

Sandbars and Sediment Storage in Marble and Grand Canyons: Response to Recent High-flow Experiments and Long-term Trends

GCMRC Project A (now Project 3)

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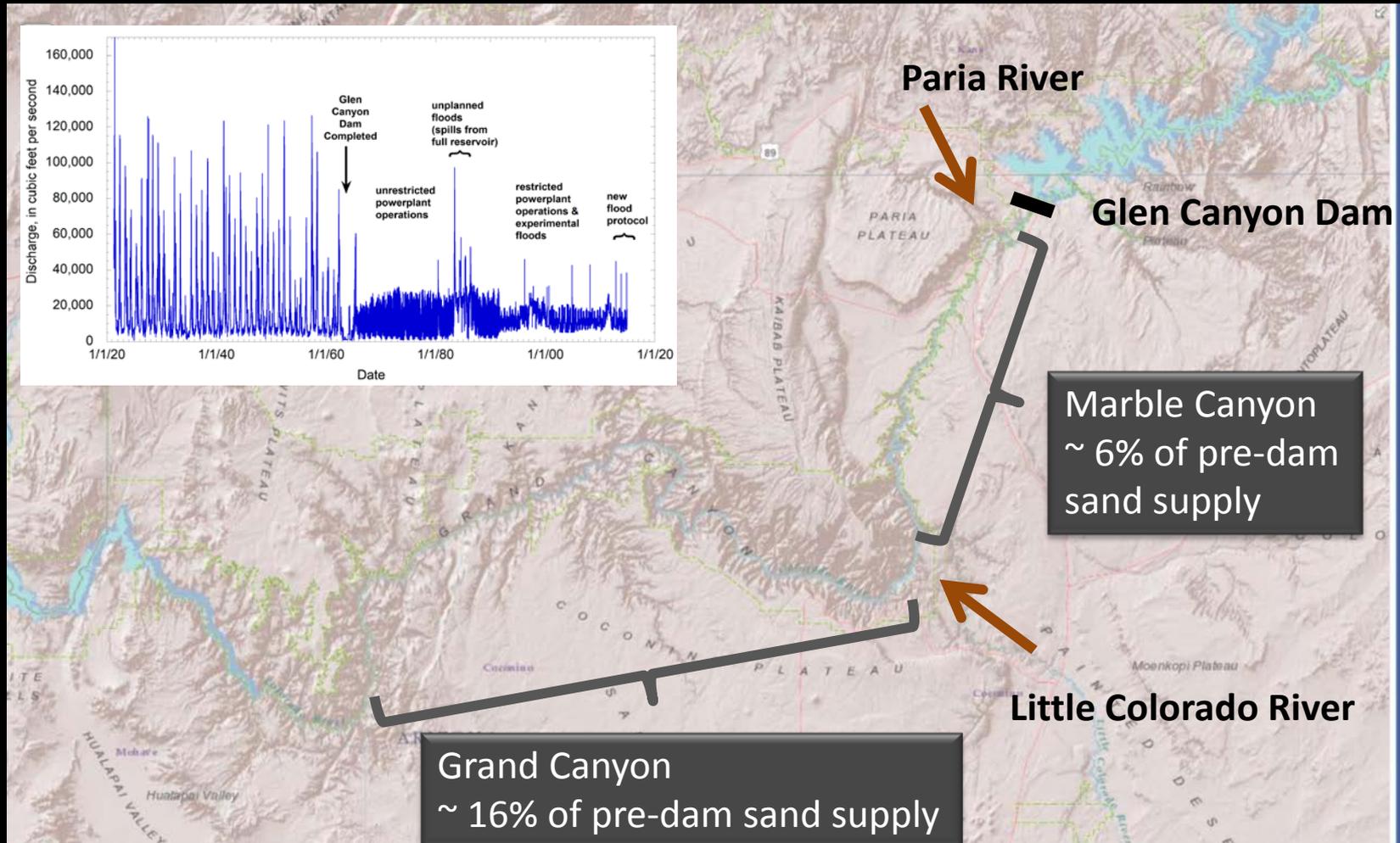
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Overview

- Sandbar response to HFEs implemented under HFE protocol
- Changes in sandbars over different time scales
 - Since start of HFE protocol
 - Since 2002
 - Since 1990
 - Since 1984
 - Pre-dam, pre-ROD, and Now
- Sand budget
 - Effect of equalization flows
 - Effect of HFEs since 2012
- Modeling, Methods for bed texture classification, Sandbar geochemistry, interactions between bed sediment and suspended sediment (won't get to these)

Review of Problem: Sediment budget affected by disruption of sand supply and change in flow regime



RM 22 R – Returned to pre-HFE size by February (about same response as 2012)



