General Monitoring and Research Plan for High-Flow Experimental Protocol

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Grand Canyon Monitoring and Research Center
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Cover: Glen Canyon Dam jet tubes release experimental high flows of Colorado River water on the morning of March 5, 2008. (Anne Phillips, U.S. Geological Survey photo.)

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PLAN 12.P6.11-12

Start Date

2011

End Date

2020 (as defined in the HFE Protocol Environmental Assessment)

Principal Investigator(s)

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Geographic Scope

The Colorado River ecosystem from the forebay of Glen Canyon Dam to the westernmost boundary of Grand Canyon National Park (river miles -15 to 277)

Project Goals

The goal of this experimental project is to test the hypothesis that a series of sand-enriched high flows will be an effective strategy for rebuilding and maintaining sandbars using dam operations (Topping and others, 2006). The details of high flow triggering criteria are in the {date} Environmental Assessment for the Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020 (hereafter referred to as the HFE EA).

The second goal will be to evaluate the effects of implementation of the High Flow Experiment Protocol on a variety of other priority AMP resources including aquatic food base, native fish, Lees Ferry trout and angler satisfaction, riparian vegetation, campsites, and archaeological sites. Special focus will be on assessing the effects of the seasonal timing of high flows on Lees Ferry rainbow trout early life-stage survival, recruitment, downstream migration and HFE impacts on native fishes especially the endangered humpback chub (*Gila cypha).*

Need for Project

Previous high flow experiments (HFE) from Glen Canyon Dam were conducted in 1996, 1997 2000, 2004, and 2008. These experiments generally concluded that the only tool available for rebuilding sand bars using dam operations is to release short duration high flows after tributary floods deposit new sand into the main channel of the Colorado River. The HFE EA is intended to build on the knowledge gained in the previous experiments and implement HFEs on a more

regular basis. A brief summary of some elements of the protocol as described in the November 19, 2010 draft EA follows:

> "The timing of high-flow releases would be March/April or October/November; the magnitude would be from 31,500 cfs to 45,000 cfs. The duration would be from less than one hour to 96 hours.
>
> This protocol is intended to be experimental in nature in order to learn how to incorporate high releases into future dam operations in a manner that effectively conserves sediment in the long-term. A number of hypotheses may be tested through this experimental protocol, including the timing of a high release to the delivery and availability of sediment in the river channel. Two approaches are: (1) the "store and release" approach that allows sediment to become stored in the channel over time before a high release, and (2) a "rapid response" approach in which a high release is timed to coordinate with a flood event in the Paria River. The store and release approach was used for the three prior HFEs and has been shown to be effective at redepositing sediment. The second approach has not been tried but is considered to have scientific merit. This rapid response alternative requires a short notice for dam operators, researchers, and downstream recreational users.
>
> Developing this protocol is important in order to implement a strategy for high-flow releases over a period of time longer than one year or one event. In the past, Reclamation has done three single-event HFEs and the benefits to sediment have been temporary. One purpose for this protocol is to assess whether multiple, sequential, predictable HFEs conducted under consistent criteria can better conserve sediment resources while not negatively impacting other resources."

The purpose of this general science plan is to outline how ongoing monitoring and research projects (USGS, 2011) will address the evaluation of the effectiveness of the HFEs. Changes to this science plan may be needed based on availability of funds and as HFEs are implemented and adjusted in an adaptive management framework (Williams and other, 2008). Additional revisions may also be required to address additional experimental activities that may be identified in the Long Term Experimental and Management Plan EIS, which will be initiated by the Department of the Interior in 2011.

The proposed approach will rely on existing quality of water, sediment, aquatic biology and other resource monitoring projects to assess the effects of HFEs. No new studies would be added, however, some existing monitoring and research efforts would be expanded or adjusted to provide information that is directly relevant to the evaluation of the HFEs.

This science plan is focused on assessing the effects of the "store and release approach" described in the HFE EA. A separate science plan could be developed to assess the effects of the "rapid response approach" described in the HFE EA, once the details of that approach are more fully described. It is expected that many of the studies described below will inform both HFE approaches, but more specific short term investigations may be needed to evaluate the efficacy of the rapid response approach.

Strategic Science Questions

A major task of GCMRC in 2010 was the synthesis of the results of the 1996, 2004 and 2008 high flow experiments (Melis and others, in press). The concluding chapter of the synthesis by

Wright and Kennedy (in press) provides direction that is relevant to the primary focus of HFE science activities:

