Effects of dam operations and vegetation management on the preservation and geomorphic condition of archaeological sites

- **Glen Canyon Dam Adaptive Management Work Group Meeting**
- **February 28-29, 2024, Phoenix, AZ**

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USGS science for a changing world
Grand Canyon Monitoring and Research Center

Program Goals: Archaeological and Cultural Resources

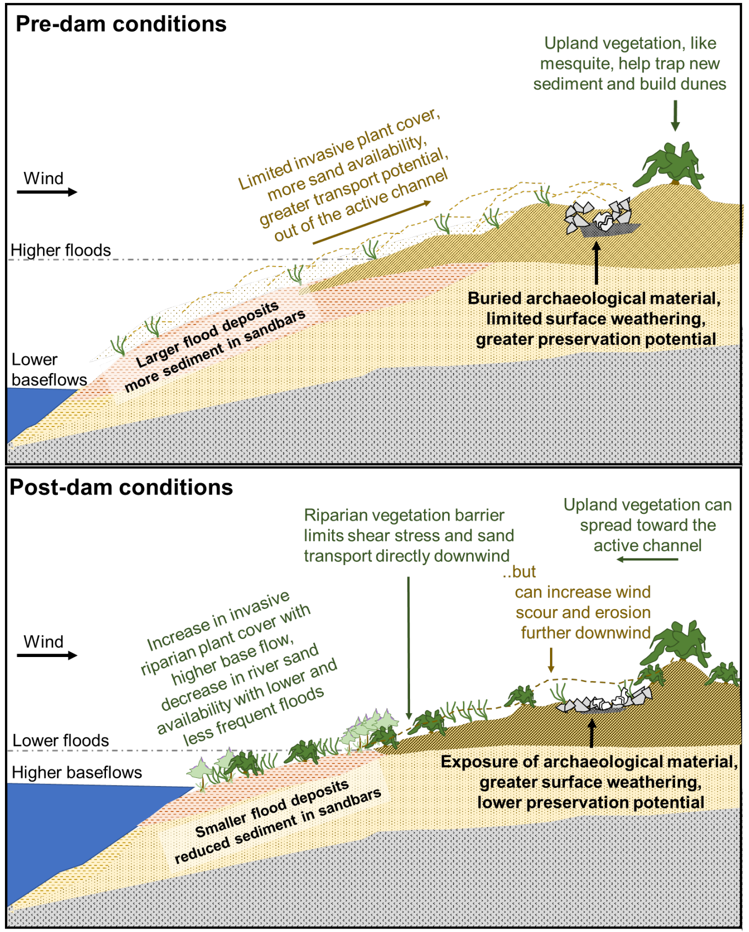
GCDAMP Regulatory Goals:

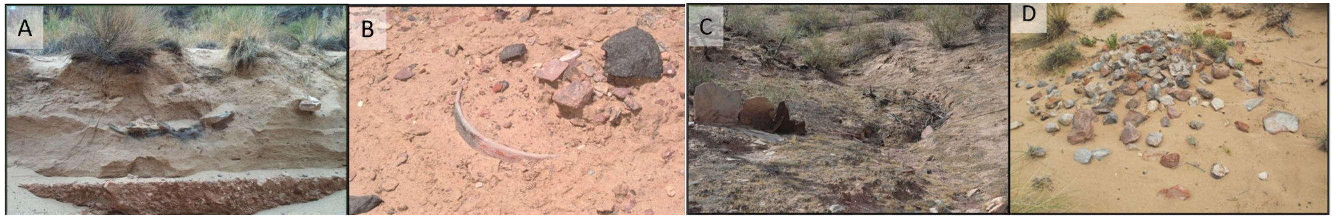
- **GCPA goal**: Operate Glen Canyon Dam so as to protect, mitigate adverse impacts to, and improve … natural and cultural resources…
- **LTEMP and NHPA goals**: "Preservation in place."
  - LTEMP Goal 1: Maintain the integrity of potentially affected NRHP-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis.

