Updates on recent learning from Project D

- **Glen Canyon Dam Adaptive Management Program Annual Reporting Meeting**
- **April 8-9, 2025**
- **Helen Fairley, Joel B. Sankey, Joshua Caster, Lauren Tango, Madeline Kelley**
- **U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center**

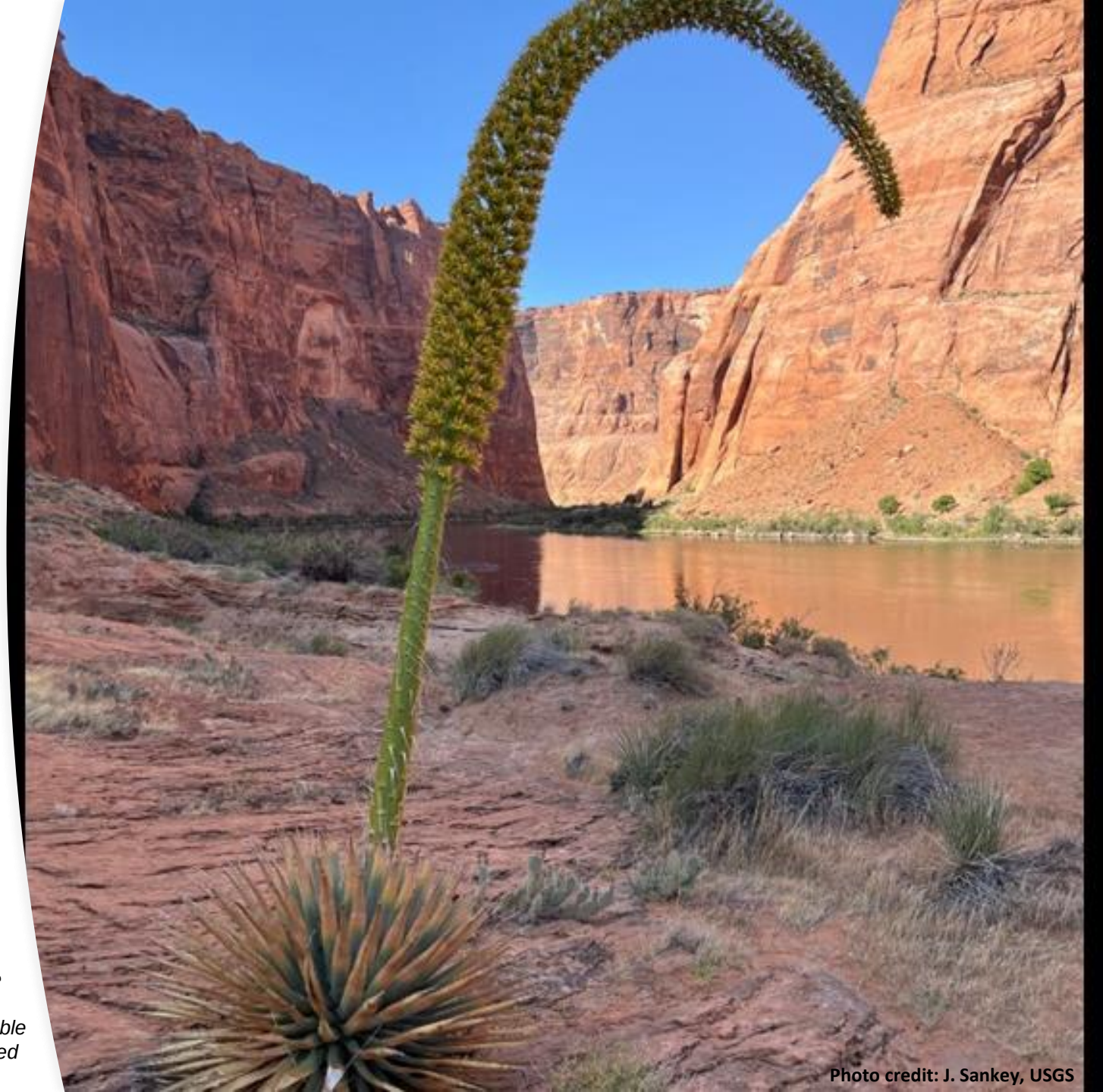

Photo credit: J. Sankey, USGS

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FY 21-24 TWP Projects: Archaeological and Cultural Resources

Triennial Workplan (TWP) projects collectively examine whether and how dam operations and experiments like HFEs, vegetation management, and site management by NPS help to achieve the LTEMP goal of preservation in place.

- GCMRC TWP
  - **Project D: Dam Operations, Vegetation Management, Archaeological Sites (USGS, Sankey, Fairley)**
    - FY2021/2022/2023/2024 ($258k/250k/266k/$349k)
- Reclamation TWP
  - Project D.3. Cultural Resources Monitoring – Grand Canyon (NPS, Ellen Brennan, Jennifer Dierker) and Glen Canyon NRA (NPS, Amy Shott)
  - Project C.7. GRCA Experimental Vegetation Treatment (NPS, Lonnie Pilkington)

Photo credit: J. Caster (USGS)

Project D Activities During FY2024

- Finalized analysis and interpretation of monitoring data acquired in FY2023
- GLCA archaeological site lidar monitoring
  - June and July 2024
- GRCA archaeological site lidar monitoring
  - September 2024
- Collaboration with GRCA NPS LTEMP Experimental Vegetation Management
- Modeling to support NPS, BOR, Post-2026
  - [Funded by BOR and NPS, not GCDAMP. Leverages Project D data and expertise]

Photo credit: J. Caster (USGS)

Presentation Outline

1. Background
2. GLCA monitoring
3. GRCA monitoring
4. LTEMP Experimental Vegetation Management
5. Modeling
6. Project D Next Steps

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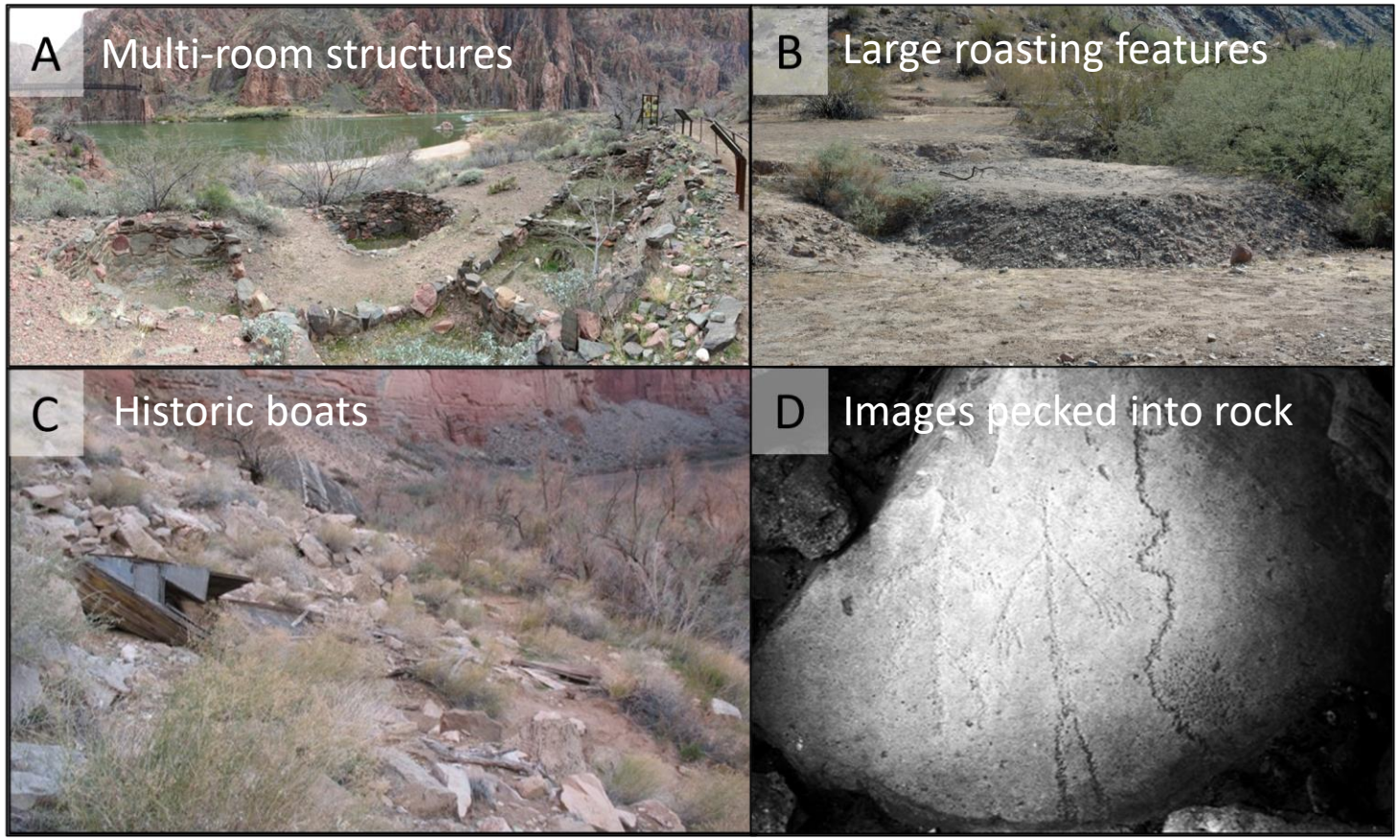
Human Activity and Archaeology Along the Colorado River in Grand Canyon

- People have occupied and used resources in Grand Canyon for at least 9,000 years
  - Indigenous peoples have inhabited the Canyon region periodically since time immemorial
  - European explorers first visited the Canyon ~480 years ago
- Today, evidence of ancestral peoples and recent historic activities is displayed in 100s of archaeological sites along the river in Grand Canyon National Park
- Many sites are deteriorating due to dam operation effects (lack of floods, vegetation encroachment, loss of sediment) and other factors (rainfall run-off, and visitor impacts)



A. Prehistoric hearth in alluvial cutbank

B. Prehistoric bowl exposed by rainfall-runoff

C. Slab structure in gully

D. Fire-altered rock exposed by wind deflation

Photo credits: J. Dierker and other National Park Service staff

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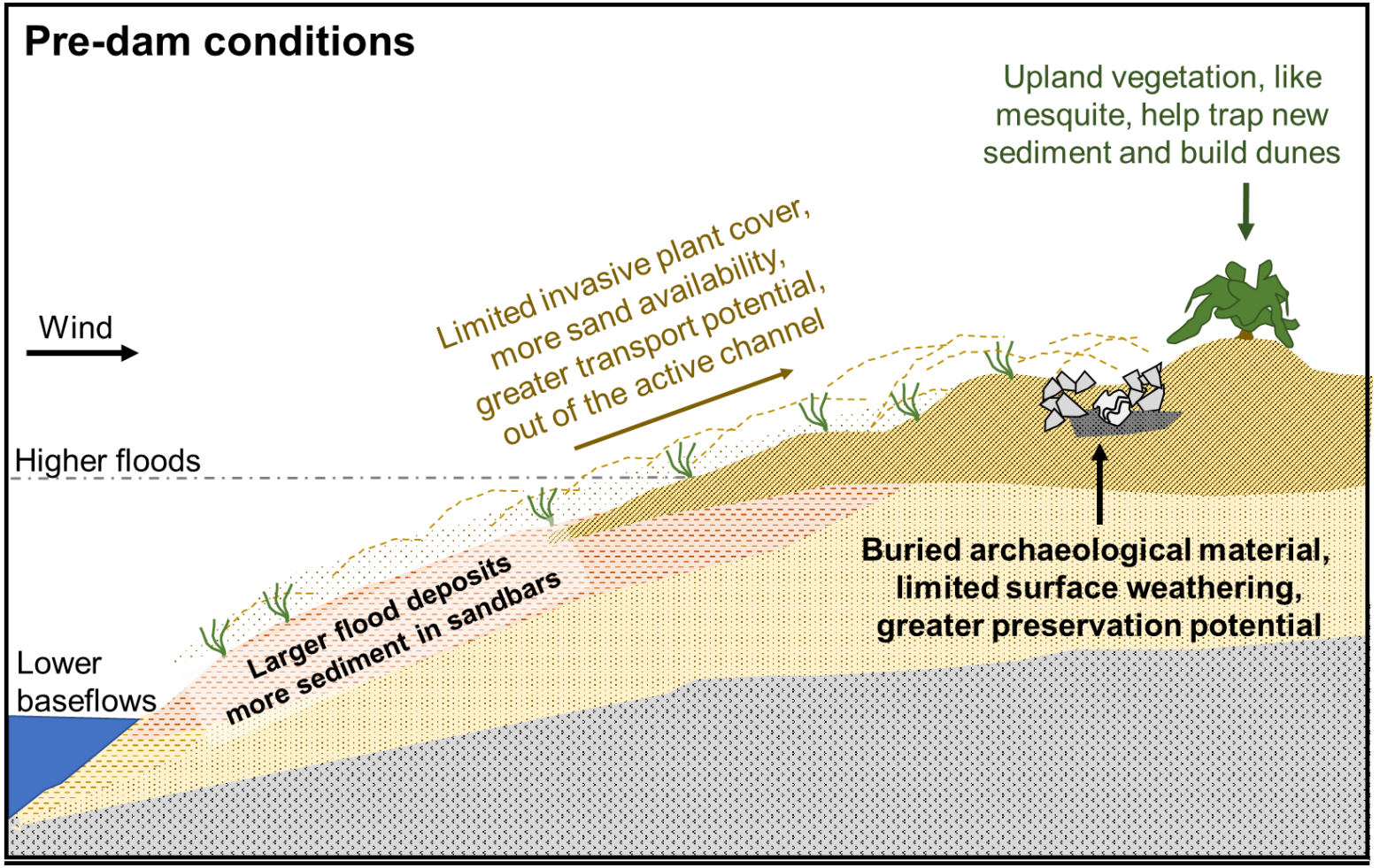
River management and archaeological site preservation

- Long term reduction in sediment supply and increase in riparian vegetation since closure of Glen Canyon Dam has increased archaeological site erosion and decreased preservation potential



