Long Term Monitoring of Camping Beaches in Grand Canyon: A Summary of Results from 1996 – 2002

Annual Report of Repeat Photography
By Grand Canyon River Guides, Inc.[1]
(Adopt-A-Beach Program)

by
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Administrative report submitted to the Grand Canyon Monitoring and Research Center by the Grand Canyon River Guides Adopt-A-Beach program

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INTRODUCTION

Adopt-a-Beach (AAB) is a program of repeat photography that monitors the condition of camping beaches from year to year. This program is conducted through volunteer efforts and implemented by Grand Canyon River Guides, Inc. (GCRG), a nonprofit, grassroots organization that represents the interests of the Grand Canyon river running community. River guides (including commercial, private, and scientific groups), who work throughout the summer months on the Colorado River, are interested in how controlled-flow releases from Glen Canyon Dam affect beaches that are used for campsites. Furthermore, factors other than controlled flows that might be affecting campsite change are addressed in this study. Throughout the continued period of this program, 1996-2002, guides have observed changes to beaches, have recorded this information through repeat photography and written comments associated with each photograph.

In 1981, the Glen Canyon Environmental Studies (GCES) began under the administration of the Bureau of Reclamation to study the effects of controlled flow releases from the dam on the downstream river ecosystem (U.S. Department of Interior 1987), including effects on sediment supply and recreational resources. Studies of sediment dynamics showed that fluctuating flow releases from the dam have had a degrading effect on sand bar deposits (Hazel and others 1993, Schmidt and Graf 1990) since the closure of the dam. However, beaches can also be replenished by high flows adequate to entrain bedload sand and cause deposition to high elevation areas of beaches (Parnell and others 1997, Wiele and others 1999). Studies of campsite resources demonstrated that impact to sand bars due to erosion decreases the carrying capacity and campable area available for river parties and backpackers (Kearsley and Warren 1993, Kearsley and Quartaroli 1997).

In 1992, the Grand Canyon Protection Act was passed by Congress to ensure that ecological and cultural resources downstream of the dam would be monitored for changing conditions imposed by operations of the dam. The October, 1996 Record of Decision for operation of the dam states that the dam:

> "....must be managed in such a way as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park....were established, including, but not limited to, natural and cultural resources and visitor use" (U.S. Department of Interior 1996).

The Grand Canyon Dam Environmental Impact Statement recommends that scheduled, high-flow releases of short duration be periodically implemented (U.S. Department of Interior 1995). Sand bars form when sediment carried by the river, either from bed load or suspended load, is deposited by the action of eddy currents in recirculation zones. This occurs primarily on the downstream end of debris fans, but also in areas along the river's channel margin (Schmidt 1990). Habitat maintenance flows (HMF) are within powerplant capacity (31,500 cfs), whereas those above this discharge are beach/habitat building flows (BHBF). The former were intended to maintain existing camping beaches and wildlife habitat; the latter to more extensively modify and create sand bars, thus restoring some of the dynamics that resulted from flooding in the ecosystem.

Inception of Adopt-a-Beach was a result of the first scheduled BHBF of 45,000 cfs scheduled for spring 1996. Specifically, the AAB program was launched by GCRG to document the effects of the high flow on camping beaches. Guides photographed beaches and recorded information about changing conditions prior to the high flow, just after the high flow, and throughout the 1996 commercial river season. The overall conclusion of that study demonstrated that the BHBF was highly effective in depositing new high-elevation sand, but that the post-BHBF high steady summer flow schedules caused rampant erosion of sand bars (Thompson and others 1997).

Camping beaches are an important resource for river guides conducting trips through Grand Canyon. Both commercial and private river trips, as well as backpackers, rely on wide sandy areas for camping and recreating. As a way to contribute to resource management, AAB now submits annual results to the Adaptive Management Program. The results and conclusions are synthesized through a representative that serves on Technical Work Group (TWG) board. River guides make the program possible, contributing 100% of the manpower, the entire data set of repeat photographs, and valuable input about the condition of beaches throughout each season and between years. Monitoring includes information on natural and human-induced impacts to beaches such as cutbank retreat, wind erosion and dune formation, rain gully formation and the effects of visitation and camping. The purpose of this report is to present the cumulative findings of data specific to this program up through the commercial boating season of 2002. Furthermore we summarize documented observations by professional river guides.

The river season of 2002 was subjected to medium and low fluctuating flows with no habitat maintenance flows or other test flows. Therefore, specific research questions imposed this year only target the longevity of deposits from previous high flows. These questions are as follows:

- How long do small spike flow deposits help maintain beaches and campable area?
- How does the quality of camping compare during Low Steady Summer Flows (LSSFs) to that during medium fluctuating flows?
- What are the main processes causing decreased beach size throughout the summer?
- Is the 1996 flood deposit of 45,000 cfs still present and how has it changed on beaches over time?
- Based on these results, what does the AAB program conclude about future resource management of campsite beaches?

Through analysis of photos and data sheets completed by guides, this report attempts to answer these and other research questions.

METHODS

Data Collection

The primary method of assessing camping beaches in this study is through analysis of repeat photography. During the summer months (April 1-October 31) volunteers (river guides, scientists, GCNP personnel) photograph a specific "adopted" beach every time they pass through the river corridor. Disposable waterproof cameras and data sheets, provided by GCRG, are distributed to all adopters of beaches. At the end of the commercial season (October), guides mail cameras and data sheets back to GCRG for analysis. A qualified scientist, who is active in Grand Canyon issues and is very familiar with AAB study sites, is contracted from year to year to analyze photographs and data, draw up results and offer conclusions to resource managers concerned with recreational and cultural interests in Grand Canyon.

This project allows each participant to take stewardship of a site, and enables him or her to detect ongoing changes over the course of a season. During each visit, guides photograph their adopted beach from pre-established photo locations that provide different views of the beach: specifically, the beachfront and an overview of the camp. In sites where overviews are impossible, a photo location is selected to reveal as much of the camp as possible. In the last 6 years, however, thick tamarisk encroachment has led to recent re-establishment of many photo locations. Re-establishment of photo locations will be ongoing as needed, in order to obtain the necessary photo angles.

