# United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, DC 20240

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Memorandum

To: Brent Rhees, Acting Regional Director
Upper Colorado Region, Bureau of Reclamation

From: Jennifer Gimbel, Chair, Glen Canyon Leadership Team
Deputy Principal Assistant Secretary – Water & Science

Subject: Approval of Recommendation for Experimental High-Flow release from Glen Canyon Dam, November 2014

On October 22, 2014, the Glen Canyon Technical Team (Technical Team) recommended a high-flow experimental (HFE) release from Glen Canyon Dam (Attachment 1, Technical Team Recommendation to Implement a Fall 2014 High Flow Experiment at Glen Canyon Dam) in accordance with the Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020 (HFE Protocol) Environmental Assessment (EA) and Finding of No Significant Impact (FONSI). The Glen Canyon Leadership Team (Leadership Team) has carefully reviewed and considered the Technical Committee's recommendation.

After a thorough discussion, the Leadership Team has unanimously decided that the recommendation complies with the HFE Protocol and decided to proceed with the recommended HFE release. This HFE would be the third conducted under the HFE Protocol and represents the utility of the HFE Protocol to allow for HFEs when conditions warrant. The recommended HFE will provide resource benefits in the near term and will also provide scientific information to be used in future decision making. The HFE will satisfy the Department's goal to ensure effective and coordinated implementation of important research that the Department of the Interior is undertaking through the Glen Canyon Dam Adaptive Management Program.

The Leadership Team would like to thank the Technical Team for the sustained hard work that has led to this recommendation. The individual efforts from members of the Technical Team and coordination of the team as a whole has made this process a success that will ensure benefits to the incomparable resources of Grand Canyon National Park and Glen Canyon National Recreation Area and effective and coordinated research to benefit the adaptive management process.

Attachment

cc:

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October 21, 2014

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 Implement a Fall 2014 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 in determining this recommendation for a high flow experiment (HFE) to be conducted at Glen Canyon Dam in November 2014 and is recommending that the Leadership Team approve a fall 2014 HFE. This controlled high flow release would be the third HFE conducted under the HFE Protocol.

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), and the Bureau of Reclamation (Reclamation). Western Area Power Administration (Western) resource specialists also participated in the process and provided information for this recommendation. Western is fully supportive of this recommendation.

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, including the tasks addressed in the July 18, 2012 memorandum from the Assistant Secretary for Water and Science. The Team also considered additional technical information and operating experience developed as a result of implementation of the 2012 and 2013 HFEs.

The Team recommends that an HFE at Glen Canyon Dam be conducted beginning November 10, 2014 with a peak magnitude of approximately 37,500 cubic feet per second (cfs) for 96 hours, as explained below.

## 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 for two purposes. First, predictive models were used to anticipate the magnitude, duration, and frequency of HFEs that might occur on a decadal time scale, based on historic sediment and hydrologic data for the Paria River. These models allow prediction of the maximum potential for sandbar building with the historic sand supply. Second, predictive models are used 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. The two basic inputs for the modeling are the hydrology, based on forecasted monthly inflow volumes from the National Weather Service's Colorado Basin River Forecast Center and Reclamation's 24-month study storage and release projections, and the estimated mass of sand that has been delivered to the Colorado River in Marble Canyon. Virtually all of this sand comes from the Paria River, but other small tributaries contribute approximately 10% additional sand supply.

A flow routing model was used to predict the rate at which the HFE release wave moves downstream. A sand transport/budget model was used to predict the mass of sand that would be transported by the 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. Sand-inflow data are based on real-time measurements of the Paria River measured at the gage near Lees Ferry and a predictive model that allows the measurements of sand transport to be extrapolated to entire HFE periods. Sand inflow from smaller tributaries is estimated as a small proportion of the inflow rate from the Paria. Modeling of Colorado River sand transport is used to predict if the duration and magnitude of an HFE release transports slightly less sand than was delivered to the Colorado River during the immediately preceding accounting period. Output of the modeling runs provides the initial recommendation for the magnitude and duration of the HFE. Because modeling only considers a simple range of possible HFE peak magnitudes and durations, the Protocol includes a review of the model output, so that other relevant resources can be considered. Thus, the Team also considered the status of resources and consideration of HFE effects on key resources in making the recommendation described here.

