October 15, 2015

To: Department of the Interior (DOI) Glen Canyon Leadership Team for the High Flow Experimental Protocol (HFE Protocol) and Non-Native Fish Control (NNFC)

From: DOI Glen Canyon Technical Team

Re: Final Recommendation to Not Implement a Fall 2015 High Flow Experiment at Glen Canyon Dam

I. Introduction

The DOI Glen Canyon Dam Technical Team (Team) has worked during the past several months to evaluate existing data and is recommending to the Leadership Team that no High Flow Experiment (HFE) be conducted in fall 2015. Although sediment conditions support conducting a 96-hr HFE in November 2015, the assessment of biological resources has raised serious concerns that a fall 2015 HFE could have negative impacts in the Canyon. Specifically, the detection of large numbers of invasive green sunfish in Glen Canyon and the risk of dispersal and subsequent establishment in the Colorado River and its tributaries have led the Technical Team to recommend that no HFE take place until the green sunfish have been eradicated.

The purpose of this memorandum is to transmit this recommendation to the Glen Canyon Dam Leadership Team in accordance with the May 23, 2012, Secretarial Directive on the Implementation of Research to Improve Conditions in the Colorado River in Grand Canyon National Park and Glen Canyon National Recreation Area. The Team includes representatives from the National Park Service (NPS), the Fish and Wildlife Service (FWS), the Bureau of Indian Affairs (BIA), the United States Geological Survey (USGS) and its Grand Canyon Monitoring and Research Center (GCMRC), the Bureau of Reclamation (Reclamation), Western Area Power Administration (Western), the seven Basin States (States) and the Upper Colorado River Commission (UCRC).

The Team has met several times in recent weeks. Resource and communications specialists have been coordinating with the Team as necessary. The Team incorporated the latest data from agency experts in making this final recommendation. In making this recommendation, the Team considered multiple issues, as summarized below. The Team also considered the Sept 30, 2015 green sunfish risk assessment memorandum prepared by GCMRC as well as additional technical information and operating experience developed as a result of implementation of the 2012, 2013 and 2014 HFEs.

The Team recommends that no HFE at Glen Canyon Dam be conducted in fall 2015.

II. HFE Protocol

As explained in the Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020 Environmental Assessment (HFE EA; Reclamation 2011), the HFE Protocol is experimental in nature and is designed to achieve a better understanding of whether, how, and when to incorporate high releases into future dam operations in a manner that effectively conserves natural resources that are intimately connected to the distribution, size, and characteristics of fine-sediment deposits. Fine sediment is sand, silt, and clay; the deposits of the Colorado River in Grand Canyon are primarily composed of sand. The HFE Protocol establishes a decision-making framework consisting of three components: (1) planning and budgeting, (2) modeling, and (3) decision and implementation.

The Protocol uses predictive models to make recommendations for specific HFEs using real-time measurements and models of the rate of sand inflow from the Paria River and forecasted hydrologic data to determine whether suitable sediment and hydrology conditions exist for a high-flow experimental release.

A sand transport/budget model was used to predict the mass of sand that would be transported by an HFE and to estimate if a proposed HFE would transport more or less sand than had been delivered to the Colorado River during the fall accounting period (July 1 to November 30). Only HFEs that removed and/or redistributed slightly less sand than had been delivered from the Paria River during the fall accounting period (a “positive sand balance”) were considered. Output of the modeling runs provides the initial recommendation for the magnitude and duration of the HFE. However, because modeling only considers a simple range of possible HFE peak magnitudes and durations, the Protocol includes a review of the model output that may modify the recommended HFE to benefit relevant resources.

Throughout the summer and fall, Reclamation regularly updated its modeling estimates based on ever increasing sediment inputs. The modeled HFE shape was based on past years’ input from scientists at GCMRC designed meet the twin objectives of providing the greatest resource benefit and developing scientific information that will help better inform future decision making.

Review of model output as well as an assessment of other relevant resources raised key concerns for biological resources. Thus, the Team also considered the status of resources and consideration of HFE effects on key resources in making the recommendation described here.

Sand Budget Model

Because sand transport can be reliably predicted, a sand transport/budget model was used to determine the largest and longest HFE that could be conducted that still yielded a positive sand balance in Marble Canyon for the accounting period, (given the mass of sand delivered by the Paria River since July 1 of any given year). Model runs iteratively cycled through the different HFE types until HFE types were identified that did not result in a negative sand balance. Following several storm events in the Paria River watershed, September 2015 model results predicted there was sufficient sediment for implementation of an HFE under the Protocol.

The sediment modeling component uses the sand transport/budget numerical model developed by the GCMRC.

Model Inputs

Model predictions require estimation of the following:

- Antecedent conditions
- Hydrographs including the potential HFE
- Sand input from the Paria River

Antecedent Conditions

The antecedent conditions required for the sand budget model are bed thickness, in meters, and median particle size, in millimeters. The most recent values represented May 2002 bed conditions. These values were updated to July 2015 by running the sand budget model for the period from 2002 to 2015 and using the results of that simulation as the antecedent conditions of the 2015 HFE model simulations.

Hydrology Input

Hydrology inputs were provided as hourly releases from Glen Canyon Dam in cubic feet per second (cfs). During the modeled period, a combination of historic hourly releases and forecasted releases were used as the hydrology inputs.

