

**Glen Canyon Dam Adaptive Management Work Group**  
**Agenda Item Information**  
**August 29-30, 2007**

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Agenda Item

GCMRC's Beach/Habitat Building Flow (BHBF) Science Planning Update

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Action Requested

√ Feedback requested from AMWG members.

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Presenters

John Hamill, Chief, Grand Canyon Monitoring and Research Center

Ted Melis, Deputy Chief, Grand Canyon Monitoring and Research Center

Matthew Andersen, Biological Program Manager, Grand Canyon Monitoring and Research Center

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Previous Action Taken

√ By AMWG:

AMWG passed the following motion at its December 2007 meeting (see response from DOI below):

AMWG recommends to the Secretary of the Interior to charge GCMRC to develop a science plan for a BHBF that addresses the concerns raised at the AMWG meeting on Dec. 6, 2006, and AMWG further charges the TWG to work with GCMRC to review the Draft Science Plan and make a recommendation to the AMWG.

√ By TWG:

At its June 2007 meeting, TWG members agreed that the Sediment Ad Hoc Group and Desired Future Conditions Ad Hoc Group would review the BHBF Science Plan and provide comments to the TWG for consideration at its October 2-3, 2007 meeting.

√ Other: **Following is the DOI response to the above AMWG recommendation (May 21, 2007 memo from Deputy Secretary Lynn Scarlett to AMWG):**

“While high flow events are the only mechanism to redeposit sediment on Grand Canyon beaches, the Adaptive Management Program has not yet addressed the long-term sustainability of beaches using these releases in conjunction with Paria River and Little Colorado River sediment inputs. Critical to this phase of the AMP is the inclusion of BHBF testing as part of the ongoing development of a long-term experimental plan.

“Consistent with this recommendation, GCMRC has been actively working to further refine its science plan for a BHBF, which will then be reviewed by the TWG and provided to the AMWG for its further consideration. Further details on the Department’s consideration of the issues raised by this recommendation were thoroughly discussed in a memorandum to Adaptive Management Work Group members from Assistant Secretary Limbaugh dated February 2, 2007.”

**Guidance provided by DOI in the February 2, 2007 memo from Mark Limbaugh to the AMWG:**

“While we fully understand that many members of the AMWG view a spring 2007 BHBF as an important opportunity to advance resource management, the best way to address a number of issues currently affecting the Adaptive Management Program, including the need for additional BHBFs, is through the development of a long-term and carefully planned program of experimental and management actions. In accordance with the AMWG’s recommendation, staff at the GCMRC have been working since the December meeting to prepare a draft science plan regarding additional BHBFs. We expect that the draft science plan will be available for initial review and comment in early February.

“As I have mentioned in my remarks to the full AMWG, and in many of the conversations I had earlier this week, it is my hope that we can work effectively together to have well-considered, approved, ‘off-the-shelf’ action plans to take advantage of these types of important research opportunities in the future.”

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Relevant Science

- There has been no relevant research or monitoring on this subject.
- The following describes the relevant research or monitoring on this subject:

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Background Information

Please see the attached document, “Addressing AMWG concerns about Future Beach/Habitat-Building Flow Testing and the Need for Science Plan Development.”

## **Addressing AMWG concerns about Future Beach/Habitat-Building Flow Testing and the Need for Science Plan Development (BHBF)**

**July 26, 2007**

### **Status**

From late December 2006 through early February 2007, the GCMRC proceeded with development of a beach/habitat-building flow (BHBF) experimental science plan, as recommended by the AMWG and directed by the DOI. Planning activities included several meetings among staff and cooperating scientists to define both single-discipline and integrated science activities that might be implemented before, during, and following future BHBF testing. Several appendices were included in the draft BHBF science plan, including ones that responded to concerns about future BHBF testing expressed by the AMWG at their December 2006 meeting (see Appendix A). The draft BHBF plan was delivered to the Science Advisors (SA) for external peer review in mid-February and the GCMRC further revised the draft plan based on this peer review during March through mid-May.

During the BHBF draft science plan revision process, meetings also occurred between the GCMRC and other DOI agencies to discuss various elements of the proposed experimental research. Additional discussions also occurred between GCMRC staff and other independent scientists that participated in the April 2007 Science Workshop on Long Term Experimental Planning.

A draft BHBF science plan was provided to the TWG in May 2007. Approximately 200 written comments were received. Written responses to those comments were provided and discussed at the June 25, 2007 TWG meeting. In response to that discussion, the TWG charged the Sediment Ad Hoc Committee to further review the draft plan and provide comments and recommendations on the technical sufficiency of the Plan to the TWG in advance of their October 2-3, 2007 meeting.

Some of the comments provided by the TWG review on the draft BHBF science plan were policy or non-technical in nature (see Appendix B). The non-technical/policy issues generally involve the following major categories of concerns:

- Concerns about the lack of desired future conditions or criteria for evaluating success of a BHBF, including which reaches of the river (e.g. Marble Canyon vs. downstream reaches) and which resources (backwater habitats, aquatic food base, camping beaches, sand bars, riparian vegetation, etc.) are the target of a BHBF test.
- Concerns about doing multiple BHBF tests as a means evaluating cumulative increases in systemwide sandbar area and volume over a decadal time scale.
- Concerns about conducting a BHBF as a “stand-alone” activity before the Long Term Experimental Plan is completed.
- Concerns about the need for additional decision criteria for a conducting future BHBF tests including ESA compliance, NPS permitting requirements, cost and availability of funds, and whether specific resource targets have been realized.
- Concerns about the legality of doing a BHBF test when the reservoir is not full.

GCMRC encourages the AMWG/DOI to develop a process to address these issues prior to consideration of implementation of the science plan.

