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photo: Jeff Behan

Glen Canyon Dam Adaptive Management Program
Adaptive Management Work Group Meeting
August 17, 2022

Paul Grams
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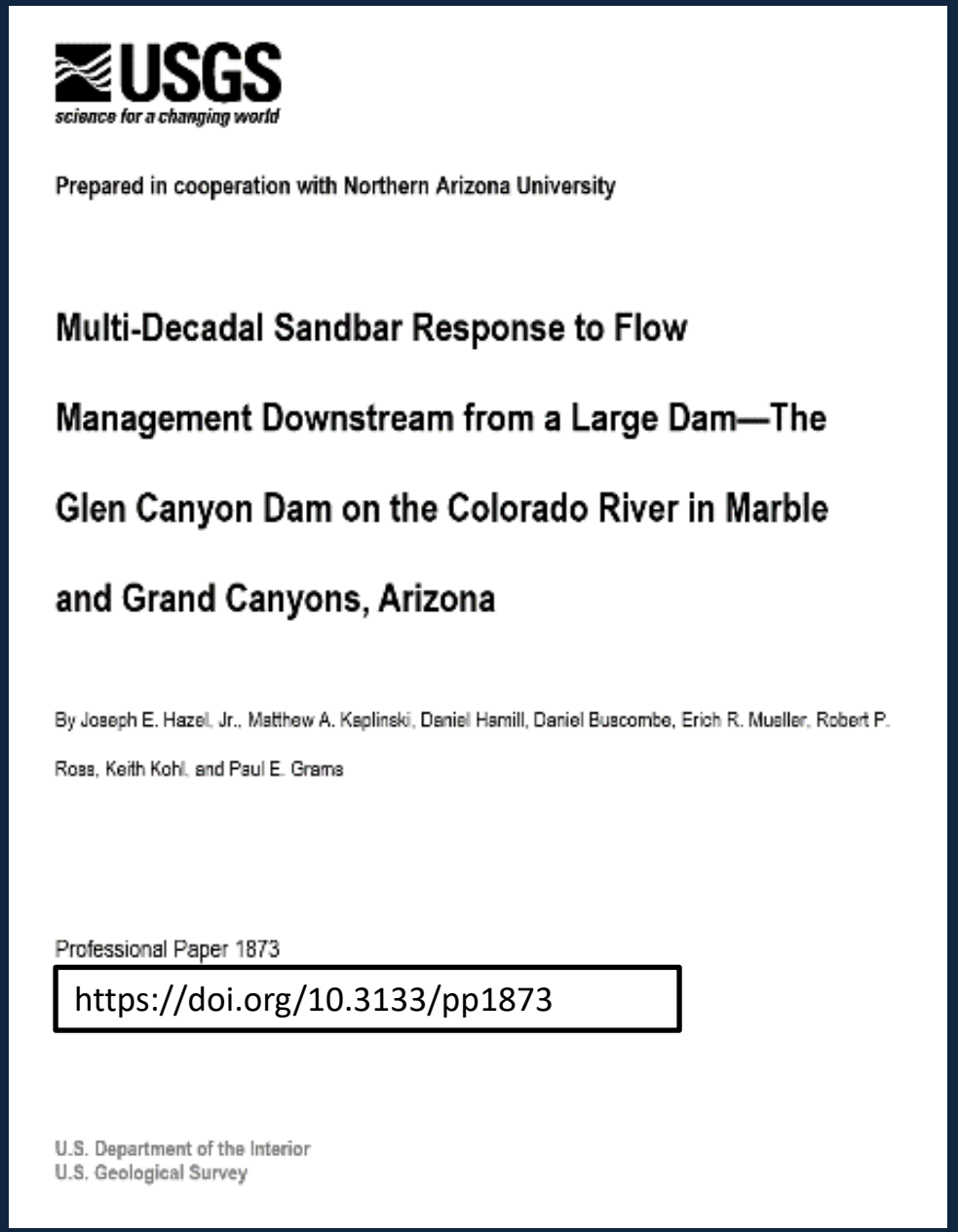

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Prepared in cooperation with Northern Arizona University

Multi-Decadal Sandbar Response to Flow Management Downstream from a Large Dam—The Glen Canyon Dam on the Colorado River in Marble and Grand Canyons, Arizona

By Joseph E. Hazel, Jr., Matthew A. Kaplinski, Daniel Hamill, Daniel Buscombe, Erich R. Mueller, Robert P. Ross, Keith Kohl, and Paul E. Grams

Professional Paper 1873
https://doi.org/10.3133/pp1873

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Overview

- Milestone documentation of methodology for sandbar monitoring program
  - Description of sites and site categorizations
  - Methods for data collection, processing, and data management
  - Development and computation of metrics used to evaluate sandbar response to dam operations
- Description of sandbar response to dam operations based on 30-year monitoring record
  - Net erosion occurred in the relatively sand depleted period with few controlled floods, also called High-flow experiments (HFEs) from 1990 to 2003
  - Net deposition occurred in the relatively sand enriched period with frequent HFEs from 2004 to 2020
- Directly related to Long-term Experimental and Management Plan (LTEMP) sediment goal to: “Increase and retain fine sediment volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes.”

The report supports the findings from previous studies and show that short-duration releases of high flows from Glen Canyon Dam can be used to rebuild and maintain the sandbar resource when those releases are timed to occur during periods of sand enrichment

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Sandbar monitoring site types

Reattachment Bars

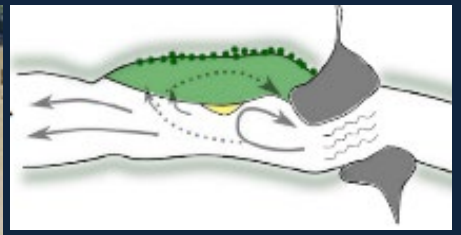
Increasing channel width

Increasing vegetation

Narrow Reattachment bars

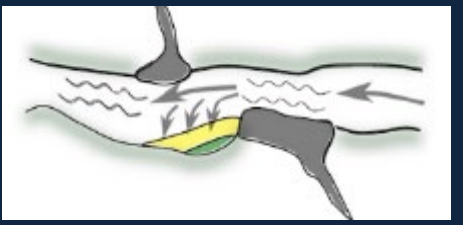
Medium Reattachment bars

Wide Reattachment bars

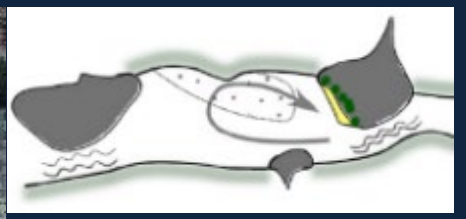


Other Bar Types

Undifferentiated bars



Separation bars



Upper pool deposits

Mueller and others (2018)

