Monitoring the Effects of the 1997 Glen Canyon Dam Test Flow on Colorado River Ecosystem Sand Bars

Sand Bar Studies Fact Sheet
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Controlled floods of appropriate stage and duration have important potential for resource management of the Colorado River ecosystem in Grand Canyon National Park. High releases are intended to scour sand on the channel bottom and redistribute it to the sandy banks and bars along the channel margin. New and existing deposits are valued components of the riverine ecosystem. They provide habitat for native and non-native fish, the substrate for riparian vegetation, erosion-protection for archeological sites, and are used for camping by river runners. The first opportunity to study physical processes during controlled flooding of the Colorado River ecosystem occurred in spring 1996, with the release of a seven day, flood of 1,274 m^3/s (45,000 ft^3/s) from Glen Canyon Dam (Webb et al., 1999). The 1996 flood was considered a short-term success but physical process studies demonstrated the importance of decreasing river sand concentrations on transport and deposition of sediment (Rubin et al., 1998; Schmidt, 1999). The possibility that a shorter duration and lower magnitude release than the 1996 flood (i.e., a non-spill release) could achieve some level of sediment conservation was of interest to the Glen Canyon Dam adaptive management program. Following significant sediment inputs from the Paria River in late summer 1997, and before the sediment was lost downstream to Lake Mead, a test flow was released to transfer some of this sediment to channel margin sand bars. Termed the 1997 Test Flow, the release started on November 3, and consisted of a constant flow of 878 m^3/s (31,000 ft^3/s) for 48 hours.

The 1997 Paria River Floods

Most of the sand supplied to the Colorado River ecosystem comes from the Paria River, about 25 km below Glen Canyon Dam, and the Little Colorado River, about 125 km below the dam (Fig. 1). In August-September 1997, the Paria River produced four large floods that delivered approximately 2.0 ± 0.4 million Mg of sand and 2.4 ± 1.2 million Mg) of silt and clay to the Colorado River (Fig. 2a) (Topping et al., 2000). This sediment input was nearly twice the mean-annual input from this tributary and ranked among the top 20% during the 75 years of gage record on the Paria River (Topping et al., 2000). The Little Colorado River was also active during this period.

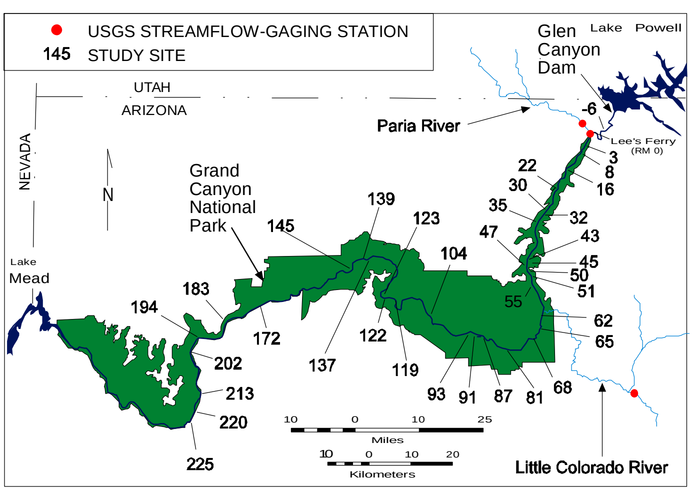

Figure 1. Location of study area, major sand supplying tributaries, USGS streamflow-gaging stations, and sand bar monitoring sites.