A data sheet (Appendix A) accompanying each photographed visit allows the adopter to comment on changes to the condition of the beach and the possible causes of changes that are visible. Also included are site location, date, time, and approximate river flow. Photographed visits for each beach average 4 per season. The number of visits for each beach can range from one to eight. Many guides take the initiative to also photograph different episodic events such as debris flow or flash flooding that recently occurred on or near their beach. Such photos can be highly beneficial to many different researchers concerned with monitoring a particular resource at a given area.

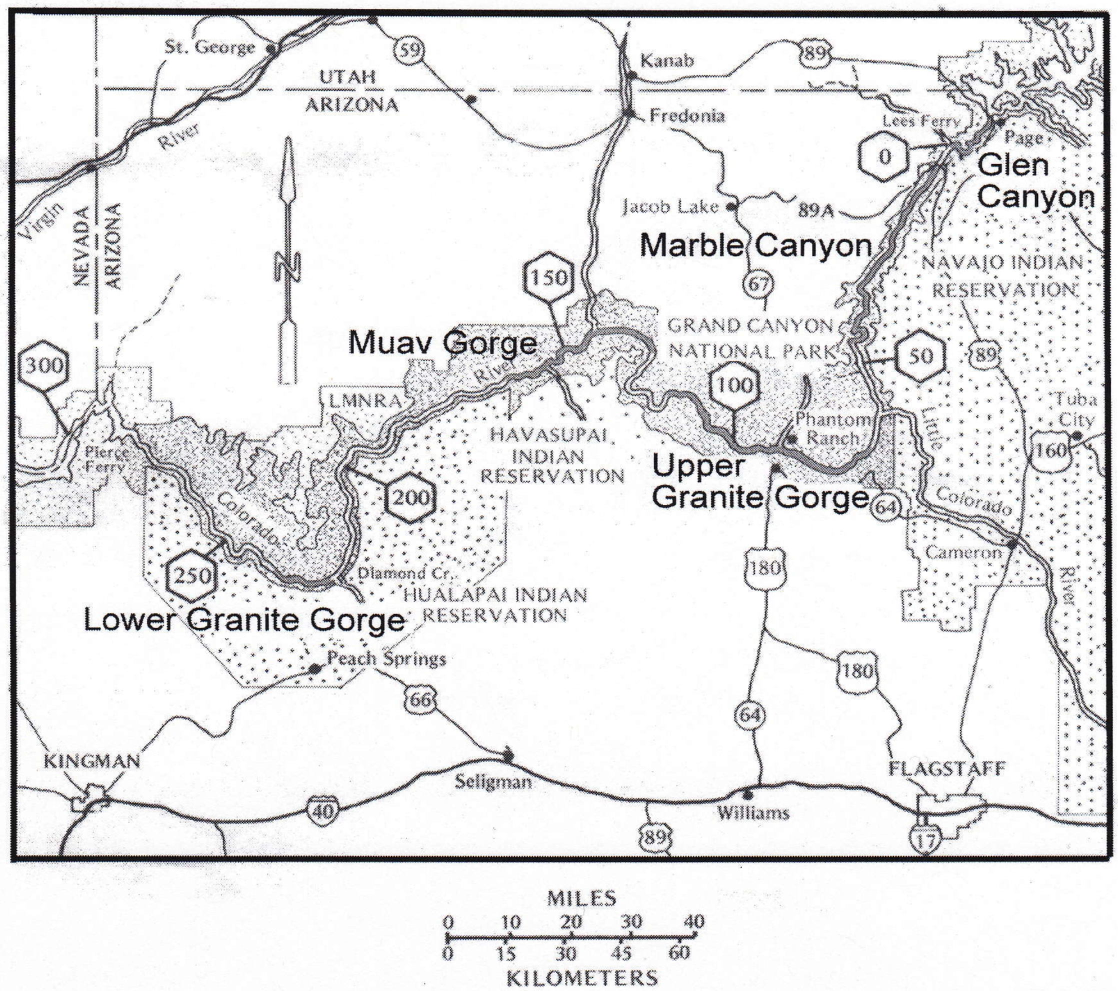
The photographs for all beaches since 1996 have been carefully labeled, and are archived at the Grand Canyon River Guides (GCRG) office and at the Grand Canyon Monitoring and Research Center (GCMRC) library. Photographs from years 1996, 2001, and 2002 have been archived digitally onto compact discs. Copies of any of these discs can be obtained from the GCRG office or the GCMRC library.

Information gleaned from photographs and from data sheets are entered into a master database using Access 2000. A cross check of the two different sources of information help to fill gaps in data and help to standardize changes from one visit to the next. For instance, if guide comments lack information about a site at the time a photograph was taken, the photo is used to assess the site for that visit. If the photo reveals little information and the guide's data sheet provides enough descriptive information about conditions throughout the site, the comments receive priority. The current Access database contains over 1,000 records of assessed changes and guide comments throughout monitoring years 1996-2002.

Study Locations

In 1996 the AAB program initially studied 43 beaches from within three *critical reaches* of the river corridor (Figure 1). The practice of assessing camping beach resources within critical reaches was first developed by Kearsley and Warren (1993), and modified for the 1996 Adopt-a-Beach study by Thompson and others (1997). A critical reach is defined as a section of the river where camps are in high demand and few in number. The same reach system has been in use for the years of study from 1996-2001. They are as follows: 1) Marble Canyon, river miles 9-41; 2) Upper Granite Gorge, river miles 71-114; and 3) Muav Gorge, river miles 131-165.

Two new critical reaches have been added to the 2002 monitoring season. The purpose is to increase the sample set of beaches in order to more widely represent the effects of beach erosion and building throughout the whole river corridor below Glen Canyon Dam. These new reaches now include Glen Canyon, from the dam to Lees Ferry (river mile 0), and Lower Granite Gorge, from Diamond Creek (river mile 226) to Gneiss Canyon (river mile 236). Results from these reaches are included in this Annual Report.



Defines a critical reach for campsite beaches along the Colorado River

Figure 1. Locations of five critical reaches along the Colorado River.