Photo credit: J. Caster (USGS)

River management and archaeological site preservation

- Native peoples occupied Grand Canyon for at least 9000 years, resulting in 100s of archaeological sites that are a tangible record of human history in this landscape
- Burial of archaeological sites by river-sourced aeolian sand provides a protective cover and resilient surface, reducing erosion potential
    - Important for 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





A. Prehistoric hearth in alluvial cutbank

B. Prehistoric bowl buried in sand

C. Slab structure eroding in gully

D. Fire-altered rock exposed by deflation

Sankey et al., 2023, Journal of Environmental Management

We use two different but complementary methods to monitor dam effects at archaeological sites

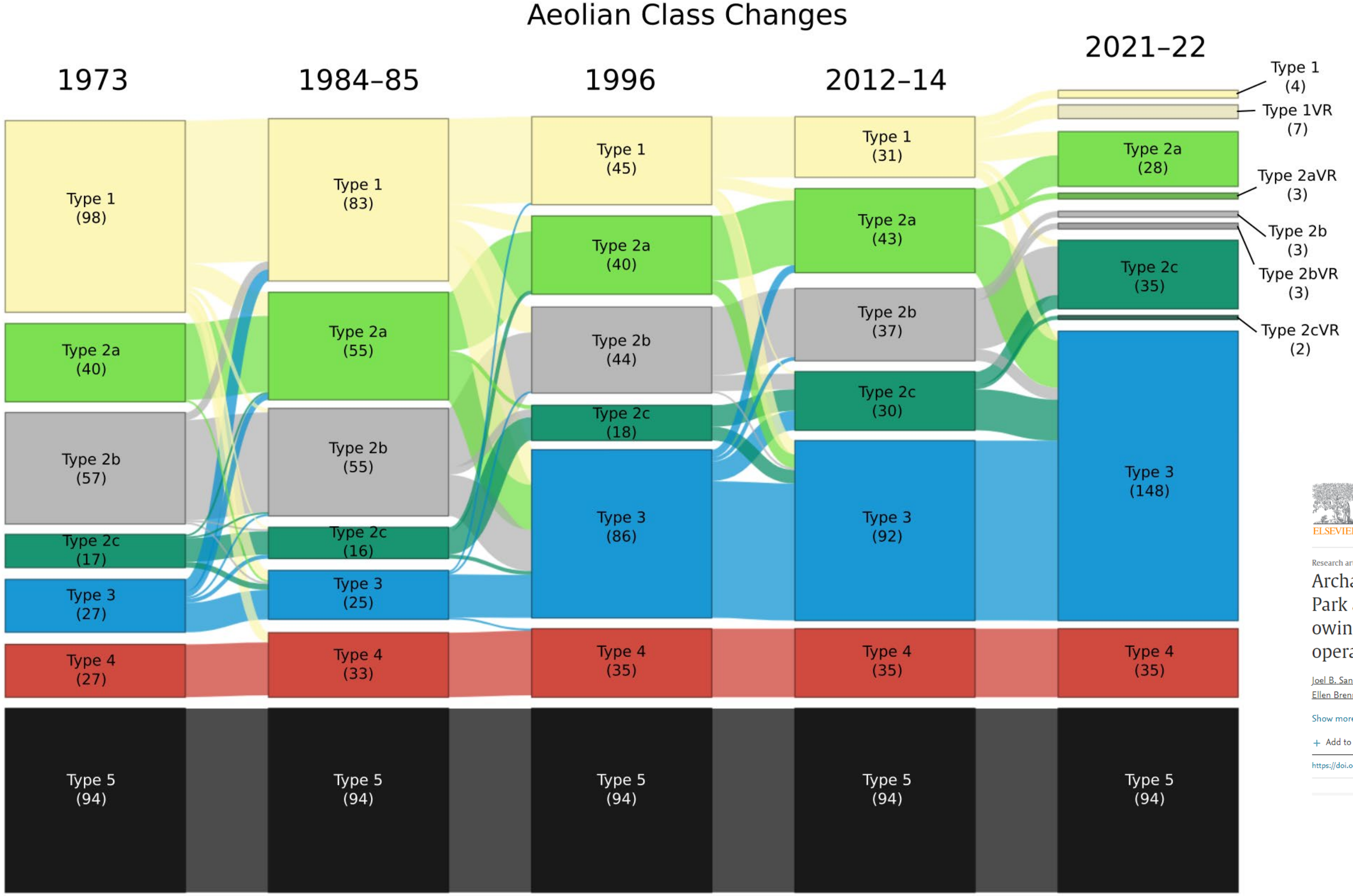
Method 1:

For entire population of sites within the Area of Potential Effect (n=362), we monitor changes in two classifications-- drainage evolution and fluvial sand connectivity -- at ~5-10-year intervals