The GCMRC's plan is to have the BHBF science plan approved by the AMWG following the TWG review and recommendation in October 2007, and seek additional guidance about whether the plan should be implemented during winter/spring 2008, if the proposed sediment trigger is reached during summer through early winter 2007-08. GCMRC recommends an AMWG conference call or meeting in early November to take action on the BHBF science plan. Regardless of whether the BHBF plan is implemented in 2008 or not, having an approved BHBF plan is desirable in that such a plan can be integrated into the long-term experimental plan that will be implemented in 2009/2010.

#### **Next Steps**

August 3, 2007: GCMRC will revise the draft BHBF science plan based on the TWG comments and send it to the Sediment Ad Hoc Group and the TWG for review.

September 14, 2007: The Sediment Ad Hoc Group will provide comments on the Draft Plan to the TWG.

October 3, 2007: The TWG will review the BHBF science plan and provide a recommendation to the AMWG.

Early November 2007 (proposed): AMWG meeting or conference call to consider approval of the BHBF Science Plan and a possible BHBF test in the winter of 2007, if the sediment trigger has been met.

## **Appendix A. Responses to Issues Raised by Members of the Glen Canyon Dam Adaptive Management Work Group about a Future BHBF Test**

During their December 5–6, 2006 meeting, members of the Glen Canyon Dam Adaptive Management Program (GCDAMP) identified issues of concern for the Grand Canyon Monitoring and Research Center (GCMRC) to consider and address in planning for a future BHBF test. These concerns are summarized below from the meeting minutes and are followed by short responses prepared by GCMRC staff and cooperating scientists.

### **ISSUE 1: WHAT ARE THE TRADE-OFFS BETWEEN THE BENEFITS OF A FUTURE BHBF TEST AND POSSIBLE NEGATIVE IMPACTS?**

This is a broad question and one that GCMRC staff worked to address with input from the entire science staff. Please see Table A-1 (below) for a summary of the pros and cons associated with a future BHBF test in late winter or early spring.

### **ISSUE 2: IF A PROPOSED FUTURE TEST IS A NEW (BHBF) TEST, THEN WHAT ARE THE NEW HYPOTHESES?**

The proposal for a future high-flow experiment is a hybrid of the two previous experiments that have been conducted in the past, and it tries to incorporate key learning from both the 1996 and 2004 BHBF tests. The next proposed high-flow experiment intends to return more closely to the original timing of spring (if sufficient sand enrichment exists at that time) for such a flow operation as described in the 1995 Operation of Glen Canyon Dam Final Environmental Impact Statement (EIS), a timing that attempts to approximate the spring flood disturbance regime of the ecosystem that typically occurred before the construction of Glen Canyon Dam. It is also a second test of the concept of implementing high-flow experiments within a period when new sand supplies are known to exist in the main channel following tributary sand inputs. The 2004 BHBF test revealed that fall sand inputs from the Paria River were retained in the upper reaches of Marble Canyon under constrained daily dam operations that varied between 5,000 and 10,000 cubic feet per second (cfs). As a result, sediment experts determined that the resulting sandbar building using the sand supply was restricted to the upper half of Marble Canyon and that the new sand did not have time under that 60-hour test to be transported to reaches downstream of about river mile 40.

Analysis of the 2004 results yielded a revised hypothesis regarding sand transport. This new hypothesis postulates that new sand inputs that enter the ecosystem from the Paria River should be allowed some limited time to be transported downstream under the 1996 Record of Decision fluctuations into lower Marble Canyon. Hence, there is an evolving question about the appropriate timing for when high-flow experiments should optimally be tested and implemented relative to: (1) the seasonal timing of when tributary sand typically is introduced to the ecosystem from the Paria River (late summer to fall), (2) how the new sand gets distributed downstream through Marble and Grand Canyons under Record of Decision operations within the months following inputs, (3) whether redistributing the new sand in a more uniform longitudinal pattern downstream before a high-flow experiment results in more uniform and robust sandbar deposition, and (4) the season in which historical flood disturbance occurs (spring).

The exact timing of a future BHBF test will depend on the magnitude of the sand inputs from the tributaries and the magnitudes of releases from the dam. If conditions include both (1) sand inputs greatly surpassing the proposed trigger for a BHBF and (2) lower dam releases, the timing of a BHBF could likely occur in spring. This would have been the scenario if a BHBF had occurred in spring 2007.

However, if conditions include both (1) sand inputs equaling the minimum required by the proposed trigger for a BHBF and (2) moderate to high dam releases, the timing of a BHBF would be much earlier (potentially late fall or winter) to still be above the trigger threshold.

The science proposed for a future BHBF test is intended to have additional studies tied to food base, fisheries, and cultural sites. Table A.2 (below) identified the science questions that will be addressed in a future BHBF test. Specific hypotheses associated with these studies are described in the experimental study descriptions included in the BHBF science plan.

### **ISSUE 3: WHAT IS THE REASON BEHIND REPLICATING THE 2004 (BHBF TEST) HYDROGRAPH?**

The concept of replicating the 2004 BHBF test hydrograph (i.e., replicating that portion of the 2004 hydrograph consisting of the rising limb, peak, and recession of the November 2004 BHBF test) was discussed extensively among cooperating sediment scientists at the 2005 knowledge assessment workshop convened by the GCMRC with stakeholders. The 2004 test hydrograph was designed on the basis of sandbar simulations for a subset of eddies under a scenario of 45,000 cfs peak magnitude and sand concentrations that were measured in the postdam era. This, along with data collected from the 1996 BHBF test, was the basis for choosing 60 hours, down from 168 hours tested in 1996, as the duration for the peak flow of a future BHBF test. The 2004 BHBF test peak magnitude was limited to 41,500 cfs, because one of the eight turbine units at Glen Canyon Dam was undergoing maintenance. The concept of replication of the 2004 BHBF test hydrograph in a future test is aimed at determining whether or not the robust sandbar-building responses that occurred under the 2004 BHBF test will occur consistently each time a BHBF test is released under sand-enriched conditions. It also allows scientists to evaluate whether there are incremental cumulative benefits to sandbar conservation in lower Marble Canyon and Grand Canyon reaches each time enriched high-flow experiments occur.

