



Interdisciplinary Sediment, Riparian Vegetation, and Cultural Resource Science

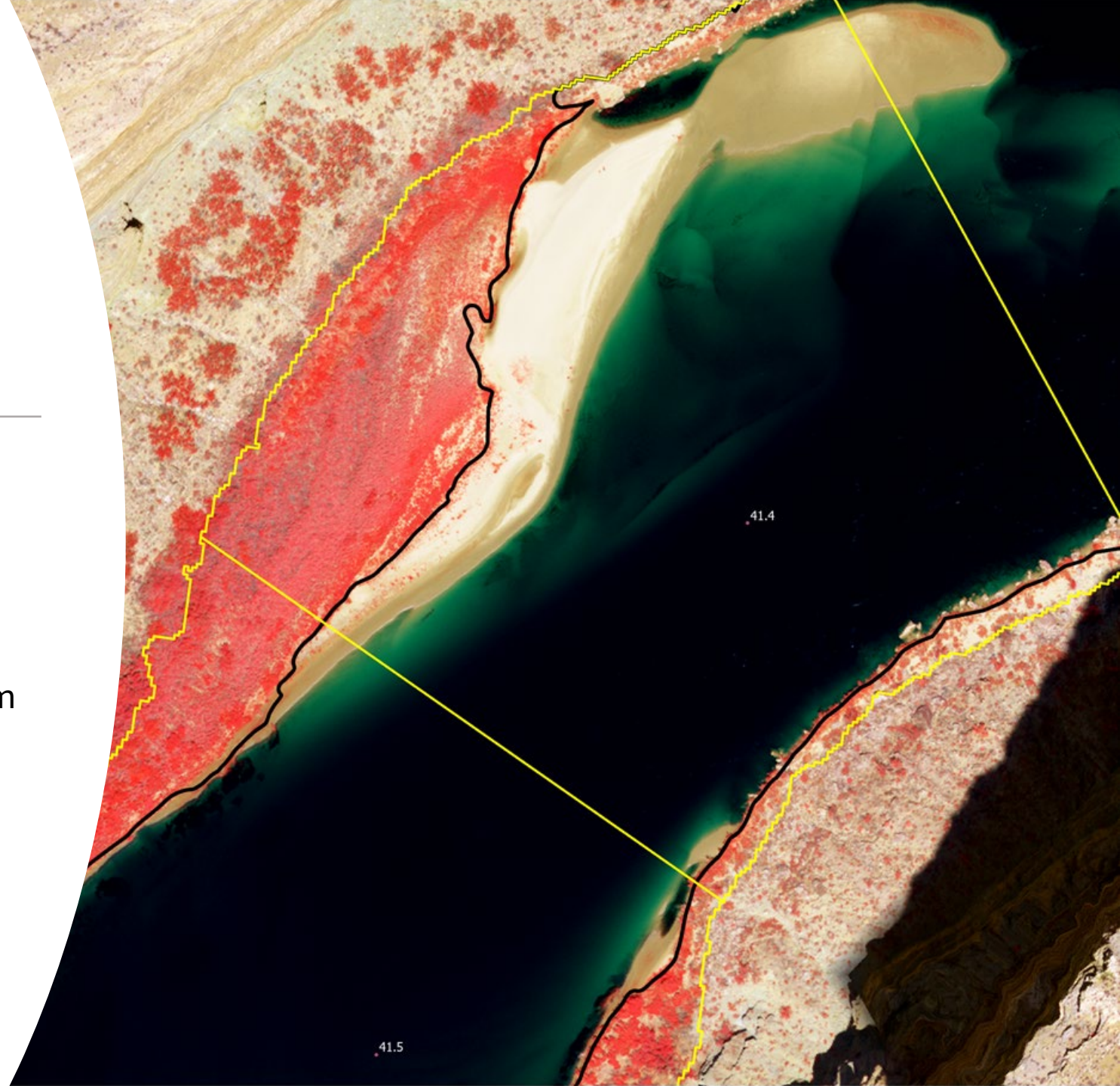
GCMRC TWP Projects C, D, L, and B Team Members¹

(presented by Joel B. Sankey¹)

Glen Canyon Dam Adaptive Management Program
Adaptive Management Workgroup Meeting
25-26 February 2026

¹ U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center

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River sediment is the matrix for the riparian ecosystem, human habitat, and cultural history of Grand Canyon



archaeological sites



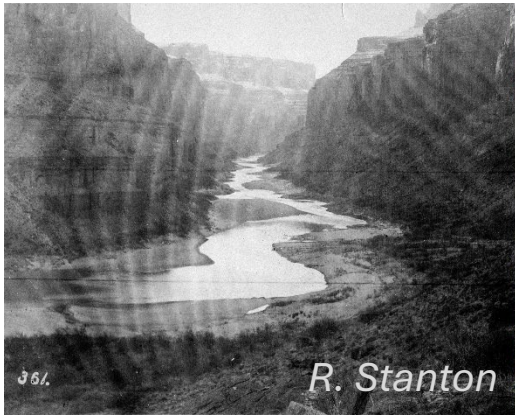
sand dunes



shoreline aquatic habitat



beaches, campsites, and riparian ecosystem



fundamental part of pre-dam landscape



and major part of post-dam river and reservoir systems (navigation, water quality, turbidity)

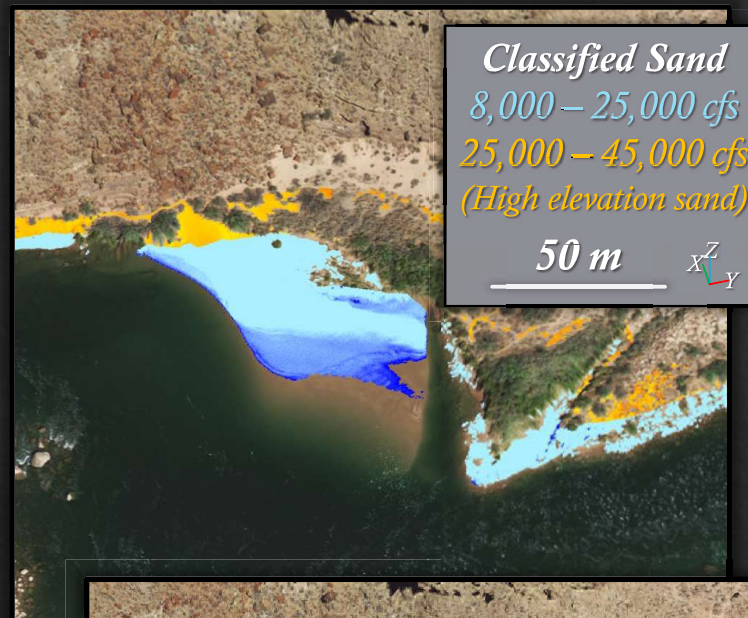
Outline

1. **Sediment and Riparian Vegetation Remote Sensing**
2. Riparian Vegetation Induced Declines in River Channel Width
3. LTEMP Goal 11 Riparian Vegetation
4. LTEMP Goal 1 Archaeological and Cultural Resources
5. LTEMP Experimental Vegetation Management

Sediment Remote Sensing

Project L: System wide detection of active river channel and sediment changes

(Associated with LTEMP performance Metric 7)



Classified Sand
8,000 – 25,000 cfs
25,000 – 45,000 cfs
(High elevation sand)

50 m



Overflight DSM
vertical changes

>1.5 m

0 m

<-1.5 m

Deposition
Erosion



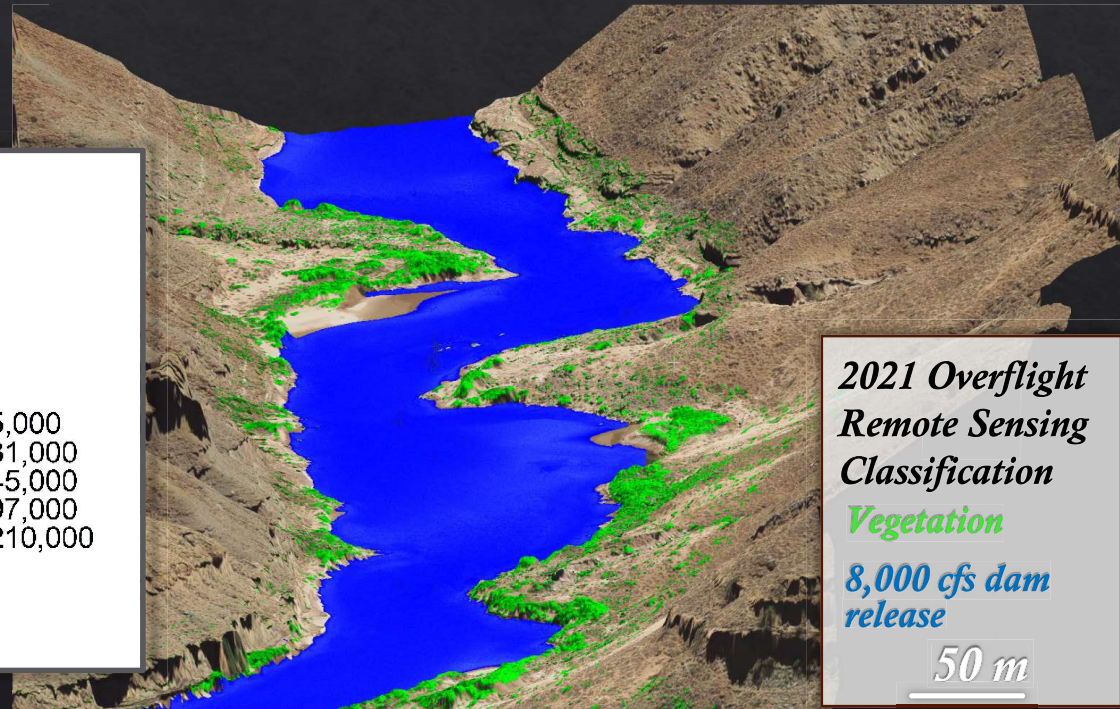
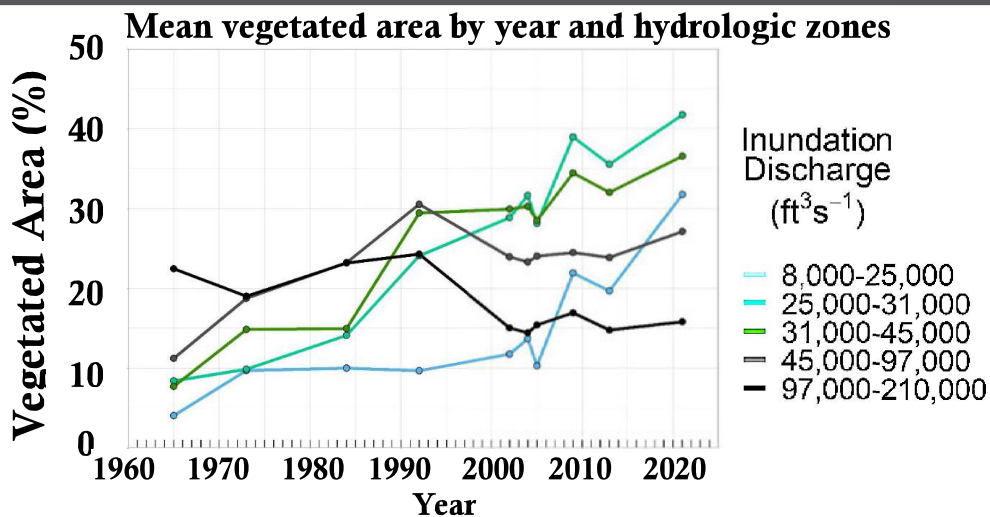
122 Mile Camp
2013 to 2021 surface changes



