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

LTEMP Sediment Goal

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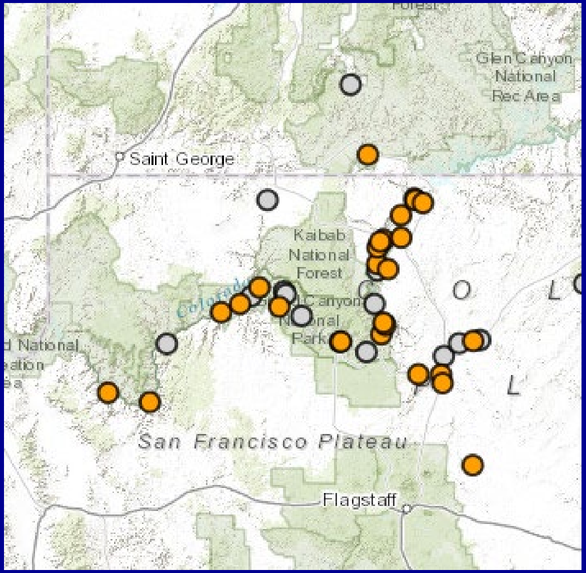
Project Overview

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



- Stage
- Discharge
- Water temperature
- Salinity (specific conductance)
- Turbidity
- Dissolved Oxygen
- 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
- User-interactive duration-curve tool for any continuous parameter

All other GCDAMP-funded projects use these data, and data from this project inform LTEMP

Citation for data and plots on most slides:

U.S. Geological Survey, 2020, Discharge, sediment, and water quality monitoring, Grand Canyon Monitoring and Research Center: accessed on January 6, 2020, at http://www.gcmrc.gov/discharge_qw_sediment/.

The USGS team

- David Topping, GCMRC
- Ron Griffiths, GCMRC
- Dave Dean, GCMRC
- Nick Voichick, GCMRC
- Tom Sabol, GCMRC
- Joel Unema, AZ Water Science Center
- Michael Robinson, AZ Water Science Center
- Megan Hines, Water Mission Area IIDD

Work completed in FY 2019 to address the following fundamental science question…

How do operations at Glen Canyon Dam affect flows, water quality, sediment transport, and sediment resources in the Colorado River Ecosystem?

- All required monitoring data collected, and *mostly* processed and posted to the web, including those data used to design and evaluate the Nov. 2018 HFE
- 2 peer-reviewed journal articles published (see list in Annual Report)
- 1 article revised/resubmitted following review at the Journal of Geophysical Research (JGR) and 1 additional new article submitted to JGR this week

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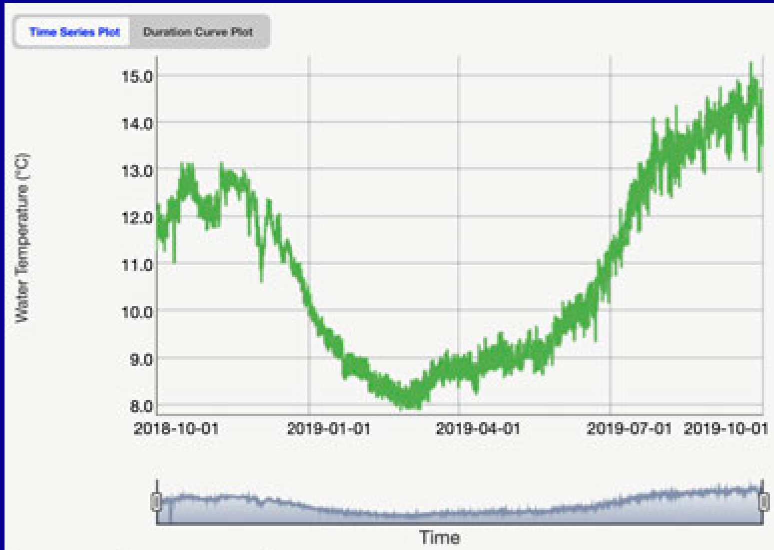
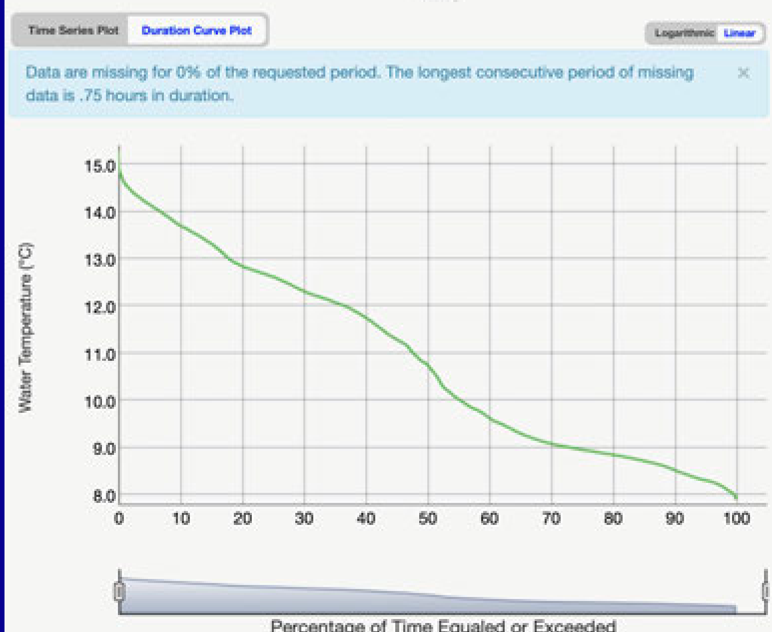
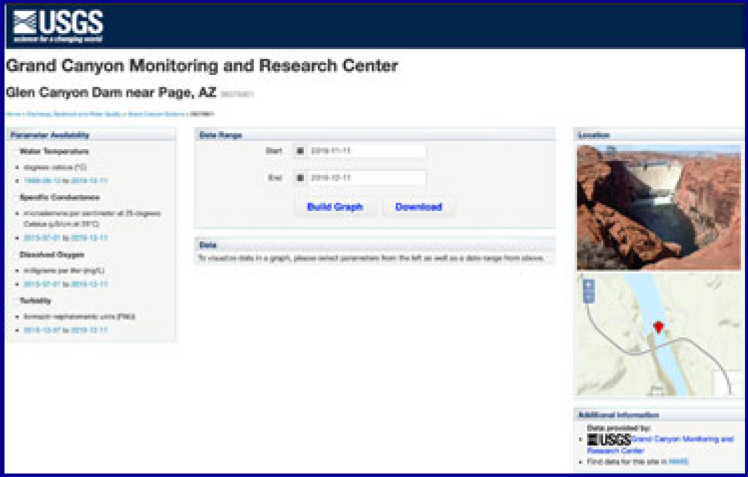
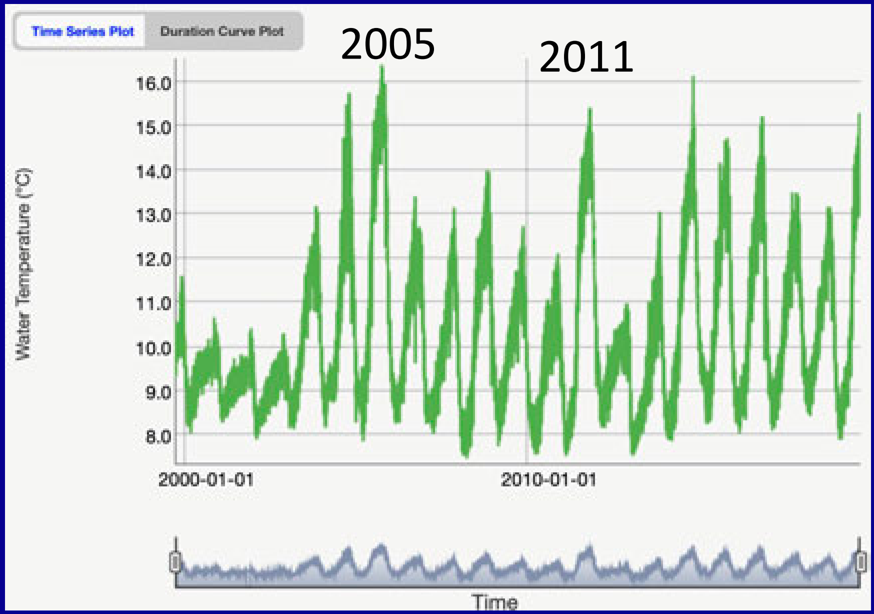
Release temperatures during summer 2019 were relatively warm