Throughout the summer and fall, Reclamation regularly updated its modeling estimates based on ever increasing sediment inputs and worked with scientists at GCMRC to ensure that the HFE design has the greatest potential to produce the greatest likelihood of effective and efficient sandbar building and conservation. GCRMC research scientists provided input concerning how the HFE might best be shaped to meet the twin objectives of providing the greatest resource benefit and developing scientific information that will help better inform future decision making.

**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 2014 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 results reliably matched measured conditions in upper Marble Canyon, which is the river segment between Lees Ferry and River Mile (RM) 30.

**Model Inputs**

Model predictions require estimation of the following:

- Antecedent conditions
- Hydrographs including of 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 2014 by running the sand budget model for the period from 2002 to 2014 and using the results of that simulation as the antecedent conditions of the 2014 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. Hourly Glen Canyon Dam releases were routed using the one-dimensional unsteady flow model developed by the USGS/GCMRC to determine hourly hydrographs at the downstream end of various modeled reaches.

### *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 $\pm$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 October 1, 2014 (the last update available for this Technical Team report and recommendation). The estimates for the lower and upper bounds were, respectively, 750,000 and 1,400,000 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 initially used a peak magnitude of 32,000 cfs rather than 45,000 cfs due to expected maintenance at Glen Canyon Dam and other limitations due to power regulation and reserves.

Beginning in September model runs have been conducted using 37,500 cfs as the peak magnitude for HFE types. This change was made to the modeling because Reclamation and Western coordinated to maximize the possible release peak rate by slightly shifting scheduled maintenance and moving power reserves to increase the Glen Canyon release capacity and thus the peak magnitude of a potential HFE. To assist with creating additional generation at Glen Canyon Dam, Western offered to move power reserves decreasing their normal 81 megawatts (MW) of regulation/reserve requirement to 40 MW which increased the maximum possible peak magnitude.

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

| **HFE No.** | **Peak Magnitude (cfs)** | **Peak Duration (hrs)** |
|---|---|---|
| 1 | 37,500 | 96 |
| 2 | 37,500 | 72 |
| 3 | 37,500 | 60 |
| 4 | 37,500 | 48 |
| 5 | 37,500 | 36 |
| 6 | 37,500 | 24 |
| 7 | 37,500 | 12 |
| 8 | 37,500 | 1 |
| 9 | 35,325 | 1 |
| 10 | 33,450 | 1 |
| 11 | 31,575 | 1 |
| 12 | 29,700 | 1 |
| 13 | 27,825 | 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 15 estimated 860,000 metric tons of sand supply in all of Marble Canyon (i.e the Upper and Lower parts) on November 10 prior to the start of a potential HFE and an estimated 130,000 metric tons on November 30 following a potential HFE and at the end of the accounting period.

The model results were compared with the lower bound estimate for sand mass balance in Upper Marble Canyon on October 1. The measured estimate was 750,000 metric tons compared to the modeled value of 900,000 metric tons for a difference of less than 20%, indicating that the model results are accurate.

Sand budget model results through October 15, 2014, determined an HFE with a peak magnitude of 37,500 cfs and a peak duration of 96 hours. Reclamation consulted with USGS/GCMRC about the modeling results, and USGS/GCMRC recommended an HFE hydrograph with maximum duration and magnitude allowable under the HFE Protocol. USGS/GCMRC recommended that a sustained 96-hr duration peak would facilitate scientific comparison with previous HFEs and thereby maximize scientific understanding of sediment transport processes. Based on the best professional judgment of its geomorphology and sediment transport experts, USGS/GCMRC recommended that maintaining maximum magnitude, 37,500 cfs under current conditions at Glen Canyon Dam, for 96 hours would provide the maximum potential benefit to fine-sediment-dependent resources in Marble Canyon. USGS/GCMRC and Reclamation also considered appropriate ramp-up and ramp-down rates. The USGS/GCMRC final recommendation for the shape of the HFE included a ramp-up rate of 4,000 cfs/hr from baseflow to powerplant capacity, ramp-up of half a bypass tube (~1,875 cfs) every hour to a peak magnitude of 37,500 cfs, a peak duration of 96 hours, and a ramp-down rate of 1,500 cfs/hr to baseflow. These recommendations were used in the final run of the sand budget model and are the basis for the final proposed HFE recommendation.