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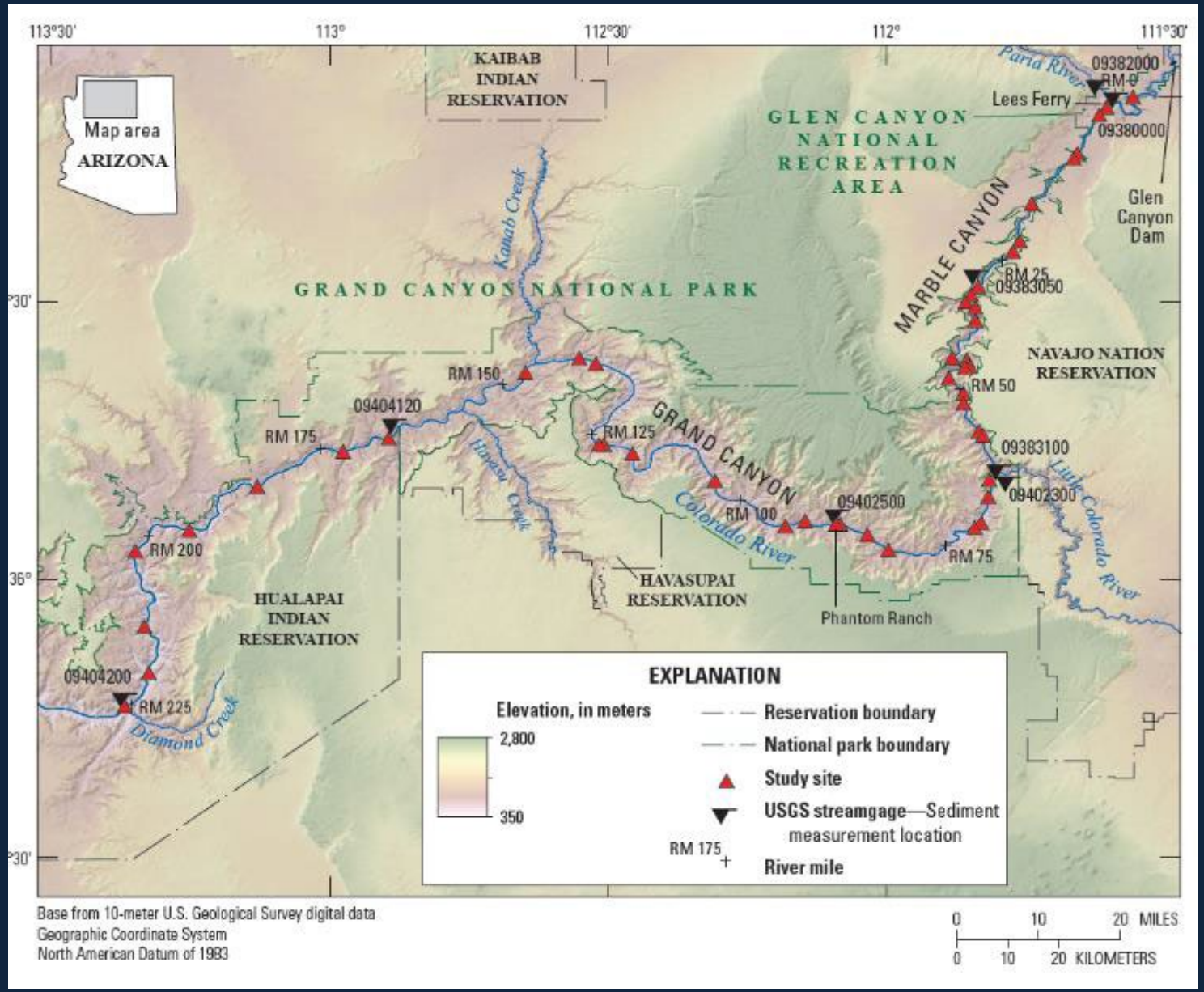
Study Sites

- 45 Long-term monitoring sites
  - 1 Site in Glen Canyon
  - 20 Sites in Marble Canyon
  - 24 Sites in Grand Canyon



