Description and Summary Evaluation of Two Proposed Experimental Options for the Colorado River Ecosystem during Water Years 2007 – 2011

For Consideration and Discussion by Members of the Glen Canyon Dam Technical Work Group at their May 24-25, 2006 Meetings

Prepared by the Grand Canyon Monitoring and Research Center in Cooperation with Members of the Science Planning Ad Hoc Group through its affiliation with the Glen Canyon Dam Adaptive Management Work group

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SECTION I – Background on Experimental Planning

Background: The Glen Canyon Dam (GCD) Adaptive Management Program (AMP) has been evaluating the Modified Low Fluctuating Flow (MLFF) regime for 10 years. Recent findings presented at the Glen Canyon Monitoring and Research Center's (GCMRC) 2005 Science Symposium and during the recent Technical Working Groups (TWG) Knowledge Assessment Workshop indicate that Glen Canyon Dam flows that are different from the MLFF during certain times of the year are likely to move the Colorado River ecosystem (CRE) in the Grand Canyon closer to the stated purposes of the Glen Canyon Dam Environmental Impact Statement (EIS) preferred alternative, and to protect and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established.

Purpose: Identify a suite of flow and non-flow actions that will be implemented or tested in FY 2007-2011. The experimental plan provides the foundation for 5-Year Monitoring and Research Plan and FY 2007-08 Biennial Work Plan.

- General Goals of Each Experimental Option
- Improve resource conditions
- Enhance understanding (learning) of relationship between proposed action and target resources.

Experimental Options Evaluated by SPG: Five experimental options were developed cooperatively by GCMRC and the SPG:

1. Continue evaluating MLFF in spring/summer/ fall, with winter ramping experiments and Beach Habitat Building Flows (BHBF) in winter/spring.
2. Continue evaluating MLFF in spring and summer, w/ winter ramping experiments and BHBF in winter/spring and stable flows in September and October.
3. Increased fluctuating flows in summer and winter, BHBF in fall, and implementation of a wide-ranging suite of management actions.
4. Seasonally adjusted steady flows throughout the year, possible spring BHBF and implementation of a limited suite of management actions.
5. Seasonally adjusted steady flows implemented incrementally over a period of 6 years, possible spring BHBF, and implementation of a limited suite of management actions.

Option 1 was dropped by the SPG in favor of Options 2 and 3. A concerted effort was made by the SPG to combine Options 2 and 3 that evolved into SPG Option A. Option 4 was dropped in favor of Option 5, which became SPG Option B. Each option consists of flow and non-flow treatments and activities that are intended enhance understanding (learning) of relationship between proposed action and target resources while also benefiting CRE resources. The descriptions included here were based on input from SPG members and/or agreements arrived at during SPG meetings. The suite of treatments associated with each experimental option is intended to be implemented at the earliest opportunity, beginning as early as Water Year 2007.

No-Action Alternative: The No Action Alternative would involve a continuation of the MLFF operation pursuant to the 1996 Record of Decision (ROD).

Assuming a continuation of 8.23 million acre foot annual releases, the No-Action Alternative would consist of daily release patterns very similar to flows that have occurred during Water Year 2006. Daily peak flows would be highest in summer months of July and August, with peaks of between 17,000 and 19,000 cfs, while the lowest peak flows would occur in shoulder season months during spring and fall. Peak flows in winter months, such as December through February, also be similar to operations that occurred in WY 2006.

The No-Action Alternative would allow for continued monitoring and evaluation of experimental treatments that were implemented during Water Years 2003 through 2006, (such as BHBF and alternative fluctuating flows during winter). Continuing MLFF would also provide an additional period of time to monitor and evaluate the effects of (a) significantly warmer summer and fall releases from the dam in 2003-2006 and (b) a reduced population of rainbow trout (RBT) on humpback chub (HBC) survival and recruitment. Additional management actions or experiments, such as BHBF, translocation of HBC or non-native fish management could be undertaken under the No-Action Alternative.

Summary Comparison of Experimental Options A and B: Major elements of SPG Options A and B are shown in a side-by-side comparison in Table 1.1. For purpose of description, each option is assumed to be implemented in association with minimum annual releases from GCD of 8.23 million acre feet. However, either of the options could be implemented under higher (or lower) annual releases.

Table 1.1. Side-by-Side Comparison of Flow and Non-Flow Treatments Proposed within Experimental Options A and B.

Flow/Non-Flow Treatment, Management Option or Conservation Measure	Option A Enhanced Fluctuating Flows (10 months), in combination with ecologically stable flows (2 months), w/ Enriched BHBF (winter/spring)	Option B Stable Flow Testing, initially in summer/fall (4 mos.), eventually moving toward Seasonally Adjusted Steady Flows in all months, w/ Enriched BHBF(winter/spring)
Implement Expanded Fluctuating Flows Testing	Yes, (all months except in September and October)	None (all releases within ROD operating constraints)
Stable Flows	Yes, but Sep.-Oct. Only	Yes, (4-12 months each year)
Beach/Habitat-Building Flow (41,000 to 45,000 cfs, 1-3 days, in spring)	Yes, (in April following sand enrichment from major tributaries)	Yes, (in April following sand enrichment from major tributaries & depending Native Fish considerations)
Ramping Rate Studies	Yes (November – August)	None (ROD ramping rates)
Tests of Exotic Fish Control, (Warmwater & Coldwater)	Yes, as needed	Yes, as needed
Build & Test (Selective Withdrawal Structure)	Yes	Yes
HBC Translocation	Yes	Depends on Further Analysis
HBC Refuge(s)	Yes	Depends on Further Analysis
HBC Population Augmentation Planning	Planning efforts toward Implementation (as needed)	No activities toward this action