**HFE Recommendation**

GRMRC and Reclamation recommend that the HFE:

- Ramp-up from base releases at 4,000 cfs/hr at approximately 9:00 am on Monday, November 10, 2014 (all times Mountain Standard Time) until reaching powerplant capacity (~22,500 cfs)
- Open first bypass tube at 1:00 pm November 10
- Ramp-up from powerplant capacity to full bypass (~37,500 cfs) at half a bypass tube (~1,875 cfs) per hour in 8 hrs

- Stay at peak release (~37,500 cfs) for 96 hrs
- Ramp-down from peak release to base releases at 1,500 cfs/hr

These recommendations result in the following release schedule at Glen Canyon Dam

- Begin ramp-up from 9,000 cfs at 9:00 am on November 10 (Monday)
- Reach powerplant capacity at approximately 12:00 noon on November 10
- Open bypass tubes at approximately 1:00 pm November 10
- Reach full bypass at 8:00 pm on November 10
- Begin ramp-down from bypass at 8:00 pm on November 14 (Friday)
- Complete HFE (back to 9,000 cfs) at 2:00 pm on November 15 (Saturday)

This recommendation ensures that monitoring to increase scientific knowledge is a priority and places a high priority on USGS/GCMRC's field collection of samples at RM87. Automated pump samplers would collect at least 2 samples during hydrograph rise. Based on the assumed travel time of the HFE release wave, and to ensure the safety of sampling crews as discussed further below, daylight conditions will be available for sampling at all sites.

## III. Assessment of Resources

In making this recommendation, the Team completed an assessment of key resources that may be impacted or affected by a 2014 HFE based on the most recent information, and in particular, information collected since the fall 2012 and 2013 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 2014 HFE as described above using the best available science.

Two 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, and a fall 2013 HFE November 11-16, 2013 with a maximum magnitude of approximately 37,500 cfs for 96 hours. The following resource assessment summarizes the results of these first two HFEs, in relation to prior HFE tests, and in developing a recommendation for a 2014 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 did not find any information that would indicate a fall 2014 HFE would have sufficient potential adverse effects to a resource that would lead to a decision to not conduct the HFE. Several issues warranted further consideration as described in this section.

**Sediment Resources:** See discussion in Section II for current sediment conditions relative to the HFE Protocol. Responses to the first two HFEs under the HFE Protocol in 2012 and 2013 were similar to previous HFEs. Both resulted in substantial deposition followed by erosion of about half the new deposits within 6 months. Response immediately after the 2013 HFE based on digital camera images of sandbars from Lees Ferry to Diamond Creek indicated that there was a substantial gain (deposition) for 21 sandbars (50% of sites), no substantial change for 16 sandbars (38% of sites), and substantial loss (erosion) for 5 sandbars (12% of sites). Comparing the 2013 HFE with the 2012 HFE found that: 9 sandbars (27% of sites) were larger after the 2013 HFE; 2 sandbars (6% of sites) were larger after 2012 HFE; and 22 sandbars (67% of sites) were about the same.

The aggregate sand mass balance conditions since inception of the HFE Protocol, i.e. for the period between July 1, 2012, and October 1, 2014 for the different segments of the Colorado River are:

*Upper Marble Canyon* – + 2.2 million metric tons (the range of this estimate is between 1.1 and 3.2 million metric tons)

*Lower Marble Canyon* – + 0.62 million metric tons (the range of this estimate is between 0.40 and 0.84 million metric tons)

*Eastern Grand Canyon* – + 0.63 million metric tons (the range of this estimate is between 0.20 and 1.1 million metric tons)

Thus, there was more sand in the Colorado River corridor on October 1, 2014, 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 eolian 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 a meeting on February 12, 2014 to meet this stipulation of the MOA by reviewing the effects of the fall 2013 HFE. No adverse effects to historic properties from the 2012 or 2013 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 asking tribes if they wanted tribal consultation meetings, and the parties were also officially notified of a potential HFE in fall 2013 on October 9, 2014 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).

HFEs may displace young fish to downstream habitats or result in mortality of young fish, in particular trout in Glen Canyon (Kennedy and Ralston 2011). However, results of research conducted during the period of the 2012 and 2013 HFEs does not support this. Trout in Glen Canyon moved very little during the 2012 and 2013 HFEs. Juvenile humpback chub survivorship in the mainstem Colorado River at the Little Colorado River actually increased over the 2012-2013 period relative to 2011-2012, although numerous factors can affect this.

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 chemistry, in particular, temperature, dissolved oxygen, and specific conductance (Reclamation 2011, Southern Nevada Water Authority unpublished data).