Method 2:

For a sample of sites, we monitor change in topography (sediment deposition and erosion) using repeat lidar surveys, once every ~3 years

Results: Fluvial Sediment Connectivity Classification



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Research article

Archaeological sites in Grand Canyon National Park along the Colorado River are eroding owing to six decades of Glen Canyon Dam operations

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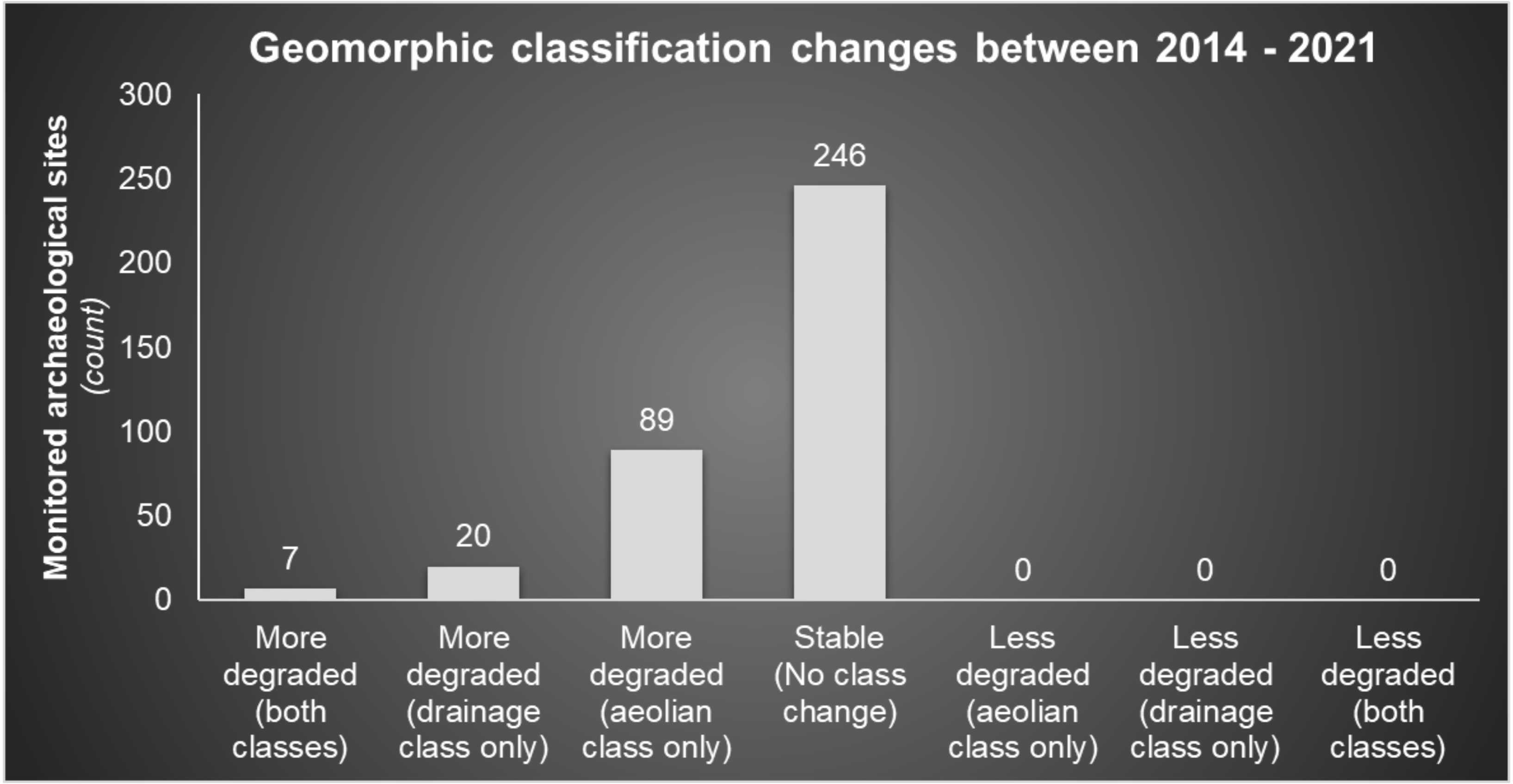
From Sankey et al., 2023, Journal of Environmental Management