> "HFEs are an important tool for rebuilding sandbars. The three previous HFEs have demonstrated the effectiveness of individual HFEs for rebuilding sandbars, particularly when they occur after sand has been stored on the channel bed downstream from the dam. A logical next step in the adaptive-management process of the GCDAMP is to evaluate the cumulative effects of multiple HFEs over longer periods of time. This would be helpful because it is still uncertain whether sandbar building during HFEs can offset or exceed the sandbar erosion that occurs during periods of typical dam operations between HFEs. Thus, it is important to consider the frequency of HFEs and the erosion of sandbars between HFEs for future HFE planning. The fundamental sandbar-related science question therefore is:
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> - Can sandbar building during HFEs exceed sandbar erosion during periods between HFEs, such that sandbar size can be increased and maintained over several years?
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> Based on studies that have been conducted to date, HFEs do not appear to be a tool that can be used to benefit humpback chub. Rainbow trout pose a threat to juvenile humpback chub rearing in the mainstem near the confluence with the Little Colorado River due to increased competition and predation. Beneficial effects of the March 2008 HFE on rainbow trout populations appear to be largely responsible for the 38-fold increase in rainbow trout observed near the confluence between 2006 and 2009. A large increase in rainbow trout near the confluence with the Little Colorado River also occurred in the year following the 1996 HFE. The November 2004 HFE did not benefit rainbow trout populations, but a preexisting downward trend in rainbow trout populations and the absence of data make this finding highly uncertain. Thus, natural-resource managers might consider proceeding with caution when implementing any HFE strategies, particularly those involving frequent spring-time events, because currently (2010) the biological response to HFEs appears to be inconsistent with management goals for humpback chub. A logical next step in the HFE process is evaluating whether the seasonal timing of HFEs affects the rainbow trout recruitment response. If fall-timed HFEs do not lead to increases in rainbow trout populations near the confluence with the Little Colorado River (or it is later demonstrated that rainbow trout do not exert strong influence on humpback chub rearing), then managers might be able to balance goals for sandbars and native fish without the need for substantial rainbow trout mitigation or removal. The fundamental fish-related science question therefore is:
>
> - Does the seasonal timing of HFEs influence the rainbow trout response?
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> An adaptive-management process for HFE decision-making would be flexible and incorporate relevant scientific information, such as near real-time information about sediment conditions downstream from the dam and information on adult population trends for rainbow trout and humpback chub, as well as other resources. Indeed, as more HFEs are conducted, strong links connecting other resources to dam operations may be identified and incorporated into subsequent HFE strategies. An integrated science-based strategy would allow for effective management of the available post-dam sand supply while considering the impacts of the strategy on other resources within an adaptive-management framework."

In addition to these fundamental strategic science questions, the HFE science plan will focus on assessing the effects of HFEs on other priority AMP resources, including the aquatic food base,

native fish (especially humpback chub), Lees Ferry trout and angler satisfaction, riparian vegetation, recreational campsites, and archaeological sites.

Table 1 identifies the specific HFE science questions associated with these resources that would be addressed with available funding included in the approved Glen Canyon Dam Adaptive Management Program Biennial Budget and Work Plan—Fiscal Years 2011-12 (USGS, 2011) (hereafter referred to as the FY 2011-12 BWP). These HFE science questions were developed by GCMRC based on the high flow synthesis report (Melis and others, in press), other relevant literature, and input provided by the HFE EA cooperating agencies.

Wright and Kennedy (in press) emphasize that there is substantial uncertainty about the outcome that may result from implementation of the HFE protocol. For example, the biological responses to fall HFEs are difficult to predict. Thus, modification of the HFE protocol may be required based on knowledge gained from biological responses to future HFEs. Modification of the protocol in response to sandbar-monitoring results may also be required, and a different HFE strategy may be justified during wet and dry climatic periods. Because of these uncertainties, the annual "status check" outlined in the EA will be a critical component of an adaptive HFE strategy. This status check would involve reviewing recent monitoring data for sand budgets, sandbar size, native and nonnative fish population trends and other resource responses. Based on the findings of these reviews, the HFE protocol may need to be adapted to address undesirable resource responses. Likewise the HFE science plan may need to be adapted based on new knowledge and learning and to address new science questions.

Science questions and related projects that had to be deferred due to funding constraints are provided in Appendix A.

Methods and Tasks

Tasks related to high flow monitoring and research are summarized below. Refer to the individual project descriptions in the FY 2011-12 BWP for more detailed descriptions. Implementation of these projects assumes that (a) the respective annual work plan projects are funded at the level indicated in the approved BWP and (b) additional funding is not available to provide expanded research and monitoring of the effects of the HFE protocol. Additional funding or reprogramming of existing the FY 2011-12 BWP would be required to expand the scope of the work. While the tasks are listed separately below, in reality many of the studies are linked. Studies will be coordinated and integrated as needed to provide a comprehensive assessment of the effect of the HFE on priority AMP resources. The priority focus will be to address and answer, to the extent possible, the HFE science questions identified in Table 1.

Task 1. Monitoring In-Channel Sediment Storage—SedTrend

Information Needs

HFE protocol science question: Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume (time domain to be addressed in the course of HFE protocol development)?

This question is related to CMIN 8.2.1. -- Track, as appropriate, the biennial or annual sandbar area, volume, and grain-size changes within and outside of eddies between 5,000 and 25,000 cfs stage, by reach; CMIN 8.5.1. -- Track, as appropriate, the biennial sandbar area, volume, and grain-size changes above 25,000 cfs stage, by reach; CMIN 8.1.1. --

Determine and track the biennial sandbar area and fine-sediment volume and grain-size changes within eddies below 5,000 cfs stage, by reach; and CMIN 9.3.1. -- Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons.

HFE protocol science question: With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?

This question is related to all of the CMIN's listed for question 1 and the following: CMIN 7.4.2. -- Determine and track flow releases from Glen Canyon Dam, under all operating conditions, particularly related to flow duration, upramp, and downramp conditions; CMIN 8.1.3. -- Track, as appropriate, the monthly sand and silt/clay volumes and grain-size characteristics, by reach, as measured or estimated at the Paria and LCR stations, other major tributaries like Kanab and Havasu Creeks, and "lesser" tributaries; and CMIN 8.1.2. -- What are the monthly sand and silt/clay export volumes and grain-size characteristics, by reach, as measured or estimated at Lees Ferry, Lower Marble Canyon, Grand Canyon, and Diamond Creek Stations?