Sand Input

Sand inputs to the sand budget model were provided as hourly loads in kilograms per second (kg/sec). During the modeled period, observed sand loads were used as input up to the date of the simulation. From the simulation date forward, zero future sand input was assumed through the end of the modeled period.

Sand inputs were measured and estimated by GCMRC. Data were made available in real-time to Reclamation through the Paria River USGS/GCMRC water quality website (www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09382000#). Estimates of sand inflow were regularly adjusted by GCMRC as field samples were processed in the USGS/GCMRC laboratory.

Paria River sand inputs were increased to account for inputs from other tributaries in Upper Marble Canyon. Inputs from these tributaries are monitored and measured but estimates are not available in real-time. The historic average of these inputs is equal to approximately 10% of the Paria River loads, and is always a very small proportion of the amount delivered by the Paria River. Thus, Paria River sand input values were increased by 10% to account for these contributions from the lesser tributaries as was done for the HFE EA.

In real time, GCMRC provides estimates of the mass of sand delivered by the Paria River. Monthly, GCMRC provides estimates of the mass of sand that remains on the channel bed and in eddies in Marble Canyon. Initially, estimates are ±40%, because they are only based on modeling predictions. However, the uncertainty in these estimates progressively is reduced, because laboratory analysis of physical samples allows calibration of the model predictions. The range of uncertainty in estimates is reported by GCMRC as an upper and lower bound. For purposes of estimating the amount of newly delivered sand that is available for downstream transport and building of eddy sandbars, Reclamation used GCMRC's lower bound estimate. Thus, Reclamation's assessment of the amount of sand that is available for transport by the HFE is the minimum amount about which the GCMRC has a very high degree of confidence (i.e., a conservative estimate). Although the uncertainty associated with GCMRC's estimate of the actual amount of sand available for transport will inevitably be reduced, use of the lower bound during the HFE planning process ensures that there is minimal risk that the HFE will entrain more sand than is actually available to be transported. Subsequent to the 2012 and 2013 HFEs, analyses demonstrated that each controlled flood actually transported much less sand than was available to build new eddy sandbars or be transported downstream.

Therefore, while the use of the lower bound during the initial planning process may be appropriate, for some future HFEs, the Technical Team may wish to evaluate whether other decision criteria, such as the total sand accumulated in previous years, should also be considered in recommendations concerning the magnitude and duration of future HFEs. This consideration may also inform potential protocol design refinements pursuant to the ongoing work in the LTEMP process.

The sand mass balance for Upper Marble Canyon, where virtually all of the available sand is presently stored, was estimated by GCMRC and provided to Reclamation. The latest estimates available were for the period July 1 to September 28, 2015 (the last update available for this Technical Team report and recommendation). The estimates for the lower and upper bounds were, respectively, 678,000 and 960,000 metric tons.

HFE Types

Appendix E of the HFE EA listed 13 possible HFE types ranging from a peak magnitude of 31,500 to 45,000 cfs and ranging in peak duration from 1 to 96 hours. Although the HFE Protocol model evaluates performance of 13 possible types of HFEs (Table 1), the HFE Protocol decision and implementation phase allows for modifications based on resource conditions and predicted benefits to resources. Thus the HFE Protocol allows for HFEs from 1 to 96 hours in duration, 31,500 to 45,000 cfs in magnitude, and utilizing the rate limits of 4,000 cfs/hour increasing and 1,500 cfs/hour decreasing as defined in the HFE Protocol Finding of No Significant Impact (FONSI; Bureau of Reclamation 2012a) and the operating criteria for Glen Canyon Dam (62 FR 9447).

The modeling for this HFE used a peak magnitude of 37,600 cfs rather than 45,000 cfs due to expected maintenance at Glen Canyon Dam and other limitations due to reservoir head and power regulation. To assist with creating additional generation at Glen Canyon Dam, Western offered to move power reserves off of Glen Canyon Dam during a potential fall 2015 HFE, thus

decreasing their normal 67 megawatts (MW) of regulation/reserve requirement to 40 MW and increasing the maximum possible peak magnitude of a potential HFE.

Table 1. The 13 HFE types tested in model runs.

HFE No.	**Peak Magnitude (cfs)**	**Peak Duration (hrs)**
1	37,600	96
2	37,600	72
3	37,600	60
4	37,600	48
5	37,600	36
6	37,600	24
7	37,600	12
8	37,600	1
9	36,350	1
10	35,100	1
11	33,850	1
12	32,600	1

All HFEs tested assumed a ramp-up rate of 4,000 cfs/hr from baseflow to powerplant capacity, a rate of half a bypass tube (~1,875 cfs) every hour up to peak magnitude, and a ramp-down rate of 1,500 cfs/hr to baseflow. These ramp rates are in accordance with the HFE Protocol EA and FONSI, 1995 EIS, 1996 Record of Decision, and the Operating Criteria for Glen Canyon Dam (62 FR 9447).

HFE Model Results

The model simulation for the lower bound estimate for Paria River sand input and the HFE hydrograph completed October 7, 2015 estimated 534,330 metric tons of sand supply in all of Marble Canyon (i.e the Upper and Lower parts) on November 8, 2015 prior to the start of a potential HFE and an estimated 67,000 metric tons on November 30, 2015 following a potential HFE and at the end of the accounting period.

Sand budget model results through October 7, 2015, determined an HFE with a peak magnitude of 37,600 cfs and a peak duration of 96 hours.