Metric 1.3: Changes in aeolian and drainage classifications reflect changes in site stability and condition linked to dam operations

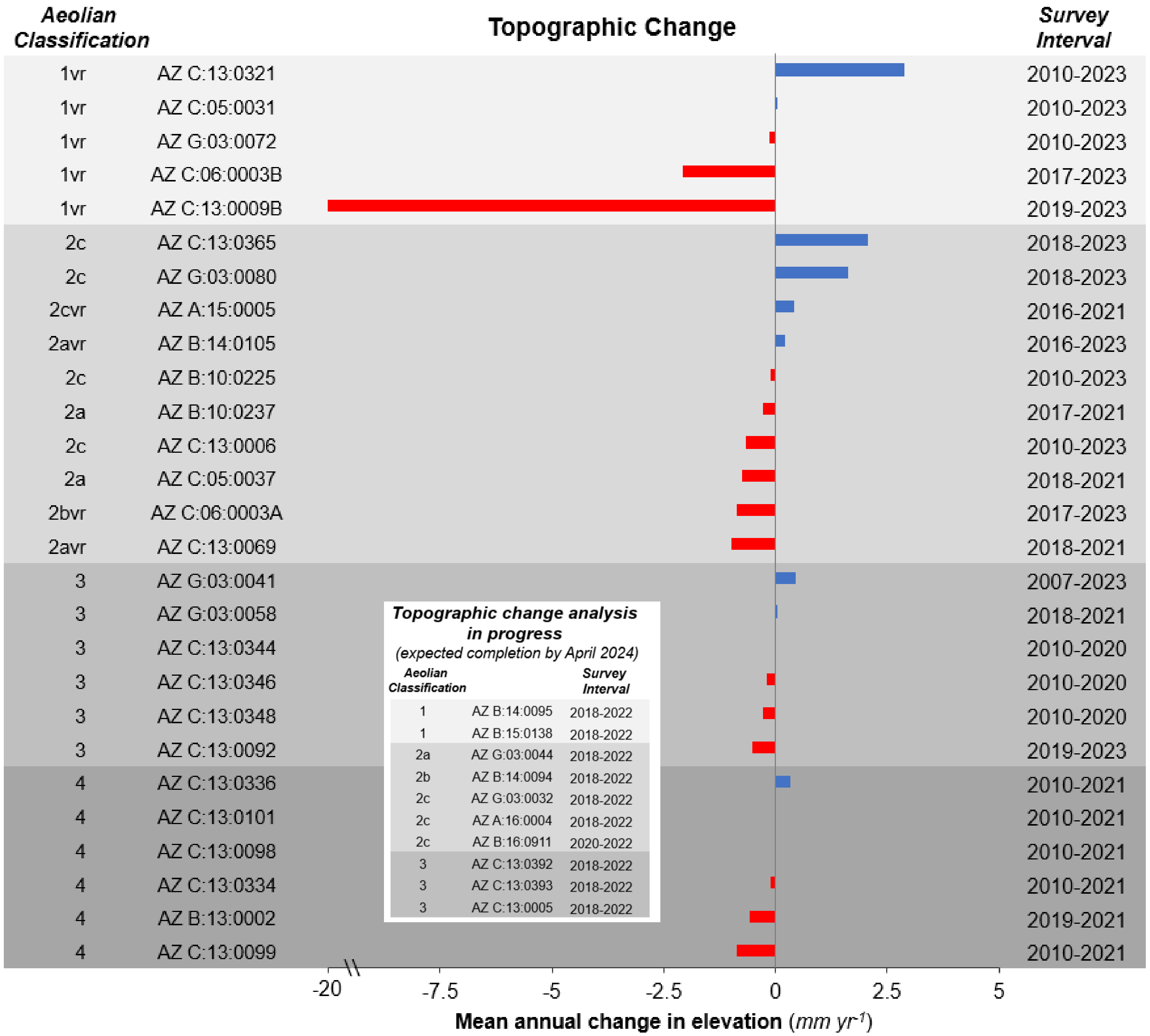
- 89 sites (24%) changed to a “less connected” aeolian class
- 20 sites (6%) changed to a more degraded drainage classification
- 7 (2%) sites changed in both respects to a more degraded condition
- Majority of sites (n=246, 68%) did not change
- No sites showed “improvement” in terms of their classifications



