United States Department of the Interior
U.S. GEOLOGICAL SURVEY
GRAND CANYON MONITORING AND RESEARCH CENTER
2255 NORTH GEMINI DRIVE, MS-5000
FLAGSTAFF, ARIZONA 86001
520 556-7094 Telephone
520 556-7092 Fax

March 25, 2002

MEMORANDUM

To: Adaptive Management Work Group

From: Barry D. Gold, Chief, GCMRC

Subject: Experimental Flows Recommendation

At the Adaptive Management Work Group (AMWG) meeting on January 18, 2002, the AMWG passed a motion instructing the GCMRC, in consultation with the TWG, to design an experimental flow sequence for WY 2002 – 2003. The document attached to this memo contains that recommendation. Rather then recommend a single treatment, GCMRC is recommending a treatment for WY 2002 – 2003 that should be considered in the context of a multi-year program of treatments, rather than a single year flow scenario. The decision to develop the WY 2002 – 2003 recommendation within the context of a program of experimental flows is motivated by the desire of GCMRC to forward a recommendation that embraces a defensible experimental design and is consistent with the principles of ecosystem science and adaptive management.

The treatment being recommended by GCMRC for WY 2002 – 2003 is intended to: (1) decrease downstream export of tributary input sediment from Marble Canyon, (2) increase retention of sediment through Beach/Habitat-Building Flows (BHBFs), (3) improve survival and recruitment of HBC by reducing competition and predation from non-native fish (primarily rainbow trout) and (4) improve and maintain habitat for young native fish.

Within the recommended experimental flow scenario for WY 2002 – 2003 GCMRC is recommending a series of treatments, depending on the timing of and whether or not one gets significant sediment inputs, that combine low flows to reduce sediment export, BHBFs to enhance sediment storage, and high fluctuating flows to disadvantage non-native fish.

In addition, GCMRC has provided a first draft of a larger set of experimental flows that can serve as a starting point for working with the Science Advisors, the TWG, and other stakeholders to develop a program of experimental flows.

The experimental treatment being proposed for WY 2002 – 2003 has been analyzed for its impact on power and its risk to other resources. It is believed that there are no significant negative effects from this proposal. In addition, the hypotheses being proposed for testing are all measurable.

TREATMENT SCENARIOS FOR WY 2002-2003

by

GRAND CANYON MONITORING AND RESEARCH CENTER

IN CONSULTATION WITH THE

TECHNICAL WORK GROUP

March 25, 2002
(Version 3.0)

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Version 3.0
Treatment Scenarios for WY 2002-2003
Prepared by GCMRC in Consultation with the TWG
(March 25, 2002)

For Consideration by the Adaptive Management Work Group
April 24-25, 2002
Phoenix, AZ

Preface

In response to the AMWG motion passed on January 18, 2002, the Grand Canyon Monitoring and Research Center (GCMRC) is recommending a program of annual experimental treatments spanning a multi-year time period rather than a single year flow scenario. The decision to expand from the specific directive of the motion to develop a single year flow scenario is motivated by the desire of GCMRC to forward a recommendation that embraces a defensible experimental design and is consistent with the principles of ecosystem science and adaptive management. If the experimental design proposed in this document is adopted by the AMWG, each treatment (e.g., high fluctuating flows from January through March) is proposed for two years. If the monitoring program measures unintended or adverse affects from a treatment, a proposal to end the treatment will be considered.

The notion that the evaluation of a single experimental flow scenario evaluated for a single year will lead to improved learning in an adaptive management framework has been repeatedly criticized. These criticisms are founded, most basically, in the recognition that an experiment without control, replication, or evaluation is not an experiment. Additionally, it has been shown that scientists have a very bad track record for predicting the outcome of single treatment evaluations, and that relying on this tact usually leads to costly mistakes. Based on these premises, GCMRC provides below a discussion of what it believes are the critical elements of a good experimental design and what general steps are required in order to execute an experiment likely to yield increased understanding of processes shaping key resources in Grand Canyon.

An experiment fundamentally relies on three elements: control, treatment replication, and treatment evaluation. The first element, control, is necessary so that the response of the key indicator variable (e.g., sediment storage) to a treatment event (e.g., Beach Habitat Building Flow) can be compared to the state of the key indicator variable during a non-treatment event (e.g., Record of Decision flow). In this way, the state of the key indicator variable during a non-treatment event is the so-called control or "baseline condition". The difference between a baseline condition and the treatment response is essentially the fundamental measure of a treatment effect. It is the cumulative affects of individual treatments, when taken together that comprise an experiment.

The second element, treatment replication, is of paramount importance in the context of a large-scale field experiment conducted in a complicated system like the Colorado River ecosystem.

This is most easily recognized by considering the suite of non-treatment factors that could be responsible for inducing a response in the indicator variable. For example, consider that humpback chub recruitment is likely mediated by a host of factors both within the Little Colorado River and in the mainstem Colorado River. If we seek to understand the relationship between humpback chub recruitment and one potential controlling factor such as competition/predation with rainbow trout, we must necessarily manipulate the abundance of rainbow trout. However, if poor humpback chub recruitment occurs under the current baseline condition of high rainbow trout abundance, and high humpback chub recruitment occurs under a treatment condition where rainbow trout abundance is lowered, we cannot necessarily conclude that competition/predation with rainbow trout is the controlling factor. This is because there may be some other factor responsible for the high humpback chub recruitment. The only way to have a chance of disentangling this situation is to have multiple treatments (replication) of high and low rainbow trout abundance and evaluate whether the relationship to humpback chub recruitment is robust across these different treatments.

The third element, treatment evaluation, is commonly referred to as monitoring. A robust monitoring program is perhaps the most critical element in a multi-year experiment since it is the mechanism that evaluates the state of the key indicator variable (e.g., sediment storage or humpback chub recruitment). The precision of the treatment evaluation is usually the most important factor in determining the likelihood that an experiment will yield valid results.

GCMRC is confident that monitoring programs for sediment and key fish species are robust enough to consider implementing multi-year experiments. Furthermore, declines in sediment and fish resources detailed in the following document illustrate the need for experimentation in order to discover policy options to reverse these disturbing trends.

GCMRC recommends the initiation of a long-term experiment beginning in year one with the treatment recommended in this document. The year one treatment is consistent with the AMWG motion. GCMRC also recommends a process for developing subsequent year treatments in consultation with the Technical Work Group, Science Advisors, and experts in the field of adaptive management and experimental design. GCMRC has included a draft series of treatments that could be implemented over o a 16-year timeframe as a point of departure for discussions with these groups.

It should be clear that from GCMRC's perspective what is covered in the following document is material that should inform and lead to a choice of the treatment to be implemented in year one of a long term adaptive management experiment. Failure to consider Adaptive Management Program efforts in this context will likely lead to erroneous or indeterminate findings and very poor use of scarce fiscal resources.

I. INTRODUCTION

The ideas presented in this document address the motion passed at the Adaptive Management Work Group (AMWG) Meeting on January 18, 2002. That motion instructed the Grand Canyon Monitoring and Research Center (GCMRC), in consultation with the TWG to design an experimental flow sequence for WY 2002 – 2003. The full motion states:

In concert with RPA flows for native fish during 2002-2003 request that the GCMRC, in consultation with the TWG, design an experimental flows sequence that tests hypotheses for conservation of sediment. Report to AMWG in April 2002 on the proposed flow sequence.

This document was prepared by GCMRC staff in consultation with the TWG[1] and constitutes GCMRC's recommendation to the AMWG for an experimental flow release pattern from Glen Canyon Dam for WY 2002 – 2003. The WY 2002 – 2003 treatment is intended to test hypotheses related to Glen Canyon Dam operations or other experiments designed to:

1) **improve retention of sediment in the Colorado River Ecosystem (CRE), and**

2) **benefit native fish populations, primarily Humpback Chub (HBC).**

In addition, these recommendations consider impacts to other resource areas. The recommendations presented herein are intended to represent treatment alternatives that can be selected for implementation in year one of a multi-year adaptive management experiment.[2]

Specific objectives of the WY 2002 – 2003 experimental treatment recommendation include:

A) Sediment related:
- ♦ decrease downstream export of tributary input sediment from Marble Canyon, and
- ♦ increase sand storage throughout channel margins with Beach/Habitat-Building Flows (BHBFs).

B) Native fish related:
- ♦ improve survival and recruitment of HBC by reducing competition and predation from non-native fish (primarily rainbow trout)[3],[4] and
- ♦ improve and maintain habitat for young native fish.

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[1] The consultative process followed in the development of this document is outlined in Attachment 1. This process resulted in a number of Frequently Asked Questions (FAQs). These FAQs are included as Attachment 2.
[2] A broader set of recommendations for a long-term experimental treatments that could be implemented the hydrology is wet or dry, is included as Attachment 3. The experimental treatment being recommended here is consistent with that larger experimental program.
[3] It is anticipated that reducing the population numbers of RBT will increase the average size of fish in the Glen Canyon reach and may lead to improvement in the overall quality of the Lees Ferry trout fishery.
[4] MO 2.6. Reduce native fish mortality due to non-native fish predation/competition as a percentage of overall mortality in the LCR and mainstem to increase native fish recruitment.

II. State of Resources in Response to Record of Decision on Dam Operations

- Data and trends on Sediment Storage and Transport

Goal 8 (and associated MO's) of the Glen Canyon Dam Adaptive Management Program's Strategic Plan, calls for the conservation of fine-sediment within the main channel to support achievement of other ecosystem goals and objectives – maintenance of physical habitats associated with the terrestrial and aquatic components of the ecosystem. The Operations of Glen Canyon Dam – Final EIS (DOI, 1995) predicted that sandbars within the active zone (diurnal fluctuations) would decrease in height and width under Modified Low-Fluctuating Flows, but that there was a 73% probability that tributary sand inputs would accumulate within the main channel over a 50-year period. Monitoring data since 1991, indicate that sand-bar volumes within the active zone have decreased under MLFF operations (Figure 1), and volumes do not show sand accumulation since 1996 above active zone, except following the 1996 BHBF (Figure 1). During the Interim Flow and MLFF periods, sediment storage increased above the active zone twice; once during a natural flood from the Little Colorado River (LCR) in winter 1993, and again during a Beach/Habitat-Building Flow in 1996. In both cases, these bar responses were temporary; suggesting that sandbar maintenance needs to occur relatively frequently to be effective.

The controlled flood experiment of 1996, deposited significant amounts of sand up to the 45,000 cfs stage, but research results showed that the sand supply for building BHBF bars came from pre-existing sand bars at lower elevations within eddies, and not from supplies that had accumulated within the main channel between August 1991 and March 1996—as was predicted in the EIS—(Rubin and Topping, 2001; Rubin et al., 1998; Webb et al., 1999; DOI, 1995). If new sediment inputs from tributaries are not conserved, then implementation of BHBF operations cannot effectively support other resource goals, such as mitigation of erosion of cultural materials within existing sand bars, restoration of recreational camping beaches, maintenance of terrestrial substrates that support riparian vegetation, or rejuvenation of near-shore habitats of benefit to native fishes.

Recent trends in sediment monitoring data (Figure 2) support the early conclusions of Laursen et al. (1976), and suggest that goals that depend on retention of fine sediment will not be achieved unless future BHBFs and other actions are strategically timed to take advantage of tributary sediment inputs that temporarily enrich the ecosystem's sand and silt supply.

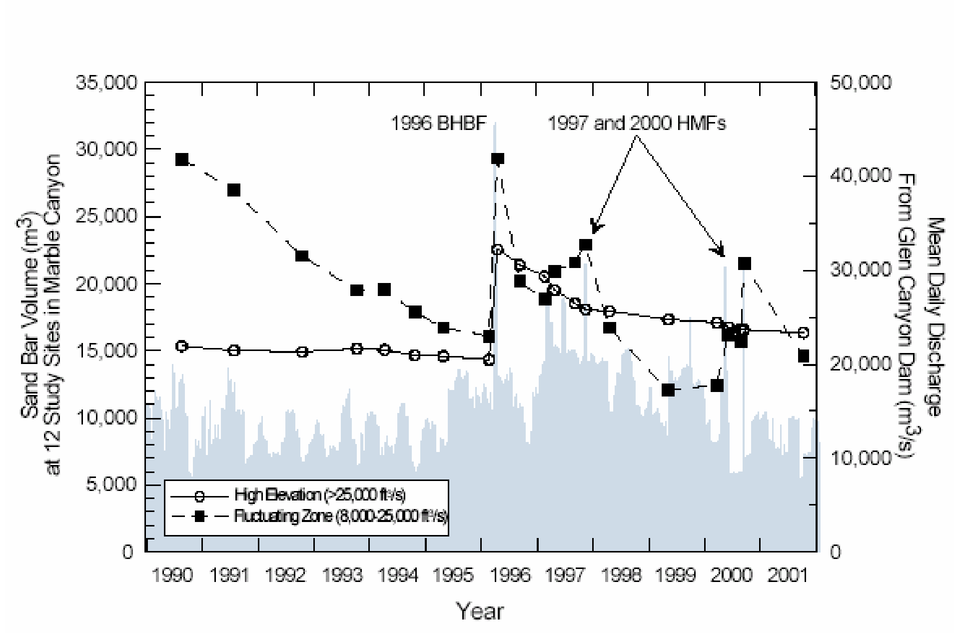


Figure 1. Changes in sandbar volume (active fluctuating zones (8,000 to 25,000 cfs) versus high-elevation (>25,000 cfs)) within Marble since the end of No-Action era (1966-1991). Data from Northern Arizona University (Parnell et al., 2002, personal communication).

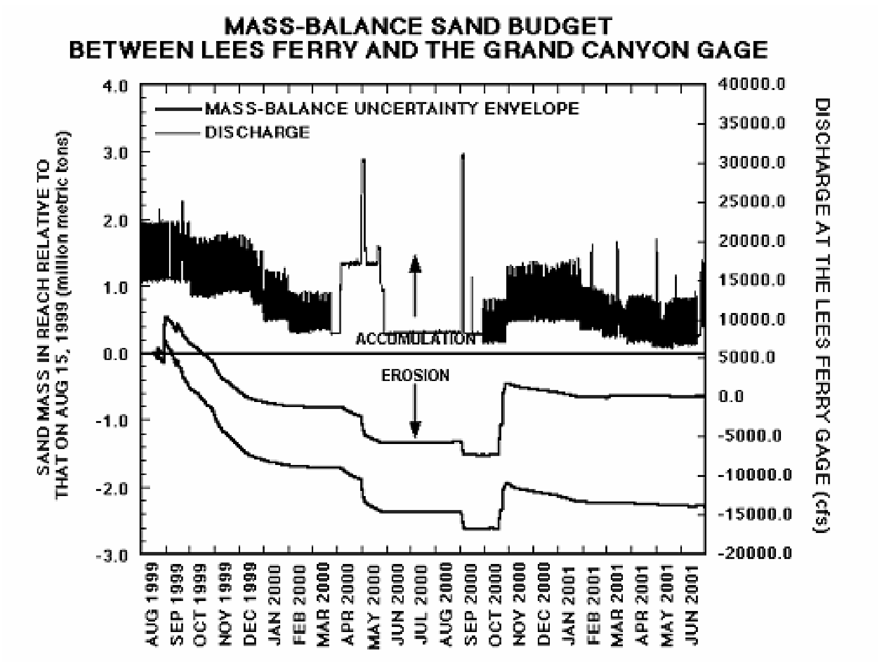


Figure 2. Cumulative sand mass balance for Colorado River ecosystem between Paria River confluence and Grand Canyon stream gage (river miles 1 to 87) that shows export of sand inputs from 1999 through June 2001, as well as additional sand exported from pre-existing sources throughout the main channel (USGS preliminary data, D. Topping, personal communication, 2002).