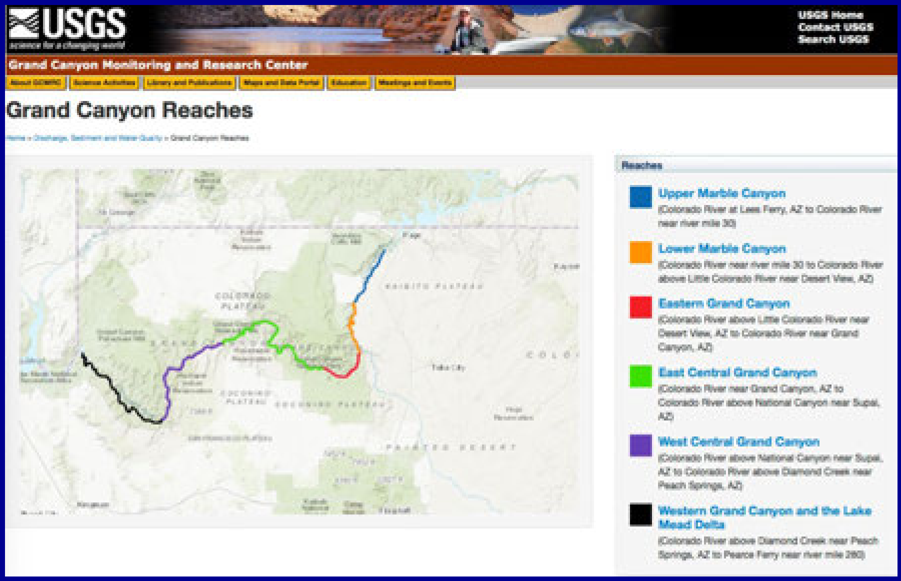






Data from USGS (2020)

Change in sand mass during sediment year 2019
July 1, 2018 – June 30, 2019
(million metric tons)

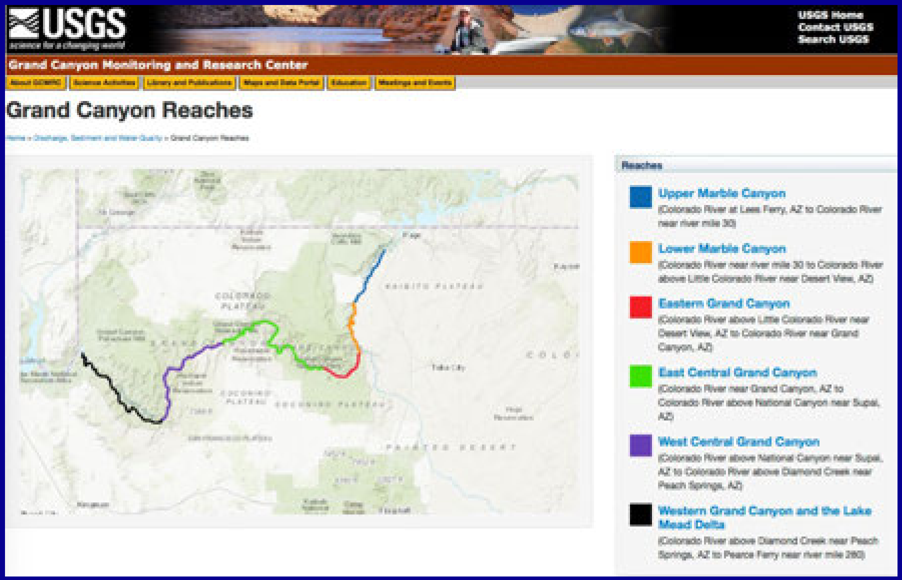


UMC	-0.0060±0.25
LMC	+0.25±0.14
EGC	+0.35±0.32
ECGC	+0.15±0.30
WCGC	+0.14±0.27
WGC/LM	+2.1±0.2

Paria River supplied ~1.2 million metric tons of sand
(135% of 1998-2017 average)
LCR supplied ~1.3 million metric tons of sand
(224% of 1998-2017 average)
Mean discharge at Lees Ferry was 12,700 ft^3/s
(93% of 1965-2017 average)

Data from USGS (2020)

Change in sand mass during July 1, 2019 – December 31, 2019 (million metric tons)



UMC	-0.15±0.05
LMC	-0.14±0.03
EGC	-0.087±0.059

Paria River supplied ~80,000 metric tons of sand

LCR supplied ~37,000 million metric tons of sand

Data from USGS (2020)

Is sand management in Grand Canyon sustainable?