SECTION II - Experimental Option Summary Descriptions

DESCRIPTION OF EXPERIMENTAL OPTION A

Introduction: SPG Option A provides for increased fluctuating flows in summer and winter, BHBF in winter/spring, and implementation of a wide-ranging suite of management/ experimental actions. Option A emphasizes achieving resource improvements using a suite of flow and non-flow actions: HBC conservation would be provided through exotic fish control, augmentation planning, translocation, Selective Withdrawal Structure (SWS) operation, annual steady flows (in September and October) and BHBF tests conducted under tributary enriched supply conditions. Increased fluctuating flows in winter and summer would be targeted at: 1) increasing hydropower generation during periods of high energy demand, 2) enhancing aquatic food base production and delivery of organic drift for potential diet to RBT an HBC, and 3) improving rainbow trout fishery below GCD. Option A also proposes several short-term experiments (such as LCR confluence ponding) to promote learning about the effects of dam operations on CRE resources.

The SPG reached the following agreements with respect to the elements of Option A:

Continued Testing of Beach/Habitat-Building Flows with a New Trigger: Experimental BHBF would occur under a new “sediment trigger.” The trigger for the a BHBF would be: 1) 0.5 million metric tons of sand is introduced by the Paria River and retained above RM 30; and 2) an additional "weighted" one million metric tons of sand is delivered by the Paria River, Little Colorado River (LCR) or lesser tributary sources in-between. To calculate the weighted input, sand from the Paria River is given full value, and sand from the LCR and other sources is valued at 50% of the actual input. Under this new trigger, the sand supply from the LCR can be factored into future sediment experiments, but there is a check on implementing a BHBF test solely on the LCR inputs to avoid scouring eddies upstream in the Marble Canyon reach.

BHBFs would also be implemented subject to the following guidelines (not rules):

- Special steady flows are not required to retain sand until the trigger is achieved
- Adequate funding is available to research and monitor effects
- Adequate water is available
- BHBF tests would not result in unacceptable, adverse impacts (e.g., tamarisk reproduction, impact HBC, food base)
- BHBF’s would promote ecological integrity of the CRE

The SPG agreed that decision guidelines for such test flows should be flexible enough to allow for BHBF research to occur on a frequent basis that allows potential benefits from repeated tests under tributary sand enriched conditions to be fully evaluated. The specific scope/objectives of effort would be based on a GCMRC proposal/plan for testing and implementing the BHBF based on new sediment trigger and BHBF guidelines.

Stable Flow Testing: The SPG asked some fundamental questions relating to future proposals for testing steady flows: “What are “steady flows?” and “Is there a range of fluctuations that is ecologically insignificant.   The SPG agreed that the GCMRC would be requested to develop a proposal to test ecologically steady flows in September, October, and possibly November to improve HBC survival and recruitment. Tests would be targeted at defining an ecologically steady flow, the level of steady flow, and the effect of a short duration spike (e.g., 1 hr/5000 cfs) to benefit food base drift. Another flow element agreed upon was that the river can not drop below 7,000 cfs. While steady flows in August may be important to young-of-year (YoY) HBC in the main stem and to minimize export of sand following tributary input, they were not included in Option A because of adverse impacts to power generation.

HBC Augmentation Planning will be included as an element Option A. Planning activities would include developing a captive brood stock/refuge population, a genetics management plan, a stocking plan, and identification of production/grow out facilities in preparation for possible need for future augmentation (as determined by Fish and Wildlife Service (FWS)). Augmentation planning was viewed as a prudent and needed safe guard in case of catastrophic loss associated with possible negative effects of the Experimental Program (e.g., SWS and the related potential proliferation of warm and cool water non-native fish).

Power Costs Analysis: Western Area Power Administration (WAPA) committed to provide estimated power costs and methods of calculation for each option for review by the Science Advisors prior to the SPG/TWG meeting in May.

Selective Withdrawal Structure: Option A includes construction of a SWS by 2011 or sooner if possible. The goal of the SWS will be to maintain ecological integrity in the CRE, coldwater trout fisheries in Lees Ferry reach, and improve main stem habitat for HBC and other native fishes. The issue of how many units to implement to achieve desired effects (i.e., are two units enough?) was unresolved and presumably would be addressed in the NEPA process.

Mechanical Removal: The scope of a the mechanical removal effort will be based on the GCMRC proposal/plan for developing, testing, and implementing methods for control of problematic non-native fishes in main stem below Lees Ferry and tributaries targeted for translocation/control. The GCMRC's plan will be coordinated with Grand Canyon National Park's efforts to remove brown trout from selected tributaries. Special attention is needed to develop public support for continuing the mechanical removal effort

Experimental Design: Option A would be implemented using a forward titration experimental design in next 5-year phase with review in 2011(or when Temperature Control Device (TCD) becomes operational) to determine appropriate actions and experimental design for the future. Actions and experimental design in the later phases of experimentation will be determined by the response of HBC and sediment to the actions implemented in the next 5 years.

Option A envisions the implementation of all of the actions described in Table 2.1. Some of these actions are ongoing while others would be implemented as soon as feasible or following appropriate research and planning. The effect of the management actions described here would be monitored, to the extent possible, throughout the program's implementation. Program implementation would be subject to change if scientific information and analysis was gathered that suggested an adverse effect of the program on the HBC population or other priority CRE resources.