Results from three experimental dam releases of 31,500 cfs that occurred in November 1997, and June and September 2000), have shown very limited to no enhancement of storage within eddies (Hazel et al., 2000a, see Figures 7-8 and 11; 2000b, see Figure 3), even under conditions when the sediment supply of the system was enhanced significantly by tributary inputs (fall 1997). This minimal response has been attributed to the relatively limited "accommodation" space available within eddies and channel margins at elevations within power-plant operating range (Hazel et al., 2000b, see Figure 4). Comparison of sandbar data indicates that accommodation space above peak power-plant range within monitoring sites increased dramatically during the 1996 controlled flood test when flows peaked at 45,000 cfs. Accommodation space for sand-bar deposition along shorelines is predicted to be even greater at stages above 45,000 cfs, on the basis of recent sand-bar simulations (Wiele and Franseen, 2001; Wiele and Franseen, in review), as well as the bar deposition response measured at many sites following the 1983 high flow (Schmidt and Graf, 1990).

- Data and trends on Humpback chub (HBC)

The most recent data available (based on sampling through 2001) suggest declines in overall abundance and recruitment of HBC in the LCR population since the early 1990's when first experimental and subsequently ROD flows were implemented. These data, presented in Figures 3 & 4 suggest that both the status and trends related to the HBC population are inconsistent with predictions of table II-7 from the EIS, as well as the adopted Goals and Management Objectives of the AMP.

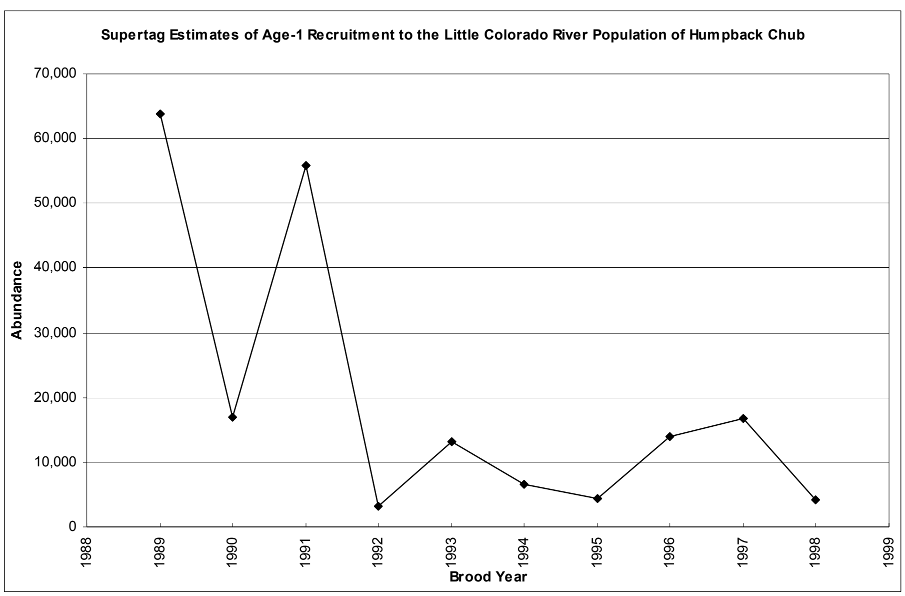


Figure 3. Estimated abundance of Age-1 recruitment to the Little Colorado River humpback chub population by brood year from model Supertag.

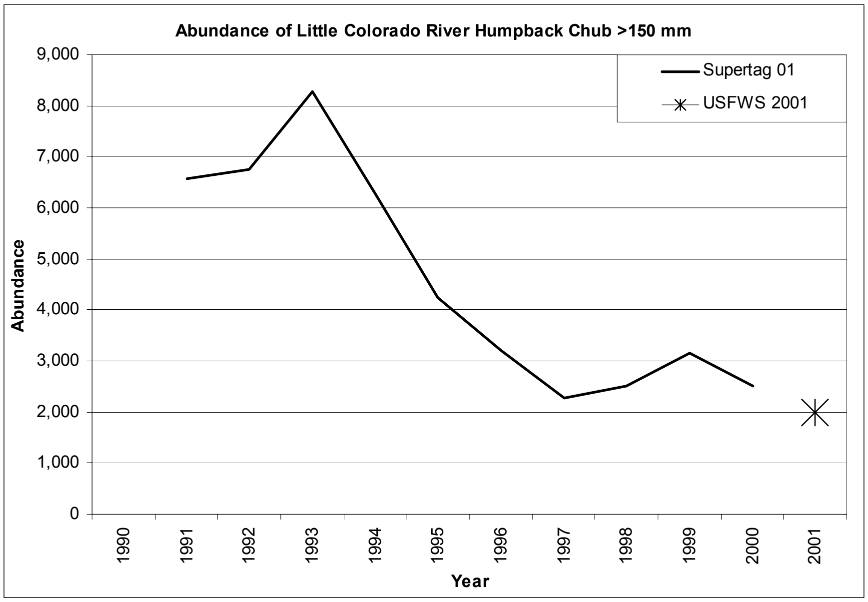


Figure 4. Estimated abundance of humpback chub larger than 150 mm in the Little Colorado River population from model Supertag (1991-2000), and from a closed population abundance estimate conducted by the USFWS (2001).

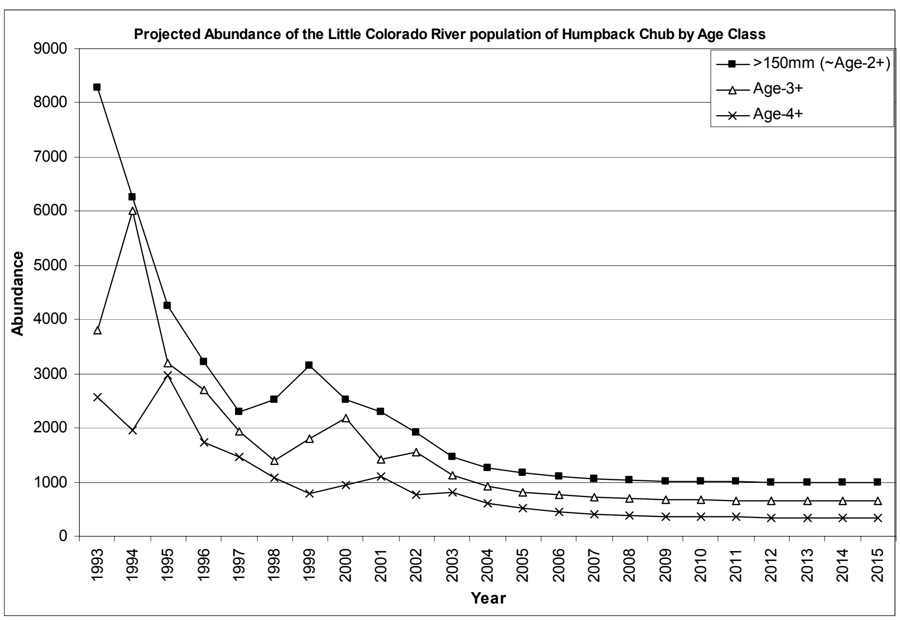


Figure 5. Projected abundance of the Little Colorado River population of humpback chub by age class assuming recruitments 1999+ are equal to 1998 recruitment.

Table II-7 suggests stable to moderate improvement in HBC populations under ROD flows. Goal 2 of the AMP and most of its associated MO's call for maintaining and enhancing the population(s) of HBC with removal of jeopardy for the species as primary driving force. Figure 5 extrapolates recent and current recruitment trends into estimates of future abundance for the LCR HBC population. Clearly this trend is in opposition to the AMP goals.

- Data and trends on Lees Ferry Trout and Non-native fish (salmonids) throughout the CRE

AMP Goal 4. Is to "Maintain a wild reproducing population of rainbow trout above the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish."

There are no management goals for non-native fish below Lees Ferry which seek to enhance population status Table II-7 of the EIS states that under ROD operations rainbow trout in the Lees Ferry reach are expected to be maintained by a natural reproduction augmented by stocking and that the population was expected to do no better than under the no action alternative.

The Lees Ferry rainbow trout fishery has been maintained by a combination of stocking and natural reproduction since the late 1960s. The fishery has been predominately maintained by natural reproduction in recent years. Since the mid 1990s RBT have increased their abundance tremendously in both the Lees Ferry reach and throughout much of the Marble Canyon and Upper Grand Canyon reaches. The abundance of RBT in the CRE below Lees Ferry has increased dramatically with current estimated abundance totaling nearly 1 million adult fish. Figure 6 shows catch-per-unit effort for rainbow trout in the LCR reach where the HBC population exists. Similarly brown trout (BRT) have also increased in abundance. It is unknown how much of these increases are due to local natural reproduction versus recruitment from other spawning area such as Lees Ferry for RBT and Bright Angel Creek for BT.

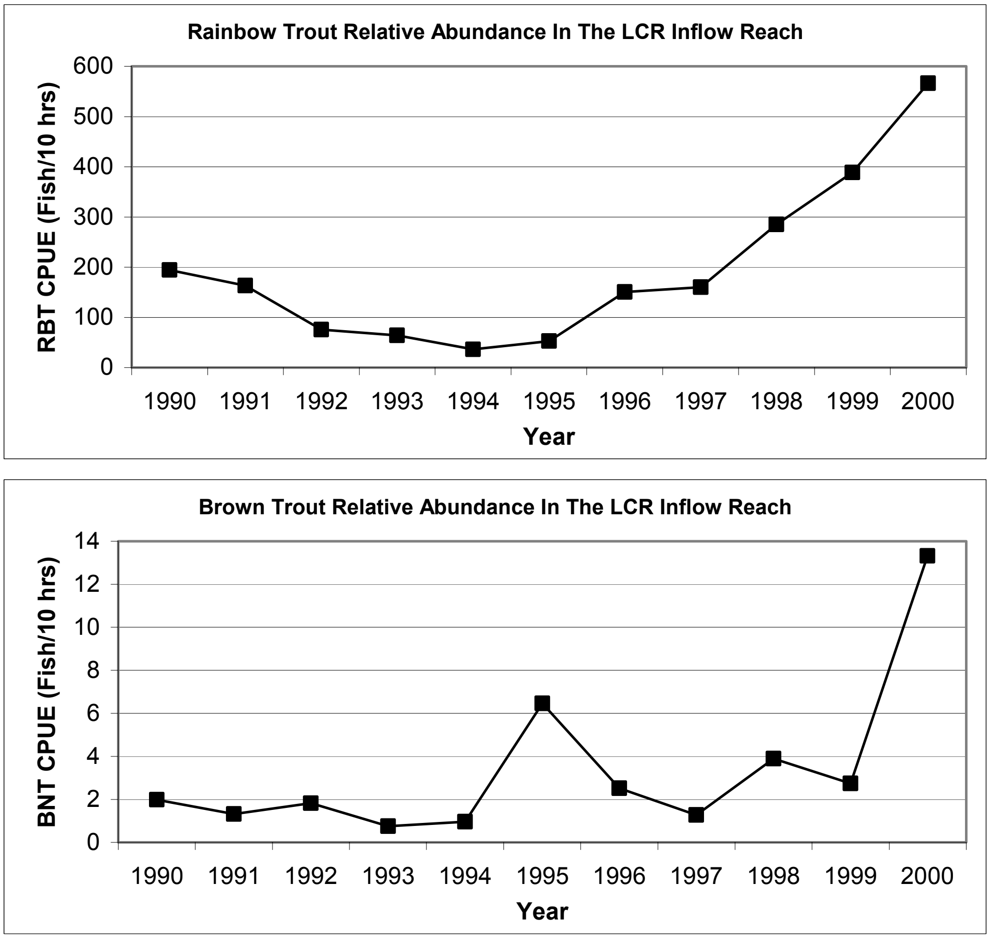


Figure 6. Relative abundance of rainbow trout (top panel) and brown trout (bottom panel) in the Little Colorado River Inflow Reach as indexed with electrofishing catch per unit effort (CPUE).

Lees Ferry Rainbow trout data and recent trends

The increase in abundance at Lees Ferry to over 250,000 age II+ fish has been accompanied by an increased catch rate for anglers along with a decline in the average size of fish caught. Recent information from fishing guides suggests a declining catch rate since September of 2001. However, GCMRC and AGFD monitoring data suggest no decline in the actual numbers of fish through March 2002. The potential of fluctuating flows to reduce spawning and recruitment success for this population may reduce overall numbers in the population and reduce catch rate somewhat. 1-2 years of suppression of spawning and recruitment at a modest level (somewhere between 10-50%) should produce trout averaging 17 inches in this fishery after a few years compared to the current average size of 13-14 inches. This would compare favorably with the AMP management goal for this species.

- Data and Trends on Cultural and Recreational Resources

Relative to cultural resources the EIS (preferred alternative) predicted that impacts to archaeological resources would be moderate with impacts to less than 157 sites, there would be moderate impacts to Traditional Cultural Properties and there would be increased protection to traditional cultural resources. A comparison of these predictions and the results of data collection indicate that cultural resources (archaeological and traditional) appear to benefit from higher flows of short duration that replenish sediments and mimic unregulated spring river conditions.

AMP Goal 9 relates to the *in situ* preservation of cultural resources. However, ROD operations do not appear to assist in meeting this goal or the related Management Objectives. Cultural sites continue to erode through the loss of channel margin sediments that buffer and help to stabilize cultural deposits. While the EIS (Table II-7) predicted moderate loss of archaeological sites, cultural resource loss is occurring throughout the system without mitigative efforts. Data from on going archaeological and tribal monitoring, indicate that erosion continues at archaeological sites under ROD operations. Monitoring of these resources indicates BHBF flows appear to benefit resources through the deposition of sediments in erosion features such as gullies. Modeled data with high sediment loads and at high flow stages (i.e., 100,000 cfs) suggests that portions of gullies at selected sites would be buried, temporarily arresting erosion through the sites. Monitoring of traditional resources indicates that higher flows appear to benefit traditional plant resources through the deposition of nutrient rich sediments and clays.

Conservation and redistribution of sediment is best understood relative to a beneficial purpose to other resources. Accumulation of sediments is most beneficial for the conservation of archaeological resources that are finite and irreplaceable. Unlike endangered species that may be encouraged to increase in abundance, a decrease in archaeological site number is irreversible. While Grand and Glen Canyons are erosional features, management actions can assist in prolonging the existence of these resources in keeping with AMWG management objectives.

III. Rationale for an Ecosystem vs. a Single Resource Experiment

GCMRC interpreted the AMWG motion as a sediment conservation experiment within the framework of benefiting native fish. The AMP is intended to use an ecosystem-science approach in testing the effects of dam operations. It also recognizes that the Endangered Species Act mandates that the Department of the Interior take action to protect endangered species. At the January AMWG meeting, GCMRC presented data that indicated sediment resources and HBC are not responding to the ROD operations as anticipated in the EIS. Given this information, GCMRC believes the AMWG should consider an experimental flow regime that takes an ecosystem science approach to address the resources of concern.

