Effects of High Flow Events on sandbars along the Colorado River, Grand Canyon

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Introduction

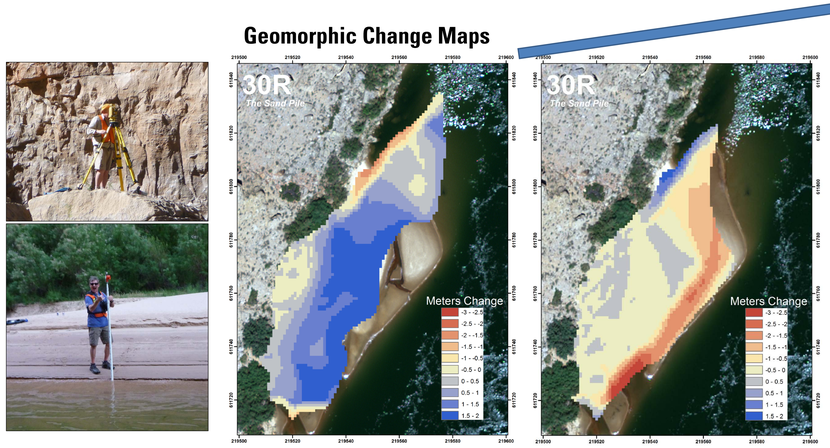
High Flow Events (HFEs) along the Colorado River downstream from Glen Canyon Dam redistribute fine sediment and re-organize local channel morphology, primarily through bar building and bed scour. Newly aggraded bars are inherently unstable, however, and normal dam operations erode the margins of bars. Thus, HFEs do not permanently aggrade bars, but do increase the long-term average volume of bars. Here we present results from remote camera repeat photography, ground-based sandbar surveys, and sandbar sedimentology and stratigraphy to illustrate sandbar response to HFEs, focusing on the recent 2012 and 2013 HFEs. Our results show that the majority of sandbars increase in size and volume in response to HFEs, although there is considerable spatial variability as some bars are more or less dynamic than others. Sandbar stratigraphy in Marble Canyon following the 2012 HFE shows inverse grading (coarsening upward), mimicking the observations at the 30-mile suspended sediment monitoring gage which shows sediment coarsening during the flood event. These observations suggest that sand supply becomes more limited over the course of an HFE, as found in previous studies. Overall these results demonstrate that HFEs build eddy sandbars. Yet, the degree to which these features persist depends on the frequency of HFEs, and careful consideration of sediment supply is necessary to avoid increasing the long-term sediment deficit.

Terrestrial Surveys

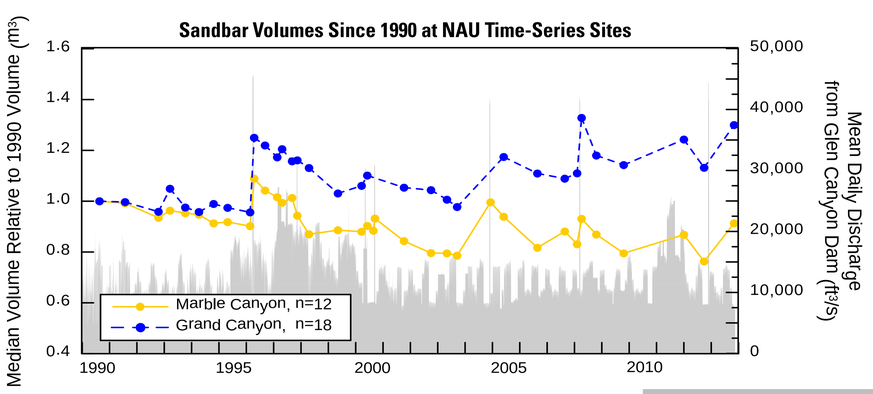
Long-term ground-based surveys of sandbar volume and area have been made since 1990 at 30 sites, with more than 40 sites currently being monitored. These terrestrial surveys are the best long-term data to quantify sandbar response to HFEs. These sandbar data focus on high elevation deposits above the 8,000 cubic feet per second stage associated with typical minimum flows; this flow stage is also roughly equal to the pre-dam median discharge of the Colorado River at Lee's Ferry.

At each long-term monitoring site, 3-dimensional digital elevation models (DEMs) are created by interpolating the survey data to a 1-m grid. Changes in sandbar volume or area can then be calculated between any two surveys in order to quantify geomorphic change at each site. These data can then be used to document the effects of HFEs at individual sites, as in the change plots for 30-mile below, or to document trends in sandbar volume for the period of record, as in the time-series plot at bottom.

Geomorphic Change Maps



Oct. to Dec. 2012 Change *Dec. 2012 to Sep. 2013 Change*



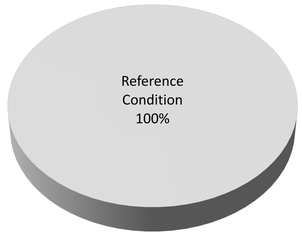
Photographic Evaluation

GCMRC maintains a network of remote digital cameras, each taking 5 daily photos at 46 different sandbars along the river. These photos can be assigned values to represent erosion or deposition. Comparing canyon-wide photosets from different time periods provides a quick and inexpensive way to evaluate the effects of different flow patters and events, such as HFE's and tributary floods.