HFE Recommendation

Although sediment conditions support a 96-hour duration HFE, the Team is recommending that no HFE take place in fall 2015 due to concerns for biological resources (discussed below).

III. Assessment of Resources

In making this recommendation, the Team completed an assessment of key resources that may be impacted or affected by a 2015 HFE based on the most recent information, and in particular, information collected since the fall 2012, 2013 and 2014 HFEs. This assessment focuses on recent findings and key resources and an evaluation of these resources relative to the proposed timing, duration, and magnitude of the potential fall 2015 HFE as described above using the best available science.

Three HFEs have been conducted under the HFE Protocol: a fall 2012 HFE November 18-23 2012 with a maximum magnitude of approximately 44,700 cfs for 24 hours followed by a slow down-ramp rate of 200 cfs per hour for 30 hours, a fall 2013 HFE November 11-16, 2013 with a maximum magnitude of approximately 37,500 cfs for 96 hours, and a fall 2014 November 10-15, 2014 with a maximum magnitude of approximately 37,500 cfs for 96 hours. The following resource assessment summarizes the results of these first three HFEs, in relation to prior HFE tests, and in developing a recommendation for a 2015 HFE.

The Team refers to Reclamation (2011) and Melis (2011) for more complete summaries of resource effects from HFEs. The following key resources were considered:

- Sediment Resources
  - In-channel sediment storage
  - Sandbar campable area
  - High-elevation sand deposits

- Cultural Resources
  - Archaeological site condition and stability
  - Access to archaeological sites by tribes

- Biological Resources
  - Aquatic food base
  - Lees Ferry trout population
  - Lees Ferry fishery recreation experience quality
  - Endangered humpback chub and other fish abundance
  - Riparian vegetation
  - Endangered Kanab ambersnail

- Hydropower and water delivery
  - Water quality
  - Water delivery
  - Dam maintenance
  - Hydropower production and marketable capacity

In our resource assessment, we found key information, specifically the presence of green sunfish in a backwater slough in Glen Canyon, that indicates a fall 2015 HFE could have potential adverse effects. This information has lead the Team to recommend that no HFE take place in fall

2015. Concern related to green sunfish as well as several additional issues that warranted further consideration are described in this section.

Sediment Resources: See discussion in Section II for current sediment conditions relative to the HFE Protocol. Responses to the first three HFEs under the HFE Protocol in 2012, 2013, and 2104 were similar to previous HFEs. All resulted in substantial deposition followed by erosion of about half the new deposits within 6 months. Response immediately after the 2014 HFE based on digital camera images of sandbars from Lees Ferry to Diamond Creek indicated that there was a substantial gain (deposition) for 22 sandbars (58% of sites), no substantial change for 11 sandbars (29% of sites), and substantial loss (erosion) for 5 sandbars (13% of sites). Annual topographic surveys of sandbars were conducted between September 23 and October 9, 2015. These data have not been processed, but preliminary field observations indicate significant erosion of sand deposited by the fall 2014 HFE occurred during summer 2015.

The aggregate sand mass balance conditions since inception of the HFE Protocol, i.e. for the period between July 1, 2012, and September 28, 2015 for the different segments of the Colorado River are:

Upper Marble Canyon: + 1.00 million metric tons (the range of this estimate is between -0.48 and + 2.50 million metric tons)

Lower Marble Canyon: + 2.00 million metric tons (the range of this estimate is between +1.60 and + 2.50 million metric tons)

Thus, there was more sand in the Colorado River corridor in Marble Canyon on September 28, 2015, than there was on July 1, 2012 when the HFE Protocol was first implemented.

Cultural Resources: Reclamation (2011) determined that the HFE Protocol could, through multiple HFEs, potentially affect historic properties and the effect would be adverse per 36 CFR 800.5(2)(iv). Reclamation also found that adverse effects to sacred sites could result from the HFE Protocol, primarily from limitation of access of tribes to sacred sites during the period of HFE releases. Reclamation completed the HFE Protocol Memorandum of Agreement (MOA; Reclamation 2012b) with affected tribes and other parties to address these effects. Effects of HFEs to cultural resources are primarily from erosion and redistribution of sediment. Inundation can directly adversely affect sites through erosion, but deposition may help protect sites directly or by providing sources of sand that can bury historic properties via aeolian transport (Reclamation 2011, Schmidt and Grams 2011). HFEs also may affect access of tribes to historic properties and alter visitation patterns to historic properties (Reclamation 2011).

The MOA has a stipulation, Stipulation 2c, that requires a meeting be conducted with the parties after each HFE event, to review the effects of the HFE, and use the results of the meeting to inform monitoring for future HFEs, and to design and implement any measures necessary to prevent or control adverse effects of future HFEs. Reclamation held an HFE Workshop on February 27, 2015 in Salt Lake City, Utah, and that meeting also served as the HFE MOA meeting to review the results of the 2014 HFE. No adverse effects to historic properties from the 2012, 2013, or 2014 HFEs were identified.

The MOA also includes a stipulation, Stipulation 2b, that requires all the parties be notified at least 30-days in advance of any planned HFEs, and consult with tribes to resolve any conflicts with tribal access to or uses of the Colorado River. DOI began notifying the parties of the potential for an HFE in early September, and the parties were also officially notified of a potential HFE in fall 2015 on September 30, 2015 via letter.

