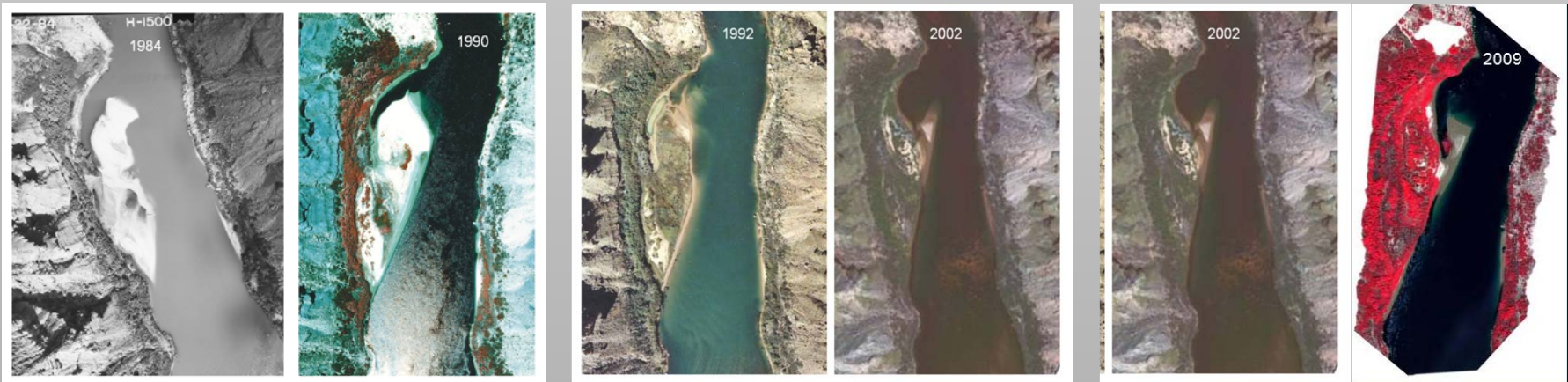




# Changes in Riparian Vegetation in the Colorado River Corridor, 1965-present



**Joel Sankey and Barbara Ralston, US Geological Survey,  
Grand Canyon Monitoring and Research Center**

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

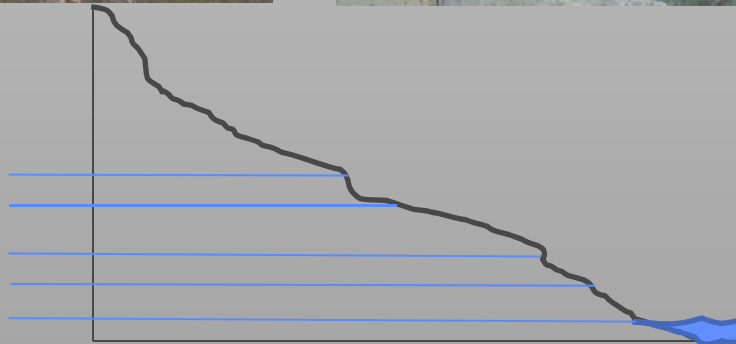
2002



2009



97000 ft<sup>3</sup>/s  
45000 ft<sup>3</sup>/s  
31000 ft<sup>3</sup>/s  
25000 ft<sup>3</sup>/s  
8000 ft<sup>3</sup>/s



# Drivers of Vegetation Change

## Plant Traits

- Life history
- Morphology
- Fluvial disturbance
- Water balance

## Relevant Flow Component

- Magnitude & timing of high & low flow
- Mean discharge (1.5-2 yr recurrence)
- Flow permanence

*Phragmites australis*



*Tamarix spp*

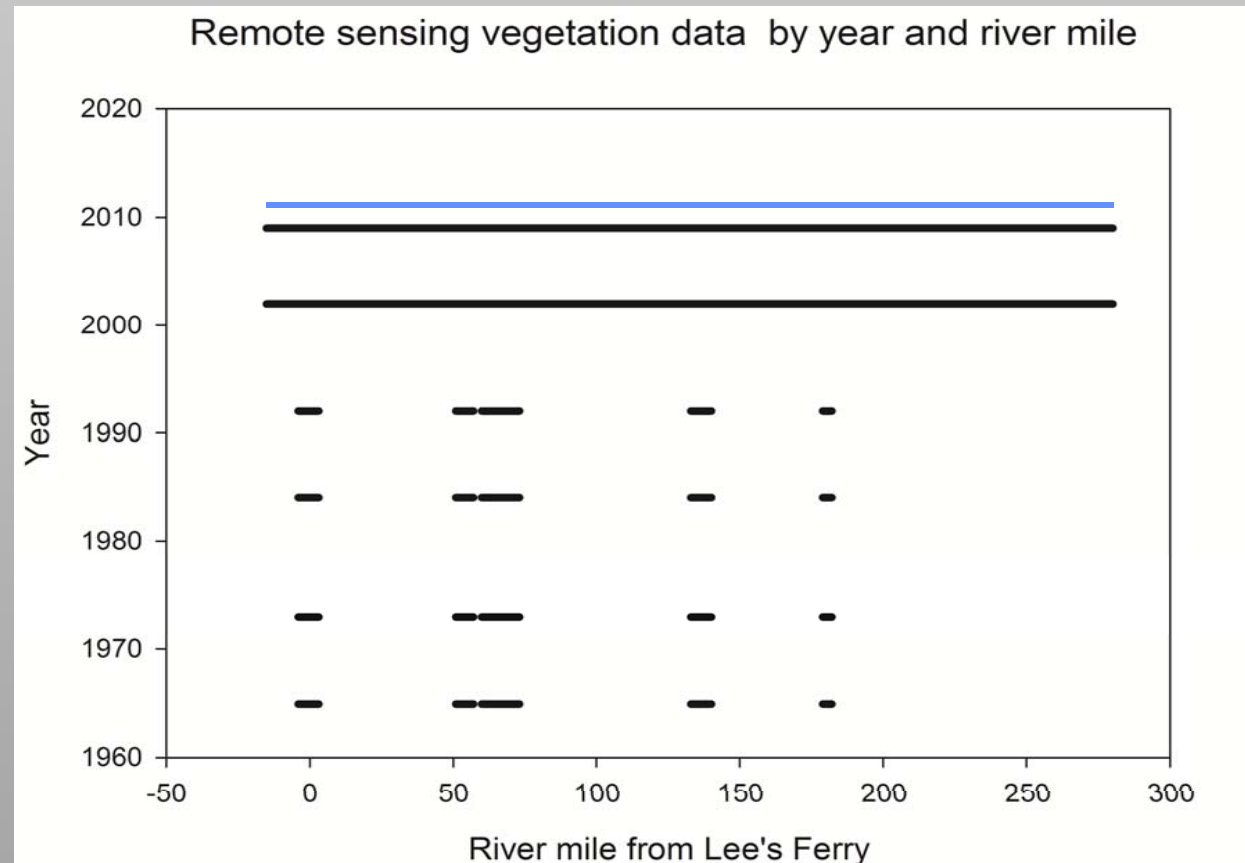


*Acer negundo/  
Prosopis glandulosa*



# Available Data

- **Aerial and digital imagery-based vegetation maps**
  - 1965, 73, 84, 92, 2002, 2009
  - **Total vegetation: segments '65-'92 (Waring, 1996); whole corridor '02, '09 (Davis, 2012) and 2013 (future – this summer's overflight)**



# Methods

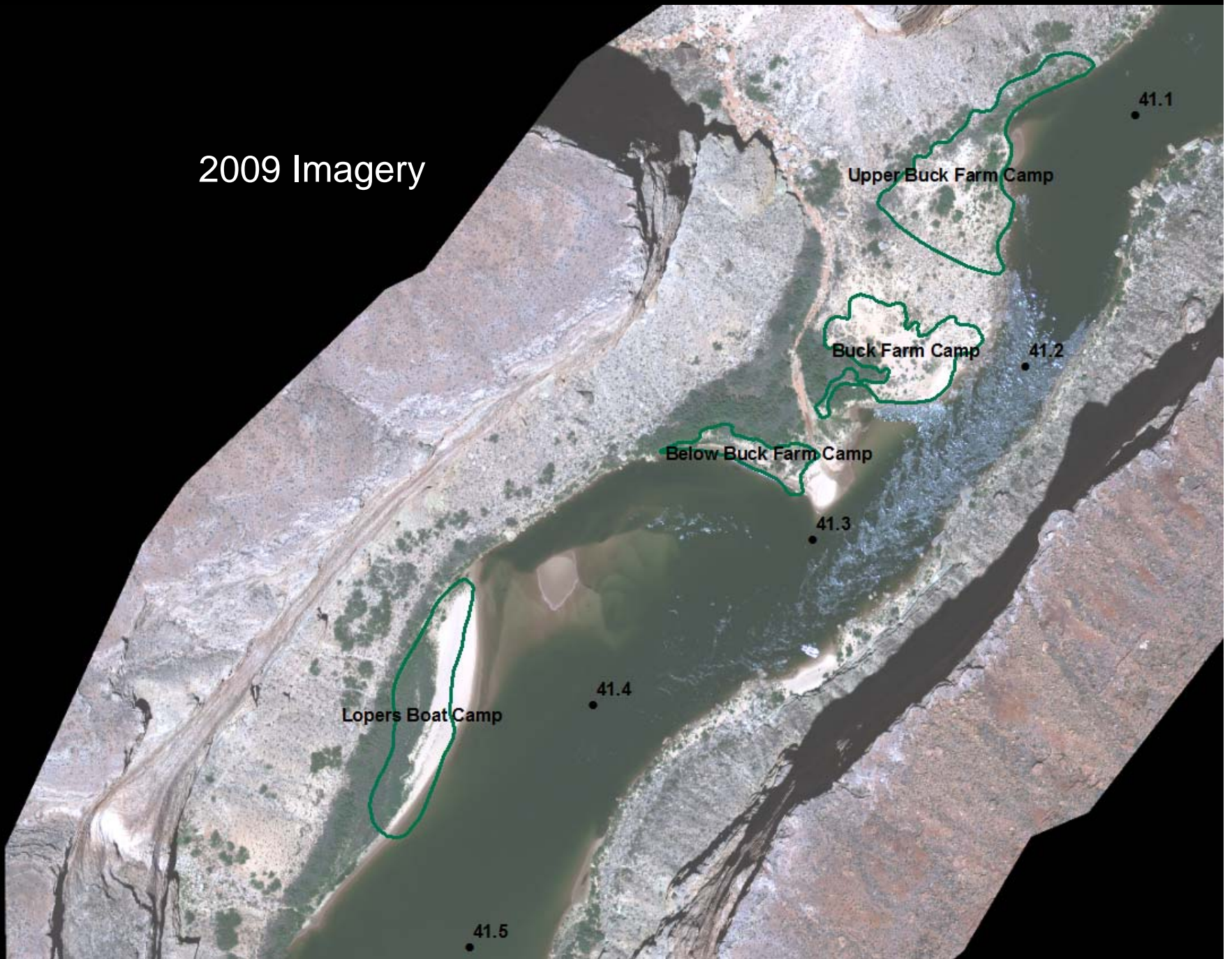
- **GIS synthesis of the existing 5 decades of GCMRC remote sensing vegetation datasets by:**
  - **Vegetation maps 2002** (Ralston and others, 2008), **2009** (NPS, 2012)
  - **Elevation Zones – 25k, 31k, 45k, 97k CFS virtual shorelines** (Magirl and others, 2008)
  - **Shoreline geomorphic units (eddies, debris fans, channel margins** (Utah State data, unpublished) )
  - **Glen Canyon Dam hydrograph**
  - **Regional climate synthesis** (Hereford and others, in review)

# Questions for Remotely Sensed Data

- **Spatial and temporal dynamics**
  - How does the composition of riparian vegetation vary spatially with river stage-elevation (elevation zones)?
  - How does the proportion of terrestrial area that is vegetated vary temporally (1965-present):
    - System-wide?
    - Among geomorphic units?
    - By proximity to the river channel?
    - By elevation zones?
  - What is the relationship of spatial and temporal variability relative to hydrology and regional climate?