The Experimental Flow Scenarios proposed in this document call for ramping rates and daily fluctuations that are outside the preferred alternative. However, these flows are within that portion of the ROD that allows for experimentation. GCMRC also believes that after the AOP process considers the experimental flow request and determines WY 2003 monthly volumes, the proposed flows can be in compliance with the current interpretation of the Law of the River. Furthermore, the interim surplus criteria ROD states that "this experimental flow program will consider both the potential for reduced frequency of BHBFs resulting from the Interim Surplus Guidelines and for experimental flows to be conducted independent of the hydrologic triggering criteria. The design of the experimental flow program will include the number of flows, the duration and magnitude of experimental flows. The AMP shall forward their recommendation of this matter for the Secretary's consideration."

IV. WORKING HYPOTHESES

Sediment- Monitoring data indicate that tributary inputs of sand do not accumulate within the river channel over multi-year periods as predicted by the final EIS, and that such inputs are transported out of the Colorado River Ecosystem within less than one year under most ROD operations. On the basis of results from the summer 2000 flow experiment, as well as historical sediment-transport data, new inputs of sand should be retained more effectively within main channel storage sites during extended periods of dam releases at or below about 10,000 cfs (Rubin et al., 2000; Topping et al., 2000a; 2000b). If such operations promote retention of sand (and finer sediment as well), then implementation of a Beach/Habitat-Building Flow following such periods should greatly increase the effectiveness of such flows in restoring and maintaining terrestrial sand bars and related resources. More efficient retention of fine sediment and silt prior to BHBFs is hypothesized to result in more rapid rates of sand bar deposition, as well as sand bars with finer grain-size distributions. Finer-textured sand bars may be less prone to rapid erosion following bar building, as well as retain a higher level of nutrients contributed to the main channel by tributaries. Enhanced conservation of tributary sediment inputs in the channel should result in elevated suspended-sediment concentrations during BHBFs, leading to rapid depositional rates during sandbar building. Elevated rates of sandbar deposition should reduce the required duration for BHBFs, and hence will limit spill volumes. If sand bar deposition is significantly enhanced by implementing BHBFs when the ecosystem's sediment supply is greatly enriched (resulting in sustainability of finer, more stable bars), then perhaps the frequency for making such releases is simply linked to timing of tributary inputs.

Native and Non-native Fish - The LCR population of HBC has not demonstrated a positive response to the mainstem flow regimes under ROD operations. While the population of rainbow trout in Lees Ferry and the populations of rainbow and brown trout in the mainstem below the Paria River appear to have shown a positive response as reflected in increased abundance. Within the ROD, there is a need to implement experimental flows, which may improve survival and recruitment of HBC. The LCR population of HBC is comprised of fish resident in the LCR and in the mainstem near the LCR confluence. Therefore flows, which affect changes in HBC status in the mainstem, may positively influence the overall LCR/HBC population.
Although, there is considerable uncertainty regarding the causal mechanism for the decline in adult HBC abundance, the predation/competition hypothesis has a higher likelihood than other mechanisms (disease/parasitism, hydrology, food-limitations, habitat degradation, etc.) for explaining the decline. In addition, this is a testable hypothesis using management flow prescriptions. Finally, it is plausible that the predation/competition hypothesis could overwhelm any benefits derived from management flow prescriptions intended to provide beneficial habitat conditions.

GCMRC believes the benefits to native fish will accrue indirectly through a reduction in predation/competition by non-native fish, primarily salmonids in the LCR reach. The model developed by Dave Speas and Carl Walters provides support for high fluctuating flows to negatively impact RBT by interfering with and disrupting spawning activity as well as reducing the recruitment of young fish.

Initial flow experiments to modify habitat have not shown a strong response in increased HBC abundance. This could be due to a number of factors including both the power of the experiment, the ability of monitoring programs to detect a change, and the short time since the most recent experiment (LSSF) has been conducted. Another possibility is that non-native and native fish interactions (i.e., predation and competition) are over-riding any potential positive effects from flows that improve habitat conditions. The treatments described here are intended to test this possibility and produce a measurable affect on non-native fish and hence on non-native and native fish interactions. The hope is that this will result in a positive effect on HBC and lead to the designing of experimental flows or other management actions that also can improve habitat for native fish, including HBC that will address Goal 2 of the AMP strategic plan.

V. EXPERIMENTAL FLOW SCENARIOS

ASSUMPTIONS

♦ **WY 2002 – 2003 Hydrology**

These experimental flow recommendations assume that WY 2002 and perhaps WY 2003 will be relatively low runoff years with low antecedent reservoir storage in Lake Powell. Thus **these recommendations are based on an 8.23 maf water year scenario.**

♦ **Mechanical Removal of Salmonids in the LCR Reach of the CRE**

In addition to the experimental flow scenarios described below, a treatment to test the efficacy of mechanical removal of salmonids in the LCR reach of the CRE is being proposed in this document as an adjunct to high fluctuating flow treatments or as an independent treatment. The mechanical removal treatment process is also designed to resolve issues pertaining to the role of salmonid predation on native fish. More detailed information on the design of this treatment and its testable hypotheses can be found in Attachment 6.

An overview of the treatment is as follows: over a two-year period six river trips would be conducted using primarily electrofishing (possibly other gear types) to capture and remove salmonids from the LCR reach of the CRE (approximately 1 mile upstream to 4 miles downstream of the LCR). Trips would last for 16 days and both shorelines would be electrofished in all suitable habitats 4 times. All salmonids captured would be removed and a subsample examined for diet analysis. This effort would be conducted in the late summer and early fall. The effort would also yield information regarding abundance of YOY HBC during this period and be complimentary to existing monitoring efforts. This treatment is referred to as **Mechanical Removal** in this document.

♦ **Sediment and Related Resource Considerations**

Recently, GCMRC's cooperating scientists have offered recommendations for how dam operations might be altered to improve sediment-conservation objectives (Rubin et al., 2000). The two alternatives intended to improve fine-sediment retention below Glen Canyon dam are: "(1) implement releases above power-plant capacity discharge immediately after substantial inputs of fine sediment from tributaries, and (2) maintain low flows following fine-sediment inputs until releases above peak power-plant discharge can be implemented."

The TWG Sediment Ad-hoc Group concurred with the above, but recognized that: 1) testing of alternative #2 could only occur in low-hydrology periods, such as 8.23 maf release years, and 2) testing of alternative #1 was not currently possible during August through December under any hydrology. The ad-hoc also recognized that low hydrology periods required to evaluate alternative #2, also present an opportunity to integrate sediment-related experimental flows with flows designed to meet the intent of the 1995 Biological Opinion.

Beyond support of testing the Rubin et al. (2000) sediment alternatives, the TWG Sediment Ad-hoc also recommended two additional flow options (TWG Sediment Ad-Hoc, 2001) for possible testing immediately after significant inputs of fine sediment: 1) "implement habitat maintenance flows (HMF) or releases at power-plant capacity, and 2) load-following releases with fluctuations and magnitude greater than ROD restrictions." While GCMRC does not believe that these offer as high a potential of conserving sediment as low flows, on the basis of existing data (Figure 1), the GCMRC believes that during high-volume summer months (July and August, following Paria River floods), or during wetter years a test of short-duration fluctuating releases up to 25,000 cfs may be warranted.

Forecasted runoff into Lake Powell for Water Years 2002 and 2003, may allow for testing of either experimental flow scenarios 1 or 3 as components of an overall integrated experimental design. An alternative experimental flow scenario (2) for temporarily increasing sand storage within eddies (power-plant operations intended to increase eddy stored sand) following July – December 2002, sediment inputs might be tested in future years when releases greater than 8.23 maf occur.

SCENARIOS

- **Introduction**

We assume the antecedent and contemporary conditions for the treatment conducted in WY 2002-2003 will be so called 8.23maf or at best average inflow years, thus allowing GCD operations to achieve constant low-flows or fluctuating flows below 10,000 cfs, in fall 2002 and perhaps in subsequent seasons. GCMRC has developed, in consultation with TWG, three experimental flow scenarios (1 , 2, and 3) when significant sediment inputs occur in the summer/fall or winter of WY 2002. GCMRC developed one experimental flow scenario (4) if no sediment inputs occur in the summer/fall or winter of WY 2002. Each is described briefly below and a figure depicting a hydrograph for the particular flow is provided.

While these hydrographs show specific daily flow levels, they are intended to be **conceptual hydrographs** whose precise nature (specific floors and ceilings, up-ramp and down-ramp rates, and durations) will need to be determined. In addition to the flow-based treatment alternatives we also include a mechanical removal treatment (described above and in Attachment 6) for salmonids in the LCR reach of the CRE which could be implemented jointly with, or independent of, high fluctuating flows.

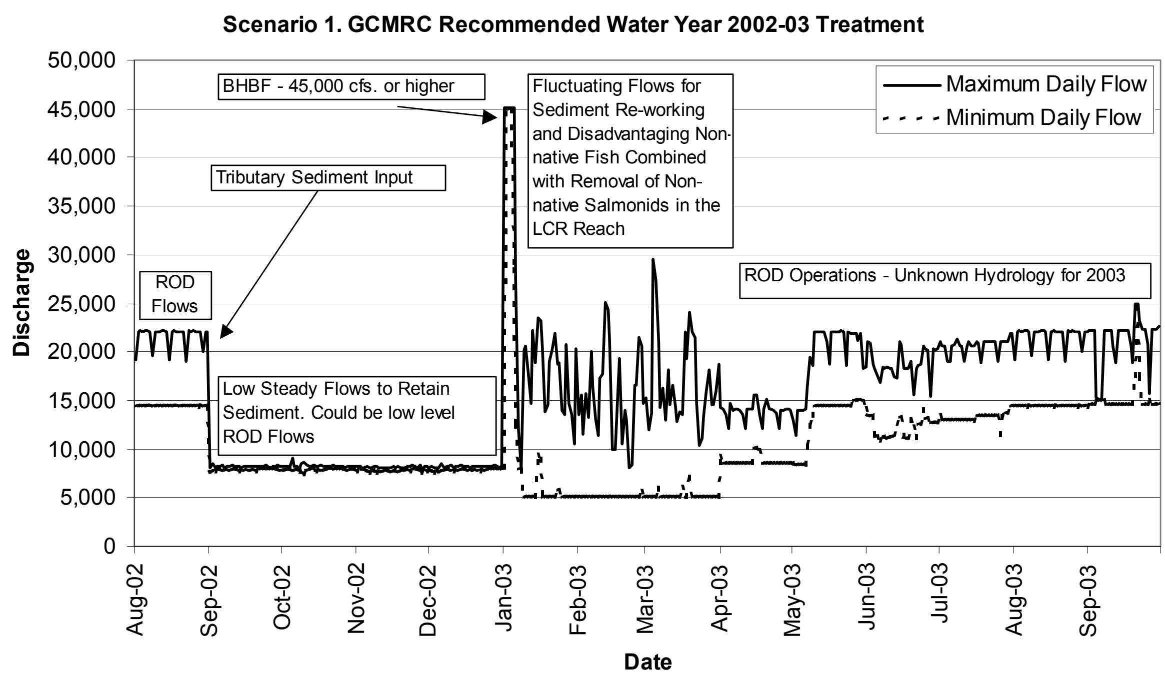
- **Common Hydrograph Elements**

Low Flows (less than 10,000 cfs) – This element of the hydrograph is intended to retain tributary sediment inputs by dropping flows low to reduce transport until a January BHBF can be conducted. This design is based on the results of the summer 2000, Low-Summer-Steady-Flow test, historical synthesis of flow and sediment-transport data analyses, and the recommendations of the sediment researchers, outlined as Alternative #2 (Rubin et al., 2000). This approach provides the greatest likelihood for enrichment of channel-stored sediment supply prior to implementation of a BHBF (January). This would allow a second test of the BHBF concept, under antecedent sediment supply conditions where we know the eddies will be full of sediment (compared with March 1996), while keeping the magnitude of the BHBF unchanged. Research findings suggest that the BHBF response under enhanced sediment supply conditions, should result in faster depositional rates for sand bars, as well as potentially larger sand bars that fill both the lower and higher portions of eddies and channel margins, as well as finer grain-size distributions.

Power Plant Operations (up to 31,500 cfs) – This element of the hydrograph is intended to store tributary sediment inputs until a January BHBF can be conducted. Results of the November 1997, peak power-plant test suggest that there will likely be little benefit to enhancing sand storage, by raising flows above 25,000cfs (Figure 1). If this alternative is to be tested at all, then the GCMRC recommends testing it during periods with high monthly volumes. Trading off sediment storage throughout the entire channel bed, for relatively little potential storage volumes within eddies (as is the premise for doing this alternative treatment) is deemed by the GCMRC as a less desirable tradeoff during periods when new sediment is likely to be better conserved by either low or constant flows.

Beach/Habitat-Building Flow (45,000 cfs BHBF) This element of the hydrograph is intended to build beaches and sandbars by moving the sediment that has previously been stored in the eddies.

<u>High Experimental Fluctuating Flows</u> –This element of the hydrograph is intended to disadvantage non-native fish recruitment in the main channel, thereby achieving the most effective long-term control on predation/competition through reduced population size. This reduction in population size in non-native fish would result from a combination of spawning disruption and creating unfavorable conditions for survival of young non-native fish. Fluctuating flows, outside those experienced since the implementation of interim flows and subsequent ROD operations might be most effective at reducing the non-native fish populations by causing lower recruitment. Over the course of multiple years, reduction of RBT and BNT abundance is intended to result in increased HBC recruitment.

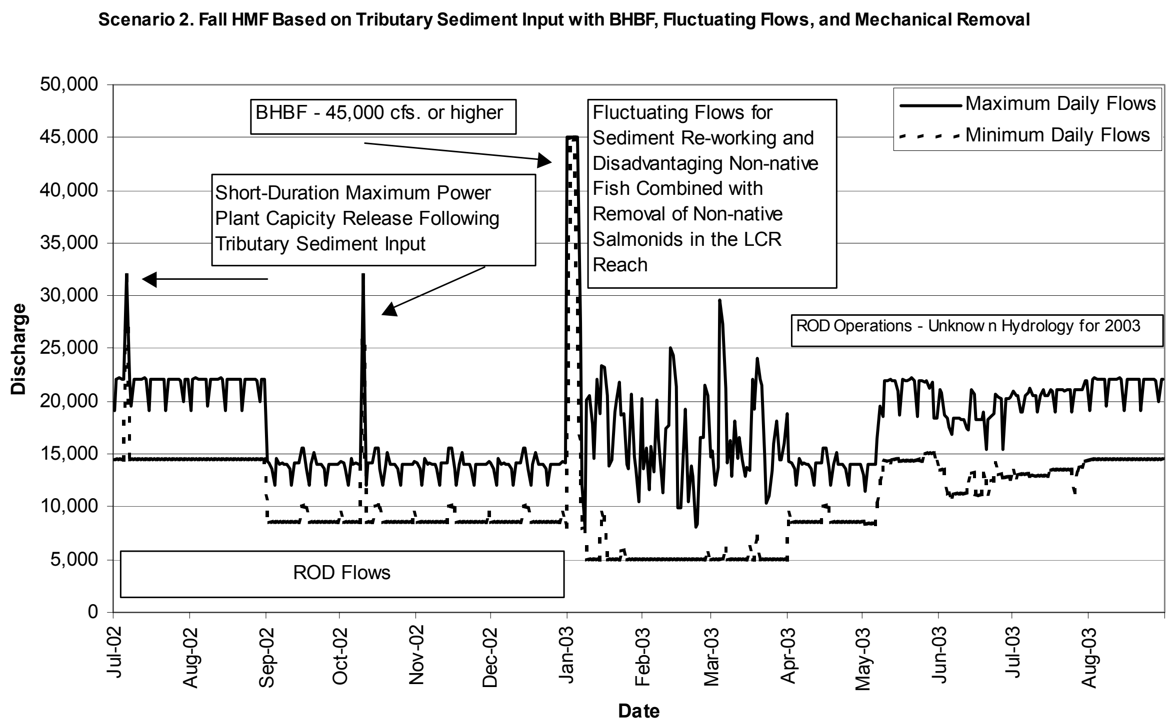


Scenario 1 Figure 7. This scenario provides for experimental flows aimed at **both** conserving sediment and benefiting native fishes. From October 2001 through June 2002 the dam follows normal ROD operations. <u>Following **significant**[5] sediment inputs in the July - December 2002 period</u> the dam is operated at a constant 8,000 cfs following sediment inputs (or perhaps a low level, e.g. 5-9,000 cfs ROD flow) until January 2003. In January 2003 a BHBF[6] of limited duration is conducted. This is followed by high experimental fluctuating flows for the main portion of the non-native spawning and emergent/juvenile season (January through March). From April – September 2003 operations would follow monthly volumes under the ROD. This portion of the hydrograph would be repeated in WY2003-04. Concurrent with the experimental flow treatment, mechanical removal of rainbow and brown trout in the LCR reach (described

