Sandbars and Sand Storage in Marble and Grand Canyons

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AND
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Overview

- Sandbar response to sediment-rich high flows
- Changes in campsites relative to changes in sandbars and vegetation
- Expanding the sample size: sandbar area in Marble Canyon, 2002-2009
- Expanding the temporal scale: sandbars in 1984
- Channel Mapping: implications for sand storage and sandbar monitoring

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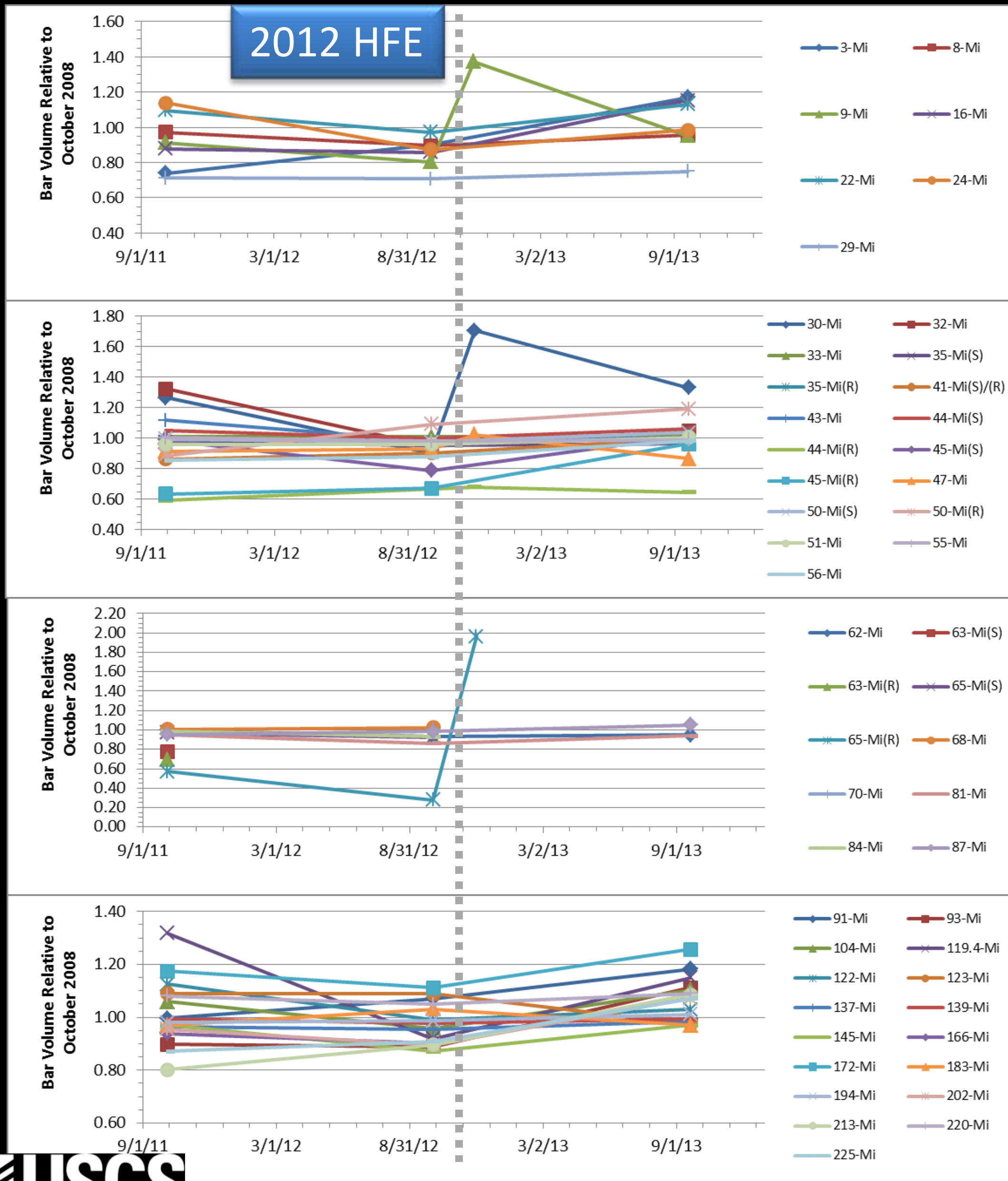
Sandbar response to sediment-rich high flows

- November 2012 HFE
  - Images from remote cameras:
    - 52% (17 out of 33): noticeable gain
    - 39% (13 out of 33): no substantial change
    - 9% (3 out of 33): noticeable loss
  - Sandbar surveys: 54% of sites (27 out of 50) larger in Oct. 2013 than in Oct. 2011
- November 2013 HFE
  - Images from remote cameras:
    - 53% (21 out of 40): noticeable gain
    - 30% (12 out of 40): no substantial change
    - 18% (7 out of 40): noticeable loss

Bob Tusso, unpublished data, do not cite

Sandbars 10 months following 2012 high flow



Upper Marble Canyon (RM 0-29)
5 of 7 sites larger than Oct. 2011

3 of 7 sites larger than Oct. 2008

Lower Marble Canyon (RM 30-62)
11 of 16 sites larger than Oct. 2011

9 of 16 sites larger than Oct. 2008

Eastern Grand Canyon (RM 62-87)
1 of 3 sites larger than Oct. 2011

1 of 3 sites larger than Oct. 2008

Grand Canyon (RM 88-225)
10 of 16 sites larger than Oct. 2011

11 of 16 sites larger than Oct. 2008

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Joe Hazel, unpublished data, do not cite

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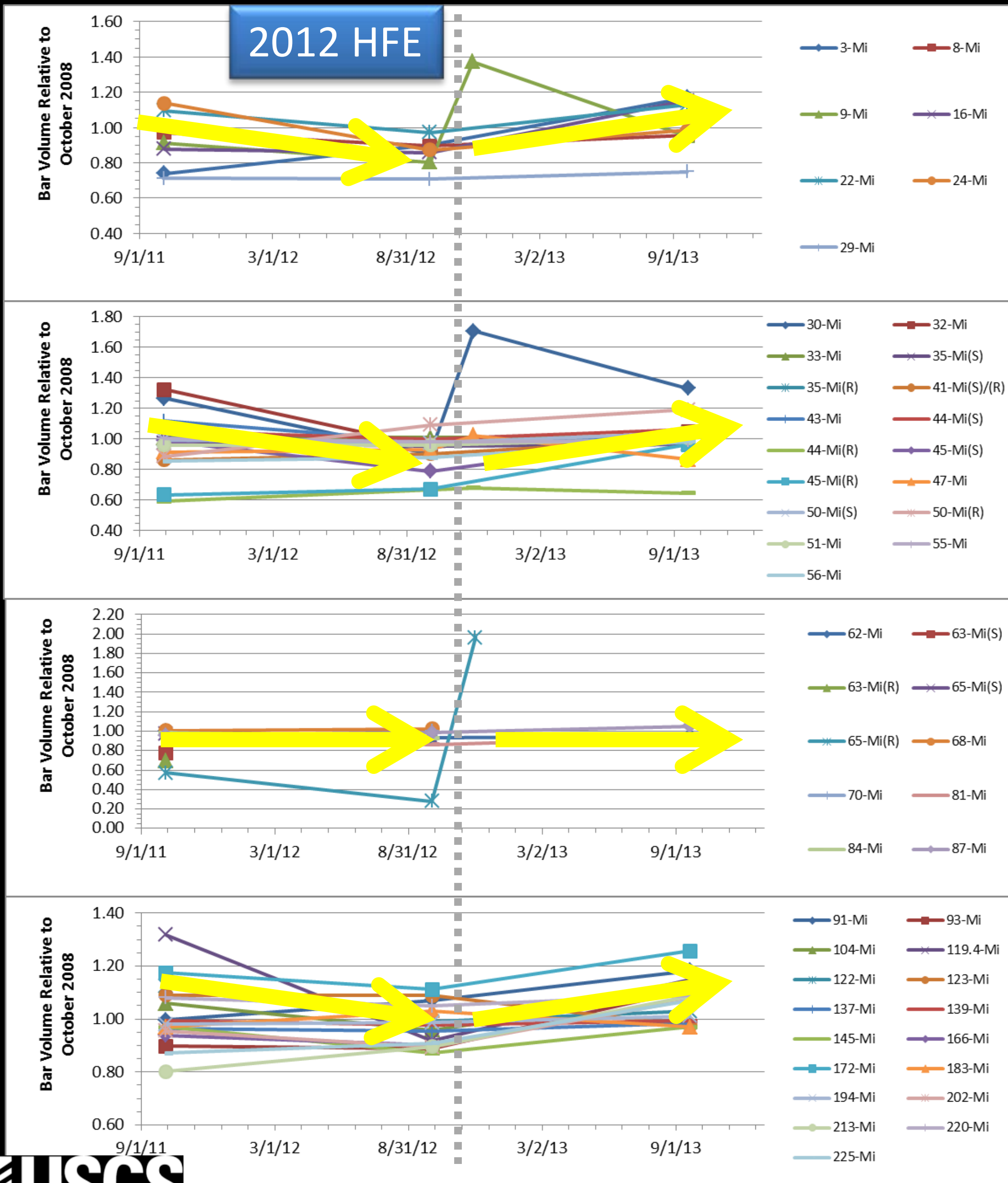

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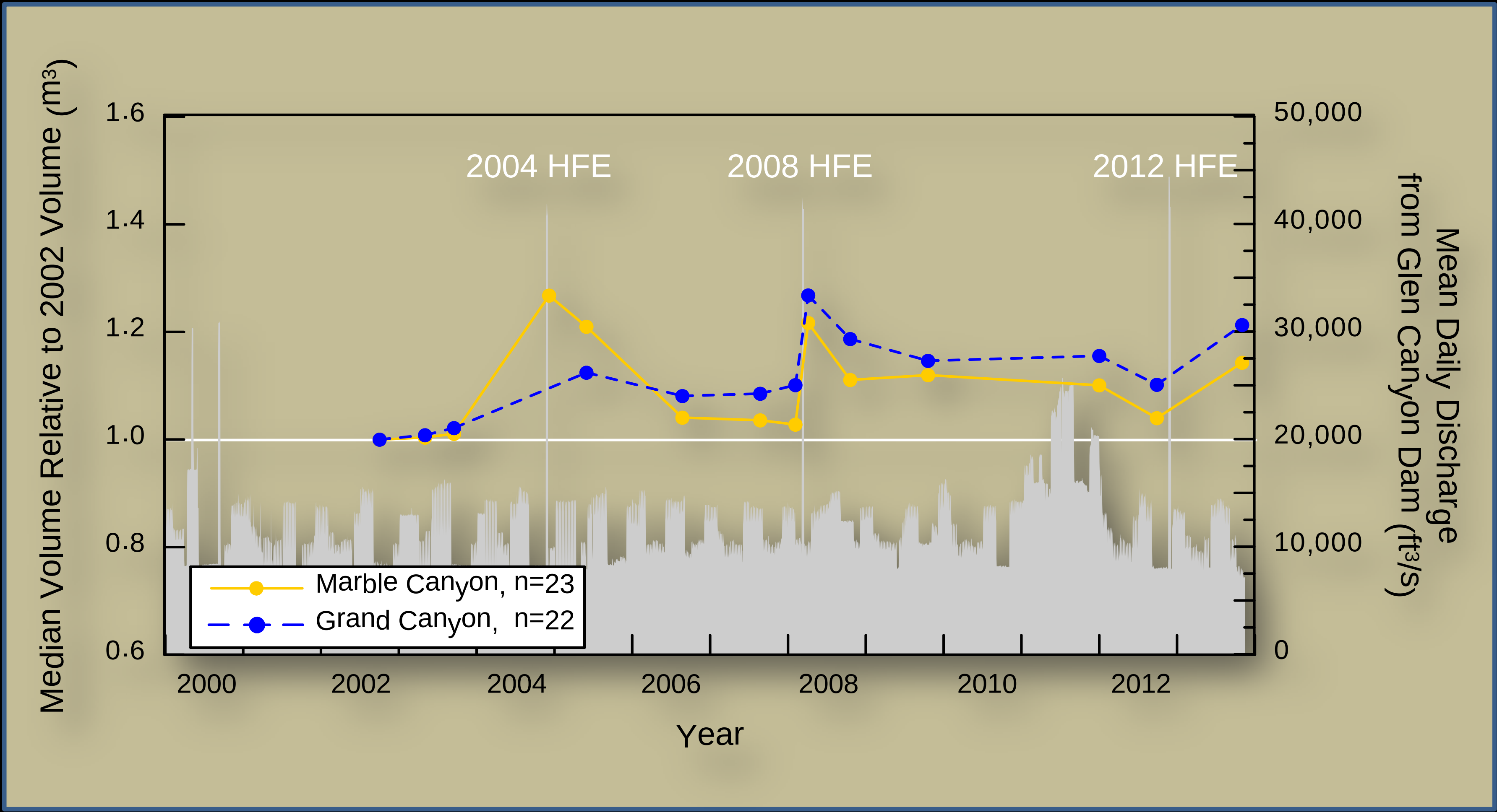