2009 Imagery





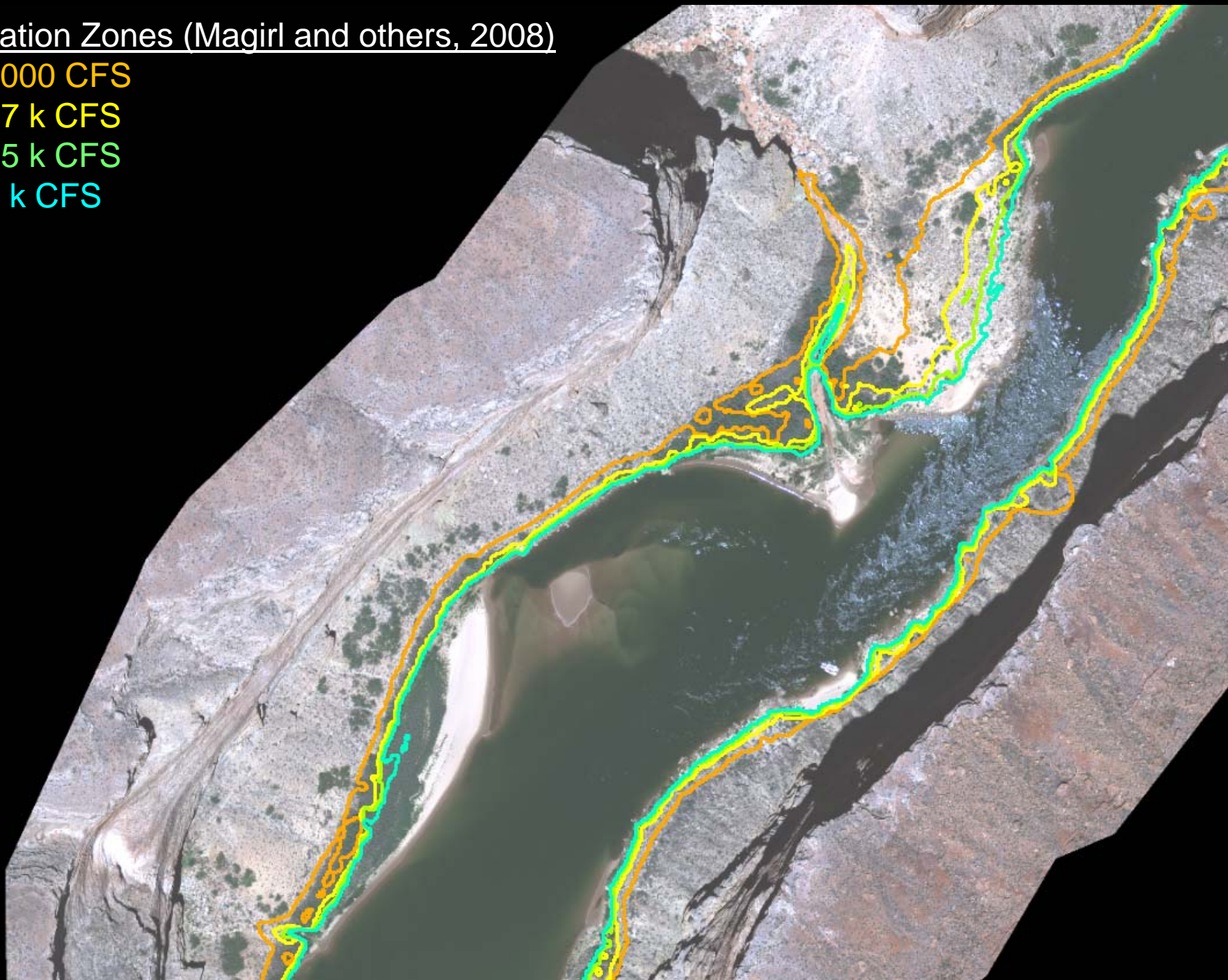
Elevation Zones (Magirl and others, 2008)

>97,000 CFS

45-97 k CFS

31-45 k CFS

< 25 k CFS





2002





2009



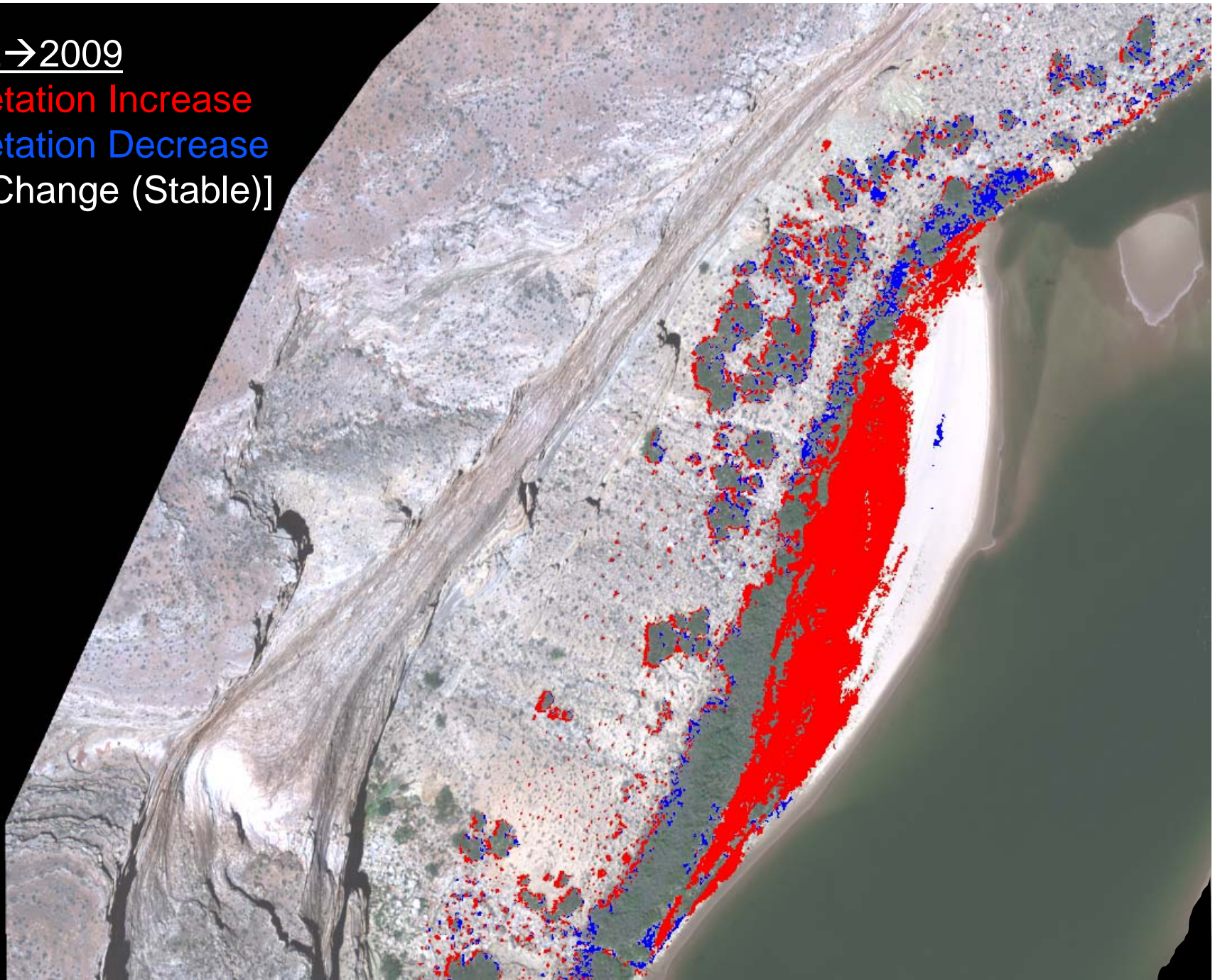


2002→2009

Vegetation Increase

Vegetation Decrease

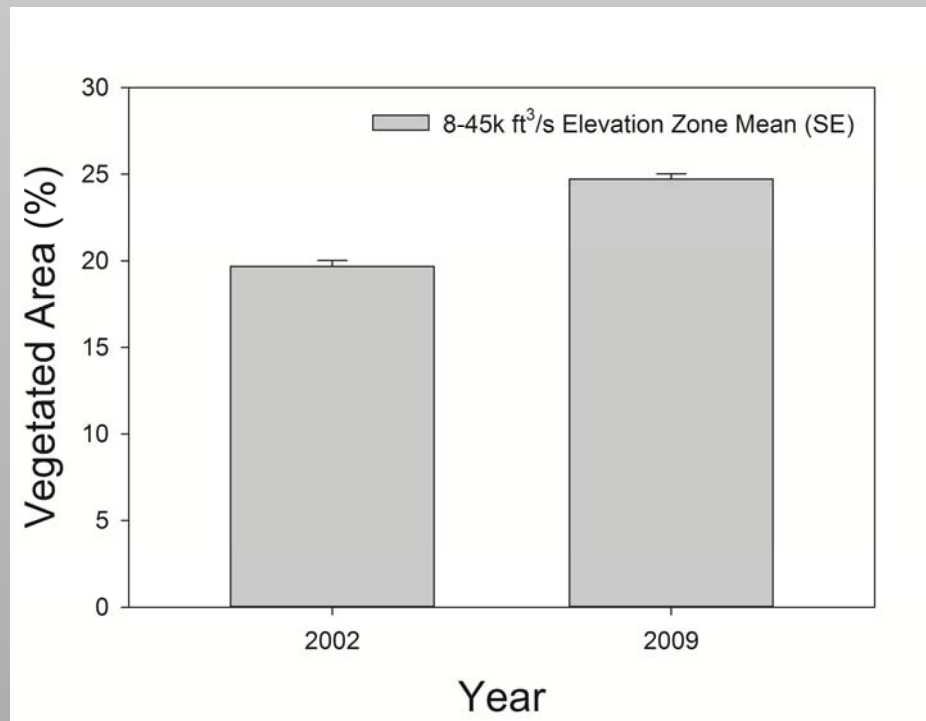
[No Change (Stable)]





