Sandbars and Sand Storage in Marble and Grand Canyons

Paul Grams (pgrams@usgs.gov): U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona


AND

Dan Hadley, Dan Hamill, Joe Hazel, Matt Kaplinski, and Rob Weber: Northern Arizona University, School of Earth Sciences and Environmental Sustainability, Flagstaff, Arizona

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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
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Bob Tusso, unpublished data, do not cite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

Joe Hazel, unpublished data, do not cite
Sandbars 10 months following 2012 high flow

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- 5 of 7 sites larger than Oct. 2011
- 3 of 7 sites larger than Oct. 2008

**Lower Marble Canyon (RM 30-62)**
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- 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

Joe Hazel, unpublished data, do not cite
Sandbars 10 months following 2012 high flow

- Sediment enriched HFEs and relatively low release volumes
- $\rightarrow$ relatively large bars 10 months following HFE

Joe Hazel, unpublished data, do not cite
**Sandbars and Sand Budget: 2011 – 2013**

**Segment**
- Upper Marble Canyon (RM 0-29)
- Lower Marble Canyon (RM 30-62)
- Eastern Grand Canyon (RM 62-87)
- Grand Canyon (RM 88-225)

**Sand Budget**
- Sand Budget trending positive
- Sand Budget trending negative
- Sand Budget trending neutral

**Sandbar Condition**
- 5 of 7 sites larger in 2013 than 2011
- 1 of 7 sites larger in 2013 than 2008 post-HFE
- 11 of 16 sites larger in 2013 than 2011
- 4 of 16 sites larger in 2013 than 2008 post-HFE
- 1 of 3 sites larger in 2013 than 2011
- 2 of 3 sites larger in 2013 than 2008 post-HFE
- 10 of 16 sites larger in 2013 than 2011
- 8 of 16 sites larger in 2013 than 2008 post-HFE

*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

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

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

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

Rob Ross, unpublished data, do not cite
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

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HFE’s and vegetation expansion has resulted in a large, stabilized bar

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HFE’s and vegetation expansion has resulted in a large, stabilized bar

- 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?
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???
Repeat Measurements of Channel Topography with multibeam Sonar

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

View is looking upstream
Black dots are 0.1 mi intervals
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)

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

Paul Grams, unpublished data, do not cite
Deposition in eddy at 35.07 (Nautiloid): 2nd ranked eddy change

+15,000 m³

Paul Grams, unpublished data, do not cite
May 2012

Paul Grams, unpublished data, do not cite
• 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

Paul Grams, unpublished data, do not cite
May 2012

Paul Grams, unpublished data, do not cite
38% of gross storage change in eddies

55% of gross storage change in channel

7% of gross storage change in bars

Paul Grams, unpublished data, do not cite
7% of gross storage change in bars

< 0.4 mm

38% of gross storage change in eddies

~0.45 mm

55% of gross storage change in channel

> 0.5 mm

Paul Grams, unpublished data, do not cite
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

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

Paul Grams, unpublished data, do not cite
Comparison with Long-term Sandbar Monitoring (NAU) Sites – Only for changes above 8,000 ft³/s stage elevation

<table>
<thead>
<tr>
<th></th>
<th>Mean Change</th>
<th>Maximum Deposition</th>
<th>Maximum Erosion</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring Sites</td>
<td>-0.06 m</td>
<td>0.54 m</td>
<td>-0.54 m</td>
<td>0.23 m</td>
</tr>
<tr>
<td>All Bars above 8,000 ft³/s elevation</td>
<td>-0.06 m</td>
<td>1.01 m</td>
<td>-1.12 m</td>
<td>0.35 m</td>
</tr>
</tbody>
</table>

Paul Grams, unpublished data, do not cite
Sandbars and the sand mass balance on the Colorado River in Grand Canyon

Sand accumulates on the bed and in eddies during low flows.
Sandbars and the sand mass balance on the Colorado River in Grand Canyon

Flooding build sandbars and export sand downstream
Following floods, sandbars erode, and the cycle can repeat... ...as long as there is enough sand.

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

*Paul Grams, unpublished data, do not cite*