Sankey et al., 2023, Journal of Environmental Management

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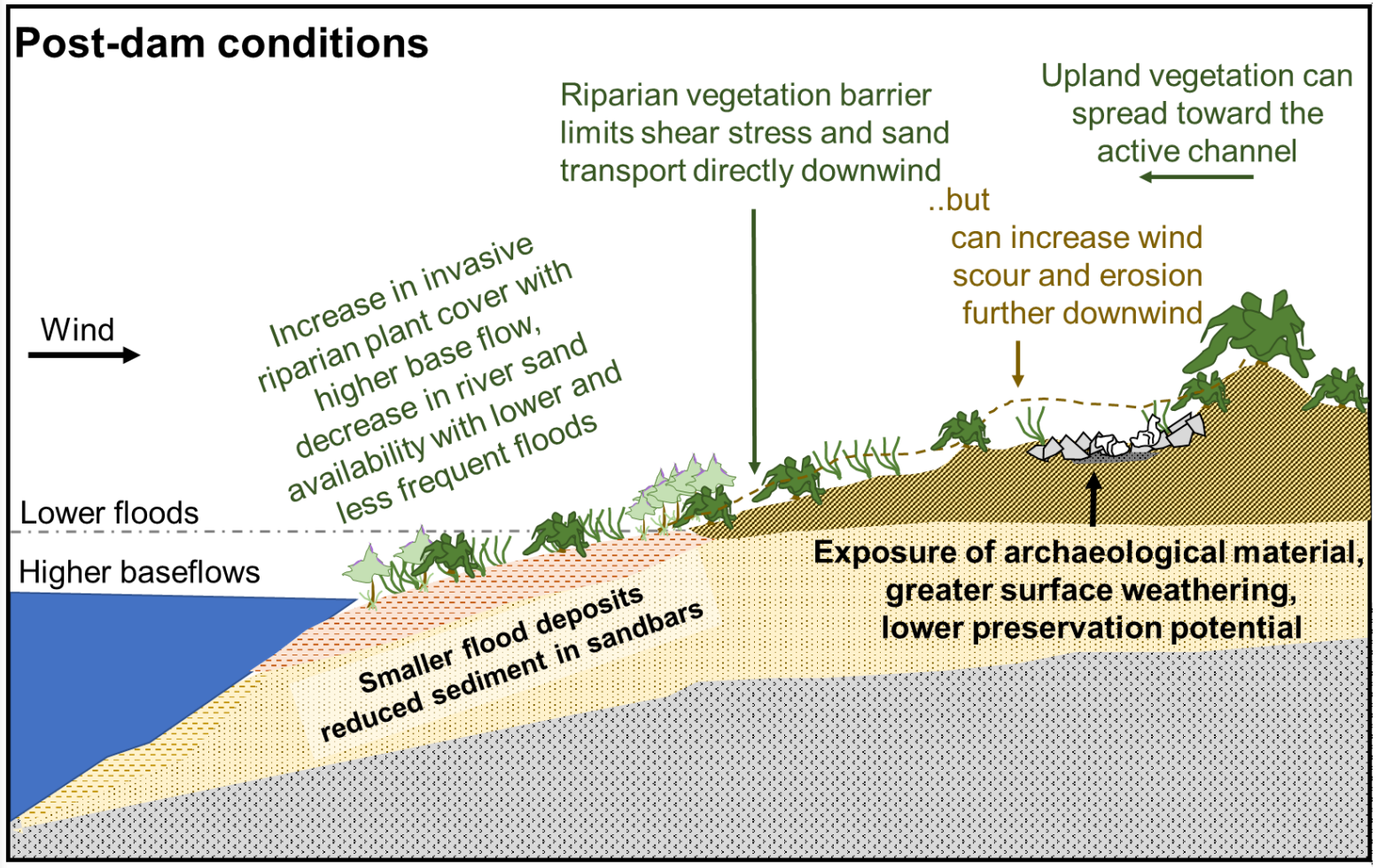

Sankey et al., 2023, Journal of Environmental Management

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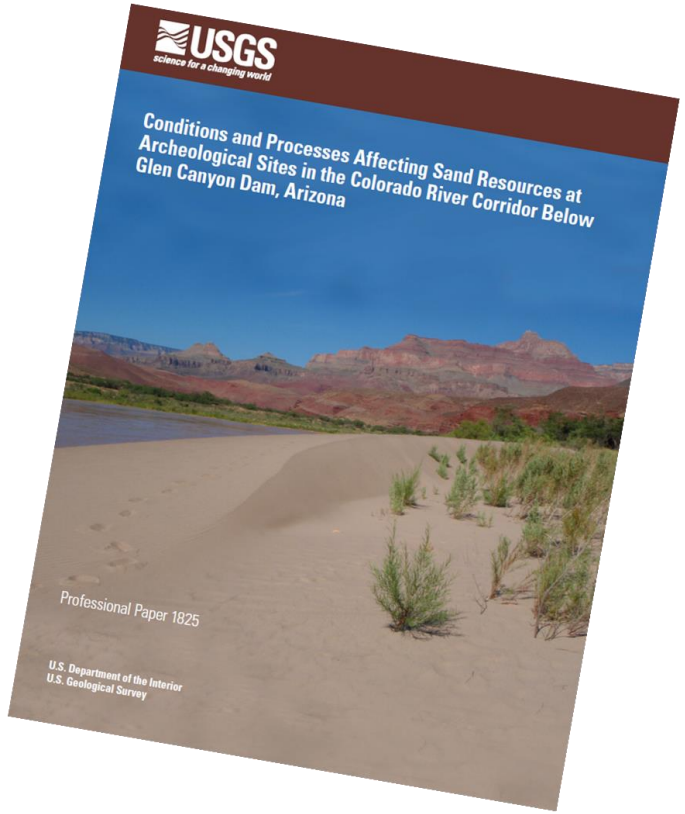
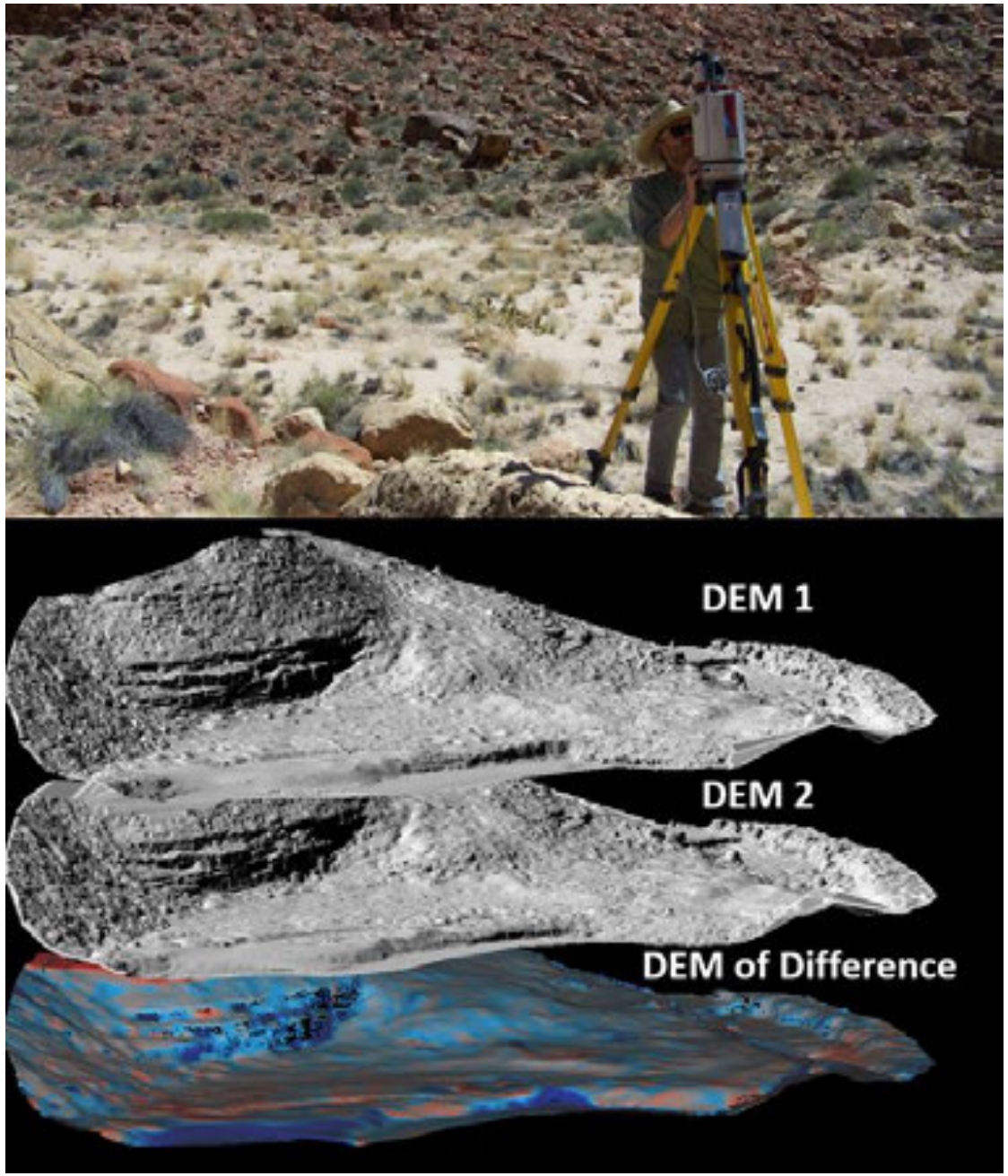
Geomorphic changes at Glen Canyon archaeological sites: 2015 – 2024

- Lauren Tango's Annual Reporting Meeting poster
- Ground-based lidar at three river corridor archaeological sites in 2024
- Sites monitored with lidar in 2015 prior to implementation of LTEMP
- How have they changed during the past decade?



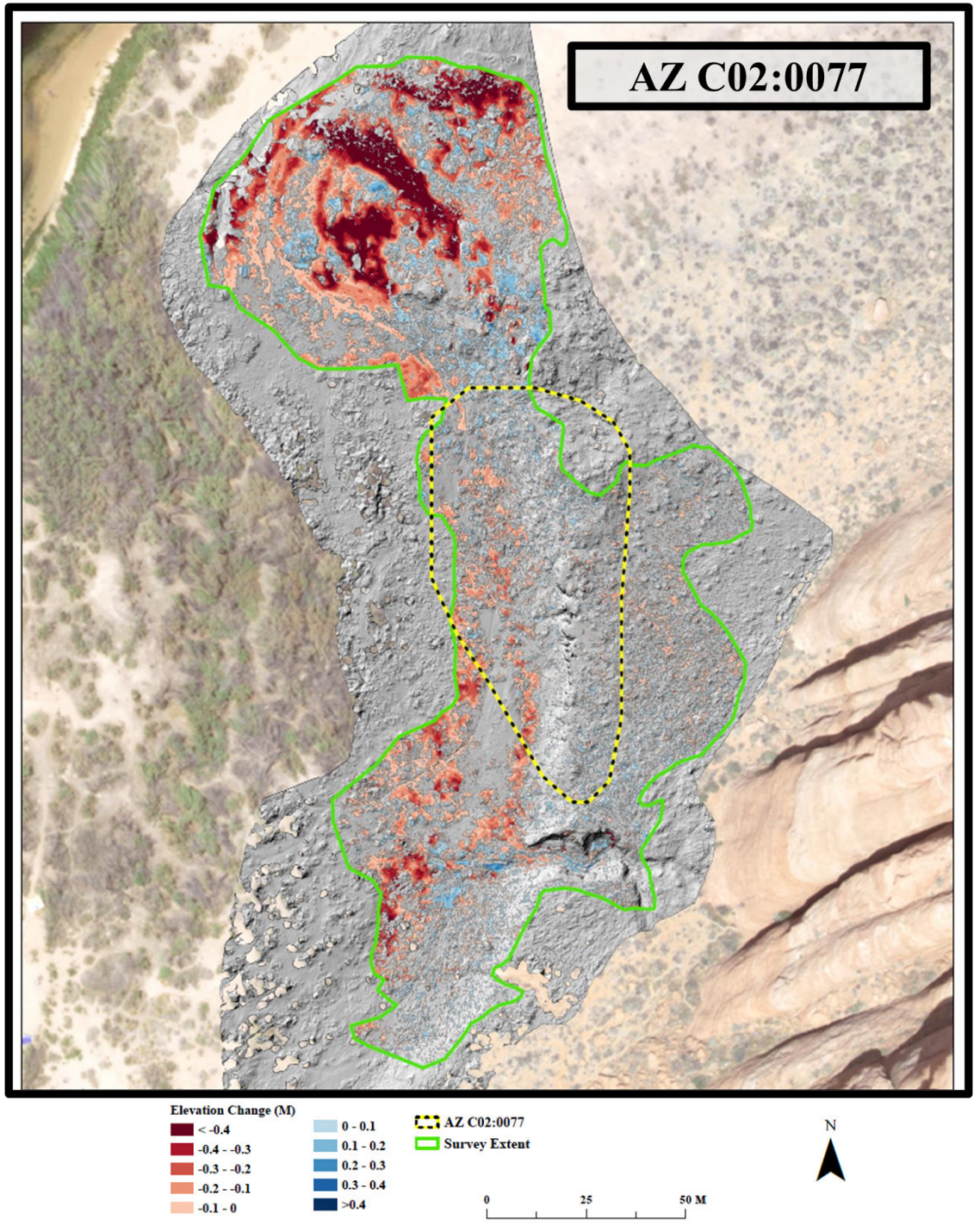
Geomorphic changes at Glen Canyon archaeological sites: 2015 – 2024

- Methods
  - Topographic change detection of repeat ground-based lidar survey digital elevation models (DEMs)



Geomorphic changes at Glen Canyon archaeological sites: 2015 – 2024

- Wind erosion and trailing by humans has contributed to erosion in and around site area