If the results from replicating the 2004 BHBF test hydrograph under sand-enriched conditions in the spring (following several months of downstream transport under the 1996 Record of Decision operations) are as good or better (more uniformly distributed sandbar responses under conditions of more uniformly distributed sand supply downstream) than those measured during the 2004 BHBF test, then this approach may be interpreted as being a sustainable strategy for longer term habitat restoration and maintenance using only downstream sand supplies. Such a replicated, positive result would also indicate that the more natural timing for flood disturbance in spring can be accomplished as well, while conserving new sand inputs before they are exported to the upper Lake Mead delta. On the other hand, if a different BHBF test hydrograph is released in the next test and the results are not as good as 2004 BHBF test results, then the lack of replication will make it very difficult to determine whether the response was due to the different BHBF test timing and supply conditions or to the different hydrograph.

Because the 2004 BHBF test hydrograph design was tied to sandbar and eddy simulations made on the basis of measured channel topography and sediment transport data, and because the 2004 BHBF test did result in robust sandbar building in the reach (upper Marble Canyon) where the sand supply was locally enriched, it seems reasonable to return to this hydrograph design for a future BHBF test to confirm its effectiveness.

### **ISSUE 4: WHAT WOULD BE THE PROS AND CONS OF A SHORTER-DURATION BHBF TEST PEAK AT 41,500 CFS (FOR INSTANCE, 30 HOURS)?**

Discussions among scientists and managers about alternative duration (shorter than the 60-hour peak tested in 2004 BHBF test) peak flows for future high-flow experiments have been ongoing during recent planning activities. There are many factors to consider related to peak-flow duration and peak magnitudes for high-flow experiments (see Table A.2, below).

**ISSUE 5: IS THERE A RISK OF A POTENTIAL TAKE OR IMPACT (OF A FUTURE BHBF TEST) ON JUVENILE HUMPBAC CHUB? HBC RECRUITMENT?**

Based on the spring season for a future BHBF test and the results of fisheries studies conducted in association with the 1996 BHBF experiment in Grand Canyon, there appears to be little risk to juvenile humpback chub associated with a future spring BHBF test. The abundance of juvenile humpback chub in the mainstem Colorado River is driven, in part, by freshet events in the Little Colorado River. Because the proposed timing of a future BHBF test is generally tied to late winter or early spring, scientists at the GCMRC expect few freshet events and therefore few juvenile humpback chub to be present in the mainstem Colorado River. This alone will reduce the number of humpback chub vulnerable to potential displacement or mortality because of a future BHBF test. Following extensive sampling to measure abundance of fish before and after the spring 1996 BHBF experiment, catch-rate metrics showed insignificant differences before and after the experiment for most fish (Valdez and others, 2001). The exceptions were a significant decrease in the abundance of small-bodied nonnative fish and a significant increase in the abundance of speckled dace. Additionally, results from telemetry and diet work suggest minimal behavioral or feeding disruptions of adult humpback chub and flannelmouth sucker associated with the spring 1996 BHBF experiment. Relative abundance of juvenile native fish was also estimated before and after the 2004 BHBF experiment downstream of the Little Colorado River confluence (GCMRC unpublished data; Coggins and others, 2005). Unfortunately, the results of the fall 2004 study were highly inconclusive owing to elevated turbidity following that 2004 BHBF test because of flooding activity in the Little Colorado River. These conditions rendered catch-rate observations taken before and after the experiment unreliable, likely due to changes in sampling gear efficiency.

The findings associated with the 1996 high-flow experiment that native fish are little affected by high-flow events are consistent with theory and other published studies. Meffe (1984) found that adapted native fish species tolerated elevated discharge associated with freshets better than introduced species. Brouder (2001) found that age-1 native roundtail chub increased or remained high in years following a late winter/early spring flood. Indeed, this differential tolerance to flooding has been suggested as a nonnative control method (Minckley and Meffe, 1987). Though these studies view high discharge events as potential displacement mechanisms rather than direct sources of mortality, there is no evidence that humpback chub recruitment would be directly hindered by a future BHBF test. On the contrary, one hypothesis is that potential humpback chub recruits might enjoy higher survival rates because of increased food resources (see experimental study 3 description, this plan) and decreased negative interaction with nonnative fishes (Valdez and others, 2001). Though it is certainly valid to hypothesize that a future BHBF test could hinder recruitment by imposing some direct or indirect mortality source, there is presently insufficient data to arbitrate among these competing hypotheses.

**ISSUE 6: CONCERNS ABOUT INSUFFICIENT FUNDS TO ADDRESS HBC ISSUE (RELATIVE TO A FUTURE BHBF TEST).**

The GCMRC believes that funding is not the major impediment to studying the effects of a future BHBF test on humpback chub. The major challenge is attempting to evaluate changes in distribution and fate of humpback chub without the appropriate techniques and/or technology to field a viable study (see Appendix B).

**ISSUE 7: WILL THERE BE NEGATIVE IMPACTS (FROM FUTURE BHBF TESTING) TO THE FOOD BASE? WILL IT CLEAN OR REFRESH THE SYSTEM?**

We are uncertain about these important questions. While we know that the biomass (a static measure) of food base components is temporarily reduced following a future BHBF test, little is known about the effect of a future BHBF test on productivity (a dynamic process measure). The GCMRC's working hypothesis included in the BHBF science plan is that after the initial reduction in food following a future BHBF test, daily production and turnover of algae, invertebrates, and possibly fish are higher than before

the BHBF test. This positive response by the food base may offset the initial negative effects such that there is little net loss of material and productivity when viewed on slightly longer time scales (months to a year). This knowledge gap is precisely why at least one additional BHBF test is needed to pin down quantitative answers for the important questions raised above.

