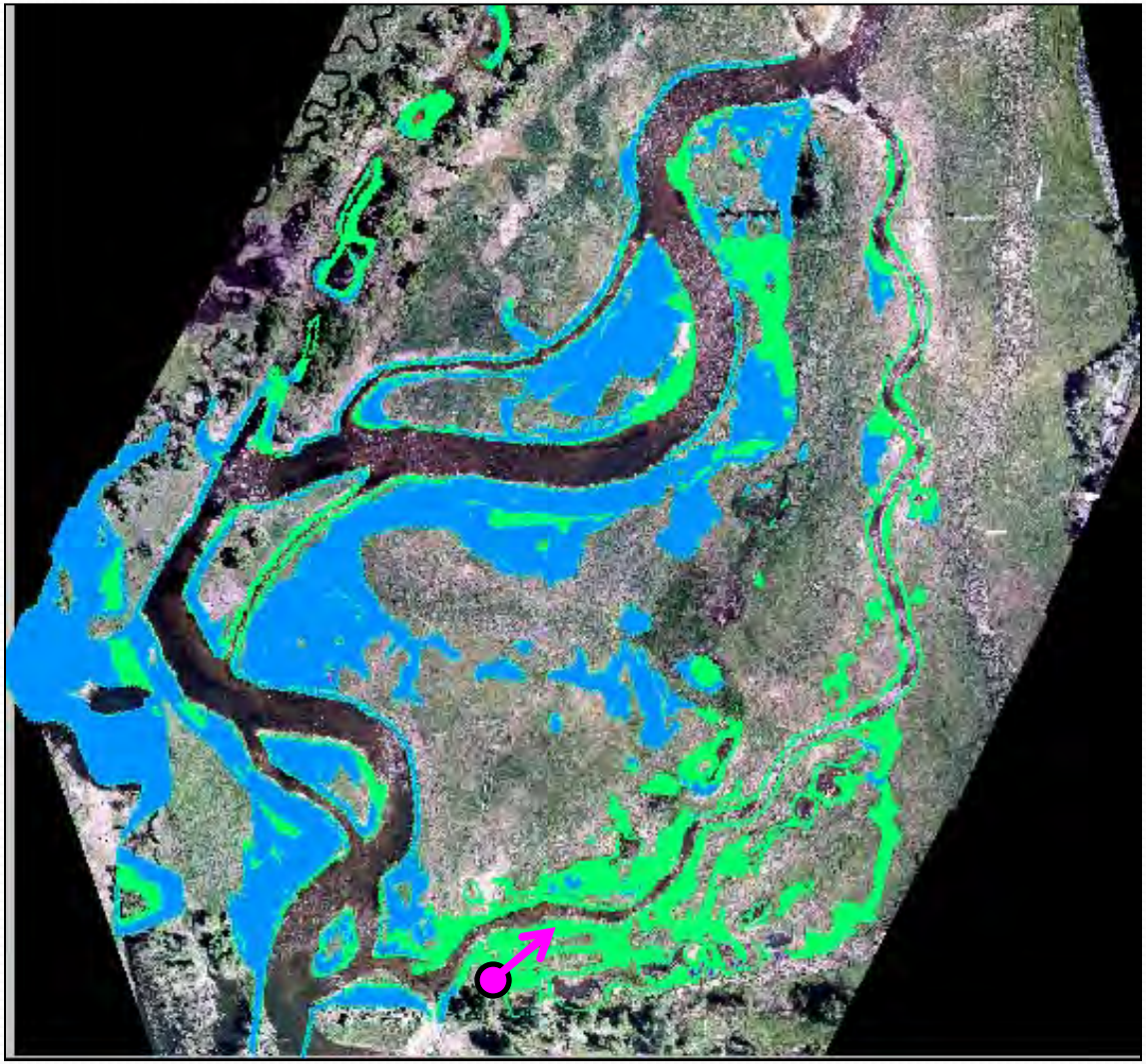


August 2010

August 2015

Real-world results

- Photo Sequences
  - Larger side channel
  - Area with high recruitment potential according to modeling work