more photos at poster session



RM 22: 2013 HFE – pre-flood



RM 22: 2013 HFE – post-flood



RM 22: 2013 HFE – 3 months post-flood

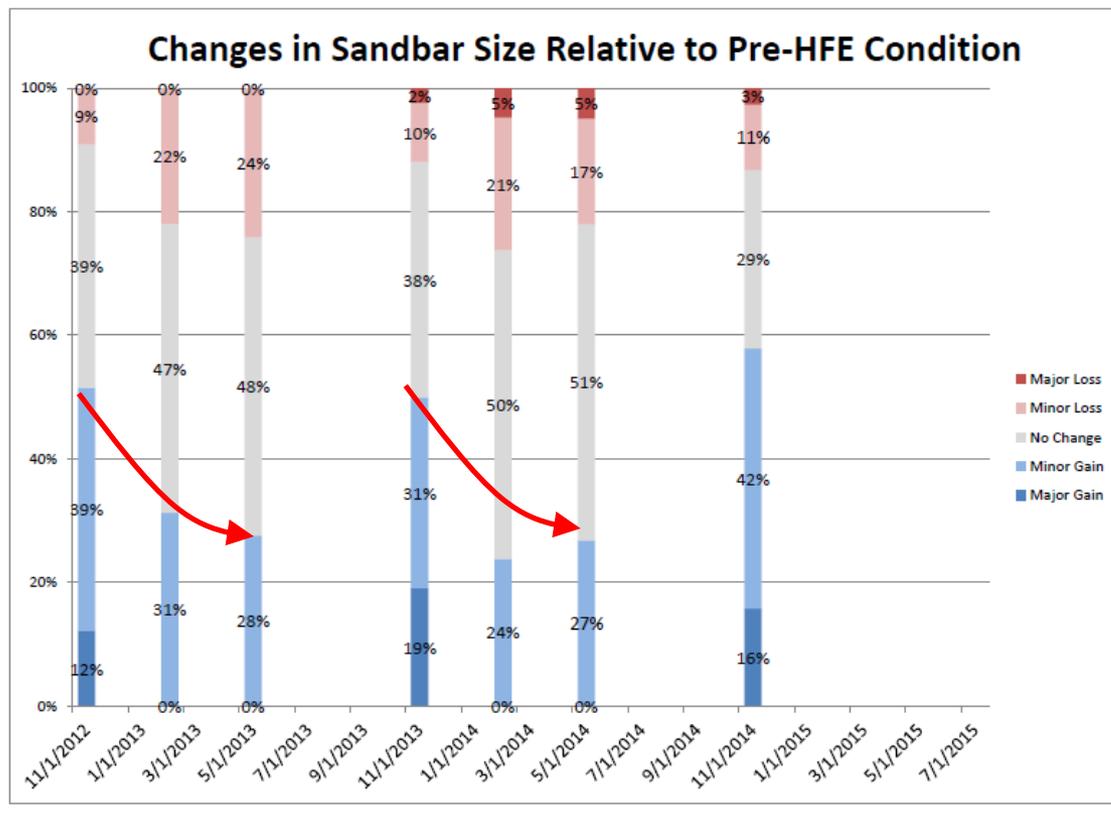


2014 HFE

- 22 sites (58%) larger
- 11 sites (29%) no change
- 5 sites (13%) smaller



Response to HFE Protocol



2012 HFE

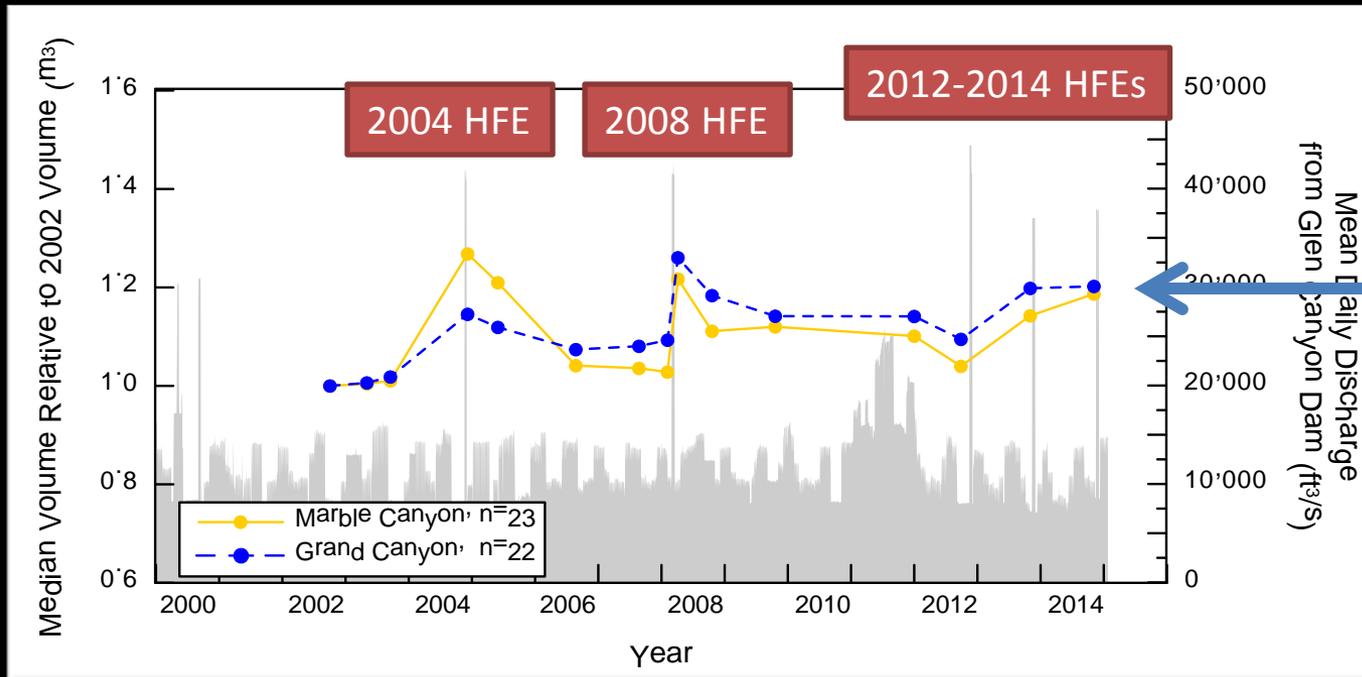
2013 HFE

2014 HFE

- Each of the HFEs in the past 3 years has resulted in sandbar deposition
 - They continue to erode in following 6 to 12 months