Biological Resources: HFEs can affect aquatic biological resources in Glen, Marble, and Grand Canyons as well as Lake Mead by changing the physical template of the ecosystem. HFEs scour the river bed, primarily in Glen Canyon, removing algae and aquatic plants and animals, which alters the distribution and abundance of aquatic animals, particularly in benthic habitats, and can result in changes to the aquatic food base for fish (Kennedy and Ralston 2011).

Controlled floods have been released from Glen Canyon Dam on the Colorado River six times since 1996. Research conducted around the March 2008 flood demonstrated that this pulse disturbance reduced biomass and cover of aquatic macrophytes, and restructured invertebrate assemblages by favoring fast-growing insect taxa (midges and blackflies) that prefer bare substrates and disadvantaging non-native and non-insect taxa such as mudsnails that prefer macrophyte beds (Cross et al. 2011). These shifts in the invertebrate assemblage and increases in drift concentrations led to dramatic increases in rainbow trout biomass. In the years after this controlled flood (2009-2012), aquatic macrophytes returned, large bodied mudsnails came to dominate, and fast-growing midges and blackflies declined (GCMRC unpublished data).

Controlled floods were again conducted in November 2012, 2013, and 2014, but long-term drift monitoring indicates these fall-timed floods did not restructure invertebrate assemblages, likely due to the seasonal scouring potential of aquatic macrophytes (GCMRC unpublished data). Specifically, primary production monitoring indicates that although these fall-timed floods temporarily reduce macrophyte cover (i.e., lower primary production) these negative effects are not persistent, and macrophyte biomass and production recovers the following spring thereby providing low-velocity habitat that favors mudsnail production. The 2008 spring-timed floods appeared to have a persistent and long-term effect (i.e., >1 yr) on macrophyte production, because this disturbance occurred at the onset of the growing season. Fall-timed floods occur at the end of the growing season at a time when macrophytes are already in the process of shunting biomass and preparing to overwinter. Thus, the timing, rather than simply the magnitude, of controlled floods on the Colorado River appears to affect food web response.

Investigations into the effects of HFEs on key fish species, namely nonnative rainbow trout and native humpback chub, indicate these events do not appear to affect young fish of either species through displacement to downstream habitats or increased mortality (Kennedy and Ralston 2011). For example, trout in Glen Canyon moved very little over intervals that included the 2012, 2013, and 2014 HFEs (GCMRC unpublished data). Furthermore, juvenile humpback chub survivorship in the mainstem Colorado River at the Little Colorado River was actually higher over the 2012-2013 and 2013-2014 periods that included HFEs relative to 2011-2012 that did not include an HFE (GCMRC unpublished data). Other fish species present in Glen or Grand Canyons may, however, respond differently. A recent risk assessment of green sunfish in Glen Canyon (Ward 2015) concluded that HFEs pose a risk to spread this invasive species from Glen Canyon to downstream areas in Grand Canyon.

HFEs may improve spawning habitat for rainbow trout in Glen Canyon by scouring fine sediment and cleaning gravel beds used for spawning. HFEs also alter the distribution of fine sediment resulting in changes in aquatic habitat, for example the creation of backwaters (Kennedy and Ralston 2011). HFEs also change the water quality in the river and in Lake Mead downstream by increasing turbidity and altering water quality, in particular, temperature, dissolved oxygen, and specific conductance (Reclamation 2011, Southern Nevada Water Authority unpublished data).

Rainbow trout densities have been decreasing in Glen and Marble Canyons since early 2012. Densities just above and below the Little Colorado River confluence increased until early 2014 then decreased sharply into late 2014 and early 2015 (GCMRC unpublished data). These changes do not appear to be a result of the fall 2012, 2013, or 2014 HFEs, but there is uncertainty in this regard, and this is a cause for concern for endangered humpback chub. Monitoring indicates that rainbow trout in Glen Canyon moved very little during the intervals that included the fall 2012, 2013, and 2014 HFEs. Approximately 90% of age-0 rainbow trout were recaptured within 0.25 miles of their initial release locations (GCMRC unpublished data). There is some evidence, based on year class structure, of local rainbow trout recruitment in Marble Canyon; although it is unclear that this has been caused directly by HFEs, it is possible, and we are uncertain whether a fall 2015 HFE would exacerbate this. Over this same period, brown trout catches at the LCR have been low. Brown trout are a highly piscivorous species known to eat humpback chub and other native species. So far, monitoring of juvenile and subadult humpback chub has not indicated that rainbow or brown trout are having an adverse effect, and humpback chub status appears stable or increasing across all age classes for the Little Colorado River aggregation (GCMRC unpublished data). Continuation of the trout monitoring program now in place will provide an assessment of the effects from a 2015 HFE, if it occurs.