Information on effects of HFEs on food base and fisheries in Glen and Grand Canyons is limited. Most information is from the March 2008 HFE. Although there was a 55% decline in total invertebrate biomass following the March 2008 HFE, rainbow trout production increased 194%, largely due to a shift in invertebrate biomass to better food sources for trout, blackflies (Simulidae) and midges (Chironomidae); (Cross et al. 2011). The March 2008 HFE also reduced biomass and production of New Zealand mudsnails (Cross et al. 2011), another beneficial effect to fish food base, as the species is indigestible by rainbow trout and Grand Canyon native fishes. Multiple HFEs could lead to a shift to more flood-tolerant invertebrate species, a potential benefit to higher trophic levels (fish). The first HFE in the spring of 1996 also led to increases in rainbow trout in Glen Canyon; increases in rainbow trout are a potential adverse effect to humpback chub because nonnative rainbow trout are known to prey on and compete with native humpback chub (Wright and Kennedy 2011).

There are fewer data to evaluate fall-season HFEs, but food base is expected to take longer to recover over the winter period. Data from the 2012 and 2013 fall HFEs do not indicate a strong effect on food base (GCMRC unpublished data). Concentrations of blackflies in the drift were elevated in Glen Canyon in January 2013 as compared to September 2012 while no change was observed midges over the same interval.

HFEs have had no measurable 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, and 2013 (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 response has been observed following fall events in 2012 or 2013. Based on provisional unpublished data, humpback chub were apparently unaffected by the 2013 HFE, with adult and juvenile populations appearing stable over the period of the HFE. Juvenile humpback chub data from a recent monitoring trip in September 2014 were not available in time to be considered in this report, but other monitoring data for various size classes of humpback chub collected this year indicate that there are no issues of concern relative to a fall 2014 HFE. The spring population estimate for adult (> 200 mm) and subadult (150-200 mm) humpback chub in the Little Colorado River appeared stable in 2014 relative to 2013 (post-HFE).

Rainbow trout densities have been decreasing in Glen and Marble Canyons, but increasing just above and below the Little Colorado River confluence (GCMRC unpublished data). This does not appear to be as result of the fall 2012 and 2013 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 period that included the fall 2012 HFE. Approximately 90% of age-0 rainbow trout were recaptured within 0.25 miles of their initial release locations. 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 2014 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 2014 HFE, if it occurs.

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, and sonic-tagged adults have been detected as far upstream as Lava Falls. Razorback sucker larvae were captured just downstream of Lava Falls in 2014. 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 the Arizona Game and Fish Department (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, since the 2013 HFE.

**Hydropower and Water Delivery:** For the proposed HFE, Reclamation and Western have coordinated to ensure that the maximum possible release from the dam can 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 ~37,500 cfs is achievable. Each month the generating units are tested to determine their specific capacity. These capacities change based on the changing elevation of the reservoir.

The best case maximum estimate for total release from Glen Canyon Dam for a HFE in November 2014 is 39,500 cfs (24,500 cfs through the powerplant and 15,000 cfs of bypass). This estimate is based on the most recent unit testing completed in September 2014 and a

maintenance assumption that seven of the eight units at Glen Canyon Powerplant will be available November 8-18, 2013. Total releases through the powerplant (with each unit at 100% gate opening) could be as high as approximately 25,600 cfs, however a raised tailwater elevation during an HFE will decrease unit efficiencies. In addition, 40MW (approximately 1,100 cfs) of system regulation will be maintained at Glen Canyon. Therefore, the estimated maximum flow through the powerplant is approximately 24,500 cfs. The bypass tubes provide an additional 15,000 cfs release resulting in a best case maximum estimated possible release of 39,500 cfs. Given the variability in efficiency, Reclamation used the lower estimate of 37,500 cfs for modeling purposes and as a target for a potential HFE due to increased certainty of achieving this release. This corresponds to approximately 90% gate opening for the available seven units.

Western completed an analysis of the potential financial costs to Western as a result of running the fall 2014 HFE. Western estimates that the HFE described in this document will have a financial impact on firm power customers of about $1.749 million due to additional power purchases to replace generation due to implementation of the HFE. The Technical Team was able to schedule the HFE to start on Monday, November 10, which resulted in better conditions for Western to market hydropower generated by the HFE and resulted in an anticipated cost savings of $200,000.

