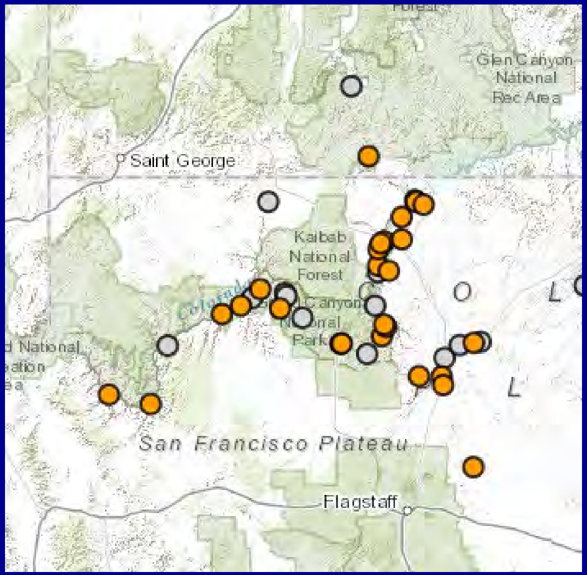
Project A: Streamflow, Water Quality, and Sediment Transport and Budgeting in the Colorado River Ecosystem

We collect, post, and analyze the following data at stations located through the Colorado River Ecosystem, including key tributaries…



- Element 1: Stream gaging
  - Stage
  - Discharge
- Element 2: Water quality
  - Water temperature
  - Salinity (specific conductance)
  - Turbidity
  - Dissolved Oxygen
- Element 3: Sediment transport and budgeting
  - Suspended- and bed-sediment data
  - Sediment loads (silt and clay loads and sand loads)
  - User-interactive sand budgets in 6 reaches from Lees Ferry to Lake Mead
- All elements
  - User-interactive duration-curve tool for any continuous parameter

Almost all other projects funded by the Glen Canyon Dam Adaptive Management Program (GCDAMP) use these data, and data from this project informs 10 LTEMP goals

Funding: GCDAMP provided $1.15 million during FY 2022

science for a changing world

Evaluation of LTEMP sand management

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Ronald E. Griffiths, U.S. Geological Survey
Matt Kaplinski, U.S. Geological Survey
Joel A. Unema, U.S. Geological Survey
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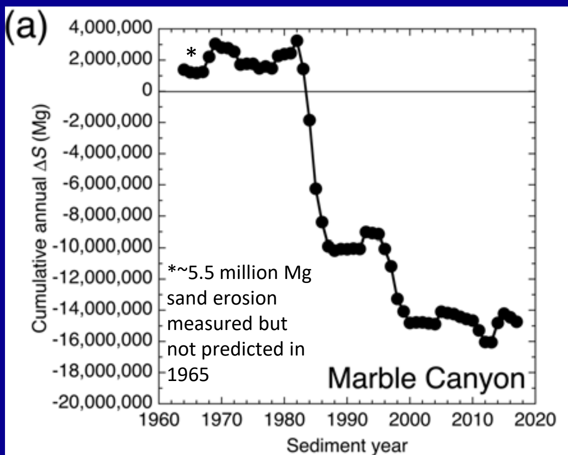
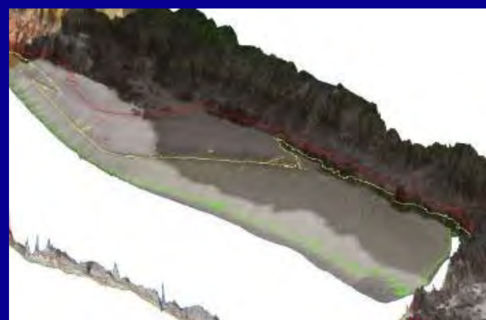
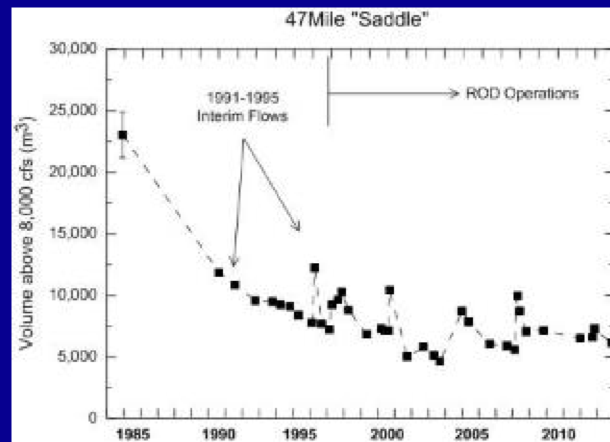
Downward spiral has likely occurred in long-term sand mass balance… and reflected in the high-elevation volume of an unknown percentage of the sandbars

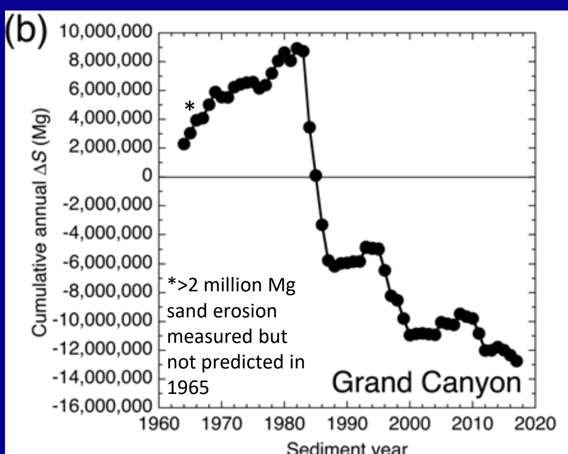
>28 million metric tons of sand eroded since 1963, mostly during 3–4 periods of sustained high dam releases (Topping and others, *JGR*, 2021)

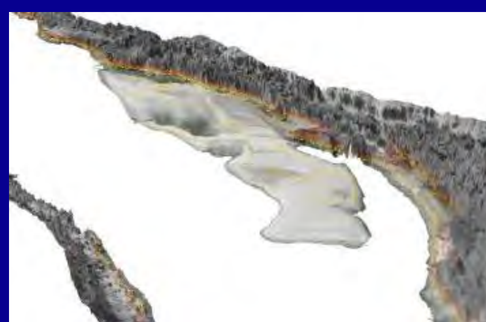
~12 million metric tons eroded in late 1990s alone (6 from Marble and 6 from Grand)

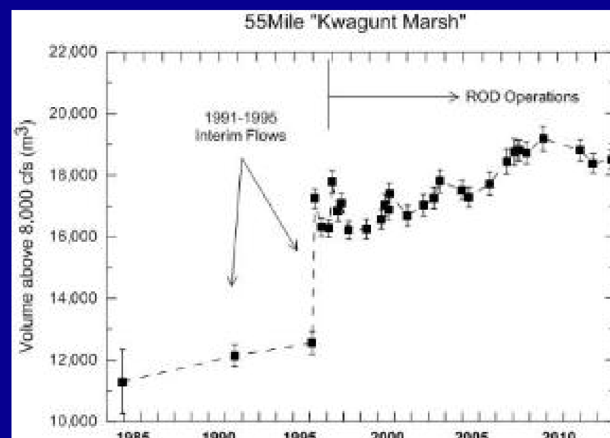












Figures from Topping and others (*JGR*, 2021)

Preliminary figures from Grams, Gushue, Hazel (do not cite)

Some of the sand involved in sandbar deposition during HFEs is part of a "bank account" that cannot be replaced

- **Although the Paria River is by far the dominant modern supplier of sand (Topping and others, *JGR*, 2021), a large percentage (~30–50%) of the sand stored in sandbars is relict "pre-dam" sand (Chapman and others, *GSA Bulletin*, 2020)**

- **Stratigraphic and ground-penetrating-radar data suggest strongly that pre-dam sand exists at depth in at least some sandbars (Barnhardt and others, *USGS-OFR*, 2001)**

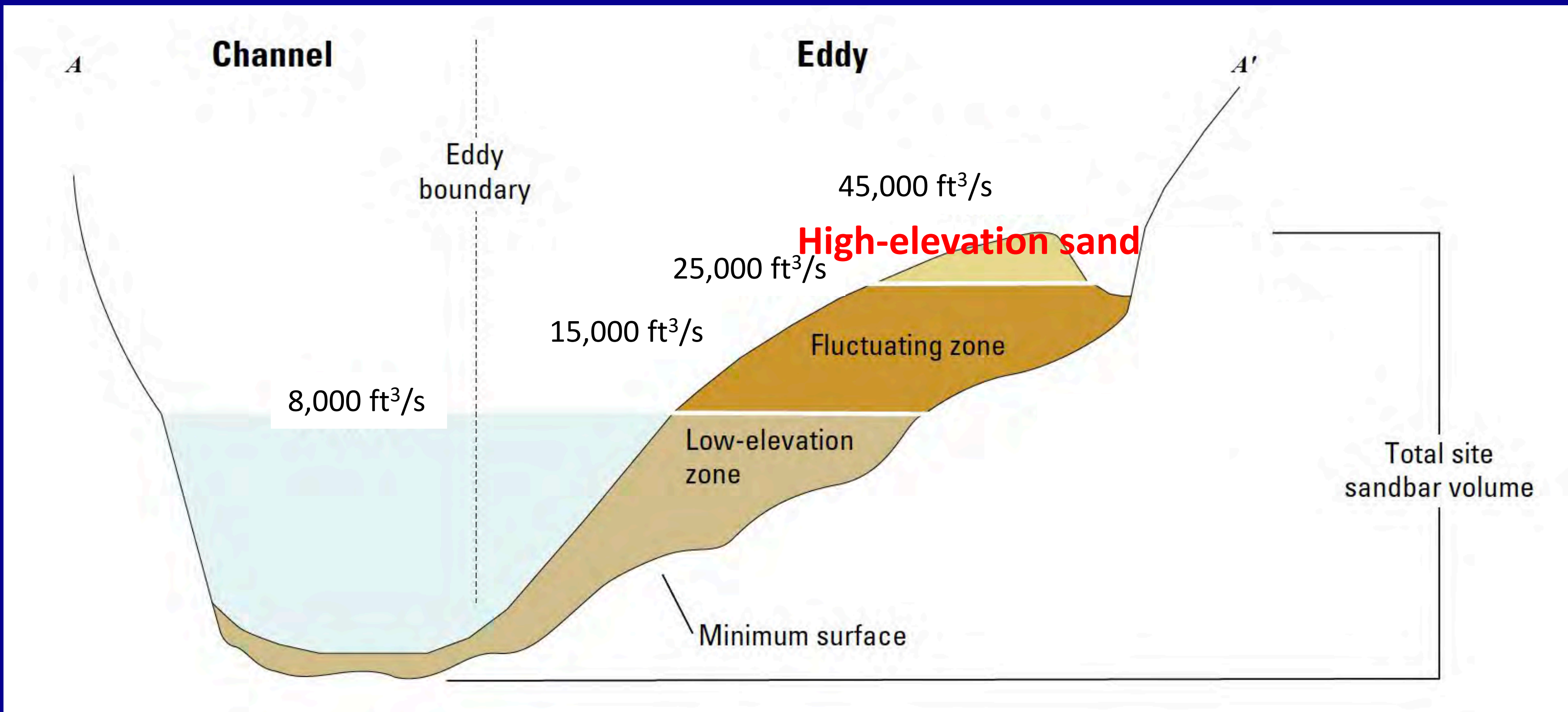


Figure modified from Hazel and others (*USGS-PP*, 2022)