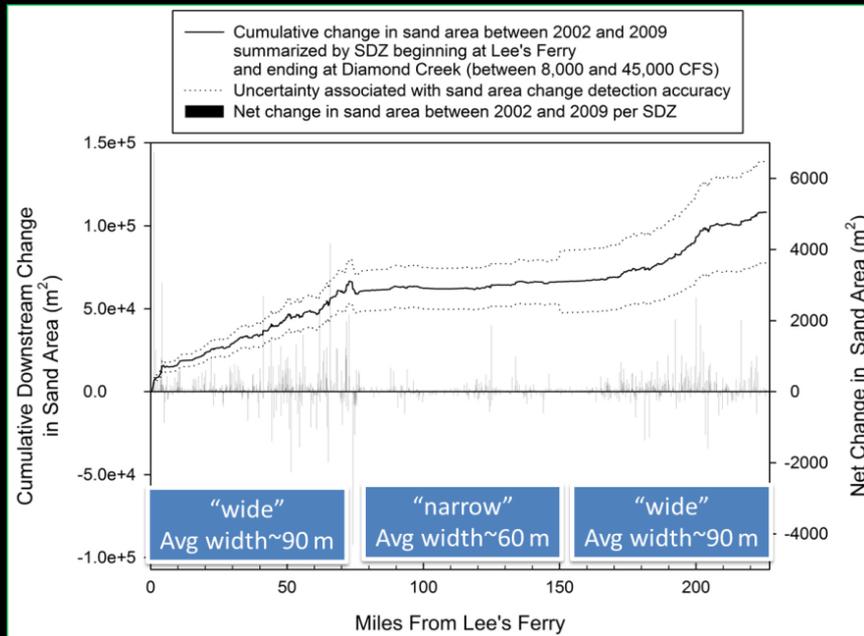


Sandbars: 2002-present



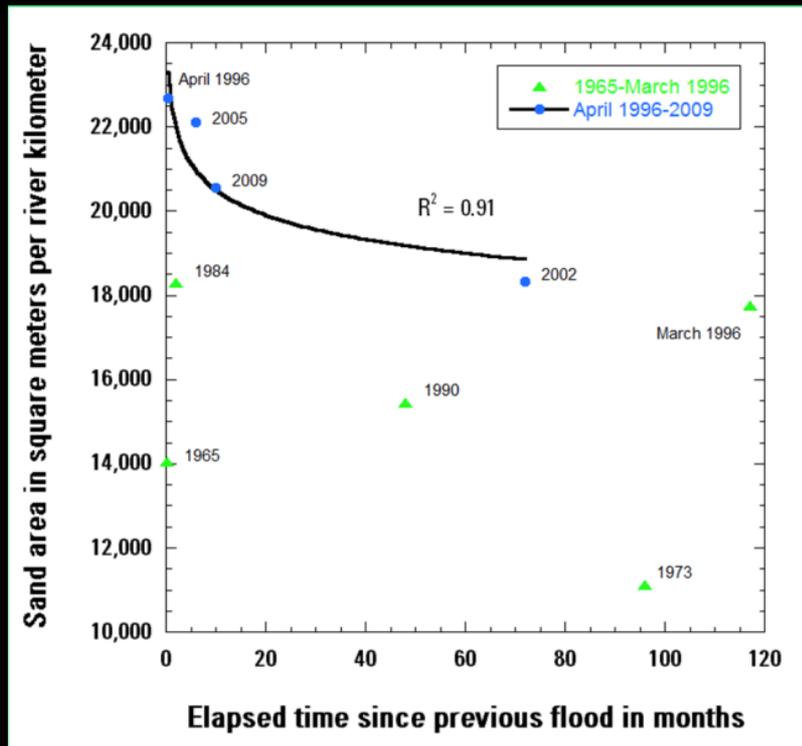
- Increase in volume in both Marble Canyon and Grand Canyon at long-term monitoring sites
 - Deposition by HFEs
 - Bars erode following HFEs, but not quite to pre-flood size
- Frequent HFEs = consistently larger bars
- Cumulative effect? No evidence yet that bars will get progressively larger.
- 2013 and 2014 HFEs were smaller than 2012 and earlier.