Project Description

This project addresses the HFE protocol science question 1 by tracking net changes in the area and volume of sandbars at stages above and below 8,000 cfs. This project also address HFE protocol science question 2 by tracking changes in sand storage for the study period. The SedTrend channel mapping project is designed to monitor the cumulative results of multiple high flows over a 5 to 10 year period. The results from previous high flow monitoring demonstrate that high flows build sandbars and that the magnitude of bar building is greatest when sand concentrations are highest. The question that is unresolved, which this program seeks to address, is whether repeated high flows and intervening dam operations can result in maintenance or increase in sandbars over longer periods of time. This objective of the project is described in detail in the goal 8 project description (PHY 8.M2.11-12). In summary, these monitoring data will allow us to determine at the end of the experimental period whether the continued use of high flows is likely to be a sustainable approach to building and maintaining sandbars or whether more sand than the tributaries supply is required to avoid progressive sand export and erosion. Because the objective is to monitor sandbars and the channel in a "typical" condition, the channel mapping should occur 6 months or more following a high flow. Thus, in some years that have high flows, channel mapping may be postponed or deferred. In the event channel mapping is deferred, about $110,000 in logistical and other expenses would be available for other uses. Personnel are retained to continue with data processing and reporting. Please refer to project PHY 8.M2.11-12 in the FY 11-12 BWP for more details on this project.

Task 2. Monitor High-Elevation Sandbar Study Sites

Information Needs

HFE protocol science question: Will multiple high flows conducted over a period of 10 years result in net increases in sandbar area and volume? (see above for CMINs)

Project Description

This project addresses HFE protocol science question 1 by tracking changes in sandbar area and volume at the long-term sandbar monitoring sites above the stage of 8,000 cfs. While the focus of task 1 is monitoring total changes in sand storage, including sandbars, at infrequent

measurement intervals, this task will monitor a subset of sandbars at more frequent intervals. See the goal 8 project description for a summary of the methods and the Goal 9 project description for a summary of the campsite monitoring component. To enable comparison with historical conditions, it is essential that this task monitor the same set of study sites (up to about 50 sites) that have been the basis of past sandbar monitoring. The data collected in task 1, above, and task 4, below, will be used to address the issues relating to the use of this small set of monitoring sites relative to the large number of sandbars that are in Grand Canyon. Only be collecting and analyzing the more spatially robust data outlined in tasks 1 and 4 will it be possible to improve the understanding of the behavior of these study sites relative to system wide behavior. In the absence of high flows, the repeat surveys of these sites have documented that the sandbars gradually erode. For this reason, the monitoring is scheduled to occur every two years unless a high flow occurs. Similarly, the surveys done immediately before and after high flows have repeatedly documented deposition. While continued quantification of the precise magnitude of deposition associated with each high flow would be beneficial, it is not critical monitoring. Instead, we propose to perform a survey approximately 6 months following each flood and use that as the benchmark monitoring record. This monitoring would be accomplished by the regular biennial sandbar survey unless the high flow occurs in an off year. In that case, an additional monitoring trip would be required. (This trip would also collect campsite data, as described under Task 3). A sandbar monitoring trip is currently planned for FY 2011, so FY 2012 is the first year that this need could occur. Monitoring of the immediate response of future high flows would be limited to information gained by daily photographs taken by remote cameras. The photographic data would allow comparison of the degree of sandbar building between past and future high flows. Currently 18 sandbar monitoring sites are instrumented with remote cameras. We propose installing cameras at an additional 20 sites before the next high flow. Please refer to project PHY 8.M2.11-12 in the FY 11-12 BWP for more details on this project.

Task 3. Monitor Campable Area at High-Elevation Sandbar Study Sites

Information Needs

HFE protocol science question: Will multiple high flows conducted over a period of several years result in net increases in campable area within the Colorado River ecosystem (time domain to be addressed in the course of HFE protocol development)?

This question is related to CMIN 9.3.1. --Determine and track the size, quality, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons (top-ranked goal 9 CMIN); EIN 9.3.1. -- How do the size, quality and distribution of camping beaches change in response to an experiment performed under the 1996 Record of Decision, unanticipated event, or other management action?; and SSQ 3-9. -- How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

Project Description

Monitoring the high-elevation campsite study sites (a subset of the NAU sandbar time series) is necessary to maintain continuity in the campable area monitoring record. Monitoring is currently scheduled to occur every two years unless a high flow occurs (see the goal 9 project description under REC 9.R1.11-12 for a summary of the planned campsite monitoring component.) In the absence of high flows, repeat surveys of the campable area at these sites have documented that the lower elevation portions of the sandbars erode while campsites on the higher elevation open sand areas that form the major component of campable area in the CRE also decrease, although much of the change appears due to vegetation encroachment and aeolian

reworking of open sand areas. While continued quantification of the precise magnitude of deposition and erosion associated with each high flow would be beneficial, it is not critical; instead, we propose to perform a campable area survey approximately 6 months following each high flow in conjunction with the proposed sand bar monitoring program following each HFE and will use that as the benchmark monitoring record. This monitoring would be accomplished by the regular biennial sandbar survey unless the high flow occurs in an off year. In that case, an additional monitoring trip would be required. A sandbar monitoring trip is currently planned for FY 2011, so FY 2012 is the first year that this need for supplementary funding could occur. Please refer to project REC 9.R1.11–12 in the FY 11-12 BWP for more details on this project.

Task 4. Repeat Systemwide Inventory of High-Elevation Sand Deposits

Information Needs

HFE protocol science question: Will multiple high flows conducted over a period of several years result in net increases in sandbar area and volume? (See above for CMINs)

Project Description

This project addresses HFE protocol science question 1 by tracking changes in sandbar area throughout the CRE between Lees Ferry and the upper end of Lake Mead above the stage of 8,000 cfs. Remote sensing can provide a system-wide quantitative measure of the area of sand exposed above the water surface at the time of imagery collection (usually about 8,000 cfs). Collection and processing of these data will provide the long-term monitoring of the area of exposed sand to evaluate the cumulative result of multiple high flows and intervening operations over the experimental period. These data will also be used to evaluate the degree to which the more precise measurements made of sandbar volume in task 2 are representative of sandbar trends throughout the CRE. These data will also be used to quantify changes in vegetation distribution that may result in increases or decreases in the area of exposed sand. See Goal 8 (PHY 8.M2) and goal 12 (DASA 12.D9) for more detailed project descriptions. This is part of the regular monitoring program that addresses high flows and does not require additional funding when high flows occur. Remote sensing data collection is scheduled to occur every 4 years.