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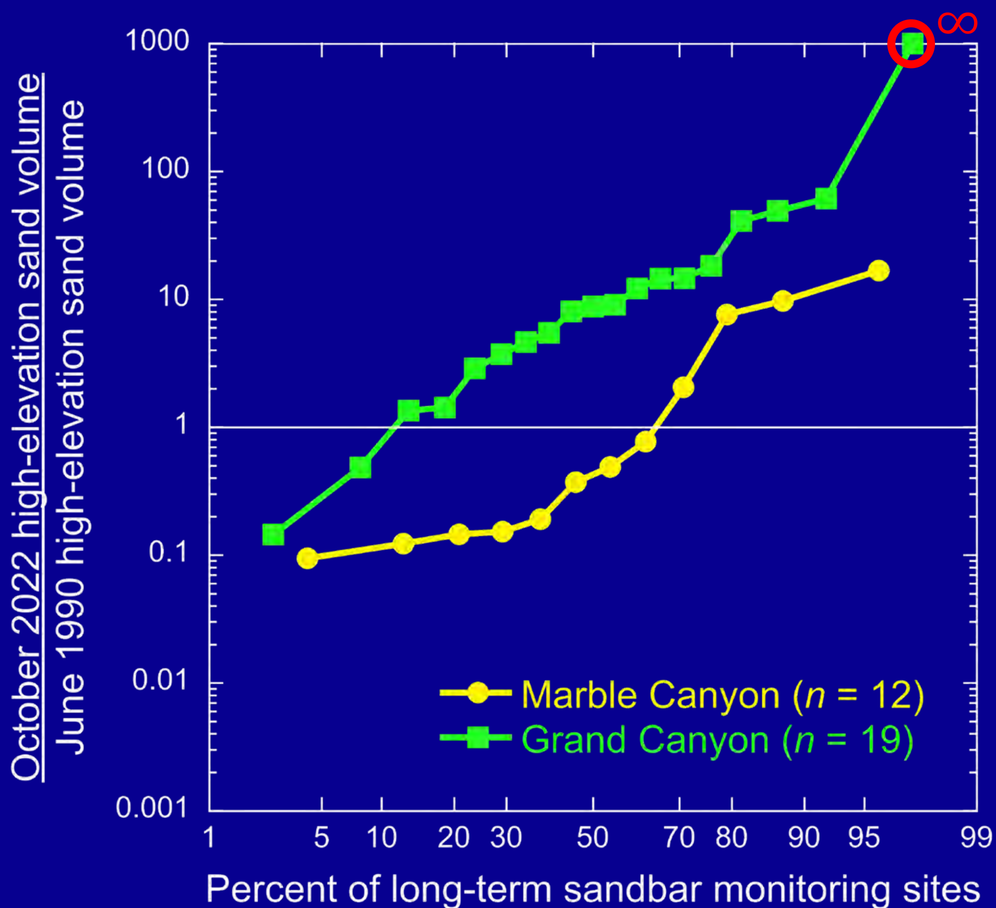
67% of the long-term sandbar monitoring sites in Marble Canyon had less high-elevation sand in October 2022 than in June 1990,



whereas only 11% of the long-term sites in Grand Canyon had less high-elevation sand in October 2022 than in June 1990

Data from USGS (2023a)

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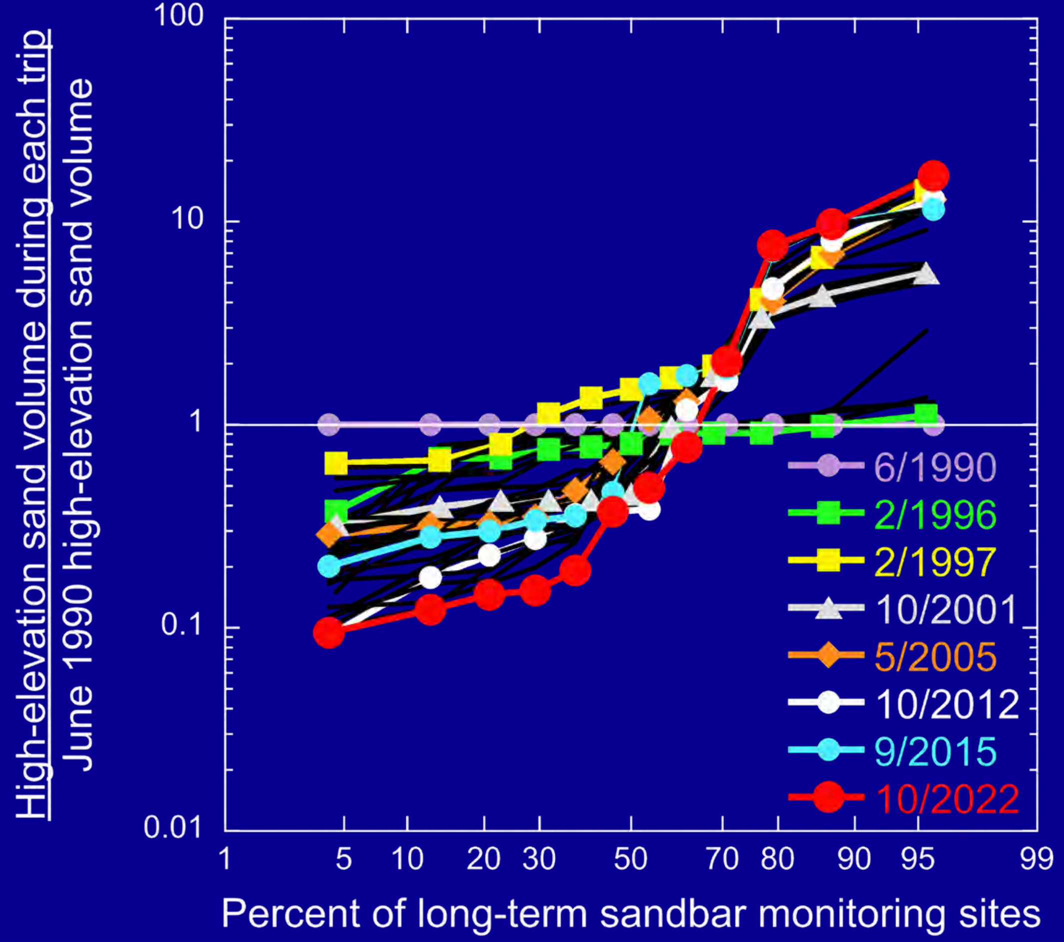
High-elevation sand at many of the long-term sandbar monitoring sites in Marble Canyon defines a downward spiral



Only repeated sand-enriched HFEs may reverse this trend, as during 2012–2014

Data from 37 surveys depicted; data from USGS (2023a)

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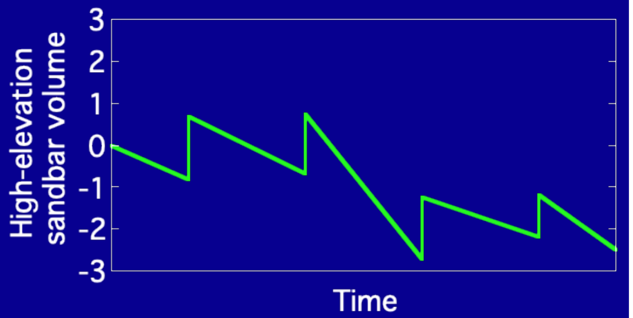
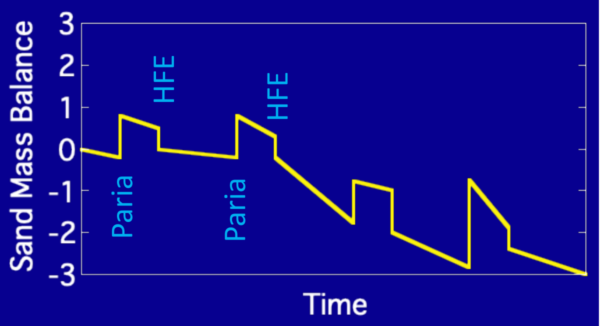
Sustainable management of sand under the LTEMP sediment goal thus requires neutral to positive trends in both the sand mass balance (i.e., the bank account) and the high-elevation sandbar volume (i.e., your expenditures) over decades

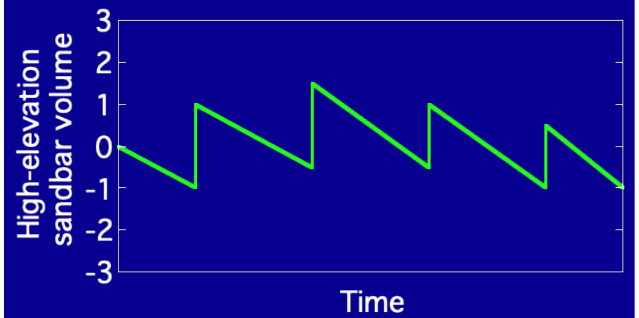
Scenario 1

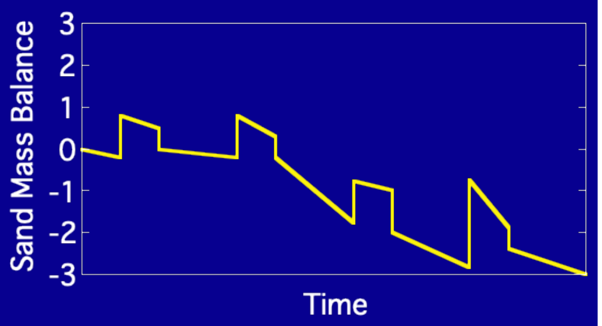




Not sustainable

Scenario 2



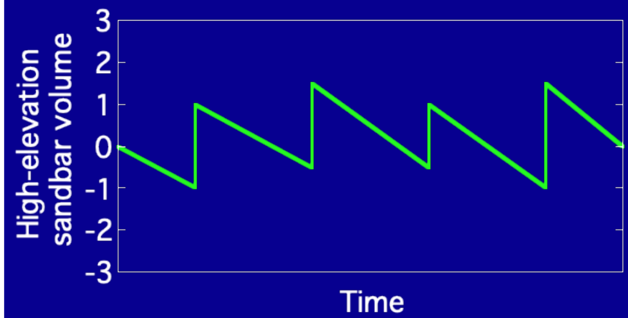


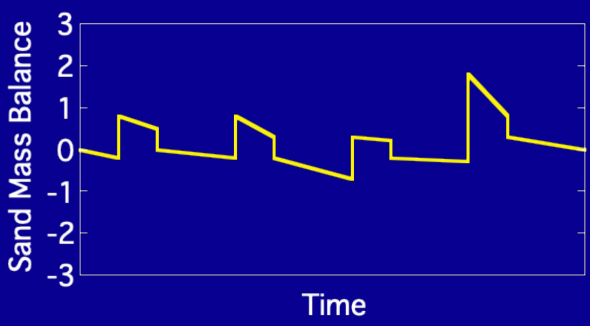
Not sustainable

Bank account mined to deposit sandbars

"Living on credit"

Scenario 3





Sustainable

"Living within your means"