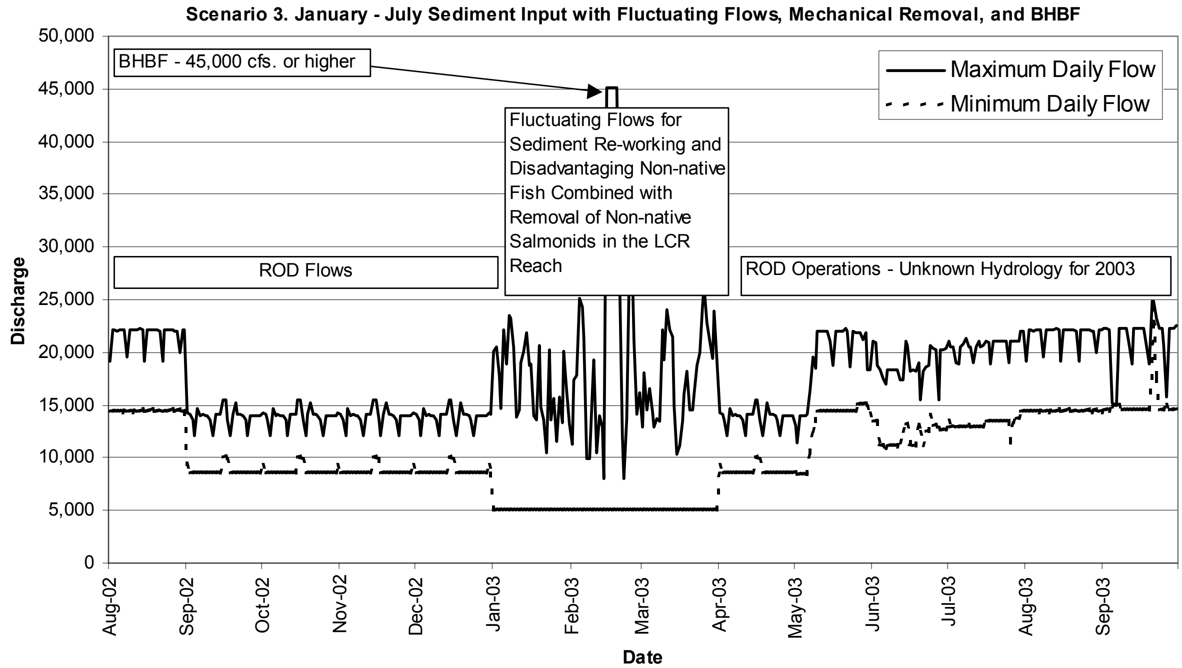
[5] A year with significant sediment inputs would be defined as a period of 1 to 30 days during which the Paria River contributes at least its long-term, annual average input of sand (about 1.4 million metric tons, or greater), to the Colorado River. These inputs may occur as either one discrete flood of many cumulative inputs over the course of a month.

[6] In every scenario where a BHBF is proposed to be released in January 2003, the BHBF should have a magnitude of at least 10,000 cfs above peak powerplant discharge, or higher depending on lake elevation.

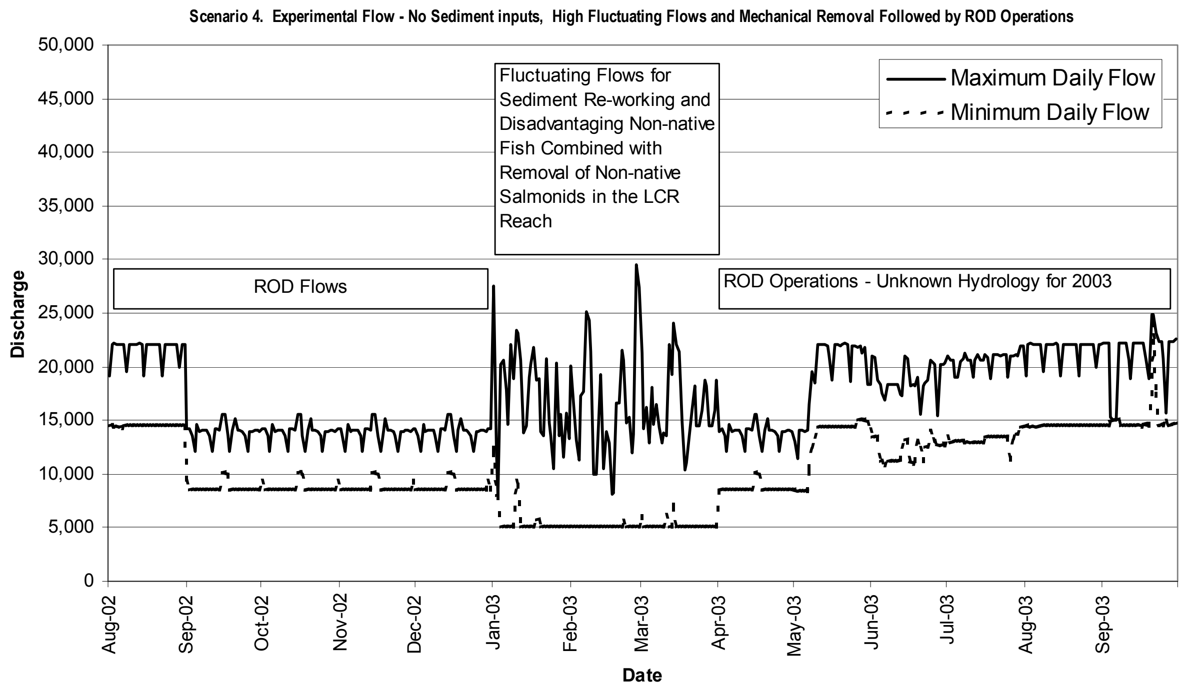
above) would be implemented. This overall treatment (flows and mechanical removal) has the most potential to result in measurable responses, which improve the Lees Ferry trout fishery, reduce non-native predation/competition on native fish in the LCR reach, enhance native fish habitat, and increase sediment retention in the CRE.



Scenario 2 Figure 8. This scenario provides for experimental flows aimed at **both** conserving sediment and benefiting native fishes. From October 2001 through June 2002 the dam follows normal ROD operations. Whenever **significant** sediment inputs in the July - October 2002 period occurs, a Habitat Maintenance Flow (HMF) is immediately triggered. This is followed by ROD operations until January 2003. In January 2003 a BHBF of limited duration is conducted. This is followed by high experimental fluctuating flows for the main portion of the non-native spawning and emergent/juvenile season (January through March). This scenario also provides for Mechanical Removal of Salmonids. From April – September 2003 operations would follow monthly volumes under the ROD. This hydrograph could be repeated in WY2003-2004.



Scenario 3 Figure 9. This scenario represents a year when there are no significant monsoonal sediment inputs but there are significant **sediment inflows in winter.** It also includes flows intended to benefit native fishes. If there are No significant sediment inputs in the August through December period the dam would be operated under normal ROD operations until December 2002. Beginning in January 2003 high experimental fluctuating flows for the main portion of the non-native spawning and emergent/juvenile season (January through March) would be implemented. From April – September 2003 operations would follow monthly volumes under the ROD. In this scenario, a BHBF would occur if significant sand inputs occurred during the January through July period. The BHBF would be released as soon as possible and in the same month that the sediment input(s) occur. The BHBF would have a magnitude of at least 10,000 cfs above peak powerplant discharge, or higher depending on lake elevation. This scenario also includes Mechanical Removal of Salmonids.



Scenario 4 Figure 10. In this scenario, no significant sediment inputs occur in the summer/fall or the winter input period. The dam is operated under normal ROD operations until December 2002. Beginning in January 2003 high experimental fluctuating flows for the main portion of the non-native spawning and emergent/juvenile season (January through March) would be implemented. From April – September 2003 operations would follow monthly volumes under the ROD. No BHBFs or HMFs would be implemented. This experiment is essentially focused on negatively affecting non-native fish populations by disrupting the non-native fish spawning and emergent/juvenile season. This scenario also includes Mechanical Removal of Salmonids.

Resource Considerations Related to GCMRC's Treatment Scenarios

For reasons outlined above, the GCMRC believes that Treatment #1 of a multi-year integrated experiment design should begin in WY 2002-03, with implementation of scenario 1, as shown above in Figure 6. If significant sediment inputs occur from the Paria River[5], then a BHBF is implemented within the previously agreed upon months (January through July 2003). In the event that new sediment does not enter the river, the fisheries treatments (mechanical removal of non-native fish, and experimental winter fluctuations) are implemented, but no BHBF occurs. This treatment design intends to provide learning in the context of the long-term experiment, and offers the greatest potential for benefiting downstream resources with the lowest risk.

Costs and Benefits to Hydropower of the Implementation of Scenario 1

(this was provided by WAPA and inserted verbatim)

Owing to the limitations of time, this analysis is limited to an examination of Scenario 1 (formerly I.A.). This scenario includes low-steady flows of 8,000 cfs following a fall sediment input, a BHBF of 43,000 cfs in January, a 4-day 8,000 cfs photo flow, and fluctuating flows on the receding limb of the BHBF and continuing through the end of March. Additional information will be available regarding other scenarios prior to the AMWG meeting on April 24 and 25, 2002.

A standard procedure for the publication of economic and financial studies performed by the Environmental and Resource Planning Office of Western's Colorado River Storage Project Management Center, includes quality assurance steps such as an in-house "reality check", a technical writing review and an outside peer review. These procedures have not been adhered to in this study because of the shortened schedule. Therefore, the following calculations and analysis should be viewed as information to inform decision-making and not as precise calculations of the impacts of proposed experimental flows.

Scope of this Study: If the scientific experiment(s) proposed in this document is implemented in Water Year 2002–03, CRSP firm electrical power customers will see no direct impact. This is because, regarding experimental flows; 1) Western delivers electrical power to CRSP customers as though no experiment occurs and 2) electrical power purchase expense that are a direct result of the experimental flows are deemed "nonreimbusable".

Western makes experimental flows "invisible" to its CRSP firm electrical power customers. It does this by modeling the CRSP electrical power system without the experiment. It calculates the electrical power that would have been available without the experimental flows. Western then makes obligations under its contract to customers on this basis. Thus, the experiment has no effect on CRSP power deliveries.

Experimental flows may cause Western to make supplemental purchases of power to meet its commitments to its customers, which are modeled as though no experiment has occurred. The cost of these purchases are deemed nonreimbusable; meaning that monies spent for this purpose are credited against Western's repayment obligations in the same year. Thus, the experiment has no affect on the rates paid by CRSP customers[7,8].

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[7] During the LSSF test flows conducted during the spring and summer of 2000, some CRSP electrical customers observed "indirect" effects. Several observed that the significant purchases by Western, concentrated at certain trading hubs increased the market price of electrical power at these hubs. If such a phenomenon actually occurred, this would represent an indirect effect of the test to CRSP electrical customers.

[8] The combination of high electrical prices during the summer of 2000, dry hydrological conditions and the LSSF test at Glen Canyon Dam, caused Western's CRSP – MC office to purchase such quantities of supplemental electrical power to meet its contractual obligations at such high prices, that Western's available funds (CRSP Basin Fund) were nearly "dried out". Western had to decrease its obligations of electrical power in subsequent months. In fact, Western has yet to fully recover.

Given the above, the study results included herein should be considered a "revenue study" or a financial analysis of Western's CRSP - MC. It compares a baseline condition in which no experiment is conducted against a change-case in which an experimental flow test occurs and calculates the differences in monthly expenditures by Western's CRSP – MC office. It is not a "trade-off" analysis: an examination of value to CRSP customers of the electrical power lost during the fall portion of Scenario 1 against the value to CRSP customers of the electrical power gained during the Winter/Spring portion of Scenario 1. In order to perform such a trade-off analysis, CRSP customer power replacement costs would have to be used.

Assumptions Used: This study assumes the following regarding Scenario 1: 1) ROD flows occur throughout the months of July and August, 2002; 2) a significant sediment input occurs on the first day of September and releases are reduced to 8,000 cfs from that time to the last day of December; 3) a BHBF occurs on the first day of January, has a two day duration and ramps up and down at ROD prescribed ramp rates; 4) a 4-day photo flow at 8,000 cfs; and 5) fluctuating flows between 5,000 cfs and 33,000 cfs on all days except Sunday from the end of the January BHBF until the last day of March 2003.

Monthly Water Volumes in the Base-case and Change-case: The following table arrays the monthly water volumetric releases from Glen Canyon Dam during the study period (July, 2002 – March, 2003)[9]:

Scenario 1, Table 1

	Release Volumes (kAF)	
Month	**Base**	**Change**
July	850	925
August	900	985
September	636	476
October	600	492
November	600	476
December	800	492
January	915	1255
February	800	900
March	800	900

Notice that water is moved in the change case from the September to December period into July and August and into the January to March period. In the change case, September through December have flows of a constant 8,000 cfs. The differences among the months are accounted for by the difference in the number of days in the month.

Study Method: The monthly volumes described in Table 1, are input into Western's HYDRO-LP model. This model simulates the hourly operation of the CRSP hydroelectric facilities over a week. Each week of the study period was modeled using the HYDRO –LP. Other HYDRO – LP inputs include, CRSP customer hourly demand, hourly sales and purchase price, electrical generating capacity and environmental constraints at Glen Canyon Dam and capacities and constraints at the other CRSP electrical facilities[10]. All input variables are identical over the study period in the base case and the change case except: 1) monthly water volumes and 2)

[9] Information on release volumes for both cases was supplied by Tom Ryan, USBR.
[10] Flaming Gorge Dam, Blue Mesa Dam, Morrow Point Dam, Crystal Dam and Fontenelle Dam. Non-CRSP hydroelectric facilities included in the model are: Elephant Butte Dam and the Upper and Lower Molina facilities.

environmental constraints at Glen Canyon Dam conform to the Scenario 1 experiment in the change case, whereas there are "ROD constraints" in the base case.

The HYDRO – LP simulates the operation of Glen Canyon Dam and produces an hourly pattern of releases for a modeled week. Each week of the study period was modeled for both the base case and the change case. The base case hourly results were compared with the change case hourly results in terms of Glen Canyon Dam generation and electrical purchases or sales made to the electrical market. The hourly differences between the two cases are summed over a month's period of time. This result is the estimate of a month's impact of the experiment.

Results: The following table describes the results of the analysis. The results are displayed by month.