Sandbars: 2002-present



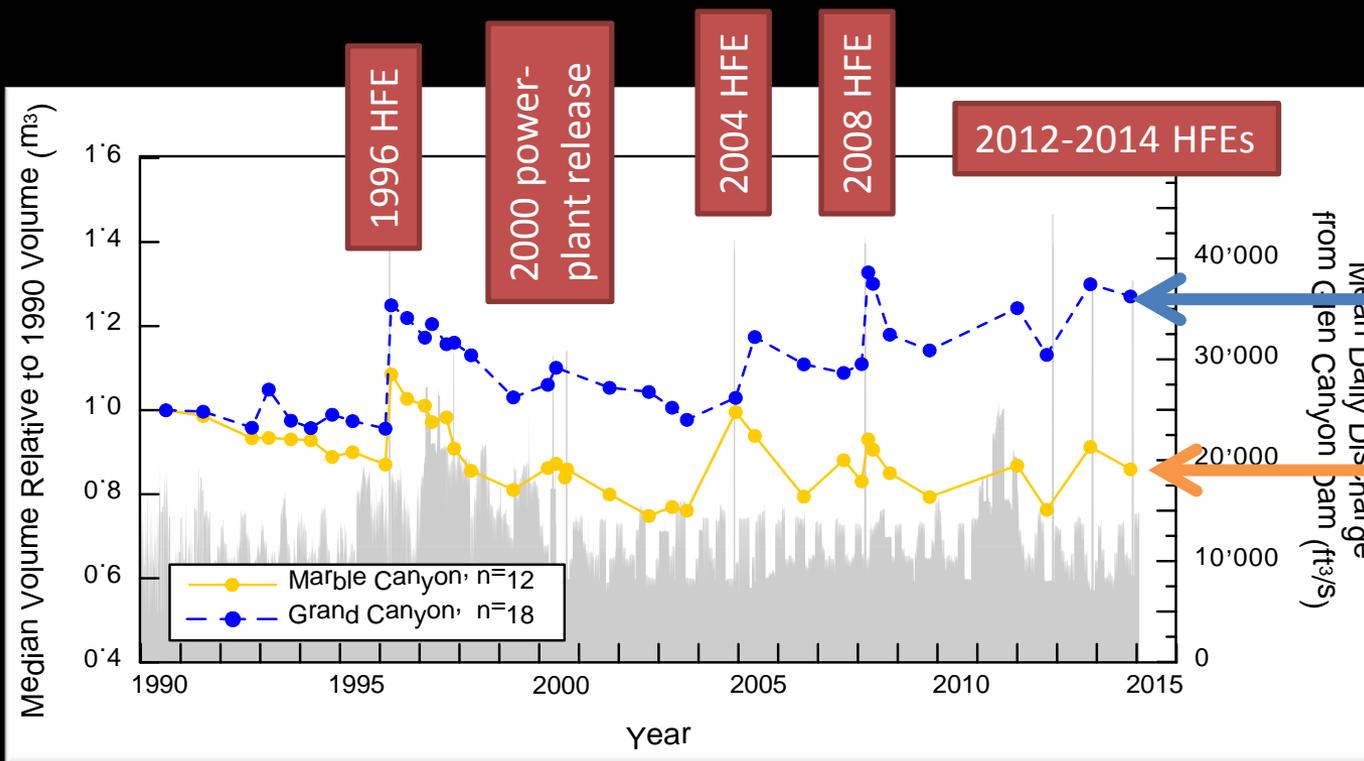
- Maps of sand area from remote sensing images (2002, 2005, and 2009) also show larger sand area in 2009 than 2002
 - Increase in wide reaches
 - No change in narrow reaches

Sandbars: 2002-present



- Maps of sand area from remote sensing images (2002, 2005, and 2009) also show larger sand area in 2009 than 2002
 - Increase in wide reaches
 - No change in narrow reaches
- **But...**
- **All images taken at different intervals following HFEs**
 - Bar area is predictable based on elapsed time since most recent controlled flood
 - HFEs have had similar effects and similar erosion rates since 1996

Sandbars: 1990-present

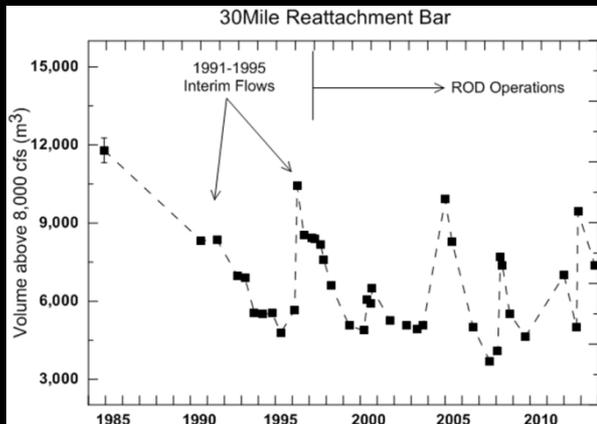
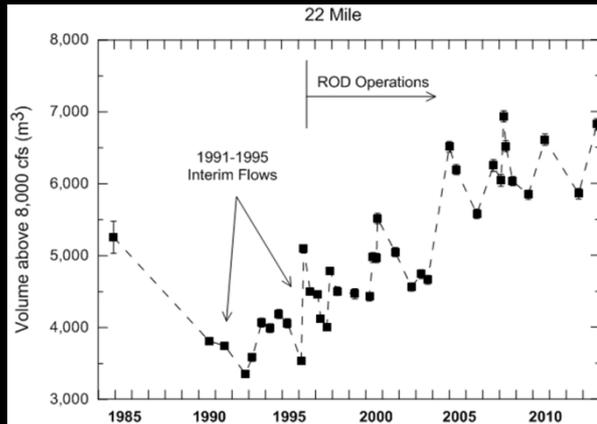
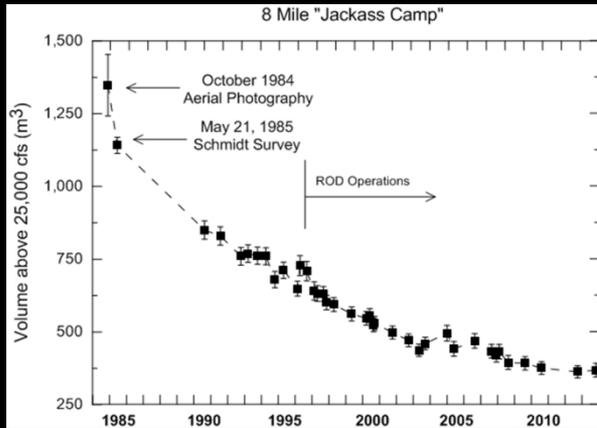


Grand Canyon: bars about as large as ever measured

Marble Canyon: bars larger than low point; smaller than early 1990's

- 30 monitoring sites have data to 1990
 - 12 in Marble Canyon
 - 18 in Grand Canyon
- Increase in sandbar volume at sites in Grand Canyon
- Marble Canyon bars still less volume than 1990, but larger than low point of 2001-2003