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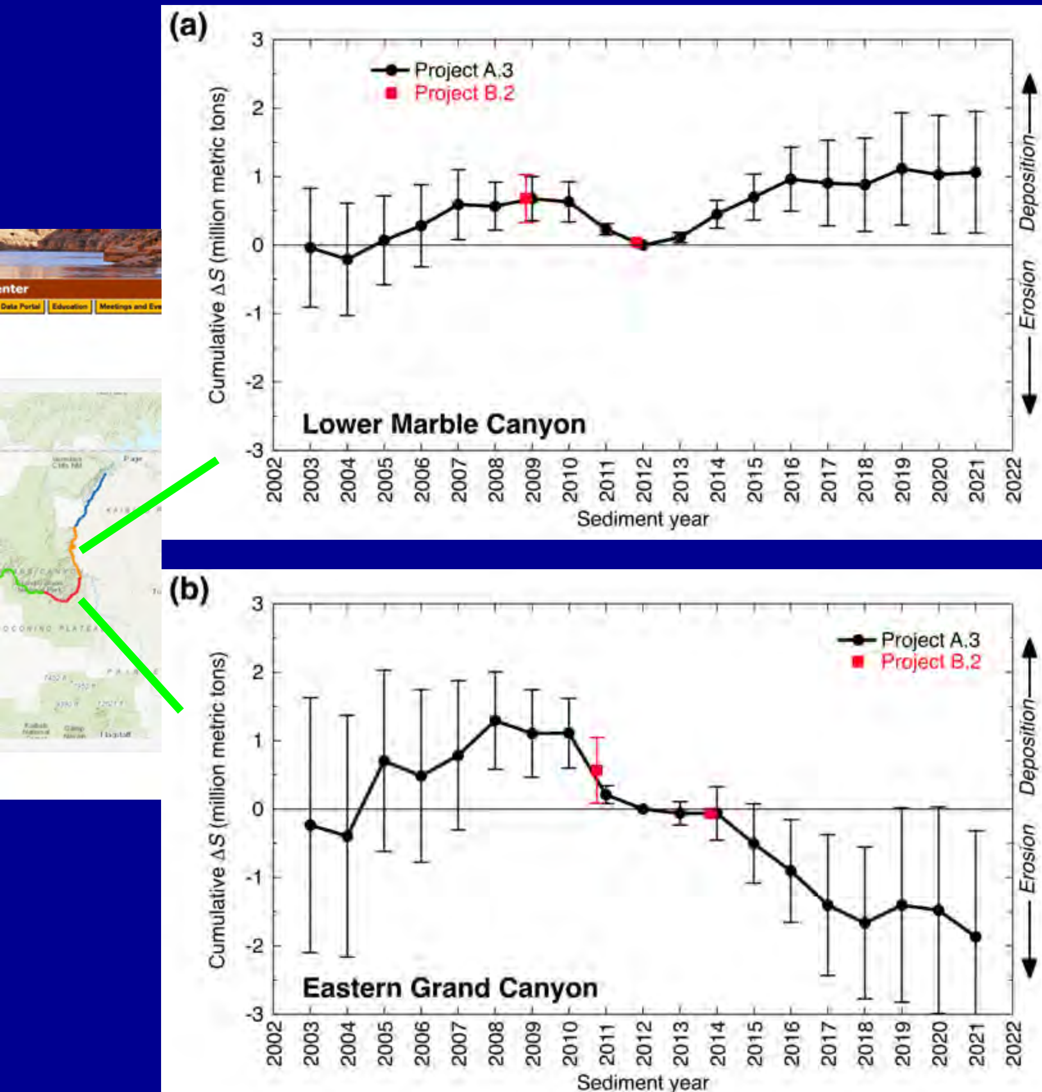
Metrics Example: The Bank Account



POSSIBLE SUCCESS! Sustainable in Lower Marble Canyon if high-elevation sandbar volume is positive during this period.

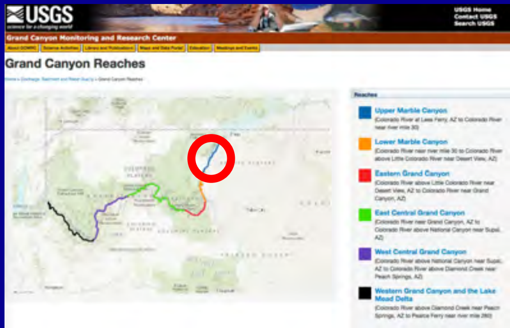
POSSIBLE FAILURE Not sustainable in Eastern Grand Canyon regardless of whether high-elevation sandbar volume is positive during this period.

Data from Topping and others (*JGR*, 2021); USGS (2023b)

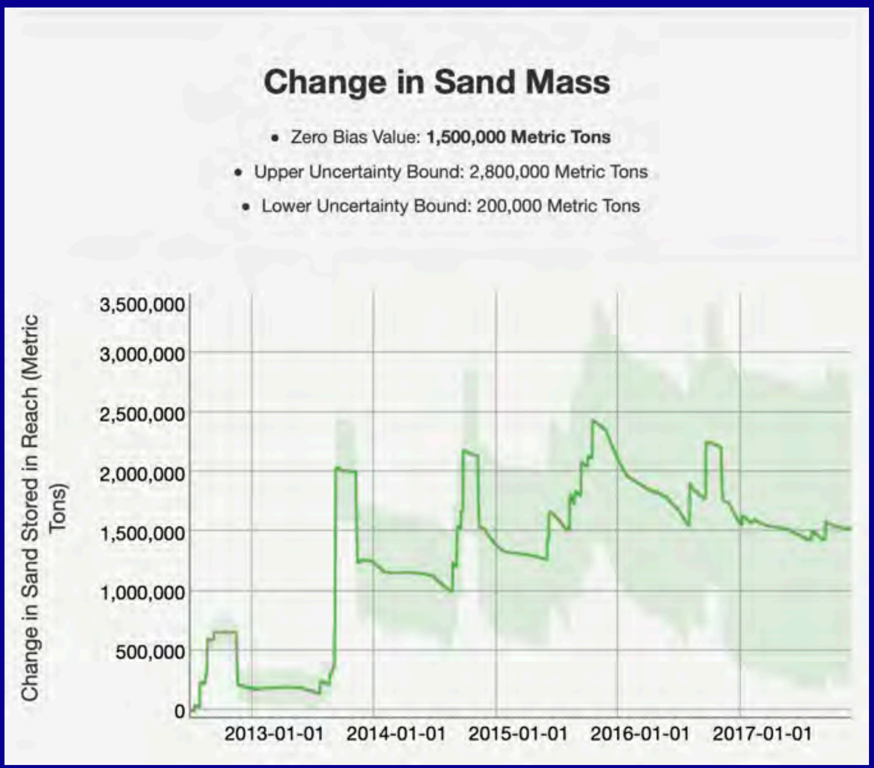
Conducting sand-enriched HFEs at every opportunity is central to the LTEMP experimental design

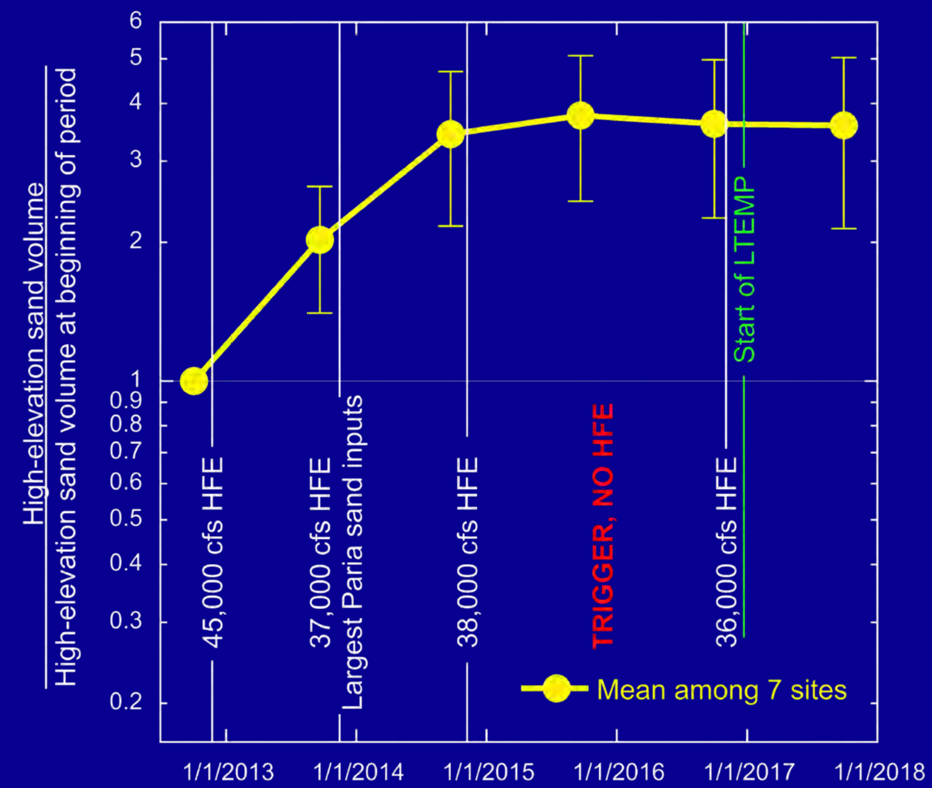
…in future controlled floods, more sand is required to achieve increases in the total area and volume of eddy sandbars throughout all of Marble and Grand Canyons. Annual tributary inputs of sand much larger than one million metric tons occur but are relatively rare. Therefore, “more sand” could be achieved directly by augmentation from sand trapped in the reservoir impounded by Glen Canyon Dam or perhaps indirectly by following each large tributary input of sand with short-duration controlled floods. Frequent short-duration controlled floods under sand-enriched conditions could result in the downstream propagation (into the downstream half of Marble Canyon and into Grand Canyon) of the gains in total eddy-sandbar area and volume observed in the upstream half of Marble Canyon during the 2004 controlled-flood experiment.

Excerpted from Topping and others (*FISC*, 2006)