Table 1 shows all popular campsites (n = 45), many of which were originally inventoried in 1996, and include beaches added in 2000 and 2001. Every beach in the inventory has an established photographic location that shows an optimum view of the beachfront and as much of the actual camping area as possible. Each year, GCRG motivates guides to adopt as many beaches as possible. To encourage a relatively complete data set from year to year, GCRG encourages adoption of high-priority beaches (n = 27) first. These beaches have been adopted for most of the study years. Usually, they are camps that can be used year after year by the river community, and thus are continually in high demand. The remaining beaches are adopted once high-priority beaches have been claimed.

The time-series photos taken within study locations allow assessment of relative change over the course of each season and between monitoring years. Assessment is standardized according to the highest average fluctuating flow of the season, and to a zone of 20,000 cfs when comparing 1996 photos (determined by Kaplinski and others 1994). From year to year GCRG assesses the number of beaches that change in size and evaluates campsite space up to the 45,000 cfs zone, the level of the 1996 BHBF. Should any flows exceed 45,000 cfs in the future, GCRG would analyze beach change up to the height of the new deposit or scour line.

Table 1. Sample set of beaches inventoried in 2002 that lie within five critical reaches.

Glen Canyon		Marble Canyon		Upper Granite Gorge		Muav Gorge		Lower Granite Gorge	
Mile	Camp	Mile	Camp	Mile	Camp	Mile	Camp	Mile	Camp
-13.0	Dam Beach	8.0	Soap Creek	75.6	Below Nevils	131.1	Below Bedrock	235.1	Travertine
-8.0	Lunch Beach	12.2	Salt Water Wash	76.6	Hance	132.0	Stone Creek	240.0	Gneiss
		12.3	Hot Na Na	81.3	Grapevine	133.0	Talking Heads		
		19.1	19 Mile	84.0	Clear Creek	133.5	Race Track		
		19.9	20 Mile	84.5	Zoroaster	133.7	Lower Tapeats		
		20.4	North Cyn	91.6	Trinity	134.6	Owl Eyes		
		23.0	23 mile	96.1	Schist	137.0	Back Eddy		
		29.3	Silver Grotto	96.7	Boucher	143.2	Kanab		
		34.7	Nautiloid	98.0	Crystal	145.6	Olo		
		37.7	Tatahatso	99.7	Tuna	148.5	Matkat Hotel		
		38.3	Bishop	107.8	Ross Wheeler	155.7	Last Chance		
		41.0	Buck Farm	108.3	Bass	164.5	Tuckup		
				109.4	110 Mile	166.4	Upper National		
				114.3	Upper Garnet	166.6	Lower National		
				114.5	Lower Garnet				

Data are analyzed according to the particular research questions asked for that year. For each year, data are grouped into two time periods: (1) summer season, beginning on April 1st and ending October 31st; and (2) winter season, the intervening period that begins November 1st and ends March 31st. Data are also categorized according to critical reach in order to rank which reaches would show more change over time. In order to determine longevity of the BHBF flood deposit, beach area at the end of summer season is compared to its pre-BHBF area. Finally, guides comment about the changing quality of campsites regarding vegetation encroachment, boat parking, steepness of slope for camp access, and rockiness. These comments together with the photographs provide an overall qualitative assessment of campsite changes over time.

Specifically, relative change to beach size, as seen either in the photos or written on field data sheets, are evaluated according to increase, decrease, or no change with respect to the previous visit. Changes pertain to the whole beach up to the 45,000 cfs line, as delimited in the photo frame, where individual physiologic features such as rocks are used for reference. Individual factors (see Appendix A) affecting camp quality changes are recorded as better, worse, or the same.

To summarize for the season of 2000, photos of beaches that immediately preceded and followed each HMF (Figure 2) were assessed for change. Data collected from the LSSF time frame were treated separately. Comparisons of beaches between time periods and between critical reaches were standardized by calculating percentages.

Water years 2001and 2002 showed medium fluctuating flows, with no high-flow mainstem spikes as illustrated in the hydrograph (Figure 3). Any beach change throughout these years was assessed along side of its corresponding hydrograph. The small spike around September 7th reflects the Little Colorado River contributing about 12,000 cfs to the mainstem because of flash flooding. This small spike was noted by many guides as having an impact on beaches.

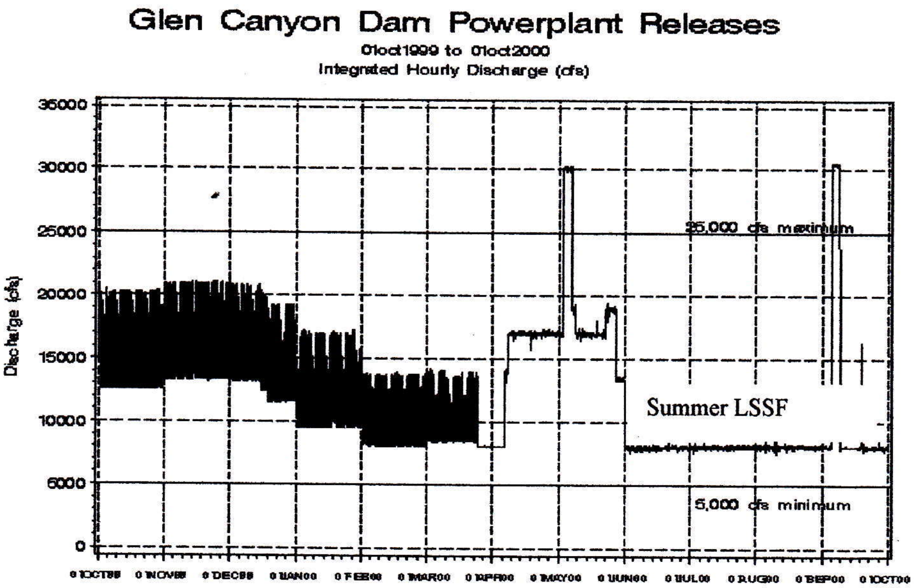


Figure 2. Average daily discharge from Glen Canyon Dam for water year 2001 (October 1, 2000 – September 30, 2001).