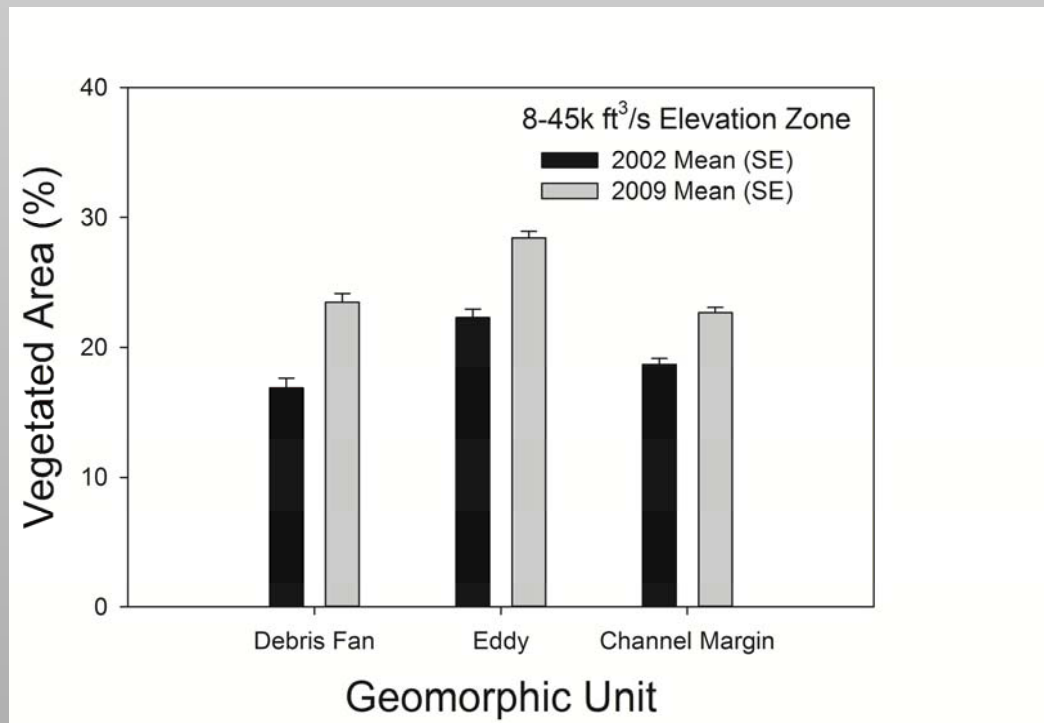
## 2002 → 2009

- Riparian vegetation increased system-wide
- 25% of the shoreline below 45,000 ft<sup>3</sup>/s elevation zone was vegetated as of 2009



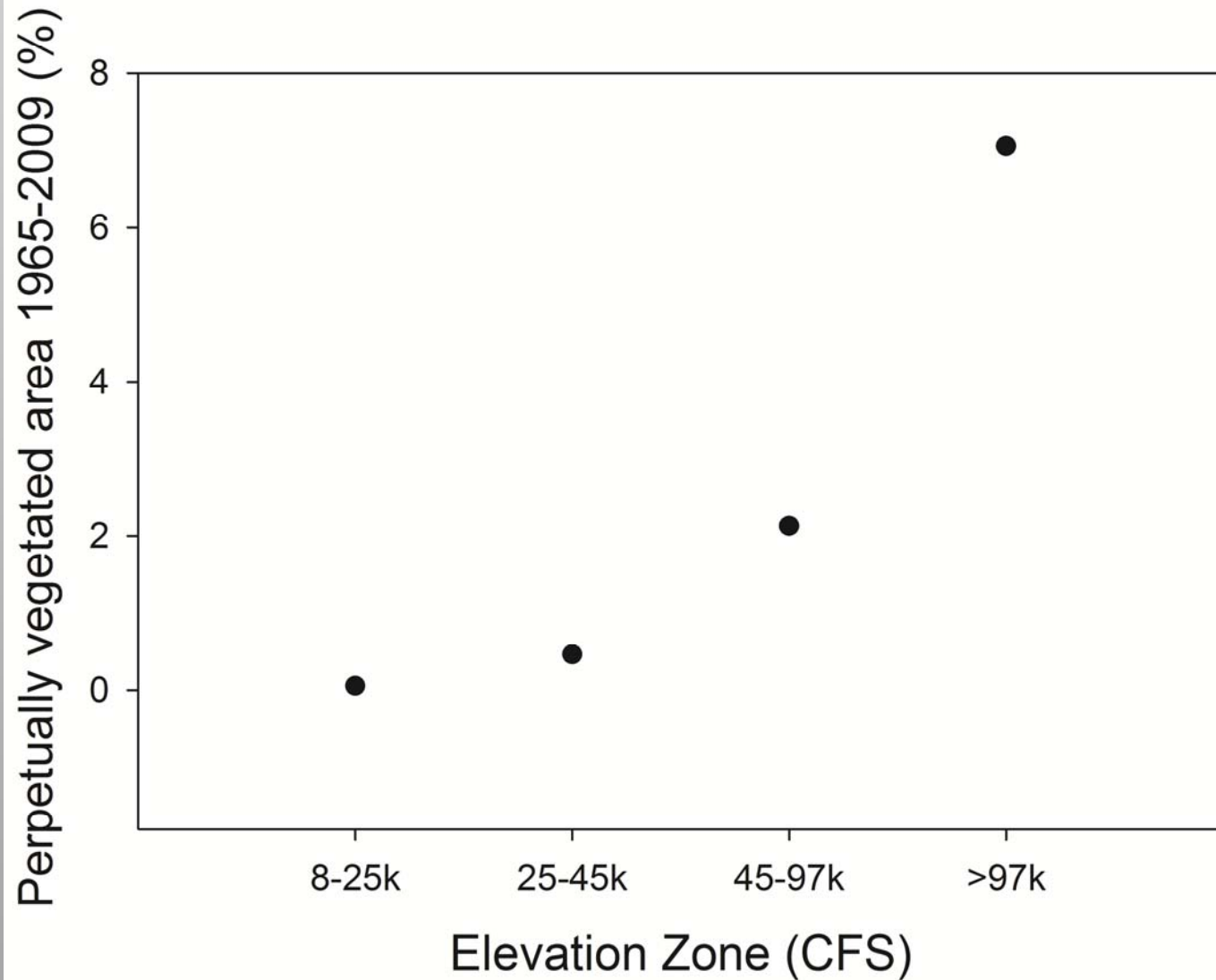
**2002 → 2009**

- Riparian vegetation increased system-wide for each major geomorphic unit below 45,000 ft<sup>3</sup>/s elevation zone**



# 1965 → 2009

- Vegetation was less stable at lower elevation zones

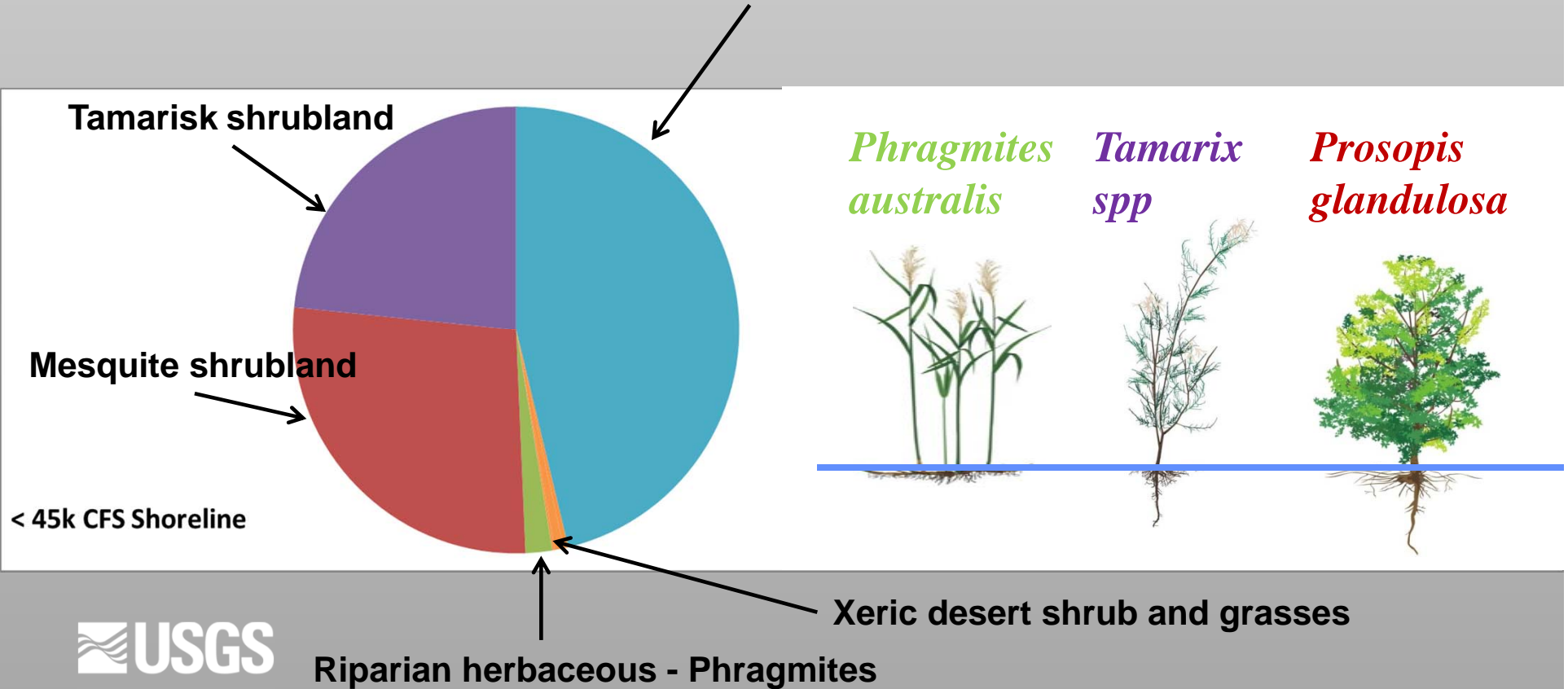




# 1965 → 2009: Vegetation composition by elevation zone

- Below 45,000 ft<sup>3</sup>/s

Riparian shrubs: Baccharis, Sand-bar Willow, Arrowweed



## 45,000-97,000 ft<sup>3</sup>/s elevation zone

- Riparian herbaceous < 1%
- Riparian shrubs < 25%
- Tamarisk ~ comparable to lower elevation zones