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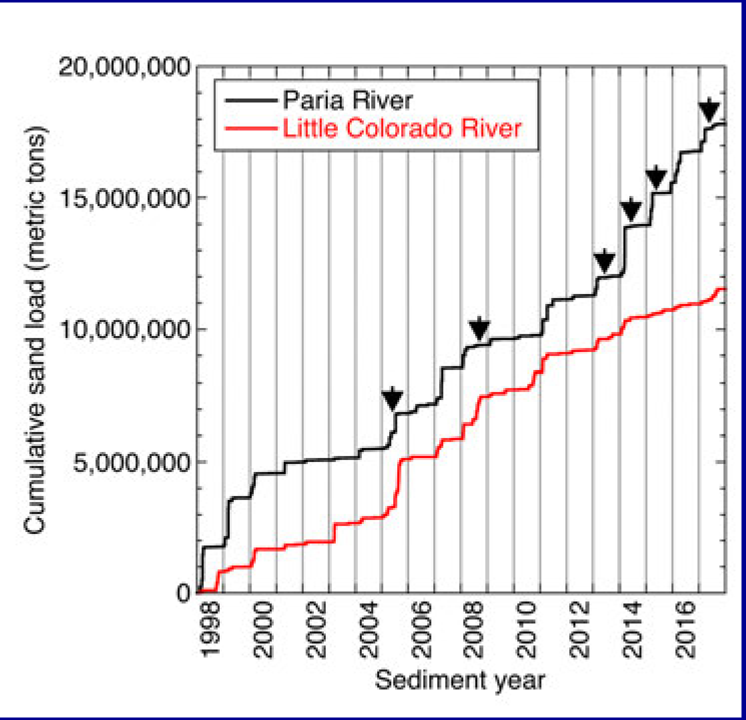
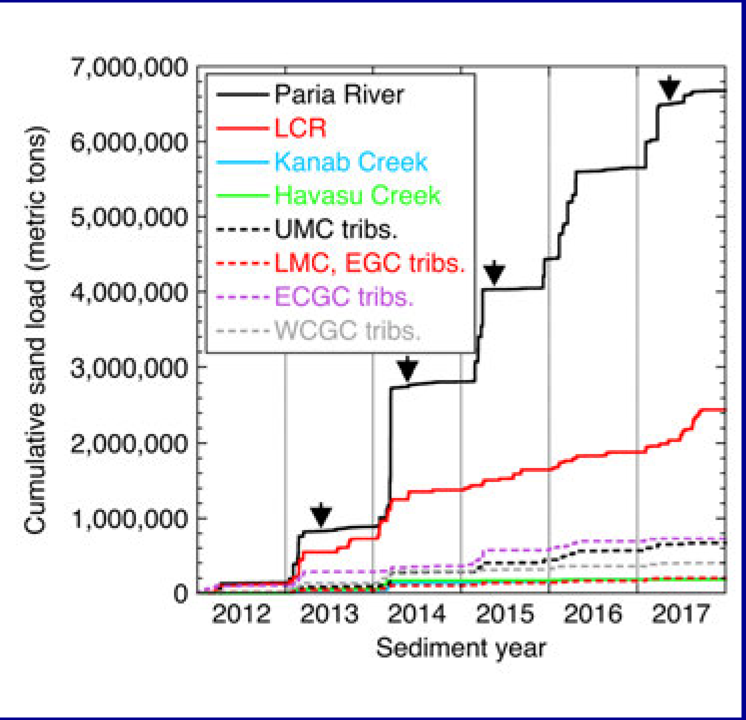
Tributary sand supply is highly episodic, with long periods of tributary quiescence when the discharge of the Colorado River is relatively high

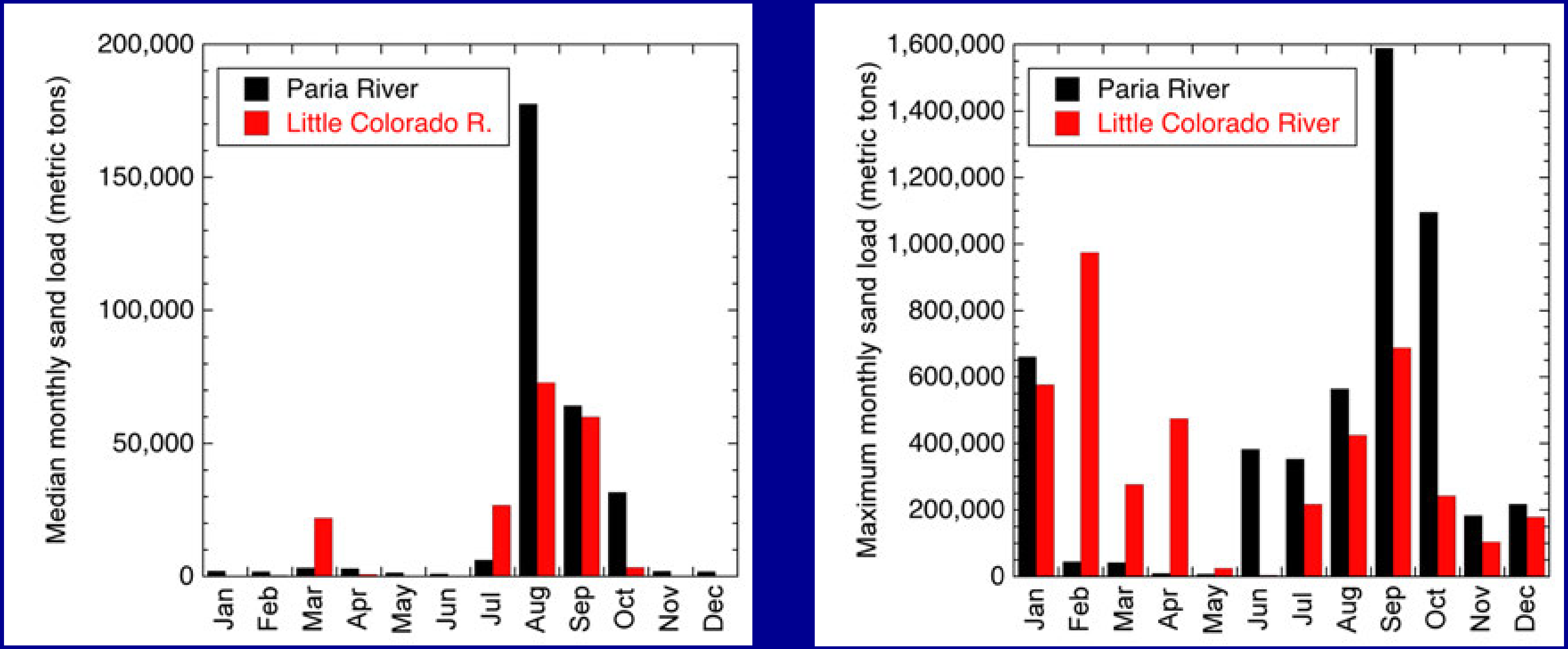




- Long periods of time between tributary floods for bed to be winnowed
- Over last ~5 years, Paria River sand supply has been above the average of 890,000 metric tons and the LCR sand supply has been below the average of 580,000 metric tons.
- Large sand-supplying floods in Paria River and LCR are poorly correlated
- Measurements indicate Paria River and LCR are only large suppliers of sand