Vegetation Remote Sensing

Project L: System wide detection of riparian vegetation changes

(Associated with LTEMP performance Metric 11.1)



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Project C.4: Vegetation Induced Declines in Channel Width with Implications for Eddy Sandbar Dynamics in the Colorado River in Marble and Grand Canyons

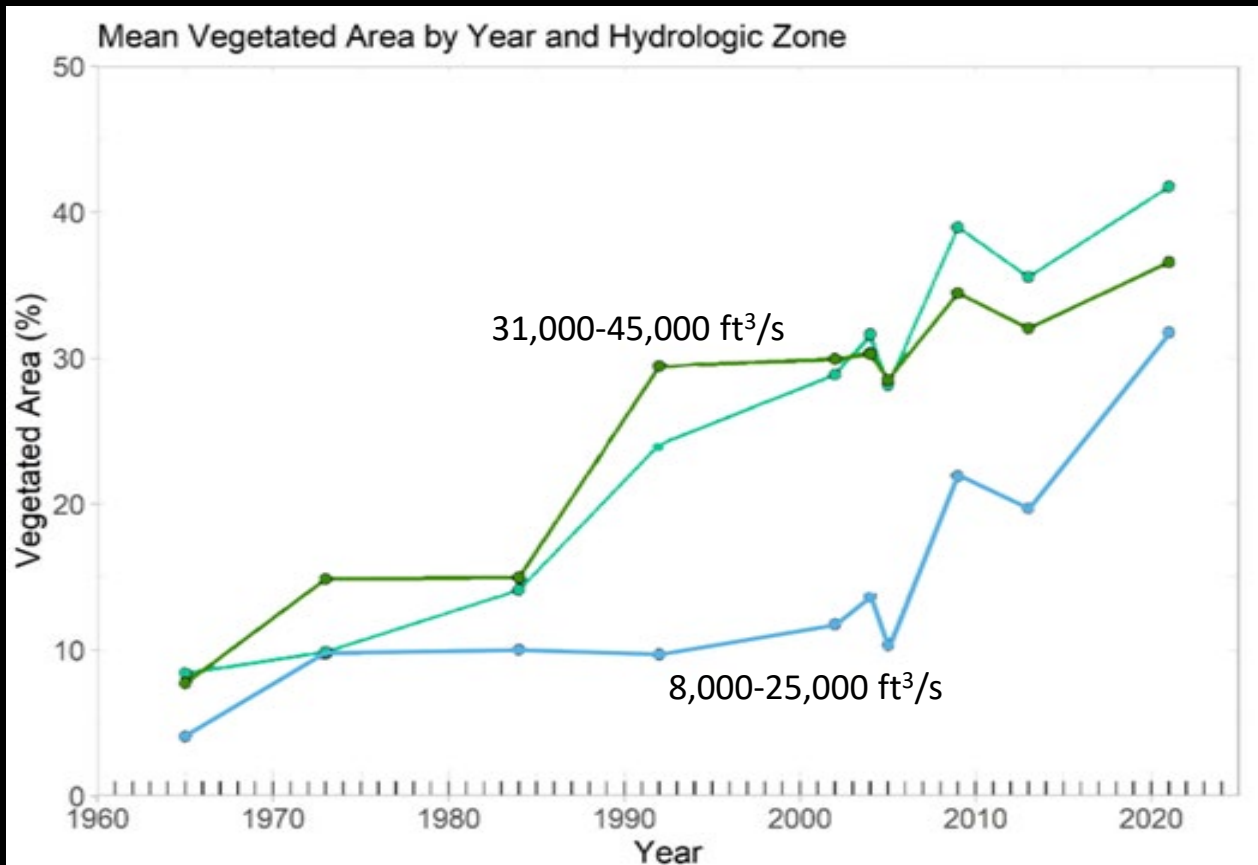
David Dean, Josh Caster, Joel Sankey, Paul Grams, Helen Fairley, Emily Palmquist
U.S. Geological Survey, Southwest Biological Science Center
Grand Canyon Monitoring and Research Center, Flagstaff, AZ

- Project Elements and Objectives
 - C.4.1 Biogeomorphic linkages between streamflow, sediment transport, and vegetation composition
- LTEMP Resource Goals:
 - Sediment
 - Riparian vegetation
- Multidisciplinary project integrating data from Projects B, C, D, and L



Riparian vegetation tracks large changes in river stage

Increase in baseflows and lack of flood disturbance = vegetation expansion
Between 8,000 ft³/s and 45,000 ft³/s stages.



Project C.4:

How has vegetation encroachment affected channel width?

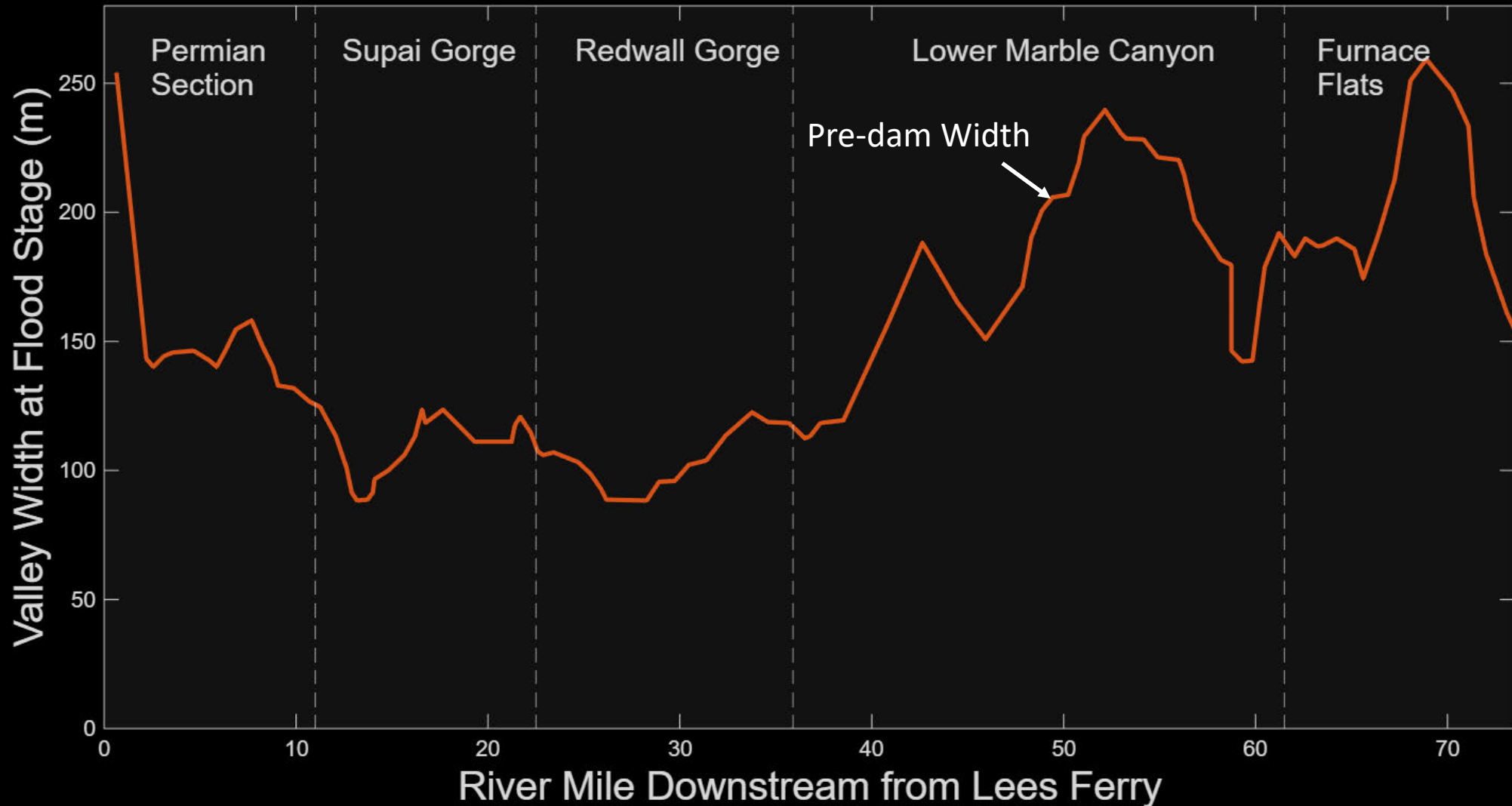
Has vegetation encroachment affected physical river dynamics?