Riparian shrubs - Baccharis, Sand-bar Willow, Arrowweed

Xeric desert shrub and grasses

Tamarisk shrubland

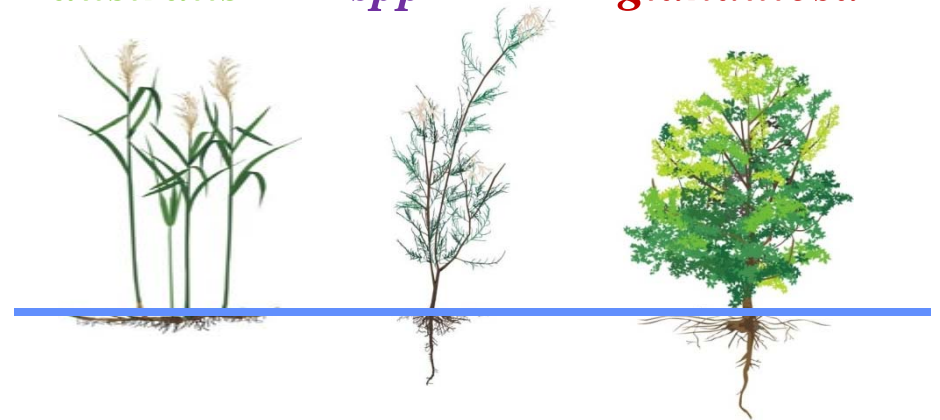
45-97k CFS Shoreline

Mesquite shrubland

*Phragmites  
australis*

*Tamarix  
spp*

*Prosopis  
glandulosa*



## Above 97,000 ft<sup>3</sup>/s elevation zone

- Riparian shrubs < 10 %
- Tamarisk ~ comparable to lower elevation zones

Riparian shrubs - Baccharis, Sand-bar Willow, Arrowweed

Xeric desert shrub and grasses

Tamarisk shrubland

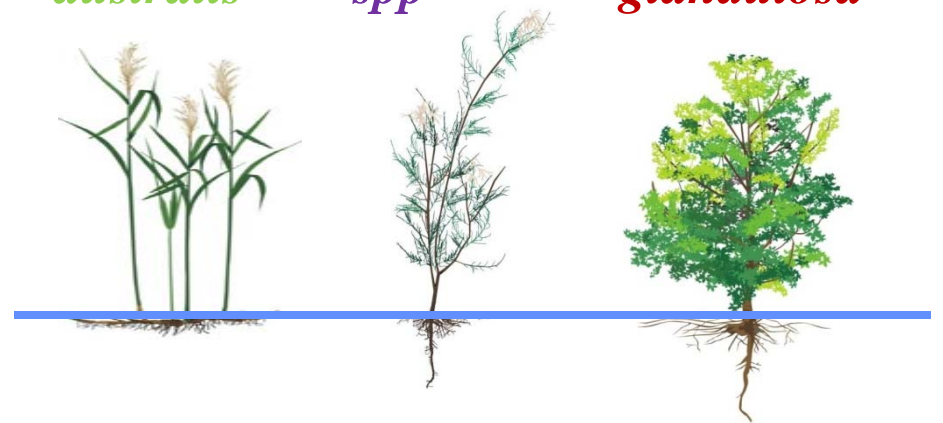
>97 k CFS Shoreline

Mesquite shrubland

*Phragmites  
australis*

*Tamarix  
spp*

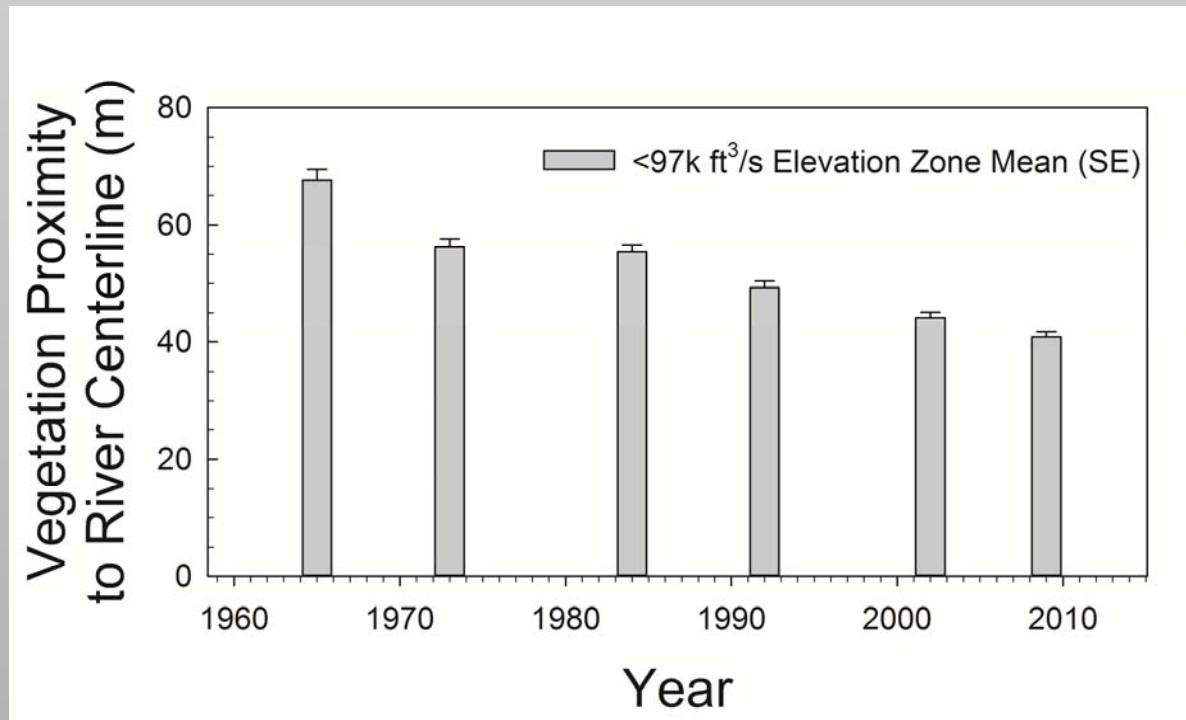
*Prosopis  
glandulosa*





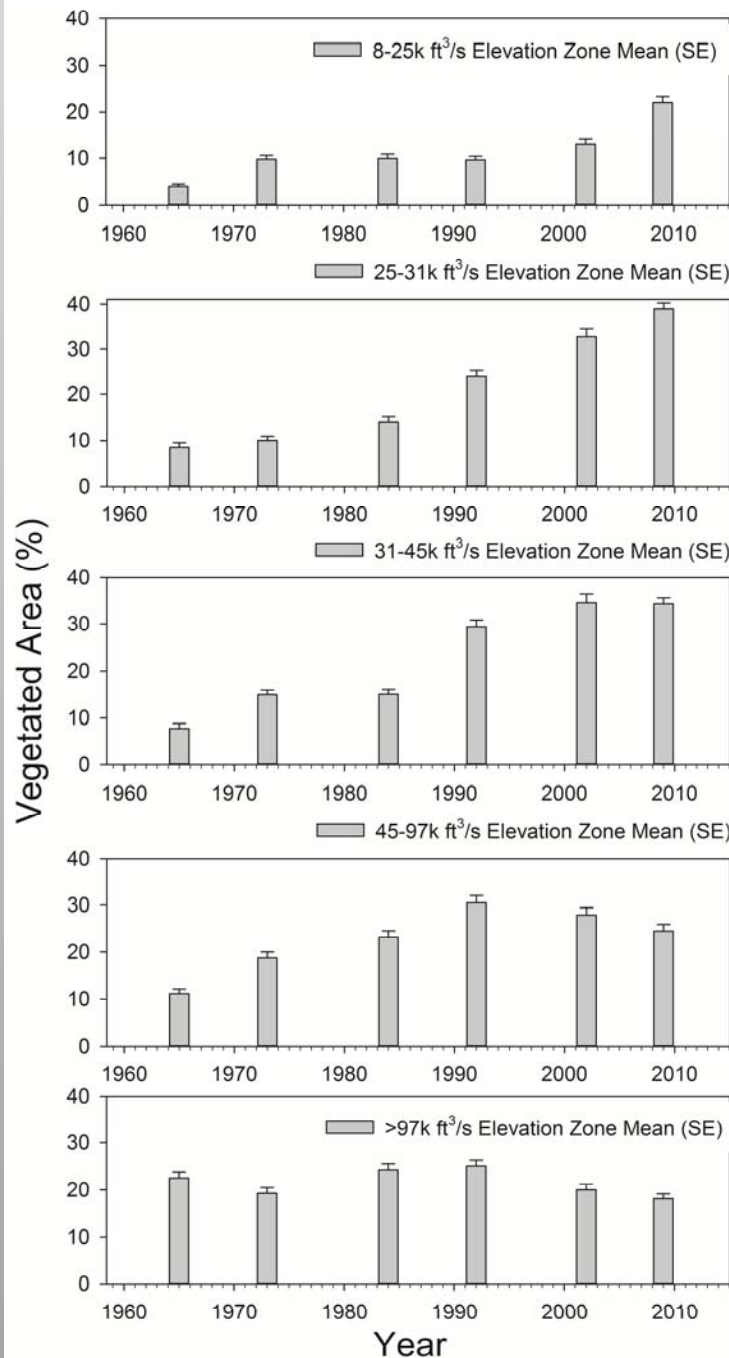
1965 → 2009

- Riparian vegetation expanded shoreward



# 1965-2009

- Long-term vegetation changes vary by elevation zone



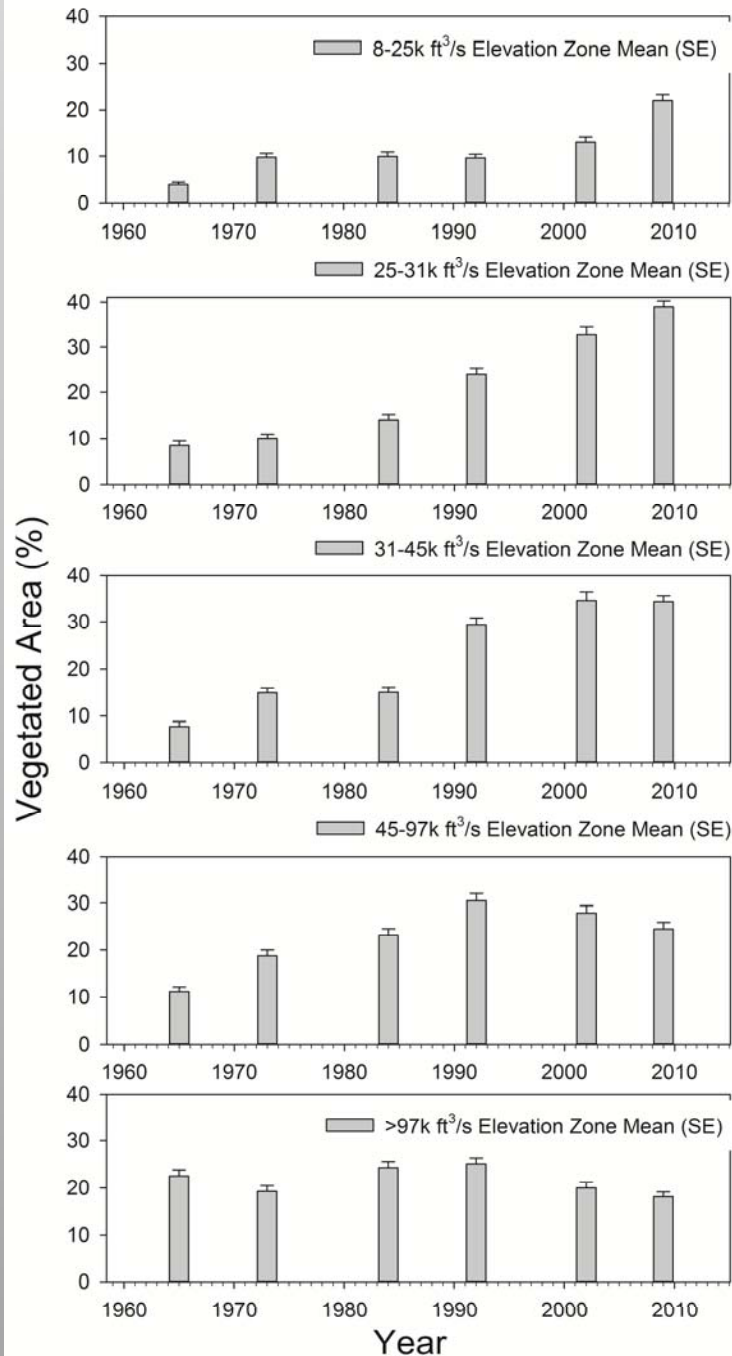
Lowest elevation zone  
- river



Highest elevation zone  
- xeric

# 1965-2009

- Long-term vegetation changes are associated with distinct hydrology of elevation zones