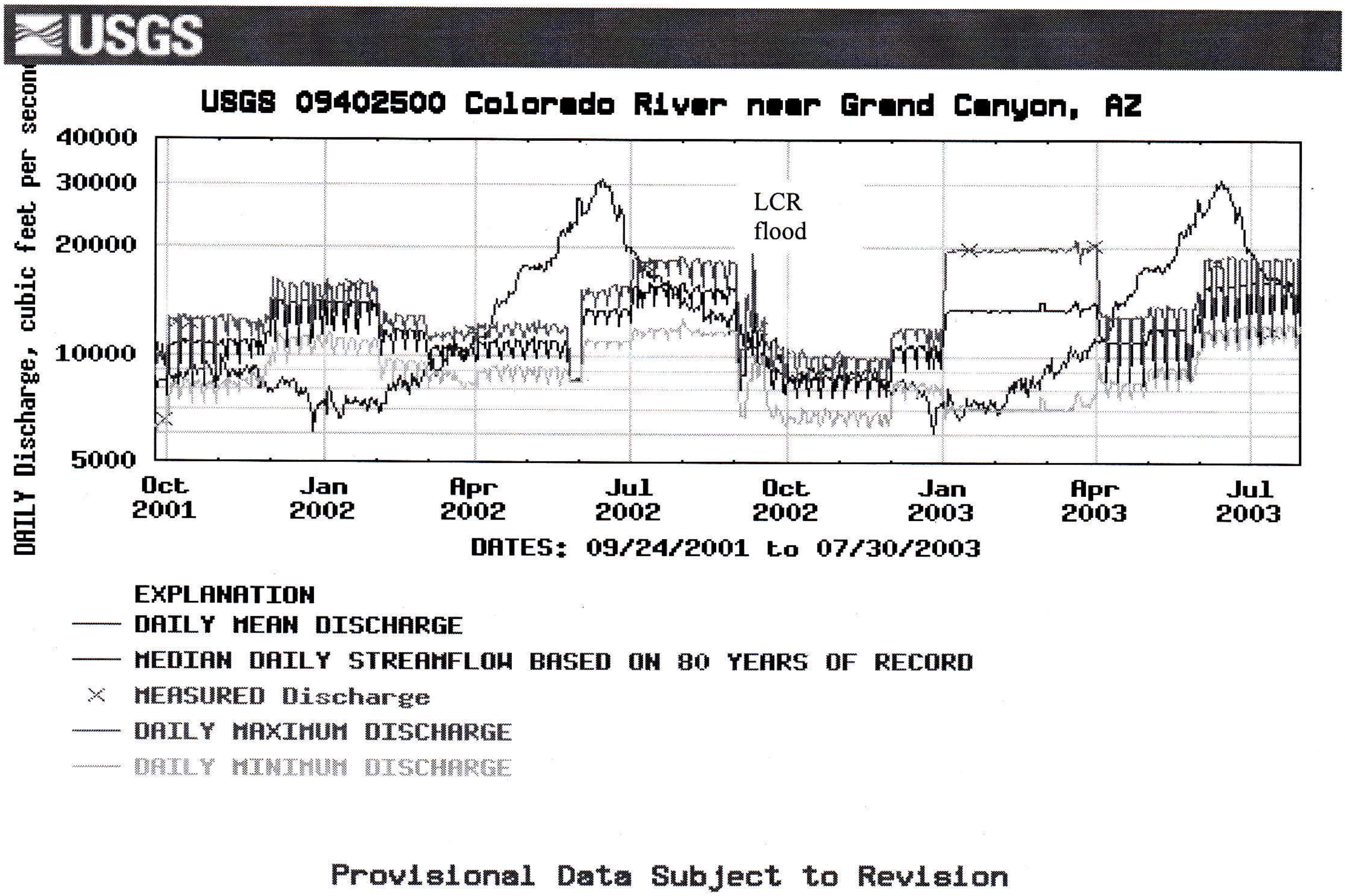


Figure 3. Hydrograph of Colorado River at Phantom Ranch. Data range from October 2001 through river season of 2002 and beyond.

RESULTS

The number of adopted beaches with useable data in 2002 totaled 45, the highest amount of sites adopted per year to date. Each record in the data base represents an individual visit to a beach where each beach has 1-5 photos associated with it. As encouraged by other Grand Canyon researchers, several adopters took extra snapshots of various episodes such as flash flooding in Schist Camp (August 2002) and Last Chance Camp (August 2001) and debris flows at Hot Na Na (July 2000). These documented events and data are available to any interested researchers through Grand Canyon River Guides or Grand Canyon Monitoring and Research Center.

Results of the Winter Season (November 1, 2001 to March 31, 2002).

In order to fill gaps between time periods of each river season, we assessed winter season change. The visible change to beaches is documented by comparing the last photo of the previous river season (usually in October) with the first photo taken the following spring (usually in April or May). Processes, such as erosion from rainfall or fluctuating flow, are often visible in the first new photo of the river season. Erosion from camping is either non-existent or minimal due to the "off-season" of river traffic. The category "Don't Know" is recorded for those beaches whose photos or data could not be interpreted.

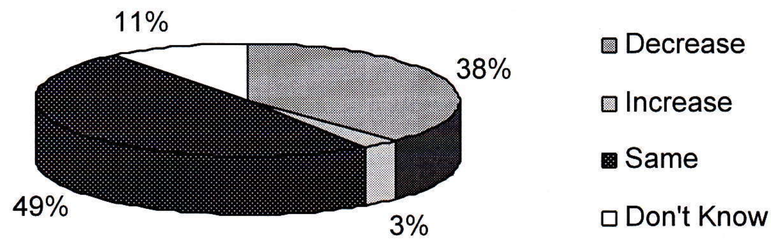


Figure 4. Percent of beaches (n=37) showing change over the 2001-2002 winter season.

Out of 37 beaches for which data was available, 38% showed a decrease, 3% showed an increase, and 49% showed no change (Figure 4). More than 12 sampled beaches showed a series of cutbanks at the beachfronts in the first set of 2002 photos. These same beaches lacked the extent of cutbank erosion as seen in the fall 2001 photos. This implies that much of this change to beach area was due to a changing flow regime over the winter months. Figure 3 shows a 5,000-cfs increase in fluctuating flow from November 2001 through March 2002. This small increase in flow for over 4 months was enough to scour away more of the beachfront at these 10 sites. This is a similar result to that in 2001, where medium fluctuating flows throughout the winter scoured away much of the HMF deposit. Higher elevation sand (above the 30,000 cfs line) appears to have been reworked by wind and incorporated into the 1996 BHBF deposit. Only 4 beaches showed effects from rainfall in winter 2002, to the extent that beach size was reduced.