Vegetation Encroachment and Channel Narrowing



Colorado River
43.9 miles
downstream
from Lees Ferry

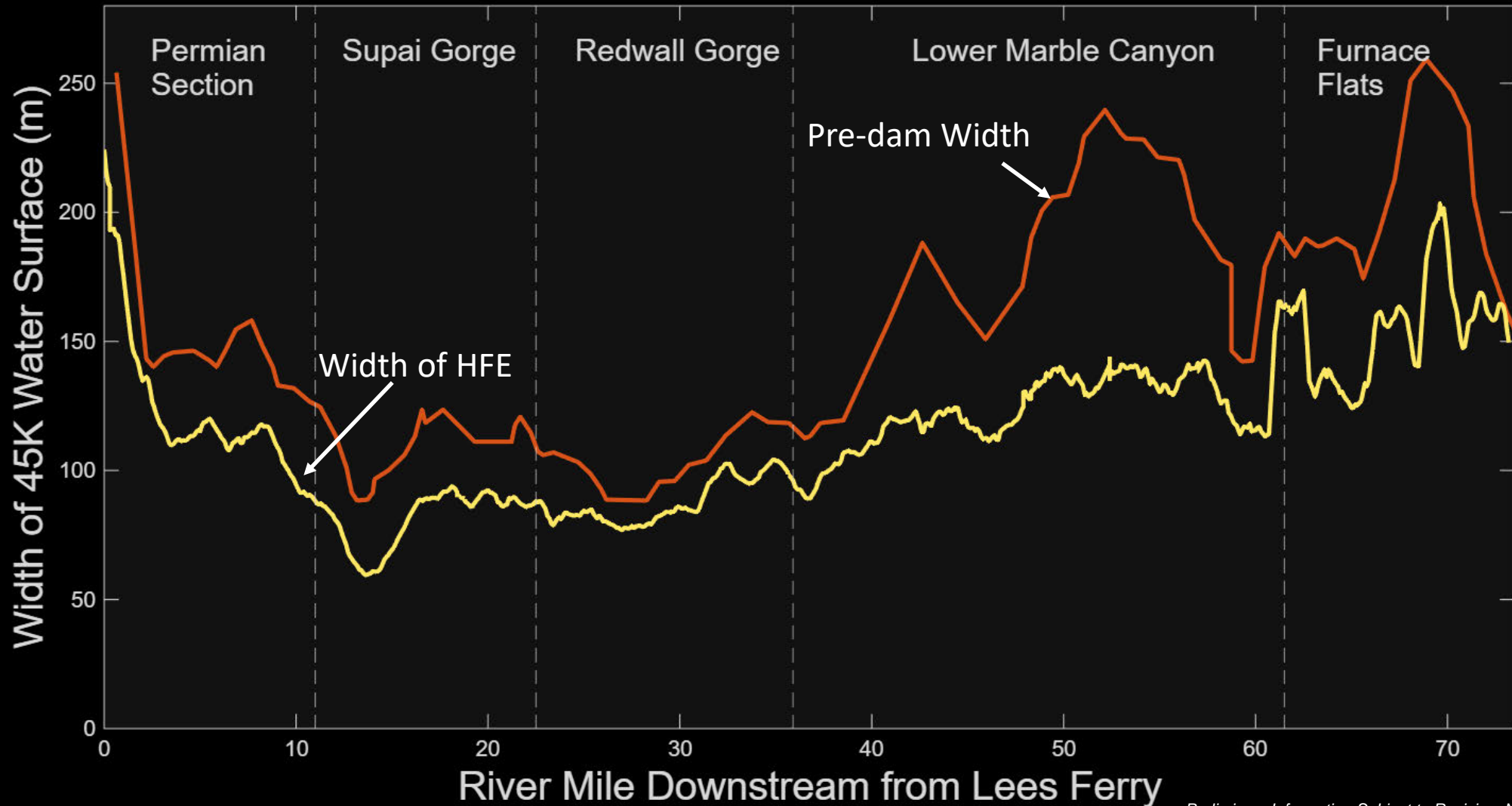
Changes in Channel Width



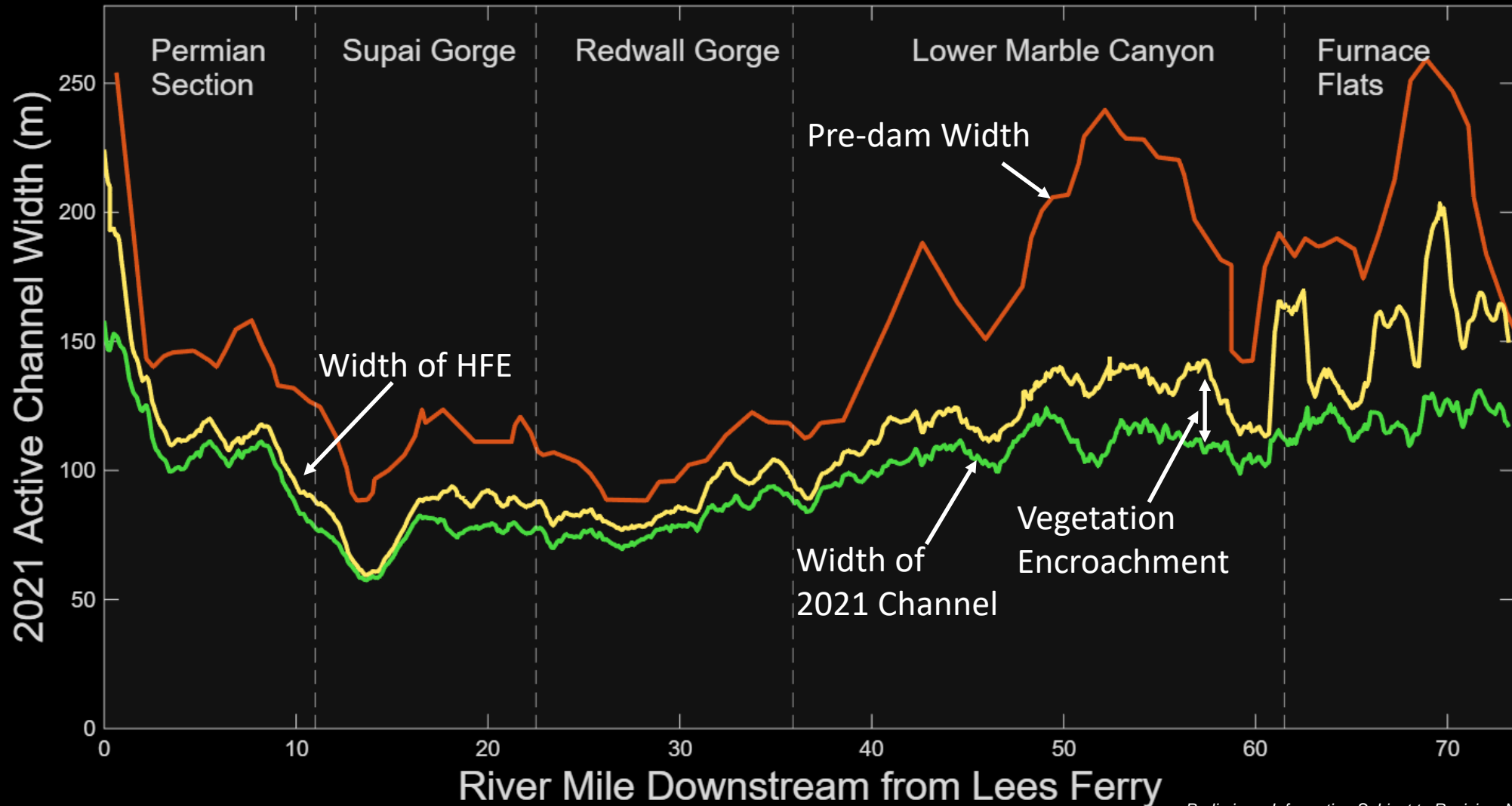
Howard &
Dolan, 1981



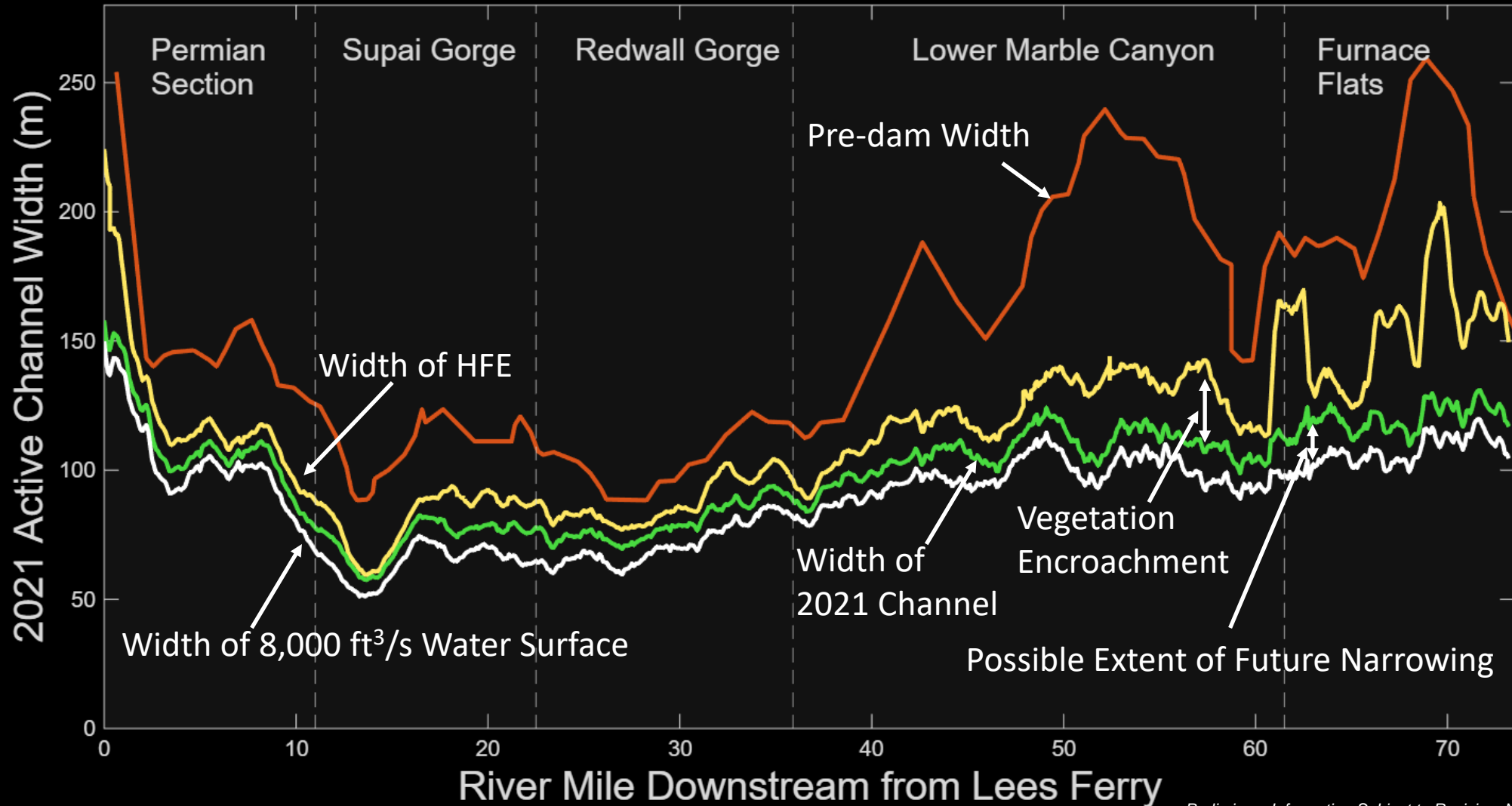
Changes in Channel Width



Changes in Channel Width



Changes in Channel Width



Project C.4 Summary

Reduced peak flows (loss of disturbance) + Increased baseflows

=

Vegetation encroachment and channel narrowing

- 1963 – 2021 – narrowing of ~23.5m or ~28.4%
- Further narrowing is likely; additional ~10m or ~10% is possible
- Loss of aquatic (e.g., fish) habitat
- Loss of eddy sandbar dynamics
- Implications for sandbar responses to HFEs