HFEs have had no measurable direct effects, positive or negative, on humpback chub or other native fish, although their populations have increased significantly over the last decade, a period that included HFEs in 2004, 2008, 2012, 2013 and 2014 (Kennedy and Ralston 2011, GCMRC unpublished data). HFEs may indirectly affect humpback chub through increases in rainbow trout populations, which can prey on young humpback chub. While increases in rainbow trout abundance have been observed following the spring flows of 2008 which included an HFE in March, no positive trout response has been observed following fall HFEs in 2012, 2013 or 2014 (GCMRC unpublished data). Based on provisional unpublished data, humpback chub were apparently unaffected by the 2012 and 2013 HFEs, with adult and juvenile populations appearing stable over the period of these HFEs. The spring population estimate for adult (> 200 mm) humpback chub in the Little Colorado River was lower in 2015 relative to 2014 (USFWS unpublished data). While this data may represent a population decline, evidence indicates that the relative condition of humpback chub in the Colorado River near the confluence of the Little Colorado River was low in late 2014 and early 2015 (GCMRC unpublished data). This data supports the hypothesis that low spring catches were due to skipped spawning as a result of less energy available for fish to devote to reproduction. A complete analysis of humpback chub data from monitoring trips in September and October 2015 was not available in time to be considered in this report, but preliminary results suggest catches of various size classes of humpback chub were relatively high both in the Colorado River and Little Colorado River (USFWS and GCMRC unpublished data) suggesting that there are no issues of concern relative to a fall 2015 HFE.

A small reproducing population of endangered razorback sucker occurs downstream in Lake Mead, and recent monitoring data indicated that razorback sucker occupy and spawn in western Grand Canyon as far upstream as Lava Falls. A single adult was caught in October 2012 near Spencer Canyon in the riverine part of Lake Mead that is within western Grand Canyon. Two adults, one untagged and one sonic tagged, were captured in the same area in 2013 (Arizona Game and Fish Department (AGFD unpublished data). Sonic-tagged adults have also been remotely detected as far upstream as Lava Falls. Razorback sucker larvae were captured just downstream of Lava Falls in 2014 and preliminary data indicates they were also collected in 2015 (NPS unpublished data). Changes in flows are unlikely to have any significant effect to razorback suckers in the Colorado River inflow area since effects of those releases are attenuated by the time the water reaches what is likely to be occupied habitat, and razorback sucker are rare in the area. The HFE flows could have some effect to spawning and recruitment if conducted during the spring, but a fall HFE will not have this effect, as spawning does not occur during this timeframe.

As described in the 2011 U.S. Fish and Wildlife Service biological opinion, endangered Kanab ambersnail would be adversely affected by HFEs (U.S. Fish and Wildlife Service 2011). HFEs will scour snail habitat resulting in loss of some snails at Vasey's Paradise. FWS found in its 2011 biological opinion that this loss of snails and snail habitat would not jeopardize the continued existence of the Kanab ambersnail. A recent report by the USGS found that Kanab ambersnails are part of a much more widespread species of snail and may not qualify as an endangered species (Culver et al. 2013).

Whirling disease, a serious disease of trout species, was detected in Glen Canyon in 2011 by AGFD. Although there is no data on how HFEs affect whirling disease, GCMRC completed an assessment of the potential for HFEs to spread whirling disease in 2012 that concluded HFEs pose little risk of spreading whirling disease, and that HFEs may reduce the prevalence of the disease by removing tubificid worms from sediments in Glen Canyon (tubificid worms are hosts to this myxosporean parasite). The AGFD has not specifically monitored for the disease in Marble and Grand Canyons. However annual monitoring of rainbow trout in Glen, Marble, and Grand Canyons did not detect symptoms of the disease in 2014 or 2015, since the 2013 and 2014 HFEs.

In July 2015, an unusually large number of nonnative green sunfish were discovered in a large backwater in the Lees Ferry Reach (AGFD unpublished data). Agency biologists agreed that elimination of this invasive species from the backwater sloughs is necessary and urgent due to the risk of negative interactions with native fish, particularly the humpback chub. Two subsequent removal trips in August 2015 using electrofishing, seining and trapping failed to deplete the population despite removing over 3000 fish (AGFD unpublished data). Agency biologists conferred and agreed that these methods were not likely to successfully eradicate this species from the area. While additional methods of removal and control were considered, an immediate need to contain the green sunfish was recognized. On Oct 7, 2015 biologists from NPS and AGFD constructed and installed a large block net at the downstream end of the main slough to minimize escapement of green sunfish until a more complete removal can be effected. Potential methods to eradicate green sunfish from Glen Canyon include mechanical approaches like electrofishing, netting, or concussive methods and chemical treatments such as piscicides or carbon dioxide. Of the methods evaluated to remove these fish, chemical treatments provide the

greatest likelihood of success (Ward 2015). NPS and AGFD, with assistance from GCMRC and Reclamation, are working towards a chemical treatment solution; however, the likelihood of a chemical treatment being completed and determined to be fully successful before a fall 2015 HFE can be implemented in November is very low, due to the high level of planning and State and Federal regulatory compliance that is necessary before initiating treatment. The risk of dispersal of this invasive species must be taken into account as the HFE is considered, since this species is adapted to using floods as a means of dispersing to new habitats and colonizing them. Bathymetric maps of the slough area and preliminary results from flow modeling indicate the area becomes a flowing side channel at flows between 20,000 and 30,000 cubic feet per second (cfs), while the minimum flows for HFEs are 31,500 cfs. The temporary block net installed at the mouth of the slough will not be adequate to contain the green sunfish if the side channel begins to flow. Eradication of green sunfish from Glen Canyon before any HFE is necessary to eliminate the risk of dispersal and subsequent establishment of this harmful nonnative in the Colorado River or any of its tributaries in Grand Canyon.

Hydropower and Water Delivery: Throughout the HFE planning process Reclamation and Western have coordinated to ensure that the maximum possible release from the dam could be achieved. While there are a number of unknown factors that might impact the maximum release rate that can be made during the HFE, Reclamation anticipates that a release of approximately 37,600 cfs would achievable.