Task 5. Monitor Archaeological Site Condition and Stability in Response to Repeated HFEs

Information Needs

HFE protocol science question: Will multiple high flows conducted over a period of several years improve archaeological site condition as reflected in increased sand deposition, increased site stability, and reduction in rates of erosion (time domain to be addressed in the course of HFE protocol development)?

This question is related to CMIN 11.1.1 -- Determine the condition and integrity of prehistoric and historic sites in the CRE through tracking rates of erosion, visitor impacts, and other relevant variables; EIN 11.1 -- Determine the efficacy of treatments (e.g., alternative flows) for mitigation of adverse effects to historic properties; SSQ 2-1. -- Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at archaeological sites and TCP sites in the CRE, and if so, how?; and SSQ 2-4. -- How effective are various treatments (e.g., repeated high flow events) in slowing rates of erosion at archaeological sites over the long term?

Project Description

The monitoring protocols being developed and piloted by GCMRC as part of project CUL 11.R1.11-12 are specifically designed to be applicable for evaluating physical changes at archaeological sites tied to changes in sediment supply under a variety of dam operations. The planned monitoring program, which will be piloted starting in FY11, will allow GCMRC and AMP stakeholders to objectively determine whether changes in sand bar area and volume resulting from repeated high flows translate into measurable changes in the amount and rates of sediment being deposited at or eroded from a sample of archaeological sites distributed throughout the CRE. In the current work plan, baseline measurements will be collected in FY11 at approximately 30 sites selected from a stratified population of cultural sites in the CRE; this stratified random sample be used to evaluate system-wide changes at archaeological sites due to dam operations, including changes resulting from any high flows conducted as part of the HFE protocol or any subsequent alternative flow experiments. Completing a robust evaluation of high flow effects on archaeological sites requires implementation of the cultural monitoring project (CUL11.R1.11-12) as currently planned; no additional monitoring beyond what is already described in project CUL 11.R1.11-12 is anticipated to be needed to evaluate the effects of an HFE protocol at archaeological sites, although timing of the monitoring trips may be adjusted to maximize the potential of the monitoring data to track HFE effects.

Task 6. Monitoring Sediment Flux

Information Needs

HFE protocol science question: With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable? (see above for CMINs)

Project Description

This project addresses HFE protocol science question 2 by tracking sand inputs and export, by reach. Monitoring of sediment (sand and finer) flux during future high flows will be conducted as part of the regular goal 7 downstream integrated quality of water program. The methods, monitoring sites, and planned products are described in the goal 7 (PHY 7.M1) project description. This task does require added work during a high flow to maintain the monitoring record because the instrumentation is vulnerable to high dam releases and additional samples are required to maintain instrument calibration.

Task 7. Monitoring the Aquatic Food Base

Information Needs

HFE protocol science question: What is the effect of a fall HFE on the food base at Lees Ferry?

This task is also central to answering questions related to the following HFE science questions (see Tasks 8, 10 and 11 below):

- *How does HFE timing and frequency affect Lees Ferry rainbow trout population dynamics and outmigration?*
- *Is it possible to manage the Lees Ferry trout population with a spring HFE held at slightly different times?*

- *What are the direct (for example, displacement) and indirect (for example, increases in rainbow trout) effects of HFEs on humpback chub?*

This question is related to ***Strategic Science Question 3-5.*** *How is invertebrate flux affected by water quality (for example, temperature, nutrient concentrations, turbidity) and dam operations?*

Project Description

The aquatic food base (AFB) project has been working since 2006 to establish a monitoring protocol that accurately captures key metrics relevant to other resources in the Colorado River, including rainbow trout and humpback chub. Based on their work to date the aquatic food base research scientists have determined that monthly monitoring of benthic organisms at Lees Ferry and at Diamond Creek, and monthly monitoring of drifting organisms is important information that supports assessment of all Glen Canyon Dam release regimes, whether modified low fluctuating flows, an experimental high flow, or other flows. Quarterly AFB sampling in Lee Ferry and Diamond Creek is included in the final FY 11 BWP (BIO 1.1M.11); while monthly sampling was funded for FY 12. GCMRC recommends additional funding to implement monthly sampling of AFB in FY 11 and beyond to support the evaluation of the future HFEs. The monthly sampling protocol was effective at detecting significant changes in AFB at Lees Ferry in response to the March 2008 HFE. These data helped explain the strong positive rainbow trout response in Lees Ferry. Monthly AFB sampling is recommended to provide the statistical power needed to detect potential changes in the AFB due to future HFEs. Collecting these data in years without a high flow provides important baseline information, including assessment of seasonal variability. Collecting these data in years when an HFE occurs allows assessment of the amount of change, if any, which occurs as a result of the high flow. See project BIO 1.1M.11-12 for a more detailed description of this project.

Task 8. Lees Ferry Fish Monitoring and the Paria River to Badger Rapids Study

Information Needs

HFE protocol science questions: How does HFE timing and frequency affect Lees Ferry rainbow trout population dynamics and outmigration? Is it possible to manage the Lees Ferry trout population with a spring HFE held at slightly different times?

The answer to these questions relates to RIN 4.2.7. What dam release patterns most effectively maintain the Lees Ferry rainbow trout trophy fishery while limiting rainbow trout survival below the Paria River?