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Goal 11 Riparian Vegetation

Emily Palmquist¹, Brad Butterfield², Nathaniel Bransky², Joel B. Sankey¹

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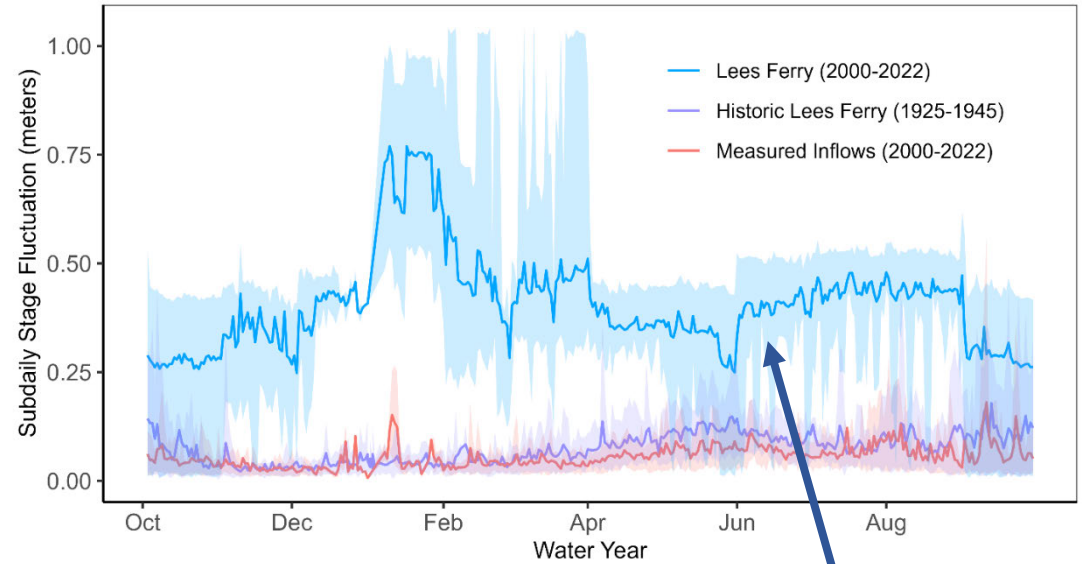
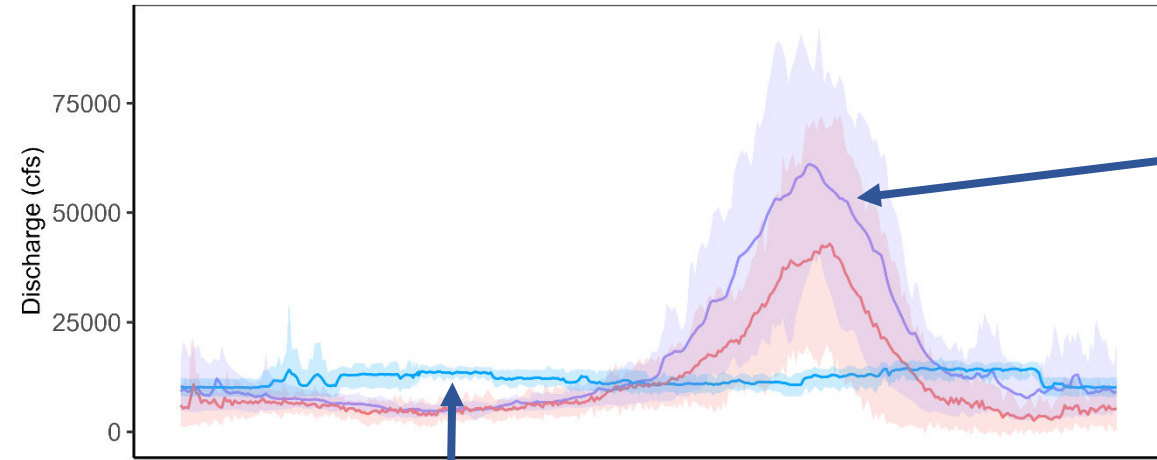
² Northern Arizona University



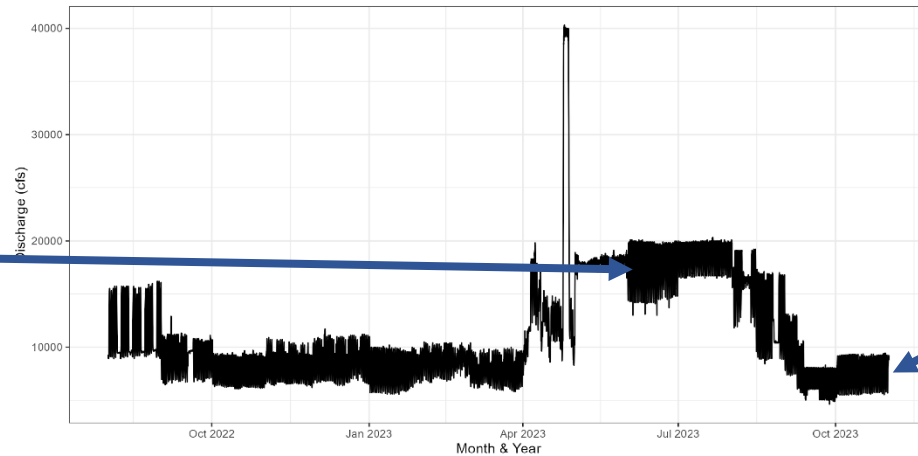
Plants are controlled by river flow

A

— 1925-1945 Lees Ferry — 2000-2022 Lees Ferry — 2000-2022 Powell Unregulated Inflows



High/low flow seasons

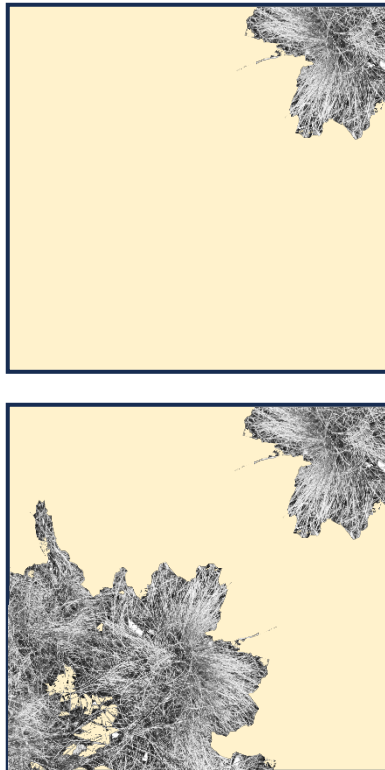


Butterfield and others, 2023;
Butterfield and Palmquist, 2025;
Mahoney and Rood, 1998;
Palmquist and others, 2025;
Poff and others, 1997;
Discharge data from U.S.
Geological Survey, 2026

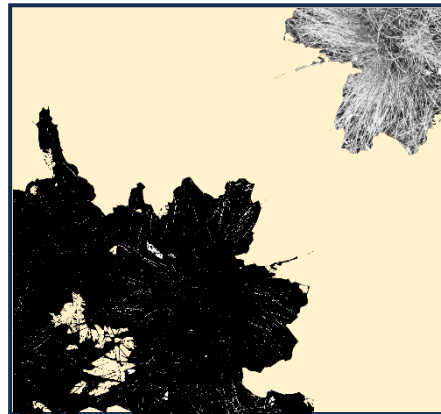
Goal 11: Riparian Vegetation

*Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are **diverse**, healthy, **productive**, self-sustaining, and **ecologically appropriate**.*