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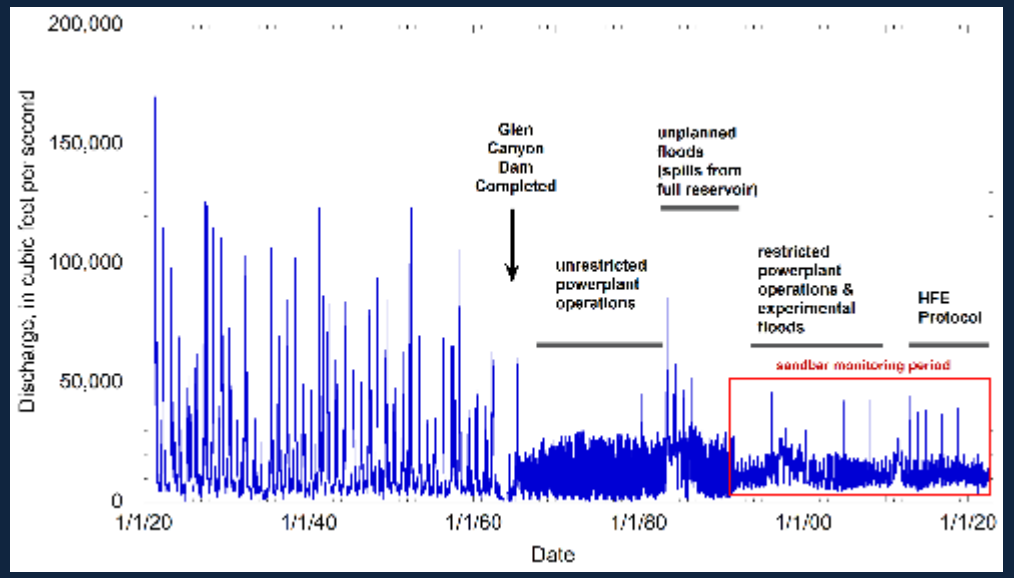
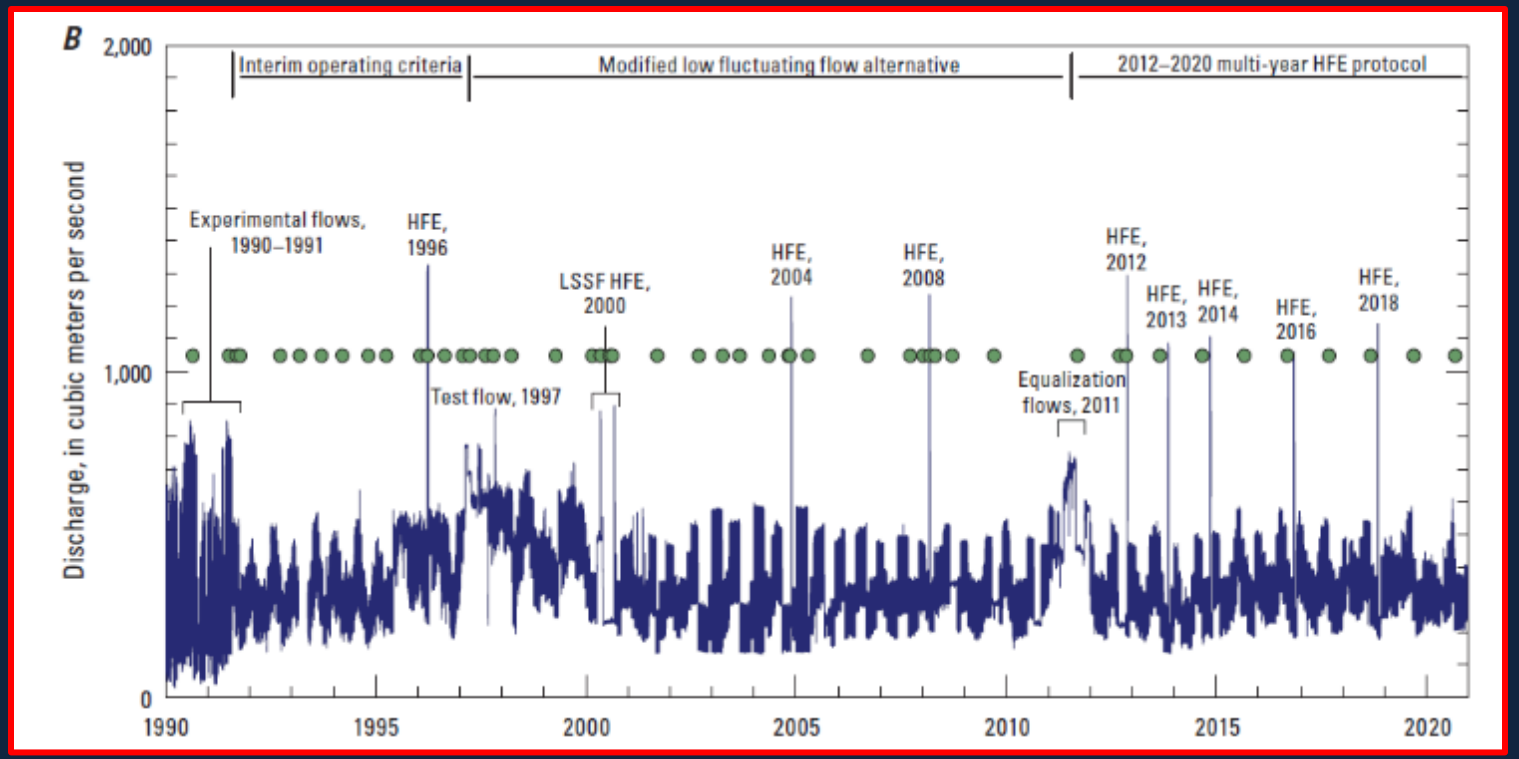
Study Period





- Monitoring spans entire period of restricted powerplant operations that began with the “interim flows” in 1991
- Up to 51 repeat surveys at some sites
- Multiple surveys per year in some years
- Annual surveys in October only since 2009

** Each green circle represents a sandbar monitoring trip.*

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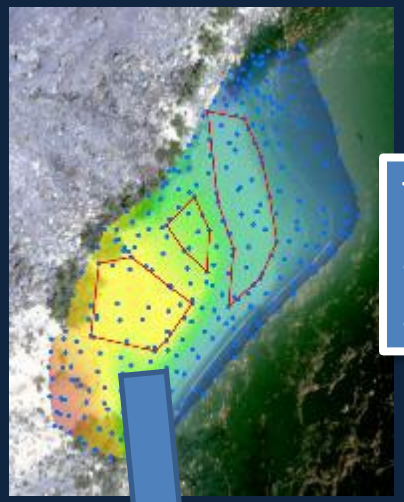
Sandbar monitoring methods

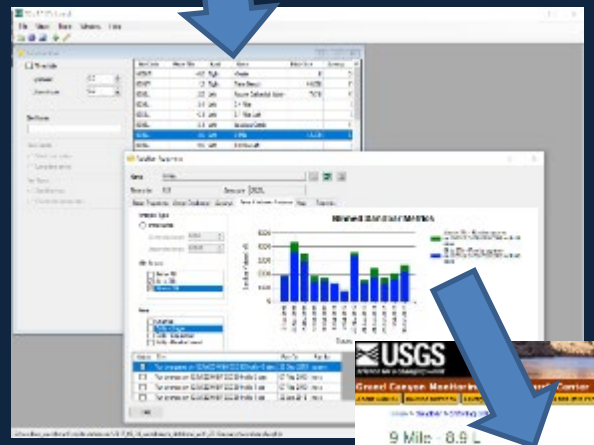
Data collection: “old school” total station and survey rod

Allows data collection down to 8,000 cfs stage and in dense vegetation. Neither of which can be done reliably with modern methods (lidar etc.)