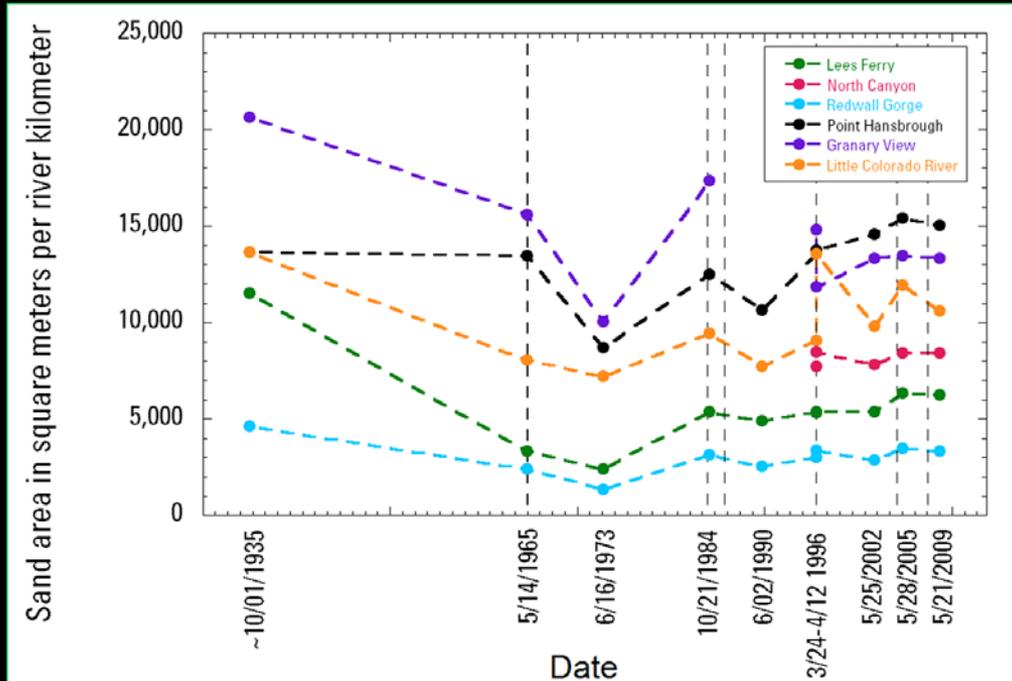
Sandbars: 1984-present



- High-resolution photogrammetry applied to aerial photographs from October 1984 to map sandbar topography
- Allows measurement of bar volume for comparison with recent measurements
- Although some bars were much larger in 1984, they were not all larger
 - Some are larger now
 - Some about the same
- Which sites require large floods (larger than HFEs) to build large sandbars?

Hazel, Gushue, and Weber
(preliminary data, do not cite)

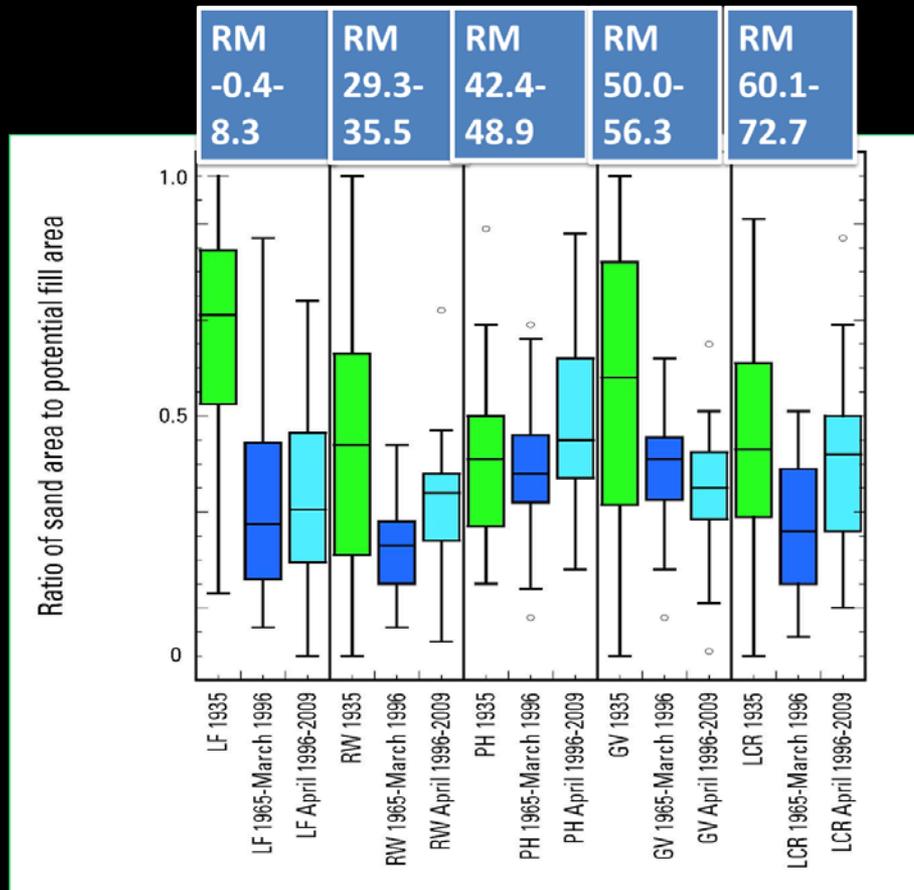
Sandbars: pre-dam, pre-ROD, and present



- Maps of sand area from air photos for study reaches mapped by Schmidt and students at Utah State
- 5 reaches between RM 0 and RM 73
- In most reaches, bars larger in 1935 than in post-dam years

YEAR	PERIOD
1935	Pre-dam
1965	Post-dam; unrestricted powerplant operations (pre-ROD)
1973	
1984	
1990	
March 1996	Post-dam: restricted powerplant operations and controlled floods
April 1996	
2002	
2005	
2009	