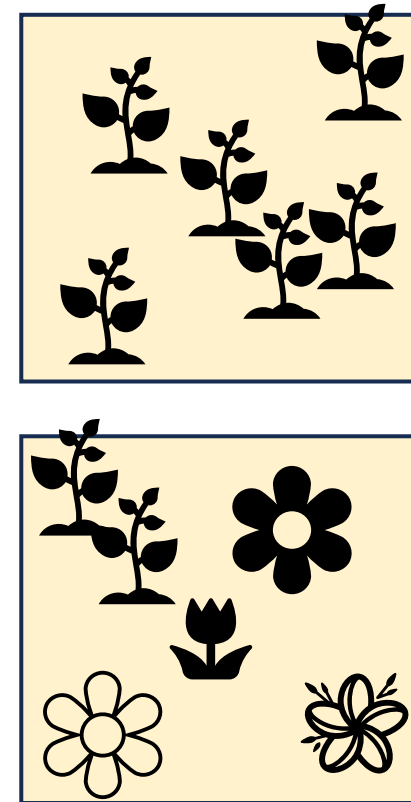
Metric 11.1 Total Living Plant Cover



Metric 11.2 Proportion Native Cover

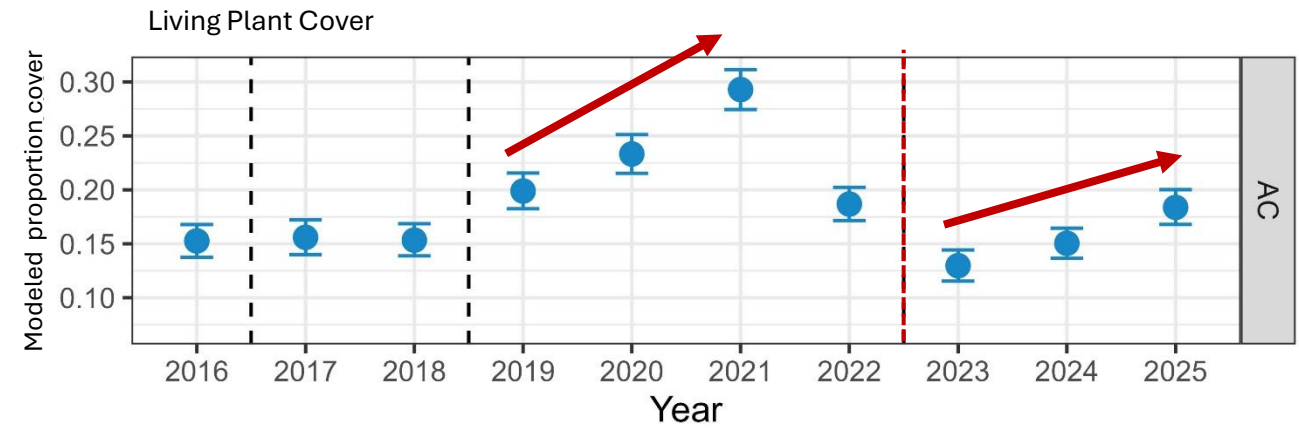
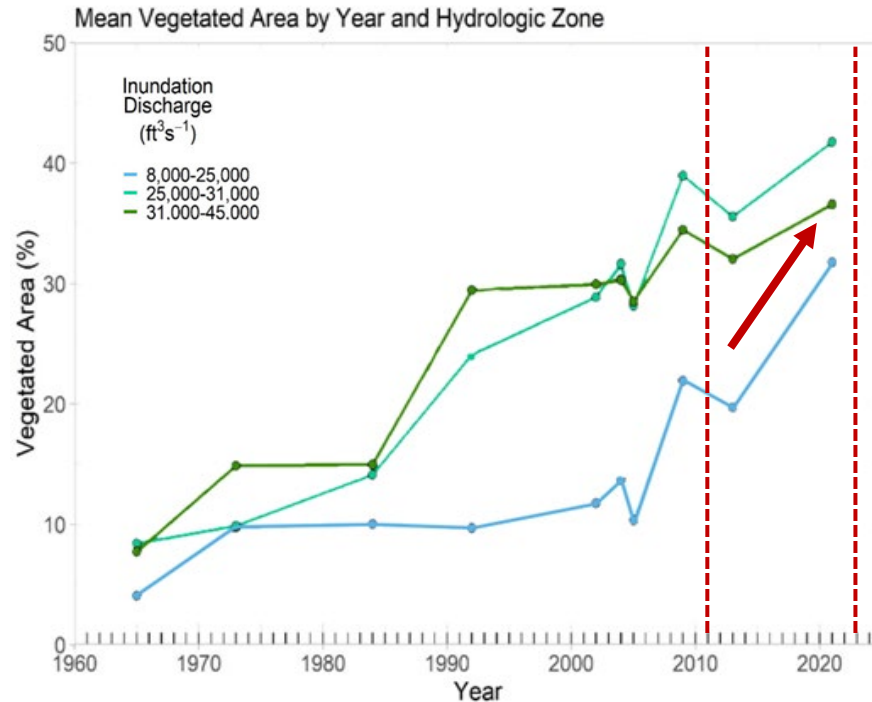
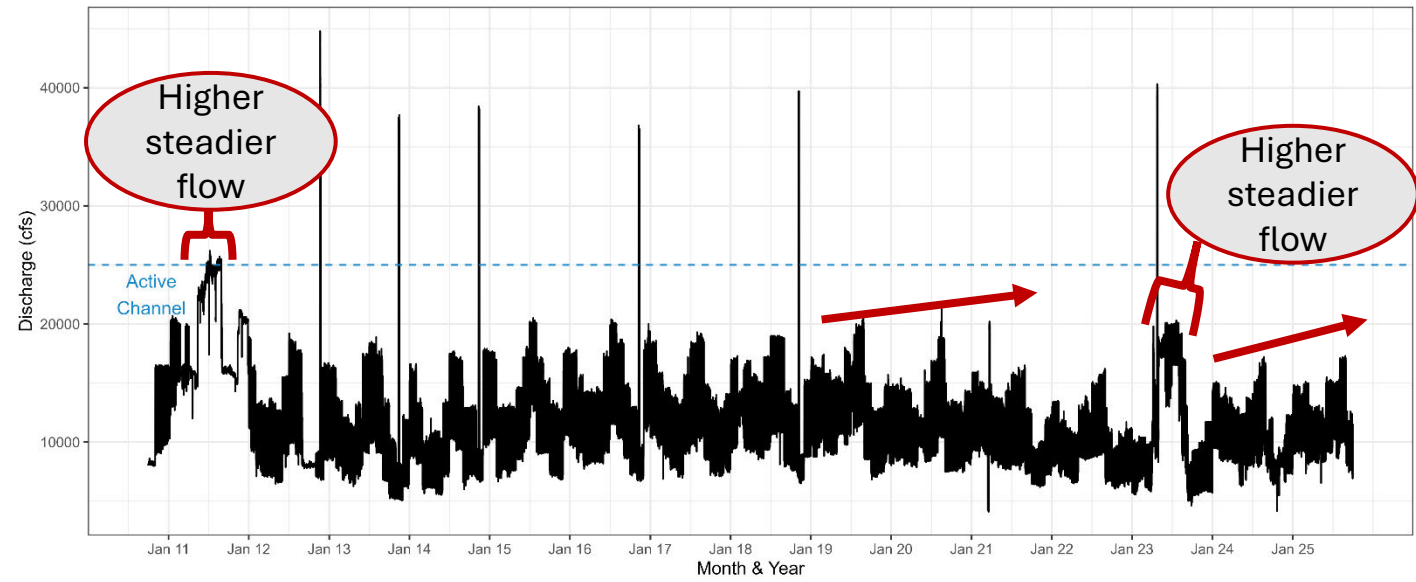


Metric 11.3 Native Species Richness



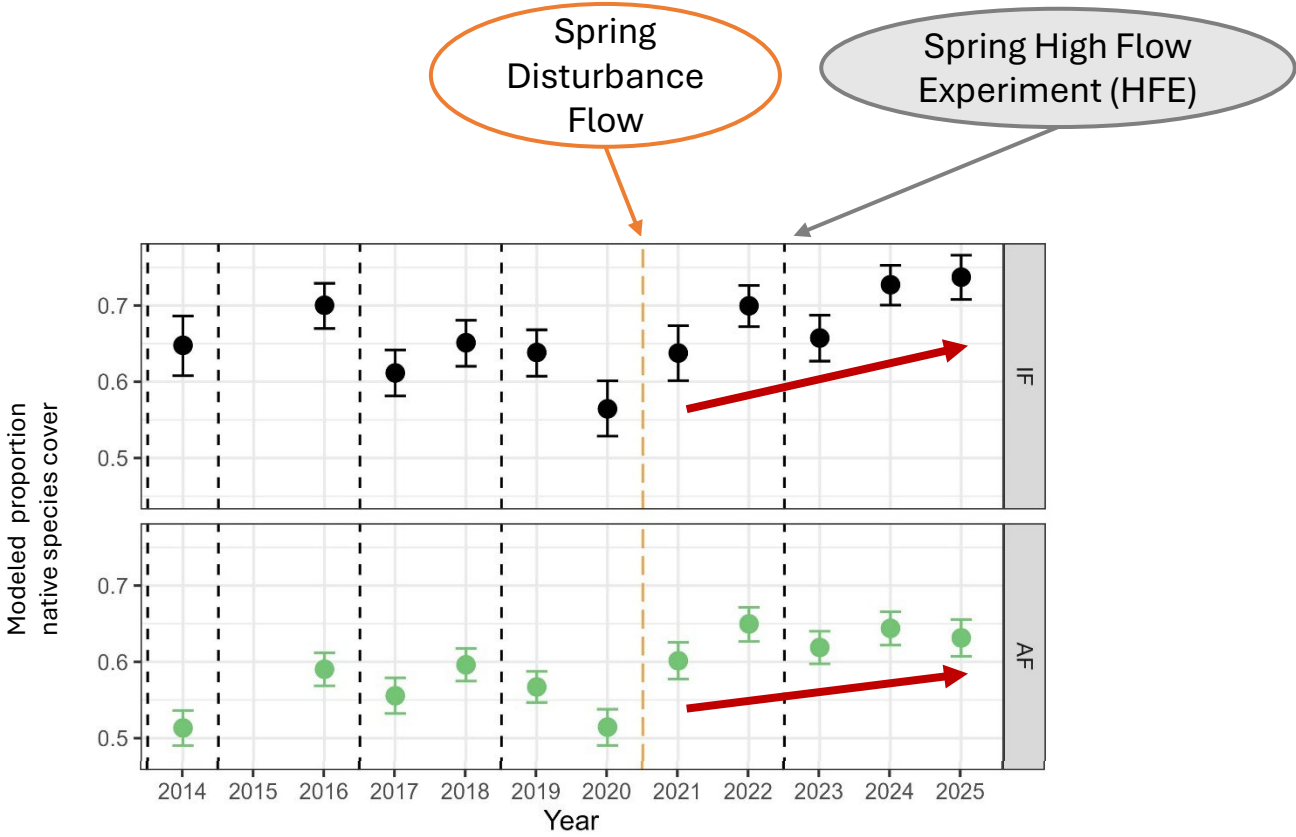
Metric 11.1 Total Living Plant Cover

- Declines with longer periods of higher, steadier flows
- Increases with predictable daily peak flows and without high flow experiments
- Increasing currently