**ISSUE 8: WHAT ARE THE IMPACTS (OF A FUTURE BHBF TEST) TO HYDROPOWER AND OTHER ECONOMIC INTERESTS (I.E., FISHING GUIDES AND RIVER GUIDES)?**

Comprehensive studies to assess the economic impacts of conducting a future BHBF test have not been conducted and therefore, the full range of economic impacts cannot be definitively determined with available information. Based on the recent economic assessment by the Western Area Power Administration for the experimental options study (conducted in 2006 by the AMWG's Science Planning Group), there would be some short term but significant economic impacts for hydropower in the form of lost revenue generation opportunities (loss of potential marketable power because of water bypassing the generators during a future BHBF test). There would also be some immediate short-term gains resulting from running the generators at full capacity during a future BHBF test, though not sufficient to offset future lost opportunity costs. In terms of recreational economic interests, there are likely to be short-term impacts to the local fishing guide economy during and probably immediately following a future BHBF test. Based on the proposed timing and duration of the event, however, and considering the hypothesized response of the aquatic food base over the long term (short-term decline followed by relatively rapid rebound and potentially increased productivity), the economic impact to recreational fishing is uncertain and yet to be studied. Projected economic impacts to commercial river runners, on the other hand, are likely to be very minimal to non-existent, because the proposed timing of a future BHBF test is before the start of the commercial boating season. The larger question that remains to be determined, and that is most critical for assessing the overall economic implications of a high-flow experiment, is whether the combined potential economic impacts of conducting a future BHBF test outweigh the potential resource benefits and societal value derived from conducting the experiment. The GCDAMP is currently lacking up-to-date, comprehensive valuation data with which to address this larger economic question. A more comprehensive study of the economic impacts of conducting future BHBF experiments could be considered during development of the Long Term Experimental Plan.

**ISSUE 9: BHBF EXPERIMENTS RESULT IN A LOT OF SEDIMENT BELOW DIAMOND CREEK, RESULTING IN ECONOMIC CONCERNS FOR THE HUALAPAI NATION. ADDITIONALLY, THERE IS AN ARCHAEOLOGICAL SITE BELOW GLEN CANYON DAM THAT GOING TO BE HARMED AND UNLESS THERE IS A PLAN FOR THAT SITE.**

In recent years, with the lowering of Lake Mead because of drought and ongoing water withdrawal, formerly submerged sand deposits at the head of Lake Mead have become increasingly shallow, creating serious challenges for down-lake navigation. Also, the exposure of formerly submerged sandbars has cut off access to a formerly popular take-out point at Pierce Ferry. The Hualapai Tribe is concerned that a high-flow experiment could exacerbate these current problems by displacing sand from the main channel into areas used as harbors and launch sites by their boat operators. At Diamond Creek and other eddies immediately downstream, sand is very likely to be transferred into the eddies (this is why the previous 2004 BHBF test built sandbars and benefited camping beaches in a reach where new sand inputs were located). Assuming the lake remains low, a future BHBF test released into Lake Mead is also likely to generate a strong current in the upper part of the lake, which would remobilize some of the channel-clogging sediment and help to redefine a clear channel through the sandbars in the upper part of the lake, but whether and to what degree sediment would be re-deposited in specific shoreline locations used by the Hualapai Nation tour operators, and whether it would have negative consequences for these commercial operations, is unknown. What is known with certainty is that a future short-term BHBF test will not solve,

nor will it significantly exacerbate, the long-term issue of sediment build-up in upper Lake Mead with its concomitant implications for future navigability.

The second part of the comment expresses concern about possible negative impacts of a high-flow experiment to archaeological sites, particularly one site located in the Glen Canyon reach. In 1996, before the first BHBF experiment, the Bureau of Reclamation funded a series of studies to evaluate and mitigate potential effects of high-flow experiments on cultural sites in the river corridor. Following completion of these compliance-driven studies, the Arizona State Historic Preservation Office issued a formal determination of "no adverse effect" for experimental flows up to 60,000 cfs (Nancy Coulam, personal comm., December 7, 2006.). Recently, a team of archaeologists and one geomorphologist from the Navajo Nation Archaeology Department (NNAD) completed a geomorphic evaluation of all archaeological sites in the Glen Canyon reach, and they concluded that one site (AZ C:2:32) has the potential to be eroded by a future BHBF test. During the 1996 mitigation work, there was considerable uncertainty as to whether this site was truly cultural, but the recent re-evaluation by NNAD confirms that this is a potentially significant archaeological site containing deposits dating to the late Archaic period, approximately 3,000 years BP. The NNAD archaeologists recommend that a portion of this threatened site adjacent to the river be excavated before conducting a future BHBF test. A draft mitigation plan has been prepared for the Bureau of Reclamation to implement, if warranted. The author of this draft plan estimates that mapping and excavation of the site could be accomplished over two 10-day field sessions with an 8-person crew (Kim Spurr, personal comm., January 22, 2007.)

**ISSUE 10: TIME IS CONSTRAINED BY THE POSSIBILITY OF ONE DAM UNIT BEING DOWN FOR MAINTENANCE AFTER MARCH.**

From our understanding of the proposed annual maintenance schedule at Glen Canyon Dam, we do not see a problem with having one of the eight turbine units at the dam non-operational annually through March during a future BHBF test, although having eight units fully operational would be optimal for sediment studies. A future BHBF test is not currently proposed for later than March.