Figure 5 compares the percent of beaches that changed for each of the study years

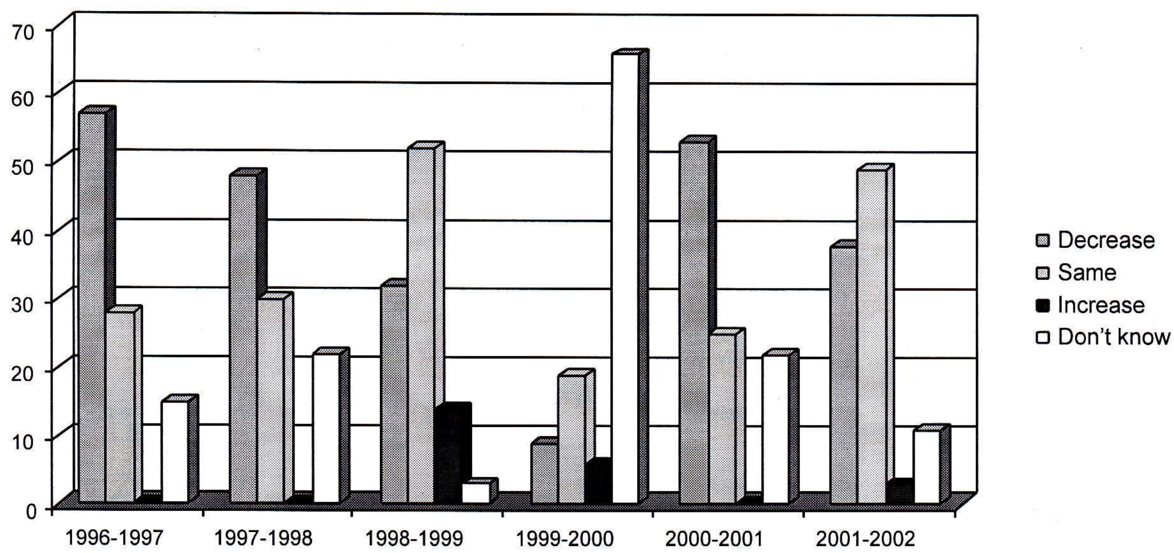


Figure 5. Comparison of change observed after each winter season, 1996-1997 through 2000-2001.

following their respective winter period. The trend demonstrates that the number of beaches decreasing in size from winter events, whether a result of fluctuating flow or rainfall, has continually fallen off until the spring 2000 HMF. The declining rate of decrease exemplifies the initial rapid adjustment of newly aggraded bars to relatively normal dam releases following the 1996 BHBF. This data agrees with that of Hazel and others (2001), where sand bar thickness has been decreasing every year since 1996, but at a decreasing rate.

The number of beaches decreasing in size then rose again dramatically in winter of 2001, 7 months after the fall 2000 HMF. By 2002, the rate of decrease has again dropped off. This repeated pattern is a testament to widespread erosion that follows a bar-building episode.

Longevity of the Habitat Maintenance Flows

Two spike flows of 30,000 cfs were released from Glen Canyon Dam for four days in early May 2000 and again in September 2000 (Figure 2). Both flows showed similar results where an average of 60% of beaches increased in size (Figure 6). The Spring HMF increased campsite area to more beaches, probably because antecedent long-term erosion had created more accomodation space for deposition compared to antecedent conditions for the Fall HMF. Most beach area was gained at the beachfront for both HMFs. Deposition from the HMFs increased beach elevation at most by approximately 0.1 meters on the higher elevation bars up to the 30,000 cfs line. When the two HMFs were compared by reach, most beaches in Muav Gorge benefited over the other reaches. The net increases to Muav Gorge beaches may be a result of greater sediment supply due to two factors: (1) distance below the Little Colorado River

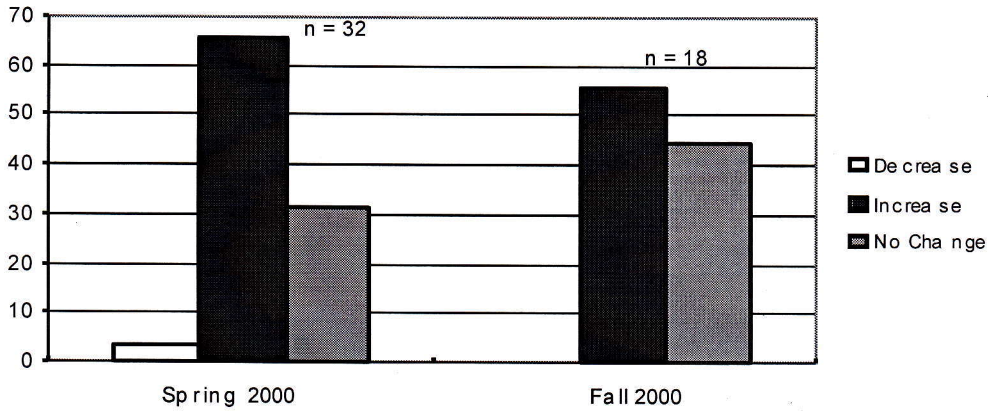


Figure 6. Number of beaches showing change due to the spring and fall HMFs

(Schmidt 1990, Webb 1996) where cumulative inputs from this tributary benefit downstream reaches in Grand Canyon; and (2) upstream erosion of beaches in Marble Canyon and Upper Gorge that ultimately benefit beaches located further downstream (Hazel and others 2002).

Photos taken in fall 2001, compared to those taken shortly after the fall 2000 HMF event, show little to no evidence of the HMF deposit remaining. Only 11% of beaches showed evidence of this deposit. By 2002, only 3 beaches showed any evidence of this deposit. Either the deposit had been mostly scoured away or the deposit is now too insignificant in size to be detected in many of the photos. This evidence supports the preliminary conclusion that the HMF deposits only last as long as flows remain very low (Thompson 2001, Hazel and others 2002). Otherwise, the HMF deposit is eroded away within a few months to a year after its emplacement.