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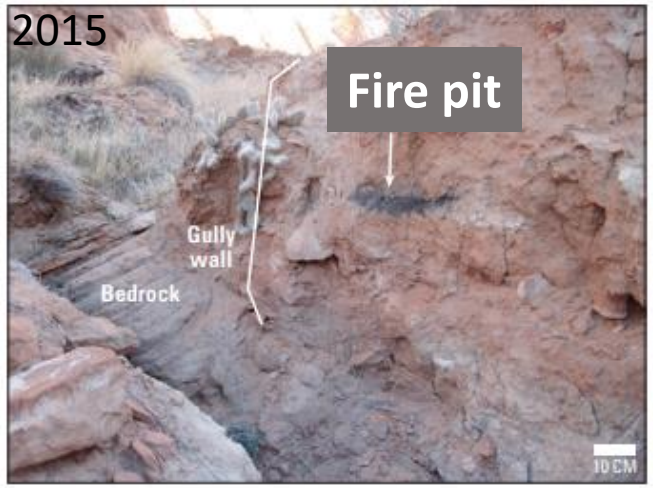
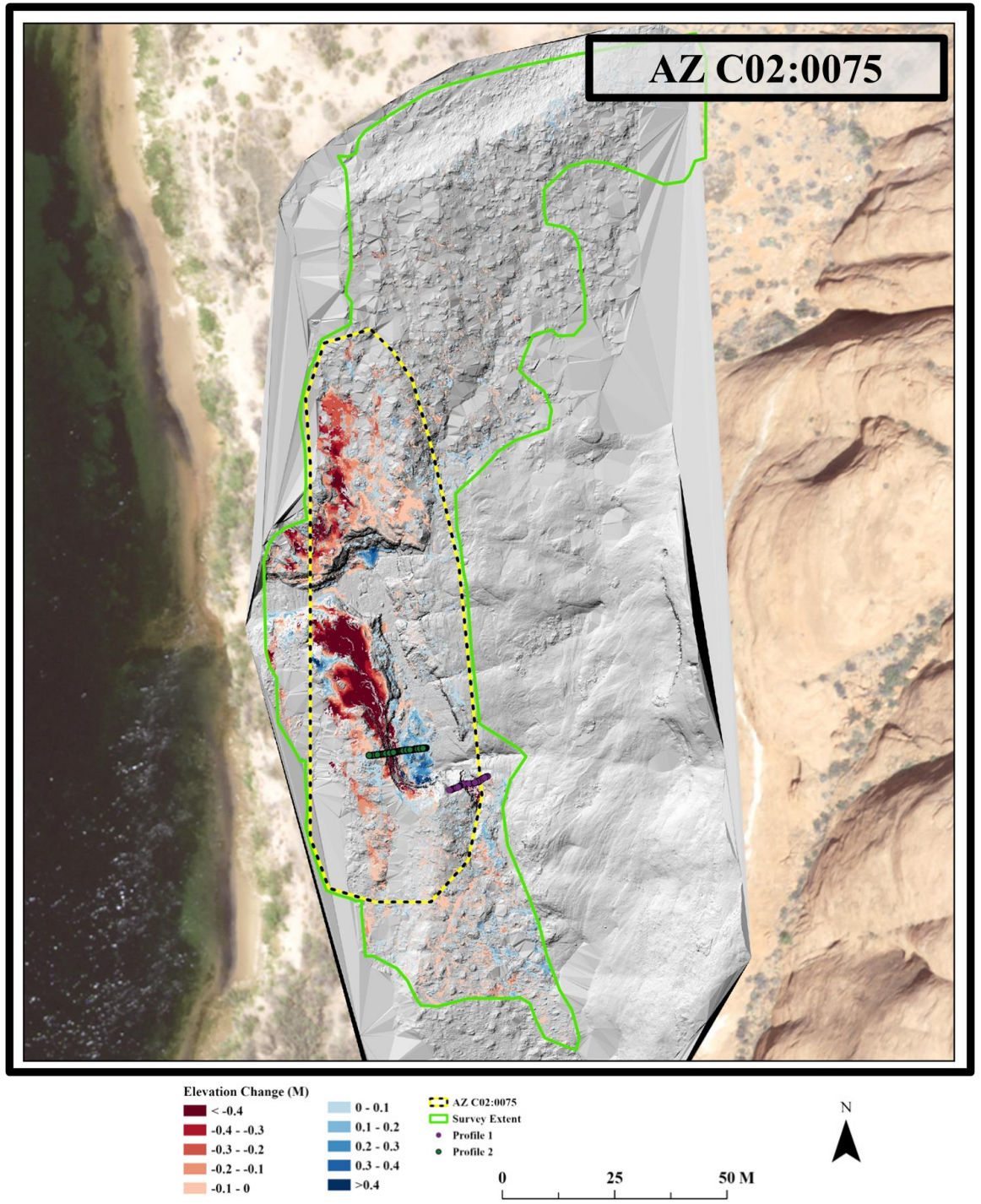
Preliminary results, please don't cite

Geomorphic changes at Glen Canyon archaeological sites: 2015 – 2024

- Erosion of gully that drains to the local base level of Colorado River
- Loss of fire pit feature (uncalibrated radiocarbon age = 2040 + 40 years before present)





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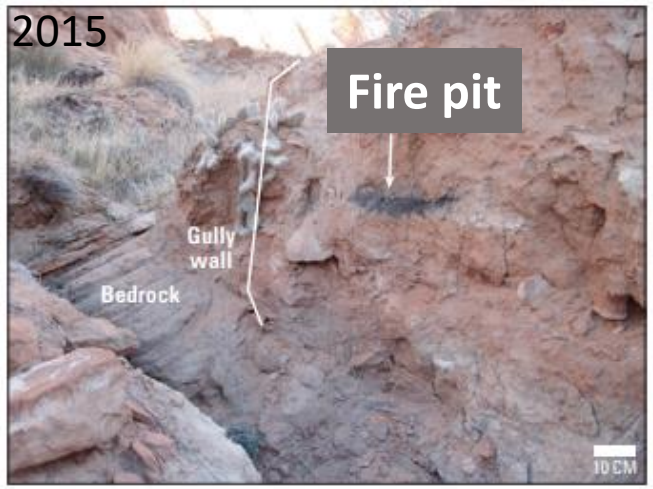

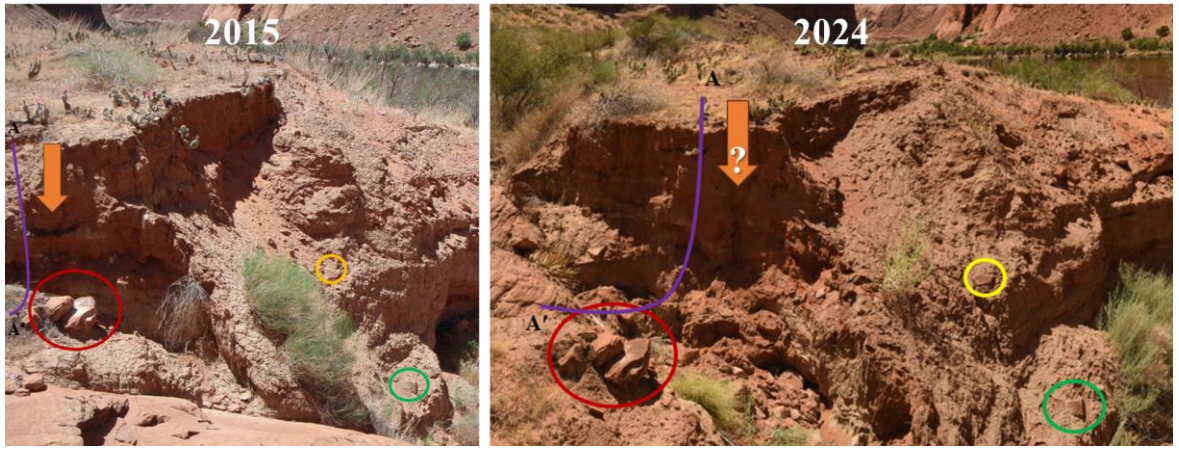

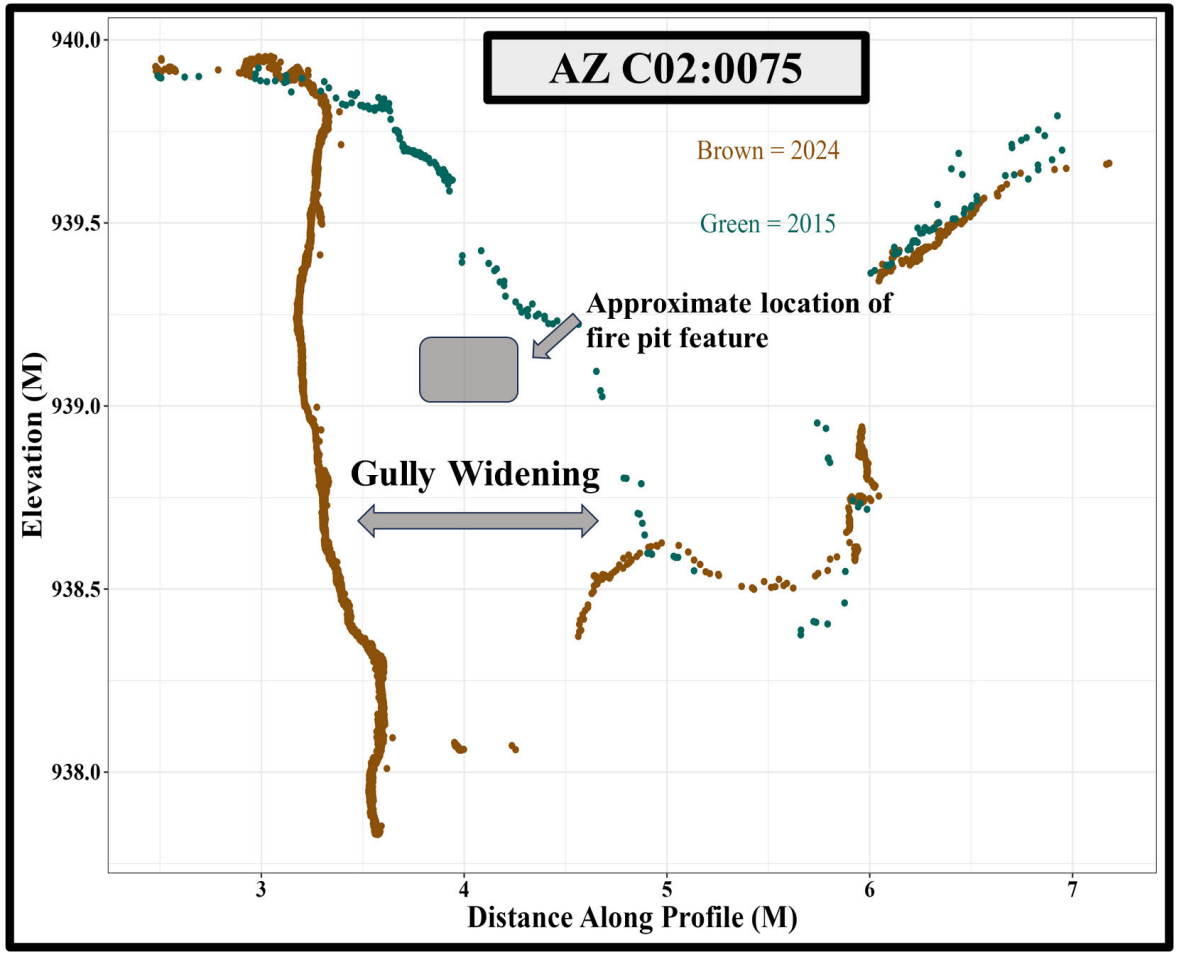

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Preliminary results, please don't cite

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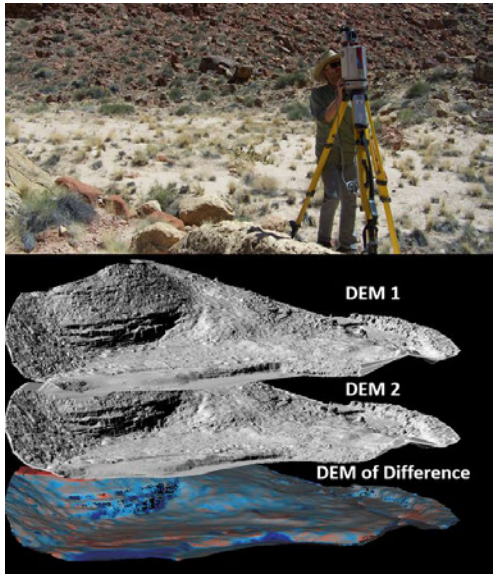
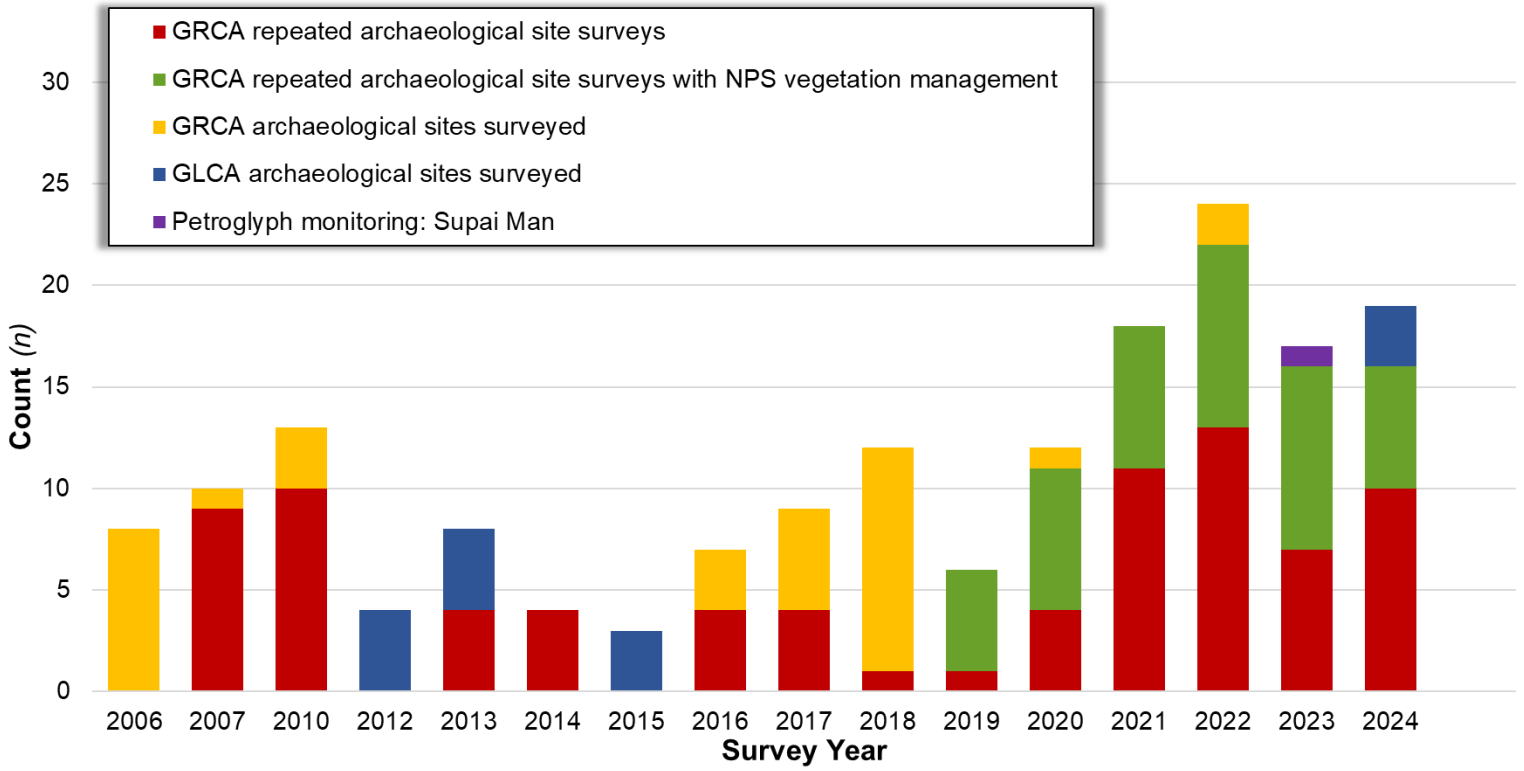
Geomorphic changes at Grand Canyon National Park archaeological sites

- 16 GRCA sites surveyed September 2024
- Long-term GRCA sample includes 36 sites or site loci with multiple repeat surveys



Summary of ground-based lidar monitoring of all archaeological sites



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Geomorphic changes at Grand Canyon National Park archaeological sites

- Data acquired in FY2024
- Topographic change detection completed for 7 sites
- In progress for 9 sites
  - Expected completion of analysis for these sites is April 2025