- Sediment enriched HFEs and relatively low release volumes
- → relatively large bars 10 months following HFE

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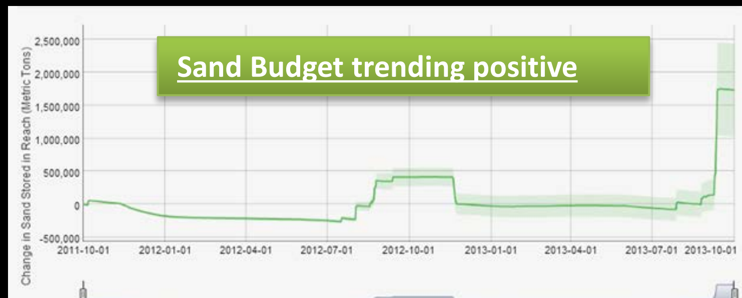
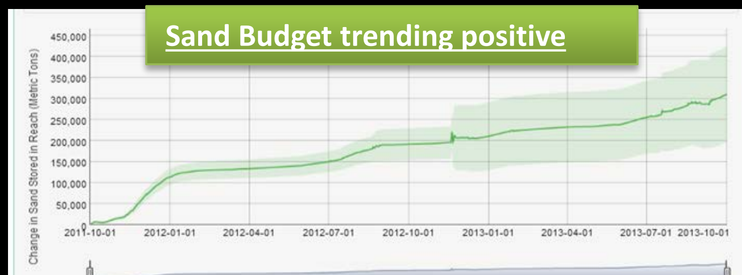
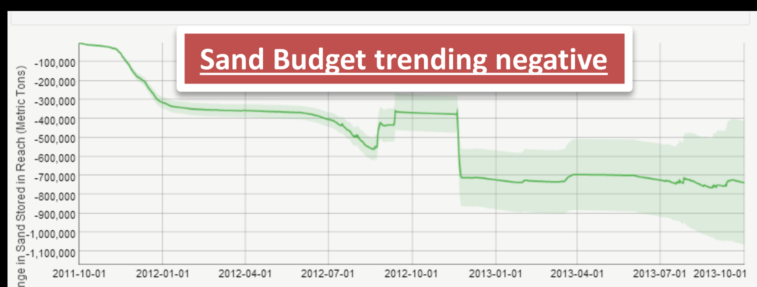
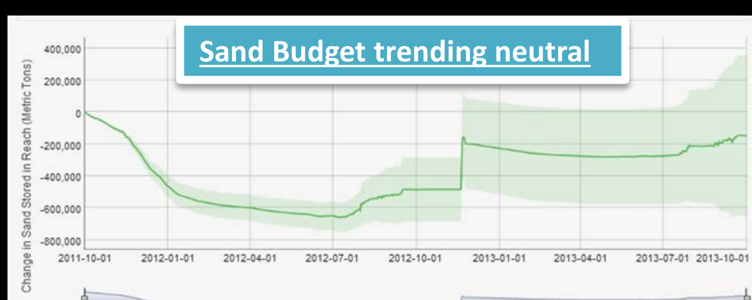
Joe Hazel, unpublished data, do not cite

Sandbars and Sand Budget: 2011 – 2013

Segment	Sand Budget	Sandbar Condition
Upper Marble Canyon (RM 0-29)		5 of 7 sites larger in 2013 than 2011 1 of 7 sites larger in 2013 than 2008 post-HFE
Lower Marble Canyon (RM 30-62)		11 of 16 sites larger in 2013 than 2011 4 of 16 sites larger in 2013 than 2008 post-HFE
Eastern Grand Canyon (RM 62-87)		1 of 3 sites larger in 2013 than 2011 2 of 3 sites larger in 2013 than 2008 post-HFE
Grand Canyon (RM 88-225)		10 of 16 sites larger in 2013 than 2011 8 of 16 sites larger in 2013 than 2008 post-HFE

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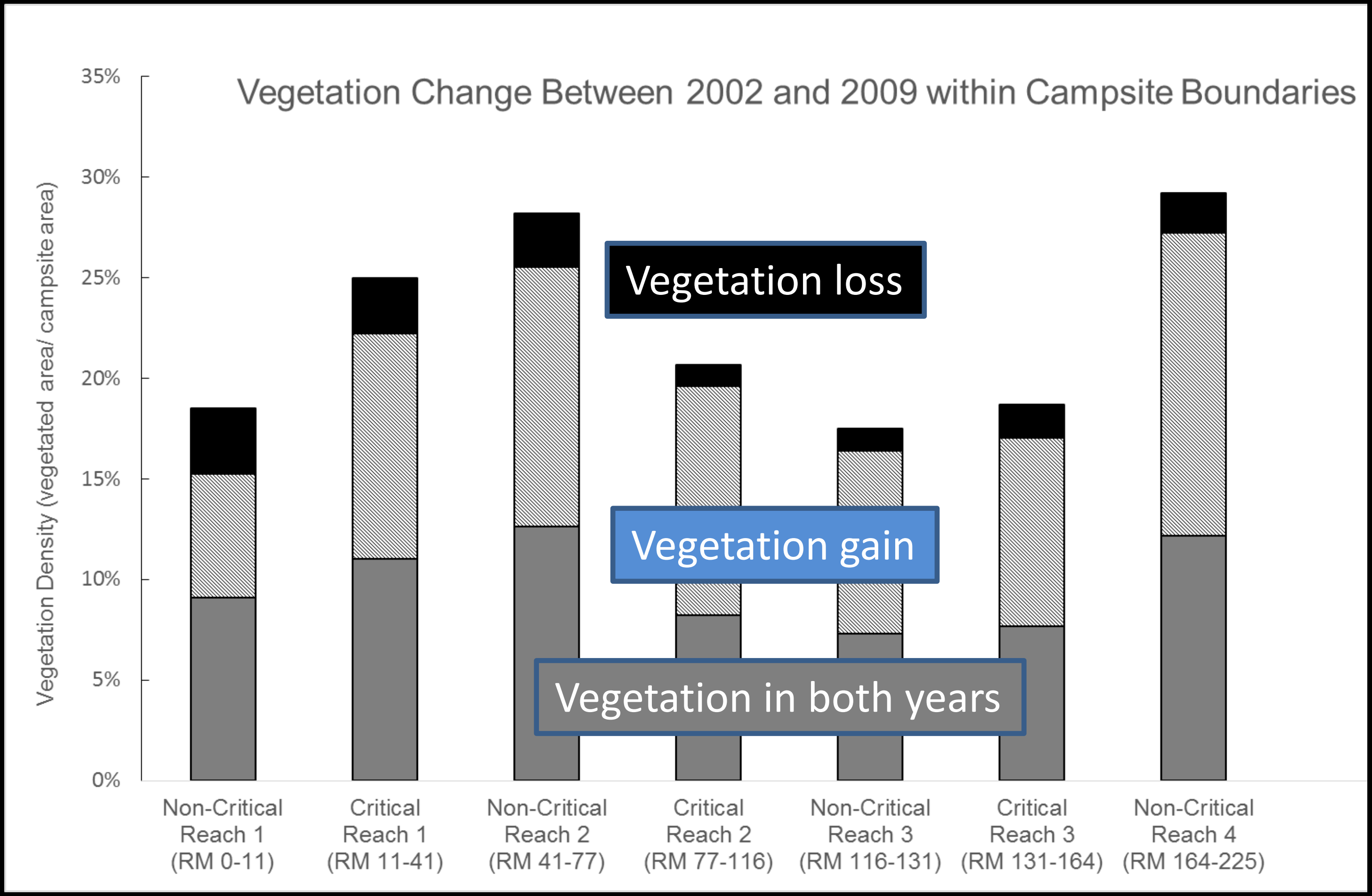
Joe Hazel, unpublished data, do not cite

Change in Vegetation Within 504 Campsite Boundaries throughout Grand Canyon based on the 2002 and 2009 Remote Sensing



- ~13% increase in vegetation cover within campsite boundaries, 2002-2009

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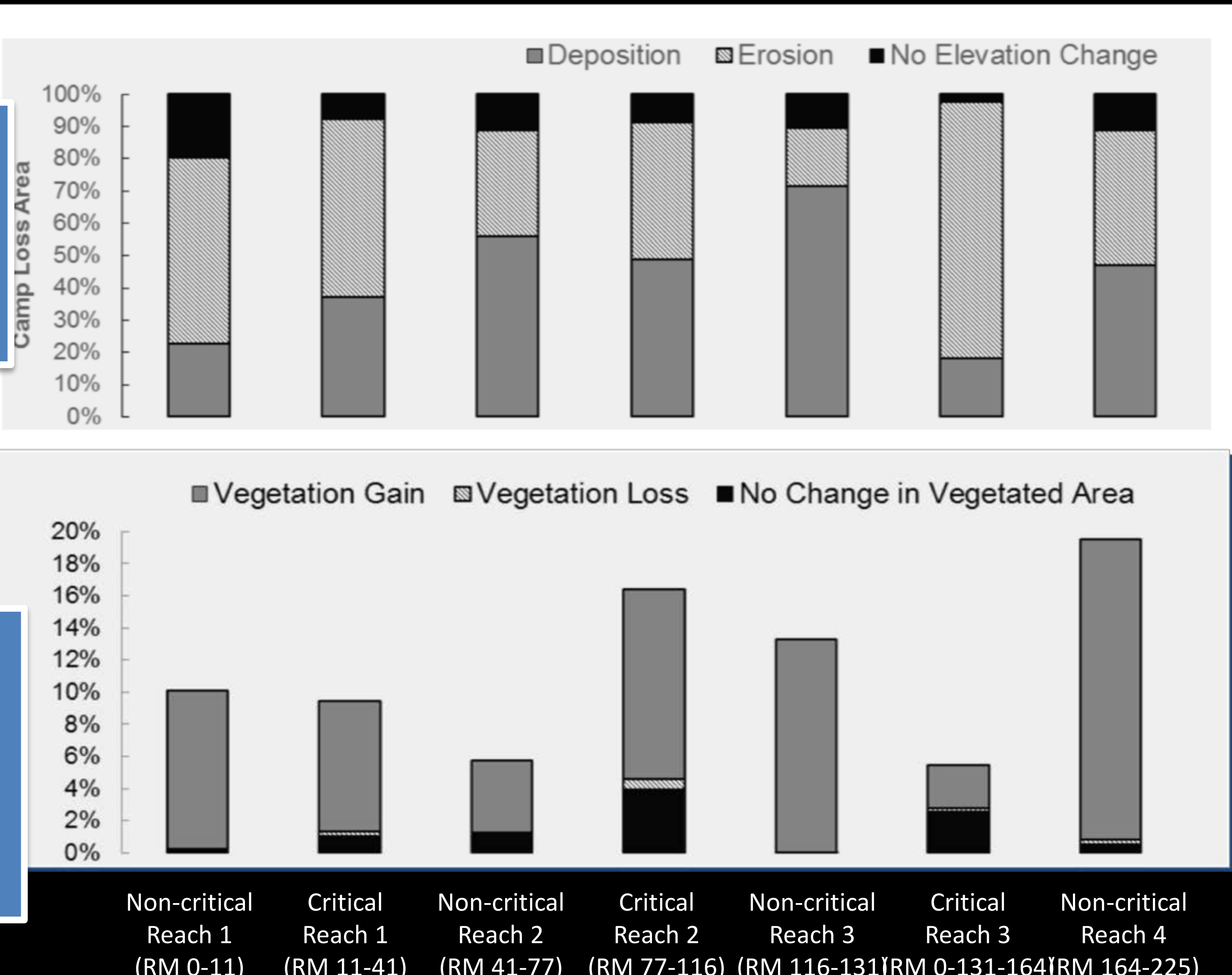
Dan Hadley, unpublished data, do not cite

Factors Contributing to Loss of Usable Camp Area at Long-term Monitoring Sites, 2002-2009