21st century data processing and analysis

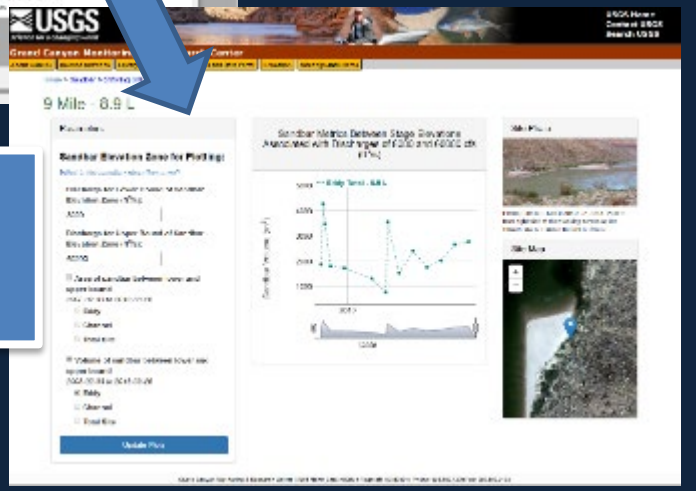


Topographic surfaces modeled in survey software



Data processed and analyzed in sql database

Data served in sandbar web application



www.gcmrc.gov/sandbar OR www.usgs.gov/apps/sandbar

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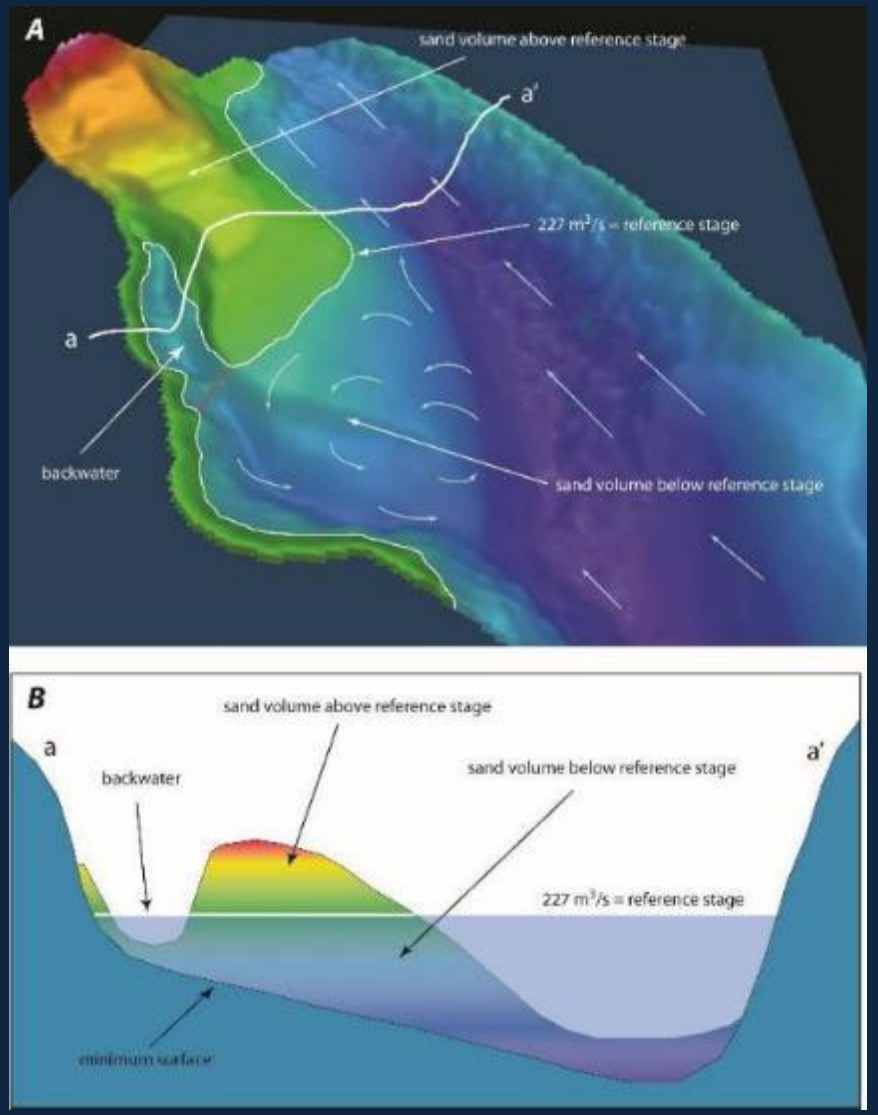
Sandbar monitoring metrics

- ***Sandbar volume*** is the volume of sand contained in a monitoring site that is above the elevation of the *minimum surface* for that sandbar
- ***Normalized sandbar volume*** is the ratio between measured sandbar volume and the *maximum sandbar volume*
  - The *minimum surface* is computed as the minimum elevation among all surveys collected over the monitoring period for every location at each study site
  - The *maximum surface* is computed as the maximum elevation among all surveys collected over the monitoring period for every location at each study site
  - The *maximum sandbar volume* is the difference between the maximum and minimum sandbar surfaces and represents a hypothetical maximum sandbar sized based on conditions observed over the monitoring period
- Metrics are computed for two elevation zones
  - The “high-elevation” zone is all sand above the 8,000 cfs stage
    - Includes sand in fluctuating zone which is only intermittently available for camping
  - The “controlled-flood” zone is sand above the 25,000 cfs stage
    - Sand in this zone is always available for camping
- The sandbar volume metrics are a direct measurement of the LTEMP sediment goal