Sankey et al., 2023, Journal of Environmental Management

Metric 1.2: Lidar Topographic Change Detection

- Currently, sample includes 27 sites with multiple repeat surveys that document net change in erosion or deposition
- Net deposition documented at 33% of these sites (n=9); most are Aeolian Class 1 or 2
- Approximately 55% of monitored sites have lost surface sediment (eroded)
- 11% have neither aggraded nor eroded
- Long-term effects of April 2023 HFE are not reflected in these results



Preliminary results, please don't cite

Metric 1.1: Change in Integrity

- Metric 1.1 is a recently added metric that is specifically focused on Integrity
- Integrity has a specific meaning in the historic preservation field and the National Historic Preservation Act: "the ability of a historic property to convey its significance"
- Integrity is not measurable. It is a professional judgment and is either present or absent (i.e., there are no "degrees" of integrity)
- Metric 1.1 documents number of sites that have lost integrity during LTEMP
- Currently all sites in the APE continue to retain integrity, despite erosion continuing to affect many sites

Eroding archaeological sites in Grand Canyon, 2017 (photos by J. Sankey)

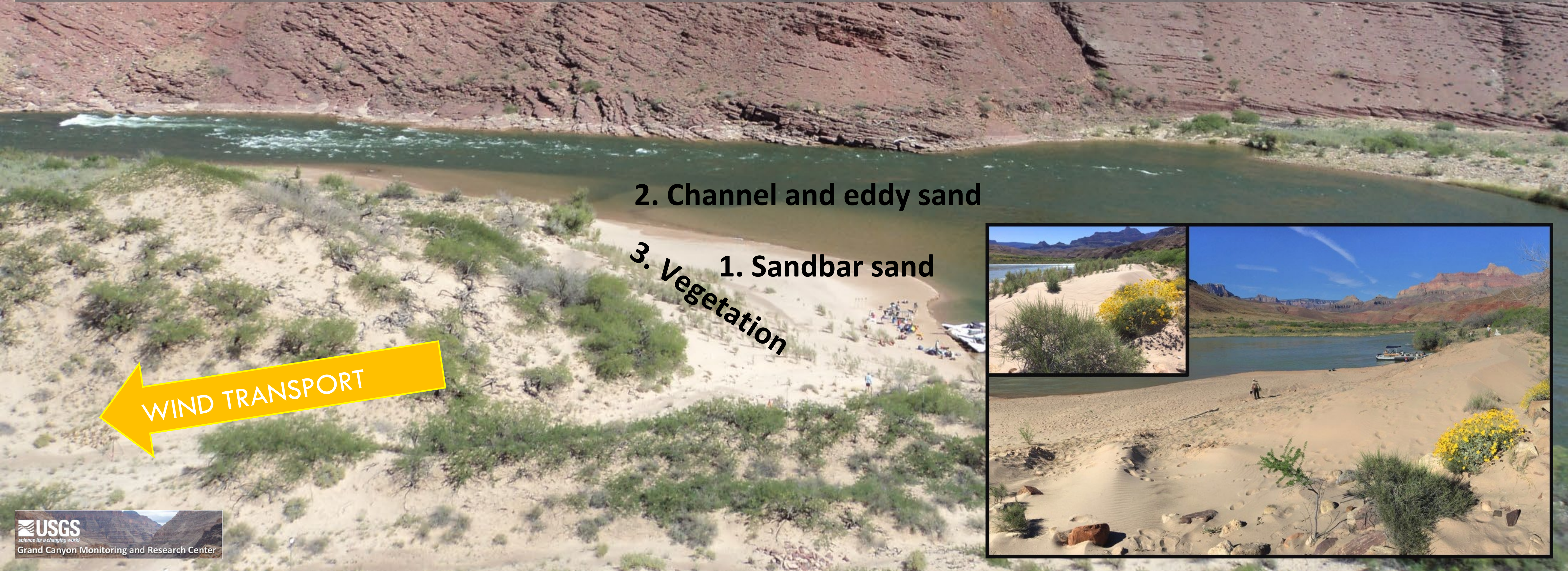
Experimental management to increase wind transport of river-sourced sand

Increase aeolian sediment supply:

1. HFEs to rebuild river sandbars (*Sankey et al., 2018, Aeolian Research*)
2. Lowering dam releases to expose sand that is normally underwater in the river channel & eddies (*Sankey et al., 2022, JGR*)