~10 to 80% of losses in usable camp area associated with sandbar erosion

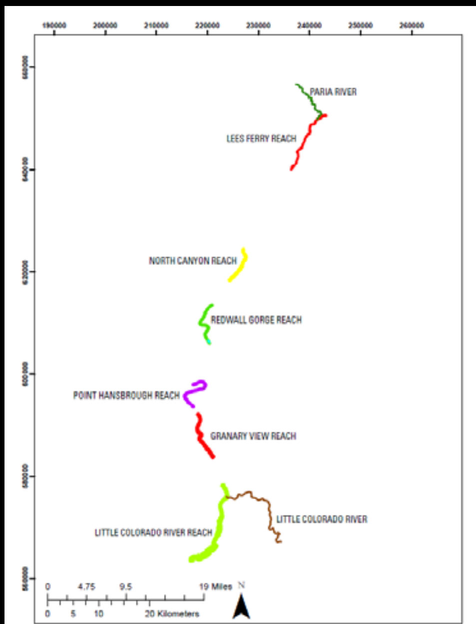


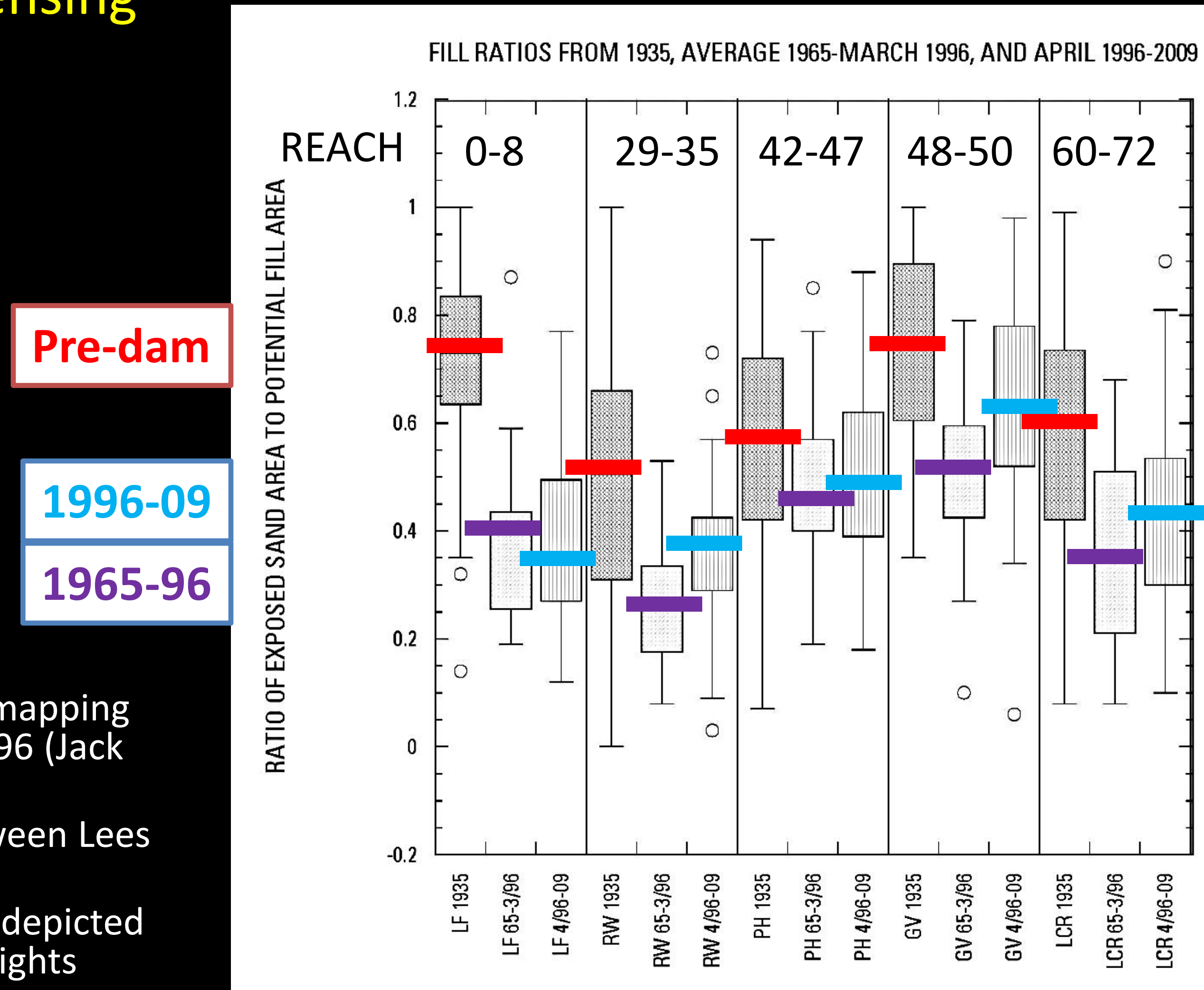
~4 to 20% of losses in usable camp area associated with increases in vegetation

USGS

Dan Hadley, unpublished data, do not cite

Sandbar Area throughout Marble Canyon based on 2002-2009 Remote Sensing





- 7 study reaches with detailed mapping from air photos for 1935 to 1996 (Jack Schmidt and students at USU)
- Covers ~50% of the reach between Lees Ferry and RM 72
- Updated with sandbar extents depicted on 2002, 2005 and 2009 overflights

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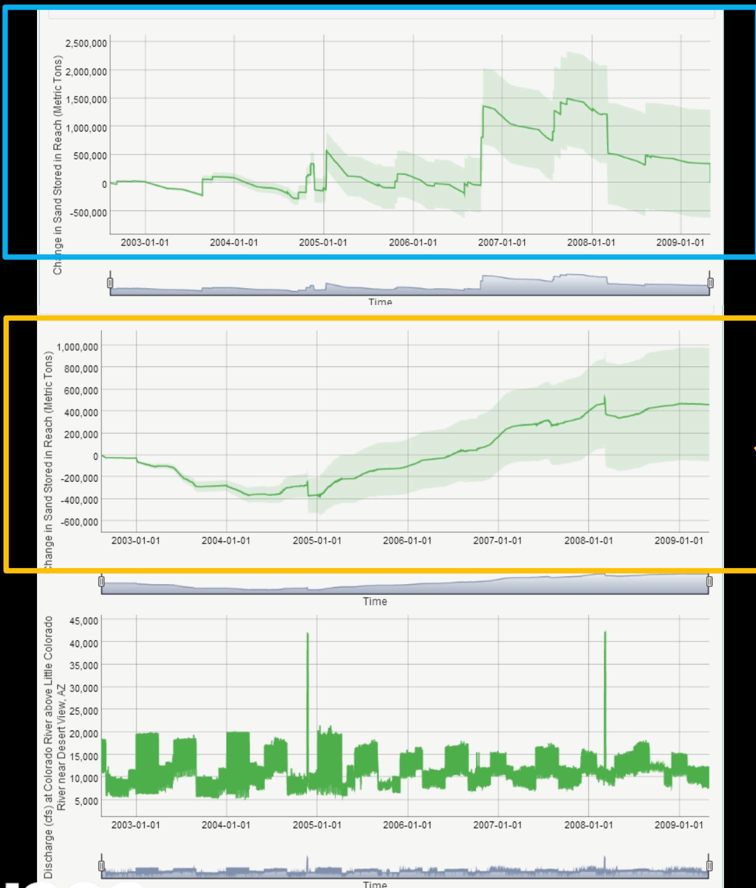
Rob Ross, unpublished data, do not cite

Sandbar Area throughout Marble Canyon based on 2002-2009 Remote Sensing

- No significant change in exposed sandbar area in period of stable (or slight positive) trend in sand budget



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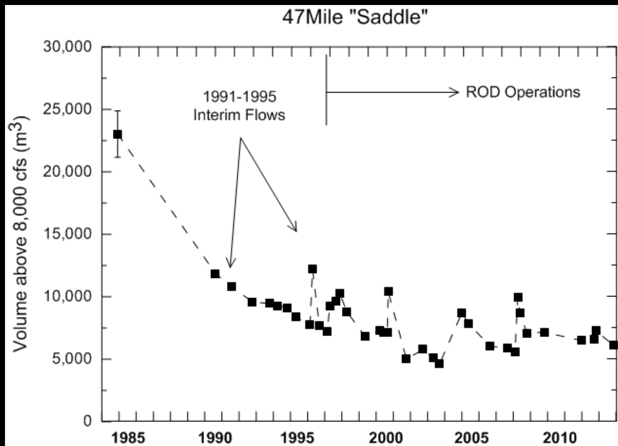
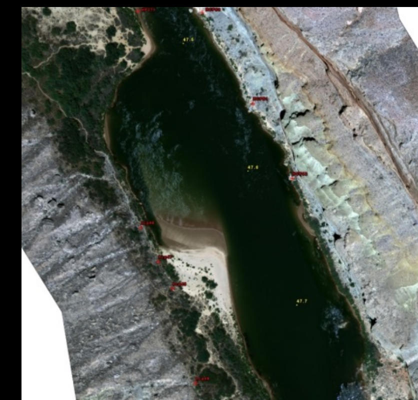
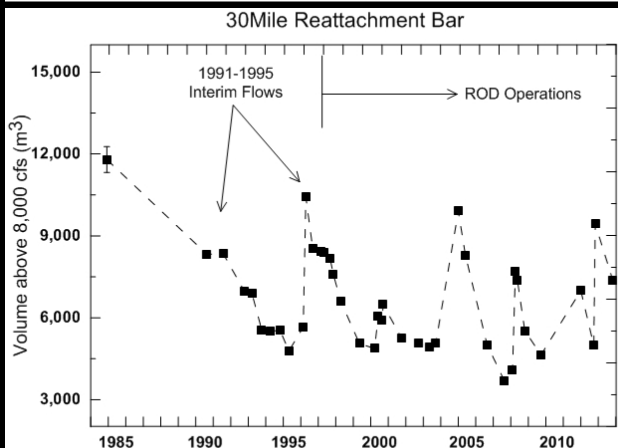
1984 2009

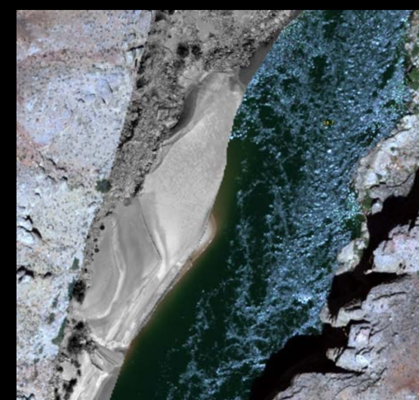


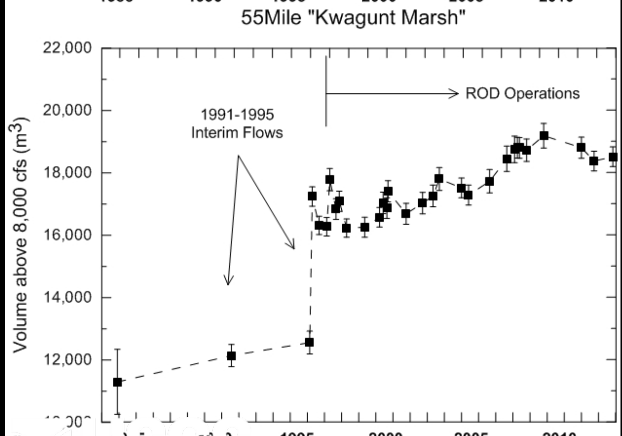
1984 bar much larger than present
Indicative of a site that requires large floods to build large bars



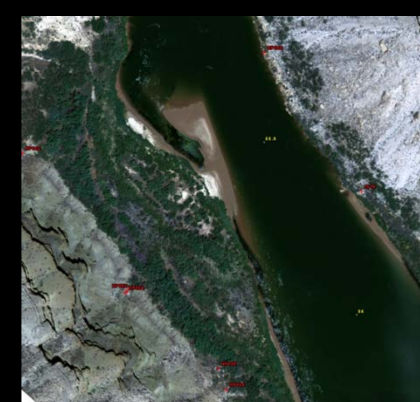


1984 bar slightly larger than present
HFE's consistently build a bar a bit smaller than existed in 1984





1984 bar smaller than present
HFE's and vegetation expansion has resulted in a large, stabilized bar



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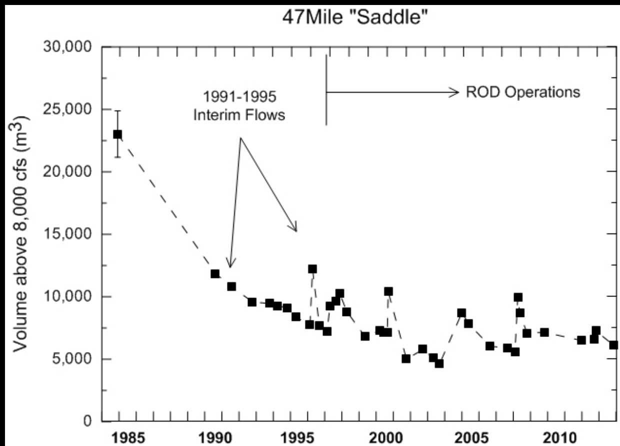