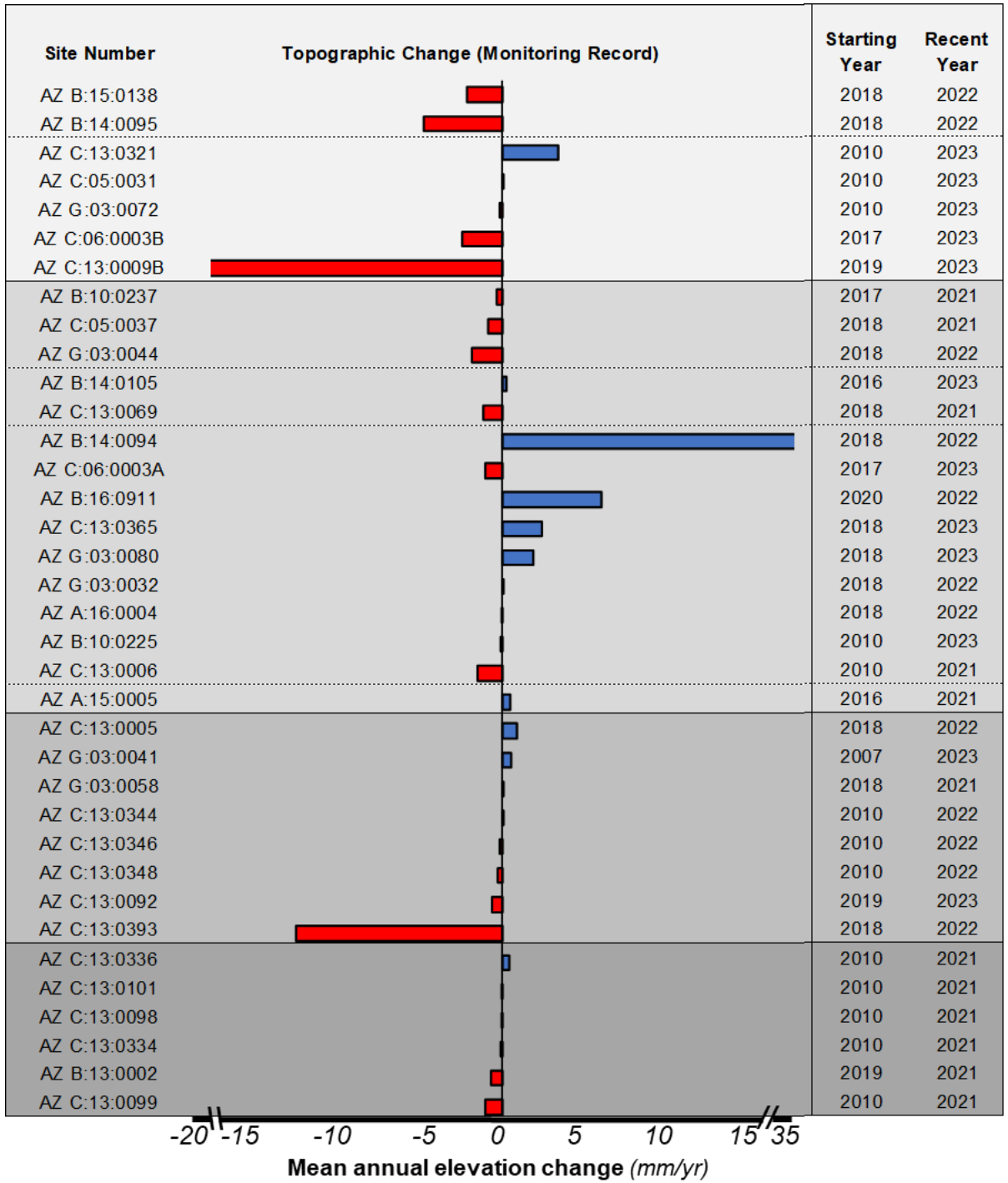
Completed	Survey Interval
AZ:C:05:0031	2023-2024
A: AZ:C:13:0321	2023-2024
B: AZ:C:13:0009	2023-2024
AZ:B:14:0105	2023-2024
AZ:G:03:0072	2023-2024
AZ:A:15:0005	2021-2024
C: AZ:C:13:0092	2023-2024

In Progress	Survey Interval
AZ:B:10:0237	2021-2024
AZ:C:05:0037	2021-2024
AZ:C:13:0006	2021-2024
AZ:G:03:0058	2021-2024
B: AZ:C:13:0336	2021-2024
D: AZ:C:13:0099	2021-2024
C: AZ C:13:0334	2021-2024
E: AZ C:13:0098	2021-2024
A: AZ C:13:0101	2021-2024

Preliminary results, please don't cite

GRCA Lidar Topographic Change Detection (LTEMP Goal 1, Metric 1.2)

- Between 2010 and 2023
  - 18 of the 36 sites had mean negative rates of annual elevation change (erosion)
  - 18 have mean positive rates of annual elevation change (aggradation from sediment deposition)
- For context, change of 1 mm per year for an archaeological site covering 0.5 hectare (1.2 acres) ~ 8 metric tons of sediment deposited or eroded each year



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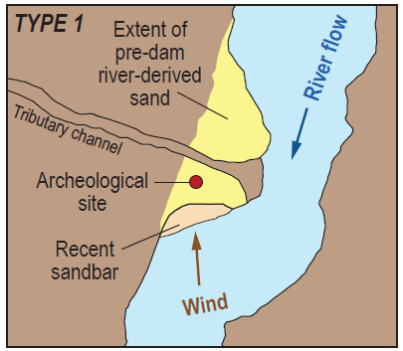
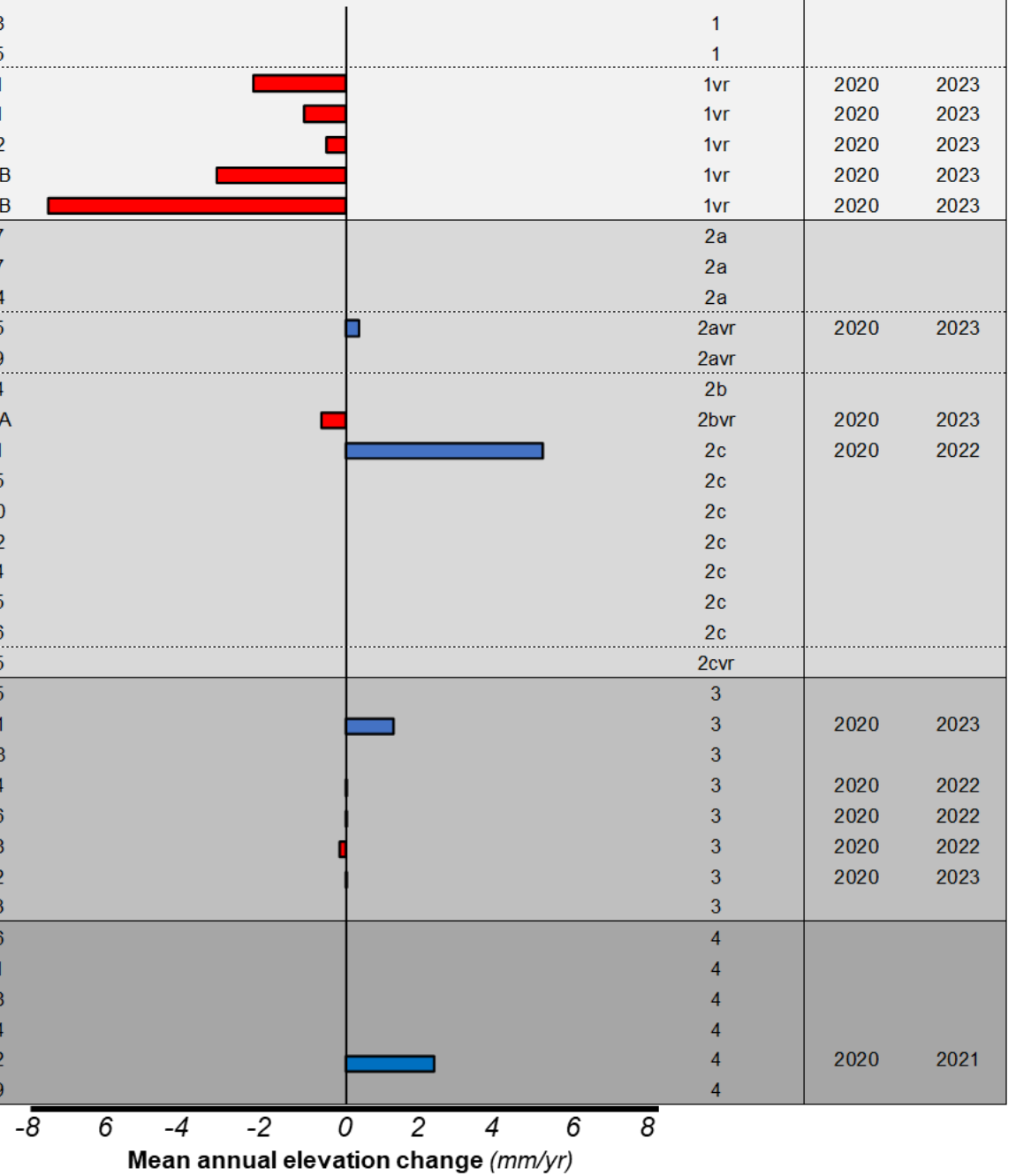
GRCA Lidar Topographic Change Detection

- Between 2020 and 2023
  - 9 of the 15 sites surveyed have mean negative (erosional) rates of elevation change
  - 5 sites exhibit a positive mean annual elevation change
- Relatively large amounts of erosion for all Type 1 aeolian classification sites which have a more direct connection to dam operations



Site Number	Aeolian Classification	Starting Year	Recent Year
AZ B:15:0138	1		
AZ B:14:0095	1		
AZ C:13:0321	1vr	2020	2023
AZ C:05:0031	1vr	2020	2023
AZ G:03:0072	1vr	2020	2023
AZ C:06:0003B	1vr	2020	2023
AZ C:13:0009B	1vr	2020	2023
AZ B:10:0237	2a		
AZ C:05:0037	2a		
AZ G:03:0044	2a		
AZ B:14:0105	2avr	2020	2023
AZ C:13:0069	2avr		
AZ B:14:0094	2b		
AZ C:06:0003A	2bvr	2020	2023
AZ B:16:0911	2c	2020	2022
AZ C:13:0365	2c		
AZ G:03:0080	2c		
AZ G:03:0032	2c		
AZ A:16:0004	2c		
AZ B:10:0225	2c		
AZ C:13:0006	2c		
AZ A:15:0005	2cvr		
AZ C:13:0005	3		
AZ G:03:0041	3	2020	2023
AZ G:03:0058	3		
AZ C:13:0344	3	2020	2022
AZ C:13:0346	3	2020	2022
AZ C:13:0348	3	2020	2022
AZ C:13:0092	3	2020	2023
AZ C:13:0393	3		
AZ C:13:0336	4		
AZ C:13:0101	4		
AZ C:13:0098	4		
AZ C:13:0334	4		
AZ B:13:0002	4	2020	2021
AZ C:13:0099	4		



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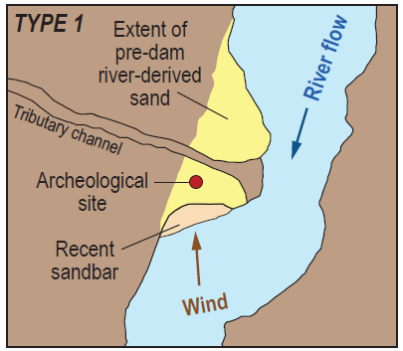
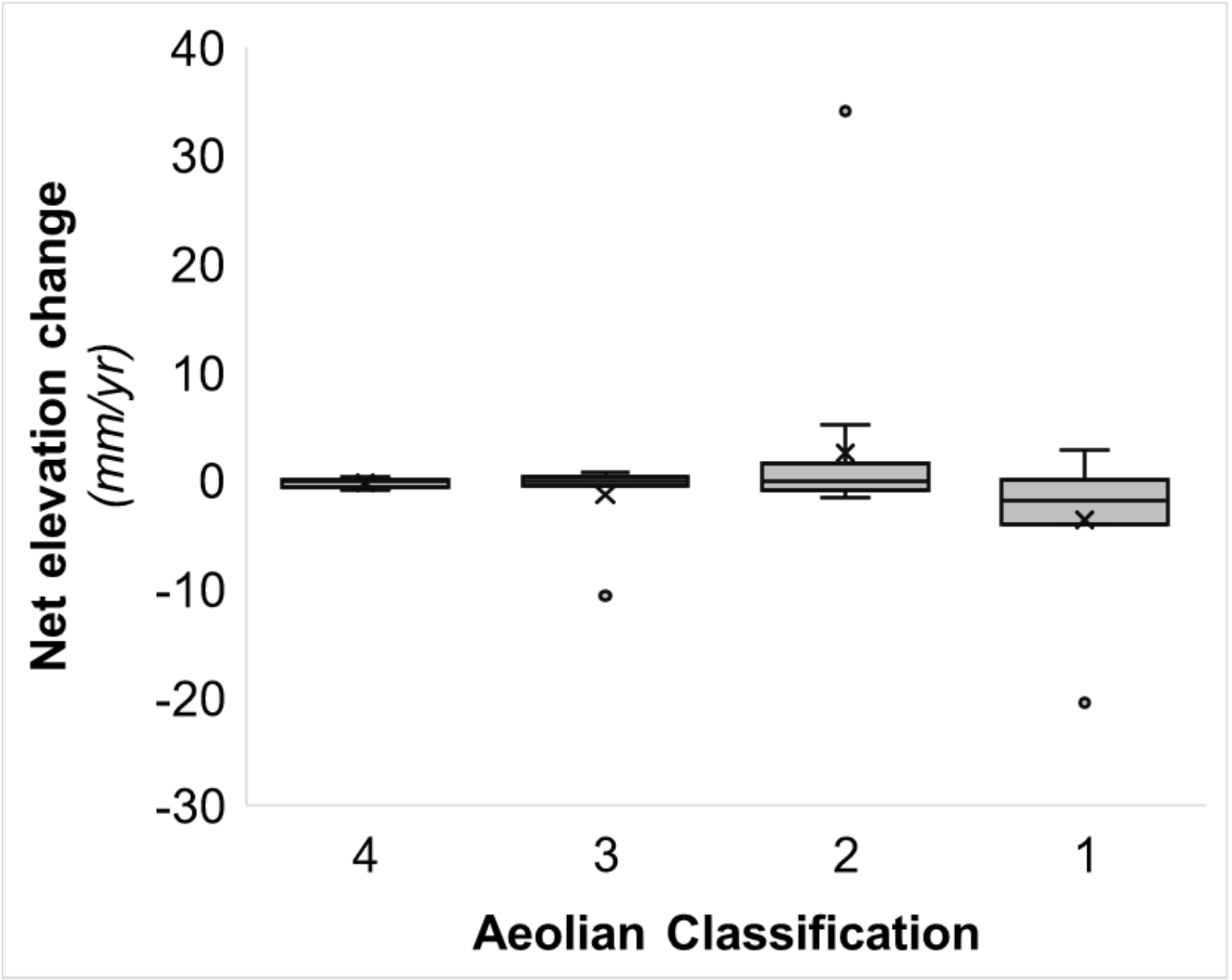
GRCA Lidar Topographic Change Detection