April 2001

August 2001

August 2002

May 2004

August 2005

June 2007

July 2010

August 2015

Beaver Influence Elsewhere on PRRP

September 2000

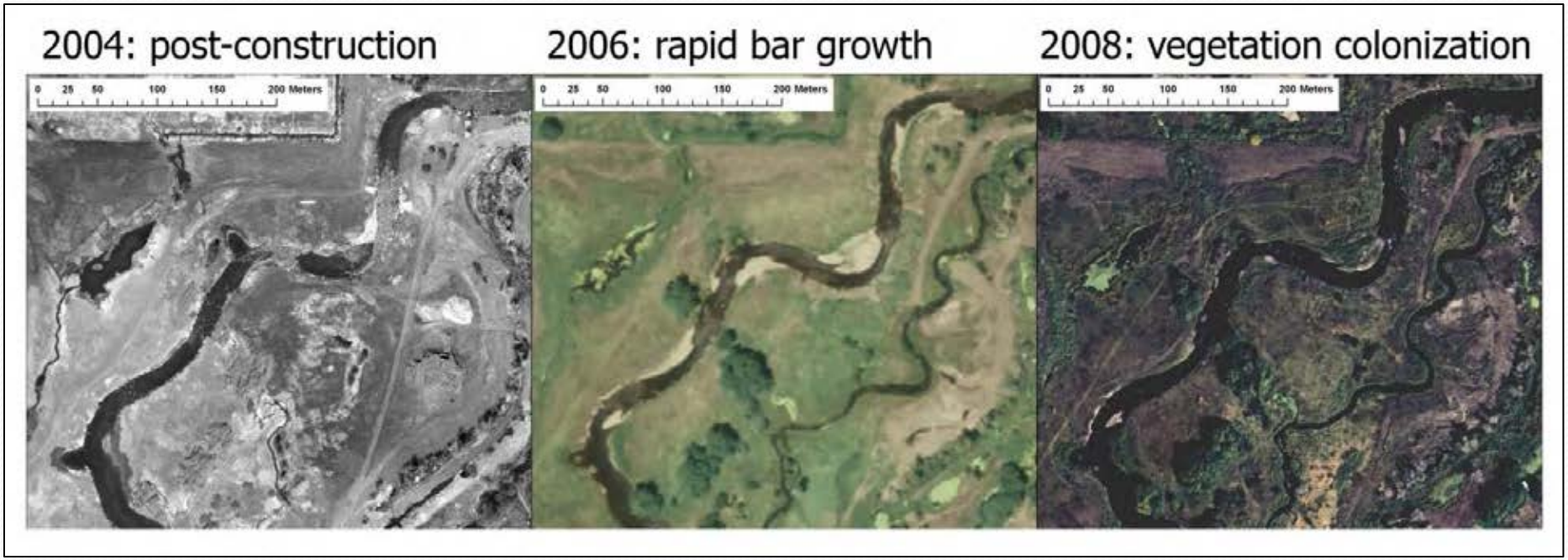
August 2001

August 2002

April 2005

June 2005

Site 6 miles downstream from modeled reach



This site is located below a never-channelized reach of Provo River that provides sediment supply for bar formation

Challenges/Lessons Learned

- Beaver can interfere with cottonwood recruitment plans!
- Much of what was a dense thicket of willow and young cottonwood in 2004 is now ponded water

Superhero?

Or menace?

Challenges/Lessons Learned

- Matching flow recommendations/ slow receding limb rate is not easy

Challenges/Lessons Learned

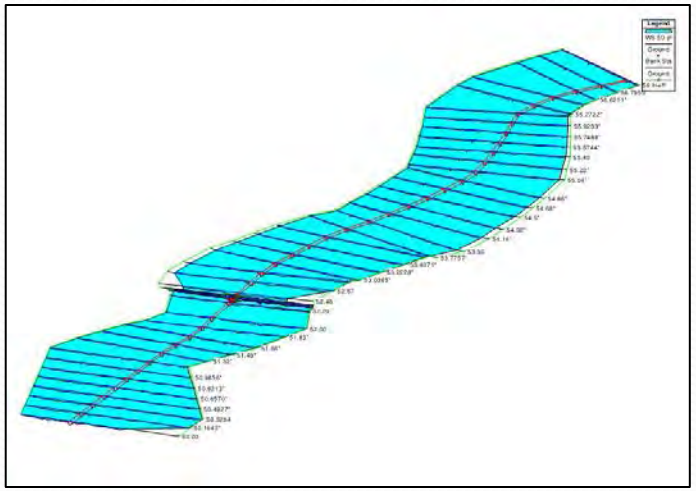
- Lack of sediment supply below Jordanelle Dam could be a limiting factor on cottonwood recruitment
  - Channel has been largely static in upper ~8 miles of PRRP
  - Minimal to no new bar formation or channel migration
  - Limitation on requirement #1:
    - Presence of moist, bare surface with fresh sediment at time of seed dispersal

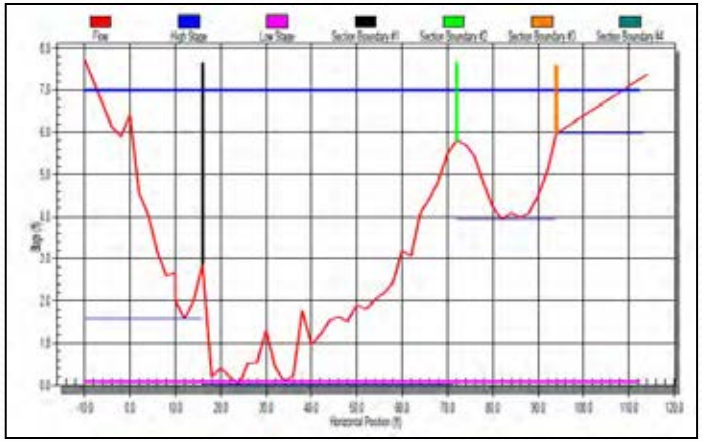
Applicability to Other Systems

- Relevant to any system with some springtime flow release operational flexibility
- Can be used as a tool for restoration project planning
  - Design “cottonwood recruitment surfaces” to match flow release hydrology
- Simpler modeling approaches are possible

Make Your Own Model!

- New technologies available for topographic data collection (LiDAR)
- Simpler modeling approaches are possible instead of River 2D
  - HEC-RAS (1D hydraulics model)
  - WinSXPRO (single cross-section hydraulics)





Make Your Own Model!

- Output information about water depth vs. discharge relationships
- Enable evaluation of flow required for
  - Initial inundation/wetting
  - Receding limb (ramp-down) rates

Questions and Discussion