Data from USGS (2020)

Monthly median and maximum sand supply of the Paria River and Little Colorado River

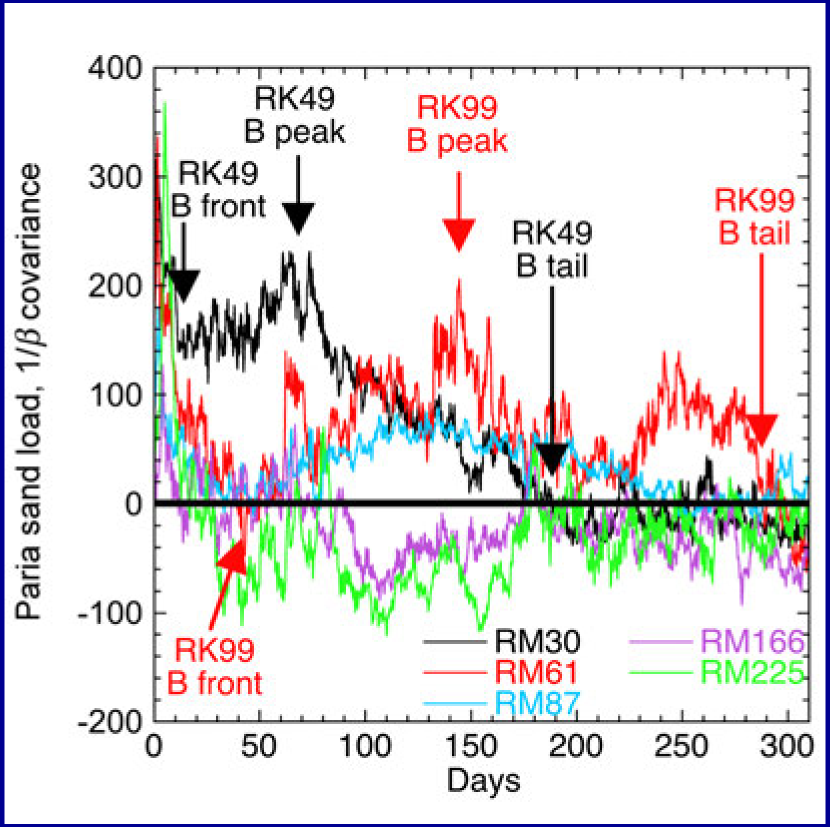


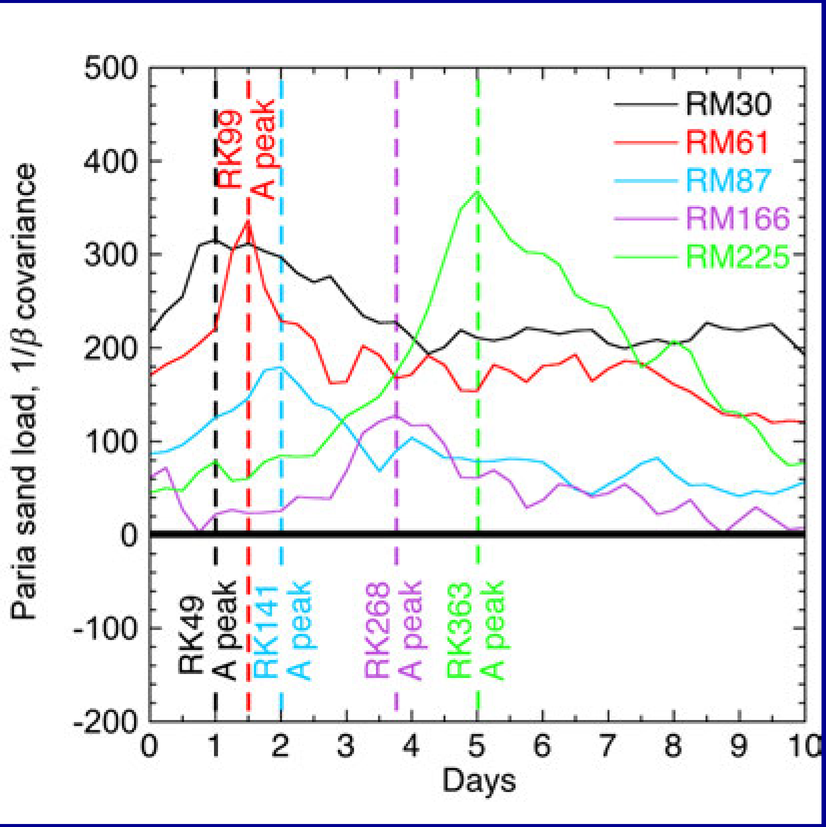
- **Almost all large Paria River floods occur during August through October**
- **Thus, spring HFEs may only rarely occur because the HFE trigger in the LTEMP is reset on December 1**

Data from USGS (2020)

Lagged-covariance analyses indicates that sand moves downstream in waves

- **Paria River floods generate sand waves with fronts that migrate to Lake Mead within ~6 days (~11% of the finest sand supplied is never retained in CRE)**
- **Maximum bed–sand fining in these waves persists in UMC for <70 days and in LMC for <150 days (finest bed sand leads to highest HFE sandbar-deposition rates)**
- **These sand waves exit Marble Canyon within a year of a Paria River flood**