- Between 2010 and 2023, net elevation change indicates that Type 1 aeolian classification sites are eroding, on average





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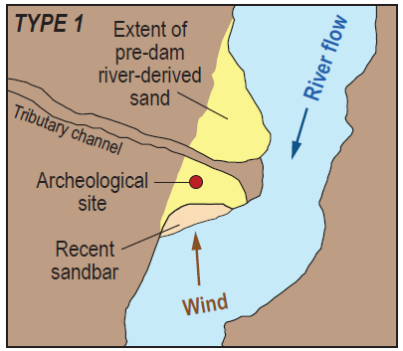
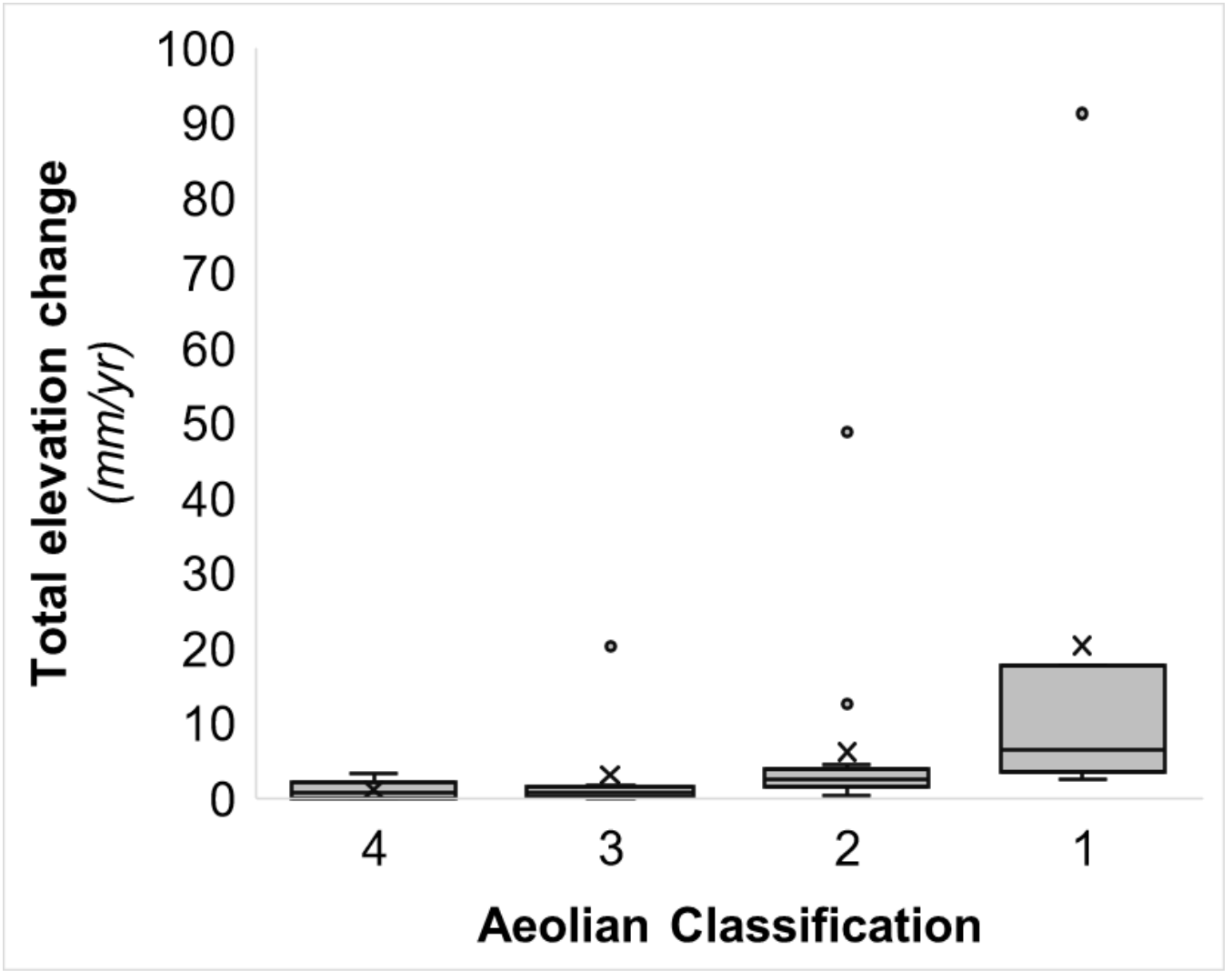
Preliminary results, please don't cite

GRCA Lidar Topographic Change Detection

- Between 2010 and 2023, total elevation change analysis indicates greater sediment transport through Type 1 sites, likely due to experimental vegetation management efforts on upwind sandbars.





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LTEMP Experimental Vegetation Management in Grand Canyon National Park

- Does removal of riparian vegetation barriers located between river sandbars and archaeological sites increase the resupply of aeolian sediment to sites?

Photo credits: J. Sankey, USGS

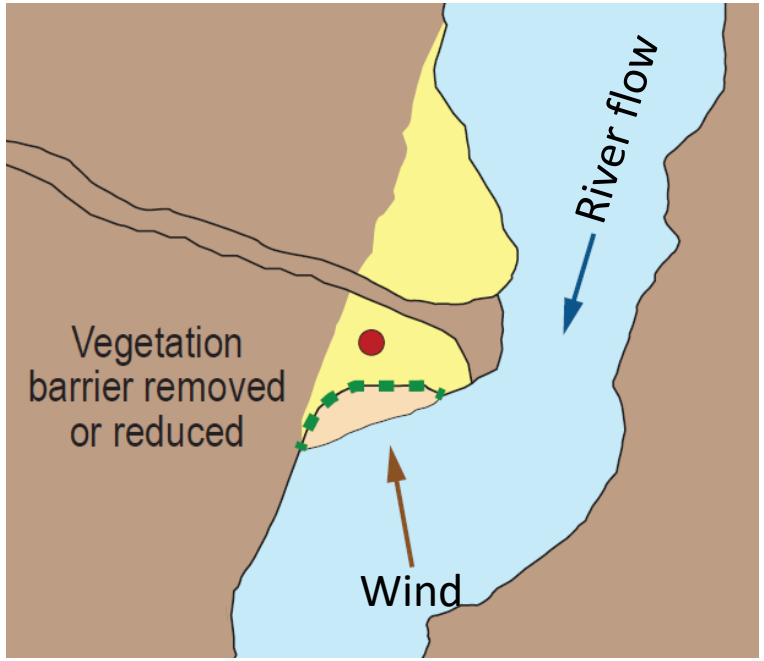

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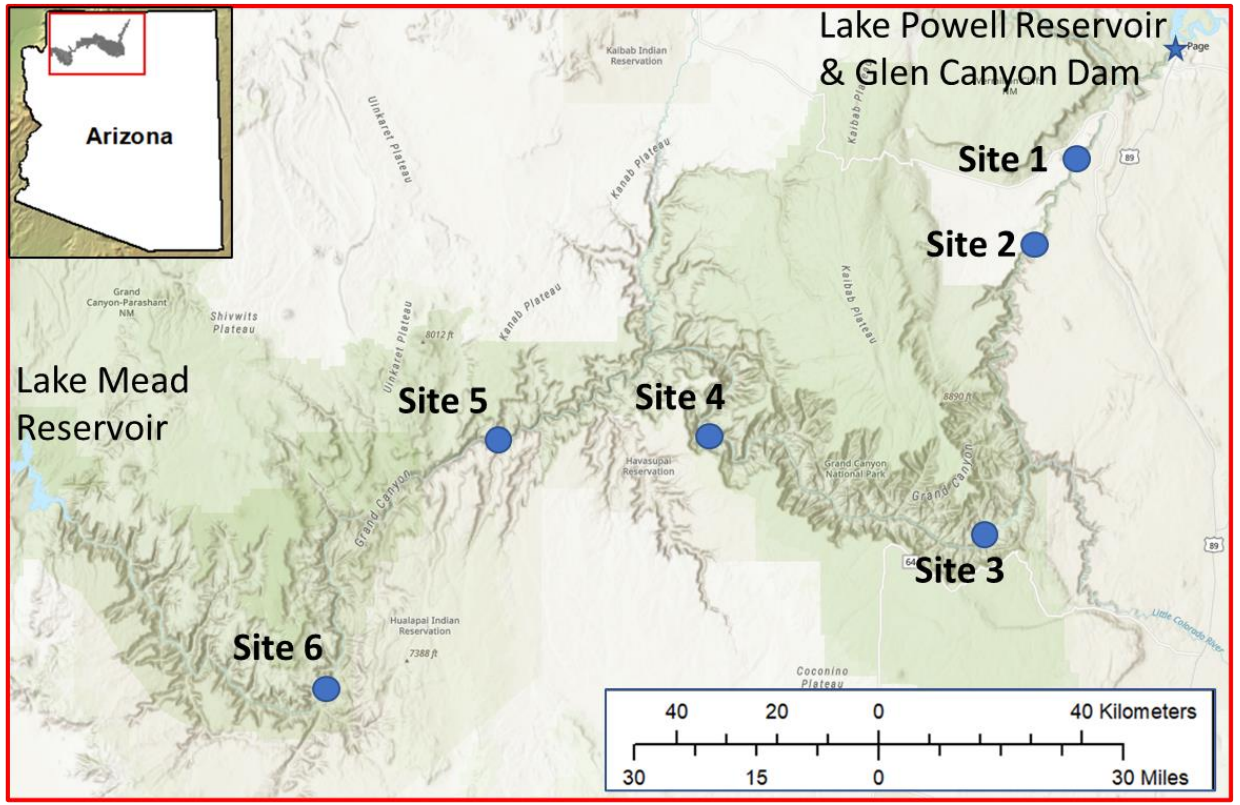
Photo credit: J. Sankey, USGS

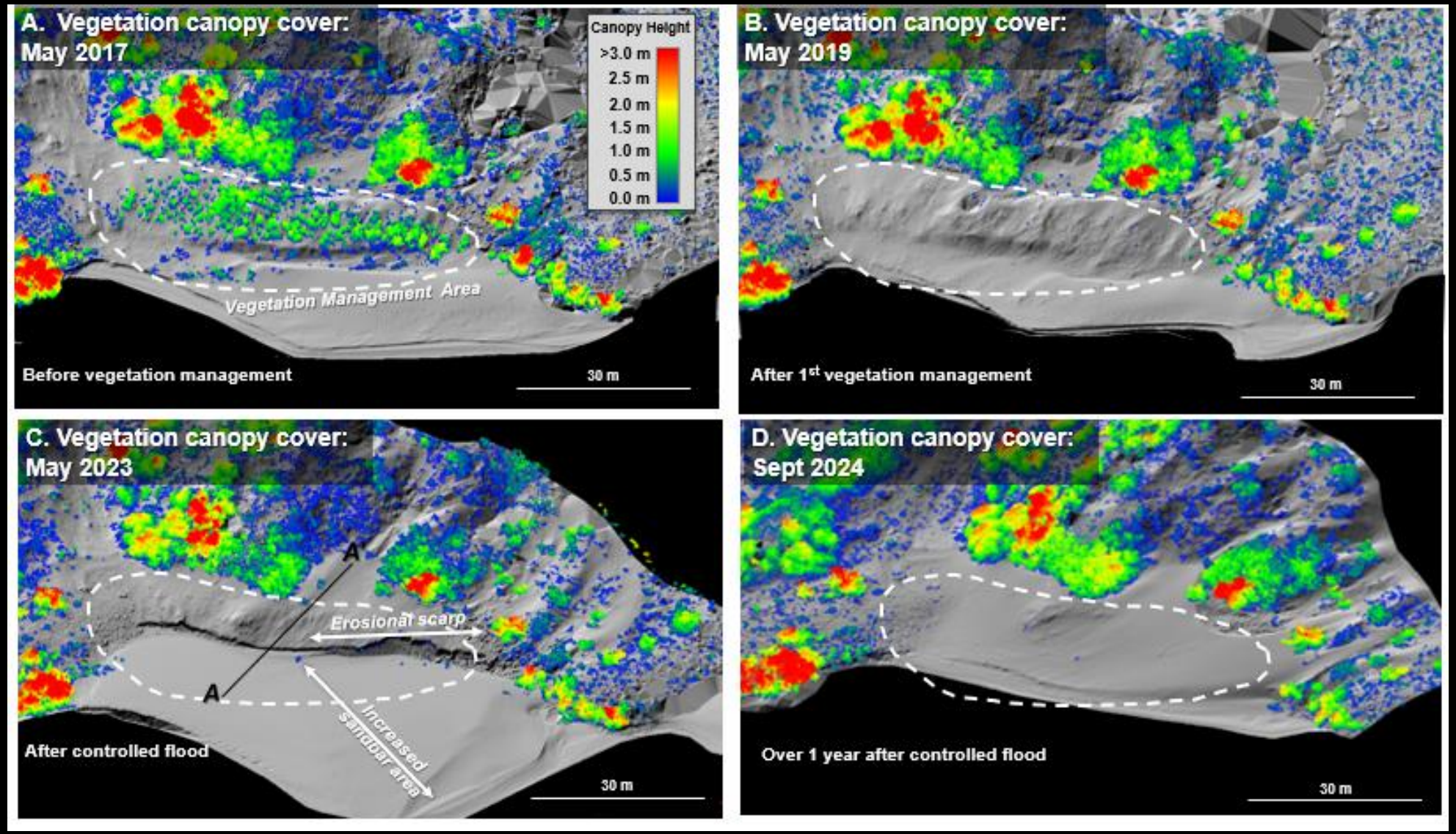
Colorado River in Grand Canyon National Park



Study sites

- National Park Service (NPS) sandbar vegetation removal annually since 2019
- USGS monitoring pre-2019 (baseline) and annually since
- HFE dam release in April 2023