Longevity of Beaches Since the 1996 Beach/Habitat Building Flow

The success of the Beach/Habitat Building Flow of 1996 demonstrated the need for periodic beach building for maintaining the campsite beaches in Grand Canyon. Over 25,000 river runners and backpackers to the Colorado River in Grand Canyon rely on these campsites for recreation. In March 1996, Glen Canyon Dam released a flow of 45,000 cfs in order to suspend sediment stored in eddies, and deposit it to high elevation sand bars. While this test flood flow benefited a large majority of campsites in Grand Canyon (Kearsley and Quartaroli 1997, Thompson and others 1997), it mined out lower elevation bars and sediment in the river channel due to its long duration (Topping and others 2000). A multitude of sediment studies determined that future BHBFs can be extremely beneficial if the duration of the high flow release is limited to 48 hours and if the Colorado River has received recent sediment inputs from the major tributaries (Rubin and others 2002, Lucchitta and Leopold 1999, Topping 1997).

Today, the persistence of this deposit is of great interest to resource managers and users of these high elevation bars. Each year, end-of-season photos are compared to pre-BHBF photos (taken in March 1996) to determine if and how many sites have returned to their original pre-BHBF condition. In a few cases, sites appeared to have lost more area compared to its pre-BHBF condition.

Figure 7 shows a trend in which the percentage of beaches returning to the pre-BHBF size have continually increased until year 2000, when the HMF of 30,000 cfs was imposed. This increase is especially prevalent in 1999, at which point 58% of beaches had returned to the pre-BHBF condition. The HMFs in year 2000 improved area for 80% of beaches. However, sand replenished to this deposit mostly affected low-elevation bars, as the spike flows were limited in stage height. By fall 2001, erosion had progressed to the point that over 45% of beaches had returned to their pre-BHBF size. Results for 2002 are similar to those in 2001. This indicates a level of quasi-stability with the remaining BHBF deposit.

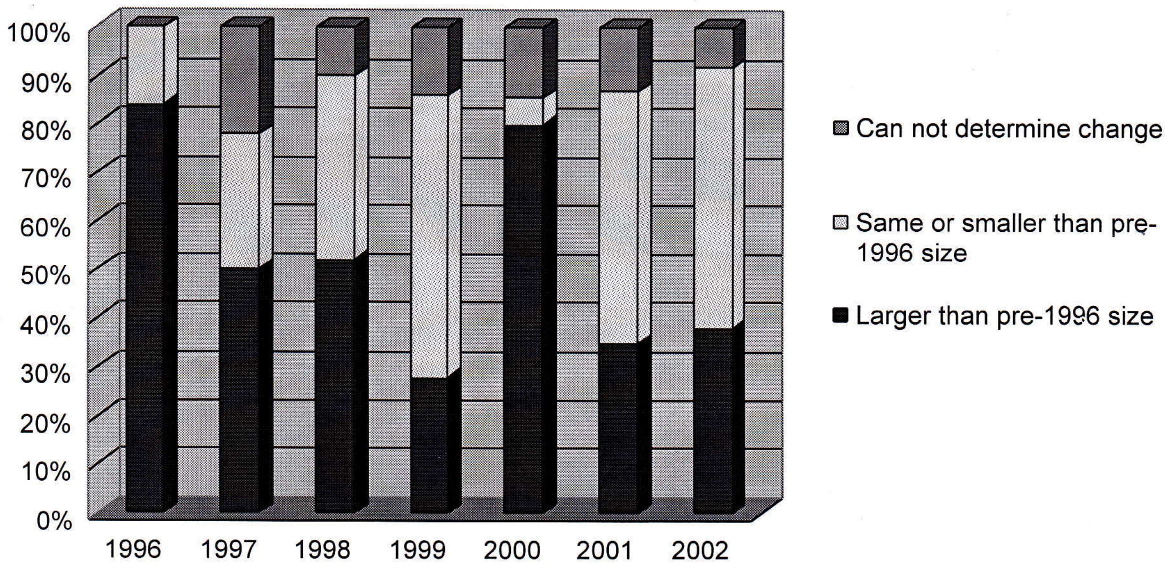


Figure 7. Relative size of beaches for each year compared to their pre-BHBF 1996 size. Comparisons were made using end-of-season photos for each year compared to pre-BHBF photos, taken February 1996.

Summer Season Change and Processes Causing Decreased Beach Size

Summer season changes to campsite beaches were divided into separate critical reaches. Lower Granite Gorge and Muav Gorge showed the highest decrease in number of beaches (Figure 8). Glen Canyon and Marble Canyon show the least number of beaches decreasing in size, probably because so much erosion had already occurred in these upper reaches since the BHBF of 1996. Moreover, Muav Gorge contained the most beaches that benefited from the HMFs of 2000 and therefore showed the most change during the 2001 and 2002 seasons. Conversely, Marble Canyon did not benefit as much from the HMFs and has therefore showed little relative change since then.

Reaches that lie below the confluence of the Little Colorado River show some beaches that increased in size. Guide comments and photos indicate that the high flash flooding from the Little Colorado River (Figure 2) helped to rebuild beachfronts. Close to 20% of the beaches in Muav Gorge increased in size, with a less number of reported increases on beaches in Upper Granite Gorge. These new deposits can also be seen in the photographs.

In order to determine primary causes of erosion, various processes were reported about beach change, whether erosional or depositional. Morphological characteristics were recorded as outlined on the data sheet in Appendix A. One primary and one secondary cause were identified for each visit per site.