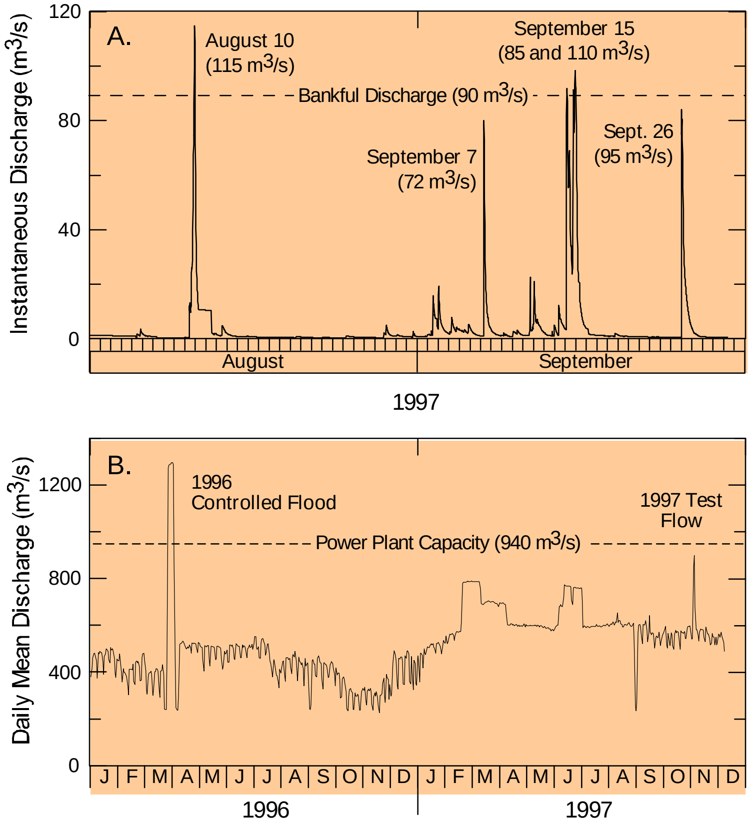

Figure 2. Discharge hydrographs. A, Instantaneous discharge at USGS streamflow gaging station Paria River at Lees Ferry, Arizona, August and September 1997. B, Daily mean discharge at the USGS streamflow-gaging station, Colorado River above Little Colorado River near Desert View, Arizona, January 1996 to December 1997.

High Elevation Sand Bars Were Monitored at 35 Long-Term Monitoring Sites

Thirty-five long-term study sites are located throughout the Colorado River ecosystem (Fig. 1). Each site contains one or more sand bars. Ground points were collected with electronic total stations and topographic surface models created using the triangulated irregular network method of contouring with surface modeling software [study site locations, descriptions, and methods are provided by Kaplinski et al. (1995) and Hazel et al. (1999)]. For each site, the volume and thickness of sand stored at high elevation within the bar was calculated and then compared to previous surveys to determine site specific changes. These values are then averaged or summed to assess reach-scale effects. We define the high elevation sand bar as bedforms deposited in eddies occurring above the 566 m^3/s (20,000 ft^3/s) stage elevation. Above this topographic level sand bars are considered campsites because the campable area is greatest and more substrate is available for riparian vegetation, marsh and wetlands. Areas below this level are regularly inundated and reworked by dam releases and typically are not available for camping or colonization by plants.

Response of High Elevation Sand Bars to the 1997 Test Flow

We examined the net high elevation change in sand thickness at the sites by producing a time series from data collected since 1996 (Fig. 3). We divided the sample population into those in Marble Canyon, upstream from the Little Colorado River, and those in Grand Canyon, downstream from the Little Colorado River. The time series demonstrate that sand was successfully redistributed to high elevation by the 1996 Controlled Flood. During the interval between the 1996 flood and the 1997 Test Flow, readjustment of the newly aggraded bars to lower, sustained high flows led to rapid but declining rates of erosion (Fig. 2b). The 1997 Test Flow did not result in aggradation great enough to compensate for the erosion that had occurred between April 1996 and November 1997. Net high-elevation bar thickness did not increase at the sites because deposition of sand on the inundated part of the bar was offset by erosion of high-elevation parts of the preexisting deposits (Hazel et al., 2000; Kaplinski et al., 2000). In general, erosion resulted from cutbanks that retreated horizontally as much as 5 m. The base of the cutbanks developed at the stage elevation reached by the 878 m^3/s flow.