Scenario 1, Table 2

Month	Study Cost / Benefit Sale to Spot Market
July	$1,137,916
August	$1,243,278
September	-$2,809,127
October	-$1,623,422
November	-$1,637,758
December	-$3,471,247
January	$4,549,863
February	$2,389,134
March	$2,113,664
Total	**$1,892,302**

A negative number denotes an expense to Western of purchasing electrical power from the regional electrical market to satisfy contractual requirements to CRSP customers that would be made if no experiment had been performed. Notice that the September – December period includes all of the negative numbers. This is because the change case has a steady 8,000 cfs released from Glen Canyon Dam during these months, whereas, under the base case condition, Western has more water available for the generation of electricity in these months and can schedule the water so that more of it is available during peak electrical demand times. Positive numbers include all other months during the study period. It is especially notable that the months of January through March are positive. This reflects both the added water in these months in the change case and the ability to schedule more of this water during the peak hours of each day. January is a positive number even though a BHBF occurs in this month that includes some water that bypasses the powerplant.

Table 2 includes a summation of the monthly results. The Scenario 1 test results in an improved financial condition for Western of about $1.8 million over the study period.

Sensitivity Analysis and Examination of the Affect of Assumptions Used: More than any others, two assumption are key in producing these results: 1) the prices used as buy/sell prices and 2) the assumption that surplus electrical energy produced on peak in the change case is sold to the electrical market.

Prices Used: The prices used for this analysis were called from Prebon Energy, an electricity broker. They are forward prices for the relevant months of the study period at the Palo Verde trading hub, both on and off peak (as quoted for 02/02/02). Just as the CRSP – MC completed HYDRO-LP simulation runs, new prices were quoted from this source that were substantially higher for the study period. Using these prices would have resulted in a different calculation of the impact of Scenario 1.

Marketing Assumption: Suppose that, instead of selling surplus electrical generation to the market, the CRSP-MC sold it to CRSP customers. This is a reasonable assumption, even though it would occur under the conditions of an experimental flow. Western would then buy electrical power to meet contractual obligations during the September through December period and then, during the January through March period sell both the electrical power that would have been produced during the base case and that additional electrical power produced in Scenario 1 to CRSP customers instead of the electricity market. The charge to CRSP long-term firm customers is less than the market price. Therefore, using this marketing assumption, Western's CRSP-MC would experience an overall reduction in revenue. There would be a negative $5.7 million over the study period. Again, this result reflects only a financial analysis, i.e., revenues gained or lost by the CRSP-MC, and do not reflect the value of electricity delivered to CRSP customers.

VI. Recommendation

- GCMRC recommends that Experimental Flow Scenario 1 be implemented if there are significant sediment inputs in the August through December period.
- GCMRC recommends that Experimental Flow Scenario 3 be implemented if there are significant sediment inputs in the January through July period.
- GCMRC recommends that Experimental Flow Scenario 4 be implemented if there are no significant sediment inputs.

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ATTACHMENT 1

GCMRC AND TWG CONSULTATIVE PROCESS TO DEVELOP EXPERIMENTAL FLOW RECOMMENDATIONS

January 18, 2002 -AMWG Motion Passed

February 7, 2002-GCMRC Experimental Flow Scenarios, Version 1.1 sent to TWG

February 8, 2002-GCMRC/TWG conference call to discuss Experimental Flow Scenarios, Version 1.1 and begin development of Frequently Asked Questions and Answers

February 11, 2002-GCMRC provides a response to the Grand Canyon River Guides (GCRG) Memo of Inquiry

February 12, 2002- Arizona Game and Fish Department (AGFD) and GCMRC met with Lees Ferry Fishing Guides at Lees Ferry

February 15, 2002 -GCMRC Mailing to TWG of Experimental Flow Scenarios, Version 1.2 and Frequently Asked Questions and Answers

February 20, 2002- GCMRC Met with Grand Canyon River Outfitters Association (GCROA)

February 26-27, 2002-TWG Meeting

- Purposes for experimental flows were agreed upon by TWG, including working hypotheses and objectives.
- The basic concepts of the Experimental Flow Scenarios, Version 1.2 experimental design were supported by TWG **(pending tradeoff analyses)**

March 18, 2002 - GCMRC distributes Version 2.0 of proposed experimental flows scenarios to TWG

March 20, 2002 – Five-hour Public conference call with held with TWG and Interested Parties to discuss Version 2.0

March 22, 2002 - GCMRC revised the Experimental Flow Scenarios, Version 2.0 based on the TWG comments and distribute Version 2.1 to TWG members for final comments

March 25, 2002-Version 3.0 of Experimental Flows Scenario distributed to AMWG

April 24 – 25, 2002 – Experimental Flow Scenarios, Version 3.0 to be reviewed by AMWG.

ATTACHMENT 2

FREQUENTLY ASKED QUESTIONS & ANSWERS
(March 15, 2002 Version)

January – July

NATIVE FISH

Q: I understand there is little direct evidence of predation by non-natives on HBC: If this is correct, why is the focus by GCMRC on non-native fish?

A: Although, there is considerable uncertainty regarding the causal mechanism for the decline in adult HBC abundance, the predation/competition hypothesis has a higher likelihood than other mechanisms (disease/parasitism, hydrology, food-limitations, habitat degradation, etc.) for explaining the decline. In addition, this is a testable hypothesis using management flow prescriptions. Finally, it is plausible that the predation/competition hypothesis could overwhelm any benefits derived from management flow prescriptions intended to provide beneficial habitat conditions.

There is considerable circumstantial evidence that would suggest that predation could be influencing survivorship of YOY HBC. Specifically,

1. There is direct evidence of predation by trout, primarily BNT (8-10%); however, there is evidence of lower predation by RBT (1-0.5%) (Valdez and Ryel 1995; Rowell 2001).
2. The positive expansion in trout abundance system-wide in the Colorado River mainstem.
3. The highest proportion of fish in the LCR inflow area are composed of trout.
4. The composition of trout, in the LCR-inflow reach, consist of 97% RBT, and 3% BNT.
5. There has been a 4-6 fold increase in relative trout abundance in the last 7 yr.
6. Assuming Valdez and Ryel (1995) mouth-gape analysis is correct, the size-class of vulnerable fish to predation is the same size-class that fails to recruit into the adult HBC population.
7. Assuming that these estimates are correct and taking into account the local distribution and change in abundance since 1990-1993, estimated annual consumption of HBC-YOY should have increased.
    a. Annual consumption of HBC corrected for recent change in relative abundance
        i. Rainbow trout = 1990-1993: 227,760   2001: >1,000,000
        ii. Brown trout = 1990-1993: 32,850   2001: 120,000

Alternately, using population estimates for just the LCR area would suggest that RBT occur in densities of approximately 7,000 fish/mile based on full channel extrapolation of electrofishing CPUE. If the region encompassing the first 5 miles around the LCR inflow represents the only part of the HBC population that successfully recruits back to the source population, and only 1% of the trout in this area prey on HBC, and HBC are only vulnerable during the year for a limited 3-month period (90d), and only 1-fish is consumed per predatory trout per day, then a conservative estimate would be 30,000 HBC consumed. This compares to an estimated annual recruitment of 10,000 – 20,000 HBC to the LCR population in recent years.

A final reason, given the uncertainty associated with the competition predation hypothesis is that from a biological and sediment resource perspective this is a low risk experiment, with testable hypotheses.

Q: -How does load-following benefit native fish?
-How is it low-risk to disadvantage non-natives and not affect native fish?

A: GCMRC believes the benefits to native fish will accrue indirectly through a reduction in predation/competition by non-native fish, primarily salmonids in the LCR reach. The model developed by Dave Speas and Carl Walters provides support for load-following to negatively impact RBT by interfering with and disrupting spawning activity as well as reducing the recruitment of young fish. The working assumption is that non-native fish overwhelm any benefits to native fish from management flows that improve habitat conditions.

Load-following destabilizes or reduces the permanence of near shoreline habitat. Conceptually, YOY for most species of fish are found along the lentic edge of the river, occupying habitat that maximizes feeding opportunities while decreasing risk from predation. When there is a change in stage fish must move laterally while following the vertical change in water edge. Repeated movement by fish and increased distance traveled, results in lateral and longitudinal displacement that increases the likelihood for predation. The greater the magnitude in change and rate the greater the effect.

Load-following can equally affect both non-native and natives fishes. There are thought to be few HBC in the mainstem during the time of the year that load-following would occur and therefore, HBC will not be negatively affected. However, the hypothesis being tested is that the current abundance of nonnative fish has created a predator/competitor load that is too excessive. It is the abundance of predators that has overwhelmed survivorship of YOY along shoreline. The intent behind this flow prescription is to disadvantage non-natives rather then benefit native fish. This experiment would test alternate hypotheses whether or not YOY survivorship is habitat limited or is predator limited.

Q: If you won't benefit native fish in the fall, why do you go to steady flows?

A: There are a number of hypotheses to test:
Ho: Turbidity reducing predation

- This hypothesis, that turbidity reduces predation by visual sight feeders is considered hierarchically second to the reduction in predator loads.

Ho: Potential benefit to native fish from more stable near shore habitat.

- GCMRC has stated that the greatest number of YOY HBC enter the mainstem during fall monsoon events, therefore there is also the potential for stable flows following these events to provide warmer and more suitable habitat conditions for these fish during the fall. GCMRC should evaluate the downstream warming potential and the increase in suitable habitat of these mainstem conditions during the Sept – Nov time period.

- Expect this potential benefit may be overcome by non-native interactions.

Ho: Lower flows result in the retention of a more natural sediment mix and higher mainstem sediment concentrations for bar building in January. The more natural mix of sediment (fines through sand) will result in better bar stability and also affect nutrient cycling

Q: Is there any response of HBC to ROD flow changes? Do we know if there are changes in the LCR that may be the cause and that will be ignored by this effort?

A: We are beginning to look at the LCR hydrology record. One would expect to see changes in LCR hydrology due to development in the watershed resulting in groundwater depletion, surface water retention, and changes runoff patterns in response to paved areas, among others. It is not clear if we will be able to correlate these with changes in HBC. The working hypothesis is that predation and competition from non-natives will overwhelm habitat effects. This hypothesis also assumes that some portion of the LCR population recruited from fish which spent part of their early life history in the mainstem and that this portion of the recruitment is being negatively affected by non-native fishes.

There are other hypotheses that might explain the decline in abundance of HBC. Although there is considerable uncertainty around all of these alternate hypotheses. Not all of the hypotheses are experimentally testable to explain the causal nature of the recent decline of HBC. For this reason, we are suggesting an experiment to reduce predators in the mainstem because it is a practical and low risk treatment. However, if we were to implement such an experiment it does not imply that the current effort monitoring the species of concern would be discontinued, or that alternate mechanisms or factors that might be also contributing to the decline would be ignored, unconsidered or omitted from the present monitoring.

Q: Can we test the warming hypothesis for October – December when YOY might emerge in mainstem?

A: Cooling is as probable as warming during this period. A temperature monitoring effort as part of the monitoring and research activities that accompanies this experiment is warranted.

Q: A published paper shows drift out of LCR in May/June, will this be affected by the proposed flows?

A: The paper by Robinson et al. is based on three years of data(1991-93). Both 1992 and 1993 were high flood years for LCR. There may be problems in the accuracy and representative sampling, i.e. annual variation. The data wasn't correlated with any mechanistic parameters. Other data have documented HBC YOY in main channel during fall with decreasing abundance moving toward winter presumably due to predation, cold temperatures, downstream movement, or a combination of these.

Q: It seems like running high fluctuating flows to impact population around LCR has a potential negative impact on the whole system?

A: This is true and intended to be so for salmonid spawning, recruitment, and food base, in the Lees Ferry reach. However this negative becomes a potential positive for native fish downstream of Lees Ferry. HBC are at a very low abundance or non-existent in the LCR reach at this time either due to downstream transport or predation, therefore no impact on native fish is expected during this time. April stabilization optimizes the recovery of the foodbase because of light regime etc. Food may not be limiting downstream in any regard.

Q: What is the potential of confusing impact of fall low steady flows vs. fluctuating flows on native fish?

A: Fluctuating flows are not believed to have any direct impact on native fish. Fall low steady flows may have secondary benefits to native fish through improved habitat conditions IF non-native predation is reduced first. We may have difficulty in the long term assigning cause and effect relationships to these two factors. However the best science data and intuition suggest that HBC may be better off as a result of these experiments.

Q: Will 1 year of experimentation allow you to see an effect on native vs. non-native fish interactions?

A: Not likely. Repeated experiments over several years would improve the probability of detecting an effect. The strength of treatment will be related to the number of years the experiment is repeated as well as the magnitude of the flow fluctuations. Effects on native fish will be more difficult to detect than effects on non-natives, which will only be measurable after several years. Changes in non-native predator abundance may detectable within 2 years**.** Prefer 2 to 3 years of experimentation.

Q: Are we applying too many treatments to measure this effect on the fish community?

A: From a biological perspective the core experiment is an annual flow regime, repeated over time, not seasonal elements of the annual hydrograph . There may be confounding effects if we consider predator removal in BAC and the LCR along with the flow experiment. The tradeoff is not doing enough to improve HBC.

NON-NATIVES

Q: Would load-following confound measuring impacts of Brown Trout removal in Bright Angel?

A: Load-following is designed to be a more systematic treatment. One year of load following vs. one-year of Brown Trout evaluations are very different. Having both would enhance the potential effort.

The hypothesis that is being tested is whether or not predation is limiting YOY HBC recruitment. Whether we have multiple treatments that are each reducing predator loads does not affect the overall nature of the test. For the test, it is not what reduces trout more effectively (flows, tributary treatments, mechanical removal), but whether the reduction of trout abundance by some means has an effect on YOY HBC recruitment? Depending on the ultimate test response (which remains unknown), a titration approach could be implemented that would allow for a measure of efficiency of one method over the use of an alternate method.

Q: Are the wheels in motion to do Brown Trout removal this Fall?

A: Grand Canyon National Park is supportive but the resources (staff and funding) are not there to do it this Fall.

Q: Could you move the load-following period to February to address the possible public concern of stranding adult trout?

A: This can be considered. One is not sure if it will have the same effect of reducing non-native spawning. Using slower down ramp strategies as well could reduce stranding of adults.

Q: Could you reduce concentrations of rainbow trout around the LCR by some other mechanism besides high fluctuating flows?

A: While GCMRC is considering a mechanical removal effort around the LCR this would be intended primarily to better understand predation and have a secondary benefit of removal in a limited area. This would not be as systemic an effect as flows would be. Feasible removal estimates for 2-4 electro-fishing trips are from 8-15% of the adult population in the LCR reach. Flows could reduce individual year classes by 50%. These efforts should be complementary. Objectives could not be accomplished by mechanical removal alone. Monitoring will allow us to determine the added benefit of LCR efforts.

Q: Are the high fluctuating flows "fishable"?

A: Yes, depending on the ramping rates. Notification will need to be provided at the ramp to minimize the safety hazard from swift changes in stage.

Q: Can you achieve the same desired downstream effects on non-native fish with lower fluctuating flows?

A: Probably not. There is a historical negative correlation between RBT recruitment and the degree of annual flow fluctuation. Experimental data suggest lower egg hatchability and fry survival under high fluctuating flows. The further one goes toward approaching recent ROD operations the less effective fluctuating flows are likely to be.

Q: Is there a problem if one were to shift the high fluctuating flows a month or two (i.e., begin in March instead of January)?

A: Spawning and emergence of RBT is spread over at least a six-month period. Moving the flows to later would miss the peak of both of these phenomena and reduce the effectiveness of the experiment. To increase the effectiveness, these flows should occur for 6 months rather than the three being proposed.