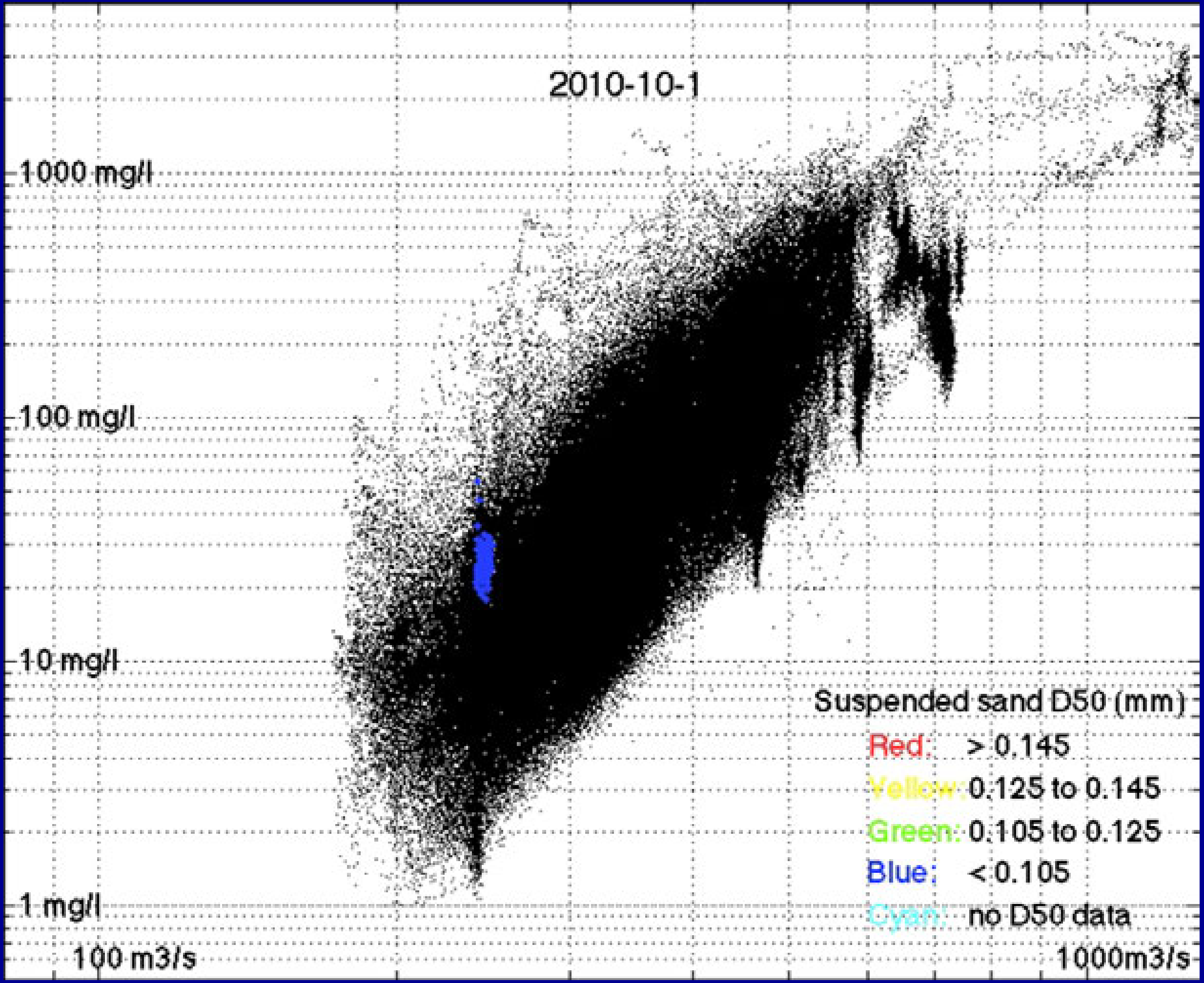




Analysis after Rubin and Topping (2001, 2008) and USGS (2020)

As sand storage increases…the bed-sand fines…leading to increased suspended-sand concentrations and increased sand export, thus self-limiting the amount of sand in storage

Colorado River near Grand Canyon, AZ, 09402500



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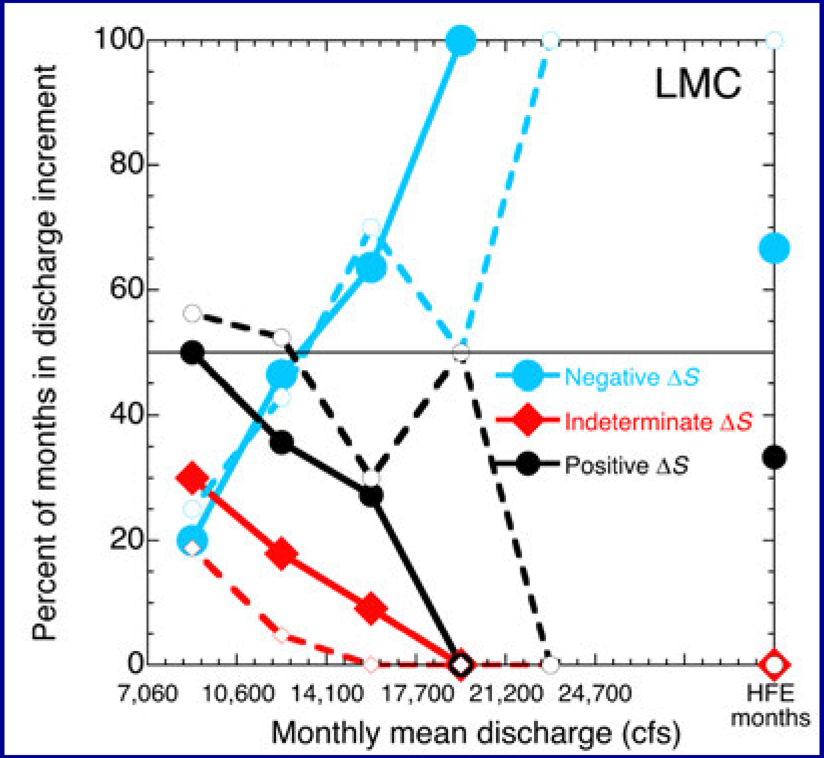
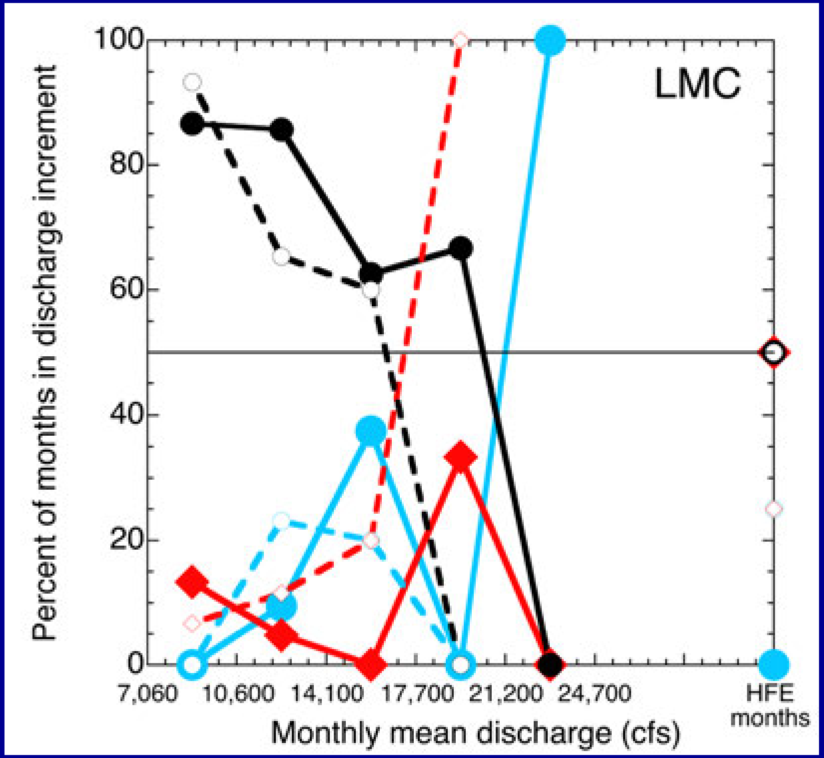
Thumbnail image of a movie available from David Topping, courtesy of David M. Rubin

As expected based on the Exner equation…
Downstream coarsening of the bed sand leads to higher probabilities of net deposition at higher discharges…whereas downstream fining leads to higher probabilities of net erosion at all but the lowest discharges.