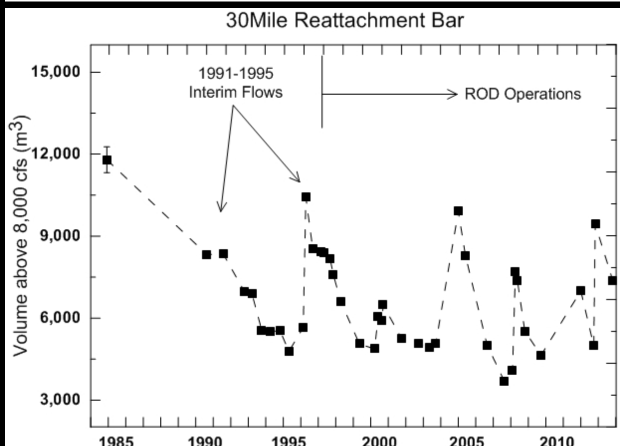

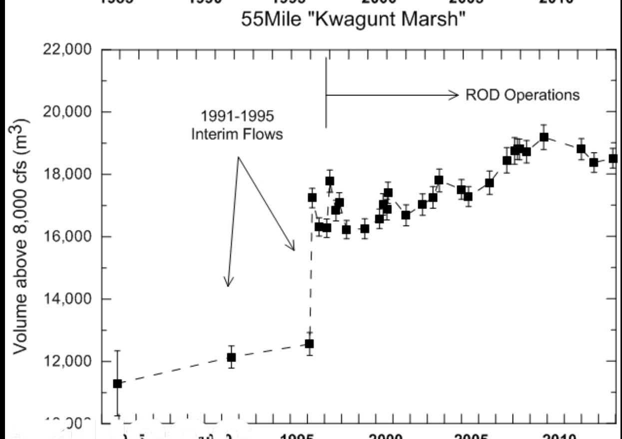

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<u>1984 bar much larger than present</u>
Indicative of a site that requires large floods to build large bars

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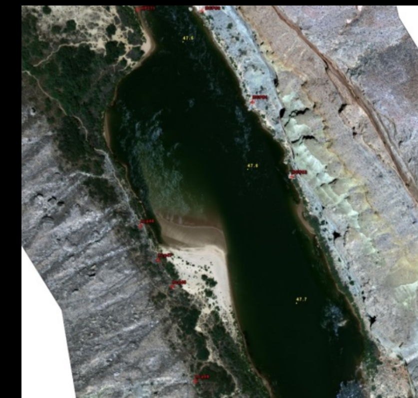
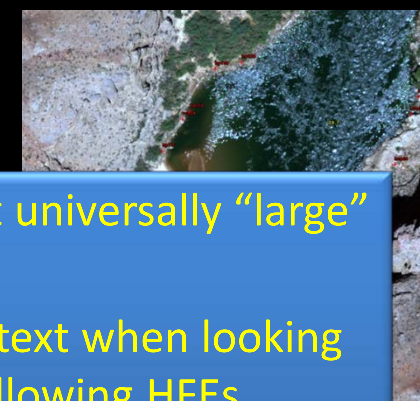
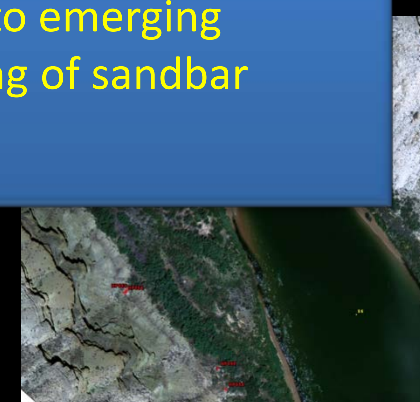
1984

2009





- Sandbars not universally "large" in 1984
- Provides context when looking at bar size following HFEs
- Contributes to emerging understanding of sandbar behavior



Joe Hazel, unpublished data, do not cite

Monitoring Sand Storage in Grand Canyon

- Track sand storage to:
  - Plan floods
  - Evaluate "progress"
  - Make predictions about long-term prognosis
- The scientific Challenges:
  - Where is the sand?
  - What controls sand storage changes at "local" and "reach" scales?

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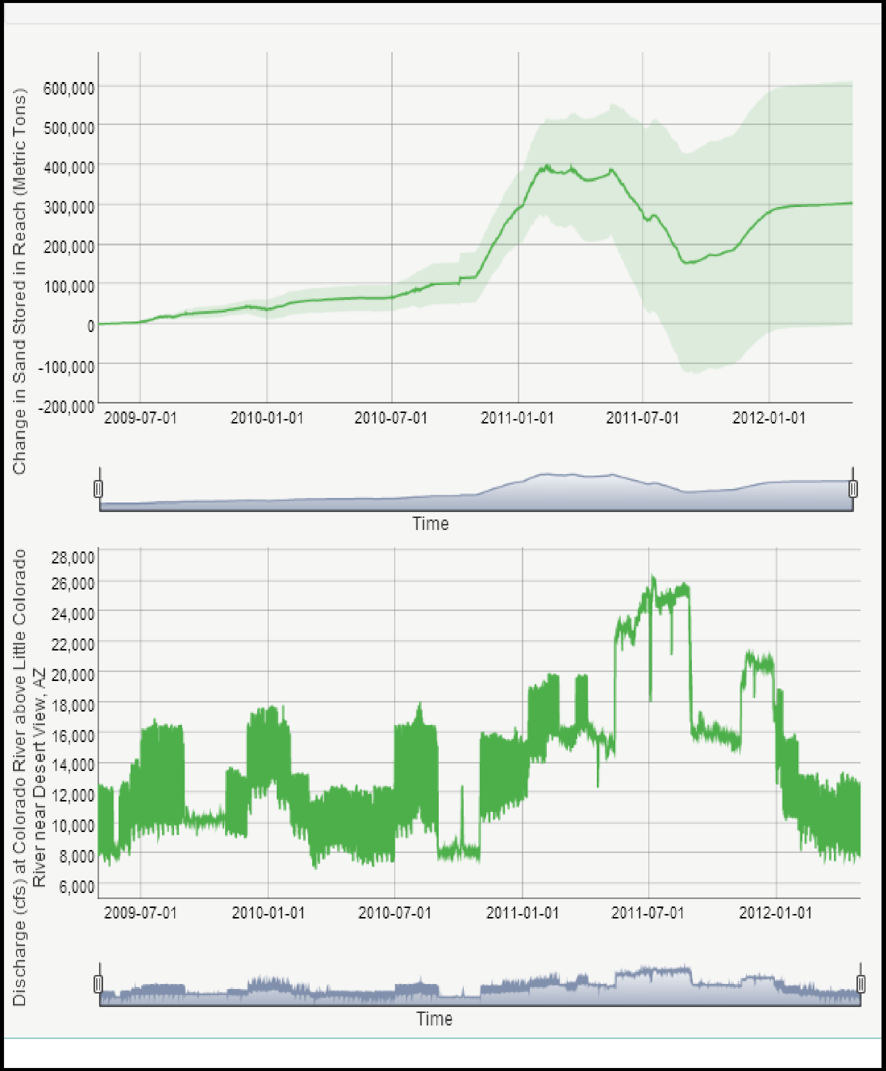
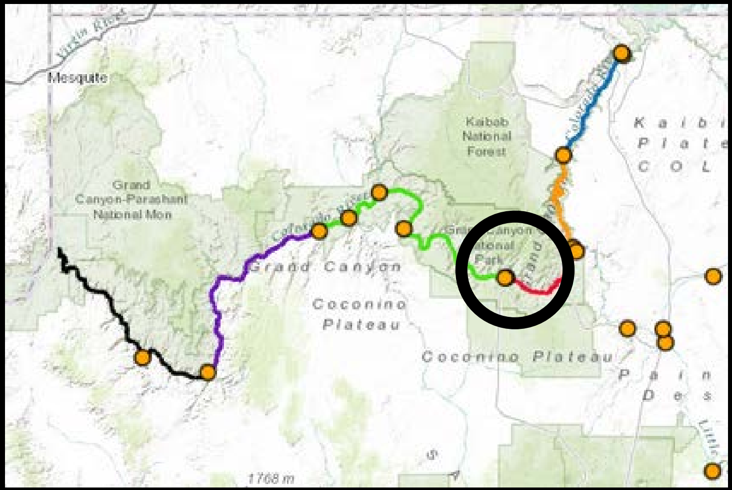
Colorado River Channel Mapping: 2009 – 2012

- Lower Marble Canyon (RM 29.4 to 61.7).
- Measurements of sand flux indicate ~0 to ~300,000 metric tons of sand accumulation
- What actually happened on the river bed and to sand bars???





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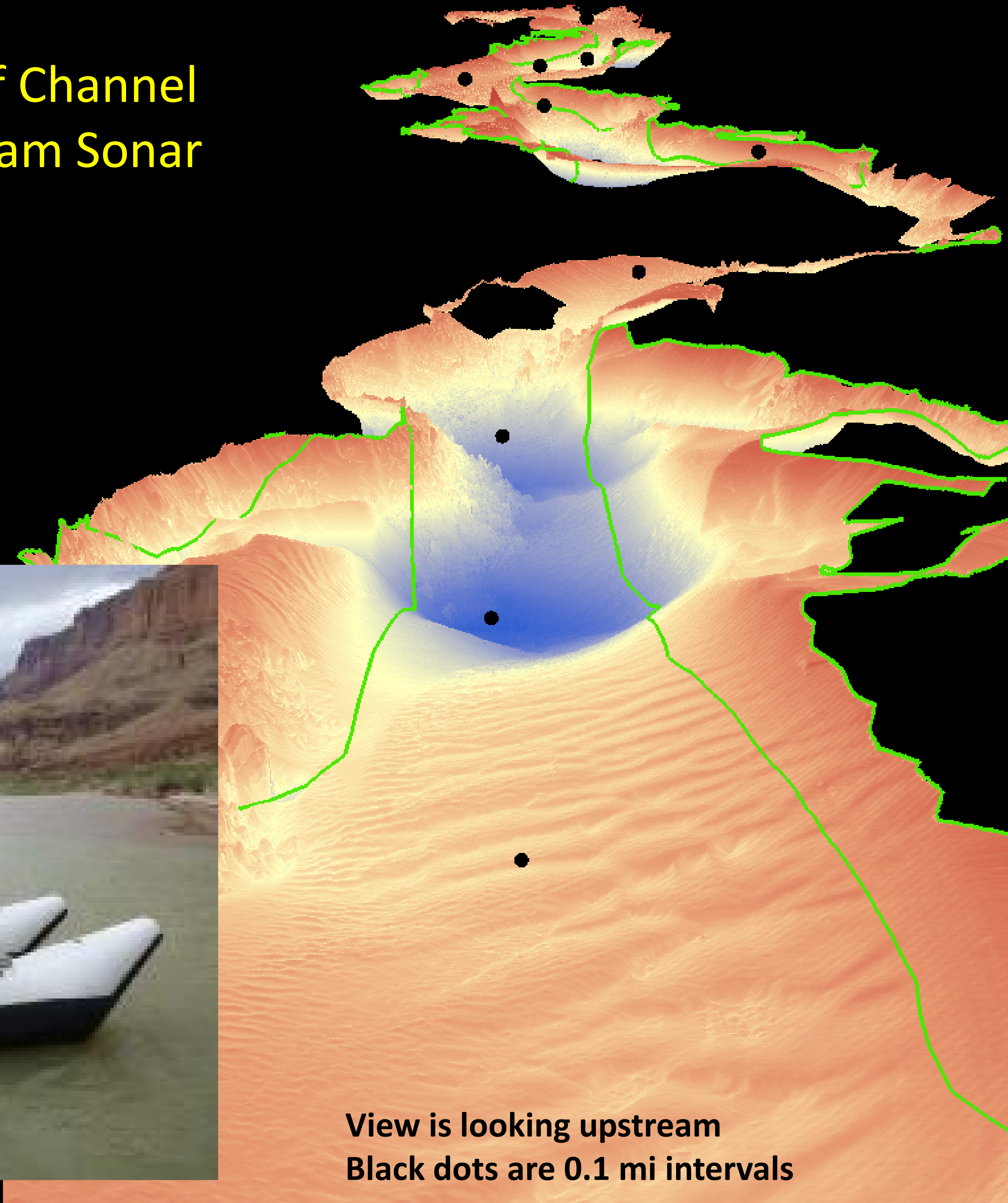
Repeat Measurements of Channel Topography with multibeam Sonar

- Make digital elevation models like this for each survey →
- Compute changes by differencing the two maps:



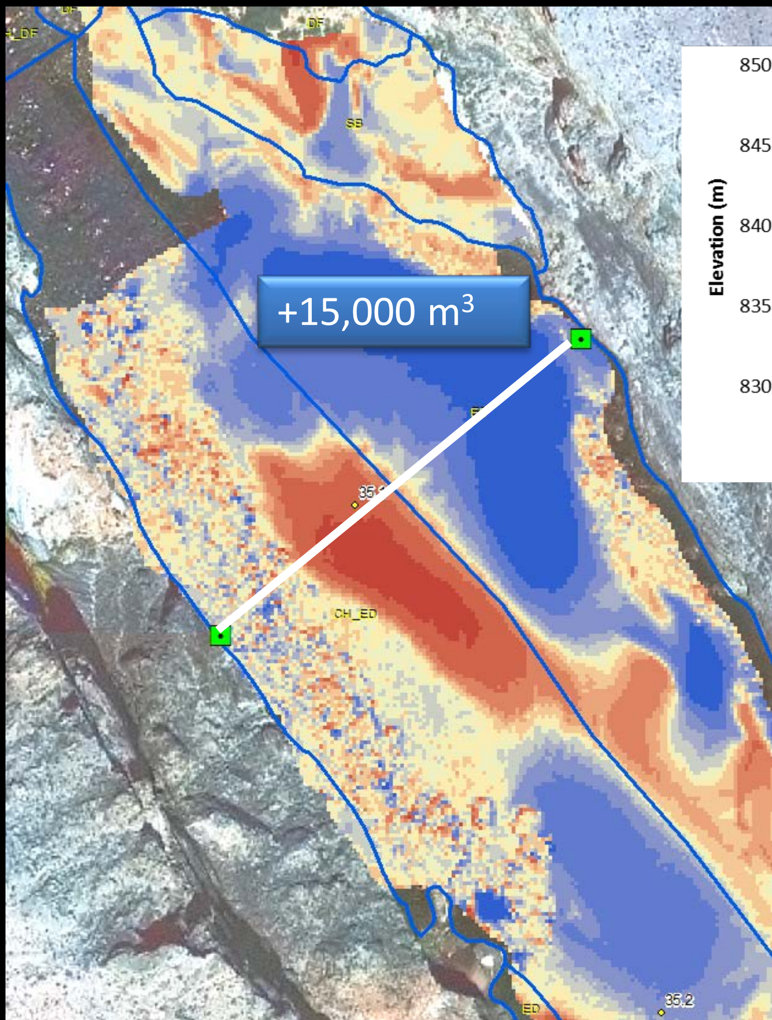
Geomorphic Base Map

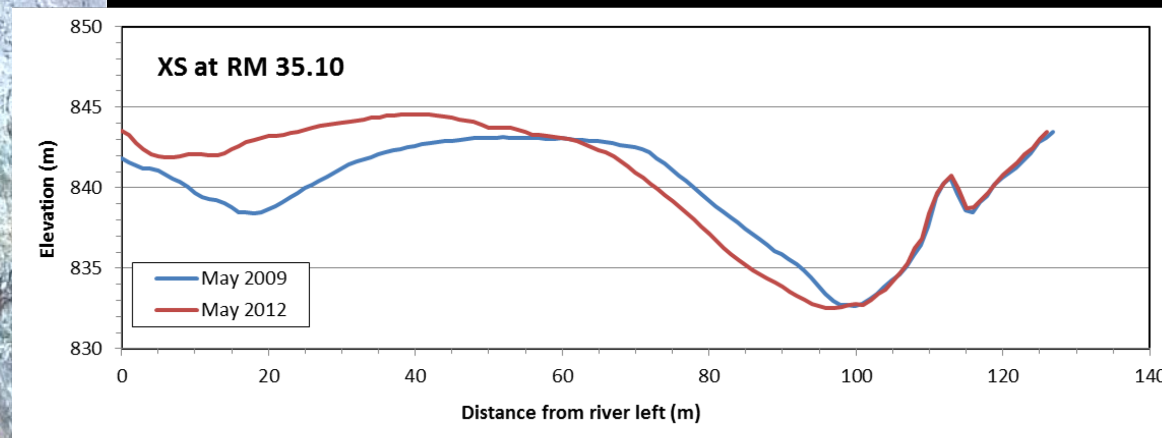
- A map to:
  - Include all Colorado River alluvial deposits
  - Identify depositional setting
    - Eddy/non-eddy
    - Separation/reattachment zone
  - Identify channel units (e.g. rapid/gravel riffle/pool)
- Map covers ALL of RM 29 to 61 (including reaches with we did not survey)

Surveyed 87% of sand bars (long-term monitoring sites are 14% of the bars in same reach)

Map Unit	Number in Study Reach	Number Surveyed	Percent Surveyed (by area)
Channel segments	229	206	84%
Eddies	222	199	89%
Eddy sand bars	204	183	87%
Channel margin sand bars	60	54	76%
Gravel bars	23	8	16%
Debris fans	142	121	55%

Paul Grams, unpublished data, do not cite





- Deposition in eddy at 35.07 (Nautiloid): 2nd ranked eddy change

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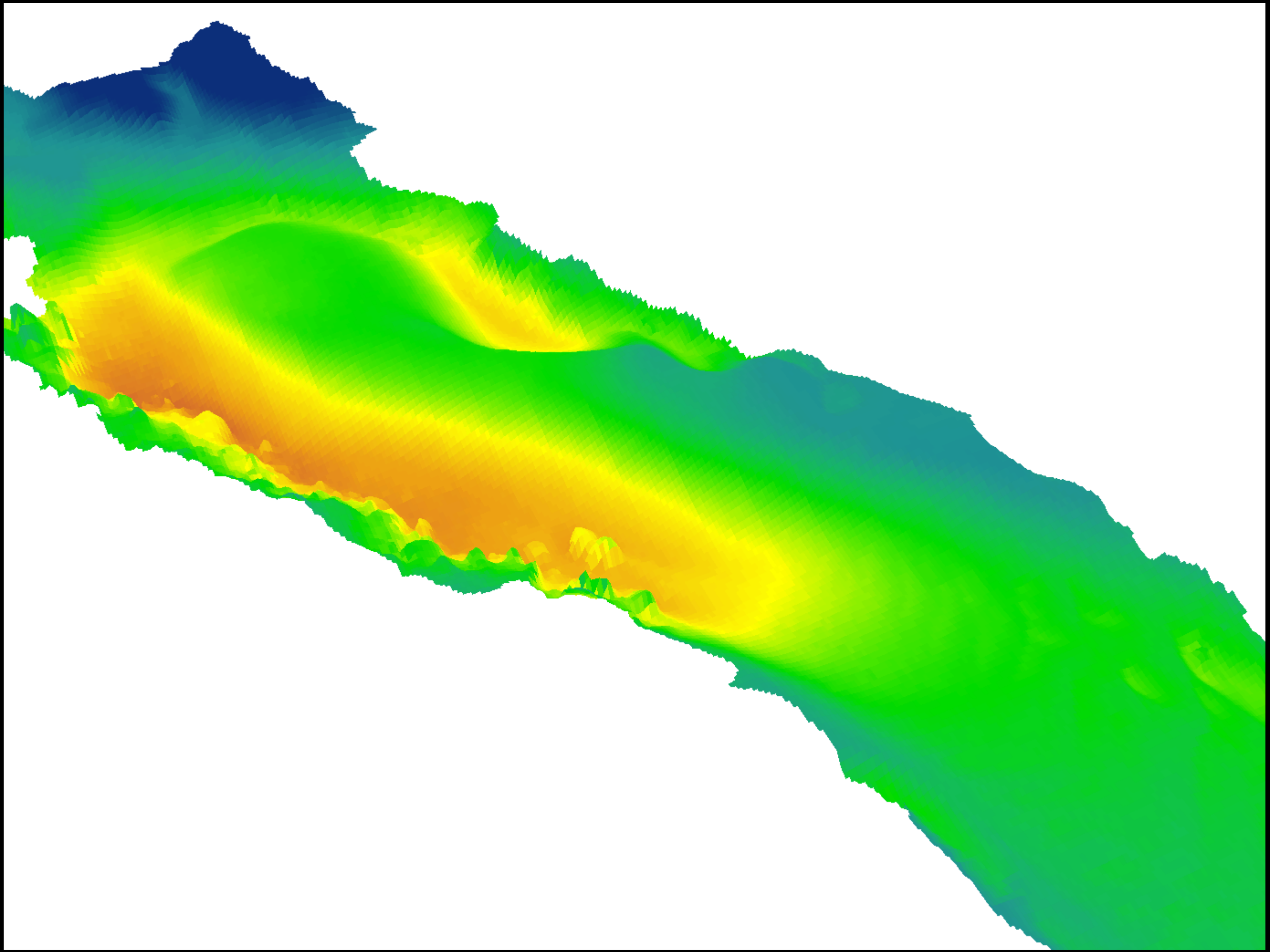
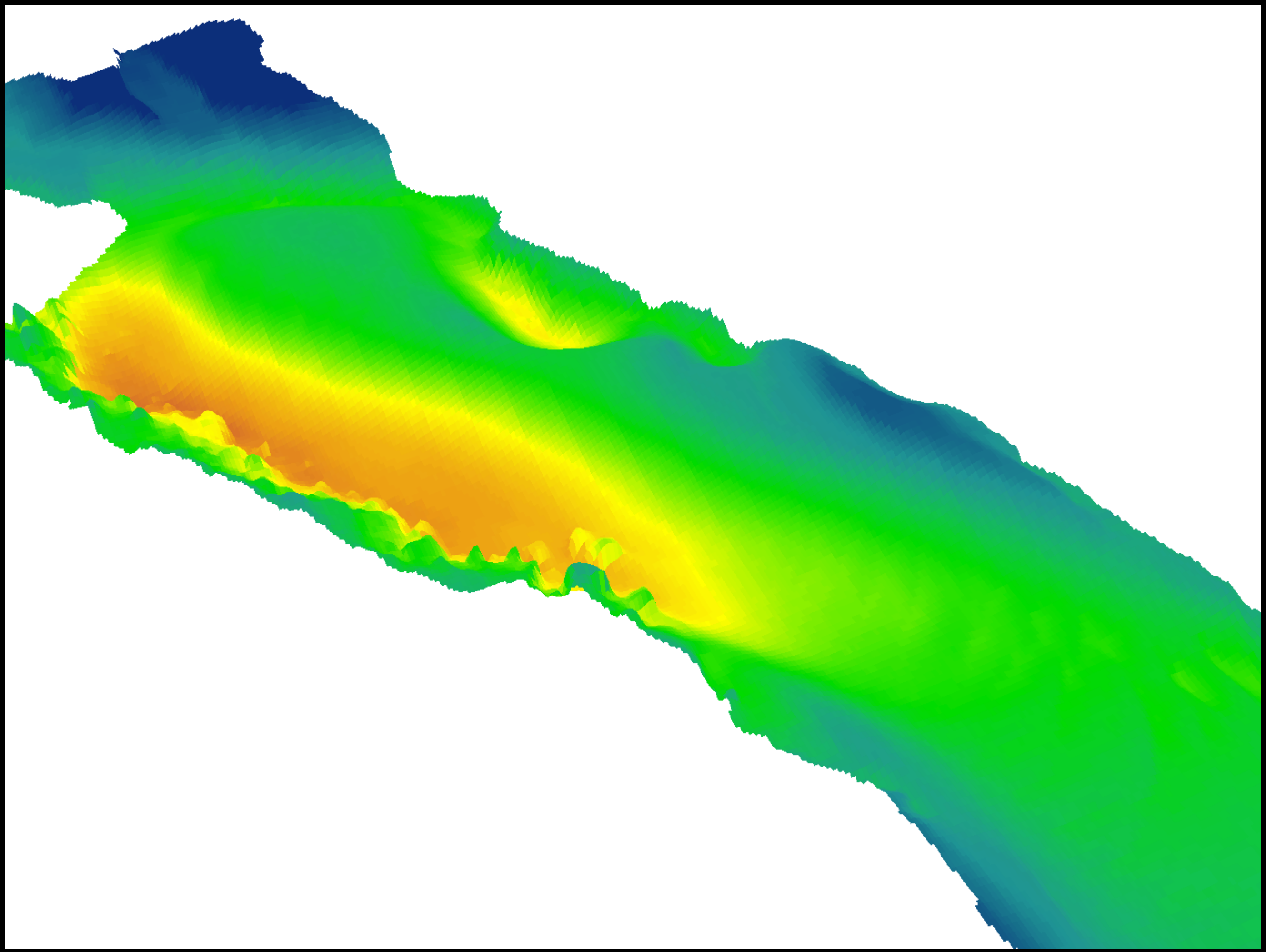
Paul Grams, unpublished data, do not cite