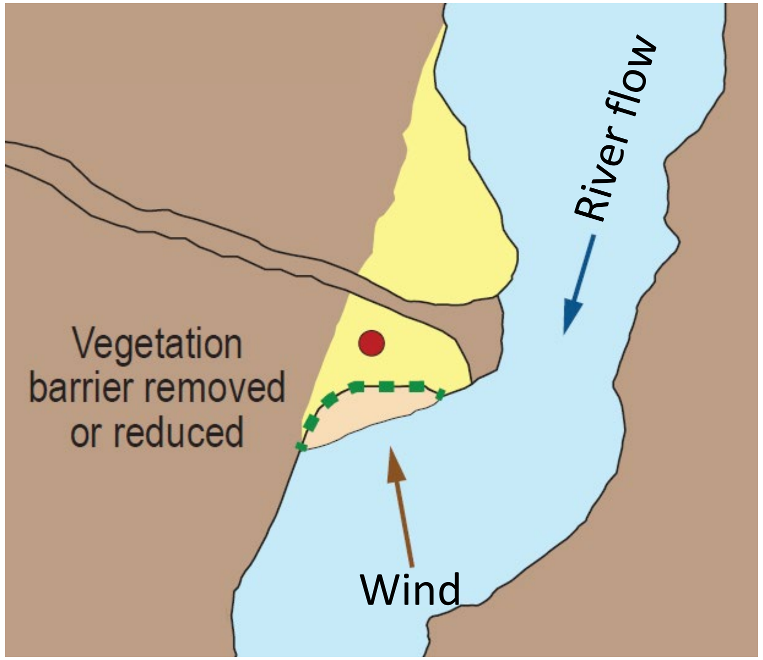
Minimize vegetation blocking aeolian sand transport:

3. Vegetation-management by NPS to remove riparian vegetation on sandbars (*Pilkington et al., 2022, Park Science*)



Research question

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



Vegetation management for dunefield archaeological site restoration

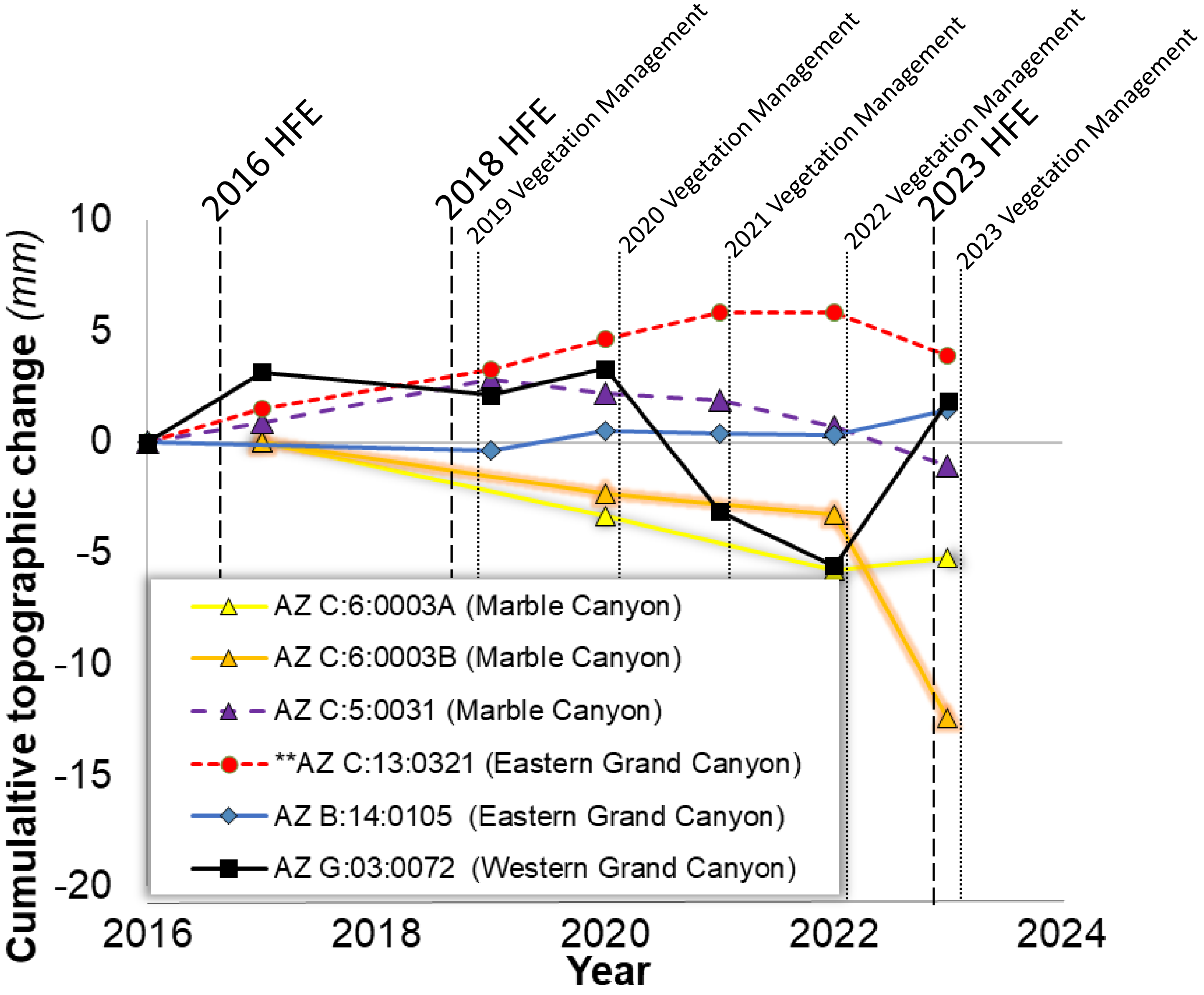
- Implemented in coastal dunefields around the world
  - Improve cultural, ecological, recreational resources
  - Protect infrastructure
- Not common for aeolian dunefield and archaeological sites in river environments