**Table A.1.** Summary of pros and cons associated with conducting a future BHBF Test

<b>GENERAL CONCERNS</b>	<b>PROS</b>	<b>CONS</b>	<b>UNCERTAINTIES</b>
AMP RESOURCES	<ul style="list-style-type: none"> <li>• Probable sandbar restoration and conservation of related physical habitats</li> <li>• Probable improvement of recreational camping sites</li> <li>• Probable enhancement of sediment transport to and mitigation of erosion at some archeological sites through secondary wind deposition</li> <li>• Creation of backwater habitats used by native fishes</li> <li>• Mimics seasonal flood disturbance to river ecosystem</li> </ul>	<ul style="list-style-type: none"> <li>• Lost hydropower capacity and revenue owing to bypass and monthly volume re-scheduling</li> <li>• Possible impact to a cultural site in Glen Canyon (to be mitigated)</li> <li>• Impact to Kanab ambersnail habitat (endangered species) at Vasey’s Paradise (to be mitigated)</li> <li>• Increased use of motorized watercraft during Colorado River Management Plan non-motor season in Grand Canyon National Park (to be mitigated through public outreach)</li> </ul>	<ul style="list-style-type: none"> <li>• Aquatic food abundance</li> <li>• Impacts and/or benefits to humpback chub remain uncertain</li> <li>• Impacts on rainbow trout fishery</li> <li>• Impacts on native and nonnative terrestrial vegetation</li> </ul>
SCIENCE (Learning by Doing)	<ul style="list-style-type: none"> <li>• Advances learning about options for achieving GCDAMP Priority Goals, especially sediment, trout fishery, food base, cultural resources and riparian habitat</li> <li>• Provides information about optimal BHBF hydrograph design to maximize benefit and minimum costs?</li> <li>• Informs interested public</li> <li>• Information transfer to other scientists and managers working on river restoration</li> </ul>	<ul style="list-style-type: none"> <li>• None</li> </ul>	<ul style="list-style-type: none"> <li>• None</li> </ul>
EXP BUDGET	<ul style="list-style-type: none"> <li>• Credible subset of studies can be implemented to address high-priority needs</li> </ul>	<ul style="list-style-type: none"> <li>• Available funding is currently insufficient to implement all proposed studies</li> </ul>	<ul style="list-style-type: none"> <li>• None</li> </ul>

GENERAL CONCERNS	PROS	CONS	UNCERTAINTIES
ECONOMIC	<ul style="list-style-type: none"> <li>• Infusion of local economic activity linked to science support, etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Foregone hydropower capacity in later timeframe (to be quantified by BOR/WAPA)</li> <li>• Potential short-term disruption of Lees Ferry angling recreation</li> </ul>	<ul style="list-style-type: none"> <li>• Financial impact is not yet fully quantified</li> <li>• Non-use values derived from resource effects are not known?</li> </ul>
INFLUENCE ON ANNUAL WORK PLAN	<ul style="list-style-type: none"> <li>• Shifts emphasis from solely monitoring to EXP research learning activities in a given year</li> <li>• New information will better inform GCDAMP process</li> </ul>	<ul style="list-style-type: none"> <li>• Number of non-experimental planned activities will need to be delayed/deferred</li> <li>• Impacts timing of some normal monitoring activities</li> </ul>	<ul style="list-style-type: none"> <li>• Full impact on a given typical annual work plan schedule is not completely known?</li> </ul>
NO HIGH-FLOW EXPERIMENTS (BHBF) ALTERNATIVE (SCIENCE/RESOURCE PERSPECTIVE)	<ul style="list-style-type: none"> <li>• Would not impact annual work plan tasks of monitoring</li> <li>• Monitoring data on downstream fate of new sand supplies under modified low fluctuating flow (MLFF)</li> <li>• No hydropower impacts</li> </ul>	<ul style="list-style-type: none"> <li>• No opportunity to benefit sand and related physical habitats (such as backwaters that may benefit juvenile humpback chub)</li> <li>• Already have abundant data on export of sand under MLFF, hence little new learning would occur</li> <li>• No opportunity to learn more about how BHBFs may limit sand export under fluctuating flows that follow</li> <li>• Missed opportunity to gather data on BHBFs as related to strategic, experimental questions about sand conservation and effectiveness of BHBFs to meet Goal #8 objectives</li> <li>• BHBFs are dependent on meeting the sediment input trigger</li> </ul>	<ul style="list-style-type: none"> <li>• There is great uncertainty about when conditions in the future will trigger an enriched high-flow experiment owing to the fact that sand inputs from the tributaries cannot be predicted</li> </ul>

**Table A.2** Science questions related to priority AMWG/AMP information needs that are addressed in the proposed BHBF science plan

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### **SEDIMENT**

- Is there a “flow-only” operation that will restore and maintain sandbar habitats over decadal timescales?
- What is the minimum duration for BHBF tests needed to build and maintain sandbars under sand enrichment?
- Do sandbars deposited by BHBF tests contribute to preservation of archaeological sites in the river corridor?
- How do post-BHBF flows affect the persistence of sandbars and related backwater habitats?

### **HUMPBACK CHUB**

- Do BHBF tests result in creation of near-shore habitats (i.e. backwaters) that can offer physical benefits to humpback chub and other native fishes?
- Do BHBF tests affect the distribution and movement of nonnative fishes?

### **CULTURAL RESOURCES**

- Do sandbars deposited by BHBF tests contribute to preservation of archaeological sites in the river corridor?
- Do BHBF tests contribute to added stability or erosion of archaeological sites located in close proximity to the river?
- How does the abundance and distribution of native and nonnative riparian species important to Native American tribes change in response to a future BHBF test?