Proposed Modifications To The Modified Low Fluctuating Flow Regime

The Glen Canyon Dam EIS Record of Decision identified the MLFF alternative as the future operational regime for Glen Canyon Dam. Proposed experimental fluctuating flows associated with Option A, include alternative operations that allow a 2X increase in the hourly down-ramping rate (3,000 vs. 1,500 cfs/hr.) during the months of November through August. In addition, daily ranges in fluctuations are allowed to expand to 10,000 or 12,000 cfs/day versus the current limit of 8,000 cfs. Months that are subject to the largest increase in daily stage are associated with winter and summer peak energy demands. January would have a daily range of 12,000 cfs, while July and August would have a daily range of 10,000 cfs rather than 8,000 cfs. Under Option A daily fluctuations would be greatest in January (5,000 to 17,000 cfs), but also relatively high in February (5,000 to 15,000 cfs), July, and August (both 8,000 to 18,000 cfs). In water years with annual volume greater than 8.25 million acre feet, release patterns consistent with the proposed pattern described here would be developed.

Proposed "Mini" Flow Experiments

In addition to the proposed daily, weekly, and annual pattern described above, Option A include a number of other experiments that would be conducted including are non-native fish management flows (e.g., summer stranding flows) and tests of the effects of ramp rate on sediment transport. The specifics of the flows that would be tested in these experiments would be subject to adaptive management as discussed below.

Summer Stranding Flows - The conceptual design of a summer stranding flow to control survival/recruitment of larval and YoY trout was proposed by Korman et al. (2005).

Korman et al. (2005) observed that YoY trout generally occupied the daily minimum flow elevation even after flows rose during the day, and thus avoided stranding when flows fluctuated. They noted substantial decreases in density following the early September reduction in the minimum daily flow from 10,000 to 5,000 in 2003 and 2004. Based on their observations and a review of the literature, they identified that the factors that affect the extent of stranding include channel morphology, substrate, fish size and age, species, time of day, exposure frequency, season, temperature, and the rate of stage change. The extent of stranding has been observed to be highest in low-angle habitats, such as Lees Ferry, with abundant cover. Small brown trout (50 cm) have been shown to be more vulnerable to stranding than larger juveniles. Stranding rates tended to increase at lower water temperatures and were highest if flow reductions occurred during daylight hours. A decrease in the down-ramping rate from 60 cm/hr. to 10 cm/hr was shown to reduce stranding of brown trout YoY by 50%.

Based on these observations, they hypothesized that if higher flows were maintained for an extended period of time, young fish would eventually move to those higher elevations. Thus, an effective stranding flow would be one that maintained elevated flows (e.g., 15,000 cfs) for 2 or 3 days and was followed by a very sharp drop in flows to a minimum flow level (e.g., 7,000 cfs). The most effective timing of such a flow would be when large numbers of YoY trout are present, (i.e., June, July, or August).

Table 2.1. Experimental Program Elements Associated with Option A, 1998 to 2011.[1] [1]Orange indicates element not implemented, green indicates element is implemented during a particular year. MLFF = modified low fluctuating flow alternative, BHBF = Beach/Habitat Building Flow. [2]Modifications relative to ROD flows include lower minimum flows during weekdays, but relatively higher minimum flows on Sundays with flows never dropping as low as ROD flows on Sundays; faster downramp rates; and experimentation with summer stranding flows and fall flows. [3]Adaptively managed to be shifted to control of warmwater nonnative species as necessary.

Water Year	Dominant Dam Operation	Mechanical Removal	Temperature Control Device (TCD)	Beach/Habitat Building Flow	Humpback Chub Comprehensive Plan Research	Humpback Chub Comprehensive Plan Habitat
2003	MLFF with experimental fluctuating flows	Trout removal	No TCD	No BHBF	No activities	No activities
2004	Same as previous	Same as previous	No TCD	No BHBF	No activities	No activities
2005	MLFF with experimental fluctuating flows and fall testing	Same as previous	No TCD	Fall BHBF	No activities	No activities
2006	Modified MLFF w/Ecologically Stable Flows in September and October [see text for description][2]	Trout and possibly warmwater species removal[3]	Complete Draft EIS/BO	Spring BHBF dependent on sediment input from Paria and Little Colorado Rivers	Research and development of augmentation approach	Expansion of humpback chub habitat (e.g., translocation to Colorado River tributaries)
2007	Same as previous	Same as previous	Complete FEIS/BO	Same as previous	Same as previous	Same as previous
2008	Same as previous	Same as previous	Initiate construction	Same as previous	Same as previous	Same as previous

Water Year	Dominant Dam Operation	Mechanical Removal[3]	Temperature Control Device (TCD)	Beach/Habitat Building Flow	HBC Comprehensive Plan Research	HBC Comprehensive Plan Habitat
2009 Knowledge Assessment	Same as previous	Same as previous	Continue construction	Same as previous	Continue research or begin implementation if appropriate	Same as previous
2010	Same as previous	Same as previous	TCD operations	Same as previous	Same as previous	Same as previous
2011	Same as previous	Same as previous	Same as previous	Same as previous	Same as previous	Same as previous
2012	Same as previous	Same as previous	Same as previous	Same as previous	Same as previous	Same as previous

Despite the expectation that a summer stranding flow could be effective in controlling trout numbers, and thus competition with and predation of HBC, a number of uncertainties exist that would be evaluated during experimentation. For instance, an observed reduction in small fish following a sharp drop in flows could reflect transport out of the reach rather than mortality. Stranding mortality of YoY fish ultimately may not affect the size of the adult population if survival at this life stage is not a limiting factor for the population or if compensatory mechanisms effectively negated the effect of increased mortality. There is also the potential for stranding of native fish species. These factors would be evaluated during stranding experiments.