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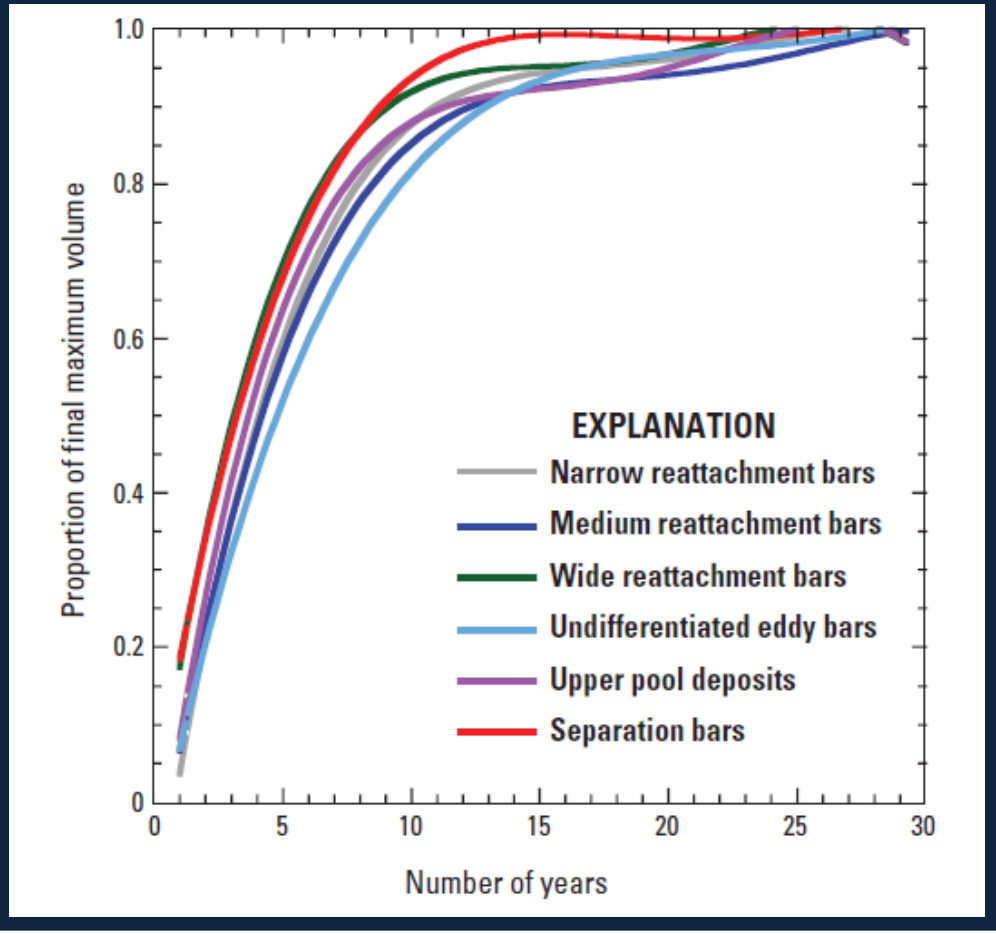
Maximum sandbar volume over time

- Maximum volume stabilized after 10 to 15 years of monitoring
  - Bars not scouring ever deeper
  - Bars not aggrading ever larger
  - *Most sandbars are eroding and rebuilding within the range of observed conditions*

→ The maximum volume used in the normalized sandbar volume metric is a stable representation of maximum potential sandbar size



Maximum sandbar volume computed in annual increments for the entire study period, averaged for each site type.

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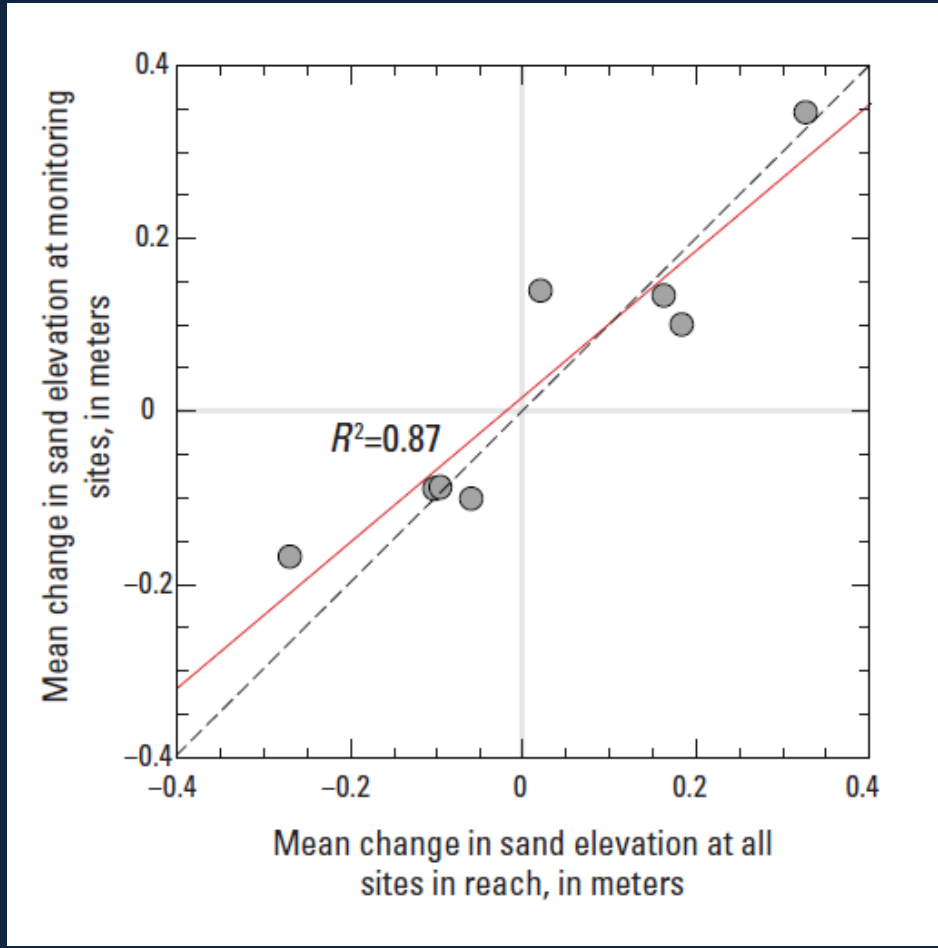
Relation between study sites and all sandbars