### **OTHER PRIORITY ISSUES**

- **Food base:** How will a future BHBF test affect food production and availability for rainbow trout in the Lees Ferry reach? What are the effects of BHBF tests on aquatic food production? How do these effects impact native fishes?
  - **Lake Powell:** Will the next BHBF test result in higher nutrient releases and shrinking of the hypolimnion? Will the operation of the river outlet works and the penstocks at capacity measurably alter Lake Powell hydrodynamics or stratification, or alter release water quality?
  - **Riparian vegetation:** Are open patches more susceptible to exotic species colonization and establishment than sites with existing vegetation following a disturbance?
  - **Kanab ambersnail:** Will the next BHBF test reduce habitat at Vasey’s Paradise in a way that impacts the ambersnail population?
  - **Camping beaches associated with sandbars:** Can the next BHBF test increase campable areas at sandbars on a sustainable basis?
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**Table A.3.** Comparison of a 60-hour to 30-hour peak duration BHBF Test at 45,000 cubic feet per second (cfs)

<b>High-flow peak duration at 41,500 cfs</b>	<b>~ Glen Canyon Dam bypass volume (Hours)</b>	<b>PROS</b>	<b>CONS</b>
<p><b>OPTION A</b> 60 hours (as determined by BHBF model simulations and recommended by sediment scientists)</p>	<p>~ 93,000 acre feet (91 hours)</p>	<ul style="list-style-type: none"> <li>• Provides most rigorous direct comparison with 2004 BHBF test data</li> <li>• Maximum sandbar restoration predicted from modeling to occur in this timeframe</li> <li>• Resulted in net positive sand balance in 2004 BHBF test</li> <li>• Allows field scientists time for replicate eddy and SS measurements</li> <li>• 108 hours shorter than 1996 BHBF test</li> <li>• Greatest influence on exporting low oxygen from hypolimnion of Lake Powell</li> </ul>	<ul style="list-style-type: none"> <li>• Bypass volume is larger than suggested alternatives (below)</li> <li>• Highest impact on hydropower</li> <li>• Highest impact on recreational users</li> </ul>
<p><b>OPTION B</b> 30 hours (alternative BHBF test hydrograph)</p>	<p>~ 56,000 acre feet (61 hours)</p>	<ul style="list-style-type: none"> <li>• Reduces bypass volume</li> <li>• Reduced impact on hydropower</li> <li>• Reduced impact on recreational users</li> <li>• Reduces potential export of new sand supply relative to option A</li> </ul>	<ul style="list-style-type: none"> <li>• Potentially limits benefits to downstream sandbar restoration</li> <li>• Limits data capture potential</li> <li>• Shorter BHBF tests result in less influence on exporting low oxygen from hypolimnion of Lake Powell</li> </ul>

## Appendix B. GCMRC responses to policy comments received during the review of the draft BHBF Science Plan

Comment Number	Page / Line	Reviewer Name and Affiliation	Reviewer Comments (Be specific)	Identify Action Requested	Response Requested	GCMRC Response / Action Taken
2	General 1	Palmer, Western	The options considered by AMWG consisted of a "package" of actions and experiments. The purpose for packaging several things together was to achieve beneficial results for HBC while protecting or improving other resources. How a BHBF, as a stand-alone activity, fits into a broader experiment isn't known. The development of a draft science plan for a BHBF (s) is useful for its eventual inclusion into an LTEP, but we believe it must remain a draft document until it is incorporated into an LTEP. Western is reluctant to recommend a stand-alone action. We must understand how it fits with actions/experiments in a "package" arrangement.		Y	The GCMRC understands WAPA's position, however the Center was directed by the Secretary's designee to continue this plan development in the meantime and report back to the AMWG with an integrated BHBF Science Plan. GCMRC believes much could be learned about the affects of a BHBF whether conducted as a stand-alone activity or part of the LTEP.
3	General 1	Palmer, Western	There are several policy issues embedded into the science plan that have not been addressed by the AMWG. In this draft of the science plan, the GCMRC has helped to identify these issues (although not specifically identifying them as policy issues). This draft therefore, can serve as the catalyst for an AMWG policy discussion. We believe this discussion should occur as part of completing the science plan. We will identify these policy issues specifically below.		Y	This comment recommends that policy issues must be resolved before a science plan can be completed. The GCMRC respectfully disagrees with this position and believes that the science plan can be completed, leaving policy decisions to be resolved at a later date. As the GCMRC has been requested to develop an "off the shelf" science plan by the Secretary's Designee, we believe that these policy issues should be resolved by the AMWG/DOI – after which GCMRC will modify the science plan according to these policy directions.
4	General 1	Palmer, Western	There should be criteria to evaluate the success of a BHBF experiment. This is needed for the experiment as a whole, for the research questions and for the individual experimental studies.		Y	Evaluating BHBF test results generally requires clear definition of what is desired. The GCDAMP could be of great assistance by defining specific resource goals. Even in the absence of clearly defined goals, the two previous BHBF tests were essential in helping scientists determine how a number of CRE resources respond to such operations. When the AMWG provides more details on what is desired for

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						sediment conservation, then results from BHBF tests can be more clearly interpreted by scientists. The current sediment evaluation strategy in the draft plan is intended to address the overarching “flow only” sediment question in a manner that can be useful in answering this question – even without the future desired conditions fully known.
14	General 1	Henderson, GCNRA	The fate of Glen Canyon should be discussed within the context of this BHBF work plan, i.e., what do we assume for this reach?			Again, there is a clear need for managers to identify the future desired condition of sediment and other resources. Scientists may then be able to identify what options are available (if any) for achieving such conditions through the use of BHBFs and other measures.
44	4 / 19-35	Palmer, Western	This is a clear description of the “end game” for BHBF experimentation. Western believes that this is a policy issue. Specifically: the “repeated BHBF tests under multiple sand enrichment scenarios” for the purpose of “cumulative increases in systemwide sandbar area and volume over decadal time scales” should be considered in a policy venue.	AMWG discussion	Y	The GCMRC would appreciate getting further input from the AMWG on this and other related policy issues. The science can help inform this discussion, but we agree that this is primarily a policy question. If multiple BHBFs are not a viable policy option decision makers will have to determine a different strategy for long term sediment conservation...
45	4 / 25	Palmer, Western	The strategy of attempting to build sandbars through multiple BHBFs in an attempt to achieve “cumulative increases in systemwide sandbar area and volume over decadal time scales” is described as only being “feasible” if the “intervening power plant releases do not completely erode the sand deposited in sandbars” by the BHBF. While the science plan doesn’t specify what degree of fluctuation is incompatible with this “strategy” and infers that this question is a subject of scientific exploration, we cannot ignore past statements and attitudes related to this. Repeatedly, in public presentations and conversations, GCMRC scientists have recommended very restrictive operations in order assure the success of the “strategy” described here. Specifically, in the science workshop held at GCMRC in April, one of the GCMRC sedimentologists recommended steady flows and another; relatively steady, low volume releases in between BHBF tests. Western feels that very restricted fluctuations will be recommended by BHBF planners once a science plan is completed and the details of a specific		Y	The science questions for this draft BHBF science plan were derived from other plans that have been approved by AMWG such as the 2007-11 Strategic Science Plan. Hence, revision of the science questions within those core documents would be needed before the questions in the BHBF Science Plan are revised. In addition, the Monitoring and Research Plan is currently being revised to include two additional strategic science questions related to sediment – specifically one about the fate of eddy stored sand between BHBFs and another about the influence of ramping rates on sandbar stability and sediment transport. Both of these science questions were derived from the Knowledge Assessment report on the basis of the July 2005 workshop.