Ponding Flows - Ponding flows are those relatively high mainstem flows that produce a quiet water area near the mouth of the Little Colorado River. This ponded area gives young humpback chub a place to grow before they enter the harsher conditions of the main channel Colorado River. It has been hypothesized that this area is important to increasing the survival of young humpback chub. The timing of ponding flows has generally been considered for the spring. Although ponding flows have been provided in the past, their effectiveness has not been demonstrated and is considered very uncertain. Ponding flows could be considered for incorporation into the proposed long-term experimental program especially in high water years or in years when equalization releases are needed.

Electrical Power Production Experiments - The 1996, ROD flows were intended to improve the status of a variety of resources in the CRE. The operational parameters of these flows were conservatively chosen to ensure that the anticipated benefits to these resources would be achieved, and operational parameters were to be reexamined and modified as appropriate through an adaptive management process. However, there has been very little experimentation directed at the operating parameters themselves. For example: would a factor of two increase in the down-ramp rate have a measurable and deleterious effect on sediment retention of Marble Canyon beaches? Does an increase in the daily variation (25 to 50 percent) produce additional drifting food for trout and humpback chub? Can New Zealand mud snails be reduced by a higher daily variation?

As part of Option A, short-term experimentation is proposed with operational parameters. This would likely include the modification of more than one operating parameter at a time since recent analysis show very little power benefit from the liberalization of just one parameter. These experiments could be conducted at any time of the year; however, they may be concentrated in the winter months when the most benefit to power resources might be achieved with little harm to other resources.

Proposed Non-Flow Management Actions and Anticipated Effects

Selective Withdrawal Structure -- Before Glen Canyon Dam was constructed, the seasonal cycle of the Colorado River included a natural warming trend in the late summer as the water temperature would increase from the near freezing winter temperature to approximately 29^{o}C. Since the dam was constructed, the temperature of the water released has become relatively steady at between 7 and 10°C because the water is drawn year round from the deep, fixed-level penstock intakes. Near the dam, these cold releases are tolerated by the trout fishery, but as this water moves downstream, it only warms to about 15.5°C which is not warm enough to allow humpback chub to reproduce in the mainstem of the Colorado River. Cold summertime water from these hypolimnetic releases can inhibit hatching and survival of eggs and larvae and it is believed that juvenile HBC (<50 mm TL) can experience thermal shock as they descend into the mainstem Colorado River from seasonally warmed tributaries.

Recent drought conditions have resulted in warmer releases as reservoir elevations have dropped. However, without a TCD, increasingly cooler release temperatures are expected. The Science Advisory Board has recommended a pilot program to install selective withdrawal structures on two of the units at Glen Canyon Dam. Option A includes implementation of this recommendation over the next 5 years (Table 2.1). However, because analyses indicate that placing temperature control devices on only two-units may not be sufficient to increase the temperature of the river to levels that will promote reproduction by HBC, Option A proposes that consideration be given to the planning and compliance work needed to construct selective withdrawal structures on enough units to increase water temperature below the LCR to levels that would improve the survival of larval and juvenile HBC.

Because increasing water temperatures in the mainstem Colorado River could potentially improve conditions for some warmwater non-native fishes that compete with or prey on HBC, additional experimentation would be warranted. The goal would be to determine the appropriate combination of cold and warmer water withdrawals needed to benefit the native endangered fish, while controlling benefits to warmwater non-native fishes in the system.

Humpback Chub Augmentation Planning- Option A includes a variety of HBC augmentation planning activities for the FY 2007-2011 period, including developing a captive brood stock/refuge population, a genetics management plan, a stocking plan, and identification of production/grow out facilities in preparation for possible need for future augmentation (as determined by FWS). Establishment of a captive broodstock would provide a genetic refuge for humpback chub. However, releasing propagated individuals from this broodstock into the wild could pose biological risks such as genetic introgression, inbreeding depression, domestication, and a potential to decrease the effective population size of the wild population (Van Haverbeke and Simmonds, 2004). To mitigate a potential catastrophe and as part of developing a captive broodstock program, a captive broodstock management plan would be developed now, an adequate facility for holding fish would be identified, and a stocking plan would be developed. Humpback chub currently being held at Willow Beach National Fish Hatchery could serve as a starting point for such a program (Van Haverbeke and Simmonds, 2004).

In addition, consideration would be given to developing grow-out ponds, where larval or juvenile fish could be held in a predator-free environment until they are large enough to survive and be reintroduced into the CRE. The fish to be maintained in these ponds could originate from captive adults spawned in captivity as part of a broodstock program or could be obtained by capturing wild larvae or juveniles.

Efforts to Increase the Geographical Extent of Occupied Humpback Chub Habitat in the Colorado River Ecosystem - In order to expand the areas inhabited by HBC and to protect the Grand Canyon population of HBC from potential catastrophic events in the Little Colorado River, it has been proposed that YoY humpback chub be translocated to other Grand Canyon tributaries.

Translocation activities were initiated in the LCR during August 2003 and August 2004, by capturing YoY humpback chub in the lower portion of the LCR and moving them to locations in the LCR upstream of Chute Falls (a natural barrier to upstream migration). Results of monitoring indicate that at least some of the translocated fish survived and grew well in the upper portion of the LCR (Sponholtz et al. 2005). This resulted in an expansion of the inhabited range of HBC by 4 km and there were indications during 2005, that some of the translocated fish were in spawning condition. It is not yet known whether offspring were produced by these fish. Expansion of the population above Chute Falls, while potentially beneficial, would not remove susceptibility of the population to a catastrophic event in the Little Colorado River.