When monthly mean bed-sand grain size is coarser upstream (dashed) or finer downstream (solid) than the 10-year median value…

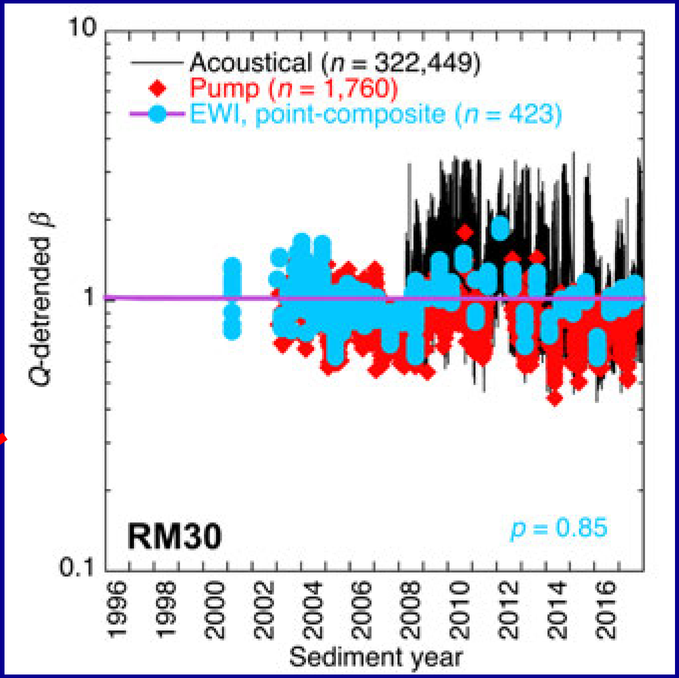


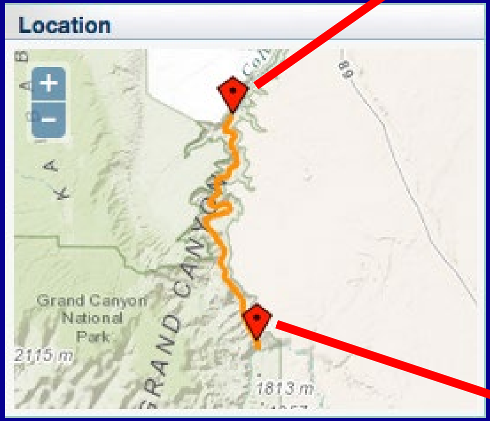
When monthly mean bed-sand grain size is finer upstream (dashed) or coarser downstream (solid) than the 10-year median value…



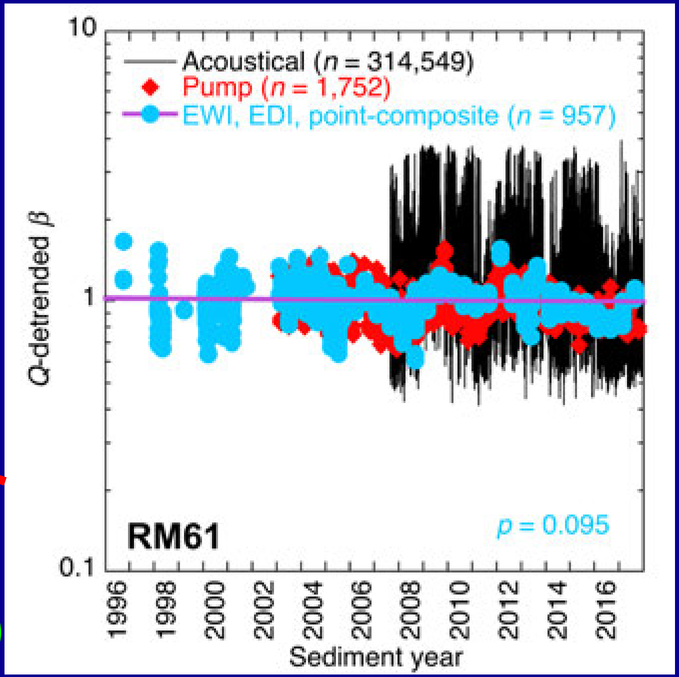
Analysis after Rubin and Topping (2001, 2008), Grams et al. (2013), and USGS (2020)

Short-term changes in bed-sand grain size are large... Long-term changes in bed-sand grain size are small