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			<p>plan are developed. We feel that significant restrictions on power plant fluctuations are incompatible with the “big picture” goals. To be more compatible with the “big picture” goals, we feel that the science plan specify an experiment in which BHBF tests are combined with fluctuating flows in order to conduct an experiment to see if sediment goals can be accomplished within the context of the “big picture” goals. This actually occurs in the project goal for Experimental Study 1.B. (page 21), where the goal is stated as “determination of the optimal BHBF hydrograph shape for a given sand-supply condition to achieve sandbar resource management goals, while minimizing negative impacts to other resources (e.g., hydropower).” To make this change, the key science question and the “strategy” will need to be modified. We provide more detail below.</p>			<p>Sediment transport modeling development proposed in this BHBF plan and in the annual work plans in FY07-08 are also intended to provide information about “big picture” questions, such as how quickly sandbars may deposit under a range of flow and sediment supply conditions related to BHBFs, as well as how effectively fluctuating flows might distribute new sand inputs downstream through the reaches of interest prior to a BHBF release.</p>
51	5 / 8	Davis, CREDA	<p>Why is it important to continue this scenario (emphasis sand conservation in Marble Canyon) rather than the reverse? More resources and those of legal import are below Marble so why are we doing so much to help this area if by doing so it harms resources downstream? There is only vague reference to native fish survival, cultural resource protection, and habitat enhancement yet no reference to sand protection to provide beaches for recreational boating.</p>	<p>Justification for sand preservation in Marble is missing. If the prime reason for sand protection &amp; enhancement is beaches for boaters, then state it so we can make decisions for BHBFs based on real reasons.</p>	Y	<p>Managers previously have indicated that Marble Canyon is a priority for sand bar conservation, due largely to concern about the limited number of camping opportunities in this reach (see also the comment from WAPA immediately below.). Also, current information suggests that humpback chub may have overwintered in the vicinity of river mile 30, so establishment of more shallow, protected habitats through building of sand bars and backwaters may also be of benefit to native fishes in the Marble Canyon reach. If sand may be conserved, even for a limited time, it may be available for more habitat building at a later time. This is a hypothesis worth testing.</p> <p>One of the objectives of a future test is to determine whether or not a more uniform sandbar rebuilding response is possible by allowing tributary sand time to redistribute more uniformly downstream before the BHBF test. In development of this science plan, the GCMRC assumed that sediment resources are important throughout the Colorado River ecosystem.</p>

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58	5 / 26	Palmer	The new (sediment) trigger is a characteristic of a policy-related issue. Based on the findings of the 2004 BHBF test, as described on page 5, an increase in sandbar total area volume occurred in the upper half of Marble Canyon. This would seem to be a positive finding for this reach. Since this reach was described in the '96 GCD –EIS as a “critical” reach for beaches, it may be that one or more of the BHBF “goals” was reached. The question remains regarding what the canyon-wide goals, if any, may be.	AMWG discussion/ decision	Y	The GCMRC would appreciate getting further input from the AMWG on this and other related policy issues.
63	5 / 41	Barger, Western	I don't support the statement that repeated experiments might occur more frequently. This implies that each time the trigger is met, there could be a BHBF. I see this as making a policy recommendation and this should be removed.		Y	This statement is made in the context of a science recommendation that the TWG and the AMWG might consider in resolving such a policy issue – depending upon how quickly managers would like to resolve the main “flow only” sediment science question. The sediment scientists suggest that this question may be answered in a relatively short period if testing occurs repeatedly after the LTEP design is resolved. Delaying tests will simply delay the full evaluation of the BHBF concept as a tool for achieving sediment objectives.
73	7 / 42-46	Davis, CREDA	Quantification of what is optimal sandbar volume has not been done and we are left with the notion that simply ‘more is better.’ Conservation to some previous level is listed as a goal without definition.	A BHBF designed merely to produce more volume for sandbars in the upper ½ of Marble and why simultaneous effort for sand bars in the lower canyon is of lesser value should be better justified.	Y	This is true and the lack of measurable goals has limited the scientists’ in their evaluation of previous BHBF tests. The GCMRC agrees that management needs to better identify the resource objectives for sand bar rebuilding. With better defined goals, GCMRC could report gains and losses in relation to a target number. The only goal we currently have to work with is that “more is better.”