HFE-Protocol Period
Upper Marble Canyon



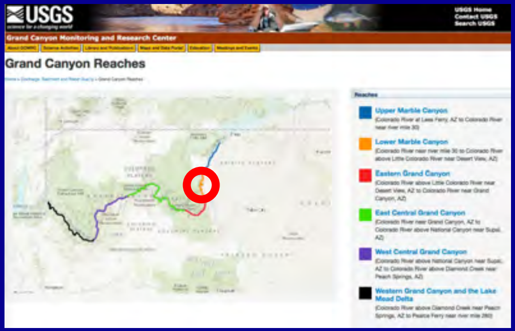


POSITIVE

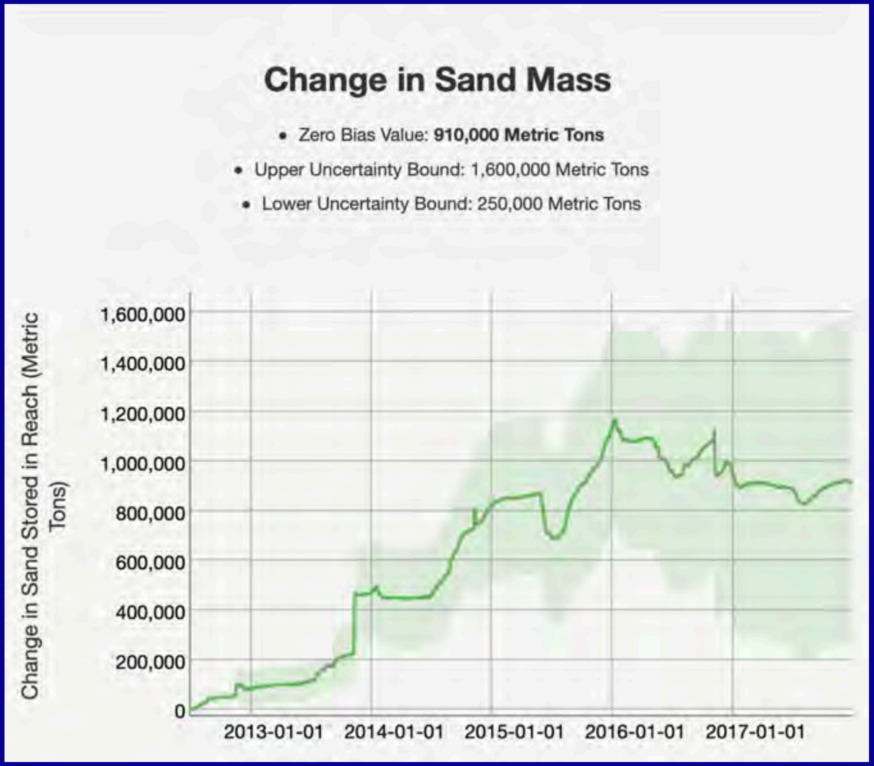
POSITIVE

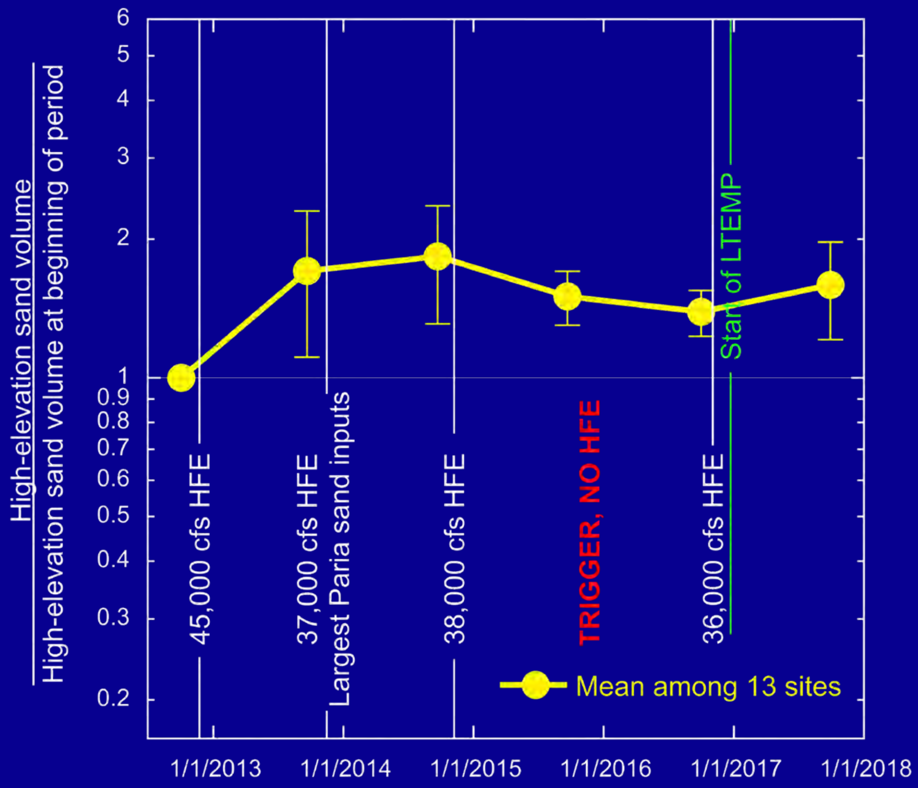
Possibly sustainable

Data from USGS (2023a, b)



HFE-Protocol Period
Lower Marble Canyon



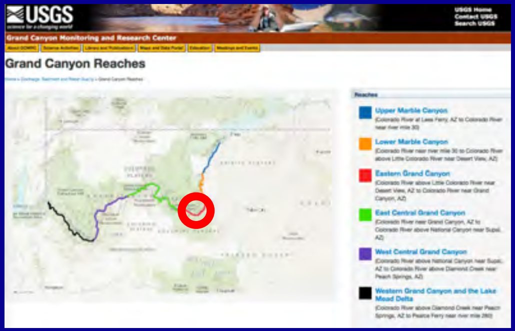


POSITIVE

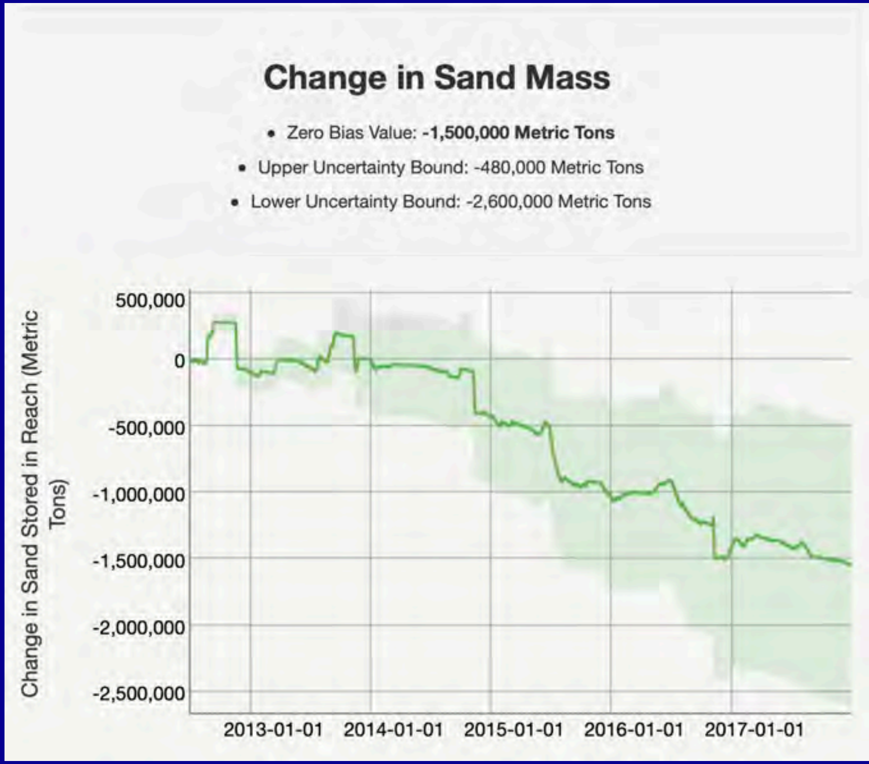
POSITIVE

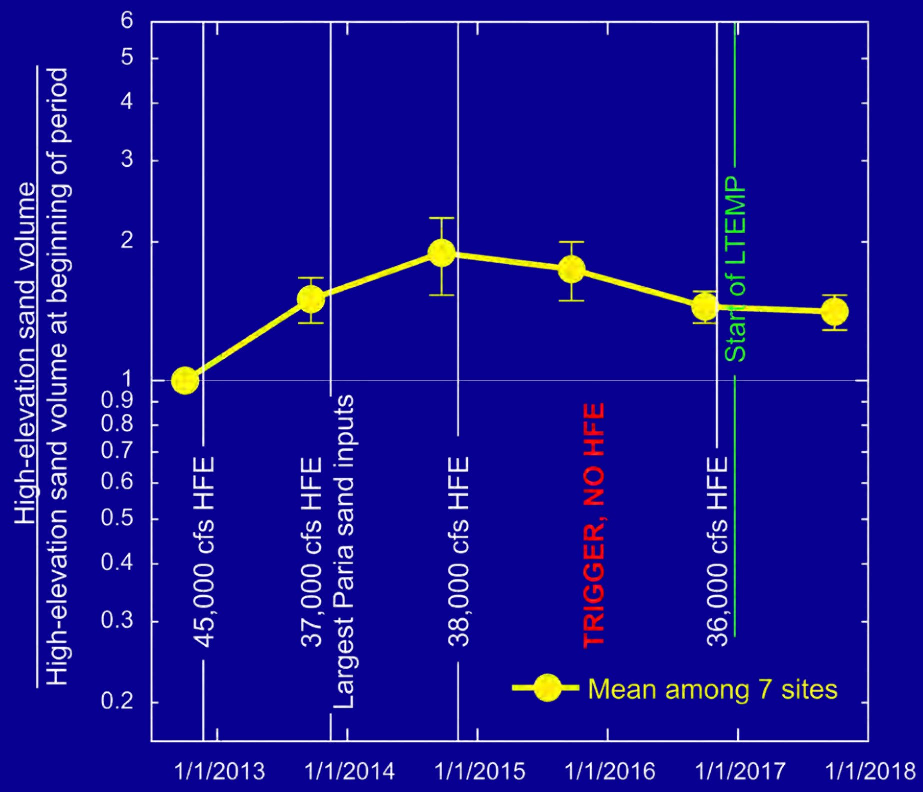
Possibly sustainable

Data from USGS (2023a, b)



HFE-Protocol Period Eastern Grand Canyon



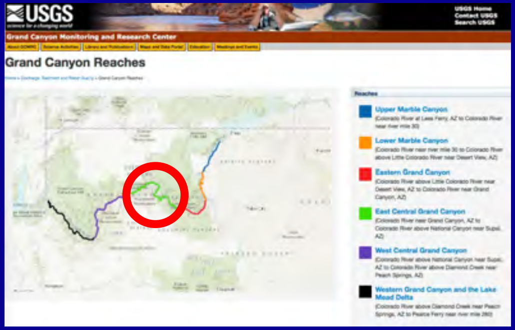


NEGATIVE

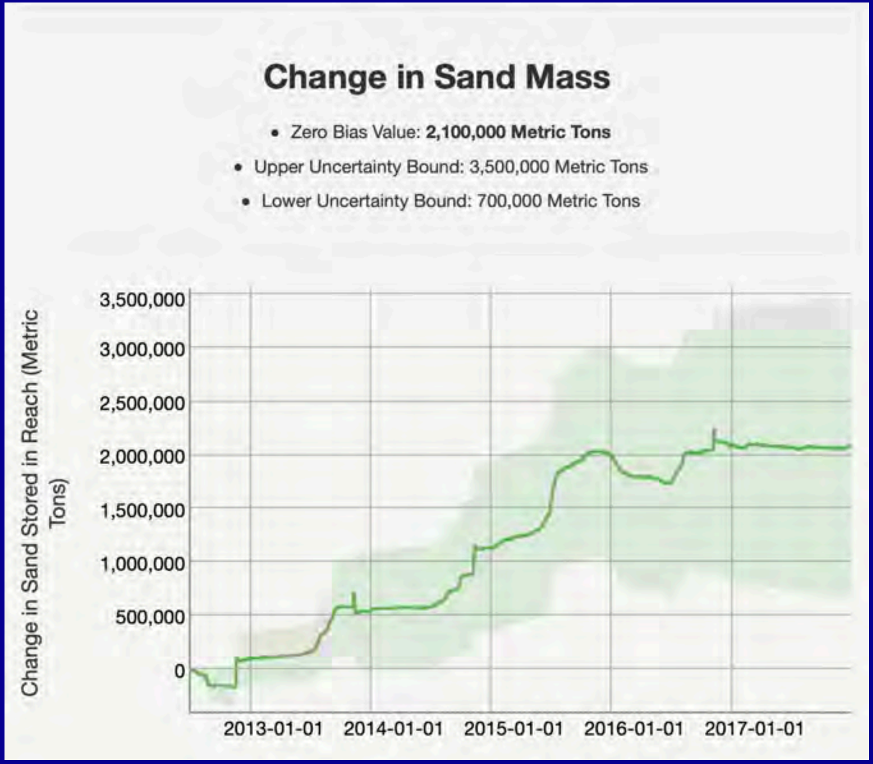
POSITIVE

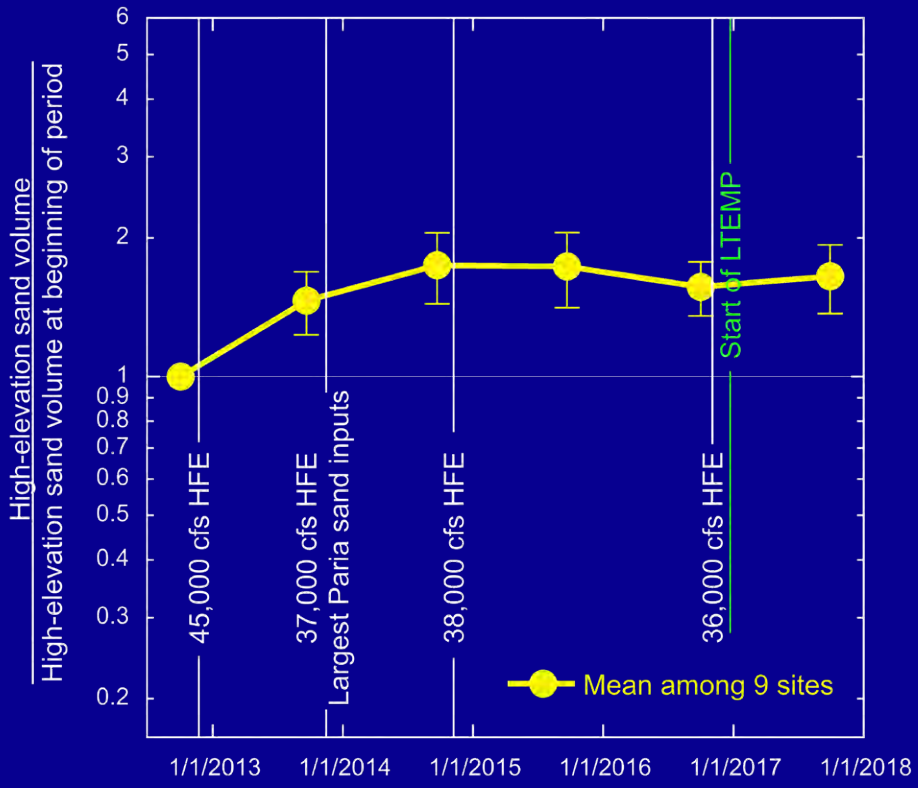
NOT sustainable

Data from USGS (2023a, b)