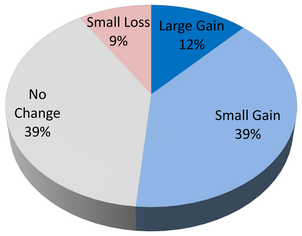
The Sand Pile (Mile 30.7)

All Sites with Cameras

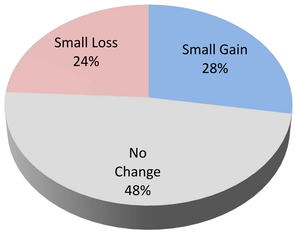
Before 2012 HFE



Immediately After 2012 HFE



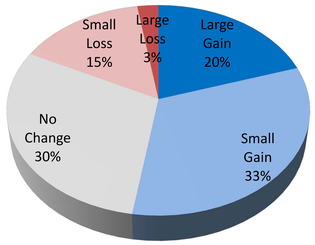
5 Months After 2012 HFE



2013 HFE Early Data

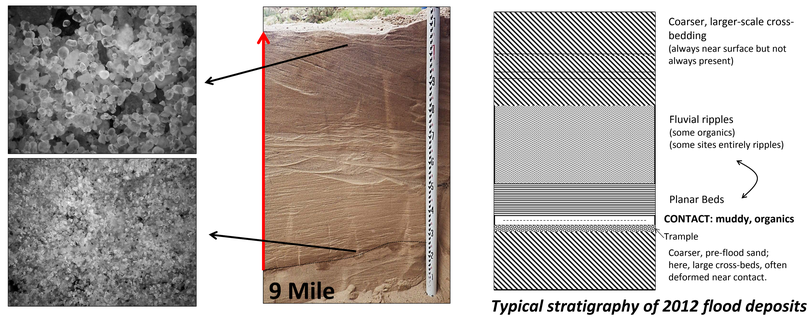
(Photos from Carbon Creek, RM 65.1)

Like the 2012 HFE, over 50% of the sandbars aggraded, and less than 20% degraded.



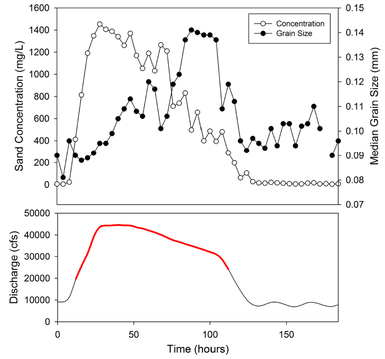
Sandbar Stratigraphy

Sandbar stratigraphy and sedimentology provides a direct linkage between changes in sandbar elevation and the sediment supply regime and flow hydraulics under which sandbars were formed. The data below show results from 10 sandbar excavations in Upper Marble Canyon following the 2012 HFE.

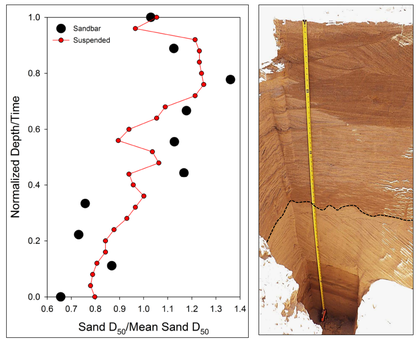


Typical stratigraphy of 2012 flood deposits

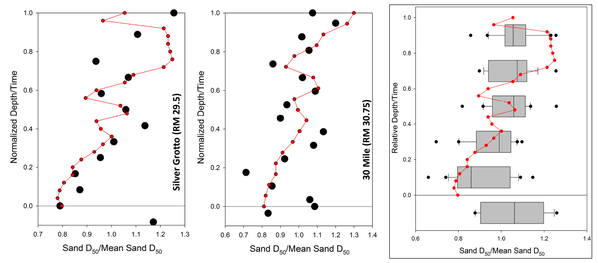
Time series of sand concentration and grain size
30 Mile gage (09383050)



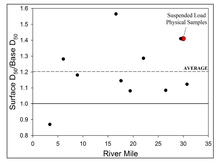
22 Mile Bar: grain size evolution strongly matches suspended load



Sites near the 30-mile gage show particularly good agreement with measured suspended load grain size.



All Sites



Top of sandbar deposit averages 1.2 times the grain size of the base of the deposit.

Sandbar surface is similar in size to pre-flood sand.

Conclusions

- **Terrestrial surveys show that sandbars in Marble and Grand Canyons appear to be increasing in volume, or staying relatively stable, since the 2004 HFE.**
- **The sandbar time-series indicates that 10 months after the 2012 HFE, sandbars were still at their largest since immediately following the 2008 HFE.**
- **Remote camera data show that the 2012 and 2013 HFEs were effective at building sandbars**
- **Sandbars show inverse grading, in general, consistent with sediment supply limitation; grain size at the top of the flood deposit averages 1.2 times that at the base.**
- **Sediment size in sandbars near sediment monitoring sites show very good correlation with changes in suspended load grain size.**
- **Together, these data suggest that sandbar volumes can be maintained in a sediment-limited river system, and that sandbar volumes are typically greatest immediately after HFEs.**

Acknowledgements

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Provisional Data – do not cite