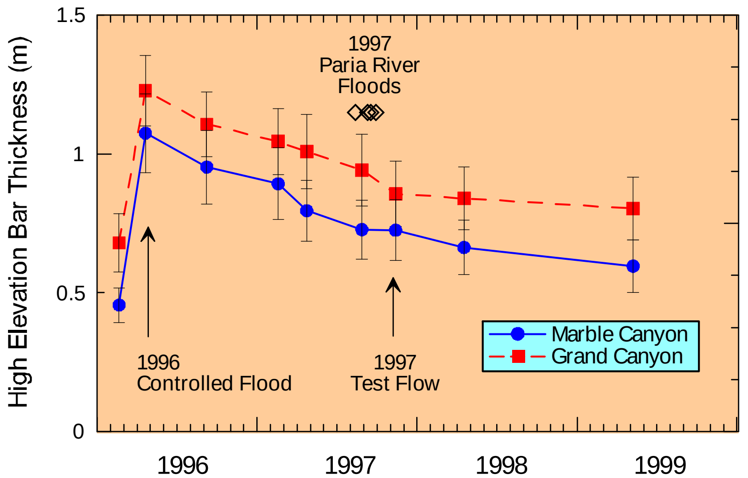

Figure 3. Average high elevation sand thickness changes in Marble and Grand Canyons versus time. Diamond symbols indicate dates of the 1997 Paria River floods. Error bars are standard error about the mean.

The Stage Change of Controlled Floods is Important for Net Bar Deposition

The 1997 Test Flow did not completely inundate the sand bars. As a result, the stage change was not high enough to redistribute sand to areas where depositional sites were open. However, the high elevation erosion trend shown in the time series in 1996 and 1997, suggests that potential depositional area was open (Fig. 3). Hazel et al. (1999) showed that the stage elevations reached during the 1996 Controlled Flood inundated areas where space was available for deposition, termed "accommodation space," and differences in depositional thickness were directly correlated with the magnitude of stage change. The stage change during the 1997 Test Flow was roughly half that of the 1996 flood at the sites (Fig. 4). Sand bar thickness change was positively correlated to the magnitude of stage change (r2=0.59, significant at the 95% confidence level) during the 1996 flood, whereas there was no significant correlation as a result of the 1997 Test Flow. We could not determine the relative importance of flood duration to net deposition. However, suspended- and bed-sediment measurments at USGS stream flow gaging stations indicate that the 1997 Test Flow depleted the supply of finer sand throughout the Colorado River ecosystem (Topping et al., 2000). The sand export rate from Marble Canyon was twice that observed during the 1996 flood. This suggests that sand supplied by the Paria River in 1997 was not effectively redistributed to the

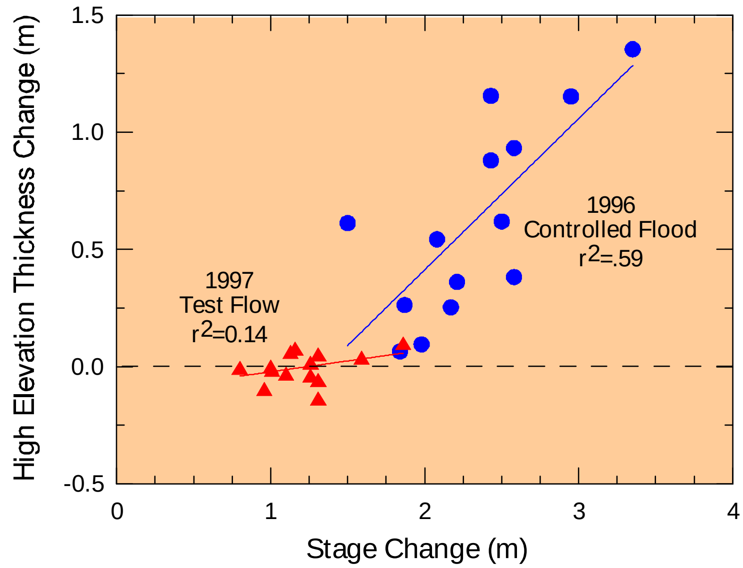

Figure 5. The relation between stage change and high-elevation thickness change in Marble Canyon. The stage change is based on the elevation difference from 566 to 878 m^3/s (1997 Test Flow) and from 566 to 1,274 m^3/s (1996 Controlled Flood) at each study site.

channel margin by the 1997 Test Flow and the residence time of this new sediment in Marble and Grand Canyons was not prolonged.

The results of this study suggest that in order to conserve tributary-supplied sediment in the Colorado River ecosystem, a greater stage increase is required to access high elevation areas available for deposition. Even the largest floods on the Paria River do not raise mainstem discharge high enough and for sufficient duration to result in deposition above stage levels reached by normal dam releases. Timing controlled high releases to coincide with or shortly follow the summer and fall sediment input season may improve the likelihood that finer sediments will be effectively conserved, especially within upstream reaches closest to the

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