Project Description

Monitoring of the adult rainbow trout population in the Lees Ferry reach has been conducted regularly since the closure of Glen Canyon Dam in 1963. In 2010, in response to the 2009 Protocol Evaluation Panel for Monitoring Grand Canyon Fishes, GCMRC and cooperating agencies, especially the Arizona Game and Fish Department, made some adjustments to the protocols for monitoring fish between Glen Canyon Dam and Lees Ferry. Monitoring of stratified random sites continues to be conducted as a tool to monitor adult rainbow trout. In addition, a sampling trip to specifically look for nonnative fishes is now conducted. The monitoring of rainbow trout redds (egg nests composed of gravel) and age-0 abundance, conducted in the 2000s as a research project, has now been added to the Lees Ferry fish monitoring, specifically because

of the utility of this method in assessing impacts of dam operations on young life stages of rainbow trout. A new research project included in the final FY 11-12 BWP adds additional fish monitoring below Lees Ferry. This additional work is intended to evaluate the age structure of rainbow trout and timing of their movement immediately downstream from Lees Ferry. The new work below Lees Ferry, conducted from the mouth of the Paria River to Badger Rapids, is also intended to begin establishing the relationship, if any, between the size and condition of the Lees Ferry rainbow trout population to downstream movement, as might occur in response to a high flow. The new monitoring between the Paria River and Badger Rapids is intended to be a precursor to and inform potential trout removal efforts in this reach. See projects a BIO 4.1M.11-12 and BIO 2.E18.11-12 for more details.

Task 9. Evaluate Lees Ferry Recreation Experience Quality

Information Needs

HFE protocol science question: How will multiple high flows conducted over the next 10 years affect recreational experience quality in the Colorado River corridor in Glen Canyon?

This question is related to CMIN 9.1.1 -- Determine and track the changes attributable to dam operations in recreational quality, opportunities and use, impacts, serious incidents, and perceptions of users, including the level of satisfaction in the Colorado River Ecosystem; EIN 9.1.1 -- How do recreational use trends, impacts, and perceptions change in response to an experiment performed under the Record of Decision, unanticipated events, or other management action?; SSQ 3-6. -- What Glen Canyon Dam operations (ramping rates, daily flow range, etc.) maximize trout fishing opportunities and catchability?; SSQ 3-7. -- How do dam controlled flows affect visitors' recreational experiences, and what is/are the optimal flows for maintaining a high quality recreational experience in the CRE?; and SSQ 3-8. -- What are the drivers for recreational experiences in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes?

Project Description

The FY2011-2012 BWP includes a recreation experience valuation study for the Glen Canyon reach of the Colorado River. This study will evaluate the value and relative importance of a suite of biophysical attributes that are affected by dam releases and which anglers and other visitors determine to be important to maintaining a high quality recreation experience in the uppermost reach of the CRE. This study will also update monetary values associated with current recreational activities in the Glen Canyon reach. The intent of this study is to provide a foundation for evaluating how different dam operations, including future high flow experiments, affect the biophysical attributes of the Glen Canyon reach that visitors value and consider to be important for maintaining a high quality recreation experience in the Glen Canyon reach. See project REC 9.R4 for specific details of the proposed study approach.

Task 10. Mainstem and Little Colorado River Fish Monitoring and Near Shore Ecology Study

Information Needs

HFE protocol science question:

1. What are the direct effects of a fall HFE on displacement of humpback chub?
2. What are the indirect effects of increases in rainbow trout associated with HFEs on humpback chub?

*This task is also related to **RIN 2.2.8.** What combination of dam release patterns and nonnative fish control facilitates successful spawning and recruitment of humpback chub in the Colorado River ecosystem*?

Project Description

The direct and indirect effects of HFE on humpback chub will be assessed based primarily on the three projects in the FY11-12 BWP: (1) The Mainstem Fish Monitoring Project, (2) Little Colorado River Fish Monitoring Project, and (3) the Near Shore Ecology (NSE) Study. These studies will also utilize information from the aquatic food base project (Task 7, above) to help assess the relative effects of factors that may be contributing to changes in humpback chub populations.

Monitoring of the Colorado River mainstem fish community has been conducted by various researchers on an irregular schedule since the 1940s. More consistent, systematic monitoring began with BOR's Glen Canyon Environmental Studies that began in the 1990s. Since 1996 mainstem monitoring has been conducted by GCMRC and cooperating agencies, especially the Arizona Game and Fish Department. The principal long-term, full river monitoring has been 2 river-wide electroshocking trips, usually conducted in the spring. For four years in the decade of the 2000s this regular pair of trips was accompanied by intensive data collection associated with the mechanical removal project conducted between river miles 55 and 75. Together these data provide a picture of the distribution and relative abundance of the most common large bodied fish species in the mainstem. Backwater seining trips, conducted during the mid 1990s and from 2003 to present, have provided a picture of the relative abundance, distribution, and species composition of native and nonnative small-bodied fishes (juveniles and adults) in backwaters. Together these efforts have provided the currently available Grand Canyon fish data, and have also shown where additional data are needed. The existing fish data show where larger concentrations of the more common species are most likely to be found and how those populations have fluctuated over time. The constraints and challenges of sampling widely in a large, turbid river are also highlighted in these data because the methods show that only some gear types are effective in the Colorado River, making some aquatic habitat types as well as fish life stages difficult, if not impossible, to sample. The springtime mainstem monitoring is planned for years when a large-scale mechanical removal trip is not conducted because a mechanical removal effort will require the people, time, and equipment that would otherwise be available for the spring mainstem monitoring. See BIO 2.4M.11-12 for more details.

Data collected as part of the mainstem monitoring along with the systematic and intensive sampling of humpback chub in the Little Colorado River (see BIO 2.M1.11-2) have previously been and will continue to be used with the ASMR model to provide estimates of adult humpback chub population size and survival and inferential assessments of juvenile humpback chub population responses to HFEs.