HFE-Protocol Period
East-Central Grand Canyon





POSITIVE

POSITIVE

Possibly sustainable

Data from USGS (2023a, b)

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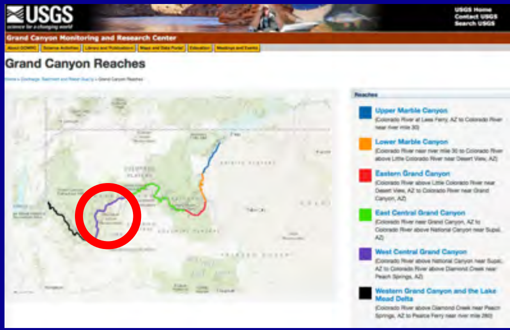
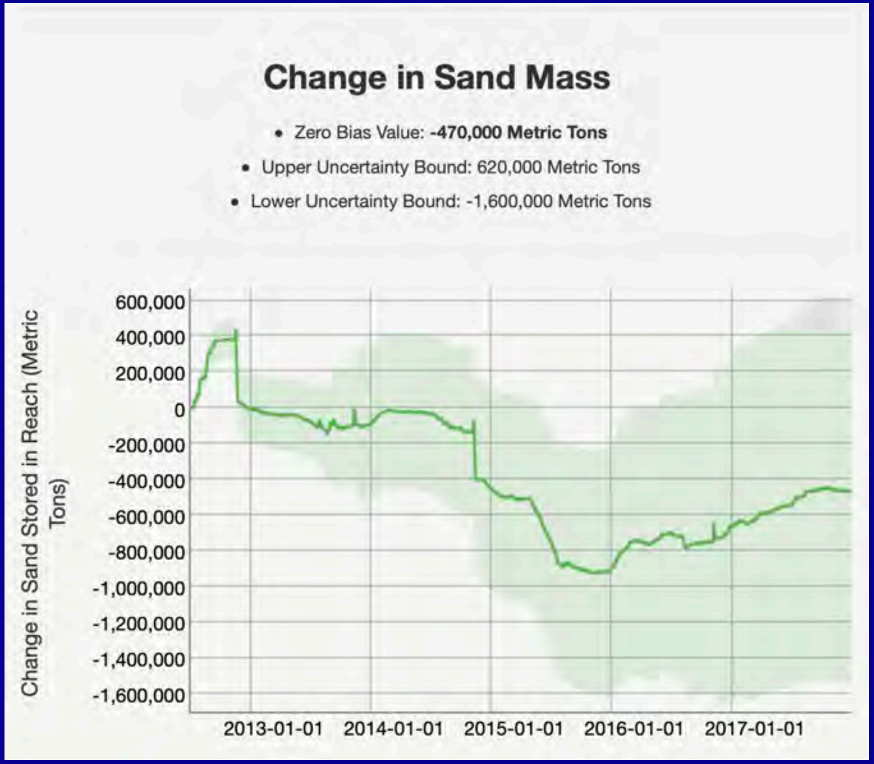
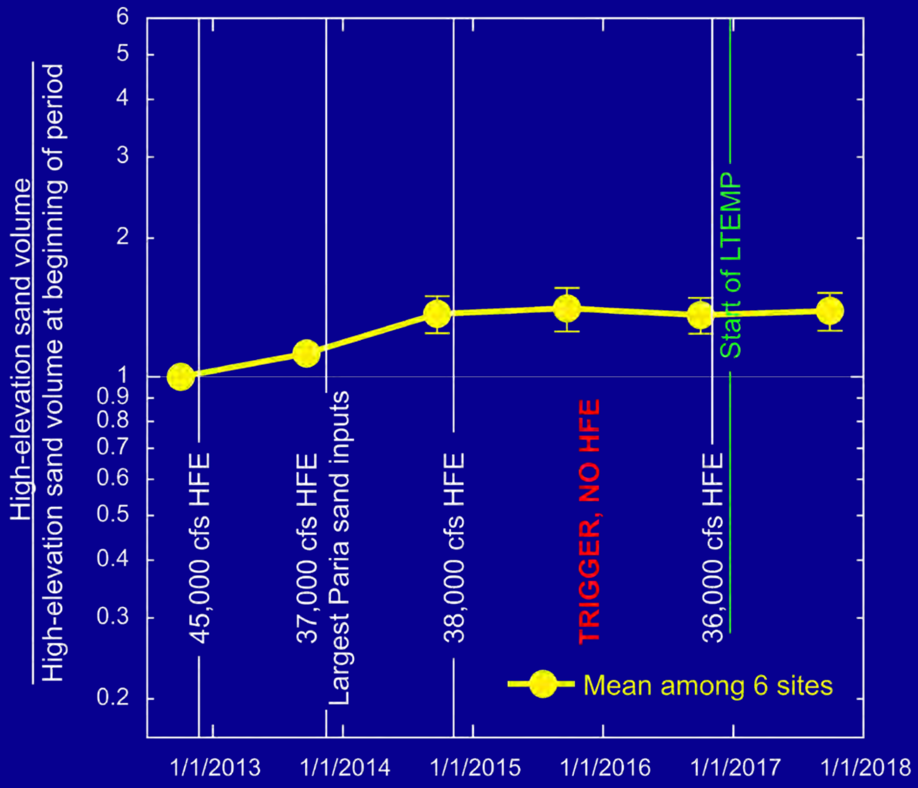


HFE-Protocol Period
West-Central Grand Canyon





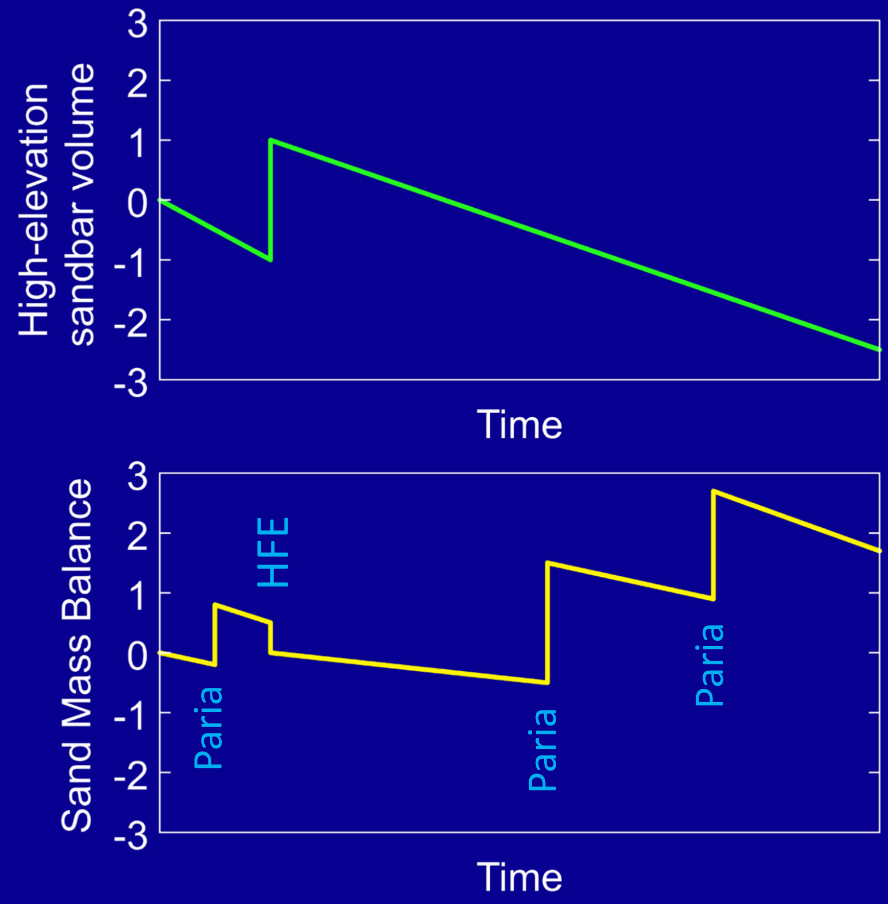
INDETERMINATE

POSITIVE

Possibly sustainable

Data from USGS (2023a, b)

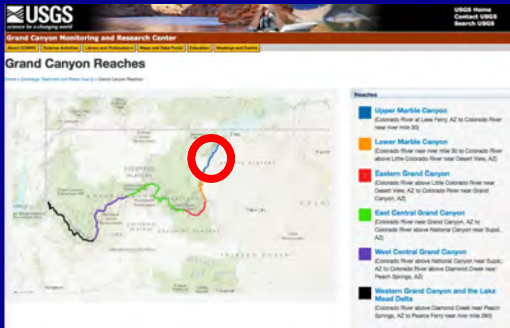
Unanticipated 4th scenario
"Abandonment of the experimental design"