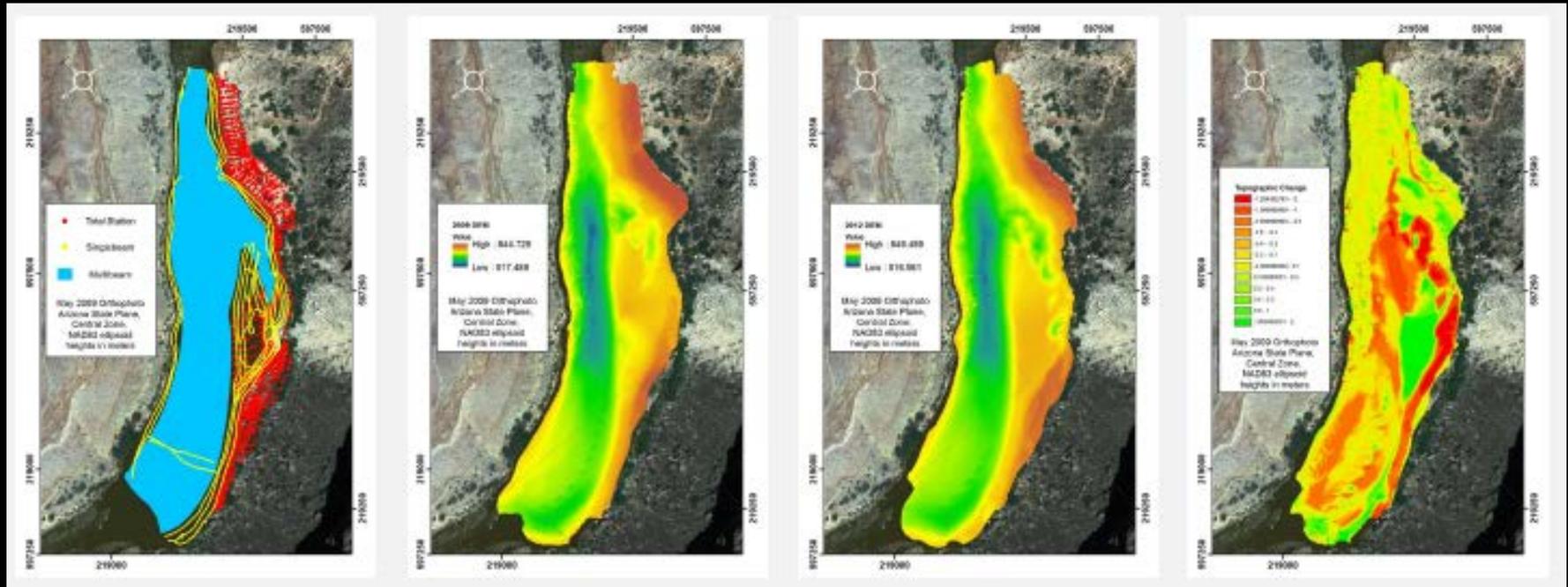
Sandbars: pre-dam, pre-ROD, and present



- Bars **smaller** in post-dam periods than pre-dam period
- Bars **larger** in period of HFEs and restricted powerplant operations (MLFF) than period without HFEs and with unrestricted powerplant operations (pre-ROD)

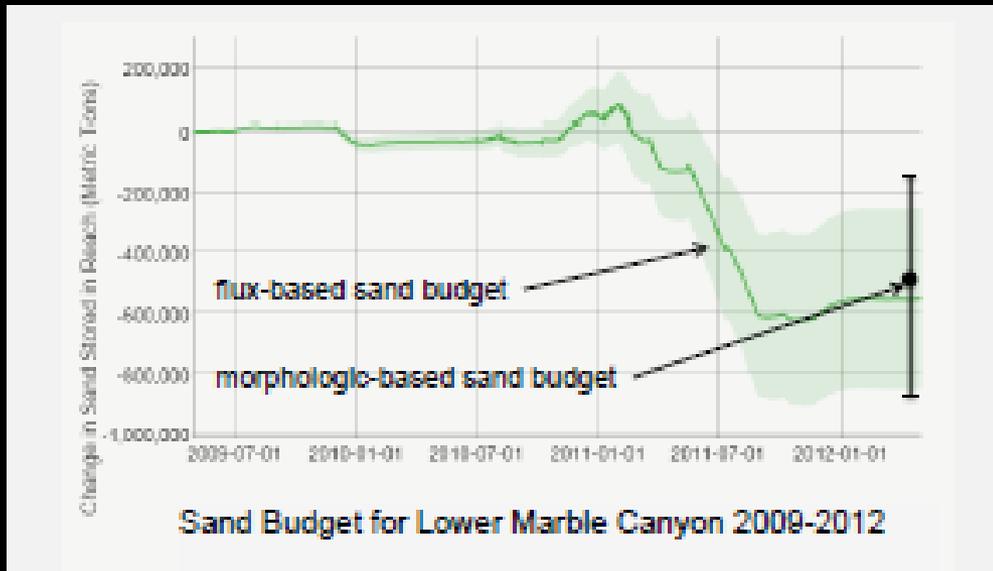
■ Pre-dam
■ Unrestricted powerplant operations; no controlled floods (pre-ROD)
■ Restricted powerplant operations and controlled floods (MLFF + HFEs)

Sand Storage in Lower Marble Canyon: 2009-2012

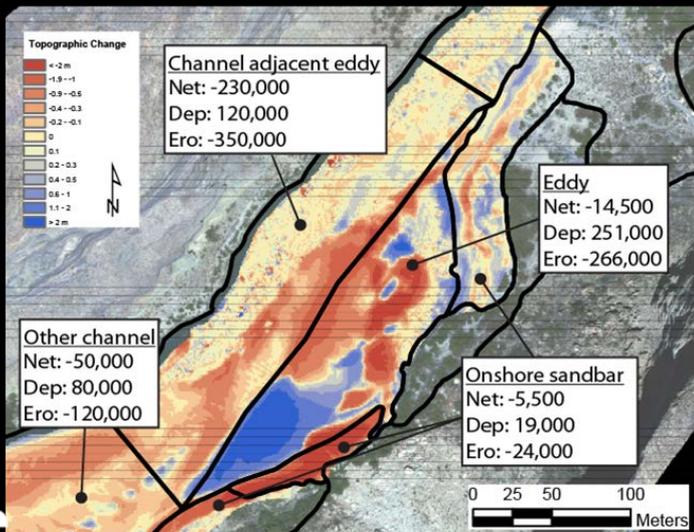


- Repeat maps of river bed used to track changes in sand storage and changes in bed texture
- Show where changes in storage occur