The best estimate for total release from Glen Canyon Dam for a HFE in November 2015 is 37,600 cfs (22,600 cfs through the powerplant and 15,000 cfs of bypass). This estimate is based on the most recent unit testing completed in September 2015, a maintenance assumption that seven of the eight units at Glen Canyon Powerplant would be available November 9-14, 2015, and an approximately 90% gate opening on the available seven units. In addition, this estimate assumes that 40MW (approximately 1,200 cfs) of system regulation will be maintained at Glen Canyon.

Western has completed an analysis of the financial costs of running the experimental flows during the fall 2012 and 2013 HFEs. Western estimates that the 2012 HFE cost approximately $1.1 million and that the 2013 HFE cost approximately $2.6 million. These are good bookends for the likely cost of running a similar HFE in 2015. The financial implications of the HFE occurs over a few months. Initially there tends to be a financial gain in November due to the increased generation, but is offset by a financial loss that occurs in December through April from water that is needed to support the experimental releases in November. In addition, water that is bypassed (or spilled) does not generate any power and thus represents lost revenue.

The release volume required in November for the modeled HFE is approximately 770,000 acre feet. The October 24-Month Study projected 600,000 acre feet release volume in November, therefore it would be necessary to reallocate approximately 170,000 acre feet from months later in the 2015 water year. Approximately 130,000 acre feet of water would be bypassed during the modeled HFE. If the HFE were to take place, Western and Reclamation would coordinate on the scheduled reallocation of monthly release volumes with the goal of protecting minimum MLFF monthly thresholds whenever practicable as described in the EA as well as maximizing the

economic value of hydropower. Hourly releases for the days prior to and after the proposed HFE in November were modeled as fluctuating between 6,500 to 9,000 cfs.

Reclamation thoroughly evaluated the effect of conducting the modeled fall 2015 HFE on the annual release volume from Lake Powell in compliance with the 2007 Interim Guidelines. Reclamation currently projects the annual release volume for water year 2016 will be 9.0 million acre feet under the minimum and most probable hydrology inflow scenarios and 11.4 million acre feet under the maximum probable hydrology inflow scneario. An HFE in November 2015 would not affect the annual release volume from Lake Powell nor the Operational Tier in accordance with the 2007 Interim Guidelines. In the HFE FONSI, Reclamation also committed to consulting with the Basin States prior to conducting an HFE as to the issue of compliance with the 2007 Interim Guidelines. Because the Team is recommending that no HFE be conducted in fall 2015, no consultation related to compliance with the 2007 Interim Guidelines was undertaken. In fall 2015, Basin State representatives participated in the development of this recommendation and concur with it.

The Pueblo of Zuni, in a letter dated September 20, 2012 expressed concern that successive iterations of HFEs under the HFE Protocol could have cumulative negative impacts on power generation and a resultant effect on raising the cost of purchasing power for individual rate payers, and that this is especially of concern to economically disadvantaged minority communities such as Zuni. The Pueblo of Zuni requested that Reclamation provide a detailed description on how the economic effects of successive HFEs on power rate payers will be monitored. Though no HFE is recommended for fall 2015, Reclamation continues to work with Western to carefully assess this issue and provide for post-HFE monitoring that will analyze, to the extent possible, effects to ratepayers from HFEs conducted under the HFE Protocol. At this time, Western does not anticipate that the cost of HFEs will cause near-term changes in power rates.

IV. SAFETY CONSIDERATIONS

As identified in the HFE Protocol EA and FONSI, potential effects on public health and safety could occur in conjunction with an HFE, primarily impacting recreational anglers and boaters. All daily fluctuations, minimum flows and maximum flows associated with any proposed HFE are within the range experienced by recreational users in the past. Reclamation and NPS continue to work together to ensure that safety measures are implemented, including restricting access to the river immediately below the dam during proposed HFEs, and as noted below, providing public notice about the timing of the HFE implementation. NPS Boating Safety Rules always apply to all boaters using the river.

Day raft trips from Glen Canyon Dam to Lees Ferry, conducted under contract by Colorado River Discovery (CRD), cannot operate during HFEs because flow into the Colorado River uses the bypass tubes at Glen Canyon Dam near the launch point for these trips. NPS would notify CRD of a potential HFR so that the company can prepare to move boats and associated infrastructure out of the river to the Lees Ferry launch ramp. Revenue losses for the period of time associated with six-day HFE are estimated at $14,000 to $16,000, with and additional costs of $600 for NPS amenities revenues, and $1,620 concession franchise fees. Given that no HFE is being recommended for fall 2015, the primary concessionaire on the Glen Canyon reach,

Colorado River Discovery (CRD), will be unaffected, notifications will not need to be made, and there is no anticipated loss of revenue.

Reclamation and NPS coordinate to address safety and security issues related to HFEs. Additionally, the NPS units work to maximize continuity of efforts and resources, particularly in those areas where responsibilities are shared, specifically Lees Ferry and Pearce Ferry. The parks have coordinated communications plans, medical plans and resource capabilities for search and rescue responses.

If an HFE were to occur, GCNP would communicate with permitted Colorado River trip permit holders that have the potential to be impacted by the HFE while rafting the Colorado River within GRCA and Lake Mead National Recreation Area. Given that an HFE is unlikely to occur, no active planning is underway to provide alternative trip dates for trips potentially affected by an HFE.