The release volume required in November for the proposed HFE is approximately 770,000 acre feet. The October 24-Month Study projected 600,000 acre feet release volume in November, therefore it is 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 proposed HFE. Western and Reclamation will 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. The most probable annual release for water year 2015 under the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead (2007 Interim Guidelines, Bureau of Reclamation 2007a and 2007b) is projected to be 9.0 maf, with all months projected to be above these thresholds regardless of the HFE release. If inflows in water year 2015 are very low, the annual release could be as low as 8.23 maf, in which case some monthly volumes could be below the MLFF monthly thresholds. Hourly releases for the days prior to and after the proposed HFE in November are anticipated to fluctuate between 6,500 to 9,000 cfs.

Releases from Glen Canyon Dam in November may fluctuate beyond the scheduled releases due to system regulation and/or reserve requirements. Throughout the entire month of November, Glen Canyon Dam will maintain 40MW of system regulation. These instantaneous release adjustments stabilize the electrical generation and transmission system and 40MW translates to a range of approximately 1,100 cfs above or below the hourly scheduled release rate. For the days prior to and after the proposed HFE, Glen Canyon Dam will also maintain 27MW of reserves. To provide system reliability, all participating electricity generators within the balancing area maintain a specified level of generation capacity (i.e. reserves) that can be called upon when an unscheduled outage occurs. If reserves are called upon at Glen Canyon Dam, releases may increase by up to an additional approximately 700 cfs. Maintaining regulation and reserves is

necessary to comply with federal regulations concerning the electric grid and for safe operation of the hydropower facility.

Reclamation thoroughly evaluated the effect of conducting a fall 2014 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 2015 will be 9.0 million acre feet under all probable hydrology inflow scenarios. An HFE in November will 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. On October 7, 2014, in accordance with the HFE FONSI, representatives from Reclamation met with representatives from the Basin States to review information relevant to the 2007 Interim Guidelines in consideration of a decision to conduct a fall 2014 HFE. Reclamation also presented additional information about the HFE (e.g., modeling information, resource assessments) to the Basin States.

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. Reclamation is working 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 the proposed HFE are within the range experienced by recreational users in the past, and Reclamation and NPS have been working together to ensure that safety measures are implemented, including restricting access to the river immediately below the dam during the HFE, and as noted below, providing public notice about the timing of the HFE implementation. NPS Boating Safety Rules will continue to apply to all boaters.

The primary concessionaire on the Glen Canyon reach, Colorado River Discovery (CRD), cannot operate its pontoon fleet during HFEs which utilize the bypass tubes. NPS has notified CRD that the HFE may occur and has updated the company on a weekly basis as new information is received. If the Leadership Team decides to conduct a fall 2014 HFE, CRD will move boats and associated infrastructure out of the river at the Lees Ferry launch ramp using a hydraulic system to other locations to avoid damage, and will make alternate arrangements for their customers during the HFE. Revenue losses for a six-day HFE in November were estimated at $14,000 to $16,000 in lost concession revenue, $600 in lost NPS amenities revenues, and $1,620 in lost NPS

concession franchise fee. Direct expenses associated with the removal of the concession assets from the river per HFE were estimated at $9,961 in payroll and fuel costs. CRD's license agreement with NPS and Reclamation acknowledges the potential for operations that can disrupt business. For the 2014 HFE, the projected largest volume day for business in this period according to CRD, Saturday November 8, will not be affected by the HFE.

Reclamation and NPS have been coordinating to ensure that safety and security issues have been addressed. Each of the three park service units affected, Glen Canyon National Recreation Area (GCNRA), Grand Canyon National Park (GCNP) and Lake Mead National Recreation Area have worked together to collaboratively plan necessary actions for the HFE. Each park unit will be affected uniquely and for different periods of time. The focus is on maximizing continuity of efforts and resources, particularly in those areas where responsibilities are shared, specifically Lees Ferry and Pearce Ferry. Each park has clearly designated responsible parties and staffing needs and actions that need to occur prior to and during an HFE. The parks have also considered communications plans, medical plans and resource capabilities for search and rescue responses. The three park units will maintain frequent communication and information sharing leading up to and during the HFE.

GCNP will identify and 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. A plan has been developed to provide alternative trip dates should the permitted river trip decide not to launch during the projected HFE. All permit holders have been directed to access up-to-date information provided by Reclamation, NPS, and the USGS/GCMRC websites. Additionally, all backcountry hikers who access the Colorado River as part of their backcountry hike will be alerted to potential campsite inundation areas.