May 2009

Paul Grams, unpublished data, do not cite



May 2012

USGS

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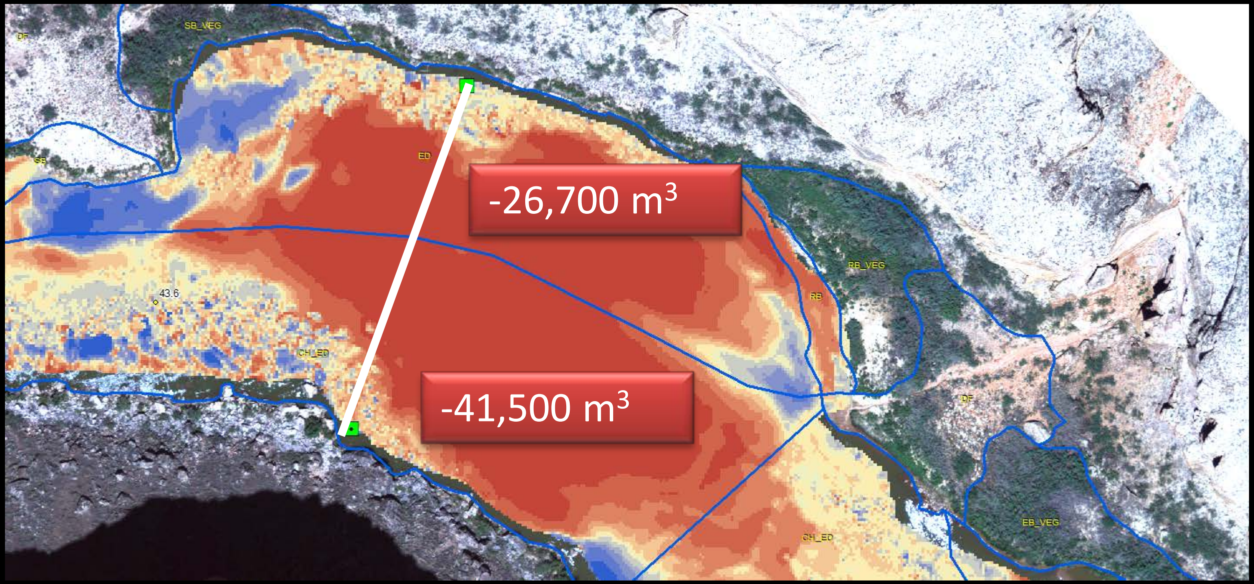
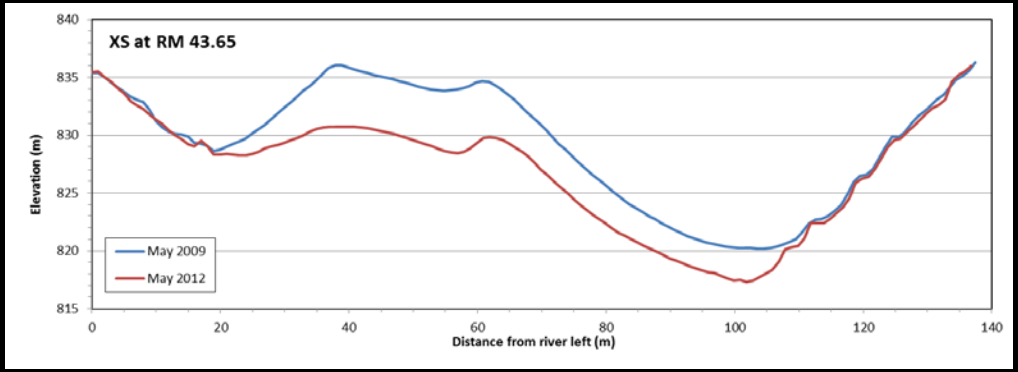


- Channel at RM 43.55: largest single change in 30-mi reach
- Eddy at RM 43.55: 3rd rank change in entire reach; largest change in eddy for entire reach



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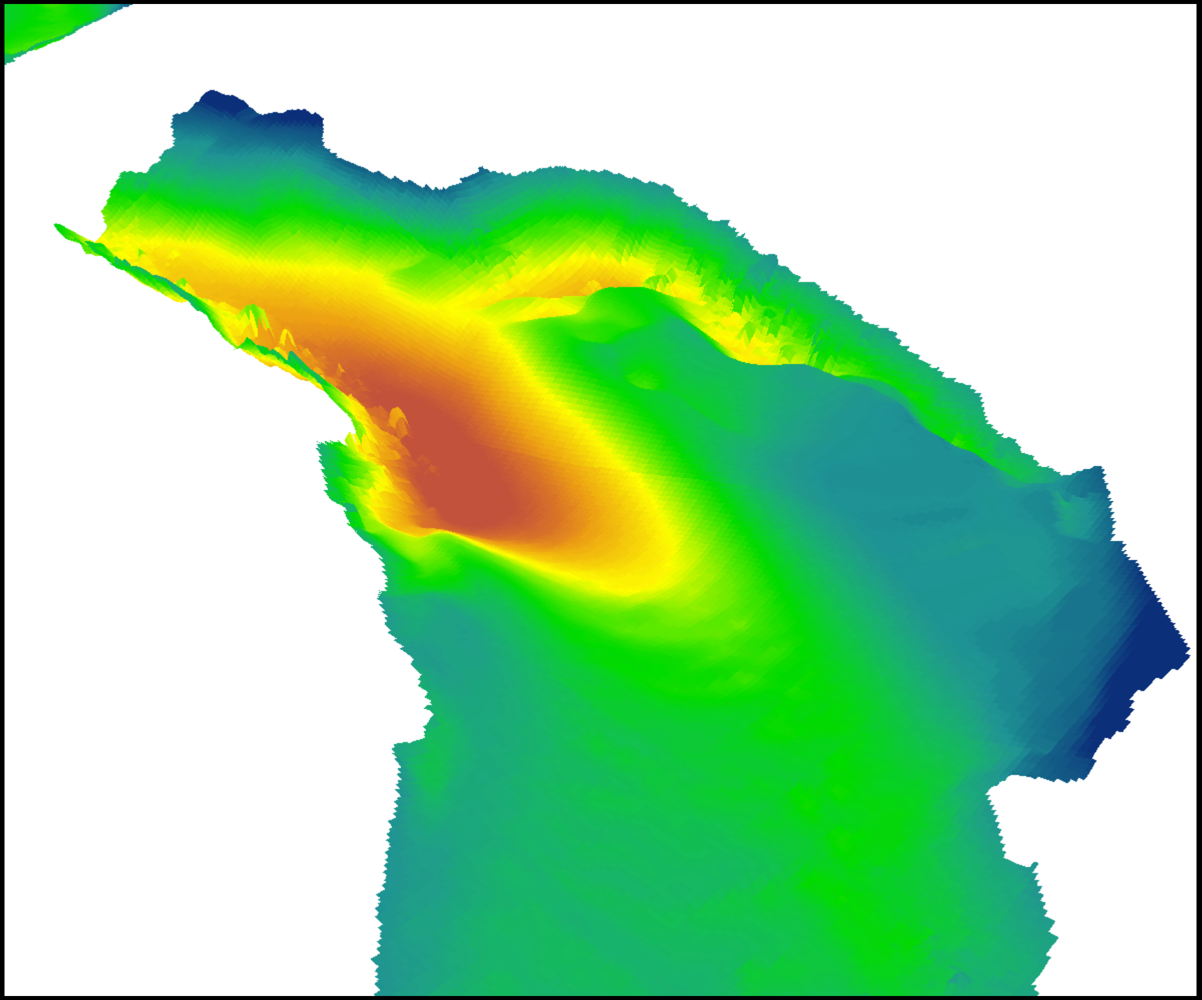

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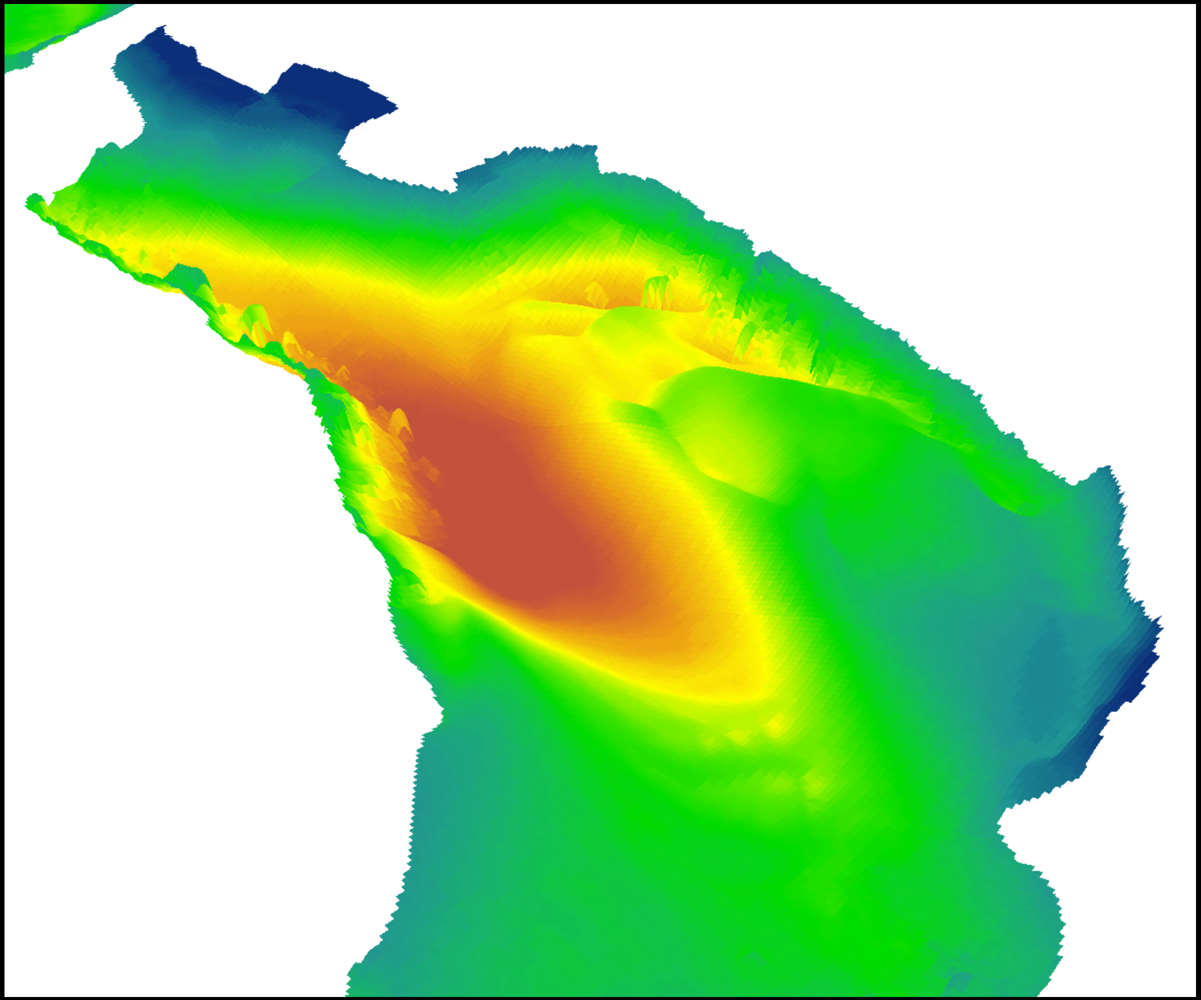

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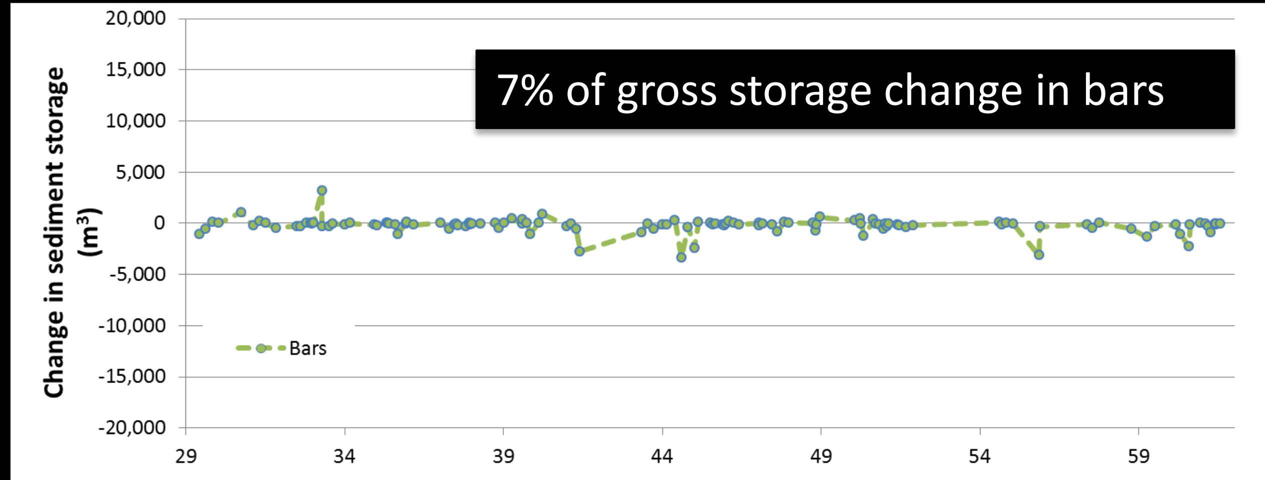