Q: If you fluctuate from 5,000 – 25,000 cfs, will you kill adult trout through stranding, perhaps several hundred a day until spawning season ends?

A: Stranding will probably occur but that mortality during this time of year will be minimal, likely an order of magnitude less than hundreds. If the estimate of a hundred fish per day over 15 miles for three months were accurate, this would represent between 5% and 10% of the adult population. Opinions are divided over whether stranding can be mitigated by removal of adult fish.

Q: Do we know the location of standing pools for adult rainbow trout?

A: These locations are documented in GCES reports and are known to the Lees Ferry trout guides. There are approximately 5-6 areas where stranding will be most prevalent. These locations are known and can be monitored by the guides and AGFD and adult trout can be monitored if needed.

Q: Could AGFD reduce non-native fish through changes in fish regulation?

A: It is unlikely that regulation would have the desired affect.

Q: Can there be more analysis to fine tune the January – March hypothesis regarding stage-relationships and timing with respect to interrupting spawning and maximize reduction in success of Redds?

A: Data exists that could be used to analyze the amount of wetted area available at different flow stages but it won't really represent the amount of destabilization that occurs from high fluctuating flows. Historical data does suggest that pre-ROD fluctuations were effective at reducing the abundance of non-native fish.

Q: Is it the fluctuating flows that are intended to reduce non-native fish?

A: Yes, through a combination of disrupting spawning activity and success as well as reducing survival and recruitment of young salmonids.

Q: Will the proposed high fluctuating flows reduce non-native fish above and below Lees Ferry equally?

A: Probably not. This response will be proportional to non-native fish abundance, which decreases downstream. There is also an unknown contribution from tributary spawning downstream, which will not be affected by these flows. Furthermore there will be some attenuation of the amplitude of fluctuations as one proceeds downstream. This argues for more rather than less fluctuation in discharges in order to achieve the desired effect in the LCR reach.

Q: Given that the guides believe Lees Ferry population abundance is beginning to decline, are the high fluctuating flows needed? The Lees Ferry Guides have reported seeing a 40% decrease in last 6-18 months in catch rates.

A: The observations of the Lees ferry Guides have not been corroborated by AGFD electrofishing data. Some new data may be available by the AMWG meeting and will be reviewed as it becomes available. Provisional field observations from downstream monitoring also show no equivalent decrease. Preliminary trip data from AGFD & GCMRC will be refined prior to AMWG to verify this and current Lees Ferry abundance.

Q: Are there different ways you could disrupt the spawning than what you've shown?

A: There are possibilities but nothing very feasible-sediment augmentation, more extreme flow fluctuations, extended flow reductions (steady low, e.g. 3000cfs flows).

<u>SEDIMENT</u>

Q: Could you use a HMF to conserve sediment instead of low steady flows or low load-following flows?

A: You might potentially store some sand and possibly some limited amount of finer sediment within eddies, but the total sand conservation achieved would be far less than if the entire channel bed was available for storage of fines under the 10,000 cfs or less flow alternative. A comparison of results from the 1996 BHBF, and the 1997, 31,500 cfs spike flow provide some valuable insights on this matter. One important concept to keep in mind is that the total potential storage for sand within eddies is only a small fraction of what can be stored within the main channel, under flow conditions that limit downstream transport.

Eddy-sand bars studied following the November 1997, spike flow (under relatively sediment-supply enriched conditions), showed a much finer grain-size distribution than bars created by the 1996 BHBF (under relatively greater sediment-depleted conditions). The 1997 eddy deposits were relatively cohesive compared with the 1996 deposits, and were much darker in color, suggesting some higher content of organics. Unfortunately, the average thickness of most of the 1997 deposits was on the order of 10-20 cm, or relatively thin compared with bar thickness measured after the 1996 BHBF. One preliminary conclusion derived from the 1997, sediment experiment was that the 31,500 cfs spike flow produced a "stage-limited" response, and that thicker and larger bars might have been deposited in November 1997, had the stage been increased to above peak power plant levels. Flows preceding the November 1997 test were not as low as those being proposed for future experiments, yet there was still evidence to suggest that at least some portion of the summer sediment inputs remained in the channel by the time the high flow occurred.

Q: Are there other options for sediment conservation in September-December? Options might include HMFs or steady 8,000 -10,000 cfs flows? Load-following between 5000-9000 cfs? Would the conceptual model or Wiele efforts help sort this out?

A: The conceptual model is not predictive in the sense that we can calculate the expected outcome of an experiment, but it may have utility in comparing the results of several options for portions of the proposed hydrograph.

Wiele's bar-evolution modeling simulations indicate that bars are most effectively deposited when a combination of high suspended-sediment concentrations and high-stage conditions occur simultaneously. Limiting downstream transport of newly input fine sediment until the release of a controlled flood is the most probable means of achieving both of the above conditions, if releasing a controlled flood during or immediately after tributary inputs is not a viable option. The conceptual model's sediment dynamic sub-model is based on the same basic premise: when abundant sand supply is available, then it will get mobilized by a high-flow release and the result will be an increase in sand storage at high stage elevations.

Q: Given that the motion focuses on sediment, how does the low load-following benefit the sediment?

A: The winter load following component of the experiment <u>is not</u> intended to benefit the sediment resource. However, there may be some advantage derived from the winter load-following with respect to modifying the newly formed bar morphologies.

Q: Will the load-following erode the recently deposited sediment from the BHBF? What sediment-related hypotheses does the load-following test?

A: Any operation following the BHBF will result in reworking of the newly deposited sand bars. This bar reworking can be viewed as "erosion," but there is no way to avoid it. The basic question remains as to what operation will export the least volume of sand downstream for any range of antecedent sand-storage conditions? A secondary consideration concerns how the operations that follow the BHBF will affect the morphology of the new bars with respect to ecosystem value. A few hypotheses might be considered:

Ho: Winter load-following <u>does not</u> result in a increased export of stored sediment.

Ho: Winter load-following <u>does not</u> modify new eddy bars in a manner that makes them more stable of greater resource value.

Ho: Winter load-following <u>does not</u> achieve eddy bar morphologies that allow for greater access to recreational users.

Q: If you go to the low load-following proposed, can you test the up- and down-ramp rates and their effects?

A: Addressing the sediment-transport dynamic issues related to ramping rates is a difficult challenge that requires very high-resolution data sets, or a very sophisticated numerical predictive capability. GCMRC has been examining an optically-based technique (LISST) for measuring suspended sediment. Results to date look promising. We will know by summer if we can use this approach to examine changes on up- and down-ramp rates. In the event that LISST technologies prove adequate for monitoring suspended-sediment transport in the Colorado River ecosystem, then these methods will be used for evaluating issues of ramping rates and relationships to sand resources, etc. Researchers at University of Arizona have studied issues of ramping rates and their impacts on the dynamics of sand bars previously. These EIS results can be reviewed again, and additional numerical simulations can be run and evaluated, pending approval by managers and on the basis of funding availability.

<u>INTEGRATION</u>

Q: What dose "RPA flows" in the AMWG motion refer to?

A: RPA flows suggest the need for experimentation to benefit native fishes, which is consistent with this proposal.

Q: Are the purposes responsive to the motion?
Materials describe two purposes: (1) sediment, and (2) benefits native fish. I thought the motion was primarily about sediment.

A: The point of the motion was primarily to test the sediment Ad hoc group's second recommendation, but GCMRC interpreted the motion as a sediment conservation experiment within the framework of benefiting native fish.

Q: Is the GCMRC draft proposal in concert with the RPA?

A: Yes. As per the FWS RPA, the draft proposal identifies the need for the development of experimental flows to test, or the implementation of alternate flows as specified in the Biological Opinion of GCD. One such flow was the 2000-LSSF experiment (SWCA 2000) that used a holistic hydrograph that was intended to produce habitat improvements that would benefit HBC, rather than a mechanistic approach specifically applied to a life history component. The approach here is more discrete and testable than the former flow scenario.

Q: Why isn't this a program of flows?

A: Given that the motion asks for a proposal to be brought back to the AMWG in April for WY 2002-2003, this is intended to be an element of a program of flows. It is clear from the conference call that there are a number of alternative ideas for experimental flows. This is the flow GCMRC recommends the AMP try first, with the understanding that this single year's flow would fit into an overall program of flows.

Q: Integrated Ecosystem Experiment: I recommend that the experiment should be less ambitious and should simply test the sediment paradigm. The experiment should be within Law of the River and the ROD. We do have to get through July and August with meeting power supplies.

A: The AMP is intended to use an ecosystem-science approach in testing the effects of dam operations. It also recognizes that the Endangered Species Act mandates that the Department of the Interior take action to protect these species. At the January AMWG meeting, GCMRC presented data that indicated sediment resources and HBC are not responding to the ROD as anticipated in the EIS. It would be irresponsible for GCMRC to make a recommendation to the AMWG for an experimental flow that does not take an ecosystem science approach and that does not address the resources of concern. It is our belief that the flows proposed in the February 8 (Version 1.1) draft are within that portion of the ROD that allows for experimentation, if ROD flows are not achieving the intended benefits. GCMRC also believes that after the AOP process considers the experimental flow request and determines WY 2003 monthly volumes, the proposed flows are in compliance with the current interpretation of the Law of the River as all of the flow elements that are proposed for testing could be implemented, following appropriate compliance, within the current interpretation of the Law of the River.

WATER FLOW ISSUES

Q: How can you conduct low steady flows or low load-following flows? Don't they violate the AOP?

A: The concerns expressed about monthly volumes and the AOP process are important ones. Annual release volumes are defined by statute and resulting operating criteria. Monthly release volumes are determined to meet annual requirements, support firm power generation commitments, and address the combined risks of powerplant bypasses, and over- and under-release of annual volumes. The GCPA did not alter the water development philosophy of the previous 1956 and 1968 Acts; thus, the financial integrity of the Basin Fund is of great concern to the States. As the AOP is developed each year, consideration is given to all the factors listed in the 1970 Operating Criteria, which include environmental concerns. The issue raised on the Feb. 8 conference call was not so much that the monthly volumes cannot be adjusted, but rather that the process of developing those monthly volumes must remain consistent with the water development and financial goals of previous Acts. If monthly volumes need to be adjusted from the typical decision making process in order to conduct an experiment, this issue would need to be addressed during the preparation of the 2003 AOP.

Q: If this is an 8.23 MAF year, July and August would be 800,000 Acre Feet and September, October, and November would be low volume months. How can you conduct the flows you describe, given these potential volumes?

A: The proposed hydrograph shows both the end of the 2002 water year (expected to be 8.23 maf) and the entire 2003 water year (expected to be about 10 maf). No adjustment to the 2002 water year hydrograph is proposed, with the possible exception of reacting to fall tributary inputs. Thus, July and August of the 2002 water year are expected to be about 800,000 af months, and GCMRC will monitor the effects of ROD releases during this year as part of a "baseline" data collection to determine the effects of ROD operations.

The reaction to fall tributary inputs is to recommend either a reduction to low steady releases (below 10,000 cfs) to conserve sediment inputs in the main channel or low fluctuating flows (5,000 – 10,000 cfs) to conserve sediment inputs in the eddies, or lastly the release of a HMF.

Q: Could UC and LC talk about a way to work this out if deliveries are lower and water volumes need to be shifted for this experiment, especially since releases from Mead wouldn't be affected?

A: This can be done as long as the Compact and the specific annual release requirements contained in the 1970 Operating Criteria can't be violated.

Q: If FY 2002 is an 8.23 MAF year and one needs to take information from Summer of 2000 and compare it to ROD flows in 2001 and 2002, do you have the baseline data collection for that comparison?

A: A similar level of effort for monitoring downstream native and non-native fish has continued since the LSSF flows of 2000. Seining at a lower level of effort is continuing. The integrated sediment data is continuing to be collected. Reduced efforts on downstream temperature is ongoing. The level of resolution and many of the specific studies intended to answer specific effects of the LSSF treatment have not been continued. Once a set of experimental flows is established and the hypotheses to be tested are articulated, GCMRC will need to review the power of the existing monitoring activities.

Q: What reservoir elevation do we need to be at to use the spillways?

A: By January 2003, Lake Powell storage elevation needs to be at 3657 feet to have 14,000 cfs of flow in either of the spillways. This level of discharge is needed for the spillway to function in a safe manner. For January 2003, the lake level is projected to be 3648 feet. As a result, there seems to be little hope that the BHBF proposed for January 2003 could exceed 45,000 cfs.

Q: December is a high power demand month, is it possible to do fluctuating flows up to 15,000 cfs. What would this do to sediment storage for a January BHBF?

A: Load following between 9,000 and 15,000 cfs during December 2002, is certainly one of the possibilities being evaluated following summer/fall sediment inputs. If the sediment inputs occurred in September, and the flows were released to 10,000 cfs or less through November, then there would be less downstream transport during the proposed December load following than if normal operations occurred throughout the September through December period. The impact on downstream transport of newly input sand during the December operations is most easily evaluated by reviewing figure 2, included in the Rubin et al. memorandum of August 2000.

Assuming: (1) that at least 500,000 tons of sand entered the main channel from the Paria River in September 2002, (2) that flows were immediately reduced to 10,000 cfs or less from the time of the input until December 1st, and (3) that the average flow for December 2002, was about 12,000 cfs – figure 2 suggests that about one-half of the newly input sediment introduced in September 2002, would be transported downstream in about 45 to 250 days, once December's operations started. Likewise, if we assume that the proposed BHBF occurred at the start of January 2003, then there is reason to believe with some certainty that less than one-half of the September sediment input would be exported downstream before the January BHBF was released.

Q: If sediment is stored in the eddies in an HMF, why do you go to monthly low flows?

A: The HMF approach foregoes hypotheses related to storing the fuller range of sediment components and the turbidity effects. Also, there is only a limited volume of sand that can be stored in the eddies and it is much less than the volume of fine-sediment that can be stored in the channel bed throughout the entire river channel. Results of the November 1997, sediment experiment (31,500 cfs) indicated that sand storage increased within eddies, but that this increase in storage was very limited compared to the volume of sand that might have been conserved had a higher flow been released that would have taken advantage of higher-elevation storage locations along shorelines. There is no basis at this time for concluding that the potential eddy-storage volume within the ecosystem is sufficient to sustain sand-bar maintenance long term. In light of this, the most conservative scientific experimental approach is to conduct the flow experiment that has the greatest likelihood of optimizing sediment conservation and sand-bar restoration/maintenance. Doing less optimal sediment treatments in the future may very well be justified during periods when reduced-flow operations are not possible, or on the basis of new findings that indicate that the fullest range of channel storage is not required for long-term sand bar sustainability.

Q: Why not test a BHBF in Fall?

A: This is viewed as outside the current interpretation of the Law of the River.

Q: Concerned that load-following is outside the ROD? Do we have compliance for fluctuating flows that violate daily ranges and proposed upramp rates?

A: GCMRC believes that this would be covered as an experiment under the ROD. We do need to check into compliance.

Q: I want to ask you to look at trade-off in fine sediment losses through a two-stage approach:
-HMF followed by a BHBF and the benefit of doing low load-following during winter-peak demand

A: Because we don't have a very robust numerical predictive capability, with respect to sediment dynamics in this system, the best way of quantifying these differences is by conducting the proposed experiment, and then comparing the results to those of the proposed alternatives. The next best way is by using empirically derived methods for estimating sediment transport, such as the method shown in figure 2, of the Rubin et al. (2000) memorandum.