Sand Storage in Lower Marble Canyon: 2009-2012

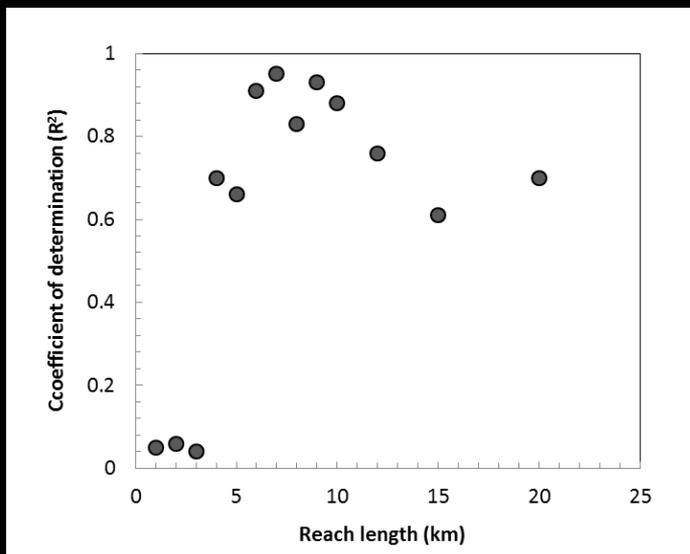
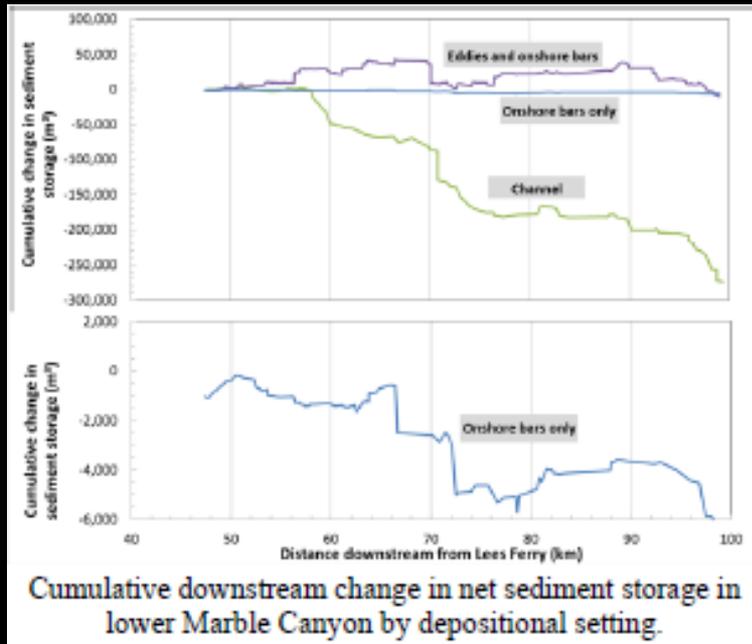


- Sand loss during equalization flows
 - Over short (3-year) period have similar uncertainty to flux measurements
 - Over long (10-20 year) period have much less uncertainty than flux measurements



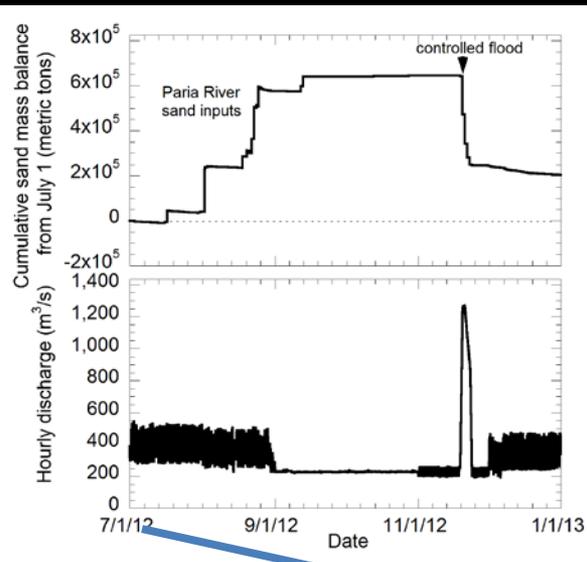
- Most erosion from channel
 - No net loss from eddies
 - But there was erosion of high-elevation (above 8,000 cfs stage) bars

Sand Storage in Lower Marble Canyon: 2009-2012

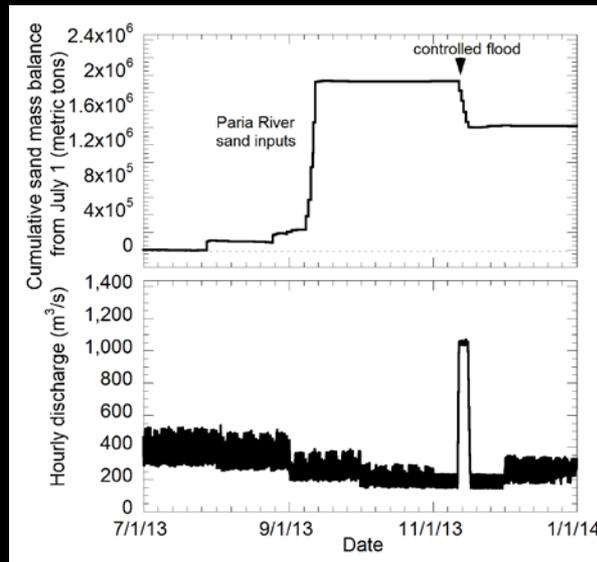


- Sand loss not uniform throughout Lower Marble Canyon
- Adjacent reaches can have very different response
- But we can now begin to define scales over which response is consistent
- Seem to be ~10 reaches of consistent response
- We can also begin to identify scales where eddy response and bar response are linked
 - Not at reaches less than ~5km
 - Yes at reaches of ~ 7-12 km
 - Less at longer reaches