Initial efforts to expand translocation activities would include research and field experimentation to identify candidate streams and to determine where translocated fish would be likely to survive. Although the goal would be to produce a fully self-sustaining HBC population outside the LCR, even establishing additional areas that contain fish that do not reproduce would result in improved protection for HBC in Grand Canyon. It is anticipated that monitoring would be required to evaluate the success of translocation efforts, to track the status of translocated fish, and to improve knowledge about the biological requirements of humpback chub.

Some initial work has been done to rank potential tributary sites (Stevens 2005) based on a variety of criteria. These criteria included the presence of barriers to fish movement, the abundance of non-native predators, abundance of native fish, habitat suitability (e.g., temperature regimes), perceived ability to remove non-natives, and jurisdictional issues. Compared to the LCR, which presently contains the best known available conditions for YoY humpback chub, the tributaries that ranked the highest were Bright Angel Creek and Shinumu Creek.

Mechanical Removal of Non-native Fishes - The presence of non-native fishes in habitats occupied by HBC is considered one of the major threats to survival of HBC populations in Grand Canyon. In addition to implementing selected flow-related actions to reduce the numbers of non-native fishes in occupied areas, advocates for Option A, believe that mechanical removal actions should also be conducted.

Since January 2003, mechanical removal using electrofishing has been conducted on an experimental basis in the Colorado River. The current mechanical removal efforts, which are ongoing, target a 24-km reach of the Colorado River that extends from 8 km upstream to 16 km downstream of the LCR. These efforts have been primarily intended to remove rainbow and brown trout, which are known predators of juvenile HBC. Over 16,000 trout were removed from the treated reach of river during 2003 and 2004 and there are indications that the abundance of trout within the reach dropped by over 50% during that time (Coggins and Yard, 2005).

In addition to electrofishing, weirs or other fish-trapping methods could be used to remove trout from tributaries. This technique may be useful for controlling trout spawning in Colorado River tributaries by removing adult trout as they move into tributary spawning areas. In 2002, a feasibility study was initiated in Bright Angel Creek, a known spawning tributary used by brown trout, to evaluate trout capture potential using a weir. During the 64 days the weir was in use, 423 brown trout and 188 rainbow trout, ranging in size from 210 to 620 mm, were captured (SWCA Environmental Consultants, 2005). This study indicated that fish-trapping methods could be an efficient and cost-effective way to remove non-native salmonids from native fish habitat and to reduce trout spawning success in tributaries. If Colorado River tributaries, such as Bright Angel Creek, are selected as sites for introducing translocated HBC juveniles (see above), such methods could be extremely valuable for reducing the numbers of non-native fishes in the tributaries or for controlling access by non-native fishes.

As part of Option A, it is proposed that mechanical removal efforts be continued as part of the long-term integrated experimental program, on an as-needed basis. If water temperatures increase as a consequence of natural conditions (e.g., low flows and low reservoir elevations) or because of the construction and operation of a temperature-control device, there is a possibility that warmwater nonnative fish species could expand to areas currently utilized by YoY HBC. To combat such expansions, mechanical removal efforts should be adapted, as necessary, to target other species, in addition to trout, that are identified as being the dominant predators and competitors with HBC.

DESCRIPTION OF EXPERIMENTAL OPTION B

The approach used to develop Option B, was to first determine the priority resources and values for experimentation by using legal and policy guidance, and an analysis of status and trends of park values. The next step was to identify the threats that limit the abundance and distribution of these resources. Finally, Option B includes an experimental approach that: a) addresses the threats; b) tests alternative management scenarios that are scientifically credible and likely to succeed in reversing declines in park values; c) provide sufficient contrast and duration to draw reliable conclusions; and d) could be implemented in the future to meet the intent of the Grand Canyon Protection Act.

Priority resources - A thorough review of legal and policy documents as well as the status and trends of park resources and values, it is clear that the distribution and abundance of humpback chub and the distribution and abundance of sediment resources are park values that have undergone significant declines in the CRE. An analysis of the status and trends of these resources suggests that the key research questions are: a) how can resource managers restore rearing habitat for humpback chub in the mainstem?; and b) how can resource managers maintain a positive mass balance of sand?

Threats - The most significant threats to the distribution and abundance of humpback chub appear to be changes in water temperature, daily flow fluctuations, non-native predators, competitors and parasites, and range contraction. The most significant threats to the distribution and abundance of sediment resources appear to be the loss of mainstem sediment inputs, daily flow fluctuations, and flow magnitude.

Experimental approach (WY 2007 to WY 2013) - From Water Year 2007 through WY 2013, the proposed Option B design tests the effects on humpback chub and sediment of equalized monthly volumes with ROD fluctuations (Flow A), combinations of steady and constrained fluctuating flows of different duration (Flows B & C), as well as seasonally-adjusted steady flows (Flow D). Flows B, C, and D are replicated (factorial design).

In addition to testing the effects of these flows on sediment abundance and distribution, and humpback chub abundance and distribution, Option B includes a rigorous evaluation of these flows on other resources, including the food base, recreation, and cultural resources. The flow regime included in Option B is expected to benefit theses resources (e.g. the food base as a result of stabilized flows, recreation as a result of increased quantity and quality of camping beaches, cultural resources as a result of counteracting erosion with increased aeolian transport of sediment).

Additional Non-Flow Treatments - In addition to these flows, Option B, advocates for non-native species control as needed through WY 2013. Other non-flow management actions such as the translocation of humpback chub to other tributaries and the development and management of an off-site genetic refuge at Willow Beach (and/or other sites) are still open to risk analysis and a discussion of the options available to meet the perceived need. Option B does not include *humpback chub augmentation, but does focus on taking steps to improve habitat below the dam. The flows associated with Option B, are summarized below in Table 2.2, and the following text.*

Table 2.2 Option B - Summary of flows for WY2007 to WY2013.