Q: There are non-ROD elements in Figure 1, load-following, low Fall releases, could include BHBF outside ROD period and HMF outside the ROD. Recommends two Figures: an ideal hydrograph and one that balances legal/policy trade-offs.

A: Given the provision in the ROD that calls for experiments if the resources are not responding as expected to the ROD flows, no elements of the proposed flows are thought to be outside the ROD. GCMRC and the TWG should review this more thoroughly.

Q: Why is a fall BHBF outside Law of the River?

A: The current interpretation of the Law of the River would prevent a BHBF from occurring for other than dam safety purposes. The triggering criteria developed to address that provide a window between January to July for conducting BHBFs.

Q: What's next? When will the public be informed?

A: This is the conceptual phase. The questions and concerns we heard today will be used to refine what we bring to the TWG in February. The TWG will provide an opportunity for public input. Following the TWG, a recommendation will be forwarded to the AMWG. We assume that detailed design work with scientists and detailed public impact will occur following that and final approval will be obtained in July? GCMRC and the AGFD held a preliminary meeting with the Fishing Guides at Lees Ferry on February 12 to provide the same conceptual material that was presented on February 8 and invite their input.

Q: **How much money do we have for this?**

A: The experimental flow fund will contain about $1 million by January 2003. Any remaining funding needs will be sought as an appropriation request or through reprioritizing AMP activities.

Q: **Can we consider 5,000 – 9,000 cfs flows in lieu of steady 8,000 cfs flows for September – December? Would low fluctuations in fall be as optimal as flat flows?**

A: Mike will provide assessment, HBC is thought to be more positive with stable flow-this period represents time of greatest historical near shore habitat loss according to recent analysis by Korman, rainbow trout might be more negative with fluctuation but probably minor this time of year, What about turbidity-Ted?? Sediment Loss??

Q: **What is the total cost impact on hydropower of the proposed experimental hydrographs?**

A: WAPA will provide.

Q: **Are the proposed experimental hydrographs a departure from the ROD, given the proposed range of daily fluctuations?**

A: The ROD allows for experimentation if there is evidence that the preferred alternative is not achieving the intended benefits. The high fluctuating flows are being proposed under the experimentation allowed by the ROD.

Q: **Can this or any hydrograph even be implemented since the AOP process is the mechanism for adjusting monthly volumes and proposing monthly volumes?**

A: To be provided

Q: **Will the falling limb of the hydrograph following the BHBF going right into high fluctuating flows allow us to test benefit of BHBF?**

A: A few days of steady flows following the BHBF, as in 1996, for monitoring may be required

Q: **Would a stepped-down hydrograph following BHBF to accomplish progressive reworking of the sediment deposits produce an eddy profile that is more stable and friendly to people using the river?**

A: [To be added]

Q: Can the duration of the BHBF be limited based on real time tracking of sediment transport so one could propose 2-5 days and truncate the BHBF based on real-time data regarding sediment transport and beach building?

A:

Q: Should the BHBF peaks be higher in stage?

A: One may want to test a higher magnitude BHBF but the hydrology under which this experiment is being proposed won't allow it. There is also value in repeating the magnitude of the 1996 BHBF and only changing duration.

Q: How much water will bypass the power plant during a BHBF?

A: To be added by BOR

Q: Can one predict the ratio of sediment stored -to- sediment exported from a BHBF? Is there an optimum BHBF level that yields maximum storage with limited export?

A: To be added

Q: What is the purpose of the 5,000 cfs low flow?

A: To provide a stable minimum foodbase level but with flow levels fluctuating enough above that to disrupt spawning and survival/recruitment of non-natives.

Q: Is the trigger for a BHBF the same if the sediment inputs are in the fall as compared to January?

A: Yes.

Q: Is compliance in place to conduct these flows or is additional compliance needed?

A: Compliance will be required.

ATTACHMENT 3

SCIENTIFIC HYPOTHESES TO BE TESTED WITH THE EXPERIMENTAL FLOW SCENARIOS

The null hypotheses to be tested within this experimental design include:

Scenario 1:

Flows below 10,000 cfs prior to BHBF – Ho_1 – Constrained operations between time of sediment input and BHBF result in the same level of sediment storage as that estimated prior to the 1996 controlled flood test.
Flows below 10,000 cfs prior to BHBF – Ho_2 – Constrained operations between time of sediment input and BHBF result in the same level of sediment storage as that associated with the 1997 peak power-plant flow release test.

BHBF - Ho_1 - The sand-bar depositional response to this second BHBF will be identical to the 1996 response in terms of depositional rates, total volume and grain-size characteristics, and,
BHBF – Ho_2 – Sand bars with finer grain-size distributions than those measured in 1996, are no more stable (erode just as rapidly) that those monitored after April 1996.

Recessional Limb – Ho_1 – A stepped recessional component of the hydrograph following the BHBF, results in the same steep-faced beach morphology as measured following the 1996 BHBF.
Recessional Limb – Ho_2 – A stepped recessional component of the hydrograph following the BHBF, results in the same rate of reworking (erosion) of newly formed sand bars as measured following the 1996 BHBF.

With Experimental Fluctuating Flows – Ho_1 – Large-magnitude fluctuations following the BHBF through March, result in the same steep-faced beach morphology as measured following the 1996 BHBF.
With Experimental Fluctuating Flows – Ho_2 – Large-magnitude fluctuations following the BHBF through March, result in the same rate of reworking (erosion) of newly formed sand bars as measured following the 1996 BHBF.

Without Experimental Fluctuating Flows – Ho_1 – Fluctuations associated with normal MLFF operations following the January 2003, BHBF, result in less steep beach-face morphology than measured following the 1996 BHBF.
Without Experimental Fluctuating Flows – Ho_2 – Fluctuations associated with normal MLFF operations following the January 2003, BHBF, result in a slower rate of reworking (erosion) of newly formed sand bars than measured following the 1996 BHBF.

Scenario 2:

Normal ROD Operations Immediately Following Sediment Inputs from Paria River – Ho_1 – Normally scheduled ROD operations following sediment inputs in July through December

2002, result in no additional export from Marble Canyon compared with stable flows contained in scenario 1.

Scenario 3:

BHBF Immediately Following Sediment Inputs from Paria River – Ho_1 – The sand-bar depositional response to this second BHBF is identical to the 1996 response in terms of depositional rates, total volume and grain-size characteristics,
and,

BHBF Immediately Following Sediment Inputs from Paria River – Ho_2 – The sand-bar depositional response to this BHBF is not significantly different than the response, in terms of depositional rates, total volume and grain-size characteristics, measured for an Alternative #2 BHBF scenario(Rubin et al., 2000).

All Scenarios:

H1: Winter high fluctuating flows does not reduce recruitment of RBT and BNT in Grand Canyon.

H2: Winter fluctuating flows as described with a 5,000cfs lower limit, does not increase export of ecosystem sand.

H3: Winter fluctuating flows does not produce eddy-bar morphologies that are more conducive to recreational and other ecosystem uses.

H4: Winter fluctuating flows will not adversely impact food base resources. Only the lower limit of the diurnal range would be constrained for purpose of limiting detrimental impact to phyto-benthos resources.

H5: HBC recruitment is not limited by RBT or BNT predation.

ATTACHMENT 4

IMPLEMENTATION PLAN

Implementation Plan

An implementation plan will be developed that addresses that steps that would be required for:

- Compliance
- Permitting
- Development of a detailed science plan
- Funding – Experimental flows account and/or new money (year end?) and/or reprogramming
- Agreement on triggering criteria
- Public outreach plan
- Other

ATTACHMENT 5

LONG-TERM ADAPTIVE MANAGEMENT EXPERIMENTAL DESIGN

In an adaptive management framework, experimental design becomes extremely important for properly managing resources and taking into account disparate stakeholder interests, policy issues, and management constraints. Experimental design is particularly critical when making difficult decisions that consider the uncertainty underlying cause and effect in a complex ecosystem. For example, to address the decline in humpback chub abundance and distribution a management prescription based on the "natural flow regime" hypothesis has been proposed for restoring critical aspects of natural ecological functioning to the Colorado River. This hypothesis presupposes that declines are solely related to habitat alteration. Alternately, invasive non-native species are acknowledged as potentially having as great of an ecological affect on loss of species diversity as has environmental degradation. Recognizing such competing or possibly complimentary hypotheses is crucial because instituting FWS RPA (REF) flows without experimentation may or may not have the desired result.

Properly designed experiments are developed so that they allow for making comparison(s) between levels of a single factor or set of factors hypothesized as being responsible. Yet, experimental designs are often compromised in situations where critical resources (i.e., endangered species and sediment) are demonstrating undesirable trends that require expeditious and accurate findings (REF). This has often resulted in a false understanding of the causal mechanisms responsible for regulating a specific resource. Correlational analysis provides the foundation for developing questions and hypotheses, yet only experimentation provides for a means to determine causal mechanisms. Unfortunately, it is a commonly held, but incorrect belief, that correlation provides an understanding of causation; rather it has often lead to further speculation, and promulgating unsubstantiated assumptions that result from a fear of uncertainty. Therefore, any type of correct inference made based on the effect of a factor or set of factors has to use an elimination or falsification process, because nothing can be proven with total certainty.

The Glen Canyon AMP must adopt a truly experimental approach if progress and learning about managing the ecosystem are to occur. A long term, multi-year to multi-decade perspective is needed. The proposed experimental construct herein uses a block-design approach for testing multiple combinations of independent variables or factors and their resource effect. For this reason, it is desirable to use a multivariate approach such that multiple comparisons between factors considered causal can be expeditiously tested and perhaps falsified. To illustrate this concept we describe an experimental design using four independent factors to be tested, they include: (1) fluctuating flows, (2) mechanical removal of fish, (3) fall flow regimes, and (4) a temperature control device. All of these are plausible and important factors, which could constitute treatment options in the CRE. Testing such a suite of factors in combination could allow us to begin determining whether or not biotic interactions such as predation and/or environmental alterations to habitat are limiting recruitment of humpback chub.

Correctly applied experiments require multiple year treatments in order to perform adequate comparisons, especially in complex and uncontrolled natural systems. Therefore, a conceptual commitment to an experimental design having a sequence of yearly treatments is required in order to compare the effects of the factors identified above on a resource response. Such comparisons within and among treatments would require a multi-year period. This multi-year approach is considered scientifically sound and essential for addressing specific stakeholder objectives. Multiple year comparisons allow for researchers to account for extraneous sources of variation that exist in complex ecosystems such as the Colorado River and confounding effects due to multiple factors.

We would suggest that monitoring and research mechanisms be in place to scientifically evaluate, on a yearly basis, the response of both the targeted resources, as well as interactions with other secondary resources in this ecosystem. Having such an evaluation mechanism would allow for a means to assess and determine whether or not to: (1) discontinue a specific treatment if observed to be deleterious; (2) prescribe a management prescription; and (3) include other factors for future testing. However, we also suggest caution in the use of such an evaluation method so as to avoid truncating an experiment prematurely without due cause. The following table illustrates various choices along with treatment elements designed to benefit native fishes in the context in which they would be considered in a longer term adaptive management experiment. This table should serve to allow adoption of a treatment for WY2002-03 as part of a longer term series of treatments to be prioritized by the AMP.

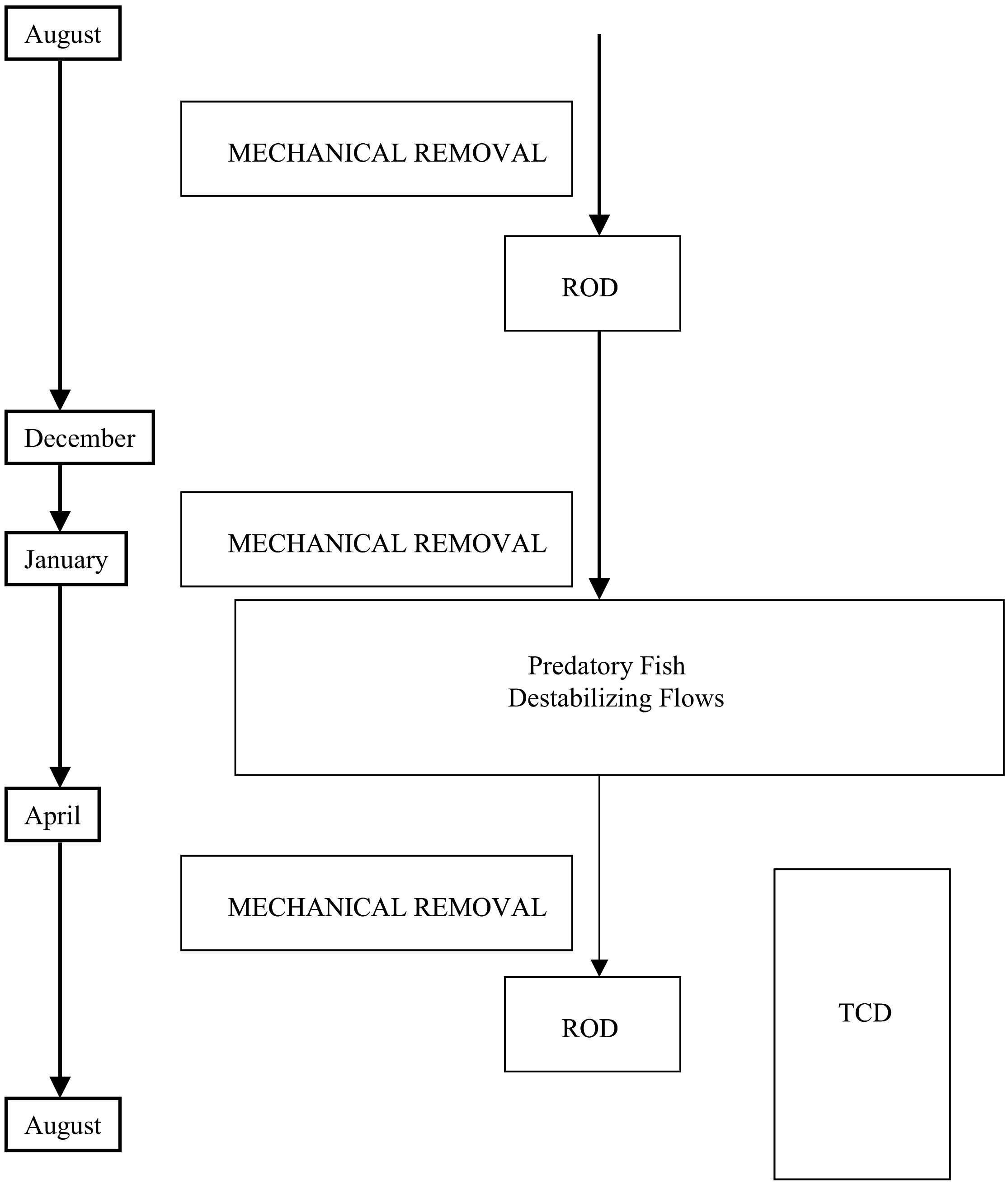
Table: Experimental Design, long-term sequence of treatments

Water Year	**Fluctuating Flows (Jan – Mar)**	**Mechanical Removal (Aug – Dec)**	**Stable Fall Flows (Aug – Dec)**	**TCD (Future)**	**BHBF (Jan – Jul)**
WY2002-03	Yes	Yes	Yes	No	?
WY2003-04	Yes	Yes	No	No	?
WY2004-05	No	Yes	Yes	No	?
WY2005-06	No	Yes	No	No	?
WY2006-07	No	No	Yes	No	?
WY2007-08	No	No	No	No	?
WY2008-09	Yes	No	Yes	No	?
WY2009-10	Yes	No	No	No	?
WY2010-11	Yes	Yes	Yes	Yes	?
WY2011-12	Yes	Yes	No	Yes	?
WY2012-13	No	Yes	Yes	Yes	?
WY2013-14	No	Yes	No	Yes	?
WY2014-15	No	No	Yes	Yes	?
WY2015-16	No	No	No	Yes	?
WY2016-17	Yes	No	Yes	Yes	?
WY2017-18	Yes	No	No	Yes	?