GCMRC and cooperators, primarily the University of Florida, have established an intensive habitat-specific research program, the NSE project, to help define small-bodied fish distributions (including juvenile humpback chub) and responses to flow changes in the mainstem just below the mouth of the Little Colorado River. The NSE Study is providing the first direct estimates of juvenile humpback chub abundance and survival in the mainstem just below the Little Colorado River. Combined with mainstem and LCR fish monitoring, these sampling efforts and resulting population estimates can be used to assess positive or negative short-term (<1-year) responses of fish populations to HFEs from events such as downstream displacement. In addition, these projects can be used to help assess long-term responses in humpback chub (and

other fish species) populations due to increases in rainbow trout populations or changes in aquatic food base that may be associated with repeated HFEs.

In 2011, the NSE project will be conducting field studies below the confluence of the Little Colorado River. Using juvenile fish previously tagged during summer and fall 2010 and sampling efforts for these fish planned for 2011 (July, August, September, and October trips), this intensive effort will be able to detect large, localized (within sampling reach) changes in small bodied fish. Any detected change could be due to downstream displacement of tagged fish from an HFE, predation by rainbow trout, or other unknown factors. A key expected outcome is that the NSE project will be able to provide a direct assessment of small-bodied and juvenile fish population responses following a spring 2011 HFE whereas previous assessments primarily assessed juvenile population responses indirectly by assessing adult populations in subsequent years. GCMRC is considering possible modifications to the NSE Study to allow for more definitive assessment of the direct and indirect effects of a HFE on humpback chub.

NSE field work is scheduled to end in the fall of 2011 and reports will be finalized and published in 2012. It may be necessary to continue some components of the NSE study to address the key science questions related to the effects of repeated HFEs on humpback chub. However, funding to support continuation of the NSE project has not been identified. See BWP project BIO 2.R15.10–11 for more details on the NSE project.

Task 11. Riparian Vegetation Monitoring

Information Needs

HFE protocol science question : How does HFE timing and frequency affect woody riparian and marsh vegetation composition? How does riparian vegetation influence sandbar building, campable area, and wind-blown transport of sand?

*The task is also related to **RIN 12.9.1** What is the impact on downstream resources of short-term increases to maximum flow, daily fluctuations, and downramp limits?*

Addressing the questions and information will require integration with Task 2-5.

Project Description

Together with cooperators, GCMRC has been monitoring the riparian vegetation community in the 2000s. Because of the distribution and extent of the vegetation community, GCMRC has been developing methods that use remotely sensed overflight imagery to assess vegetation changes. Part of this development has included identification of the limitations of the overflight data. An important limitation is that understory plants and herbaceous species, are difficult if not impossible to detect from aerial data. Therefore, the GCMRC monitoring program includes a field component that monitors vegetation at established vegetation transects on a biennial schedule. Repeated sampling at established vegetation transects allows for the establishment of natural variability versus changes associated with a large-scale disturbance, like a controlled flood. Vegetation monitoring using transects is scheduled to take place in 2011 and odd-numbered years thereafter. Supplemental monitoring of vegetation in 2012 would be needed if a controlled flood occurred in 2012 and subsequent even number years (2014, 2016, etc). Monitoring vegetation in years with a high flow release allows for assessment of high flow short

and long term impacts to riparian vegetation. The approved budget covers the cost of field transect monitoring in 2011. See BIO 6.1M.11-12 and DASA 12.D9.11-12 for details.

Task 12. Kanab Ambersnail Monitoring

Information Needs

> **HFE protocol science question:** How do KAS populations and habitat vary over a 10 year period of repeated high flows?
>
> ***This task is also related to CMIN 5.1.1.*** *Determine and track the abundance and distribution of Kanab ambersnail at Vaseys Paradise in the lower zone (below 100,000 cfs) and the upper zone (above 100,000 cfs);* ***RIN 5.1.9.*** *How can incidental take for Kanab ambersnail at Vaseys Paradise be minimized?; and* ***RIN 5.2.2.*** *How does the size and quality of the habitat used by Kanab ambersnail change in response to an experiment performed under the 1996 Record of Decision, unanticipated event, or other management action?*

Project Description

Knowing the extent of habitat is needed in the event of a high flow experiment to develop a biological opinion and to determine snail densities. Changes in snail numbers can be associated with changes in vegetation. Vegetation monitoring at Vaseys Paradise indirectly monitors the snails by assuming that if the preferred habitat is present, snails are present. Total habitat can be measured using remote methods, but the composition of the habitat may still require on-the-ground sampling.

Annual monitoring will focus on determining the percent cover, diversity, and distribution of vegetation that constitutes KAS habitat. This project will:

- Monitor relocated vegetation associated with high-flow experimental conservation measures
- Sample vegetation plots at Vaseys Paradise to determine patch composition and areal extent (fall of each year) and sample for the presence of KAS in plots
- Compare previous vegetation composition to previous vegetation/habitat surveys to assess habitat
- Provide abundance estimates of snails

In prior experimental high flows the low-elevation habitat for Kanab ambersnail has been temporarily removed during the experiment, then replaced so as to maintain this habitat. The cost of implementing this management action is approximately $16,400 in addition to annual monitoring costs. Refer to BIO 5.R1.11 for more details.

Task 13. Lake Powell and Lees Ferry Water Quality Monitoring

Information Needs

HFE protocol science question: How do high flow releases affect water quality (especially DO and temperature) in the fore bay of Lake Powell and in the Colorado River between the Dam and Lees Ferry?