- Strong correlation between sandbar response at long-term monitoring sites and larger population of sandbars

→ The collection of long-term monitoring sites provides a good representation of overall sandbar response*

** This evaluation has only been possible for sites in Marble Canyon and Eastern Grand Canyon (river miles 0 to 88).*



Comparison of average change at long-term monitoring sites with average change at larger set of sites using data from channel mapping program for Marble Canyon and Eastern Grand Canyon

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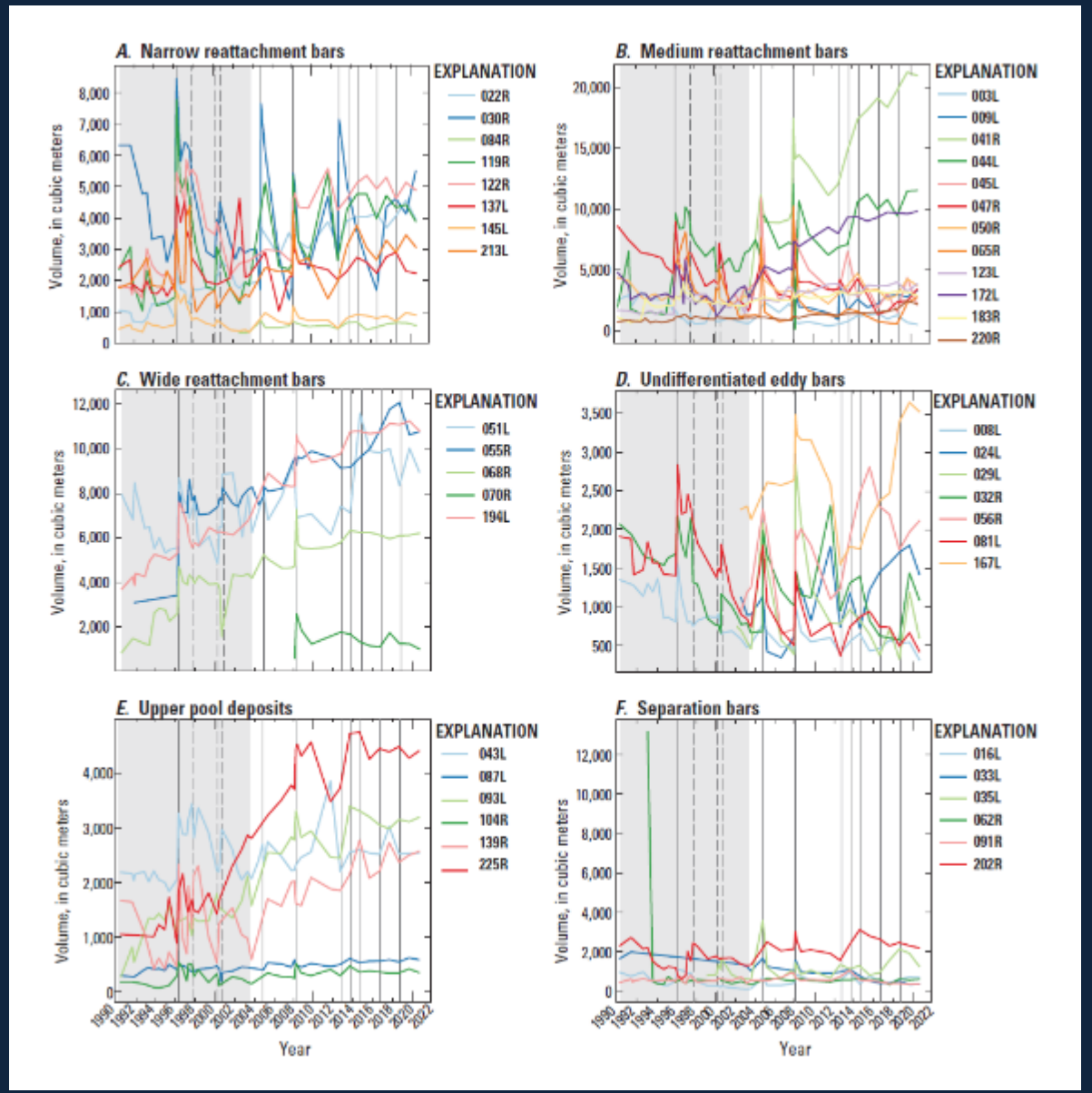
Results – All sites for entire monitoring period

Wide variability among the individual sandbars, but can clearly see effects of HFEs and similar behavior within site types