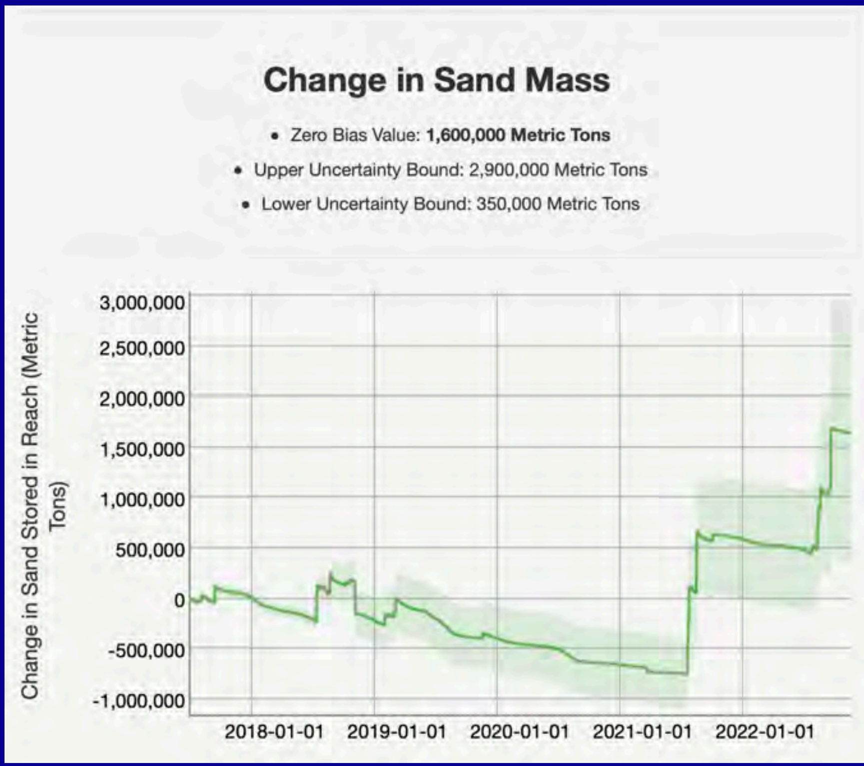


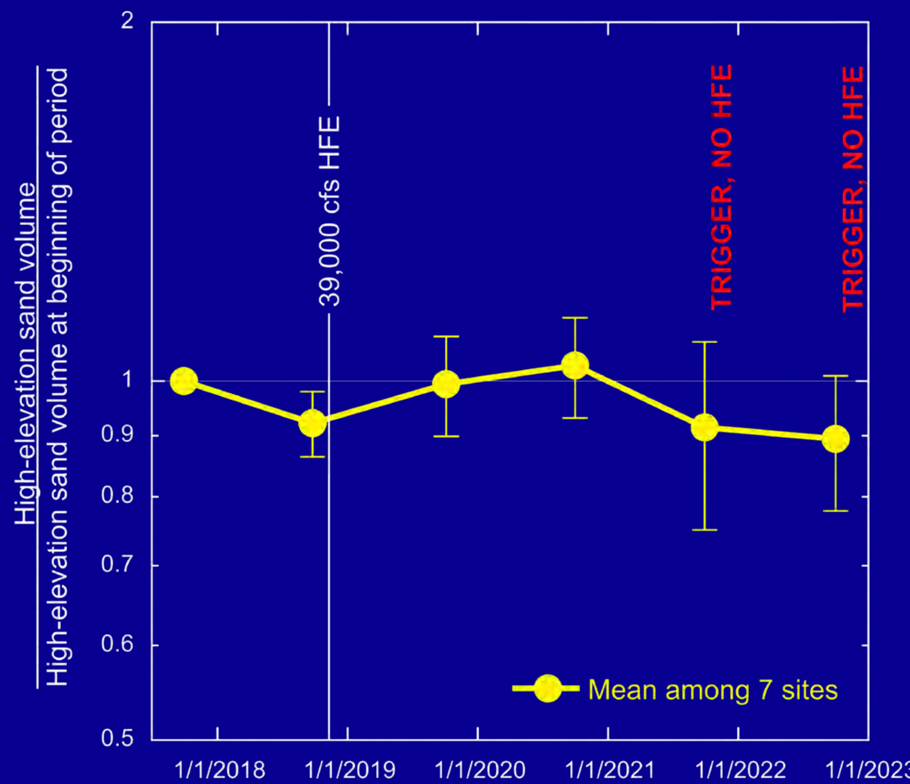
Sandbars erode to low levels perhaps difficult to recover from

Export rate increases as bed-sand fines

LTEMP Period
Upper Marble Canyon







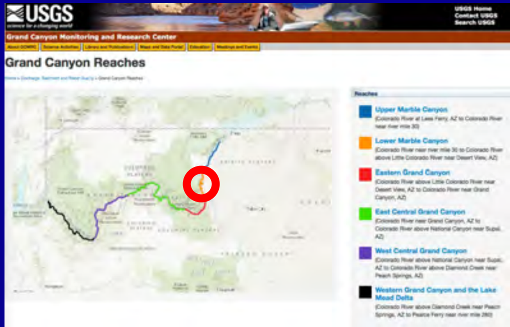
POSITIVE

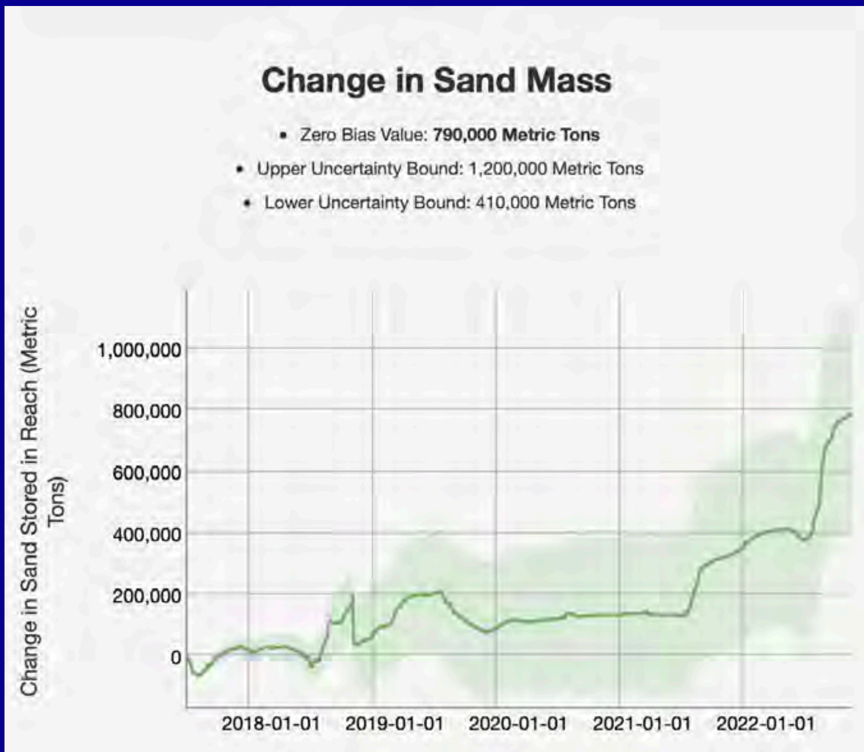
NEGATIVE

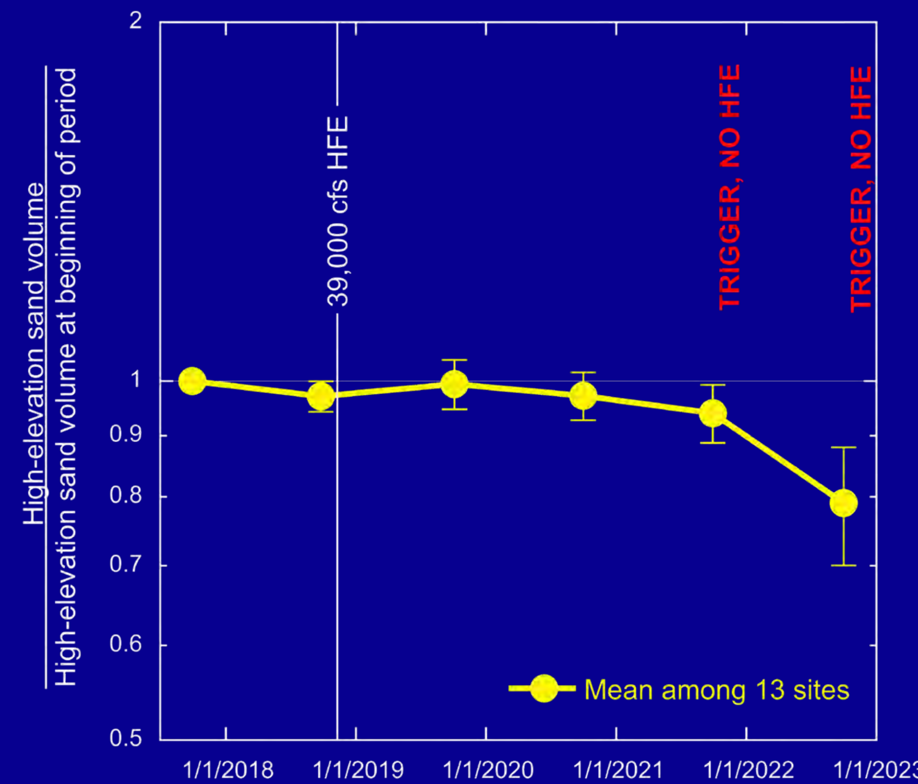
Failing to follow LTEMP experimental design; sandbar erosion

Data from USGS (2023a, b)