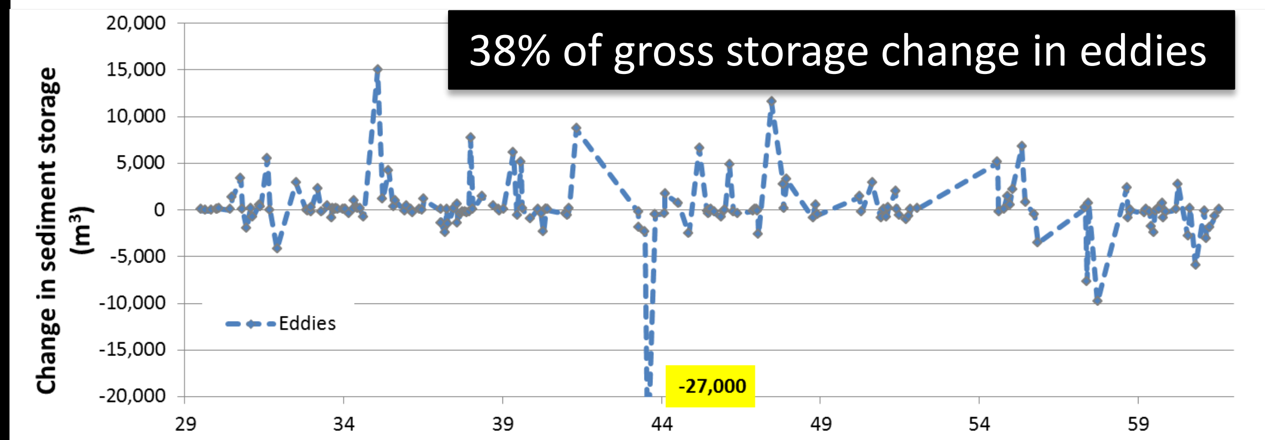

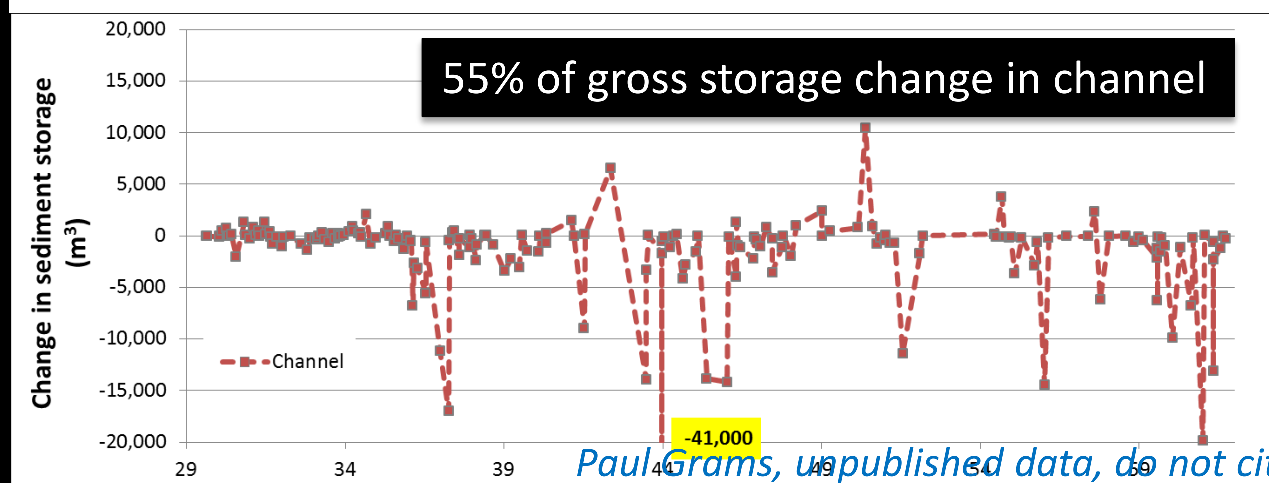

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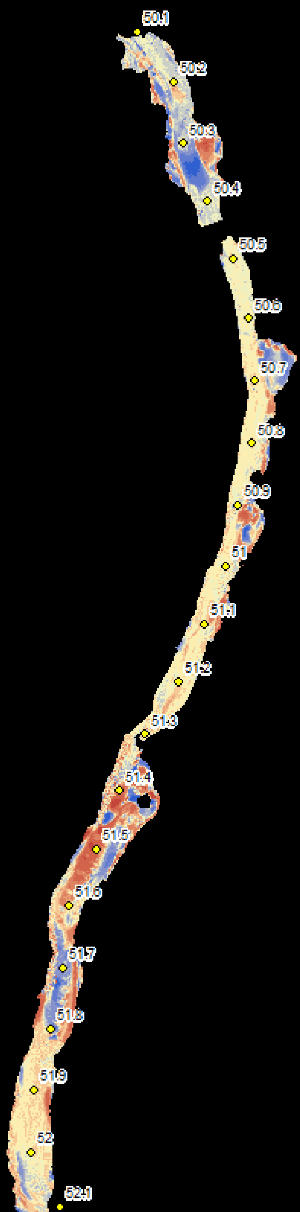

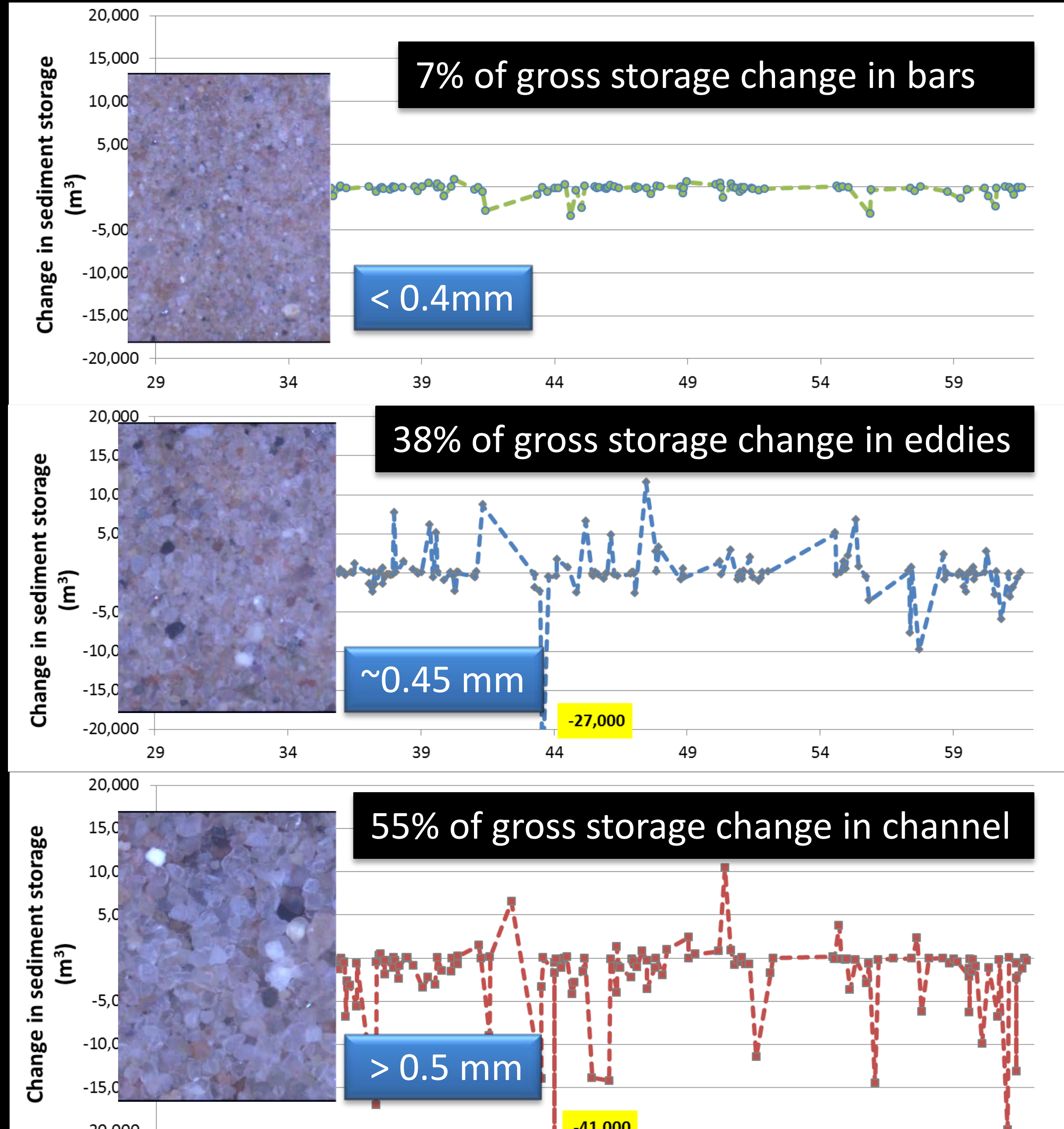

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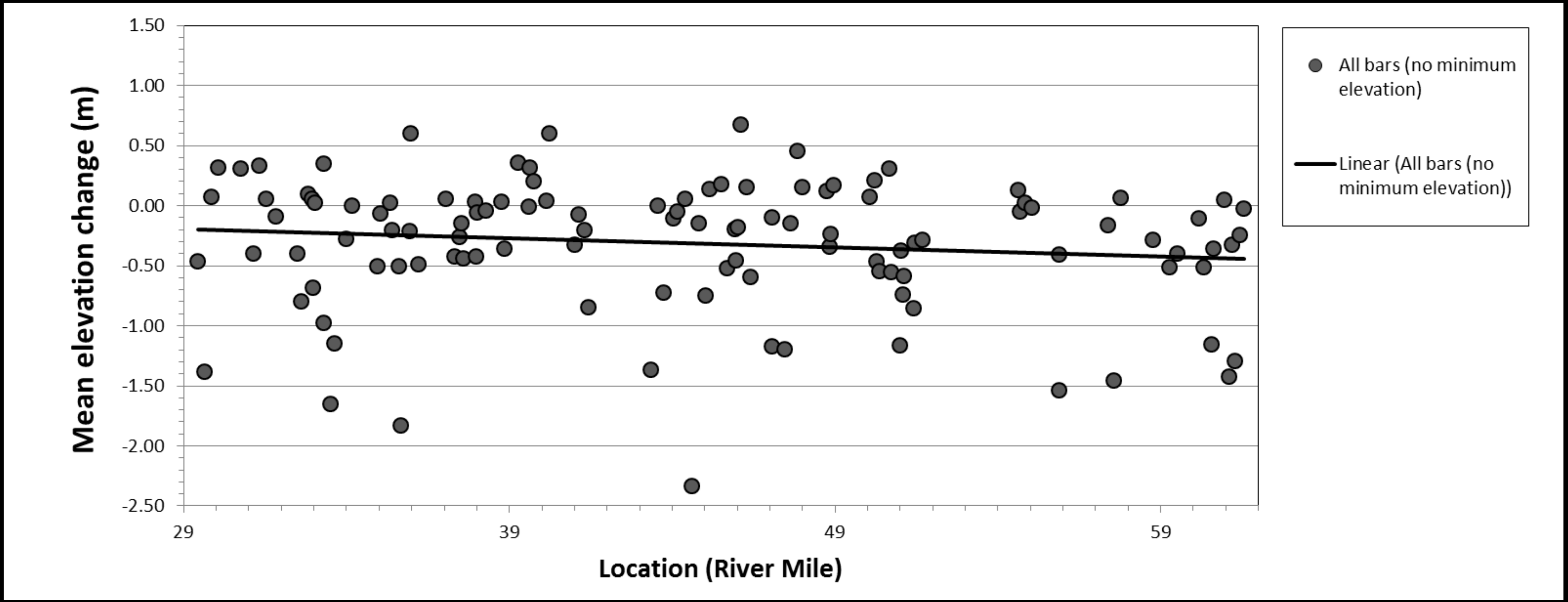
Average Sandbar Change