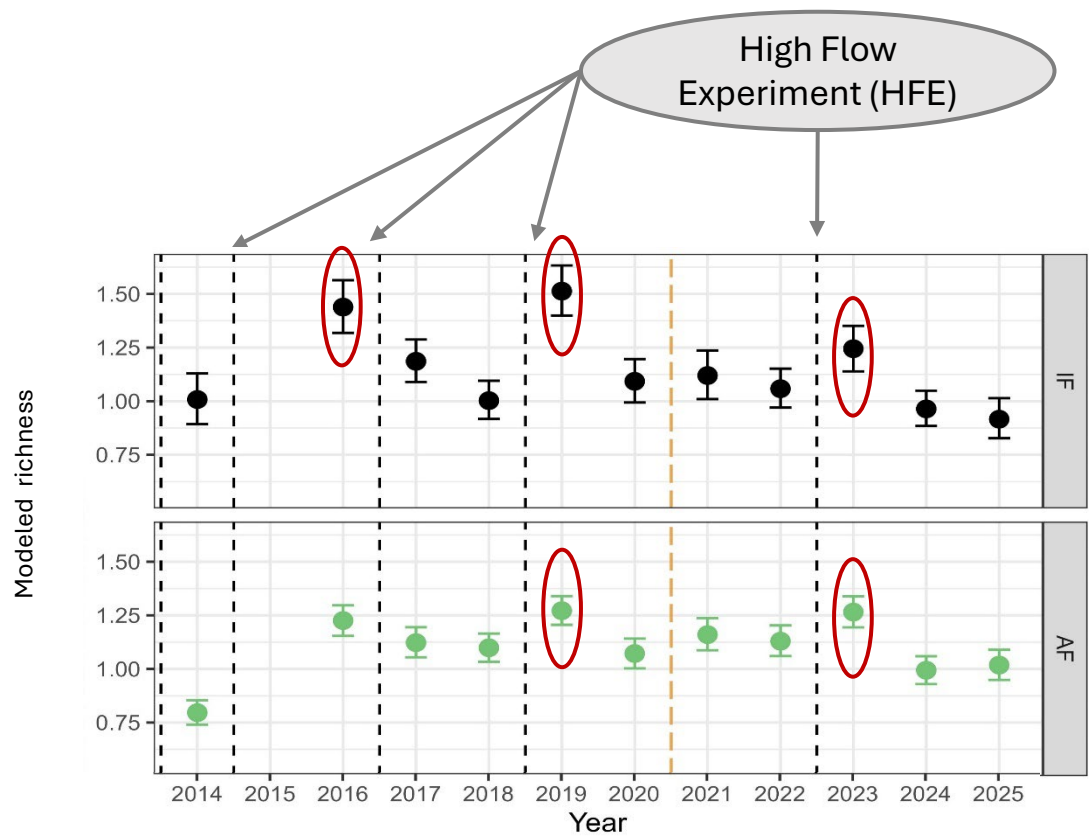
Metric 11.2 Proportion Native Cover

- Spring disturbance may increase proportion native species
- Higher recently



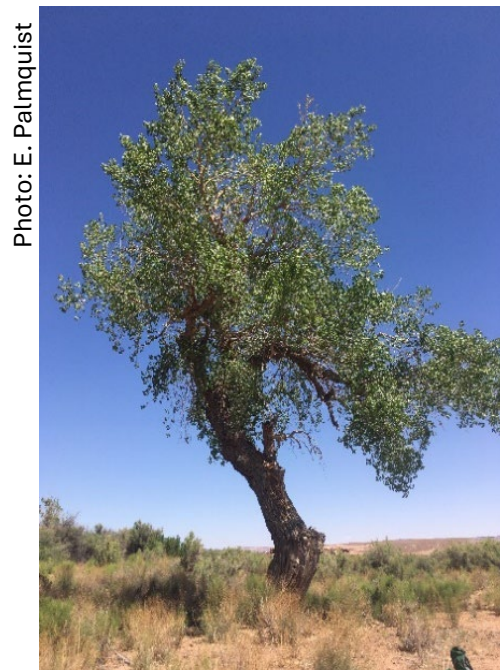
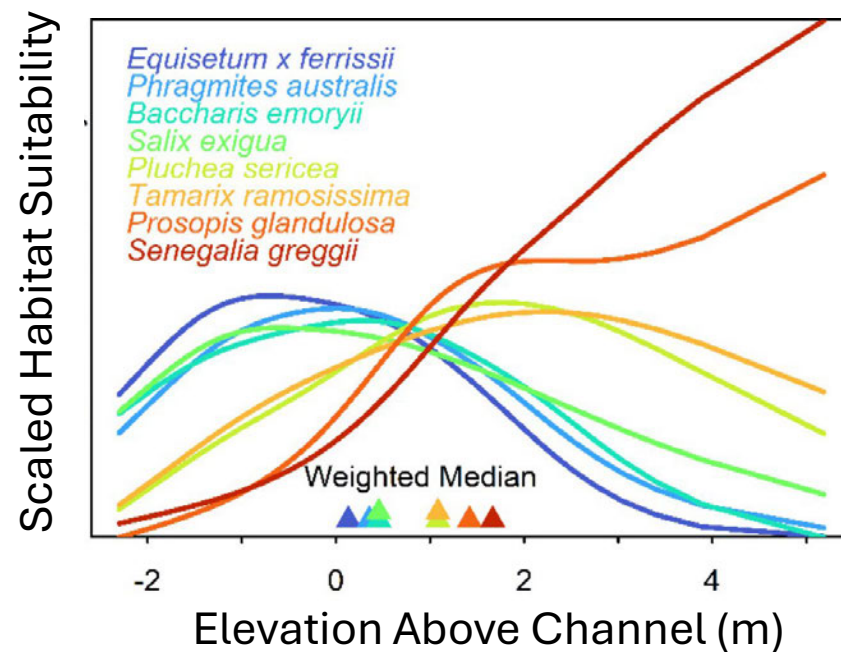
Metric 11.3 Native Species Richness

- High flow experiments can increase richness
- Declines between HFEs



Plant species do not respond in the same way to river flow changes.

- Recorded almost 400 species, ~ 40 of which are common
- Metrics summarize overall patterns, but hide individualistic responses



Butterfield and Palmquist, 2024ab;
Butterfield and Palmquist, 2025;
Palmquist and others, 2023a;
Palmquist and others, 2025

We have conducted research on species responses to river regulation for many species.

- We can attribute effects of specific dimensions of streamflow to habitat suitability for some of these species
- Can make some inferences based on ecological similarities/differences among species
- Case Study: arrowweed (*Pluchea sericea*)
 - Likes it not too wet, not too dry
 - High monthly summer flows improve habitat suitability
 - Daily fluctuations exclude arrowweed from near channel habitat
 - Likes sand!! HFEs support habitat.

Butterfield and others, 2020;
Butterfield and others, 2023;
Butterfield and Palmquist, 2024a;
Butterfield and Palmquist, 2024b;
Butterfield and Palmquist, 2025;
Palmquist and others, 2023b
Palmquist and others, 2025

Photo: Freshwaters Illustrated



Photo: B. Butterfield



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Goal 1 Archaeological Sites and Cultural Resources

Helen Fairley¹, Joshua Caster¹, Joel B. Sankey¹

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¹ U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center

² Northern Arizona University

Goal 1 Archaeological Sites and Cultural Resources

- Cultural sites are embedded in sediment derived from the Colorado River
- Loss of sand leads to loss of human history



LTEMP Goal 1

- *Maintain the integrity of potentially affected NRHP-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis.*

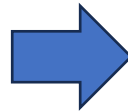
Three metrics are used to evaluate whether the goal for archaeological sites and cultural resources is being achieved:

- *Metric 1.1 Current Integrity Status*
- *Metric 1.2 Topographic Change at a Sample of Sites*
- *Metric 1.3 Change in Vulnerability to Loss of Integrity*

Metric 1.1: Current Integrity Status

- Simple accounting of the number of sites that have lost integrity since start of LTEMP

- Integrity is “the ability of a historic property to convey its significance”
- Integrity is a professional judgment, determined by land managers
 - NPS
- Integrity is either present or absent
 - no degrees
- Integrity differs from condition
 - Site condition can deteriorate while retaining integrity

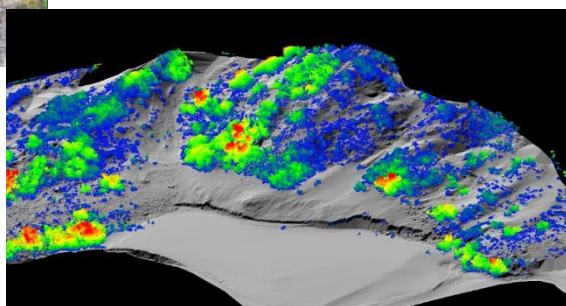


Current Integrity Status:

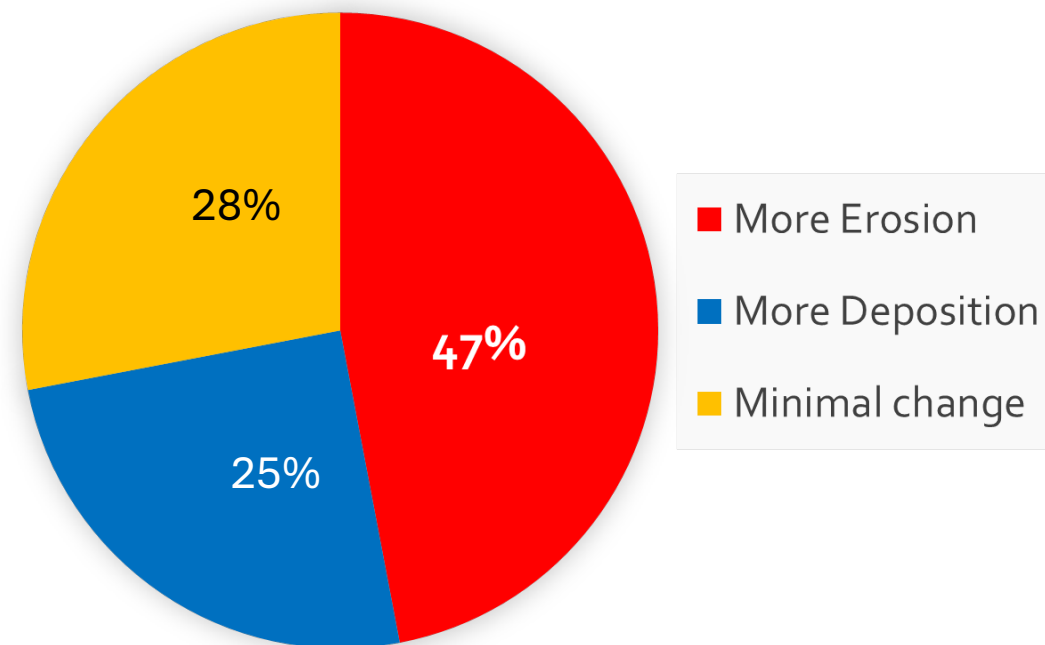
No historic properties within the Area of Effect from dam operations have lost integrity since the start of LTEMP.