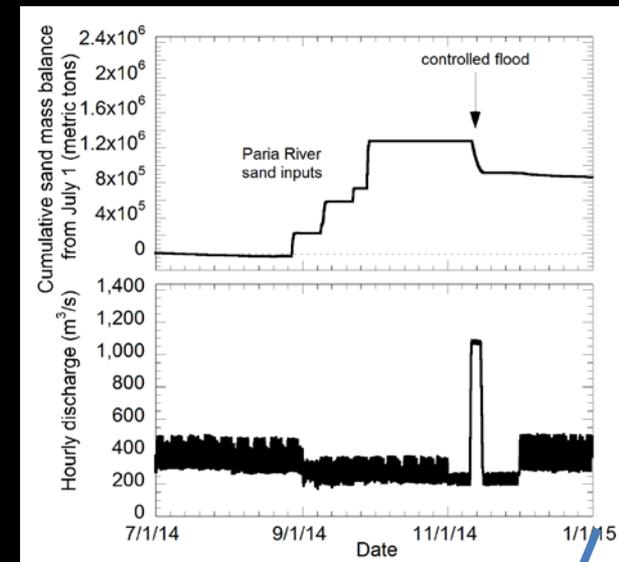
Sand Storage in Marble Canyon During HFE Protocol



2012 HFE



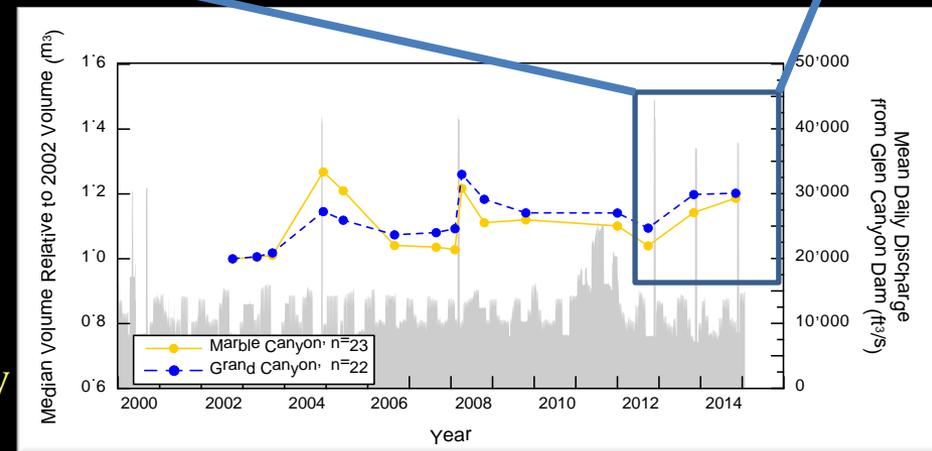
2013 HFE



2014 HFE

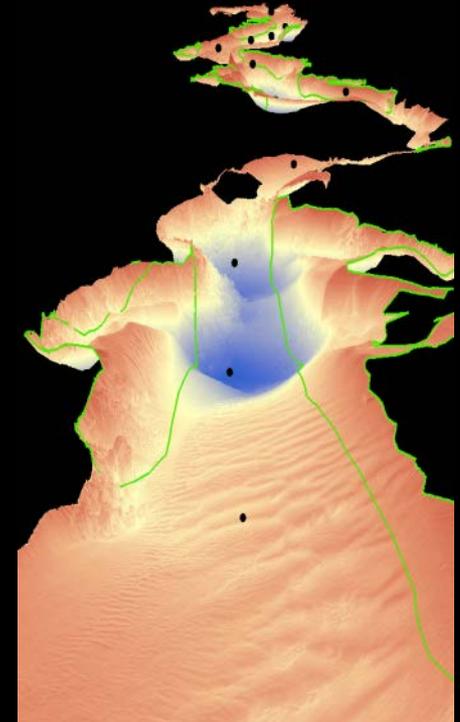
- Since 2012, each year has had enough sand accumulation to have a controlled flood and have sand accumulation
- Accumulation has more than replaced “evacuation” that occurred in 2011

Hazel et al. (preliminary data, do not cite)



Summary

- HFEs continue to build sandbars
- Bars continue to erode between HFEs
- Results in larger bars than would occur in absence of HFEs
- No evidence for “progressive” increases in sandbar size throughout Marble Canyon
 - May occur in Grand Canyon and at some sites in Marble Canyon
- Trends: 2002 to 2014
 - Based on looking at lots of sandbars on air photos, bar area about the same, but variable depending on when you’re looking (how long since most recent HFE)
 - Based on looking at NAU long-term monitoring sites (45 sites in Marble and Grand Canyons), bar volume larger now than 2002



Summary

- Equalization flows cause sand evacuation
 - The eddies appear to provide a large buffer during periods of evacuation
- First three years of HFE protocol has been a period of low annual release volumes and good tributary sand supply
 - Bar deposition without depleting sand from storage
 - Sand has accumulated in Marble Canyon, replenishing sand evacuated during 2011 equalization