GCNRA has identified and will 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. During past HFEs, relatively few recreational boaters traveled upstream from Lees Ferry. Information about the pending HFE and safety considerations will be provided to recreational users at Lees Ferry in coordination with the Technical Team Communications group. Information will also be provided via public media, the GCNRA web site and on-site NPS staff. A fact sheet explaining potential impacts to park visitors will be developed and distributed to potentially affected visitors. Notifications will be provided at Lees Ferry and Phantom Ranch and the fact sheet will be available at these locations, as well as the GCNP Backcountry Information Center and primary visitor center.

In addition, safety considerations regarding sampling efforts by GCMRC have been incorporated into planning to ensure that safety of field staff is an overarching priority. There is a lag between the time that water is released from the dam and the time that water arrives at a particular downstream location (often referred to as "travel time"). USGS crews will have been deployed to locations in the days before the high flow release and will be supported by motorized rafts, and boats and cableways. They will be making critical measurements of discharge, suspended sediment transport, and organic drift. At sites downstream from the Paria River (RM 1), work can only be safely conducted during daylight hours. This is especially the case on the first day of the HFE when the water surface typically is covered with woody debris that potentially can clog

props of outboard engines or snag equipment suspended from cableways. Likewise, large logs that float just below the water surface, can pose a threat to the safety of sampling staff. To address these issues, all field measurements by USGS personnel will be done during daylight hours in order to maximize the safety of field personnel.

## V. COMMUNICATIONS PLAN

The third HFE conducted pursuant to the High Flow Protocol presents an excellent opportunity to increase scientific understanding for the general public and to explain to the public the purpose of the HFE Protocol and expected beneficial impacts. The communications/public affairs aspect of the 2014 HFE will not include a public/media event at Glen Canyon Dam, but will include communications product development and media coordination.

Reclamation's Upper Colorado Region Public Affairs Office in primary coordination with National Park Service and U.S. Geological Survey public affairs contacts and DOI is leading development of communications product development. Several communication products are being developed including a news release and a web page for the 2014 HFE. If the decision is made to proceed with the HFE, and a public event is planned for the HFE, materials will be distributed and social media channels including Facebook and Twitter will be used to alert the media and public to the event and these information items. NPS, FWS, USGS and BIA public affairs contacts are currently working with Reclamation to develop these products.

If the Leadership Team decides to conduct a fall 2014 HFE, a press release will be sent to the media list via e-mail. A final news release would be expected to be issued by the Secretary's office.

## 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. If the Leadership Team decides to conduct a fall 2014 HFE, the Technical Team will coordinate to report initial findings at the 2015 Glen Canyon Dam Adaptive Management Program (GCDAMP) Annual Reporting Meeting on January 27-28, 2015 in Phoenix.

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 will address in 2015 if a 2014 HFE takes place. The first is 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, is 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 will combine these two commitments, and, if a fall 2014 HFE occurs, will conduct a workshop in 2015 with GCDAMP stakeholders to evaluate the results of the first three HFEs, and will complete the a written report of the HFE Protocol findings and 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 2014 is not being implemented as 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 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 2015.

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 2014 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 23 and October 10, 2014. This assessment of the size and distribution of HFE deposits approximately 11 months following the 2013 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 2013 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, 2014 meeting. On October 7, 2014, DOI, Reclamation and GCMRC staff met with the Colorado River Basin states and presented much of the information in this report. Reclamation also conducted a webinar with the Technical Work Group (TWG) on October 17, 2014 to present this information to, and get input from, the TWG. On October 9, 2014, the required 30-day advance notification was given to the MOA signatories, including the tribes, of the potential for an HFE in November 2014.

## VIII. CONCLUSION

Preparing to conduct an HFE required coordination of many details and effective communication amongst agency technical staff. The Team members relied heavily on multiple 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 proceed with implementation of the HFE is based on the careful research developed over the last 15 years, the specific information developed relevant to implementation of an HFE in November 2014 as described in this report, and the inclusion of monitoring of the HFE to ensure continued learning and adaptation. 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.