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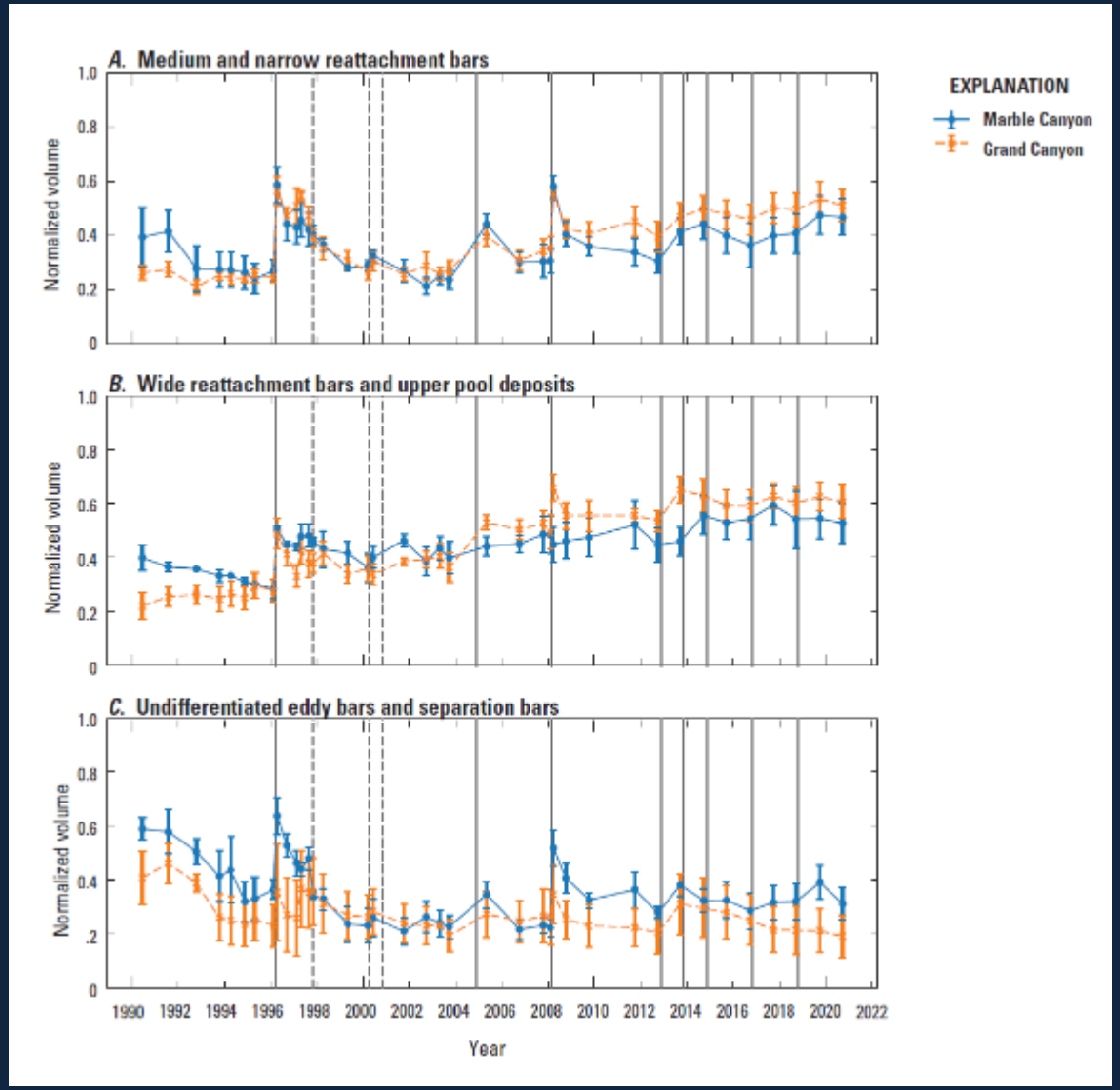
Results – By site type and reach

- Grouping of response among bar types that behave similarly
- Deposition by HFEs
- Erosion during periods between HFEs
- Response is generally similar at sites in Marble Canyon and Grand Canyon



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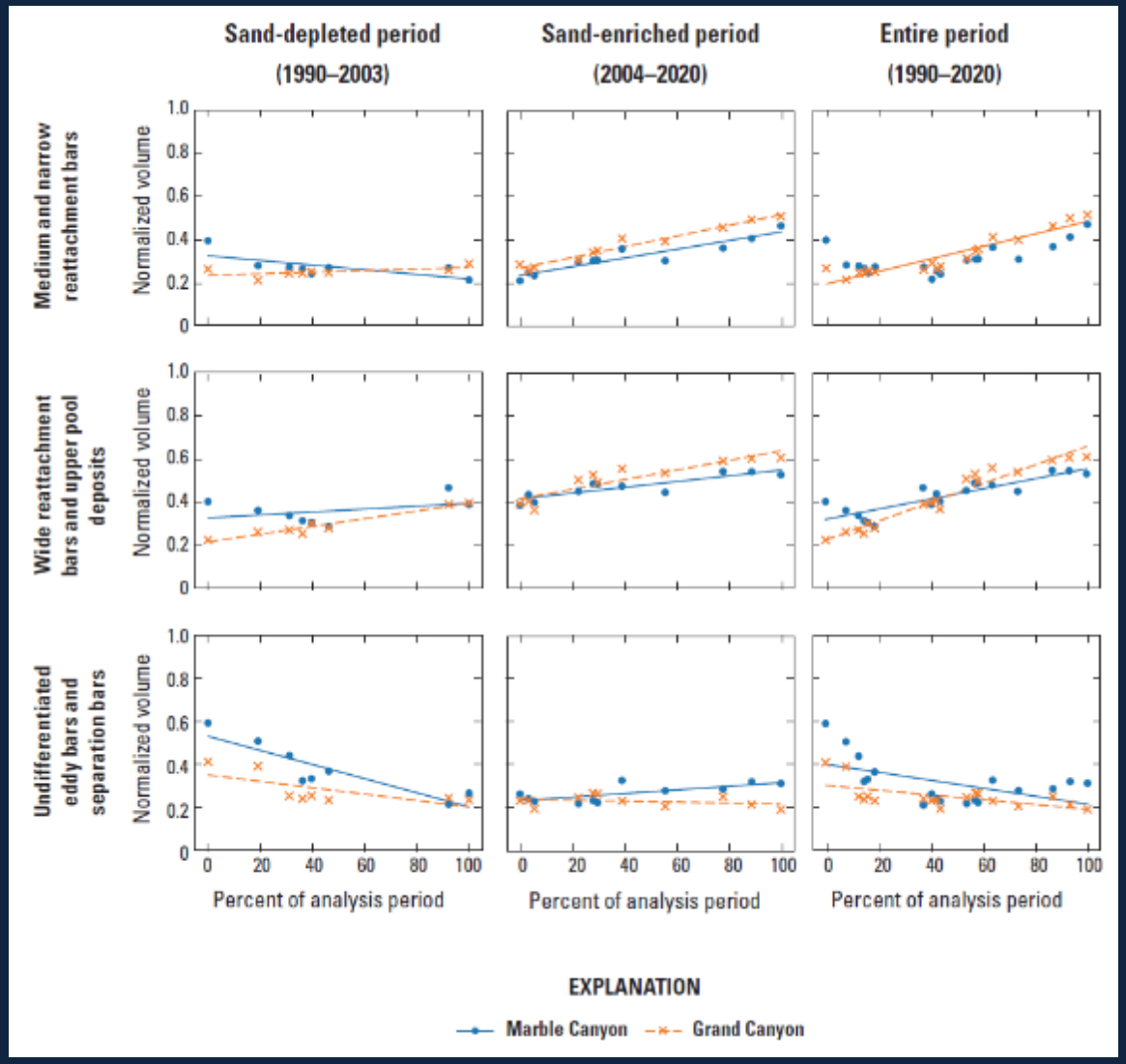
Results – Response to dam operations and sand supply