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78	9 / Fig 1.2	Palmer, Western	<p>The following should be added to this decision tree:</p> <ul style="list-style-type: none"> <li>- the first box includes only a sediment trigger. In fact, prior to another BHBF test, Western and Reclamation will need to assure that funds are available to cover electrical contractual obligations – a financial trigger. Also, a BHBF will need ESA compliance. We'd like to have that completed so that decision makers know what commitments of resources are required from the action agencies as mitigation and/or conservation measures prior to recommending a BHBF test – an ESA trigger. Perhaps these added triggers can be described as precursors to “following” the decision tree in Figure 1.2. In any event, they will need to be determined and added to the plan.</li> <li>- the lower left-size box should eliminate “changing intervening operations” (if what is meant is further restriction) and should add, “increased peak magnitude, timing or hydrograph shape.”</li> <li>- the second box should be changed to measure the changes in camping beaches and back-water habitats (see our comment below).</li> </ul>			<p>The GCMRC suggests that such issues be resolved through discussions between TWG and AMWG members and then the requested revisions could be made through a more collaborative process tied to whatever the stakeholder group recommends for future BHBF implementation. The current diagram is mostly tied to understanding of how sediment dynamics occur in response to the BHBF; As the TWG/AMWG and DOI develop Desired Future Conditions tied to BHBF evaluations, this diagram could be revised with more detail to become more meaningful to all involved in future BHBF testing. The current figure is meant to be mostly conceptual and intended to highlight the primary science evaluations that need to be made relative to experimental BHBF actions... Sediment scientists believe that this generic approach to answering the “flow only” sediment question is reasonable.</p> <p>The BHBF plan could be revised to include additional triggers, but those would presumably need to come from the TWG/AMWG/ Management Agencies</p>
87	10 / 30-36	Palmer, Western	<p>Reference is made to the '95 EIS. The ROD allows a BHBF only when a hydrological trigger is reached. This ROD restriction exists in order for BHBFs to be implemented in accord with legal restrictions. BHBFs have twice been tested in the past to test the utility of BHBFs as management actions to be implemented in under the ROD constraints. This restricts the timing of a BHBF to the “forecast” and “run-off” season. In line with our comment #1 (above), the policy issue is how the AMWG would (or would not) recommend a deviation from these criteria for testing purposes. For example, the “Cook-Moody” proposal, passed by the AMWG in 1998, recommended a test of a BHBF with a magnitude of 60 k cfs (when hydrologically triggered).</p>	AMWG Discussion/ decision	Y	<p>The GCMRC concurs with the suggestion that this issue be discussed by the AMWG, after careful review of the meeting minutes relating to the “Cook-Moody” proposal, purportedly passed by the AMWG. It is, however, unclear to the GCMRC where on page 10 the language referred to in this comment occurs?</p>

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101	13 / Table 1.2	Palmer, Western	Sediment is an intermediate resource and has utility to the extent it accomplishes two things: 1) it maintains and/or increases camping beaches in critical reaches and 2) it maintains and/or increases backwater habitats. It may therefore be less than useful to have a focus on questions related to mass balance. This may or may not be the same as the “sandbar fate” study that is directed at eddy sandbars. If backwater habitats are a subset of eddy sandbars, we suggest evaluating whether a BHBF maintains or increases backwater habitats only.(to be clear, if a BHBF proves to “conserve” sediment inputs, but in locations that do not provide HBC habitat, we would suggest that the BHBF did not achieve the management objectives). This comment is in line with the AMWG science questions on page 11. We suggest that the focus of the gathering of data and the analysis be on the HBC questions.	AMWG Discussion/ Decision	Y	The GCMRC concurs with the suggestion that this issue be discussed by the AMWG as soon as is feasible. We also propose adding a spring backwater/near shore sampling effort to help address the reviewer’s concerns. Without defined management objectives, we cannot say if they have been achieved or not.
169	52 / 11	Warren, Western	Similar to our ESA comment above, what is required of the NPS for permitting purposes should be worked out in advance so that decision makers know what the requirements are. In addition, logistical limitations need to be known in advance so that decision makers know if significant science activities will be suspended or lost as a result of the BHBF test.		Y	The GCMRC encourages future discussion of this topic among the appropriate agencies to work out the details related to permitting, compliance, and logistical challenges for future BHBF testing. This is a science plan, not a compliance document. GCMRC would be happy to work with management agencies if there are technical questions regarding compliance matters.
170	52 / 38	Davis, CREDA	The conduct and timing of the science trips are well known to the NPS by their participation on the AMWG. Also, how does the conduct of a BHBF during the winter non-motorized season fit with the NPS policy especially since 9 trips will be taken over a 3-month period?	It seems appropriate and feasible to routinely obtain such permits well in advance of any potential BHBF (6 weeks seems too tight) to allow NPS adequate time and avoid any delays.		May have to request exceptions to non-motor rules depending on timing.

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171	66 / 38-40	James, CREDA	See also comment 3 above. How many times does a particular BHBF need to be performed to “confirm its effectiveness,” if the 2004 test “did result in robust sandbar building in the reach (upper Marble Canyon)”?		Y	This question will need to be jointly discussed between scientists and managers on the basis of the 2004 test results, as well as after the next such test. Management will need to decide how much certainty is needed before future BHBFs can be implemented as managed actions. Scientists are still trying to determine that BHBFs under sand enriched conditions can lead to repeated sand bar building and maintenance, but the desired future conditions are still nebulous.
175	68 / 26-35	James, CREDA	Disagree that economic impact assessment has “not been conducted and can not be definitively determined with available information”.	Suggest rewording as follows: Specific studies to assess the economic impacts of conducting future BHBF experiments need to be undertaken following determination of a specific experimental plan and timetable.”	Y	The analysis completed in conjunction with the experimental flows option analysis in fall, 2006 was a financial impact analysis, not a complete economic analysis. Furthermore, the financial impact analysis that was completed was limited in breadth and scope, due to there not being sufficient specificity about the frequency or timing of proposed BHBFs for each option and with varying hydrological scenarios. A more comprehensive study of economic impacts of conducting future BHBF experiments could be considered during development of the Long Term Experimental Plan.