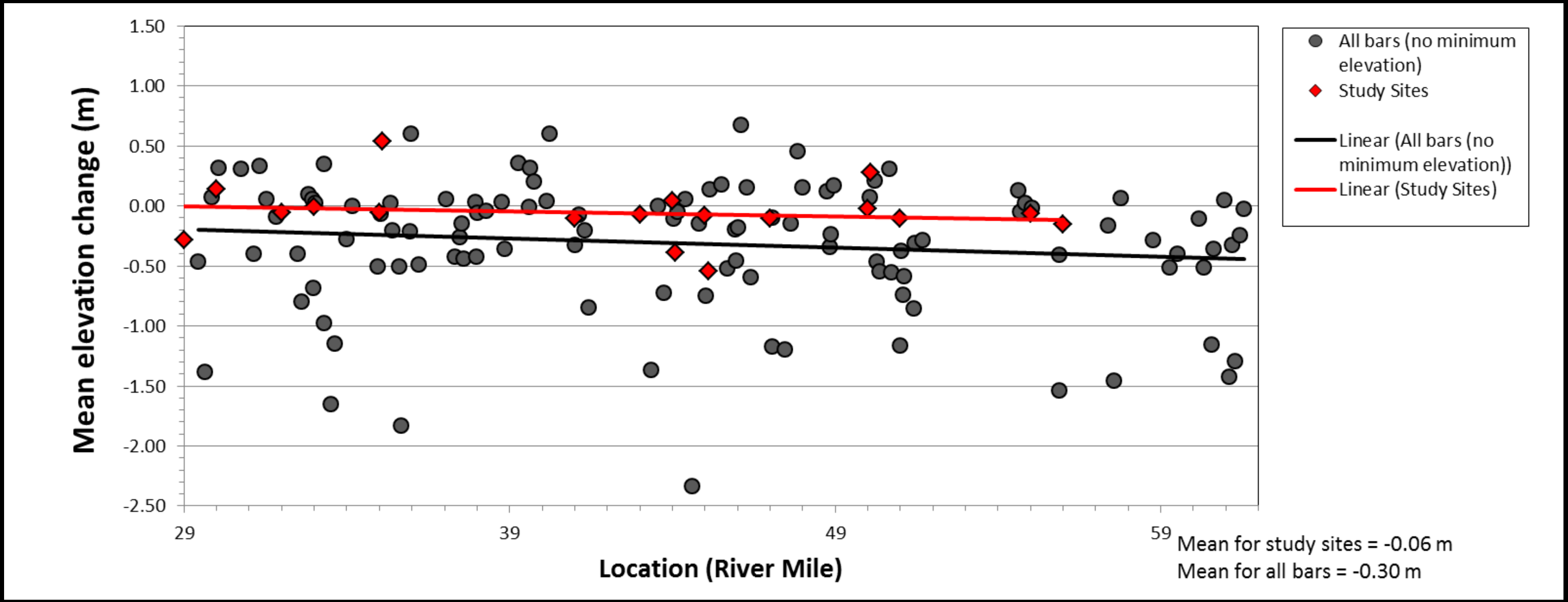
- Bars net erosional for May 2009 to May 2012 period
- Mean erosion of about 30 cm

124 Bars in 30-mi reach
18 with > 10 cm deposition
65 with > 10 cm erosion
41 with < 10 cm change

USGS

Paul Grams, unpublished data, do not cite

Comparison with Long-term Sandbar Monitoring (NAU) Sites

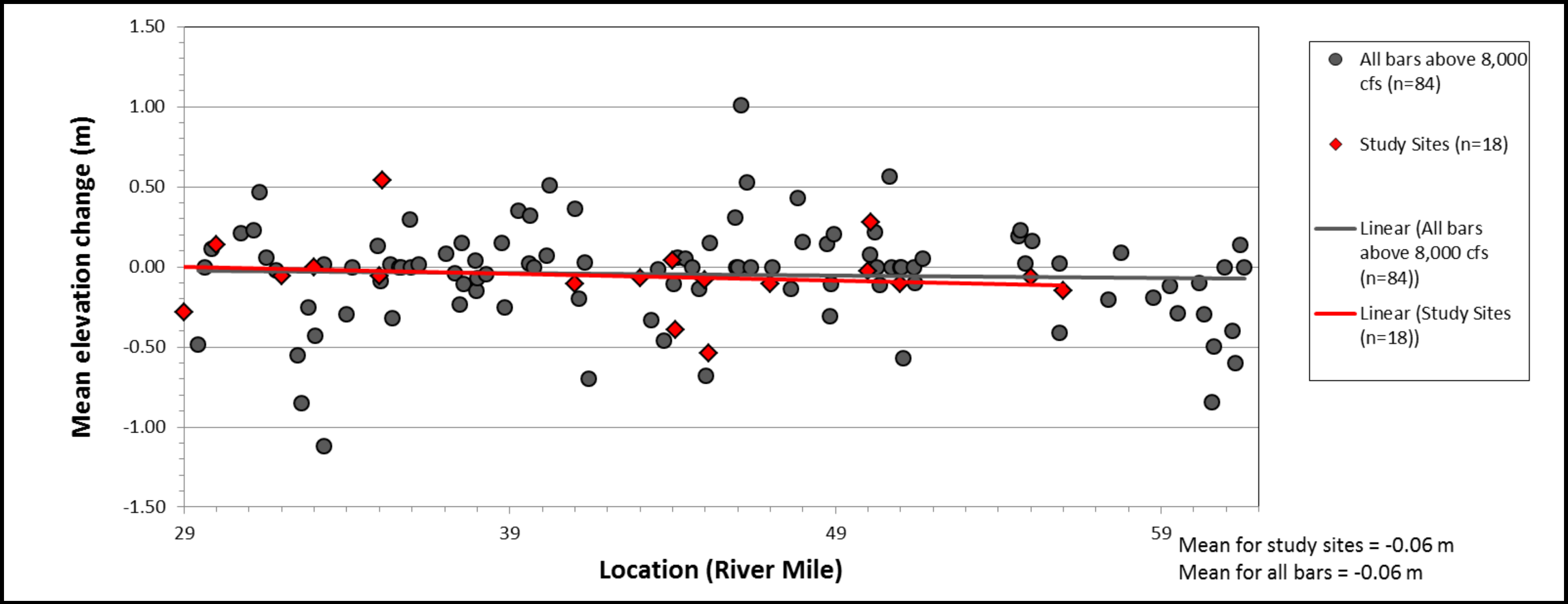


- Both sets show net erosion
- Less variability and less erosion at NAU sites
- However, the data for the NAU sites only show changes above the 8,000 cfs stage, while the channel mapping data includes erosion below that elevation

USGS

Paul Grams, unpublished data, do not cite

Comparison with Long-term Sandbar Monitoring (NAU) Sites – Only for changes above 8,000 ft^3/s stage elevation



	Mean Change	Maximum Deposition	Maximum Erosion	Standard Deviation
Monitoring Sites	-0.06 m	0.54 m	-0.54 m	0.23 m
All Bars above 8,000 ft^3/s elevation	-0.06 m	1.01 m	-1.12 m	0.35 m

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Sandbars and the sand mass balance on the Colorado River in Grand Canyon

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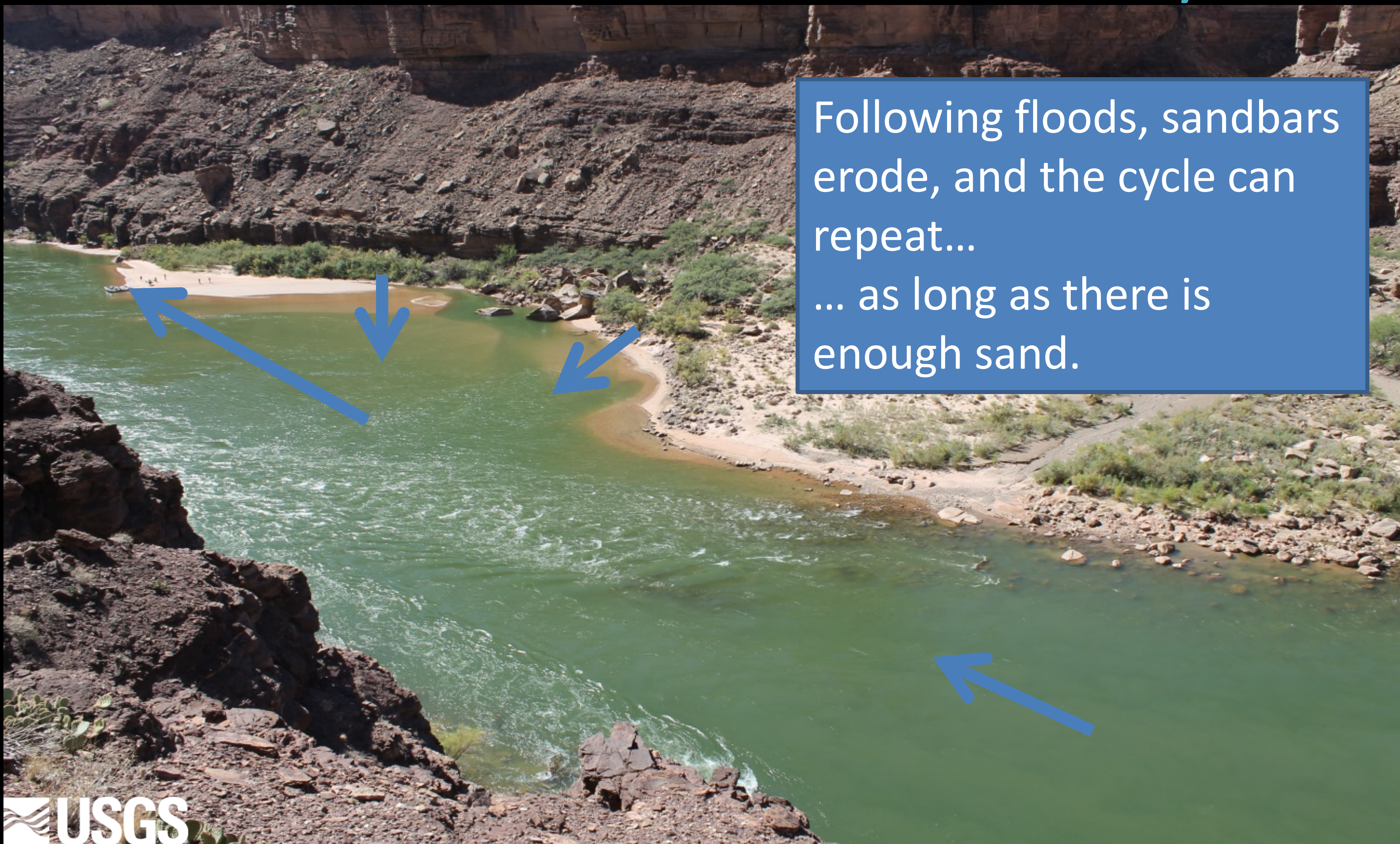

Summary

- High flows
  - Recent sediment-rich high flows (Nov. 2012 & Nov. 2013) have built sandbars on par with other high flows
- Campsites
  - Vegetation is an important cause of usable camp area change at some sites
  - Erosion causes a larger proportion of change at many sites
- Sandbar area in Marble Canyon from Air Photos
  - Sandbar area remains substantially lower than predam period
  - Sandbar area is larger in recent period than the pre-1996 period
  - Sandbar area has been approximately stable between 2002 and 2009
- Sandbars in 1984
  - Analyzed at 6 sites
  - Some sites show larger bar in 1984, some similar or smaller than present
  - Will be valuable in improving understanding of different behavior of different sites in response to floods
- Channel Mapping: implications for sand storage and sandbar monitoring
  - Bars, eddies, and channel do not have same trend for period
    - Bars (negative storage change)
    - Eddies (slightly positive storage change)
    - Channel (negative storage change)
- Change in bars measured by channel mapping (84 exposed bars) agrees with change measured by long-term sandbar monitoring (18 bars) for same reach
    - BUT: Those changes are less than 7% of the changes in the reach

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Paul Grams, unpublished data, do not cite

Summary

- Periods with relatively low releases, ample Paria river sand inputs, and sediment-rich high flows (most of 2002-2013):
    - may have approximately stable sand budgets
    - and sandbars may be stable (air photo analysis of many bars), or increase in size (long-term monitoring of relatively few sites)
- Periods with above average releases (e.g. 2011 equalization flows)
    - cause net scour from the channel and a decrease in sandbar size