TIME-LINE

TREATMENT TYPE:

- Fluctuating Flows
- Mechanical Removal
- No Low Stable Flow
- Temperature Control Device



ATTACHMENT 6

AN EVALUATION OF THE EFFICACY OF MECHANICAL REMOVAL OF NON-NATIVE SALMONIDS IN THE CRE BELOW THE PARIA RIVER

(MECHANICAL REMOVAL TREATMENT)

INTRODUCTION

Background

Recent analyses of historical humpback chub (HBC) data suggest that the abundance of the Little Colorado River (LCR) population of HBC is in decline. These analyses utilized mark-recapture data in an open population model to construct estimates of the population recruitment (1989-1997 brood years) and sub-adult and adult abundance (>150 mm total length; 1991-1999). The decline in the abundance of sub-adult and adult fish appears to be the result of continued low recruitments beginning with the 1992 brood year. As these weak year classes have entered the sub-adult and adult portions of the population, the overall abundance of adult HBC has declined from a peak of 8,517 in 1993 to 3,388 in 1999. The overall trends in recruitment and abundance are supported by two additional analyses. First, the downward recruitment trend is supported by trends observed in the catch-rate (CPUE) of Age-1 and Age-2 HBC from hoopnet sampling in the LCR (GCMRC unpublished analyses). Second, a closed population mark-recapture experiment conducted in the LCR during the spring of 2001 indicated the population contained only 2,090 (95% C.I. 1611-2569; HBC >150 mm total length; USFWS *in prep*.). Combined, these three independent analyses provide sufficient evidence to conclude that the Little Colorado River population of HBC is in decline.

Of paramount importance in conserving this population of federally endangered humpback chub is determining the factors contributing to this population decline and implementing management actions designed to minimize the effect of those factors. Although all of the factors that may be responsible for the recruitment decline beginning in 1992 it is still unclear, we have identified a list of likely factors that could be acting either singly or in combination. These factors include: 1) Colorado and Little Colorado River hydrology, 2) infestation of juvenile HBC by Asian tapeworm, 3) predation by or competition with warm-water native cyprinids and catastomids and non-native cyprinids and ictalurids within the LCR, and 4) predation by or competition with cold-water non-native salmonids within the Colorado River.

The body of evidence available to evaluate specific hypotheses varies among the postulated factors. For instance, beginning in August 1991 the operation of Glen Canyon Dam was changed to reflect the so-called "interim operating criteria". This hydrology, and the subsequent ROD flows that continue to present, can be generally characterized as having less severe daily flow fluctuations than the previous 28 years of load-following hydrology. Temporally, this major change in Colorado River hydrology correlates closely to the decline in HBC recruitment. Additionally, it is possible that the initial decline in HBC recruitment in 1992 was caused by the nearly continuous flooding in the LCR that occurred during the summer of 1992, particularly during the early summer time period when larval HBC emerge (Robinson et al. 1998). It is also possible that the high infestation rate of juvenile HBC by the introduced parasite Asian tapeworm is a causative factor. HBC infected with Asian tapeworm were first found during 1990, and infestation rates during 2001 have exceeded 90% (Anindo Choudury, pers. comm.). Finally, predation and competition by fishes either within the LCR or in the Colorado River may be driving the HBC recruitment trend. Although robust relative abundance data does not exist for non-native fishes within the LCR, there has been a large increase in the abundance of non-native salmonids in the Colorado River near the confluence of the LCR (LCR Inflow Reach RM 56.6-68.3; Gorman and Coggins 2000; Figure 2).

While it is difficult to determine which factor is most responsible for the HBC recruitment decline, a likely significant factor is negative interactions (predation and competition) with non-native fish. Interaction with non-native fish is implicated in the decline and extinction of native fishes throughout the Colorado River basin (Tyus and Saunders, III 2000 and references therein). Given the potential threat of predation and competition by rainbow (RBT) and brown trout (BNT) in the LCR Inflow reach of the Colorado River, we propose the immediate initiation of a multi-objective study to evaluate the potential effect of RBT and BNT predation on HBC recruitment and the efficacy of mechanical removal of RBT and BNT from the LCR Inflow reach.

Need

In response to a motion passed by the AMWG directing the GCMRC to design a set of experimental flows to test several sediment conservation hypotheses, the GCMRC proposed an integrated set of experimental flows to test not only hypotheses related to sediment conservation, but also hypotheses related to improving HBC recruitment. The flows related to testing fish hypotheses center around the notion of improving future HBC recruitment by reducing the number of adult RBT and BNT residing in the system downstream of Lees Ferry. Conceptually, this is to be accomplished primarily by reducing RBT and BNT recruitment by inflating the early life mortality rate of these fishes with highly fluctuating flows during their winter and spring spawning and rearing seasons. Although these experimental flow scenarios have not been formally presented to the AMWG, comments have been solicited from most of the stakeholder groups.

To date, a significant number of stakeholder groups have expressed concern about the winter and spring flow fluctuations called for in the experimental flows. Sport fishing interests are adamantly opposed to the fluctuating flows fearing significant negative impacts to the Lee's Ferry trout fishery. Additionally, several stakeholder groups have specifically asked: (1) whether or not reducing RBT and BNT abundance will improve HBC recruitment, and a related question (2) are RBT and BNT significant predators of HBC. The treatment proposed in this attachment is intended to answer these questions as well as several questions formulated by the Technical Work Group (TWG) of the Glen Canyon Dam Adaptive Management Program. The TWG has identified a series of research information needs (RINs) specifically related to RBT and BNT predation on HBC. These include: "RIN 2.4.1-What are the most effective strategies and control methods to limit non-native fish predation and competition on native fish?; RIN 2.4.2-Determine if suppression of non-native predators and competitors increases native fish populations?; RIN 2.4.4-What are the target population levels, body size and age structure for non-native fish in the Colorado River ecosystem that limit their levels to those commensurate with the viability of native fish populations?; RIN 4.2.6-To what extent are RBT below the Paria River predators of native fish, primarily HBC? At what size do they become predators of native fish, especially HBC, i.e., how do the trophic interactions between RBT and native fish change with size of fish?" (GCMRC 2001).

Objectives

The study described in this proposal is motivated by the following classes of objectives: (1) efficacy of mechanical removal of adult RBT and BNT from the LCR Inflow reach, (2) RBT and BNT predation, (3) survival/retention rate of juvenile HBC in the LCR Inflow Reach, and (4) effect of adult BNT and RBT in the LCR Inflow reach on the population dynamics of the LCR HBC population.

Efficacy of Mechanical removal of adult RBT and BNT from the LCR Inflow reach

1. Determine if mechanical removal of RBT and BNT using electrofishing methods is an effective method of reducing adult RBT and BNT abundance in the LCR Inflow reach.
2. Estimate abundance of adult RBT and BNT in the LCR Inflow reach prior to each removal event.
3. Estimate changes in adult RBT and BNT size composition in response to removal events.
4. Determine trout immigration rate (Seasonal and Annual) into the LCR Inflow reach between removal events.
5. Evaluate methods of carcasses disposal.
6. Estimate gear efficiency for use in constructing cost/benefit analyses of future mechanical removal efforts.

RBT and BNT Predation

1. Estimate the instantaneous proportion of adult RBT and BNT residing in the LCR Inflow reach that are piscivorous.
2. Determine relationship between adult RBT and BNT total length and likelihood of piscivory.
3. Estimate the relationship between adult RBT and BNT total length and gape.
4. Estimate the relationship between HBC total length and body depth.
5. Estimate the relationship between adult RBT and BNT total length and prey body depth.
6. Estimate adult RBT and BNT diet composition.

Survival/Retention Rate of Juvenile HBC in the LCR Inflow Reach

1. Estimate fall/winter mortality rate of HBC in the LCR Inflow reach.

Effect of Adult BNT and RBT in the LCR Inflow Reach on the Population Dynamics of the LCR HBC Population

1. Evaluate the relationship between adult RBT and BNT abundance in the LCR Inflow reach and juvenile HBC survival/retention rate in the LCR Inflow reach.
2. Evaluate the relationship between adult RBT and BNT abundance in the LCR Inflow reach and recruitment to the LCR HBC population.

Study Area

The LCR Inflow reach is recognized for having the highest abundance of adult and juvenile HBC in the Colorado River mainstem (Valdez and Ryel 1995). We have selected a sampling reach (60.8 RM - 65.6 RM) that encloses a high proportion of this extant population. The proposed sampling effort will be spatially distributed within a discrete 7.8 km reach. The upstream and downstream endpoints are bounded by hydraulic and geomorphic control (Stevens et al., 1997); however, it is not impermeable to system-wide fish movement. For this reason, we are proposing to conduct a depletion effort that is both spatially discrete, and repeated seasonally over a period of two years. We are proposing to conduct annually, three depletion trips in mid-September, January, and May. The sampling efforts are scheduled to coincide with seasonal HBC-YOY dispersal from the LCR to the Colorado River Mainstem (August-September), followed again by early winter and spring sampling.

Electrofishing

A series of four, nightly, single-pass depletion efforts will be conducted in fishable habitat using two-electrofishing boats that concurrently sample the river on opposing sides. Sampling equipment, methods and electrical configuration used will be consistent with the established GCMRC fish handling and sampling protocols (Ward 2002). The sampling time required to complete each single depletion pass has been estimated at 2-days (16-hrs / reach depletion; SD ± 2.8, n = 57), with an initial estimated catch of 727 fish for the first depletion pass. Using a depletion method, the catch-rates of single depletions passes are regressed against the cumulative catch for the trip to determine an initial population estimate (Hilborn and Walters 1992). This depletion effort will be repeated seasonally over two years, for a total of six (four?) times, to determine how removal of fish using a series of depletion passes (4) per trip in a discrete designated area will influence the relative abundance of the remaining fish stock. Since we will be unable to control for migration, recruitment and mortality occurring at a local level, comparisons among trip population estimates and trip catchability coefficients (Q) are to be analyzed in order to evaluate if mechanical removal methods are an effective means to control for undesirable fish species. Additionally, electrofishing catch-rate will be used to measure juvenile HBC relative abundance.

Hoop-net sampling

In conjunction with trout depletion efforts, an estimate of juvenile HBC relative abundance (CPUE) will be determined using a combination of gear types (electrofishing and hoop-nets). Owing to the established NPS non-motor season (16 September to 15 December; NPS 2001) additional electrofishing sampling is unrealistic. For this reason, a total of 30 hoop-nets (24"x 36") will be fished for a 4-day period at pre-established transects that are presently used as part of the long-term monitoring program, and checked at 24-hr intervals (Gorman and Coggins 2000). In addition to this annual netting effort (mid-September and January depletion trips), USFWS has proposed (VanHaverbeke 2002) to resample these same transects using hoop-nets on an annual basis during November. This supplemental netting effort will provide an additional CPUE datum to determine relative abundance of this vulnerable size-class during a period of motor use restrictions and will comply with NPS regulations. Following Valdez and Ryel (1995), these CPUE data will be used to construct survival/retention rates of juvenile HBC in the LCR Inflow reach.

Stomach contents

Predation by non-native trout species has been hypothesized to be the major factor responsible for the observed decrease in overwinter survival and recruitment of humpback chub (HBC) (Valdez and Ryel 1995; Gorman and Coggins 2000). To maximize data collection efforts without adversely affecting the electrofishing depletion sampling, an additional processing boat will be used to collect, transfer, and transport captured fish to an established base-station. On average, a linear distance of 3.8 km will be electrofished nightly. The processing boat will routinely receive data sheets and transfer fish caught within each of the designated sub-reaches (1-km increments); and also process, measure and release all native fish collected within these sub-reaches. All trout (RBT & BNT) will be transferred to the base-station for processing; where fish will be euthanized and measured for standard measures and meristics; fore- and hind gut dissected, removed and incised; stomach contents inspected for piscivory and preserved (ETOH 95%), and cataloged, stored, and transported for further laboratory assessment. Three assessment levels have been established to evaluate the presence of trout piscivory. All euthanized fish will be worked up (< 2-hr after capture) to avoid undue loss to secondary digestion; however, only the gross assessment level will be conducted in the field.

Laboratory Assessment

Predation

To develop an estimate of the proportion of piscivorous trout in the LCR inflow, all trout sampled are to be assessed for the presence or absence of fish in the gut contents; however, it will represent an instantaneous proportion of the population, rather than an actual predation rate. Dietary analysis is problematic, owing to differential rates of digestion and the difficulties associated with recognizing and identifying accurately specific items from partially digested material. To evaluate for fish presence/absence and distinguishing taxonomic characteristics of prey items a series of voucher specimens will be developed from previously collected specimens, as well as accumulating from the gross field assessment a comparative library of anatomical characters and traits. Additionally, we are going to explore alternate as well as develop analytical methods that will assist technicians in accurately identifying prey items. We will explore methods using dye-markers (e.g., tetracycline) or protein markers to discern for the presence or absence of cartilaginous and ossified characters by separating from partially digested material.

Dietary analysis

Gut contents are to be analyzed from a set of sub-samples that are randomly selected and stratified by fish size. The dietary analysis is to quantify ingested phytobenthic and macroinvertebrates using a combination of analytical methods (volumetric, weight, and numeric counts) (Marrero and Lopez-Rojas 1995; Rowell 2001). Seasonal and inter-annual differences in the availability of the aquatic food base (standing biomass and drift) are to be linked to fish feeding habits and electivity preferences.

Data collection activities

All collected specimens and data sheets are to be assessed for completion, accuracy, and data entry errors, and sample specimens are to be cataloged, organized and stored for later transport. All data will be entered following trips consistent with GCMRC format structures.

Fish disposal

All fish carcasses are to be disposed of by pulverizing in an electric grinder. Additionally, to avoid confounding sampling efforts through the attraction of fish, all effluent slurry is to be evacuated in the mid-river channel downstream of the established study reach boundary.

Data Analysis

During the course of this study, long term monitoring activities will continue to track the recruitment of HBC into the LCR population. Specifically, program SUPERTAG (GCMRC unpublished analyses) will be updated annually to produce continuing estimates of annual recruitment and abundance. Long term monitoring data will also be used to estimate instantaneous abundance of HBC >150 mm total length residing in the LCR during the spring spawning season, and to estimate the abundance of Age-1 fish (recruitment) residing in the LCR during the fall. With these data sets in hand, we will eventually be able to examine the relationship between adult RBT and BNT abundance in the LCR Inflow reach and survival/retention rates of juvenile HBC in the LCR Inflow reach. We will also have the ability to examine the relationship between adult RBT and BNT abundance in the LCR Inflow reach and concurrent brood year specific recruitment to the LCR HBC population.

Trip Schedule

The estimated time to complete depletion estimates will require sampling 10-days per trip. For purposes of controlling costs, technical personnel will hike-out at Phantom Ranch on the 12^{th} day of the trip. Boats, equipment and sample data are to be transported downstream to Diamond Creek for take-out. The estimated cost of the mechanical removal treatment is $200,000 per year, or $400,000 over the two-year treatment.

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