Current Operations  
(<25k ft<sup>3</sup>/s)

Powerplant  
Operations  
(25-31k ft<sup>3</sup>/s)

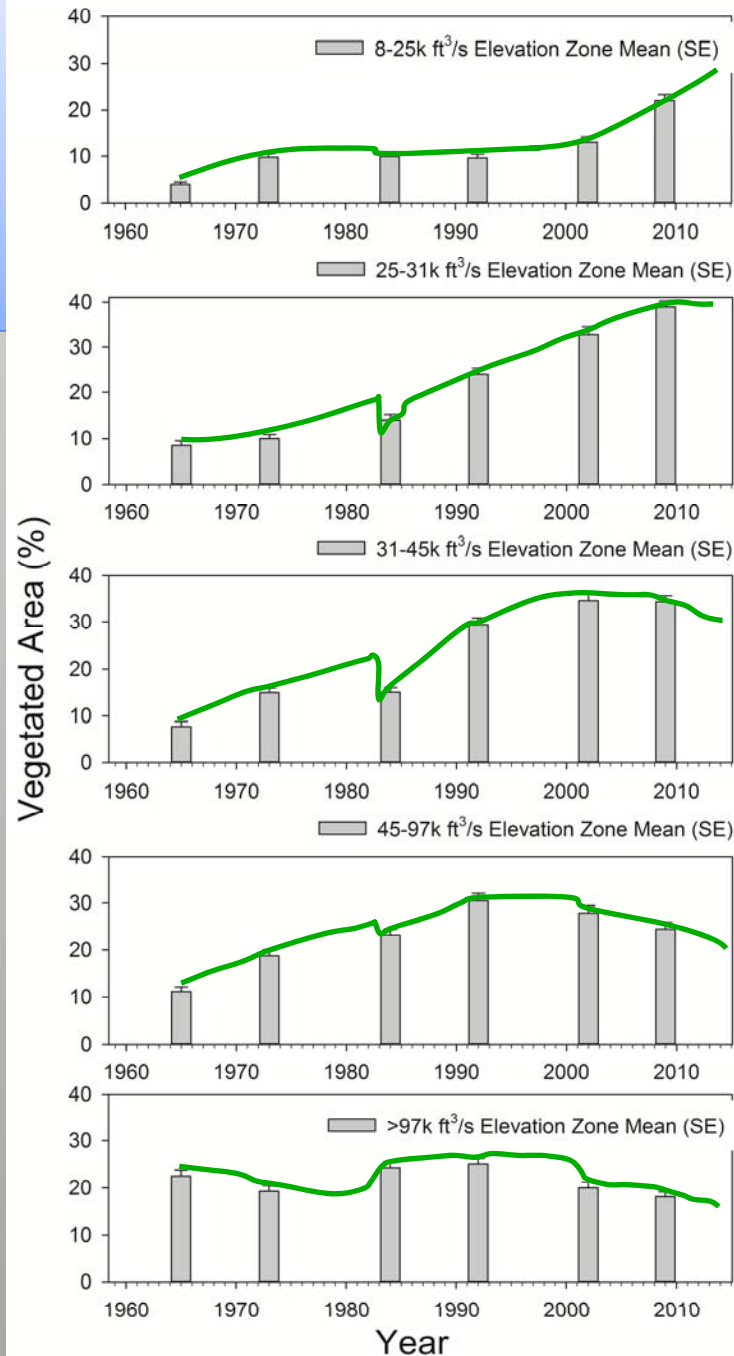
Recent HFE's  
(31-45k ft<sup>3</sup>/s)

Rare post-dam  
Floods (45-97k ft<sup>3</sup>/s)

Never inundated  
post-dam  
(>97k ft<sup>3</sup>/s)



**More variability likely exists than is captured at the temporal resolution of available data**



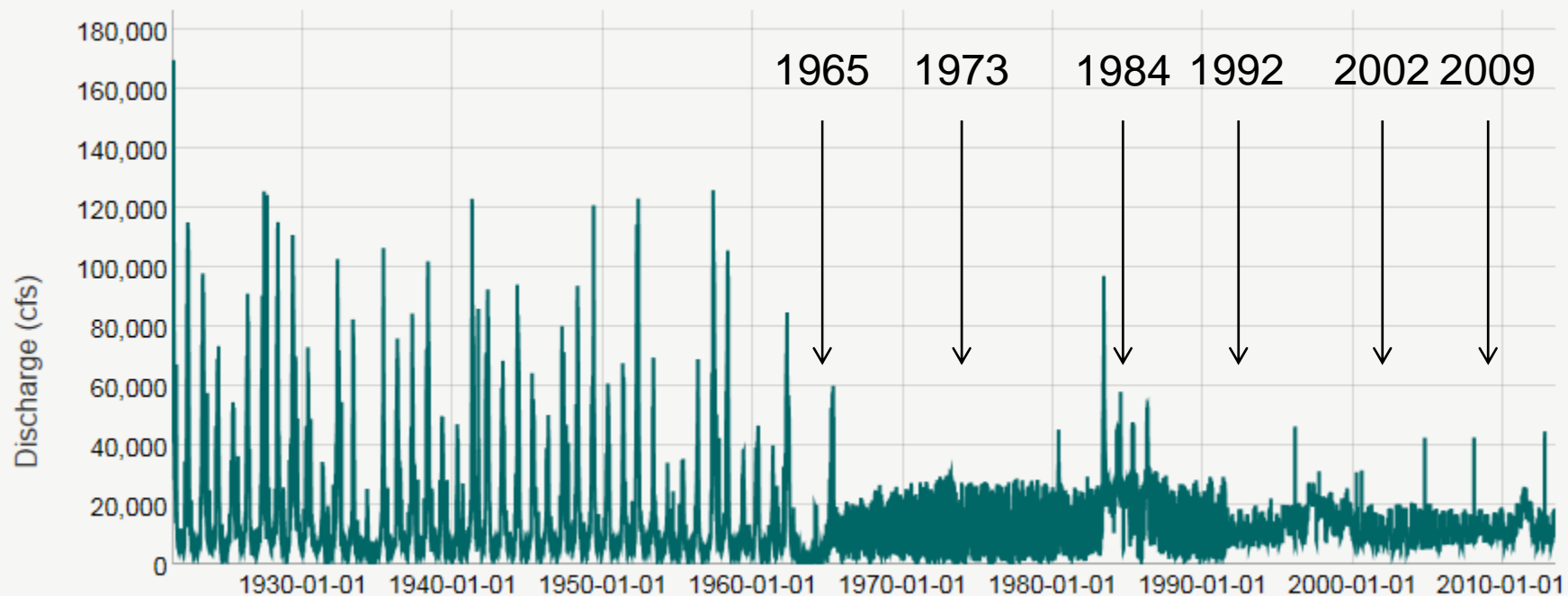
**Current Operations (<25k ft<sup>3</sup>/s)**

**Powerplant Operations (25k-31k ft<sup>3</sup>/s)**

**Recent HFE's (31k-45k ft<sup>3</sup>/s)**

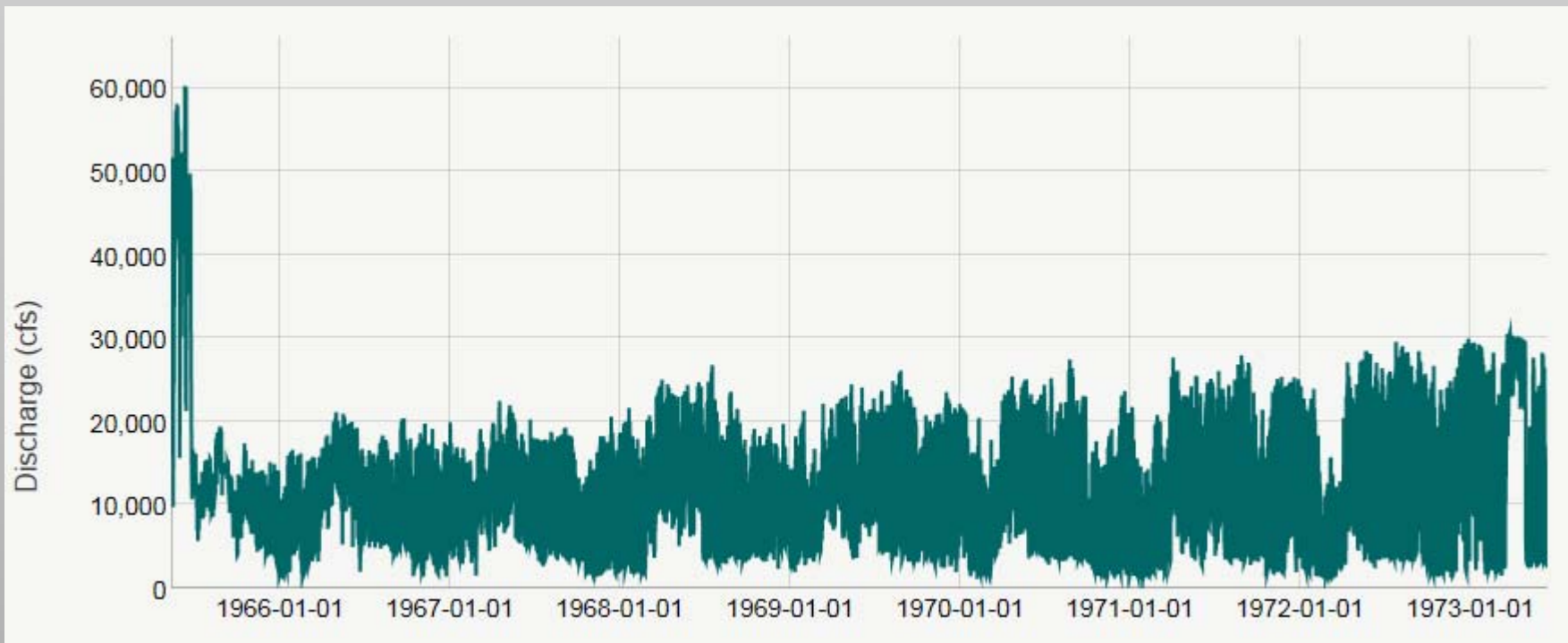
**Rare post-dam Floods (45k-97k ft<sup>3</sup>/s)**