Dates	Flow	Monthly volume[1]	Discharge (cfs)[2]	BHBF[3]
October 2006 to July 2007	A	700	ROD fluctuations (7500-13,500)	No
August 2007 to November 2007	B	620	Steady (10,000)	No
December 2007 to July 2008	C	720	Constrained fluctuations (⦸ 4000 daily)	One or more if triggered
August 2008 to November 2008	B	620	Steady (10,000)	No
December 2008 to July 2009	C	720	Constrained fluctuations (⦸ 4000 daily)	One or more if triggered
August 2009 to March 2010	B	620	Steady (10,000)	No
April 2010 to July 2010	C	820	Constrained fluctuations (⦸ 4000 daily)	One or more if triggered
August 2010 to March 2011	B	620	Steady (10,000)	No
April 2011 to July 2011	C	820	Constrained fluctuations (⦸ 4000 daily)	One or more if triggered
August 2011 to March 2012	D	620	Steady (10,000)	No
April 2012		1060	Steady (14,285)	One if triggered
May 2012		800	Steady (13,300)	No
June 2012		790	Steady (13,160)	No
July 2012 to March 2013	D	620	Steady (10,000)	No

[1] Monthly volume is based on the assumption of an 8.23 maf release year. If more than 8.23 maf will be released, then discharge will be adjusted proportionally so that monthly volumes remain approximately equal.
[2] Minor fluctuations are allowed for AGC purposes.
[3] BHBF are 41,000 to 45,000 for 1-3 days depending on research objectives.

April 2013		1060	Steady (14,285)	One if triggered
May 2013		800	Steady (13,300)	No
June 2013		790	Steady (13,160)	No
July 2013 to September 2013		620	Steady (10,000)	No

Flow A (Equalized monthly volumes) - This block tests the level of sediment accumulation under equalized monthly volumes and ROD flows. Equalizing monthly volumes eliminates months with high sediment export rates, maintains a higher minimum flow throughout much of the year for increasing food base productivity, and retains daily fluctuations for load following. These flows will allow testing of the hypothesis that stable near-shore habitats will support growth and recruitment of young humpback chub. No BHBF will occur in conjunction with these flows.

Flow B (Short-term steady flows) - These blocks test whether four or eight months of steady flows are sufficient to provide humpback chub rearing habitat in the mainstem. The blocks begin in August when the highest numbers of young-of-year normally enter the mainstem. The steady flows provide a stable near-shore environment and an increase in water temperature (especially in backwaters). These flows will allow testing of the hypothesis that stable near-shore habitats will maximize food base productivity, but be low enough to allow for sediment accumulation. No BHBF will occur in conjunction with these flows.

Flow C (Constrained fluctuations) - Fluctuations are constrained to reduce sediment transport and still allow growth in the food base while providing some fluctuations to reduce impacts on hydropower generation. These flows will allow testing of the hypothesis that stable near-shore habitats will support growth and recruitment of young humpback chub.

During these flows, a BHBF will occur immediately once the sediment input trigger is met. The trigger is met when: 1) 0.5 million metric tons of sand is introduced by the Paria River and retained above RM 30; and 2) an additional "weighted" one million metric tons of sand is delivered by the Paria River, Little Colorado River or sources in-between. To calculate the weighted input, sand from the Paria River is given full value, and sand from the LCR and other sources is valued at 50% of the actual input. However, a BHBF will not occur if there is a high risk of unacceptable negative impacts (this criterion will be quantified if possible) to young-of-year humpback chub residing in the mainstem.

Experimentation with limited duration "supply conditioning" fluctuating flows may occur before the BHBF to test whether prescribed fluctuations will more evenly distribute the sediment input and thus conserve a larger proportion of the accumulated sediment. In addition, if a subsequent sediment input trigger is met during the same block of experimental flows, then another BHBF test will immediately occur.

Flow D (Seasonally-adjusted steady flows) - These flows are designed to mimic, in part, a natural hydrograph. A BHBF will occur in April of 2012 and 2013, when it is likely to have the least impact on young-of-year humpback chub and other native fish. The BHBF is contingent on the accumulation of 1.5 million metric tons of tributary supplied sand in Marble Canyon. No “supply conditioning” fluctuating flows will occur.

Experimental approach (WY 2014 and beyond) - For experimentation starting in WY 2014, proponents of Option B, advocate a timely reassessment of the status and trends of park values, as well a reassessment of our knowledge of the effects of flows, temperature and non-native control and further testing (as needed) of both daily and seasonally variable flows, temperature (using a SWS), BHBFs, and non-native control in a factorial design. Based on the modeling results evaluated to date, Environment favors a pilot SWS with three or four units to maximize the duration of warm water when YoY humpback are the most vulnerable to the negative effects of cold water.

SECTION III

Estimated Impact Of Option A And B On The Colorado River Ecosystem

The two experimental options described above were evaluated by the GCMRC staff and cooperating scientists relative to their operational flow elements and predicted influence on: 1) downstream water temperature, 2) suspended-sand transport, 3) hydropower economics, 4) river stage variation, 5) stability of shoreline habitats, 6) productivity of the food web, 7) drift, 8) recreational camping and 9) potential for wind-blown sand to mitigate erosion of cultural sites located above the active fluctuating zone (5,000 to 25,000 cfs).

Throughout the experimental planning process, attempts were made to use best-methods and simulation capabilities to predict how key resources would be influenced by the various experimental operations being proposed. Although quantitative estimates were attempted for Options A and B, with respect to suspended-sand transport in March 2006, the estimated costs and benefits to hydropower associated with Option A were derived from a projected annual hydrograph that was significantly different than the one used to estimate the sediment transport values. Because the economic benefit estimated for Option A was associated with an annual hydrograph that was not similar to data for Option A, comparisons of the two experimental options are presented here in only a very general way.