Project Description

Monitoring of the water quality in Lake Powell, the reservoir impounded by Glen Canyon Dam, provides an important piece of information in the assessment of any high-flow release impacts to the reservoir itself or to downstream resources that rely on the water released from the dam. Data from the Lake Powell monitoring program provides a basis from which the effects of a high-flow release can be evaluated. As part of the GCDAMP work plan, regular water-quality monitoring of the Lake Powell forebay is conducted on a monthly basis. The entire reservoir is sampled at multiple locations on a quarterly basis. This monitoring will be conducted in years without a high flow release to support continued characterization of the reservoir and effects to its water quality.

Existing monitoring of Lake Powell water quality provides an important baseline. Leading up to a high flow release this standard monitoring is particularly important for establishing antecedent conditions, which vary from year to year. Immediately following a high flow release, additional water quality monitoring is needed to assess changes in water quality that may occur. Changes to the released water quality, especially dissolved oxygen, were observed in previous high flow releases.

In years with a high flow release, some additional monitoring will be conducted so that high flow impacts to the water-quality of the reservoir and dam releases can be assessed. The primary focus will be the establishment of additional monitoring sites in the Glen Canyon Dam tailwater during the high-flow release to assess changes in combined releases between the dam and Lees Ferry. See BIO 7.1M.11-12 for details

Task 14. Evaluate Effects to Hydropower from Repeated HFEs

Information Needs

HFE protocol science question What are the effects of repeated HFEs on hydropower production and marketable capacity at Glen Canyon Dam?

*This task is also relevant to **CMIN 10.1.** Determine and track the marketable capacity and energy produced through dam operations in relation to various release scenarios; and **SSQ 3-4.** What are the projected hydropower costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase experimental design)?*

Project Description

In FY2011-2012, GCMRC proposes to undertake an evaluation of WAPA's GTMax model and explore the utility of this model and potentially other existing models for assessing economic costs associated with alternative operating scenarios at Glen Canyon Dam. Depending

on the outcome of this assessment, the GTMax model or an alternative model may be used to assess potential costs and benefits to hydropower from implementing a series of HFEs, as well as for evaluating other alternative experimental operational scenarios in the future. See project: HYD 10.R1.11-12 for specifics about the proposed study.

Products/Reports

Primary reporting of results of the above tasks will be performed in the context of annual reporting and publications as described in the work plans associated with each individual monitoring project (see individual project descriptions in the FY 2011-12 BWP). In addition, a summary of relevant results and findings specific to each individual HFE will be provided in USGS Open-file Reports and/or Fact Sheets in the following fiscal year. A thorough analysis and synthesis of results of the multi-year experiment will be provided at the conclusion of the HFE protocol experiment.

Budget

GCMRC anticipates that the tasks described above will be funded as part of ongoing monitoring and research projects included in the approved GCDAMP BWP, including the use of experimental funds as summarized in Table 2. Changes to the work plans included in the FY 11-12 BWP or in the allocation of experimental funds (Table 2) could adversely impact implementation of the tasks described above and the ability to address the science questions listed in Table 1. Several funding shortfalls are identified in Table 2, including:

1. No funding is currently available to collect and analyze monthly aquatic food base samples (as opposed to quarterly sampling which is now funded) ($100K in FY 11).
2. The NSE study is suited to assessing the direct and indirect effects of repeated HFEs on humpback chub. Only one field season remains in this project (FY11) and adjustments or amendments to the NSE study will be needed to specifically address issues related to the impacts of rainbow and brown trout on humpback chub or assess possible displacement of young humpback chub by a fall HFE (amount to be determined)
3. No funding is currently available for annual riparian vegetation monitoring ($50K every other year beginning in FY 12)
4. No funding is currently available for to monitor water quality in the forebay of Lake Powell and the tailwater of GCD shortly before and after an HFE ($9.3K)

Finally, additional funding would be needed to address the HFE science questions/projects outlined in Appendix B and to implement a yet to be developed science plan for the “rapid response HFE” described in the HFE EA.

Science Support for a Potential Spring 2011 HFE

A scaled-down version of this plan would be implemented in response to a potential March-April 2011 HFE owing to the short lead time available to plan and execute a full scale science plan. The primary focus of that plan would be to assess the rainbow trout response to a spring HFE, preferably, at a time later than either the 1996 or the 2008 HFE.

Table 1. HFE science questions that will be the focus the HFE EA Science Plan

Sandbars, Camping Beach, and Archaeological Sites

1. Will multiple high flows conducted over a period of 10 years result in net increases in sandbar area and volume?
2. With the available sand supply (i.e. tributary inputs) is the approach of using repeated floods to build sandbars sustainable?
3. Will multiple high flows conducted over a period of 10 years result in net increases in campable area within the Colorado River ecosystem?
4. Will multiple high flows conducted over a period of 10 years improve archaeological site condition as reflected in increased sand deposition, increased site stability, and reduction in rates of erosion?

Aquatic Food Base and Fish

5. What is the effect of a fall HFE on the food base at Lees Ferry?
6. How does HFE timing and frequency affect Lees Ferry rainbow trout population dynamics and out-migration?
7. Is it possible to manage the Lees Ferry trout population with a spring HFE held at slightly different times?
8. What are the direct effects of a fall HFE on displacement of humpback chub?
9. What are the indirect effects of increases in rainbow trout associated with HFEs on humpback chub?

Recreation

10. How will multiple high flows conducted over a period of 10 years affect recreational experience quality in the Colorado River corridor in Glen Canyon?

Riparian Vegetation and Springs

11. How does HFE timing and frequency affect woody riparian and marsh vegetation composition?
12. How does riparian vegetation influence sandbar building, campable area, and wind-blown transport of sand?
13. How do Kanab ambersnail populations and habitat vary over a 10 year period of repeated high flows?