LTEMP Period
Lower Marble Canyon







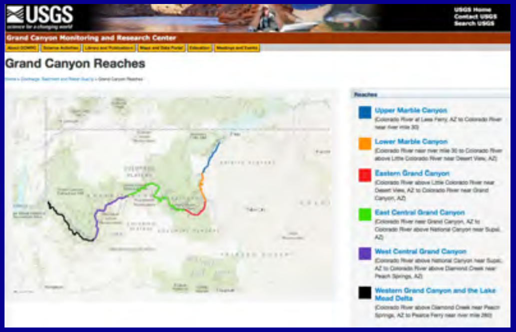
POSITIVE

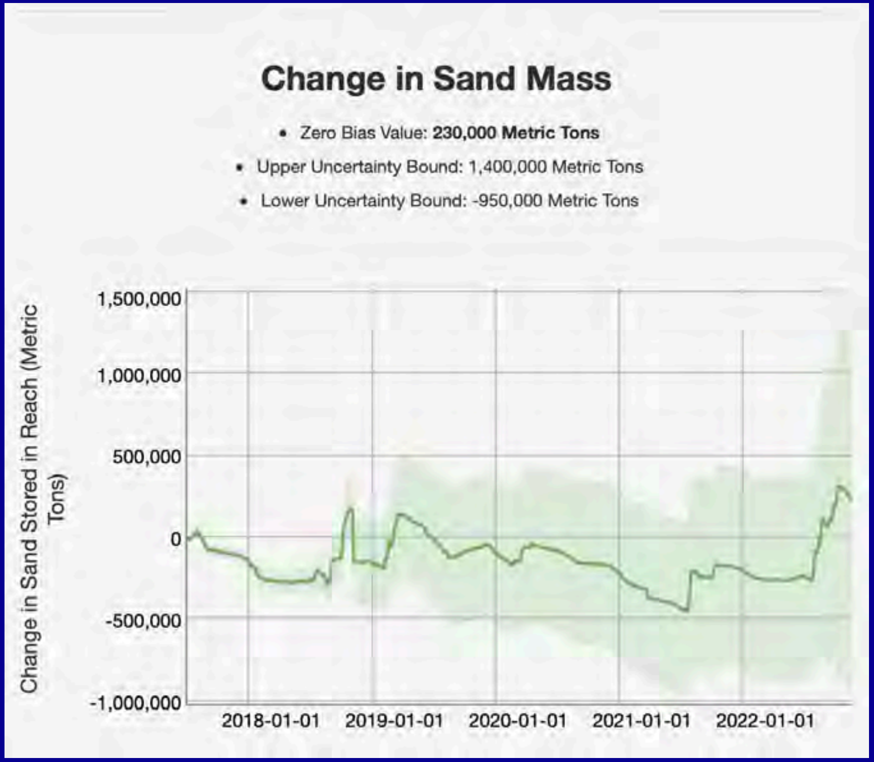
NEGATIVE

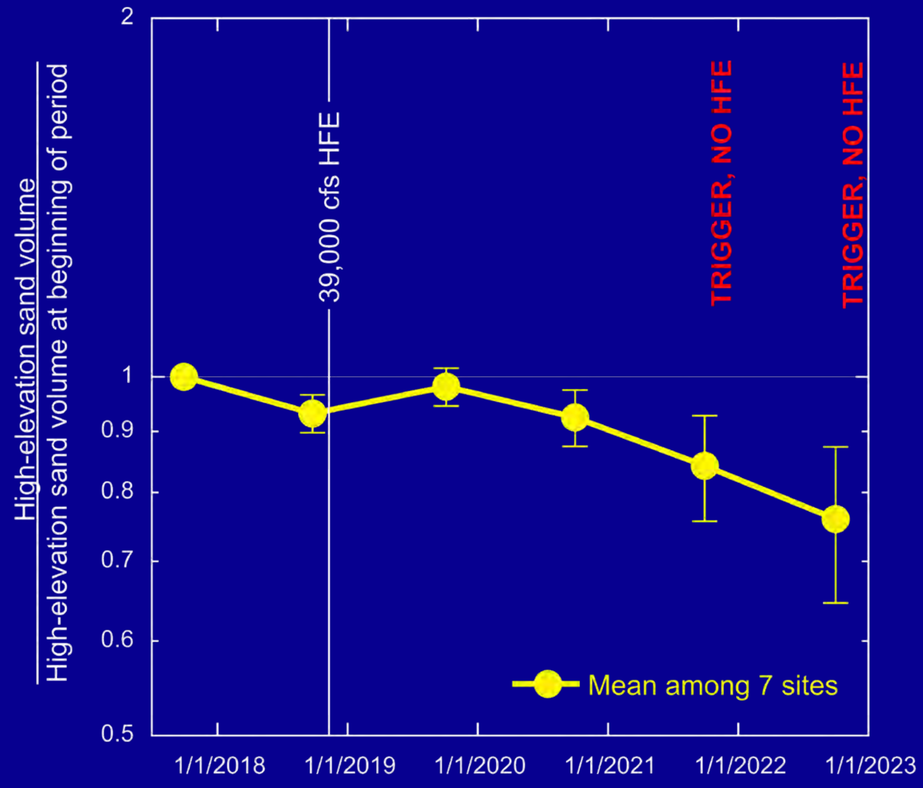
Failing to follow LTEMP experimental design; sandbar erosion

Data from USGS (2023a, b)

LTEMP Period
Eastern Grand Canyon





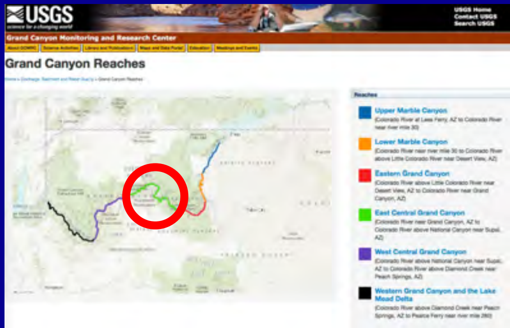


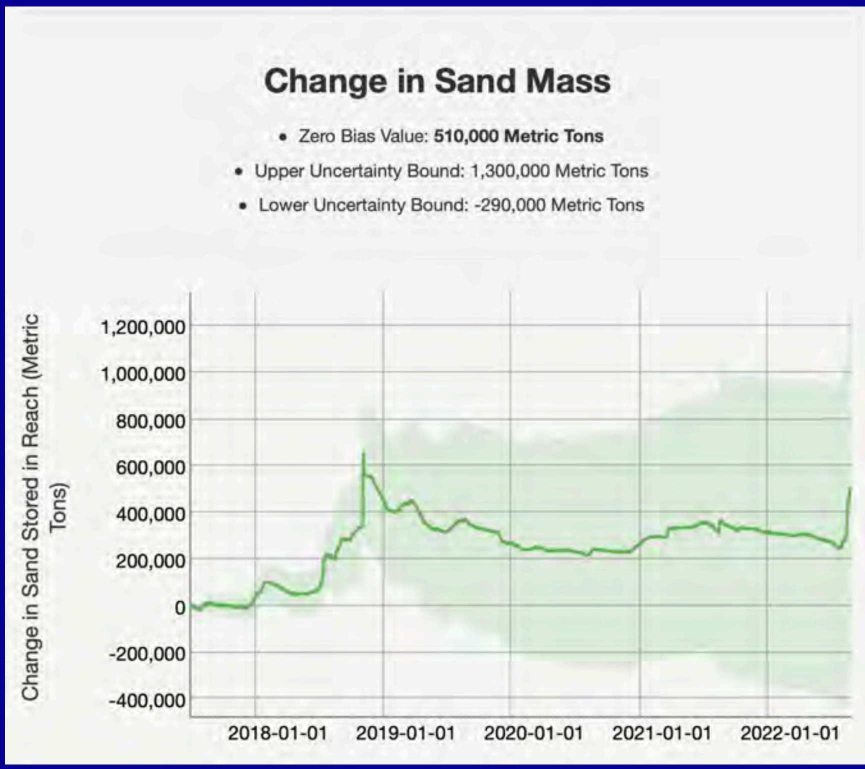
INDETERMINATE NEGATIVE

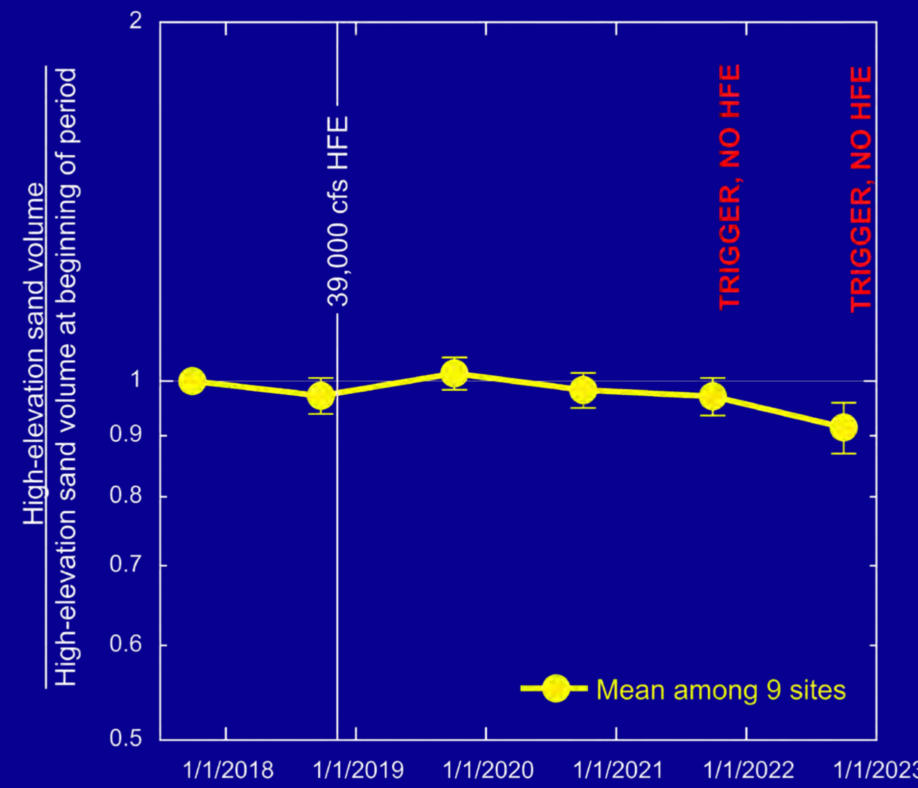
Failing to follow LTEMP experimental design; sandbar erosion

Data from USGS (2023a, b)

LTEMP Period
East-Central Grand Canyon





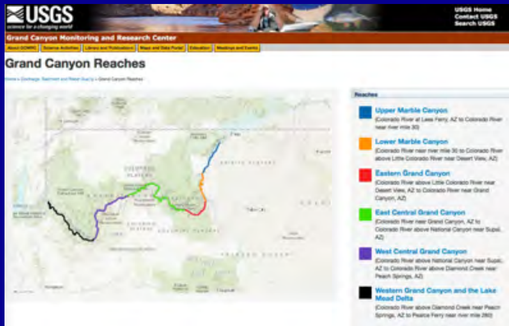


BARELY INDETERMINATE

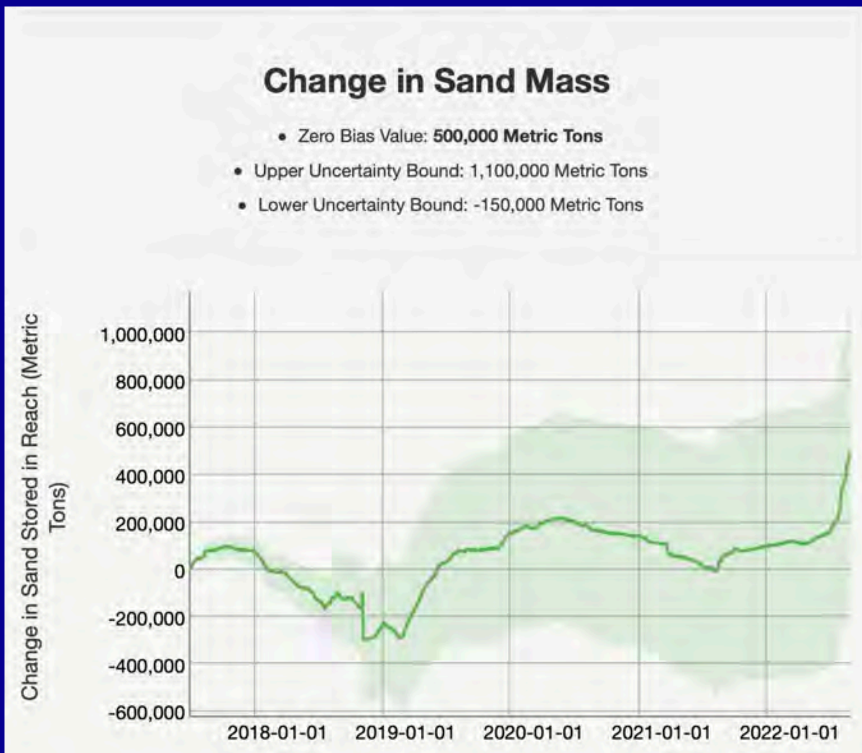
NEGATIVE

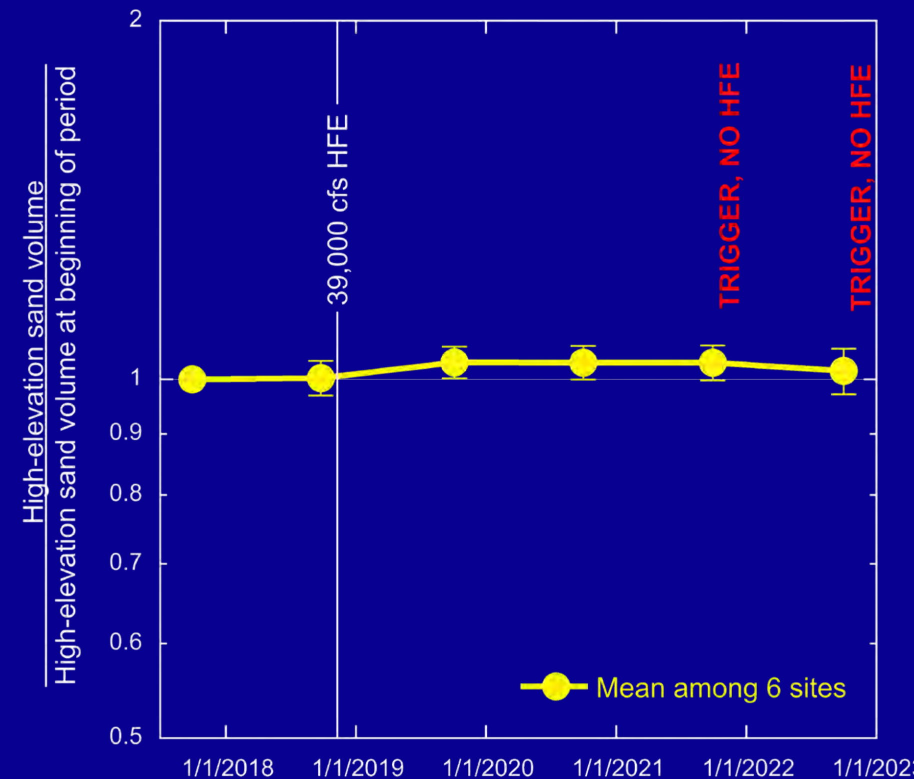
Failing to follow LTEMP experimental design; sandbar erosion