Estimate of Influence on Downstream Water Temperatures

Flow Patterns - The reduced peak fluctuating flows associated with Option B results in lower flow velocities for water released from Glen Canyon Dam, and therefore promotes more downstream temperature increases in late summer and fall months than flows associated with Option A. In addition, stable flows in summer months, such as August, associated with Option B, promote increased warming in late summer months when dam releases tend to be at their annual warmest. Summer flows under Option A are not stable until September, October, and possibly November so Option B tends to provide more potential for both downstream warming and stability in late summer when young-of-year native fish could be flushed from the Little Colorado River into the main channel habitats by summer spates. Near-shore aquatic habitats, such as backwaters are thought to warm most efficiently under more stable flows, while fluctuating flows tend to disrupt warming by diurnal filling and draining the water in them.

Selective Withdrawal Structure - Estimating effectiveness of Selective Withdrawal Structure operation has been recently undertaken by Reclamation. On the basis of the simulations run for historical hydrology for Water Years 1992 through 1994, release temperatures from Glen Canyon Dam appear vary from about 7 to approximately 22 degrees Celsius annually under the proposed SWS design. The degree to which release temperatures are elevated also appears to vary relative to hydrology and storage conditions in Lake Powell, as well as the total number of units (2 vs. 4 vs. 6 vs. 8 of 8) that are retrofitted with external intake structures at the dam. While all of the simulations for these historic hydrologic conditions achieve a release temperature of 15 degree Celsius with a minimum of two of the eight units operated with SWS, the duration over which that temperature can be sustained can be expanded under certain hydrologic conditions through addition of SWS's on all eight units (WY 1994 simulation). Under the hydrologic conditions of WY 1993, little if any increase duration of warming was associated with simulated releases between 2 and 8 SWS's. Operation of a variable number of SWS's in combination with either diurnally varied or stable release patterns also influences the degree to which dam releases are additionally warmed at water moves downstream through the ecosystem.

Estimate for Suspended-Sand Transport

Option A - On the basis of recent sand-transport data collected below Glen Canyon Dam, sediment scientists (S. Wright and D. Topping, personal communication) estimate that the operational releases associated with Option A would result in a relative, moderate increase in suspended-sand transport compared to Record-of-Decision operations that have occurred under 8.23 MAF annual releases since 2000. Although sand transport would be elevated during winter and summer months, when experimental fluctuating flows were enhanced, sand transport would also be reduced in the months of September and October, under "ecologically" stable flows. The net, overall influence of the combined operations is predicted to increase annual sand transport, but not dramatically when compared with ROD operations. While tributary sand inputs would likely accumulate in the main channel during fall months with ecologically stable flows associated with Option A, recent monitoring data suggest that average to below average sand inputs would be quickly exported downstream during peaking operations in summer and winter under Option A. Elevated sand transport of newly input sand supplies during November through December fluctuating flows could possibly help in distributing new sand deposits on the bed of the main channel more evenly downstream throughout reaches, such as lower Marble Canyon and Eastern Grand Canyon prior to High-Flow testing after December when sediment triggers are met. This concept must be field tested, as the idea of a more uniform sand bar restoration response following tributary sand inputs and a limited period of fluctuating flows with daily peaks between 14,000 and 16,000 cfs, is a hypothesis.

Option B - On the basis of recent sand-transport data collected below Glen Canyon Dam, sediment scientists (S. Wright and D. Topping, personal communication) estimate that the operational releases associated with Option B would result in a substantial reduction in suspended-sand transport during the initial year (*Flows A*) of Option B, and an even greater reduction in sand-transport for years in which seasonally-adjusted steady flows (*Flows D)* occur, compared to ROD operations that have occurred under 8.23 MAF annual releases since 2000. Monitoring data collected since 1999 suggest that tributary sand supplies would likely accumulate within the main channel under Option B experimental operations in all months of the year. Accumulation of annual tributary sand inputs prior to implementation of BHBF's was an original strategy identified in the 1995 final EIS on Glen Canyon Dam operations for restoring sand bars and related habitats.

Relative Estimates for Costs and Benefits to Hydropower

Option A - On the basis of some very preliminary economic modeling conducted by Western Area Power Administration, an attempt is made here to characterize the relative costs and benefits to the hydropower resources, with respect to the Colorado River basin fund. Only general, relative comparisons are presented here for the costs and benefits of Options A and B.

For purposes of simple comparative analysis, the benefit to the hydropower resource associated with Option A is defined as +X. The estimated costs to hydropower associated with Option B will be therefore described as –nX.

Relative to the ROD, operations associated with Option A are thought to provide benefit to hydropower by reducing the extent to which the Colorado River basin fund must currently be used to purchase replacement power to meet customer need. This benefit is associated with the ability to more optimally follow customer demand throughout the day during high-demand months associated with winter and summer.

The annual benefit to hydropower under Option A of +X is somewhat limited by the proposal to release "ecologically" stable flows during the months of September and October during each experimental year. The benefit to hydropower during the remaining ten months of the year is derived from the ability to test an hourly downramp rate that is twice as large as what is normally allowed under the ROD (3,000 cfs/hr vs. 1,500 cfs/hr), in combination with the ability to exceed the daily range of the ROD by 25 to 50 percent in months of peak energy demand (ranges of 10,000 to 12,000 cfs in some winter and summer months).