**References Cited**

Bureau of Reclamation. 2007a. Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead, Final Environmental Impact Statement. Bureau of Reclamation, Upper and Lower Colorado Regions. http://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html

Bureau of Reclamation. 2007b. Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead, Record of Decision. Bureau of Reclamation, Upper and Lower Colorado Regions. http://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf

Bureau of Reclamation. 2011. The Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020 Environmental Assessment. Bureau of Reclamation, Upper Colorado Region. http://www.usbr.gov/uc/envdocs/ea/gc/HFEProtocol/index.html.

Bureau of Reclamation. 2012a. Finding of No Significant Impact for the Environmental Assessment for Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona through 2020. Bureau of Reclamation, Upper Colorado Region. http://www.usbr.gov/uc/envdocs/ea/gc/HFEProtocol/FINAL-FONSI.pdf.

Bureau of Reclamation. 2012b. High Flow Protocol Memorandum of Agreement. Bureau of Reclamation, Upper Colorado Region. http://www.usbr.gov/uc/envdocs/ea/gc/HFEProtocol/FINAL-FONSI.pdf.

Bureau of Reclamation and U.S. Geological Survey Grand Canyon Monitoring and Research Center. 2014. Glen Canyon Dam Adaptive Management Program Triennial Budget and Work Plan—Fiscal Years 2015–2017. Prepared by Bureau of Reclamation Upper Colorado Regional Office Salt Lake City, Utah and U.S. Geological Survey Southwest Biological Science Center Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Approved by the Secretary of the Interior September 29, 2014.

Cross, W.F., Baxter, C.V., Donner, K.C., Rosi-Marshall, E.J., Kennedy, T.A., Hall, R.O. Jr., Wellard Kelly, H.A. and R.S. Rogers. 2011. Ecosystem ecology meets adaptive management: food web response to a controlled flood on the Colorado River, Glen Canyon. Ecological Applications 21(6): 2016–33.

Culver, M., Herrmann, H.W., Miller, M., Roth, B. and J. Sorenson. 2013. Anatomical and genetic variation of western Oxyloma (Pulmonata: Succineidae) concerning the endangered Kanab ambersnail (Oxyloma haydeni kanabense) in Arizona and Utah. USGS Scientific Investigations Report 2013–5164. http://pubs.usgs.gov/sir/2013/5164/,

Kennedy, T.A. and B.E. Ralston. 2011. Biological responses to high-flow experiments at Glen Canyon Dam. Pages 93-125 *in* Melis, T.S. (ed.). Effects of three high-flow experiments on the

Colorado River ecosystem downstream from Glen Canyon Dam, Arizona. U.S. Geological Survey Circular 1366, 147 p.

Melis, T.S., ed. 2011. Effects of three high-flow experiments on the Colorado River ecosystem downstream from Glen Canyon Dam, Arizona. U.S. Geological Survey Circular 1366, 147 p. https://www.usbr.gov/uc/rm/amp/twg/mtgs/11jan20/Attach_03b.pdf.

Schmidt, J.C., and P.E. Grams. 2011. The high flows – physical science results. Pages 53-92 *in* Melis, T.S. (ed.). Effects of three high-flow experiments on the Colorado River ecosystem downstream from Glen Canyon Dam, Arizona. U.S. Geological Survey Circular 1366, 147 p.

U.S. Fish and Wildlife Service. 2011. Final Biological Opinion on the Operation of Glen Canyon Dam including High Flow Experiments and Non-Native Fish Control. http://www.usbr.gov/uc/envdocs/ea/gc/HFEProtocol/Appdx-H.pdf.

Wright, S.A. and T.A. Kennedy. 2011. Science-Based Strategies for Future High-Flow Experiments at Glen Canyon Dam. Pages 127-147 *in* Melis, T.S. (ed.). Effects of three high-flow experiments on the Colorado River ecosystem downstream from Glen Canyon Dam, Arizona. U.S. Geological Survey Circular 1366, 147 p.