Experimental Vegetation Management:
Basalt Camp example 2018 - 2024



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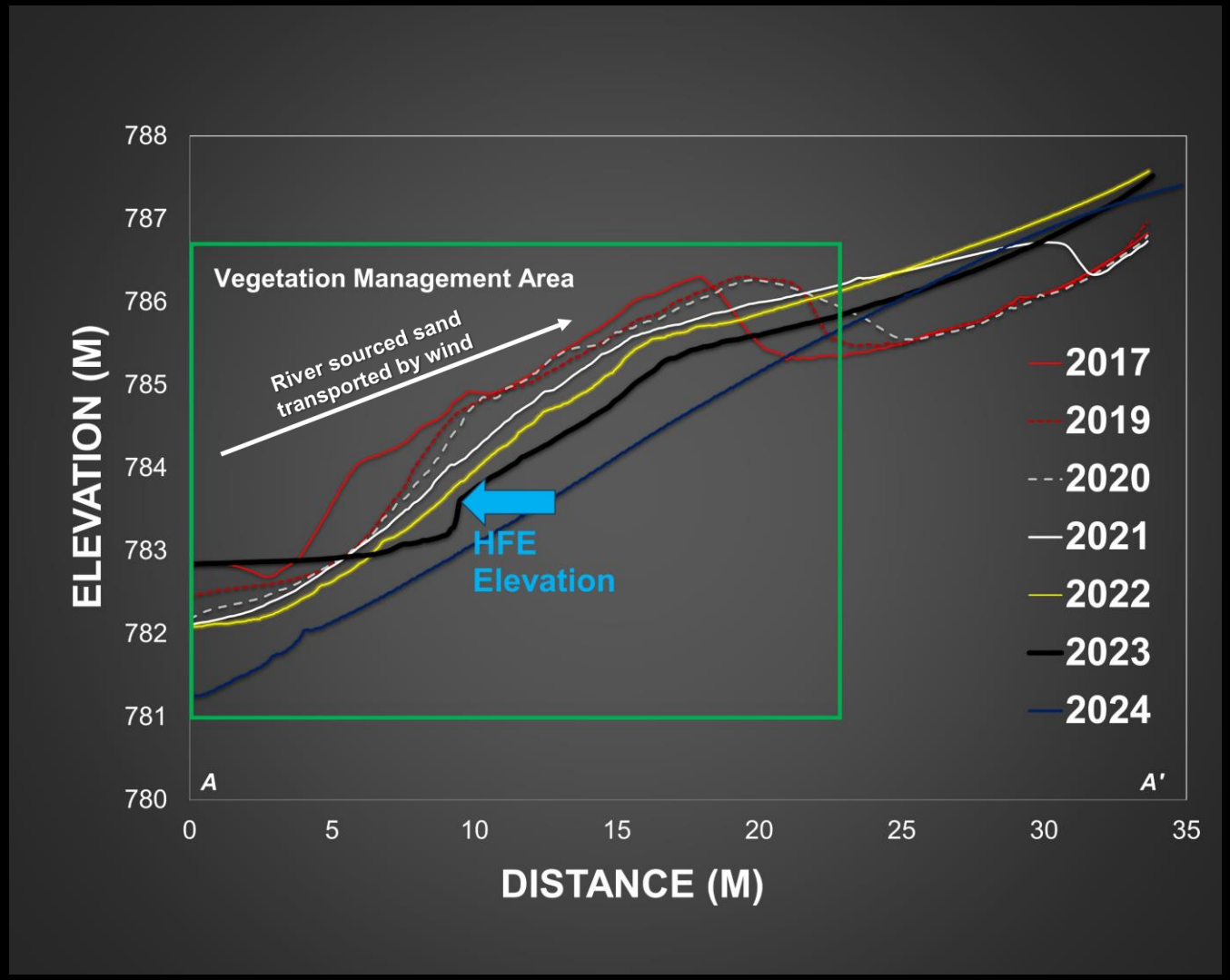
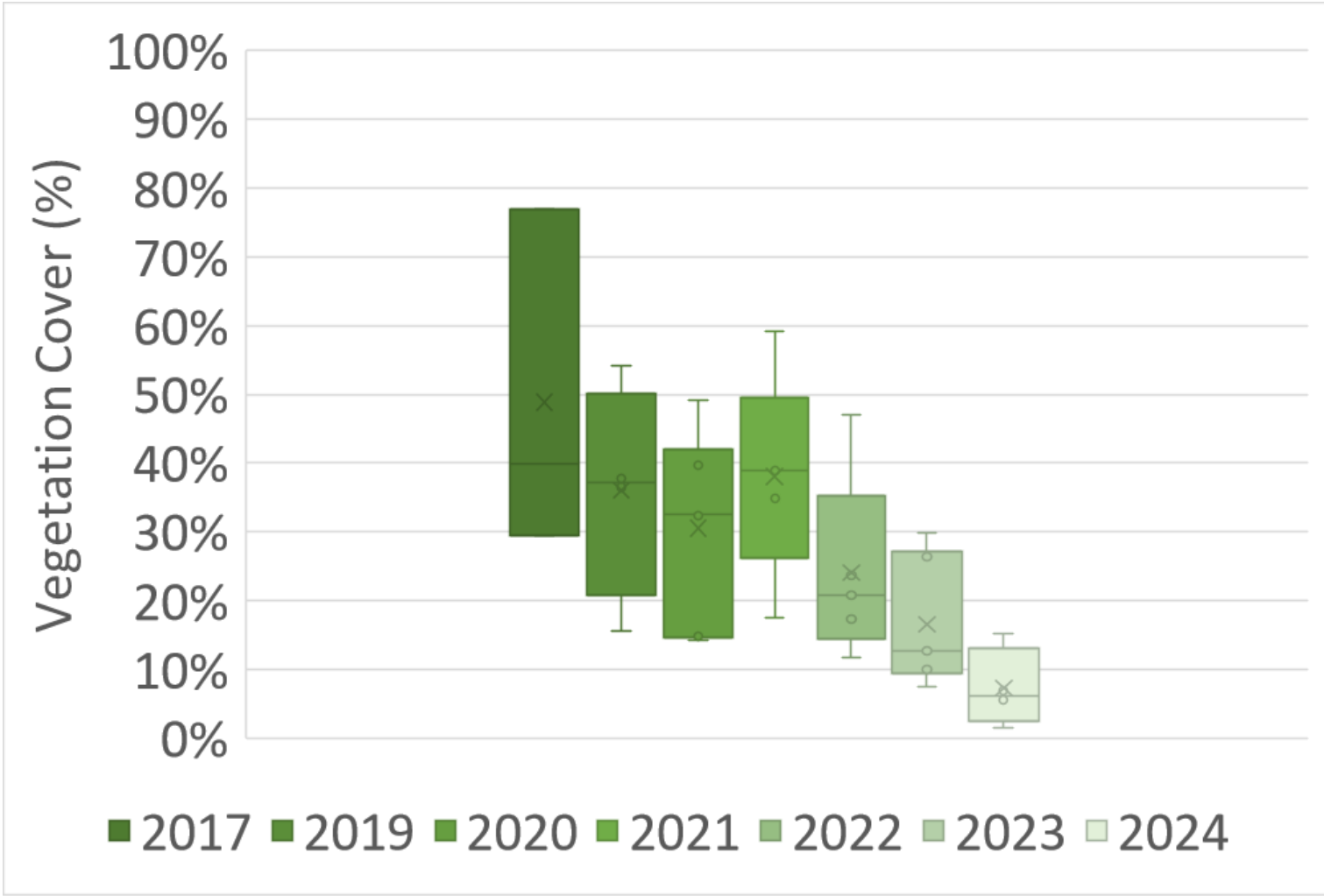
Experimental Vegetation Management: Basalt Camp example 2018 - 2024



Preliminary results, please don't cite

Lidar measured vegetation cover

- Decrease in vegetation cover at the six sites since annual sandbar vegetation removal implemented by NPS began in 2019
  - Successfully reduced vegetation cover in the vegetation management areas



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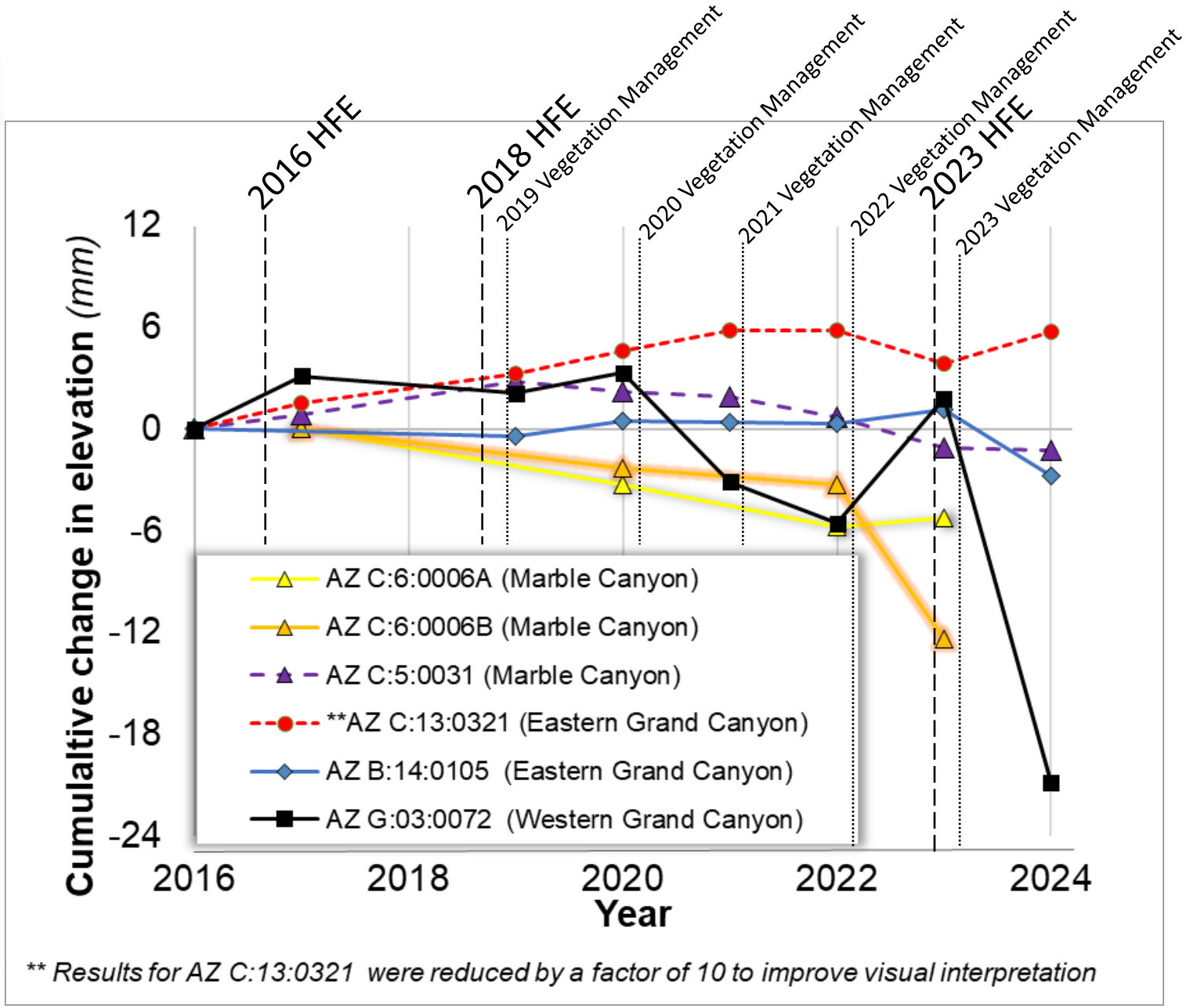
Preliminary results, please don't cite

Lidar measured topographic change at downwind archaeological sites

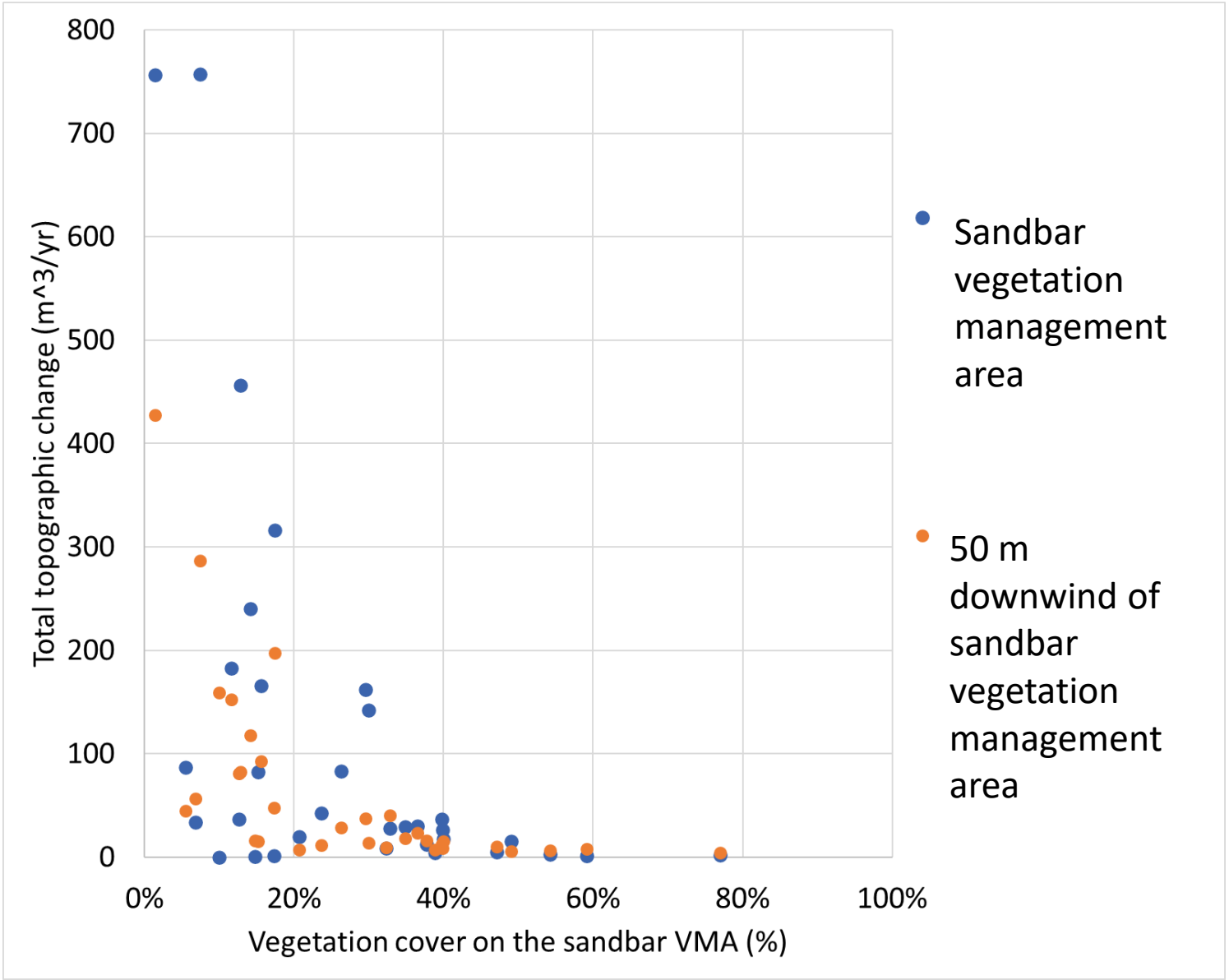
- Cumulative topographic changes from sediment erosion and deposition at archaeological sites downwind of sandbar vegetation management areas