Figure 9 shows the percent of all beaches that changed in size throughout the summer

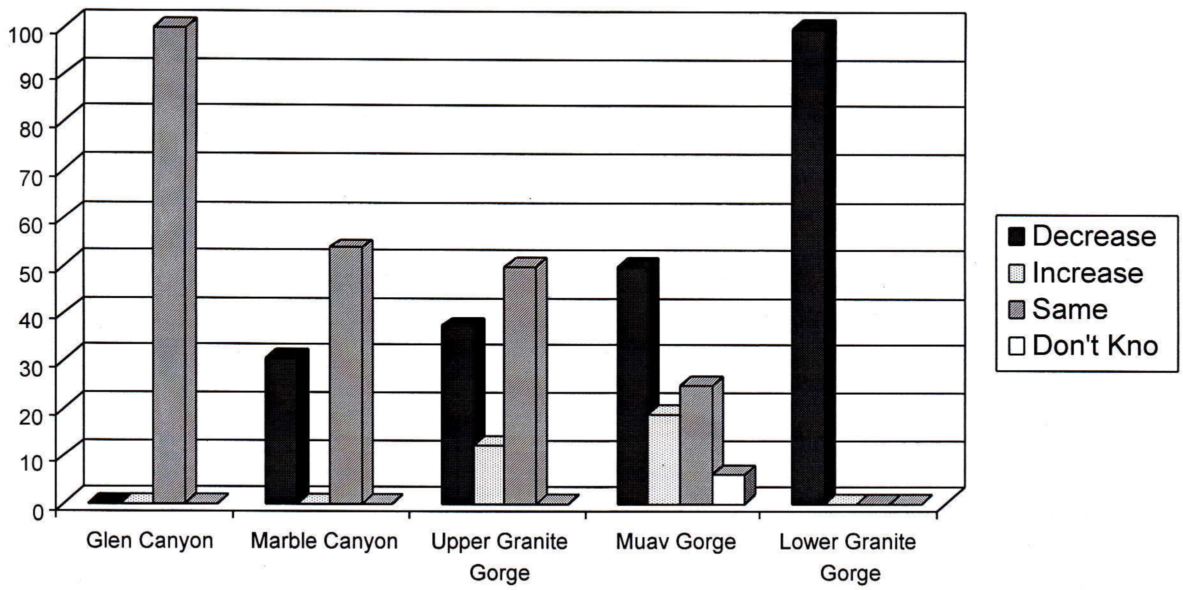


Figure 8. Summer season change to beaches (n=45) in 2002. Cumulative changes per beach were separated into critical reaches.

season. Moreover, all identifiable processes that contributed to negative change were recorded. Erosional processes were primarily a result of medium fluctuating flows throughout the months of July-August, as reported by guides; and secondarily, a result of flash flooding from rain during the monsoon season. Beaches impacted by fluctuating flows showed progressive cutbank retreat through the month of August. Beaches impacted by rain showed loss in area due to gully formation or rock and gravel influx. Erosion from people and wind were less significant, although impacts were seen on most beaches.

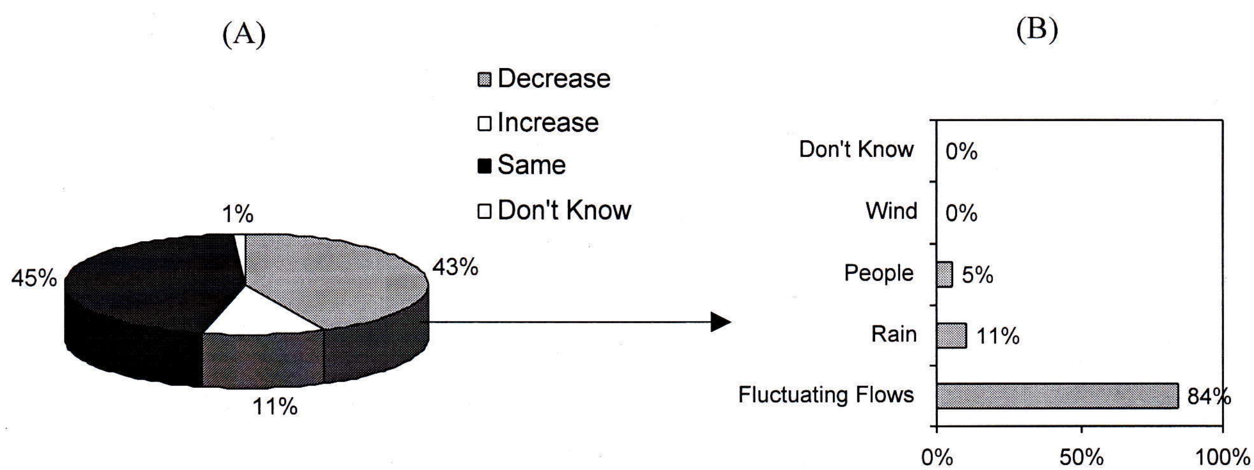


Figure 9. (A) Percent of beaches showing cumulative change throughout the 2002 river season. (B) Percent of beaches negatively impacted by a dominant process.

Camping Quality

During the Low Steady Summer Flows (LSSFs) of year 2000, guides responded that many small new beaches, upstream and downstream of their adopted beach, became available for camping. Also, adopted beaches such as Clear Creek, Olo, and Talking Heads (all of which are mostly under water at higher flows), again became useable camps under the LSSF. Camping quality, defined as available campsite space and ease of using a beach for camping, was assessed for change throughout the season. With the onset of the LSSF after the spring HMF (Figure 10A), 51% of beaches showed "much improved" campability, according to guide responses. These camps contained more sandy beachfront property, decreased rockiness for better boat parking, or a relatively flat bench for kitchen set-up and camping. The rest of the sampled beaches remained either the same for useable space or became more inaccessible due to increased rockiness for boat parking.