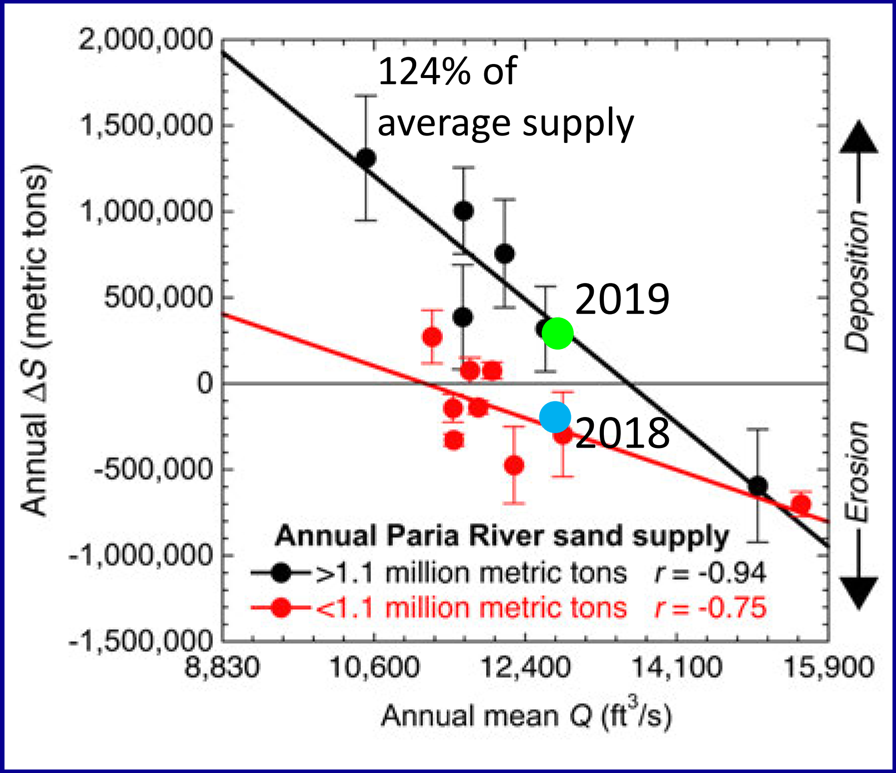
Lower Marble Canyon



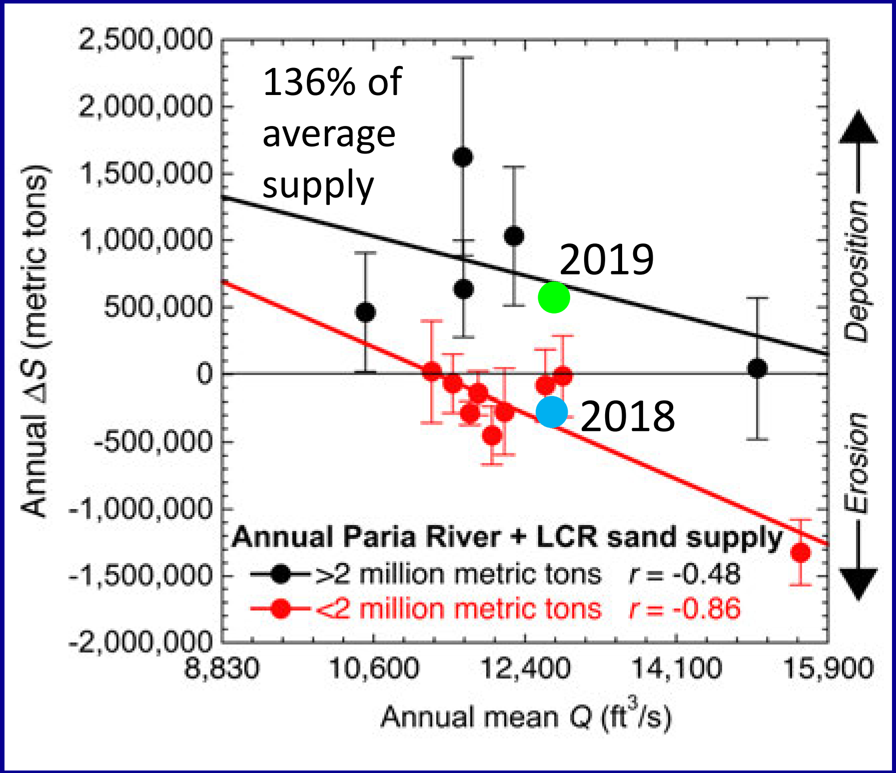
Analysis after Rubin and Topping (2001, 2008) and USGS (2020)

Influence of grain-size changes on sand transport and erosion/deposition is reduced over > annual timescales and longer segments

Marble Canyon



Grand Canyon

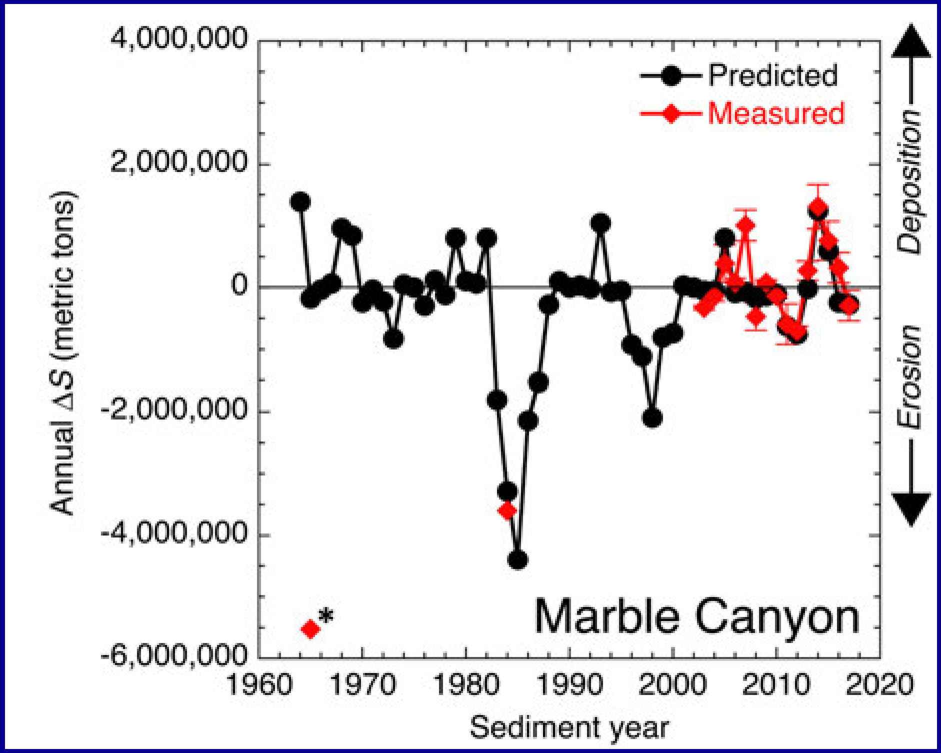


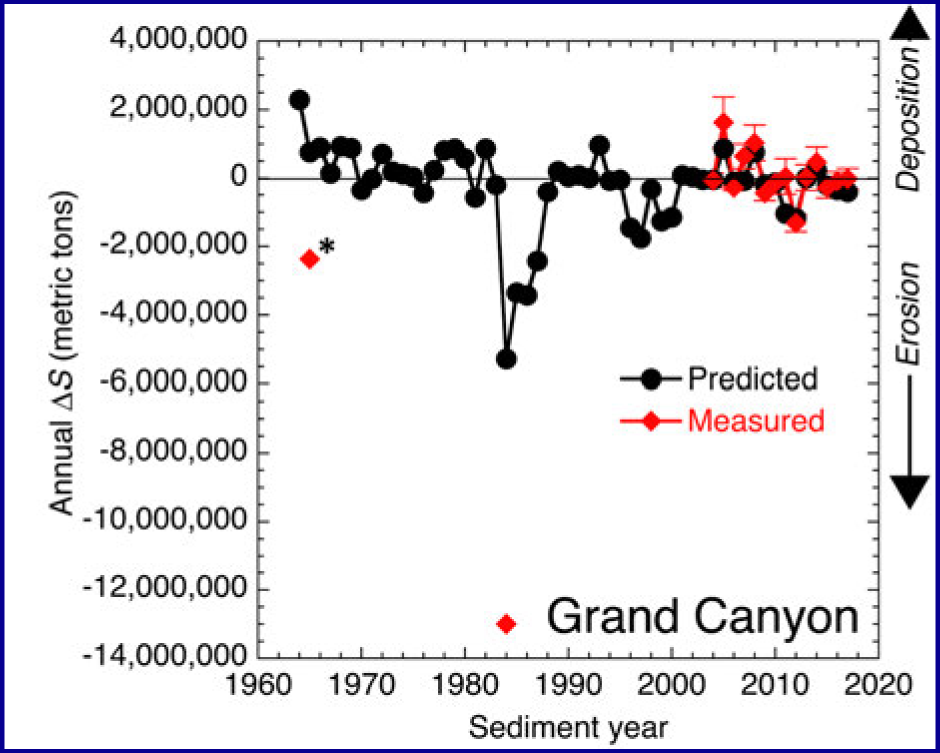
Analysis utilizes measurements from sediment years 2003-2017