Preliminary results, please don't cite

Lidar measured topographic change

- Greatest total topographic change occurred at vegetation management sites and years with lower vegetation cover
  - Observed within the vegetation management areas on the sandbars and at long distances (50m) downwind of the sandbar vegetation management areas
  - Threshold levels of vegetation cover on sandbars could be managed to promote aeolian transport or deposition of river sand



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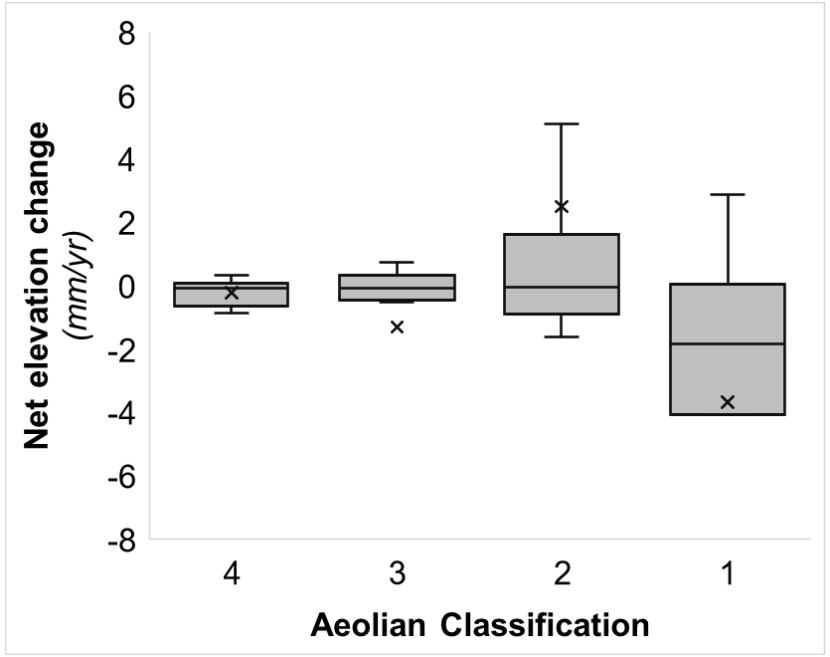
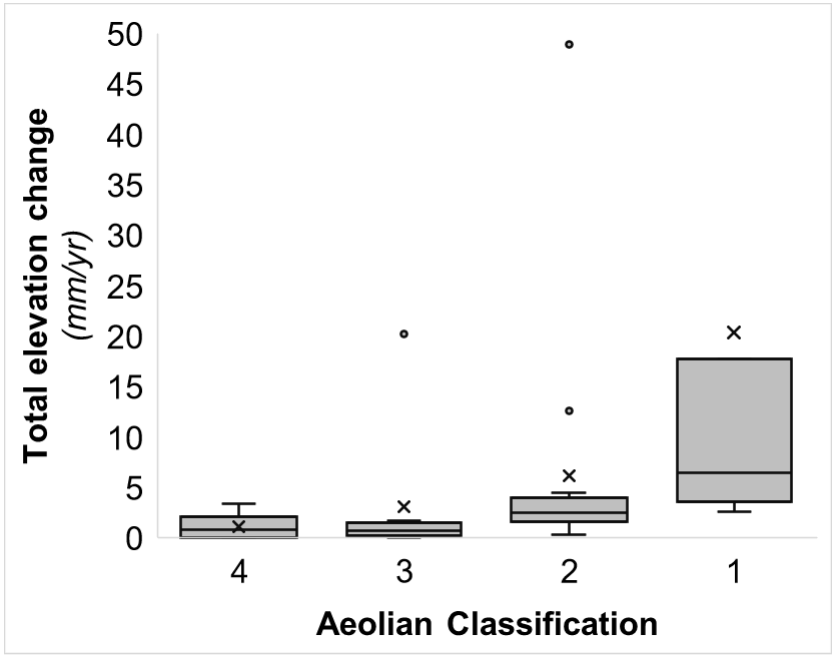
Preliminary results, please don't cite

Lidar Topographic Change Detection (Metric 1.2)

- Beginning in 2025, Project D will collaborate with the Hopi Tribe, NPS and others to identify new experimental management strategies to retain sand on sites





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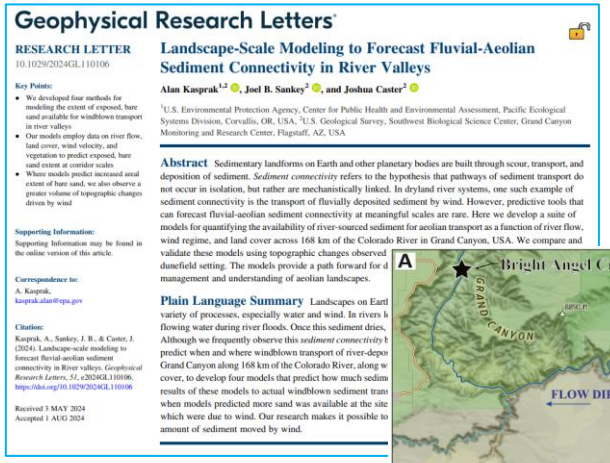
Modeling River Sourced Aeolian Dunes to Support NPS Management Goals

- Kasprak (2024) model to evaluate alternatives for SEIS and Post 2026
- Funded by BOR and NPS, not GCDAMP
  - Leverages Project D data and expertise



Geophysical Research Letters

RESEARCH LETTER
10.1029/2024GL110106

Landscape-Scale Modeling to Forecast Fluvial-Aeolian Sediment Connectivity in River Valleys

Alan Kasprak[1,2], Joel B. Sankey[2], and Joshua Caster[2]

[1]U.S. Environmental Protection Agency, Center for Public Health and Environmental Assessment, Pacific Ecological Systems Division, Corvallis, OR, USA, [2]U.S. Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, Flagstaff, AZ, USA

Key Points:
- We developed four methods for modeling the extent of exposed, bare sand available for windblown transport in river valleys
- Our models employ data on river flow, land cover, wind velocity, and vegetation to predict exposed, bare sand extent at corridor scales
- Where models predict increased areal extent of bare sand, we also observe a greater volume of topographic changes driven by wind

Supporting Information:
Supporting Information may be found in the online version of this article.

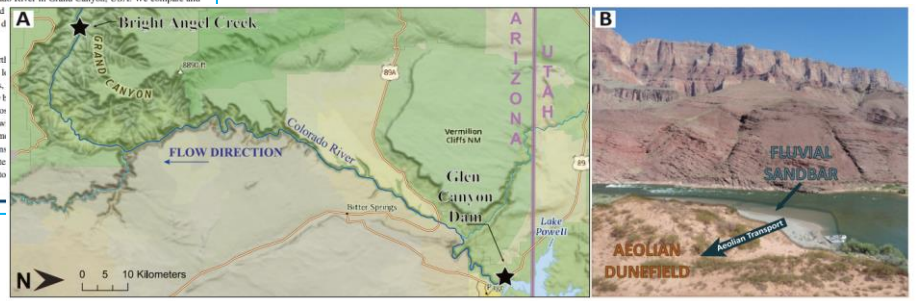
Correspondence to:
A. Kasprak,
kasprak.alan@epa.gov

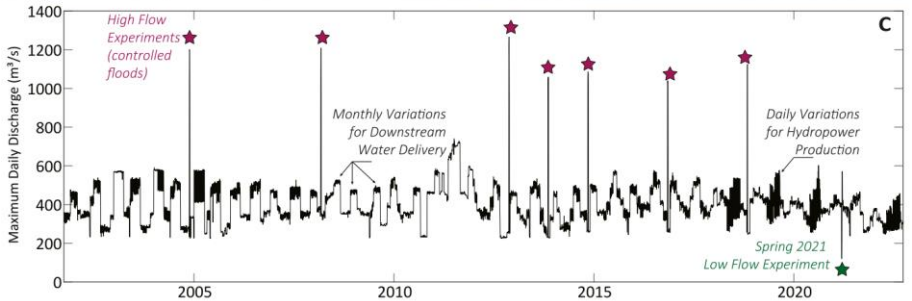
Citation:
Kasprak, A., Sankey, J. B., & Caster, J. (2024). Landscape-scale modeling to forecast fluvial-aeolian sediment connectivity in River valleys. *Geophysical Research Letters*, *51*, e2024GL110106. https://doi.org/10.1029/2024GL110106

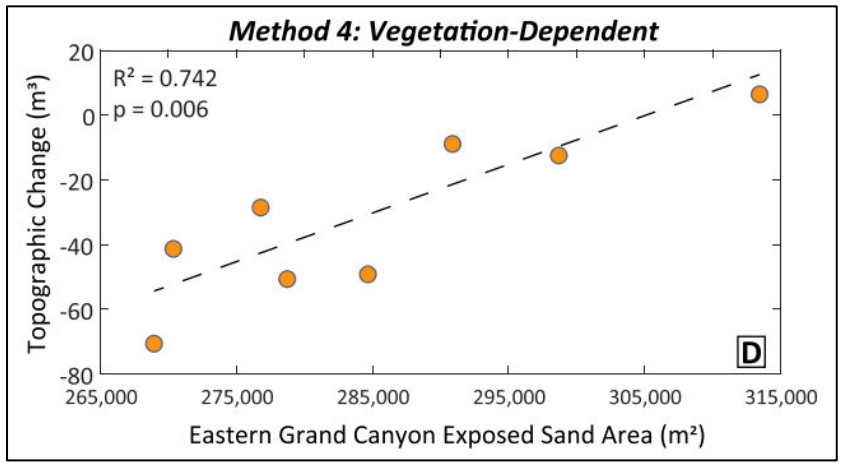
Received 3 MAY 2024
Accepted 1 AUG 2024

Abstract Sedimentary landforms on Earth and other planetary bodies are built through scour, transport, and deposition of sediment. *Sediment connectivity* refers to the hypothesis that pathways of sediment transport do not occur in isolation, but rather are mechanistically linked. In dryland river systems, one such example of sediment connectivity is the transport of fluvially deposited sediment by wind. However, predictive tools that can forecast fluvial-aeolian sediment connectivity at meaningful scales are rare. Here we develop a suite of models for quantifying the availability of river-sourced sediment for aeolian transport as a function of river flow, wind regime, and land cover across 168 km of the Colorado River in Grand Canyon, USA. We compare and validate these models using topographic changes observed
dunefield setting. The models provide a path forward for d
management and understanding of aeolian landscapes.

Plain Language Summary Landscapes on Eartl
variety of processes, especially water and wind. In rivers l
flowing water during river floods. Once this sediment dries,
Although we frequently observe this *sediment connectivity* b
predict when and where windblown transport of river-depos
Grand Canyon along 168 km of the Colorado River, along w
cover, to develop four models that predict how much sedim
results of these models to actual windblown sediment trans
when models predicted more sand was available at the site
which were due to wind. Our research makes it possible to
amount of sediment moved by wind.

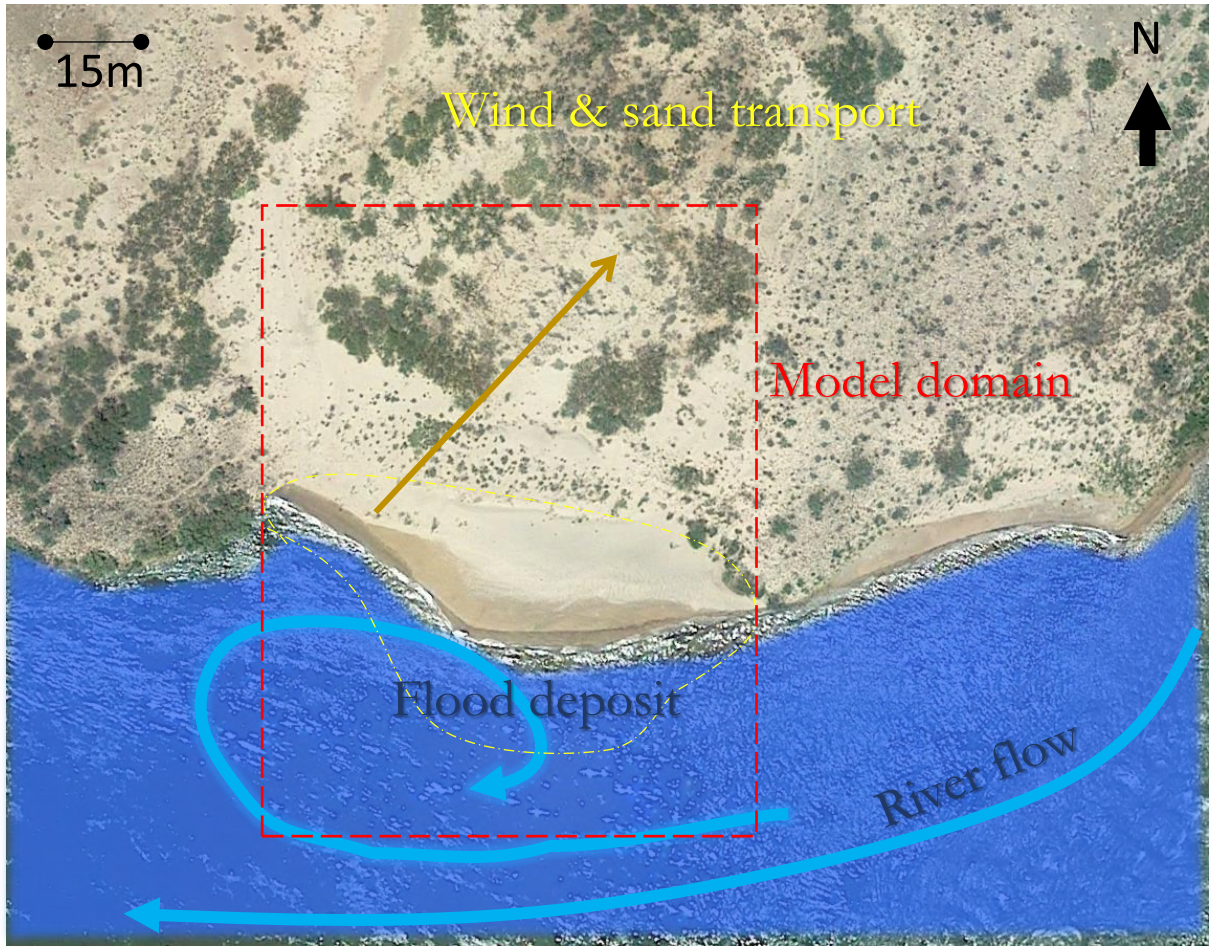






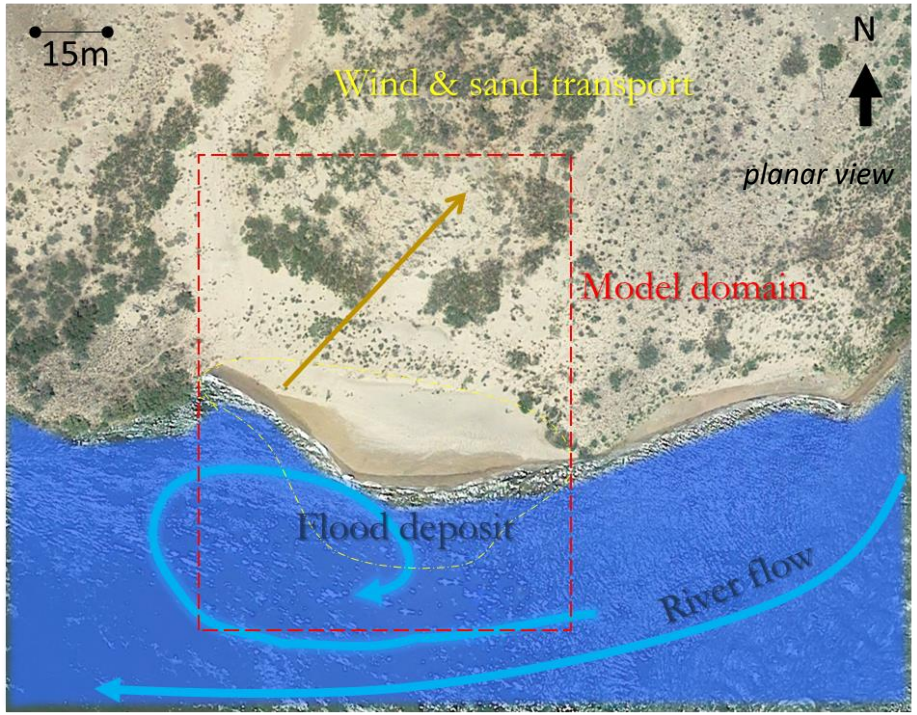
Modeling River Sourced Aeolian Dunes to Support NPS Management Goals

- Maddy Kelley's Annual Reporting Meeting poster
- Funded by NPS, not GCDAMP
  - Leverages GCMRC (Projects A, B, D, L) data and expertise
  - Adapts numerical model developed for coastal environments to explore site specific aeolian processes
  - Incorporates topography, wind strength, river stage, sand supply, grain size, vegetation cover into sediment flux estimates and geomorphic change results.