Option B - Proposed experimental operations associated with Option B impose additional costs to the hydropower resource by increasing the need to use the Colorado River basin fund to purchase replacement power during months when flows are steady or when fluctuating operations are constrained beyond what the ROD would normally allow to meet customer energy demand.

An estimate of the increased replacement power costs associated with the initial years of implementing Option B (*Flows A and B*) are approximately -3X, or three times greater than the benefit associated with Option A, with respect to reduced impact to the Colorado River basin fund. An estimate of the increased replacement power cost estimates associated with the final years of implementing Option B when flows are held stable throughout the year (*Flows D*), are approximately -6X, or six times larger than the estimated economic benefit associated with Option A, with respect to increasing replacement power costs and impact to the Colorado River basin fund. These relative cost/benefit assessments do not include the influence of BHBF releases.

Estimate for the Increased Daily Stage Variation

Option A - Estimates were made for the additional difference in daily minimum river stage that would occur as a result of summer (August) operations associated with Option A versus daily lows that would occur under the Record-of-Decision diurnal operations. Comparison of Option A and ROD flows indicates that the difference in stage for daily flows in late summer would be increased by 1.7 to 2.6 feet, depending on river width and river mile. Implications of increased daily variations in stage associated with Option A are somewhat uncertain with respect to influence on native fishes. Such increased fluctuating daily range may increase drifting organic matter, but the operation may be limiting in the overall primary and secondary productivity of the ecosystem.

Option B - has periods of fluctuations that result in daily stage variations that are typical of ROD operations in shoulder-season months (6,000 cfs) during implementation of *Flows A*, under 8.23 MAF releases. A decrease in the variation of daily stage to 4,000 cfs per day occurs toward the end of *Flows A* and throughout *Flows B and C*. Otherwise, Option B mandates flows that are stable in all other periods except for times that BHBF's occur.

Stability of Shoreline Habitats

Option A – experimental operations in this alternative provide for "ecologically" steady flows each year, but only during the months of September and October. During these fall months, stage varies by about 2,000 cfs per day.

Option B - Flows associated with Option B provide for stable shoreline habitats 4 out of 12 months a year when *Flows A* occur, with additional stable flow months being progressively added as the experimental option is continued through *Flows B and C*. Ultimately, during *Flows D*, all flows are stable, except during short periods in the spring when BHBFs are released following sediment input triggers. Overall, Option B experimental operations provide for greater shoreline habitat stability through time and initially result in more stable shoreline habitats throughout the ecosystem during late summer and fall months (August through November) compared to stage changes that occur under Option A (ecologically stable flows in September and October, only).

Productivity Associated with the Aquatic Food Web

Option A has wider-ranging daily changes in stage during winter and summer months compared to either the ROD or Option B, but limits daily low stages in summer to 7,000 cfs. Increased fluctuations may result in lower aquatic productivity as compared to option B. The limits on daily low stages in summer (7000 cfs) may mitigate some of these impacts.

Option B - Although some uncertainties remain in this area of resource response, generally, it is estimated that more stable flows should result in greater overall productivity below the dam. A more constant submerged environment allows more aquatic macrophytes to establish and grow. Hence, Option B is predicted to result in increased food base initially under limited fluctuations from spring through July and stable flows in August into fall. Large operational changes from August to September are avoided. Option B operations would presumably result in increasingly greater aquatic productivity as flow stability is increased throughout spring, summer and fall seasons. Conversely, relatively less aquatic productivity would be derived from implementation of operations associated with Option A where fluctuations are larger than ROD in July and August.

Transport of Drifting Organics

Option A – for a given level of productivity, fluctuating flows are likely to promote more drifting organic matter from upstream to downstream than will typically occur under more stable flows. However, the overall, long-term abundance of drifting material downstream is most likely limited by the overall productivity. For organic material to be present in the drift it must first be produced.

Option B – has more limited fluctuations than in Option There remains uncertainty about what the overall influence of Options A and B would be compared with ROD operations. While implementation of either of the experimental options would provide new opportunities to resolve this uncertainty.

Recreational Camping Areas

Option A - wider daily ranges in fluctuating flows during summer and winter months will generally reduce the area of sand bars that are available for camping (above the daily peak flow stage for any given amount of sand bar abundance throughout the ecosystem).

Option B - provides more limited daily ranges and will therefore result in larger camping areas being available for recreational uses.

Cultural sites and terrestrial vegetation associated with sand deposits

Minimizing the extent to which daily flows vary with respect to stage may allow for larger portions of near-shore sand bars to remain desiccated throughout the year. Once sand deposits are dried out and remain dry, wind transport of sand and silt may occur in directions that transport fine sediment upslope in to cultural site preservation areas. Sandy, near-shore habitats along the river that are subjected to repeated wetting and drying are often the sites of colonization and establishment of terrestrial vegetation, both native and non-native. Colonization of new plants in these near-shore settings may help stabilize sand deposits, but may also reduce the degree to which wind can redistribute sand upslope to higher locations where cultural preservation sites are eroding.

Option A – with wider daily stage changes, more area of any given sand bar will tend to be inundated and wetted more frequently. The wet areas of the sand bar may be exposed to influence of blowing wind during the part of each day when the river stage is at its minimum, but the potential for sand grains to be windblown will be limited compared to similar exposure of the sand bar under dry conditions.

Option B – more highly constrained fluctuating flow operations provide more stable flow conditions than either those of Option A or the ROD, and therefore may result in more wind-transported sand (for any given shoreline sand bar abundance) being carried into cultural sites if sand deposits are abundant nearby at lower elevation (presumably, maintained by successful restoration and maintenance influences of period BHBF implementation under enriched sand-supply conditions).