Data from USGS (2023a, b)



LTEMP Period
West-Central Grand Canyon





LIKELY POSITIVE

ZERO SLOPE

Sustainable ? Sandbars starting to degrade

Data from USGS (2023a, b)

Tributary sand inputs increase storage and EXPORT

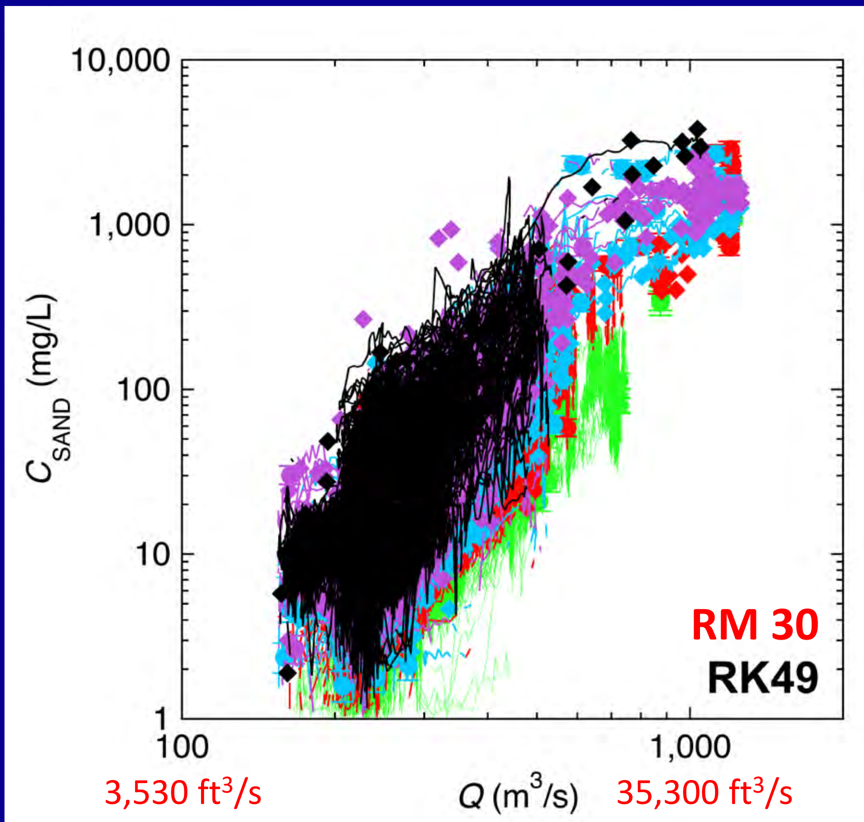
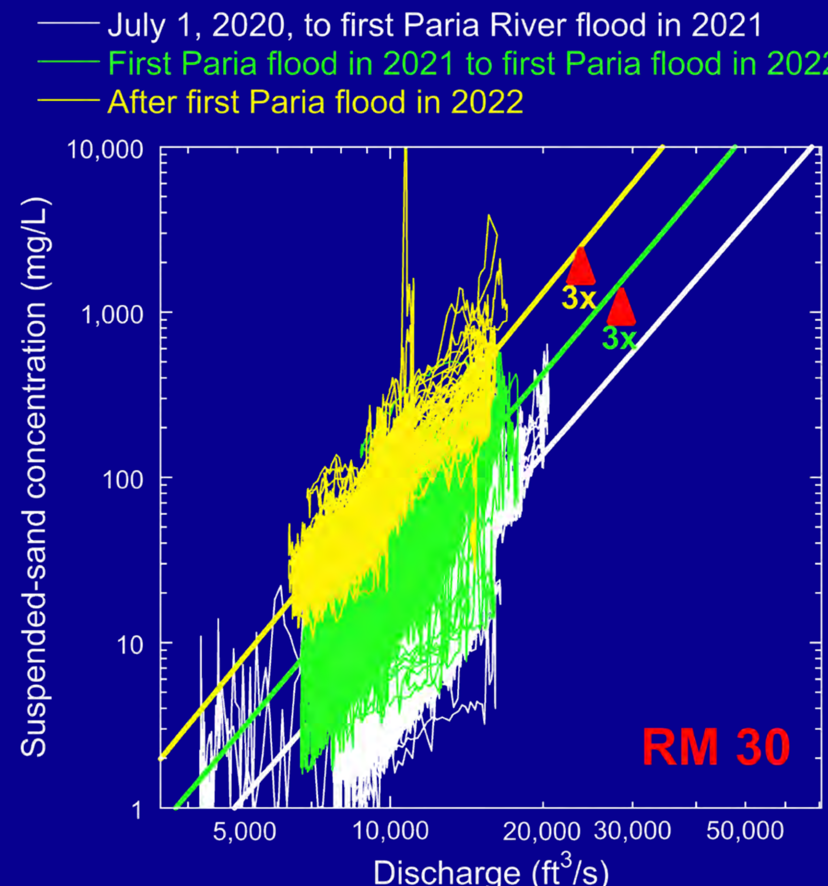


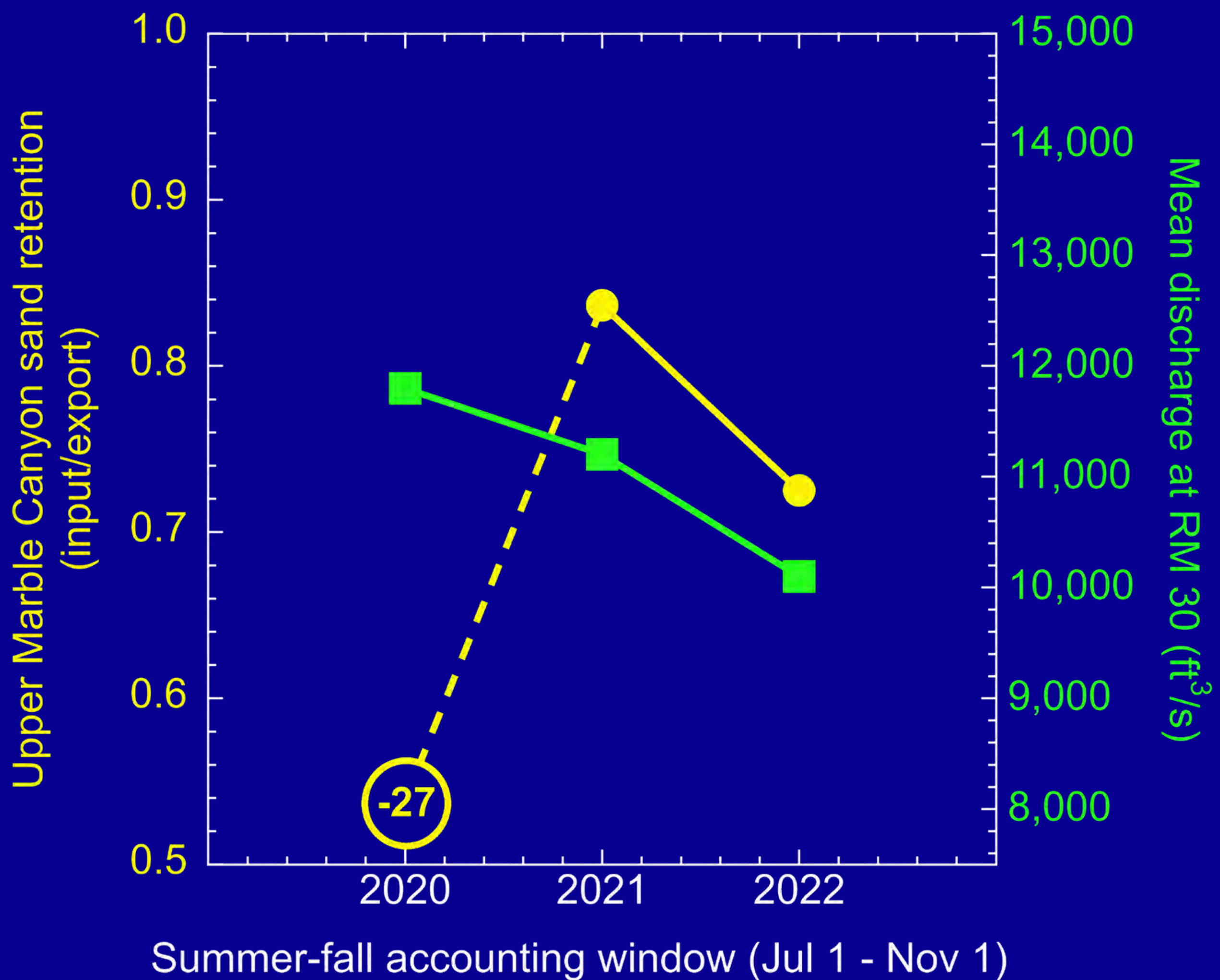
Figure from Topping and others (*JGR*, 2021)



Data from USGS (2023b)

Bed-sand fining offsets effect on sand transport of lower dam releases

Despite similar sand-supply magnitudes, sand retention decreased faster between 2021 and 2022 than did discharge



Data from USGS (2023b)

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Conclusions

- LTEMP sand management is failing because of the abandonment of the experimental design
- 6 years of LTEMP, 3 HFE triggers, only 1 HFE
- Dam maintenance schedule has also compromised LTEMP; last full-magnitude HFE was in 2012
- A substantial number of sandbars in Marble Canyon are at their lowest condition since monitoring began
- Although sandbar gains did occur during the HFE-Protocol period, it remains unclear if it is possible to rebuild sandbars to their early 1990s condition because of the large amount of sand eroded during the high flows of the late 1990s (1997 had the second longest period of sustained high discharge after 1984; Topping and others, *USGS-PP*, 2003)
- LTEMP may reach its conclusion and we may still not know if sustainable sand management is possible

Thank you

References

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- Topping, D.J., Grams, P.E., Griffiths, R.E., Dean, D.J., Wright, S.A., and Unema, J.A., 2021, Self-limitation of sand storage in a bedrock-canyon river arising from the interaction of flow and grain size: *Journal of Geophysical Research: Earth Surface*, v. 126, e2020JF005565. https://doi.org/10.1029/2020JF005565

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USGS science for a changing world

Project A work completed in FY 2022 addressed the following two hypotheses paraphrased from the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) Environmental Impact Statement (EIS) and earlier GCDAMP documents

- Glen Canyon Dam can be operated such that the sand resources in the Colorado River ecosystem (CRe) are sustainable.
- Glen Canyon Dam can be operated such that the other CRe resources affected by dam operations can be sustainably managed. In this usage, "dam operations" refers to the amount and quality of the water released from the dam, where "amount" refers to stage and streamflow, and "quality" refers to temperature, salinity, turbidity, and dissolved oxygen.

FY 2022 products

- All required monitoring data collected but only LARGELY processed and posted to Project A's website (https://www.gcmrc.gov/discharge_qw_sediment/) and to NWIS
- 1 peer-reviewed journal article in the *Proceedings of the National Academy of Sciences NEXUS*, 1 peer-reviewed article in *Water Resources Research*, and 1 USGS OFR published; 1 USGS Professional Paper in press and 1 USGS OFR through review (see list in Annual Report)

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