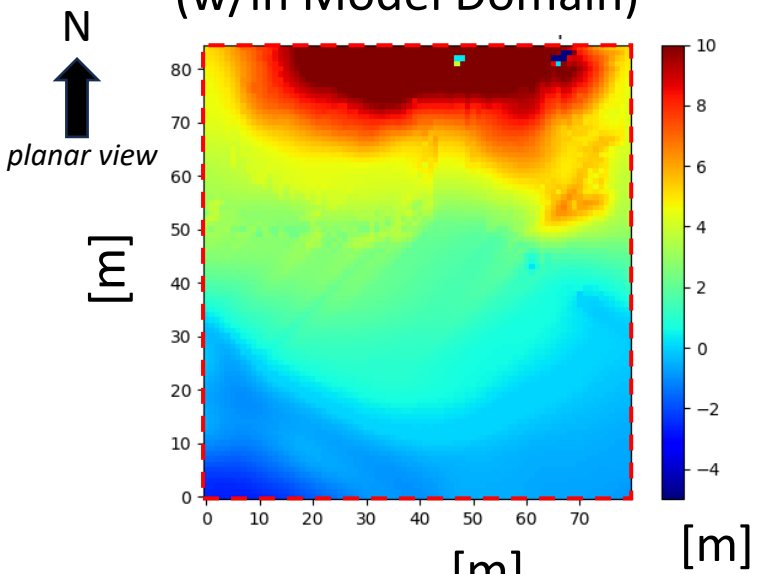


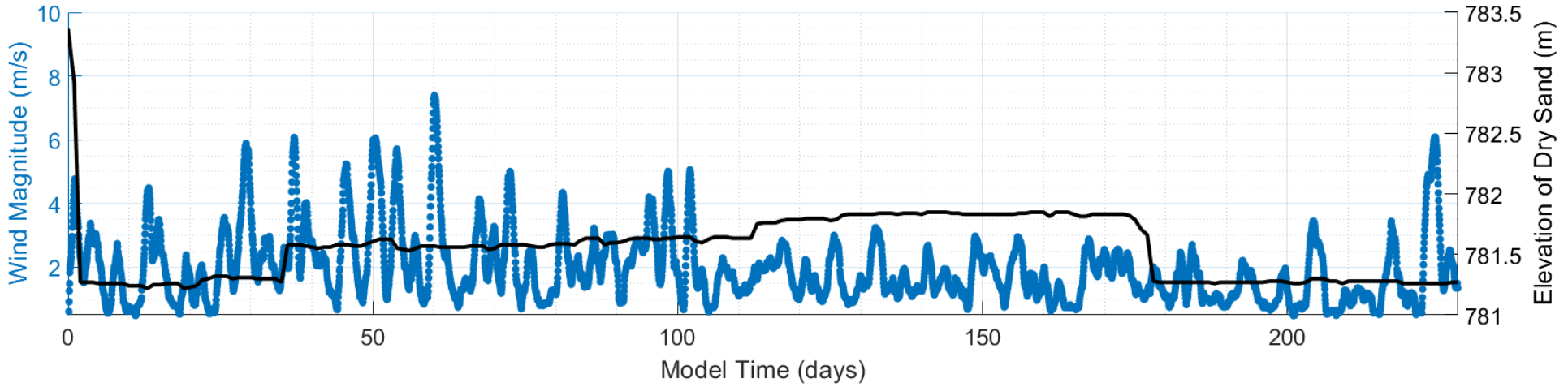
Preliminary results, please don't cite

Modeling River Sourced Aeolian Dunes to Support NPS Management Goals



Final Topography
(w/in Model Domain)





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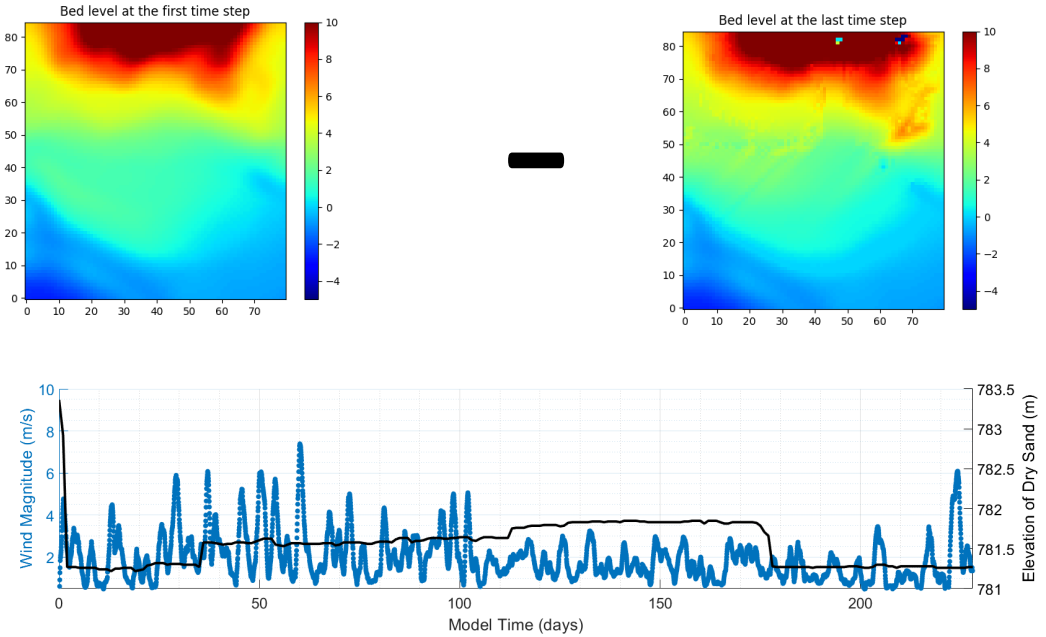
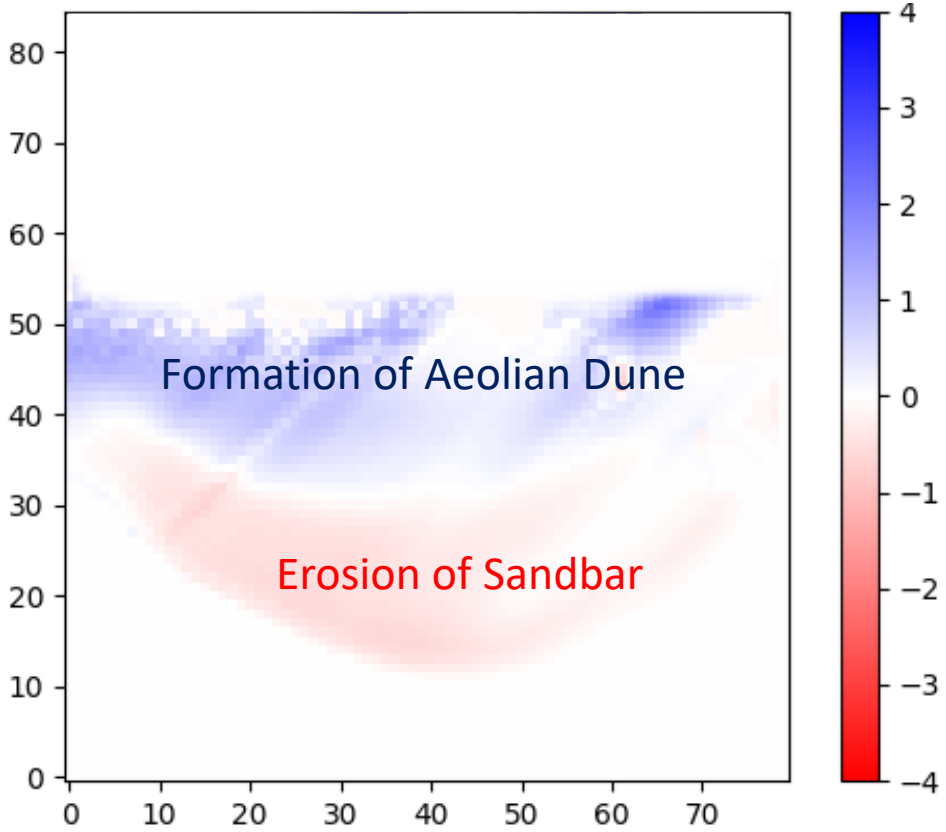
Modeling River Sourced Aeolian Dunes to Support NPS Management Goals



DEMoD



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Presentation Outline

1. Background
2. GLCA monitoring
3. GRCA monitoring
4. LTEMP Experimental Vegetation Management
5. Modeling
6. Project D Next Steps

Next Steps for Project D

- Continue to monitor archaeological sites and collect data to report on LTEMP metrics 1.1-1.3
- Continue to evaluate effectiveness of LTEMP HFE and vegetation management experiments
- Develop experiments with the Hopi Tribe, NPS and others to identify new strategies to retain sand on sites.

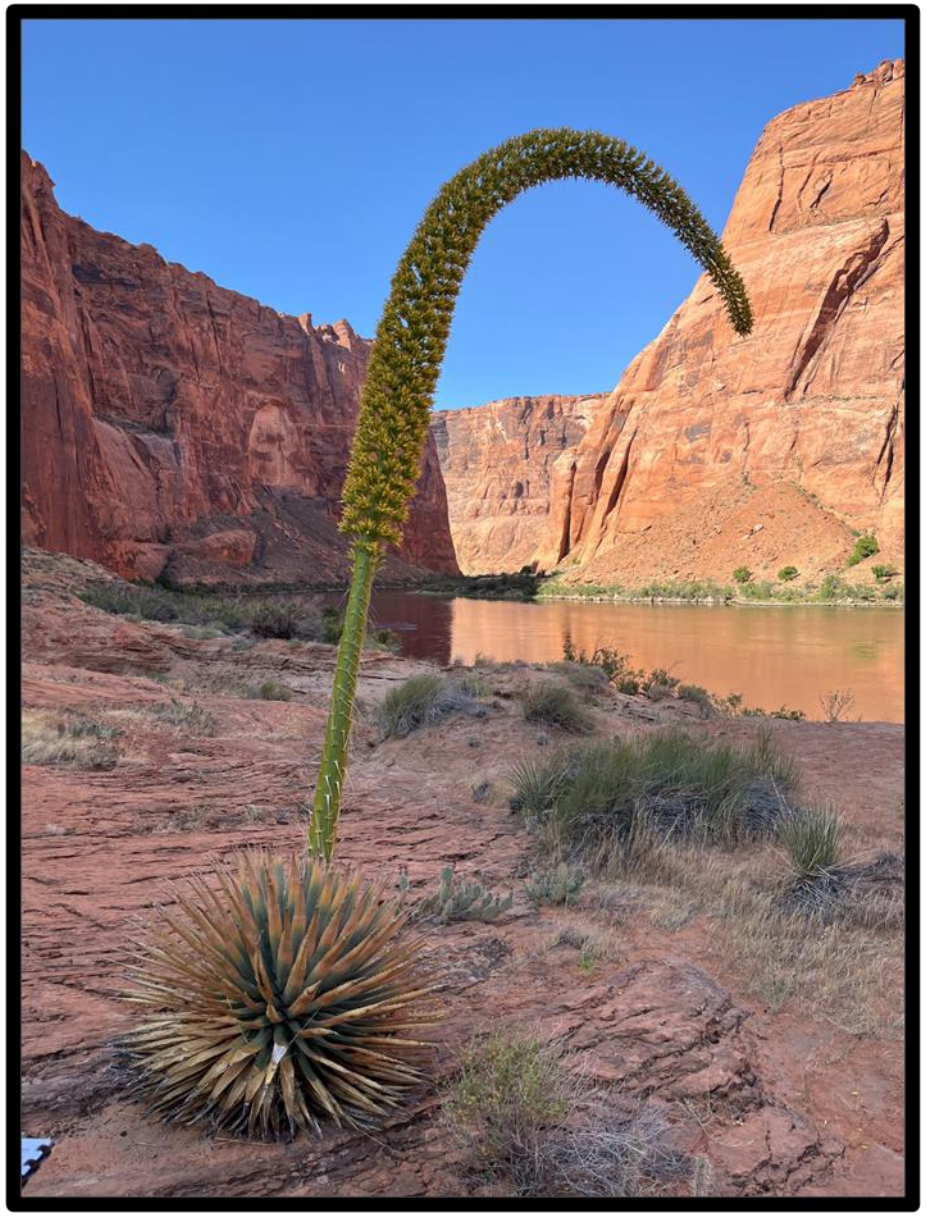

Photo credit: J. Sankey, USGS

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East, A.E., Sankey, J.B., Fairley, H.C., Caster, J.J., and Kasprak, A., 2017, Modern landscape processes affecting archaeological sites along the Colorado River corridor downstream of Glen Canyon Dam, Glen Canyon National Recreation Area, Arizona: U.S. Geological Survey Scientific Investigations Report 2017–5082, 22 p., https://doi.org/10.3133/sir20175082.

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