If an HFE were to occur, GCNRA would communicate with the holders of commercial use authorizations for commercial services (primarily fishing guides) on the Colorado River within GCNRA to provide information on the time and duration of the HFE. Given that an HFE is unlikely, no additional informational messaging has been developed.

V. COMMUNICATIONS PLAN

If an ultimate decision is made not to conduct a fall 2015 HFE, DOI, NPS, USGS and Reclamation public affairs officers will develop appropriate communication strategies and FAQ's to address commonly asked questions and provide outreach and education to the public. This outreach will include updates to all relevant agency web sites and media outlets as requested.

VI. POST HFE-REPORTING AND FEEDBACK

Reclamation committed in the HFE EA and FONSI to provide reports on effects of HFEs conducted in a given year. Although we are not recommending a fall 2015 HFE, if a fall 2015 HFE were conducted, the Technical Team would coordinate to report initial findings at the 2016 Glen Canyon Dam Adaptive Management Program (GCDAMP) Annual Reporting Meeting in January 2016.

Members of the Technical Team will schedule additional meetings as necessary and will also report ongoing findings at meetings of the GCDAMP Technical Work Group and Adaptive Management Work Group. Reclamation also has a commitment to provide an annual monitoring report to the FWS Arizona Ecological Services Office (AESO) in compliance with the 2011 Biological Opinion; this report will also include a summary of effects of HFEs conducted under the protocol. Also, under the HFE Protocol MOA, Reclamation will conduct a reporting meeting with the signatories to that agreement, describing the effects of the HFE. Reclamation will use the monitoring information and feedback from AESO and the MOA signatories to inform monitoring for future HFEs, and to design and implement any measures necessary to address any adverse effects that may occur due to future HFEs.

There are two similar commitments in the HFE Protocol FONSI that Reclamation addressed in 2015, after the 2014 HFE. The first commitment was to undertake a review in 2014 of the first two years of implementation of the HFE Protocol through a workshop with scientists to assess what has been learned. This commitment is part of the FWS 2011 Biological Opinion on the HFE Protocol. The second commitment, from the HFE Protocol FONSI, was to conduct a comprehensive review of the HFE Protocol after multiple events (at least 3) have occurred, with GCDAMP stakeholders, to document and standardize planning tools and information sharing approaches as part of the implementation of the HFE Protocol. As a result of consultation with FWS, Reclamation combined these two commitments and conducted a workshop on February 27, 2015, in Salt Lake City, Utah, with GCDAMP stakeholders and MOA signatories to evaluate the results of the first three HFEs, and completed and submitted to FWS a draft written report of the biological opinion reporting results in 2015.

In addition, GCMRC developed a science plan for the HFE Protocol that describes a program of monitoring and research activities that support ongoing information needs associated with implementation of the HFE Protocol. The approach described in this science plan relies on water quality, sediment, aquatic biology, and other resource monitoring and research projects funded in the GCDAMP Fiscal Year (FY) 2015-17 Triennial Budget and Work Plan (TWP, Reclamation and GCMRC 2014). These projects will inform the effect of future HFEs on the downstream resources of Glen, Marble, and Grand Canyons. These projects from the TWP are further discussed below.

Project 2, Streamflow, Water Quality, and Sediment Transport in the Colorado River Ecosystem, and Project 3, Sandbars and Sediment Storage Dynamics: Long-term Monitoring and Research at the Site, Reach, and Ecosystem Scales, are essential components to implementation of the HFE Protocol because the protocol calls for high flow releases from Glen Canyon Dam whenever a specified minimum amount of fine sediment delivered from the Paria River is exceeded. Project 2 is the measurement program needed to document the HFE Protocol. Project 3 supports the direct measurements of the volume of fine sediment, especially sand, that is stored on the bed of the Colorado River, in its eddies, or at higher elevation along the river's banks; these measurements allow assessment of the effectiveness of the HFE Protocol. A significant accomplishment of these programs in FY13–14 was the development of web-based interfaces to serve sediment transport and water quality data, calculate fine sediment mass balances, and to serve photographs of approximately 50 sandbars located from Lees Ferry to Diamond Creek. The latter data allow stakeholders to evaluate the effects of controlled floods implemented under the HFE Protocol.

As described in the HFE Protocol EA, the HFE planned for fall 2015 would not be an isolated event, but as a component of a longer-term experiment to restore and maintain sandbars with multiple high flows over a period of several years. The monitoring data that are needed to assess the outcome of this multi-year experiment include annual sandbar monitoring at selected long-term monitoring sites, periodic monitoring of changes in sand storage in the river channel, and measurements of sandbar size at more than 1,000 sites based on aerial photographs that are collected approximately every 4 years. These activities are described in detail in the TWP. It is also important, however, to evaluate the sandbar building response of each high flow to assess whether the sandbar building objectives are being achieved incrementally. This evaluation will

be based on sites that are monitored by remotely deployed digital cameras and repeat topographic surveys of sites that will occur in spring and fall 2016.