**Never inundated post-dam (>97k ft<sup>3</sup>/s)**



# 1965-1973

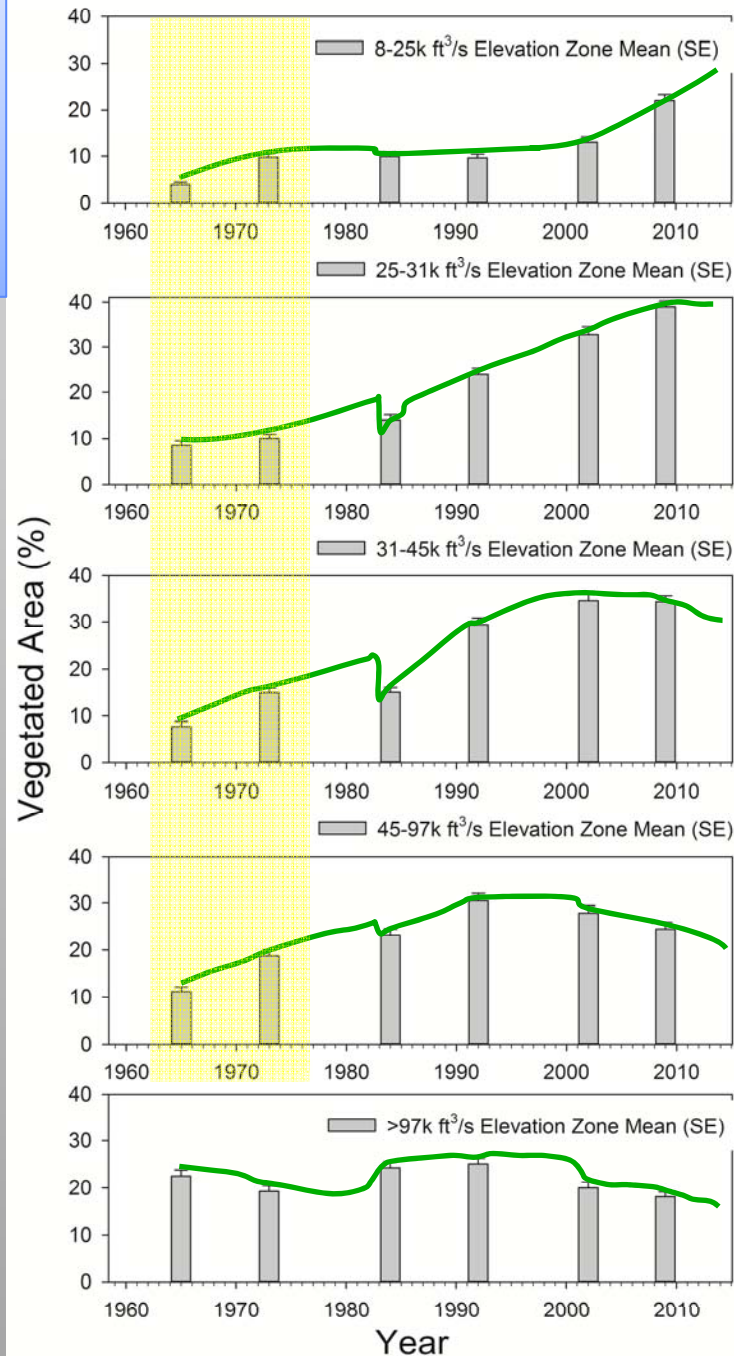
1.5 y recurrence ~ 26,600 ft<sup>3</sup>/s





**1965-1973:**

- **Vegetation expansion below 97,000 ft<sup>3</sup>/s**



**Current Operations (<25k ft<sup>3</sup>/s)**

**Powerplant Operations (25k-31k ft<sup>3</sup>/s)**

**Recent HFE's (31k-45k ft<sup>3</sup>/s)**

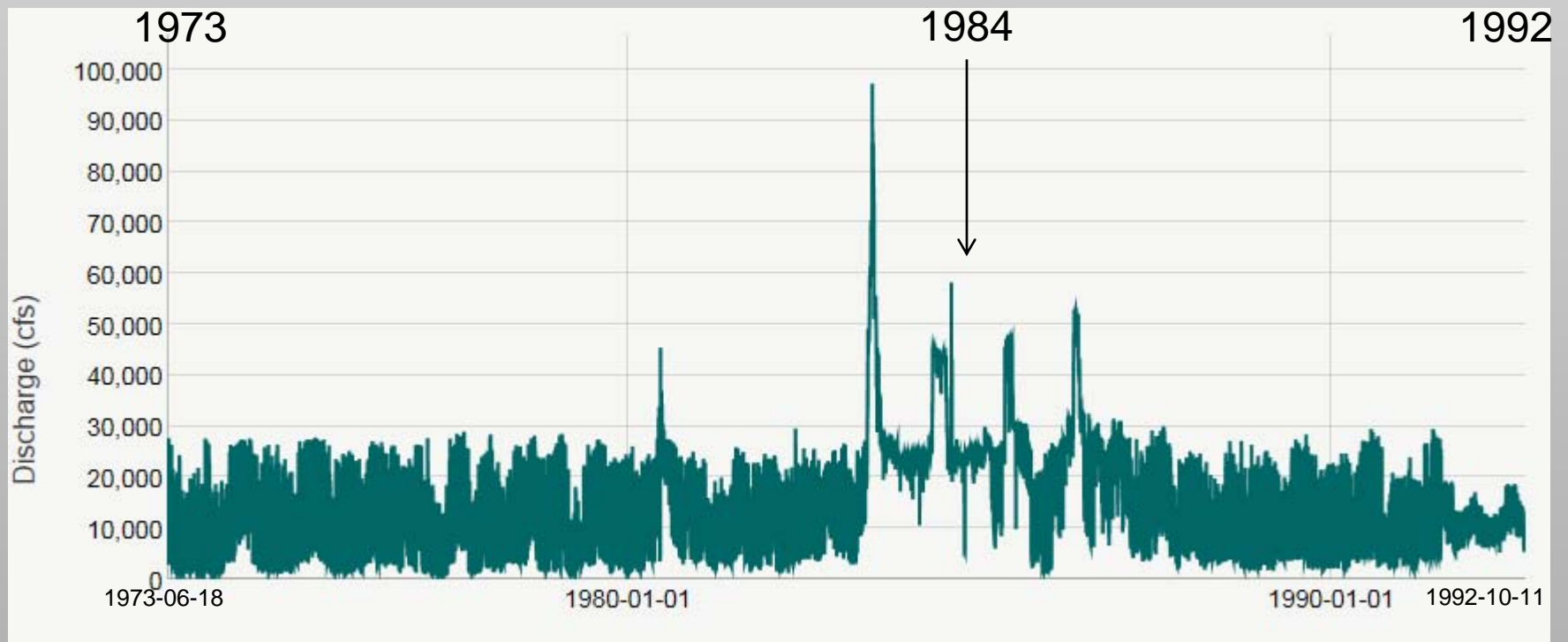
**Rare post-dam Floods (45k-97k ft<sup>3</sup>/s)**

**Never inundated post-dam (>97k ft<sup>3</sup>/s)**

## 1973-1984-1992

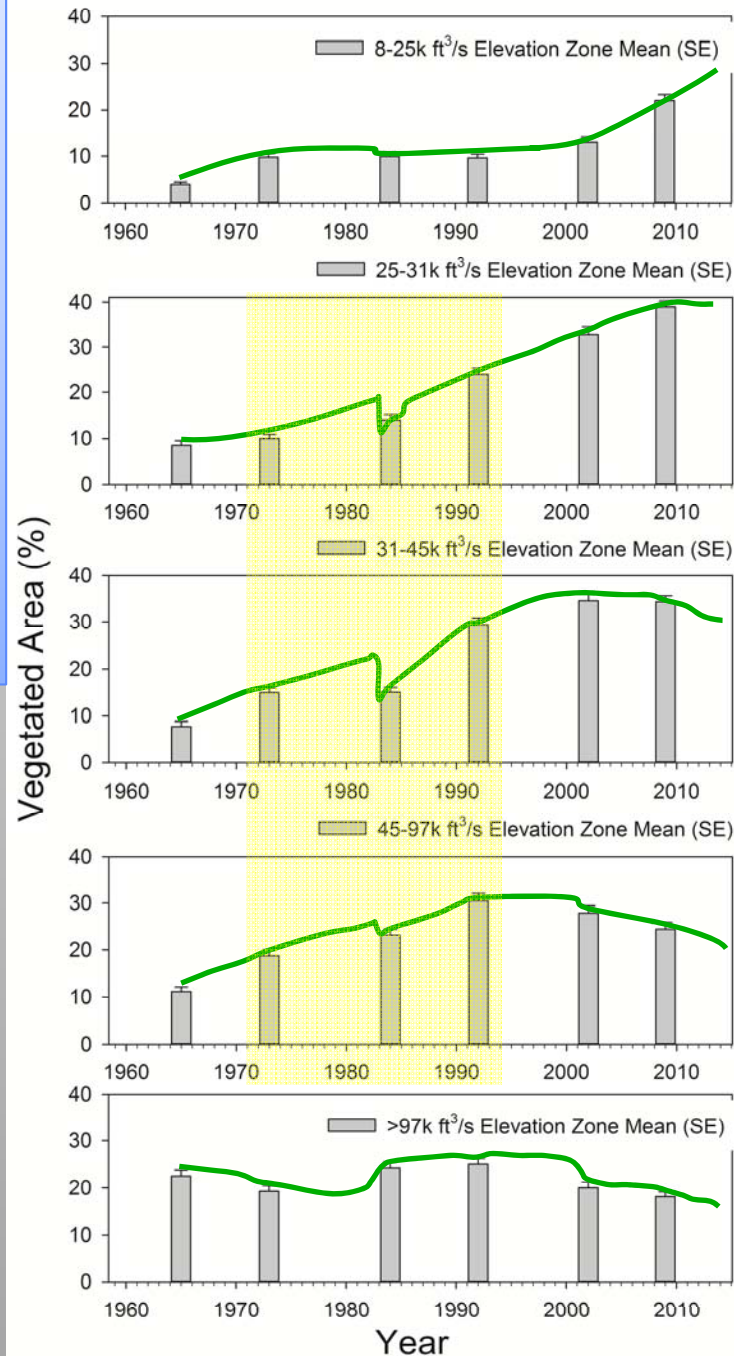
1.5 y recurrence ~ 28,400 ft<sup>3</sup>/s ('73-'84)