1965-2017 mean discharge = 13,700 ft^3/s

Data from USGS (2020)

Hindcasted changes in sand storage using these simple relations provide perhaps a lower bound on sand erosion since closure of Glen Canyon Dam





*Values determined from USGS daily sediment measurements at RM0, RM87, Paria R., and LCR gages during April-June 1965 and proportionally assigned to Marble or Grand Canyon based on the lengths of the Marble Canyon and EGC segments

After USGS (1970), Garrett et al. (1993), and USGS (2020)

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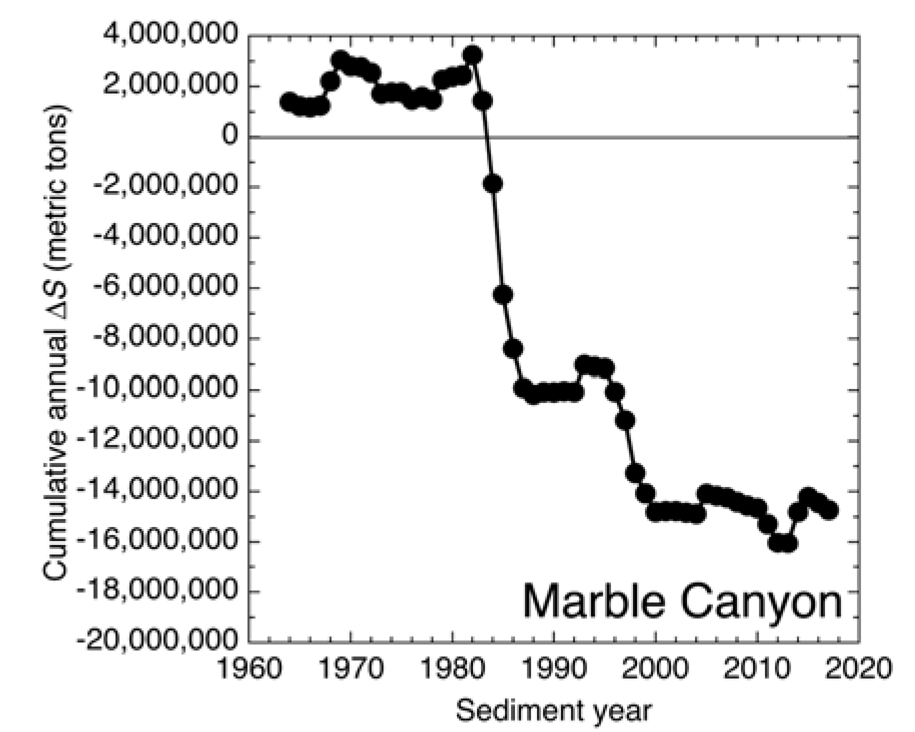
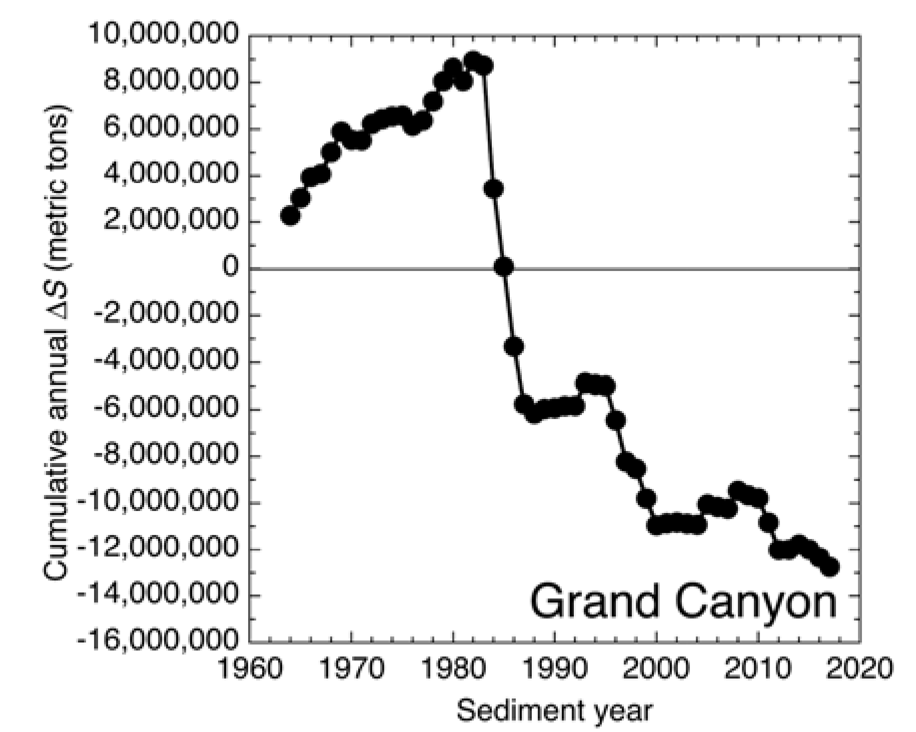
>28 million metric tons of sand have likely been eroded from the Colorado River in Grand Canyon National Park since 1963…mostly during 3 periods of high dam releases





After USGS (2020)

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Conclusions

- Sand supplied during a tributary flood migrates quickly downstream as a sand wave
- Grain-size changes associated with sand-wave migration leads to several orders of magnitude discharge-independent variation in sand concentration
- Sand storage is largely self-regulating in that the fining of the bed sand as sand-storage increases leads to greater downstream export
- Extremely large increases in sand storage, as occurred at low discharge pre-dam, are likely impossible at the higher discharges generally released from Glen Canyon Dam
- Multi-year sand accumulation is only possible during years of above-average tributary sand supply and below-average dam releases
- Below-average dam releases are required in the absence of above-average tributary sand-supply years to maintain a zero sand mass balance
- Maintaining a level of sand storage sufficient for maintaining sandbars may require timing periods of higher and lower dam releases based on the tributary sand-supply conditions
- Whether the sand resources of the Colorado River in Grand Canyon National Park can be sustainably managed in perpetuity remains an open question


Thank you