Metric 1.2: Topographic Change at a Sample of Sites

- Evaluates the amount of net deposition or erosion measured at a sample of sites
- Relies on lidar survey measurements of topographic change that are collected approximately once every 3 years

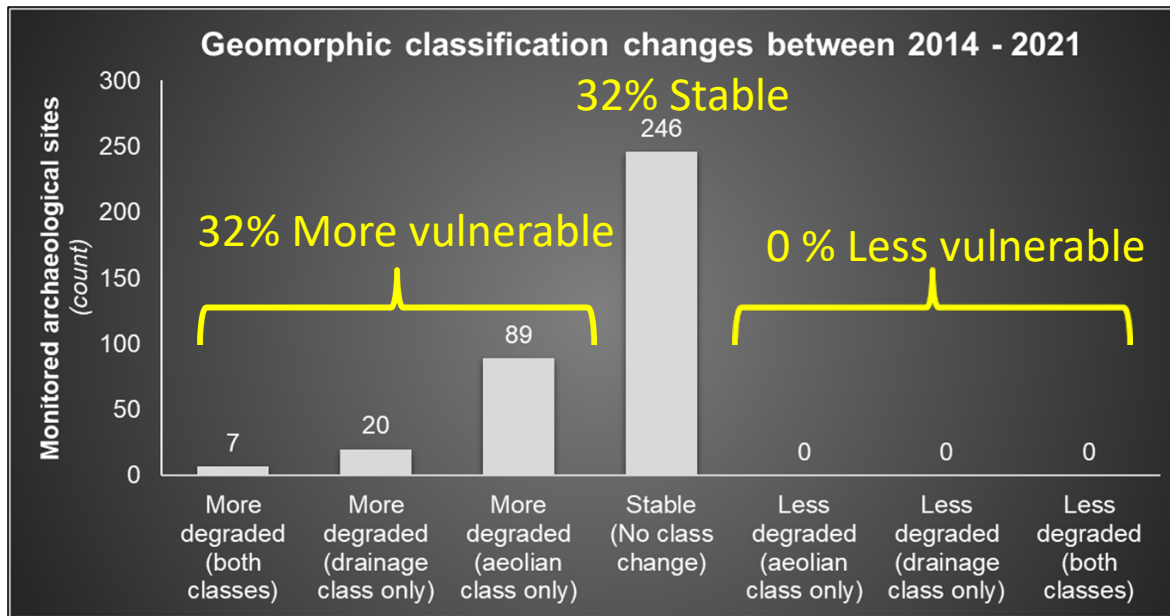


Percentage of Sample Sites (n=36) with
Topographic Change by Type

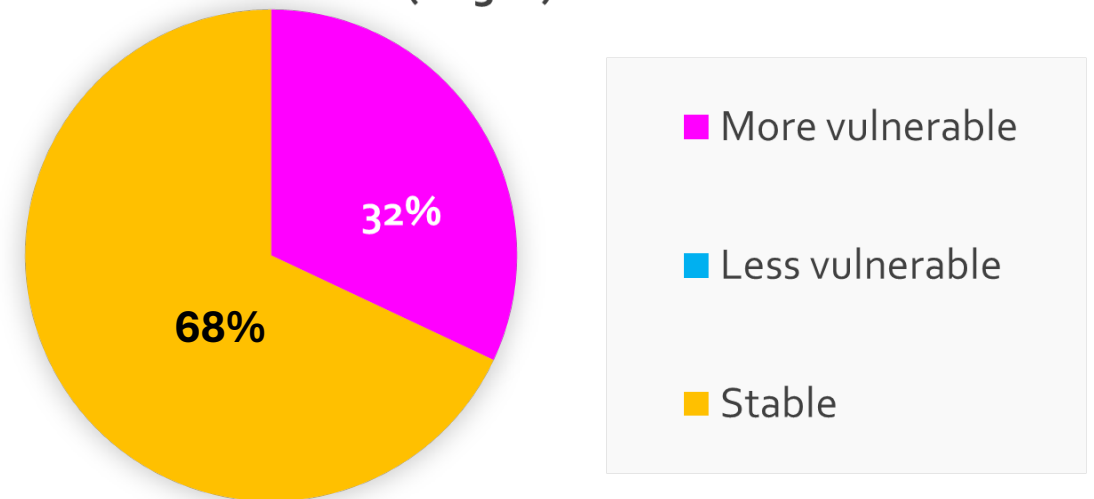


Metric 1.3: Change in Vulnerability to Loss of Integrity

- Combines two classification schemas that reflect effects of dam operations on key geomorphic characteristics of archaeological sites that affect sites' preservation potential
- The geomorphic characteristics tend to change slowly; therefore, they are re-evaluated only once every 5-10 years



Change in Vulnerability of Total Site Population (N=362)



Goal 1 Archaeological Sites and Cultural Resources

Summary of All Metrics

- Integrity status of archaeological sites and other historic properties has not changed since 2017
- Many sites are eroding, along with the Colorado River-derived sediment matrix that helps to preserve sites *in situ*
- Many archaeological sites are more vulnerable to future loss of integrity
- Erosion is counter to management goal to maintain or improve archaeological site condition
- Environmental management opportunities: floods, low flows, riparian vegetation management

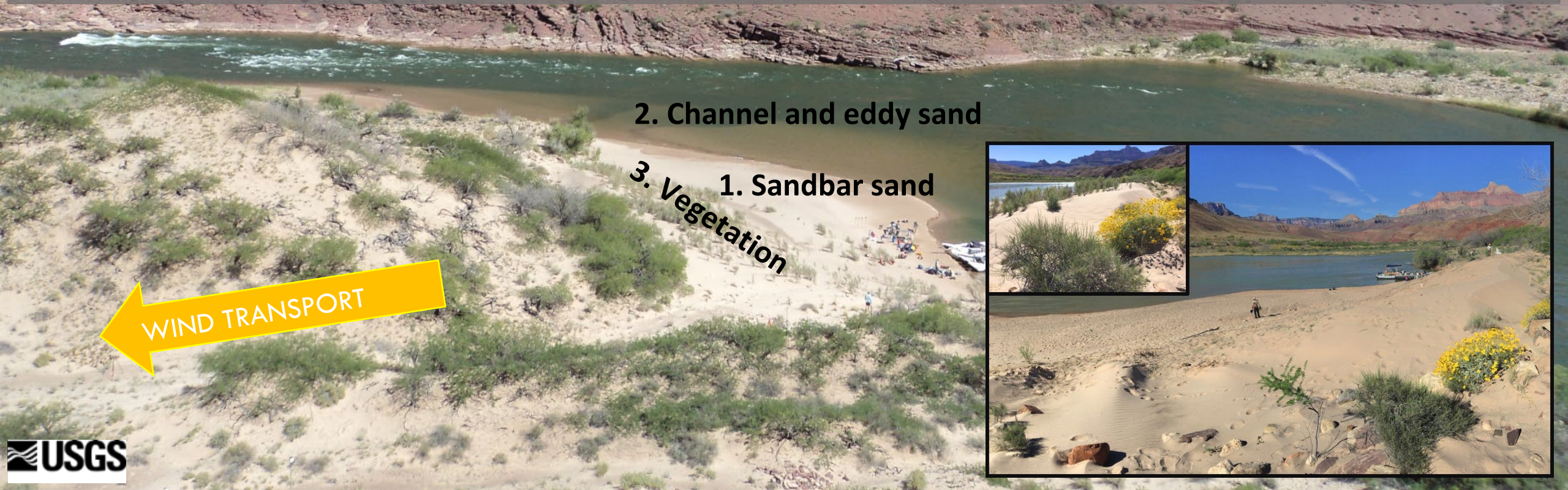
Experimental management to increase river-sourced sand supply to dunefields and archaeological sites

Increase aeolian (wind) sediment supply:

1. High Flow Experiment (HFE) dam releases to rebuild river sandbars (*Sankey and others, 2018, Aeolian Research*)
2. Lowering dam releases to expose sand that is normally underwater in the river channel & eddies (*Sankey and others, 2022, JGR-ES*)

Minimize vegetation blocking aeolian (wind) sand transport:

3. Vegetation-management to remove riparian vegetation on sandbars (*Pilkington and others, 2022, Park Science*)



2. Channel and eddy sand

1. Sandbar sand

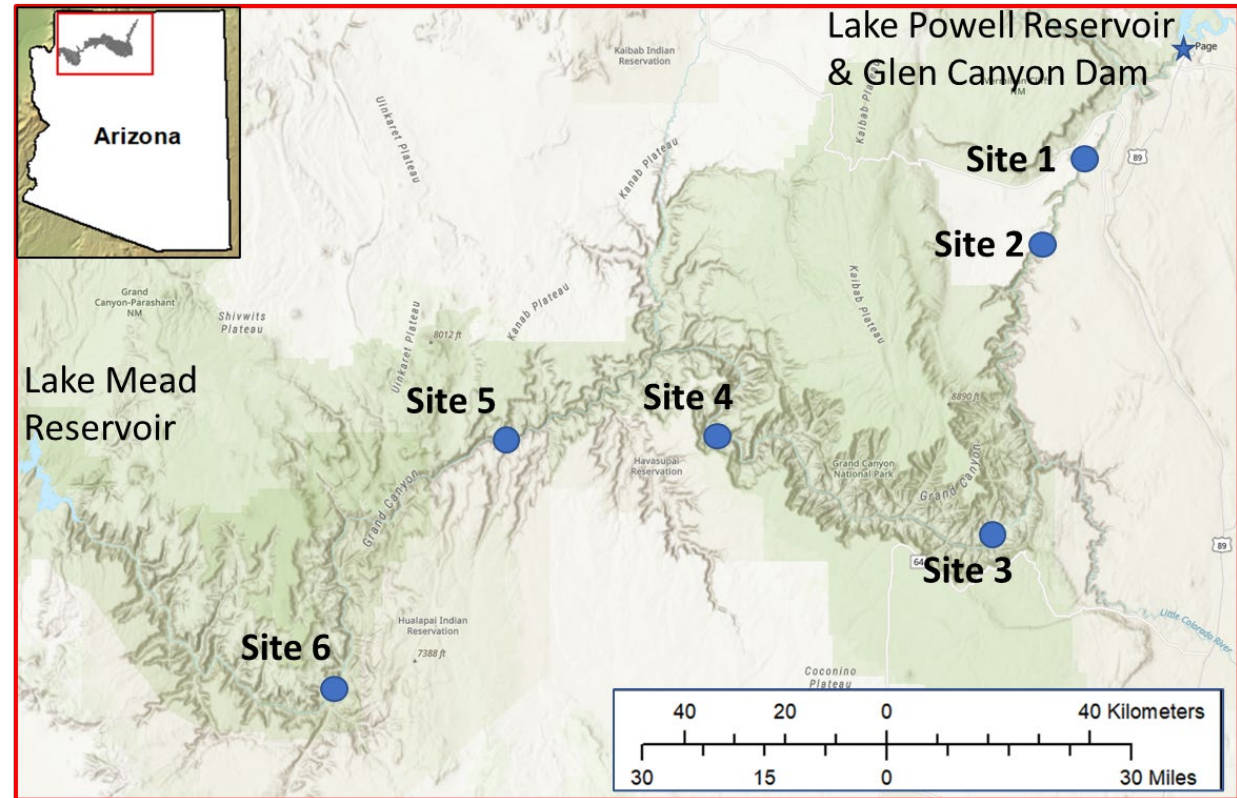
3. Vegetation

WIND TRANSPORT

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Colorado River in Grand Canyon National Park