1.5 y recurrence ~ 29,100 ft<sup>3</sup>/s ('84-'92)



## 1973-1992:

- **Vegetation expansion 25-97 k ft<sup>3</sup>/s elevation zones**
- **Rapid decrease and then increase in riparian vegetation in response to large floods**



Current Operations  
(<25k ft<sup>3</sup>/s)

Powerplant  
Operations  
(25k-31k ft<sup>3</sup>/s)

Recent HFE's  
(31k-45k ft<sup>3</sup>/s)

Rare post-dam  
Floods  
(45k-97k ft<sup>3</sup>/s)

Never inundated  
post-dam  
(>97k ft<sup>3</sup>/s)



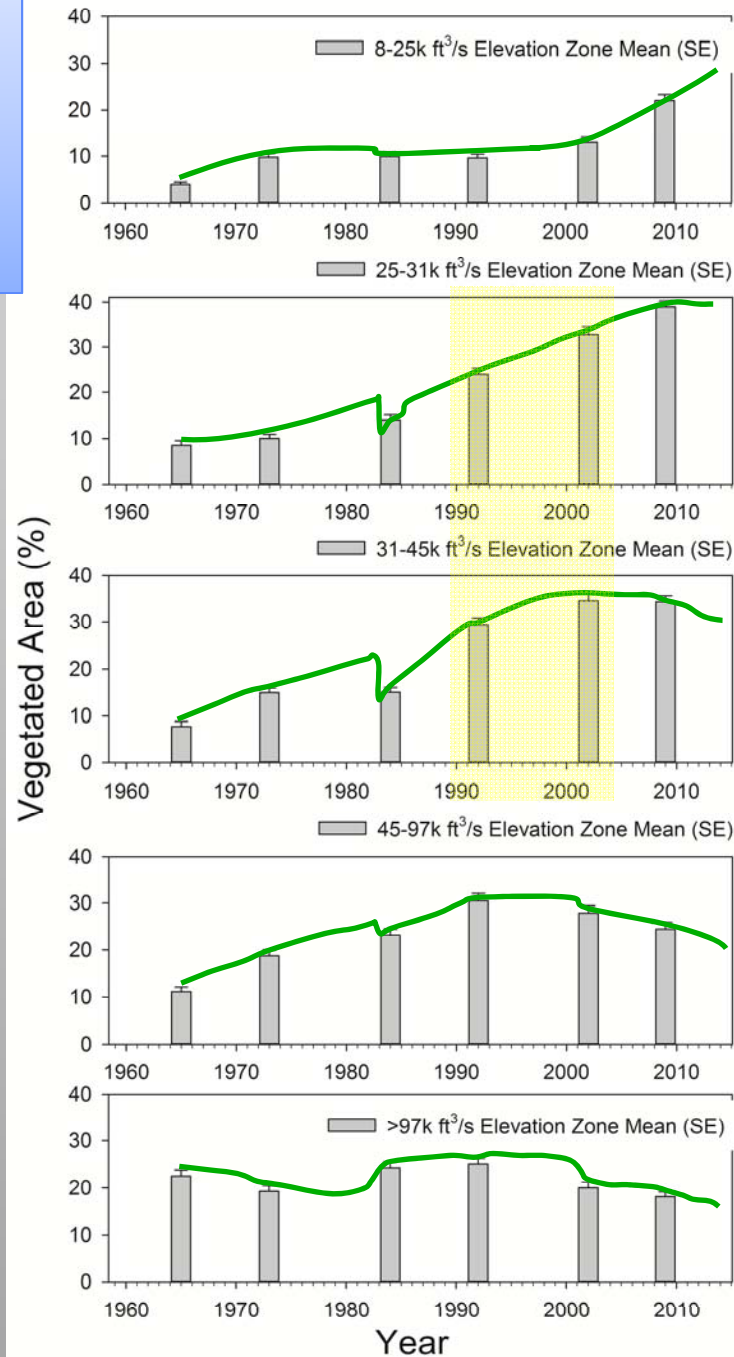
# 1992-2002

1.5 y recurrence ~ 21,600 ft<sup>3</sup>/s



## 1992-2002:

- Vegetation expansion 25-45 k ft<sup>3</sup>/s elevation zones



Current Operations  
(<25k ft<sup>3</sup>/s)

Powerplant  
Operations  
(25k-31k ft<sup>3</sup>/s)

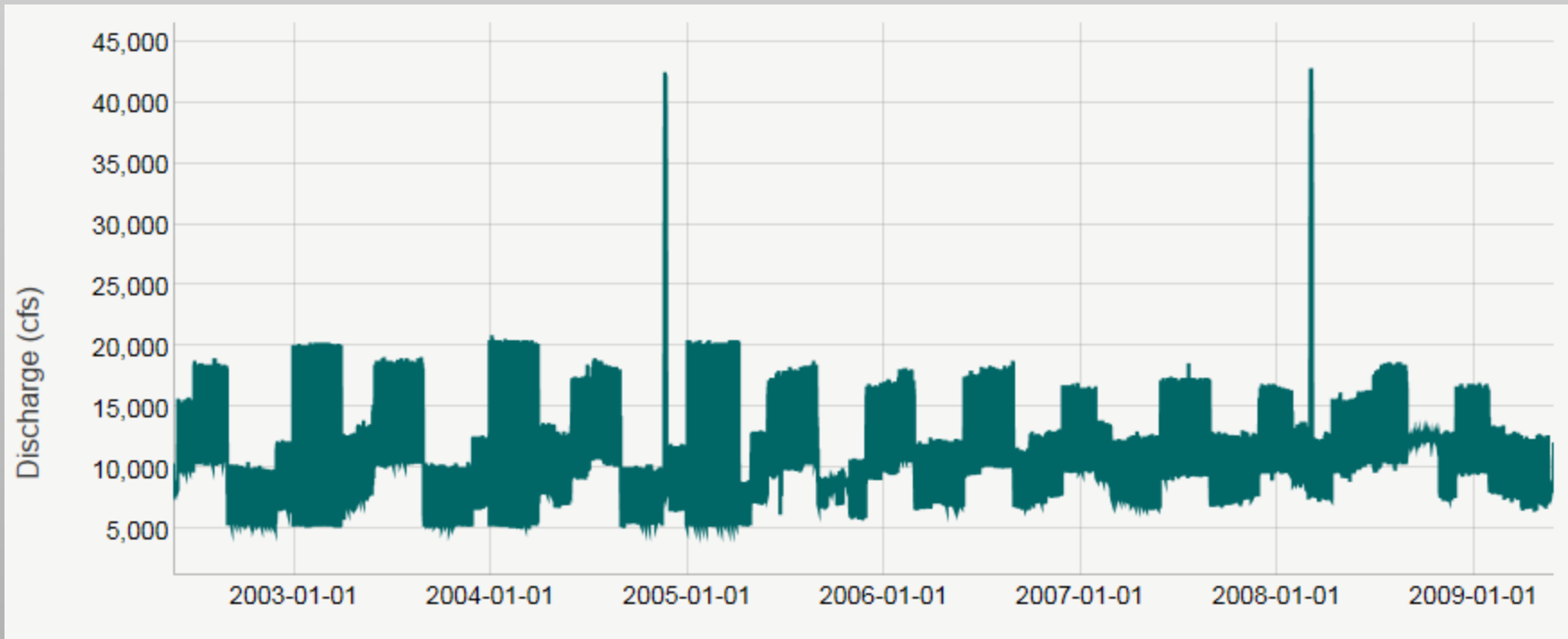
Recent HFE's  
(31k-45k ft<sup>3</sup>/s)

Rare post-dam  
Floods  
(45k-97k ft<sup>3</sup>/s)

Never inundated  
post-dam  
(>97k ft<sup>3</sup>/s)

# 2002-2009

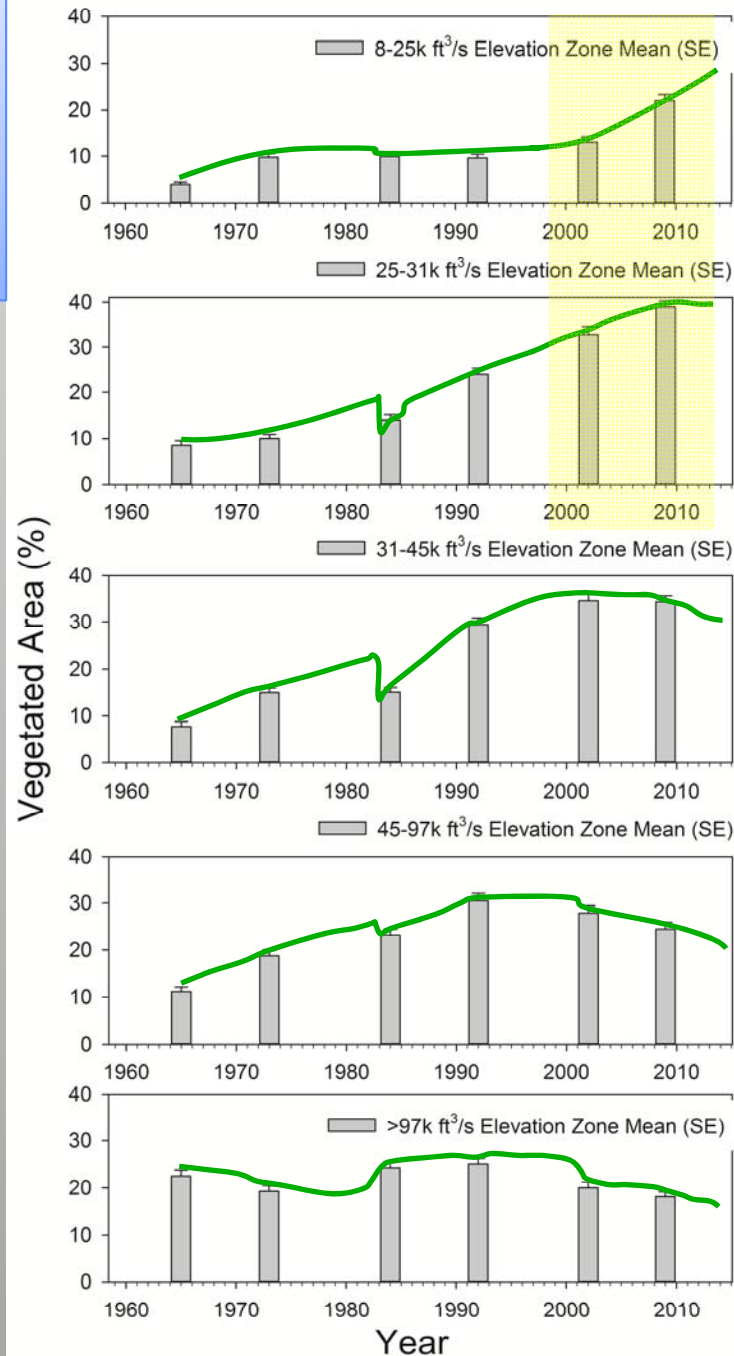
1.5 y recurrence ~19,000 ft<sup>3</sup>/s