GCMRC scientists have installed digital cameras that capture 5 images every day at 43 sandbar monitoring sites throughout Marble and Grand Canyon between Lees Ferry and Diamond Creek. The images acquired by these cameras will be used to evaluate both the magnitude and spatial distribution of sandbar building caused by the HFE. They will also be used to assess the rate of post-HFE sandbar erosion. GCMRC scientists tested the effectiveness of this monitoring method based on images collected at 22 sites, from Lees Ferry to Diamond Creek, for the 2008 HFE. The assessment of sandbar gains and losses based on a categorical ranking of changes from the images agreed with the changes detected by detailed topographic surveys at 86% of the sites. Because the remote cameras are monitoring the same sites that are monitored by the annual surveys and the same sites that were monitored during the previous high flows, it will be possible to evaluate sandbar-building effectiveness of the planned 2015 HFE relative to the previous HFEs. NPS will also be providing post-HFE monitoring of sandbars using photography.

All of the long-term sandbar monitoring sites, located between Lees Ferry and Diamond Creek, were surveyed between September 22 and October 9, 2015. This assessment of the size and distribution of HFE deposits approximately 11 months following the 2014 HFE provide the most informative assessment of sandbar-building effectiveness. These measurements, now being analyzed, will indicate the degree to which deposits created by the fall 2014 HFE provide enhanced sandbars for use in the following summer recreation season and whether the HFE Protocol is resulting in cumulative increases in sandbar size.

Project 4, Connectivity along the Fluvial-Aeolian-Hillslope Continuum: Quantifying the Relative Importance of River-related Factors that Influence Upland Geomorphology and Archaeological Site Stability (called Project J in the FY13–14 Work Plan) is focused on monitoring and research concerning geomorphic and weather processes that affect cultural resources above the active channel of the Colorado River. This project seeks to address longstanding issues associated with monitoring of landscape change near archaeological sites and other culturally significant properties. The project directly supports evaluation of the HFE Protocol effects to cultural resources by measuring deposition and erosion of river-derived sediment (sandbars) and consequent aeolian sand transport and efficacy of these processes in *in situ* preservation and impacts of archaeological sites.

Projects 5 (Food base Monitoring and Research), 6 (Mainstem Colorado River humpback chub aggregations and fish community dynamics), 7 (Population Ecology of Humpback Chub in and around the Little Colorado River), 8 (Management Actions to Increase Abundance and Distribution of Native Fishes in Grand), 9 (Understanding the Factors Determining Recruitment, Population Size, Growth, and Movement of Rainbow Trout in Glen and Marble Canyons), and 10 (Where does the Glen Canyon Dam rainbow trout tailwater fishery end?- Integrating Fish and Channel Mapping Data below Glen Canyon Dam) concern the fishes of the Colorado River and its tributaries, the food base on which those fish depend, and the habitats in which the food base and fishes occur. Project 5 is a new stand-alone effort designed to continue monitoring of the aquatic food base and to conduct research to resolve questions about the current condition of the aquatic invertebrate community in Glen Canyon. Many of the research and monitoring projects on native and nonnative fish in the mainstem Colorado River are included in Project 6.

Project 7 is a research project intended to resolve uncertainties about humpback chub and their life history in the Little Colorado River and near its confluence with the mainstem Colorado River. Management actions focused on benefitting native fish and funded by the GCDAMP are included in Project 8, as is a proposed review of the fisheries program by an external protocol evaluation panel (PEP). Project 9 concerns the rainbow trout fishery of Glen Canyon as well as the factors influencing the distribution and movement of rainbow trout in Marble Canyon. Project 10 focuses on improving understanding of the relationships between physical habitat in Glen Canyon and Marble Canyon and rainbow trout recruitment and distribution. These projects work in concert to maintain long-term monitoring data sets of key aquatic resources in the Colorado River ecosystem while also looking to minimize redundancy and increase efficiency and to continue addressing persistent scientific uncertainties that have plagued management of the aquatic ecosystem. These projects work directly to evaluate the HFE Protocol through a set of monitoring and research efforts designed to evaluate the effect of HFEs on the physical habitat of the aquatic ecosystem, the aquatic food base, and concomitant changes in the nonnative fishery (predominantly rainbow trout in Glen and Marble canyons), the native fishery downstream, including endangered humpback chub, and the interactions between the native and nonnative fishery, in particular the effect of predation and competition from rainbow trout on humpback chub.

VII. CONSULTATION

Reclamation and GCMRC presented much of the information in this report that was available at that time to the Adaptive Management Work Group at its August 27-28, 2015 meeting. Representatives of the Colorado River Basin states participated in the development of this recommendation and concur with it. Reclamation also intends to present the findings and recommendation of this report to the Technical Work Group (TWG) on October 20-21, 2015. On September 30, 2015, the required 30-day advance notification was given to the MOA signatories, including the tribes, of the potential for an HFE in November 2015.

VIII. CONCLUSION

Determining whether to recommend an HFE required coordination of many details and effective communication amongst technical staff of multiple agencies. The Team members relied heavily on the staff in each of the agencies in making this recommendation. The Team has thoroughly evaluated the issues discussed above, and has taken into consideration the information and analysis included in the HFE Protocol EA and FONSI. The Team's recommendation to not implement a HFE in fall 2015 is based on the careful assessment of resources and best available science. In particular, the Team is recommending that no HFE be conducted in fall 2015 because of the detection of green sunfish and the concern that an HFE could disperse this harmful nonnative downstream into the Colorado River. The Team recognizes the need to eradicate the species prior to conducting an HFE and the timeline for doing so is not feasible within the fall 2015 HFE window (October through November 2015). The success of this important initiative is in large part due to the commitment of the Team to ensuring that the HFE Protocol is a success.

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