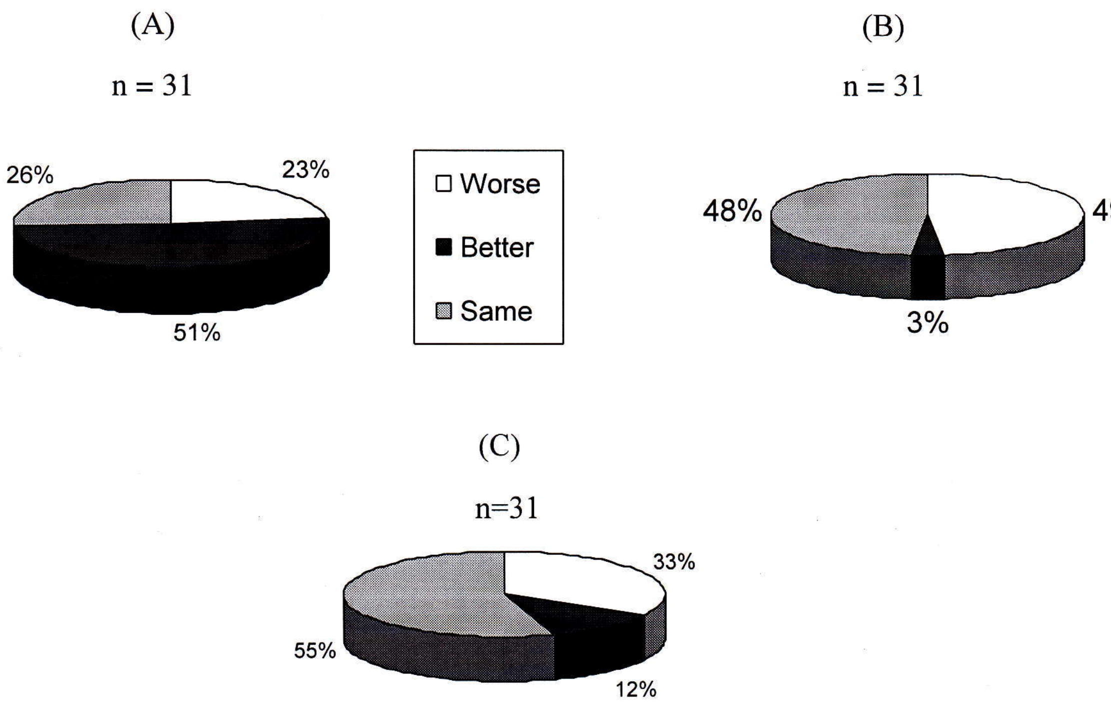


Figure 10. Campsite conditions during: (A) the LSSF- first response by guides with the onset of the LSSF; (B) river season 2001 – the first response of the season by guides; and C) river season 2002 – the last response of the season

Campsite conditions throughout the 2001 season were far worse compared to the 2000 season, according to guide responses (Figure 10B). Flows during the summer of 2001 fluctuated between 7000 and 14,000 cfs, which decreased camping area and rendered the lower beach areas useless. During the summer of 2002, flows fluctuated slightly higher, between about 12,000 to 18,000 cfs. Several complaints were recorded that beaches had returned to their previously rocky state as that before the HMFs.

Several other factors that contribute to campsite quality were included as questions on the 2001 data sheets (Appendix A). Unfortunately, most guides neglected to report on the changing quality of camping throughout the season. Only a few remarks were recorded regarding increasing tamarisk encroachment and the increased presence of red ants at some campsites. Increasing vegetation can be clearly seen at most campsites in the photos from year to year. However, further analysis and funding would be needed to determine the relative rates of vegetation encroachment on campsite area over time. This could be easily accomplished, though, using the existing AAB photo archive that covers years 1996 to present.

CONCLUSIONS

Results of this study since 1996 show that beaches have continued to decrease in size, system-wide even shortly after the HMFs of 2000. Over years 1996-1999, the net effect of controlled flow releases from Glen Canyon Dam resulted in the continued winnowing of beachfronts, cutbank retreat, and loss of camping areas. Most negative impacts from fluctuating flows were reported in 1997 (O'Brien and others 2000). Erosion to beaches through years 1998-1999 continued, but effects were not as profound. This decreased magnitude of change through the years since 1996 reflects two geomorphic processes: (1) the increased stability of beach fronts as they attain an angle of repose, and (2) decreased amounts of sediment that can be eroded from beaches (O'Brien and others 2000, Hazel and others 2002). By fall 2001, most beaches that had initially gained area from the HMFs of 2000 had returned to their 1999 condition.

Many factors are contributing to long-term erosion of these beaches. Primarily, erosion from medium and high fluctuating flows that contain low sediment concentrations have resulted in conditions that are similar to those before the BHBF of 1996. Secondary processes contributing to erosion are listed here ranked according to magnitude of impact: (1) gully formation from flash-flooding/rainfall; (2) beachfront erosion from campers; and (3) wind deflation. Some campsite area loss is due to encroachment of vegetation, mostly tamarisk.

Campsite area and quality can be greatly enhanced by implementing BHBFs well above power plant capacity, given there is available sediment inputs from the Paria and/or Little Colorado Rivers (Lucchitta and Leopold 1999, Hazel and others 2002, written responses by Grand Canyon river guides 2001). Over 80% of guides agreed that camping (useable space and quality) had improved dramatically during the LSSF that followed the spring HMF 2000. Moreover, camps that would normally be under water became available for use. By spring 2001, most guides reported worse camping conditions that continued on into 2002. This is attributed to relatively higher fluctuating flow zones on beaches, rendering the lower camping area useless, and eroded beachfronts that presently expose rocks.

The results of 7 years from this monitoring program show that the BHBF of 1996 was the most beneficial management action for replenishing and rebuilding beaches for campsite use. All other subsequent test flows produced small new deposits that only lasted for 7-12 months, at most. These results suggest that any newly deposited sand within power plant capacity will be quickly eroded if followed by medium or high fluctuating flows released from Glen Canyon Dam. This was evidenced by 3 events: (1) High fluctuating flows (of about 27,000 cfs) following the 1996 BHBF eroded much of the new deposit at all beach sites through the summer of 1996 and 1997; (2) High fluctuating flows following the fall HMF of 1997 stripped away the new deposit entirely by spring 1998; and (3) Medium fluctuating flows following the fall HMF of 2000 eroded most of the new deposit by spring 2001. To date, about 30% of beaches show evidence of high-elevation sand (above 30,000 cfs line) deposited by the 1996 BHBF. However, the amount of sand appears to be diminishing year after year.

Annual implementation of HMFs in spring and in fall would help preserve camping beaches by maintaining the beachfront. A regimen of BHBFs that exceed power plant capacity followed by low fluctuating flows is needed periodically to rebuild campsite areas above the 30,000 cfs line. However, future BHBFs need to have enough sediment in the system so as to preserve Marble Canyon beaches and lessen impacts on beachfront areas (below the 20,000 cfs line) systemwide.

Acknowledgments

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