**2002-2009:**

- **Vegetation expansion below 31k ft<sup>3</sup>/s elevation zone**



**Current Operations (<25k ft<sup>3</sup>/s)**

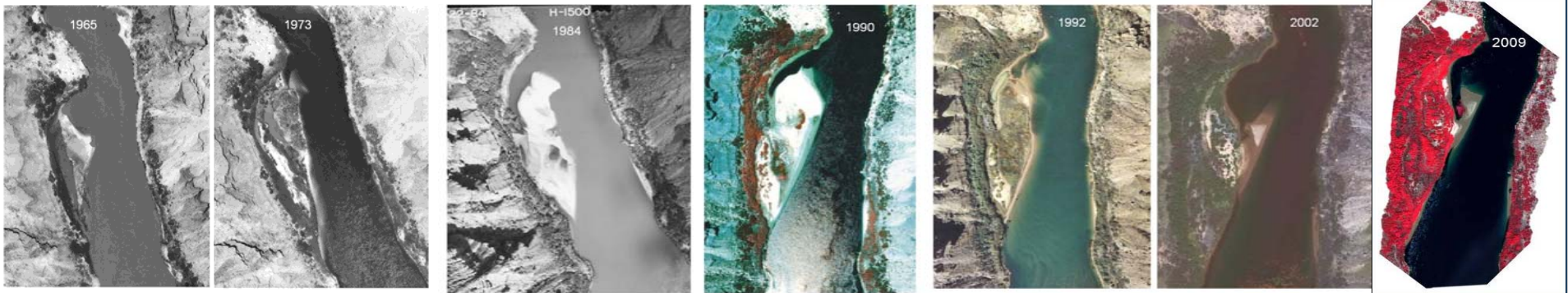
**Powerplant Operations (25k-31k ft<sup>3</sup>/s)**

**Recent HFE's (31k-45k ft<sup>3</sup>/s)**

**Rare post-dam Floods (45k-97k ft<sup>3</sup>/s)**

**Never inundated post-dam (>97k ft<sup>3</sup>/s)**

# Summary



- More riparian vegetation exists than in previous 5 decades at the lowest elevation zones (<45k ft<sup>3</sup>/s)
- Riparian woody vegetation expanded shoreward
- HFEs of present magnitude/duration do not appear to affect the longer term trend of expansion
- Vegetation change is significantly related to river hydrology at lower elevation zones (<45k ft<sup>3</sup>/s) and regional climate at higher elevations (>97k ft<sup>3</sup>/s)
- Remote sensing datasets allow both large-scale change detection and local-scale analysis to quantify plant response to changing dam operations.





# Changes in Riparian Vegetation in the Colorado River Corridor, 1965-present



Stanton Photo 1890, Cardenas Creek, Natl. Archives

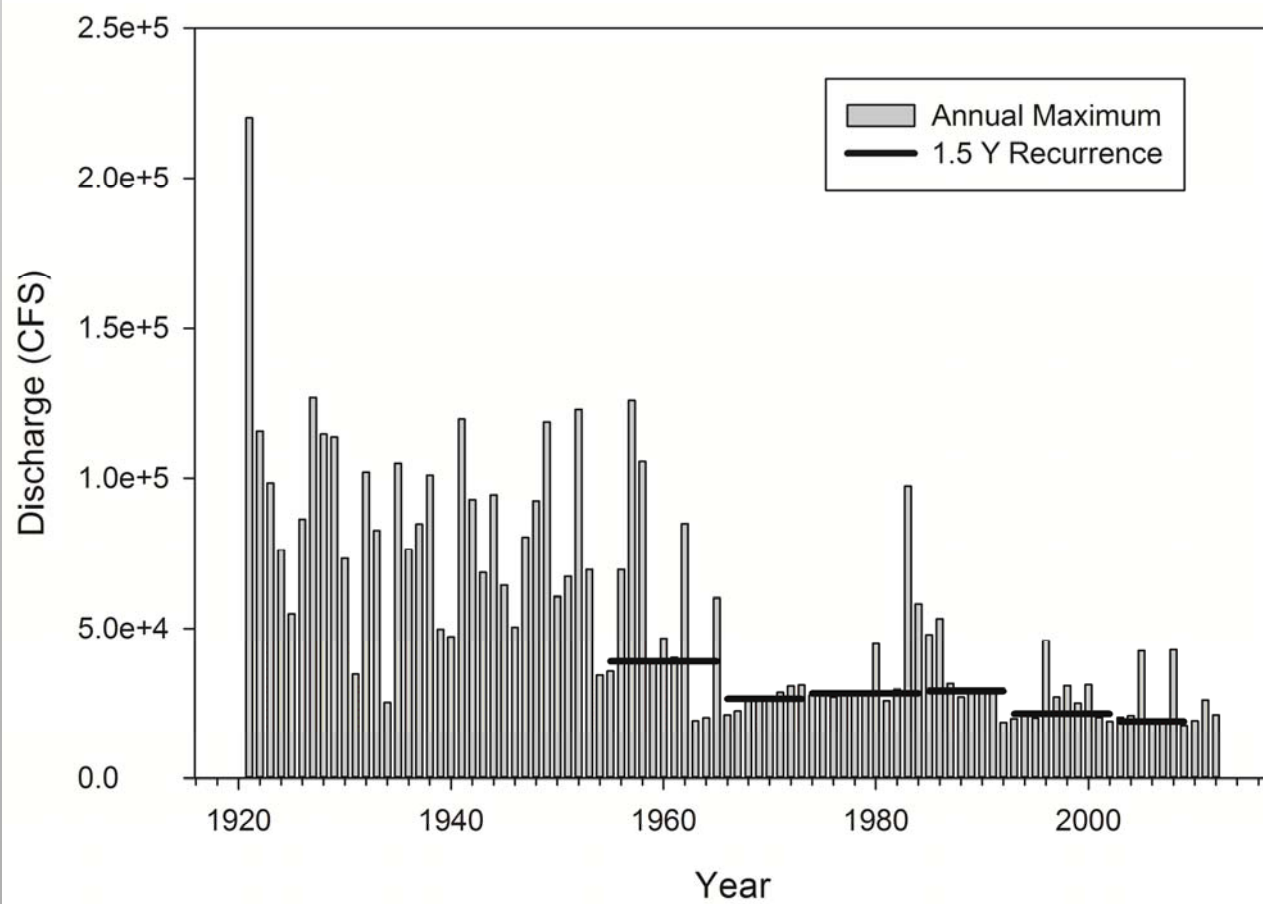


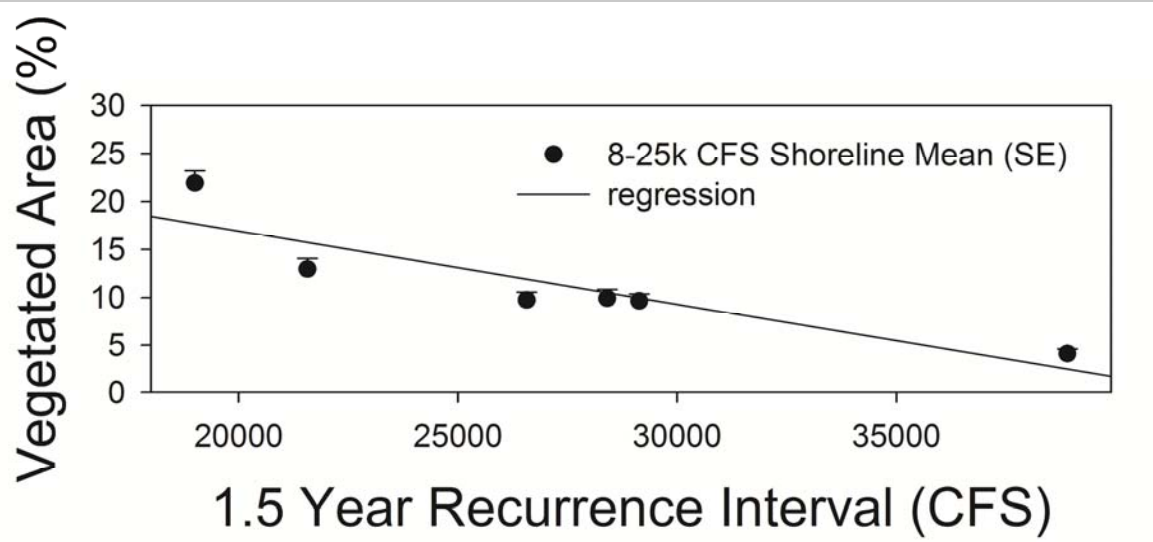
Repeat photograph 2003, Cardenas Creek, USGS

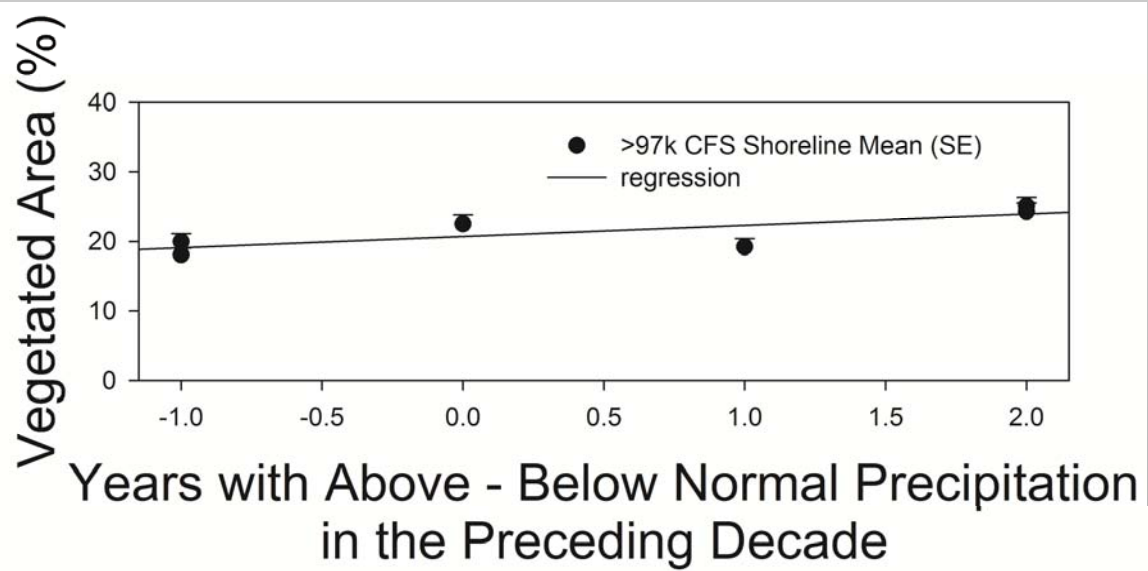
**Joel Sankey and Barbara Ralston, US Geological Survey, Grand Canyon  
Monitoring and Research Center**











# Overview

- Drivers of vegetation change
- Remotely-sensed data and questions
- Methodology
- Preliminary results