- Significant difference in response between the *sand-depleted period* and the *sand-enriched period*
- The *sand depleted period* was 1990 to 2003 with:
  - Average discharge of 13,300 ft^3/s
  - Above average sand inputs from Paria River in five out of the 13 years (38% of years)
  - One HFE
- The *sand enriched period* was 2004 to 2020
  - Average discharge of 12,400 ft^3/s
  - Above average sand inputs from Paria River in nine out of the 16 years (56% of years)
  - Seven HFEs

Net erosion or no change for all bar types during sand-depleted period.
Net aggradation for most bar types and no net change for two bar types during sand-enriched period.



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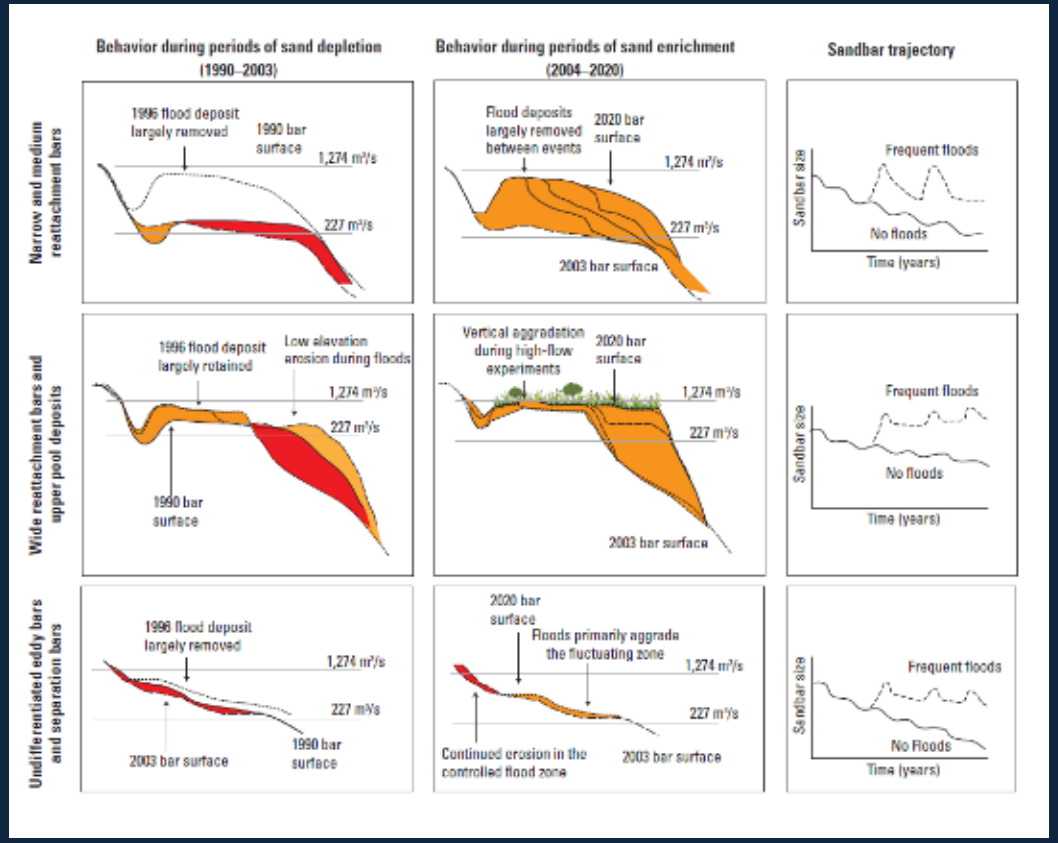
Summary

- The normalized sandbar volume metric based on the maximum volume provides a robust characterization of sandbar volume for the range of conditions that have occurred over the 30-year monitoring period
- Increases in sandbar size occurred almost exclusively during HFEs
- Erosion occurred during sand-depleted period with few HFEs
- Deposition occurred during sand-enriched period with several HFEs
- Thickness of deposition is proportional to HFE magnitude



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- Narrow and medium reattachment bars are most dynamic and responsive to HFEs
- Separation bars and undifferentiated bars are less dynamic but also maintained by HFEs
- Wide reattachment bars and upper pool deposits are stabilized by vegetation and aggrade over time, decreasing the effectiveness of HFEs at increasing sandbar volume at higher elevations

Report:
Hazel, J.E., Jr., Kaplinski, M.A., Hamill, D., Buscombe, D., Mueller, E.R., Ross, R.P., Kohl, K., and Grams, P.E., 2022, Multi decadal sandbar response to flow management downstream from a large dam The Glen Canyon Dam on the Colorado River in Marble and Grand Canyons, Arizona: U.S. Geological Survey Professional Paper 1873, https://doi.org/10.3133/pp1873

Associated data release:
Grams, P. E., Hazel, J. E., Jr., Kaplinski, M., Ross, R. P., Hamill, D., Hensleigh, J., Gushue, T. (2020). Long term sandbar monitoring data along the Colorado River in Marble and Grand Canyons, Arizona. U.S. Geological Survey Data Release. https://doi.org/10.5066/P93F8JJK

Interactive website:
www.gcmrc.gov/sandbar OR www.usgs.gov/apps/sandbar

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photo: Geoff Gourley

Joe Hazel retired in June 2021 after 30+ years at Northern Arizona University and as a cooperator with Reclamation and USGS on sandbar and sediment-related projects in Grand Canyon

NORTHERN ARIZONA UNIVERSITY

GRAND CANYON RIVER GUIDES

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