Water Quality

14. How do high flow experiments affect water quality (especially DO and temperature) in the forebay of Lake Powell and in the Colorado River between the Dam and Lee's Ferry?

Hydropower

15. What are the effects of repeated HFEs on hydropower production and marketable capacity at Glen Canyon Dam?

Table 2A. FY 2011 budget for research and monitoring projects related to the proposed high flow experimental protocol as included in the approved FY 2011-12 BWP. The amount of Experimental Funds that will be used in year with and without an HFE is also shown.

Task	Project Number	FY 11 Budget*	Exp Funds No HFE	Exp funds With HFE
Task 1 – SedTrend	PHY 8.M2.11-12	$464,476	$250,000	$140,000
Task 2 – Sandbar monitoring	PHY 8.M2.11-12	See task 1	50,000	50,000
Task 3 – Campable area monitoring	REC 9 R1.11-12	74,319		
Task 4 – Remote sensing of sandbars	DAS 12.D9.11-12	243,873		
Task 5 – Archeological site monitoring	CUL 11.R1.11-12	352,279		
Task 6 – Sediment flux monitoring	PHY 7.M1-11-12	984,888		110,000
Task 7 – Aquatic food base monitoring	BIO 1.M1.11-12	236.568	**a**	**a**
Task 8 – Lees Ferry trout				
• Adult and YOY trout monitoring	BIO 4.M2.11-12	215,710	22,709	22,709
• Paria to Badger Rapid Study	BIO 2.E18.11-12	432,518	195,918	195,918
Task 9 – Lees Ferry recreation experience	REC 9.R4.11	25,000	25,000	25,000
Task 10 – Native Fish				
• Mainstem fish monitoring	BIO 2.M4.11	283,090		
• LCR fish monitoring	BIO 2.M1.11	572,942		
• Nearshore Ecology Study	BIO 2.R15.11	697,039		**b**
Task 11 – Riparian vegetation				
• Veg transect ((biannual)	BIO 6.M2.11	149,883		
• Veg Mapping	BIO 6.M1.11	84,883		
Task 12 – Kanab Ambersnail Monitoring w/o mitigation	BIO 5.M1.11	20,506		
Task 13 – Lake Powell and Lee Ferry Water Quality	BIO 7.R1.11	182,002		**c**
Task 14 – Hydropower	HYD 11.WAPA	106,950		**d**
Total		$5,126,926	$543,627	$543,627

* FY 11 budget is based on the assumption that **no** HFE will be conducted. Budget amounts will be adjusted up or down depending on whether an HFE is conducted.

a. $100K needed in FY 11 to restore monthly food base sampling
b. Additional funding would be needed to amend/extend the NSE project to address effects of HFEs on juvenile HBC (displacement and rainbow trout effects)
c. $9,300 required to monitor water quality in the forebay of Lake Powell and the tailwater of GCD shortly before and after a HFE
d. Scope of the economic analysis will depend on ultimate scope of Goal 10 (Hydropower) activities supported in the BWP

Table 2B. FY 2012 budget for research and monitoring projects related to the proposed high flow experimental protocol as included in the approved FY 2011-12 BWP. The amount of Experimental Funds that will be used in year with and without an HFE is also shown.

Task	Project Number	FY 12 Budget	Exp Funds-No HFE	Exp funds With HFE
Task 1 – SedTrend	PHY 8.M2.11-12	$429,183	$250,000	$140,000
Task 2 – Sandbar monitoring	PHY 8.M2.11-12	See task 1		50,000
Task 3 – Campable area monitoring	REC 9 R1.11-12	40,298		
Task 4 – Remote sensing of sandbars	DAS 12.D9.11-12	254,975		
Task 5 – Archeological site monitoring	CUL 11.R1.11-12	359,362		
Task 6 – Sediment flux monitoring	PHY 7.M1-11-12	1,002,389		110,000
Task 7 – Aquatic food base monitoring	BIO 1.M1.11-12	329,349	100,000	100,000
Task 8 – Lees Ferry trout				
• Adult and YOY trout monitoring	BIO 4.M2.11-12	223,710	22,709	22,709
• Paria to Badger Rapid Study	BIO 2.E18.11-12	453,029	195,918	195,918
Task 9 – Lees Ferry recreation experience	REC 9.R4.11	25,000	25,000	25,000
Task 10 – Native Fish				
• Mainstem fish monitoring	BIO 2.M4.11	539,107		
• LCR fish monitoring	BIO 2.M1.11	595,001		
• Nearshore Ecology Study	BIO 2.R15.11	Reporting only		**a**
Task 11 – Riparian vegetation				
• Veg transect ((biannual)	BIO 6.M2.11	0	**b**	**b**
• Veg Mapping	BIO 6.M1.11	61,063		
Task 12 – Kanab Ambersnail Monitoring w/o mitigation	BIO 5.M1.11	20,684		
Task 13 – Lake Powell and Lee Ferry Water Quality	BIO 7.R1.11	188,063		**c**
Task 14 – Hydropower	HYD 11.WAPA	??		**d**
Total		$4,521,213	$568,627	$643,627

* FY 12 budget is based on the assumption that **no** HFE will be conducted. Budget amounts will be adjusted up or down depending on whether an HFE is conducted.

a. Additional funding would be needed to amend/extend the NSE project to address effects of HFEs on juvenile HBC (displacement and rainbow trout effects)
b. $50K additional required for annual vegetation monitoring
c. $9,300 required to monitor water quality in the forebay of Lake Powell and the tailwater of GCD shortly before and after a HFE
d. Scope of the economic analysis will depend on ultimate scope of Goal 10 (Hydropower) activities supported in the BWP

Appendix A. List of deferred science questions and related projects to address those questions

To be complete later