Photos taken before (top) and after (bottom) removal of invasive vegetation to restore a coastal dunefield at Doughboy Bay, Stewart Island, New Zealand (Konlechner et al., 2014, Dynamic Environments)

An intact oven (top) in a coastal dunefield occupied by Maori ancestors, Mason Bay, New Zealand. The oven was exposed (top) and eroded (bottom) due to reduction in the supply of windblown coastal sand owing to encroachment of invasive vegetation (e.g., panel a). (Hilton and Konlechner, 2014, University of Otago)

Lidar measured topographic change at archaeological sites downwind of sandbar vegetation management areas

- Experimental removal of vegetation on river sandbars by NPS began in 2019
- Has contributed to some, but not all, of the associated downwind archaeological sites being buried by windblown river sand over time
- Cumulative topographic changes likely dependent on frequency and timing of HFEs and vegetation management, as well as downwind distance to archaeological site, and other factors



*** Results for AZ C:13:0321 were reduced by a factor of 10*

Preliminary results, please don't cite

Incipient aeolian dune on sandbar (wind blown river sand) that grew following the 2023 Spring HFE and migrated inland towards vegetation management area, downwind dunefield and archaeological sites.

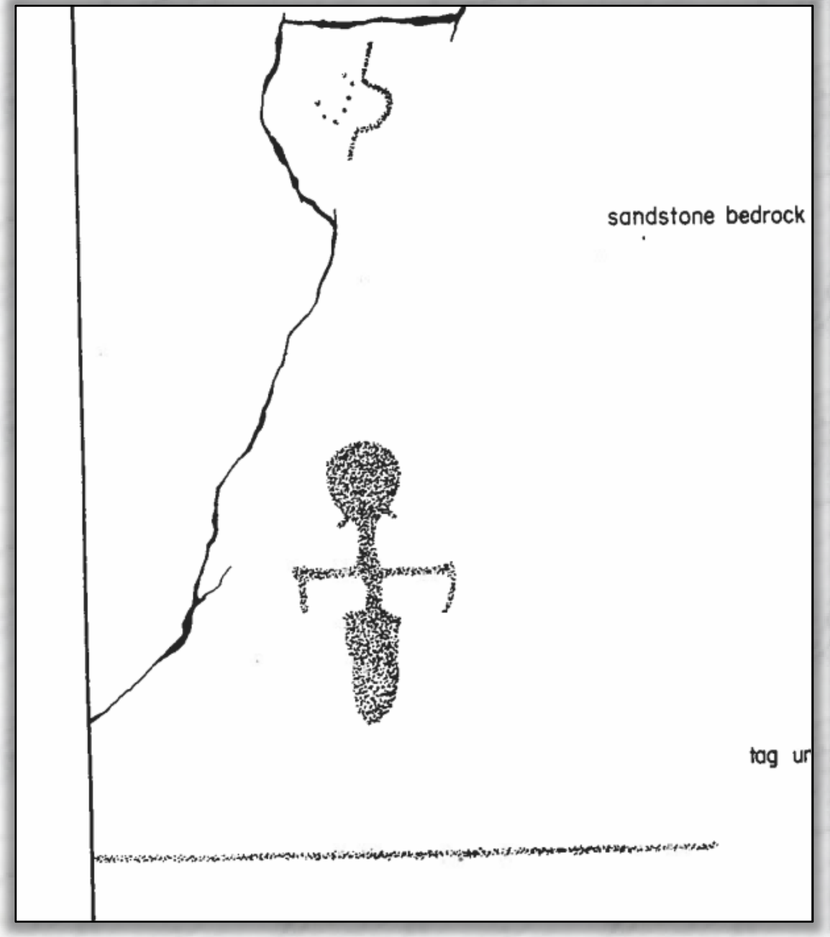
September 2023

Preliminary results, please don't cite

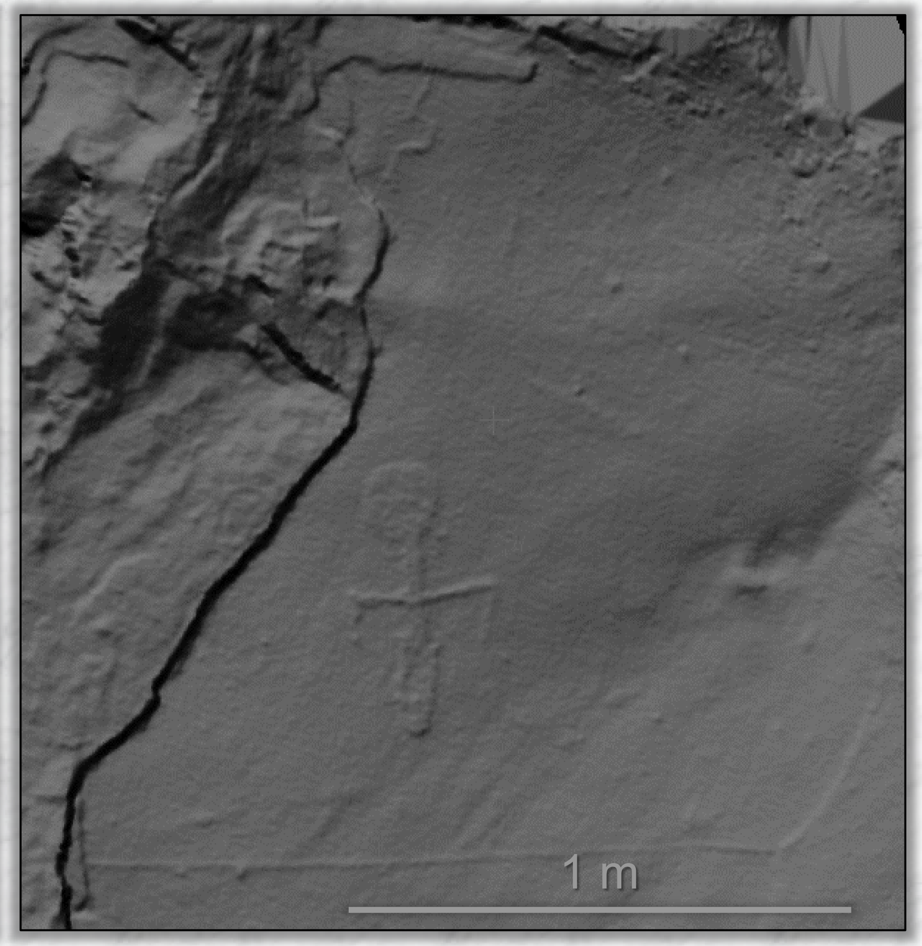
Monitoring for Potential Threats to Grand Canyon Rock Art

In 2023 LTEMP Cultural PA requested USGS-GCMRC monitor C:06:0005 "Supai Man" rock writing site for degradation using LiDAR and photogrammetry

September 1990
Feature Map



April 2023
5 mm Lidar Relief Model



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