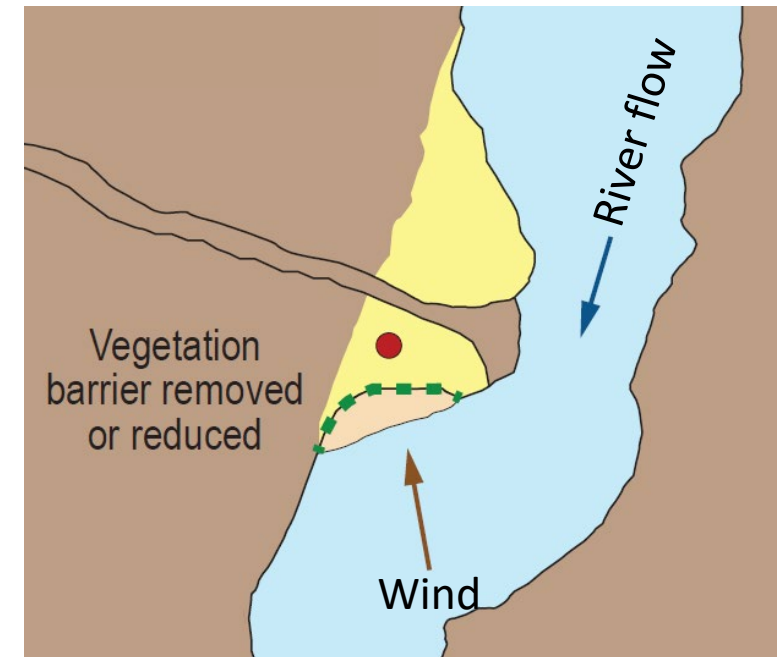


LTEMP Experimental Vegetation Management

- National Park Service sandbar vegetation removal annually since 2019
- High Flow Experiment (HFE) dam releases in November 2018 and April 2023
- USGS monitoring pre-2019 (baseline) and annually since

LTEMP Experimental Vegetation Management Science Question

- Does removal of riparian vegetation barriers located between river sandbars and dunefields increase the resupply of wind transported river sediment?

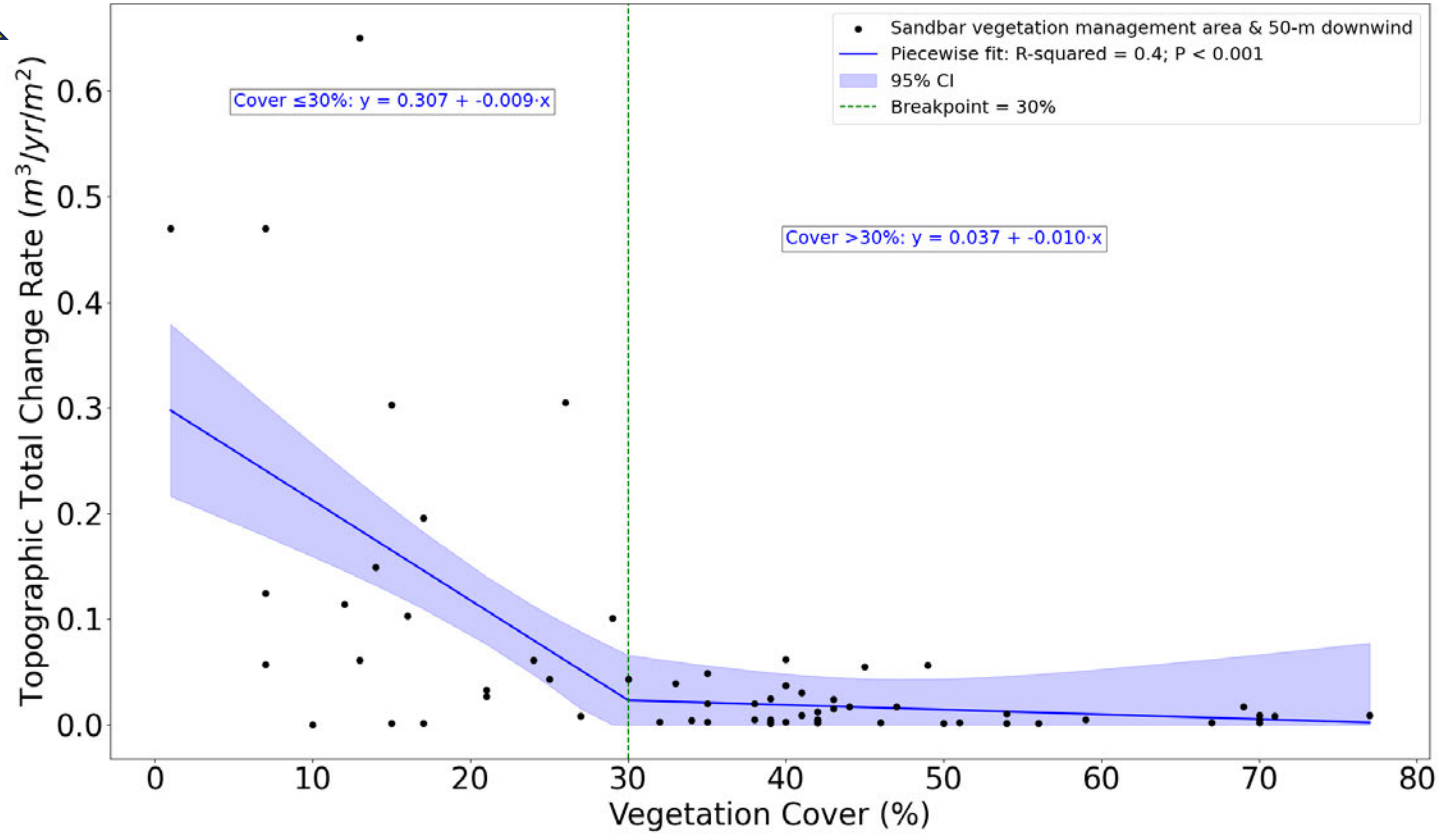


LTEMP Experimental Vegetation Management Results

Following sandbar vegetation removal:

1. Vegetation cover ↓
2. Sediment erodes on sandbars and deposits in downwind dunefields
3. Sediment mobility ↑
4. ↓ Cover = ↑ Sediment mobility

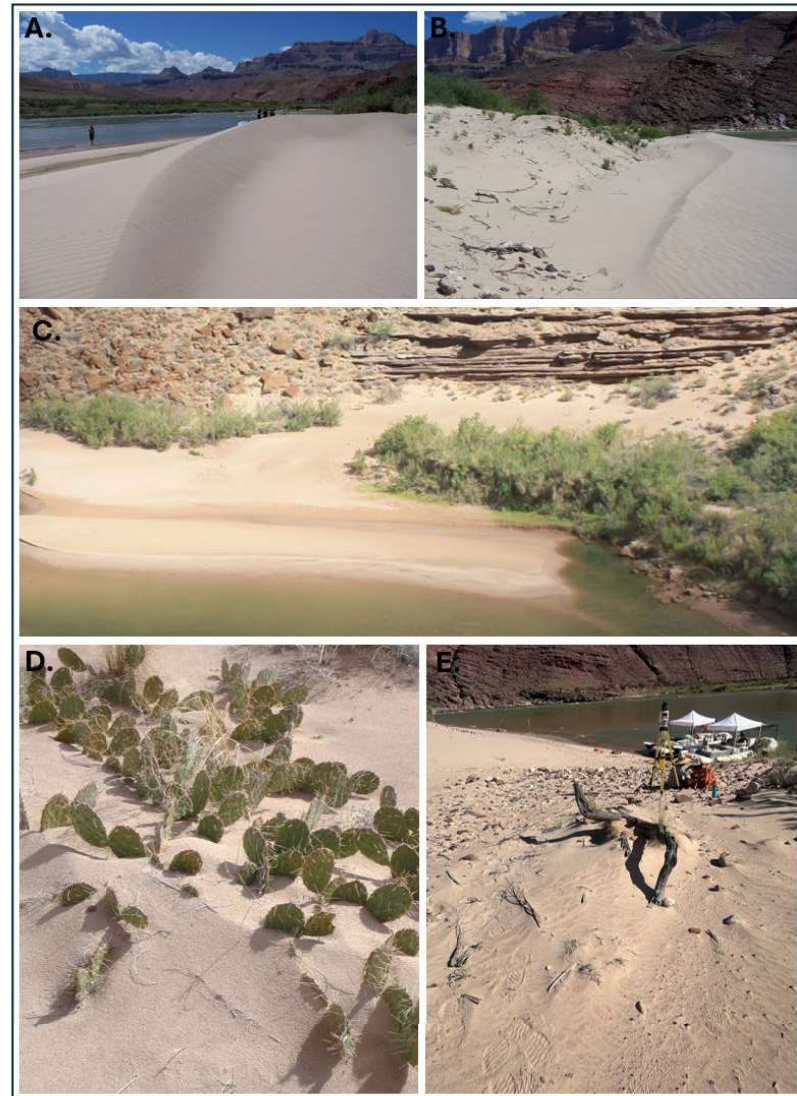
↑ Increasing Sediment Mobility



← Decreasing Vegetation Cover

LTEMP Experimental Vegetation Management Key Points

- Regular implementation of HFEs needed to resupply river-sourced sand to sandbars
- Riparian vegetation removal on sandbars can increase wind transport of river sand to dunefields and archaeological sites when implemented frequently
- Reducing sandbar plant cover to low level (>0 %, <30 %) allows for wind transport while maintaining vegetation



Thank you for listening!

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