RECLAMATION

*Managing Water in the West*

# Glen Canyon Dam Fall 2014 HFE Recommendation

Glen Knowles
Bureau of Reclamation

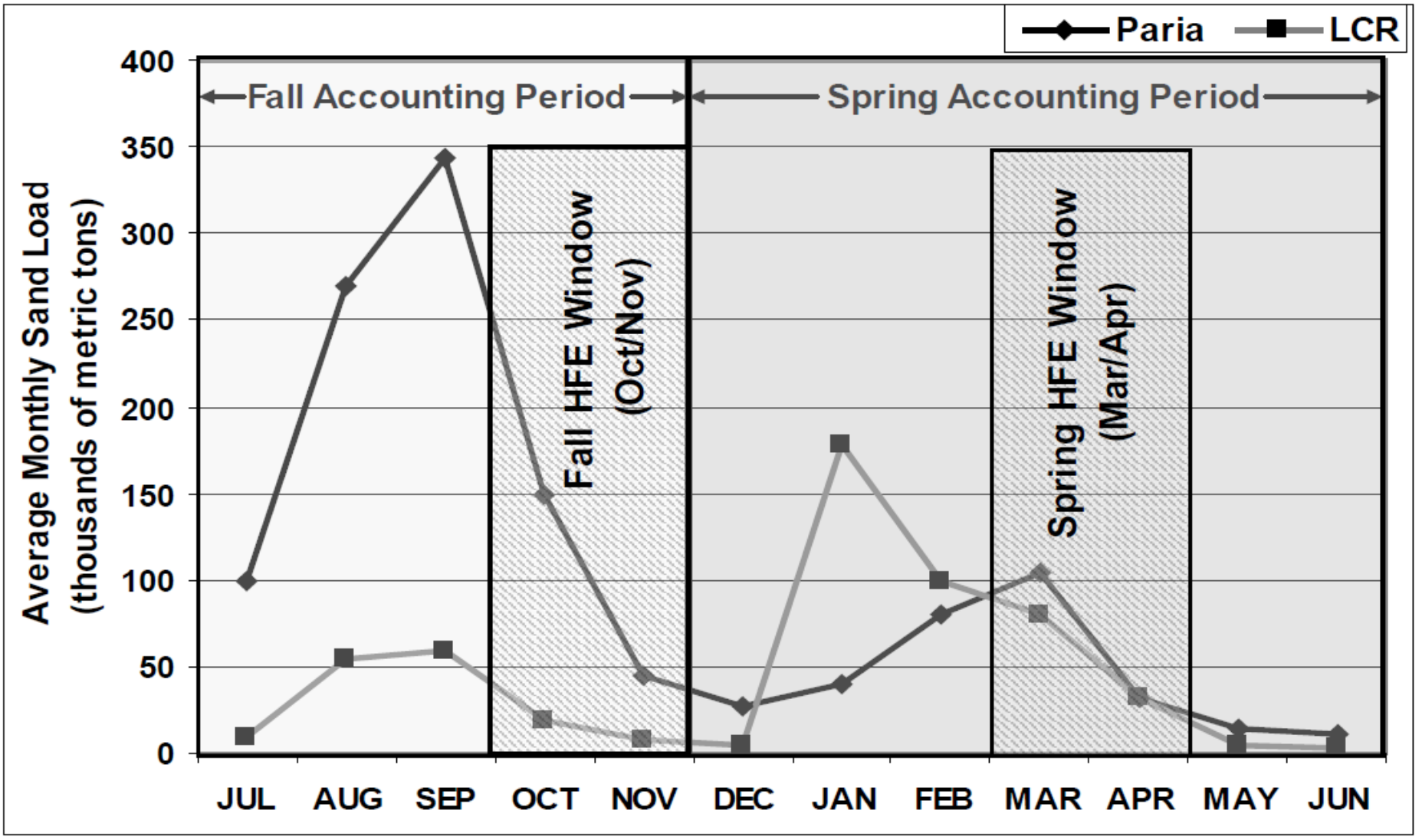
DOI Glen Canyon
Leadership Team
October 23, 2014

U.S. Department of the Interior
Bureau of Reclamation

# HFE Decision Making Process

1. Planning and Budgeting Component
   - Annual resource status assessment
     - Annual Agency Reporting
     - GCDAMP Budget and Work Plan Process
2. Modeling Component
3. Decision and Implementation Component
   - Review Modeling Component
   - Review Status of Resources
   - Consultation with agencies and tribes, AMWG and TWG input
   - Staff Recommendation/DOI GCD Leadership Team Recommendation

# Modeling Component






RECLAMATION

# HFE Protocol Parameters

**Possible Timing**

- **March-April and October-November through 2020**
- **Spring HFEs will not be considered until 2015**

**Duration range**

- **1 hr – 96 hrs (at full magnitude)**
- **1 ½ days – 6 ½ days (including ramping)**

**Magnitude range**

- **31,500 cfs – 45,000 cfs (depends on maintenance)**
- **2014 projected available release for November is 37,500 cfs (7 of 8 units available)**

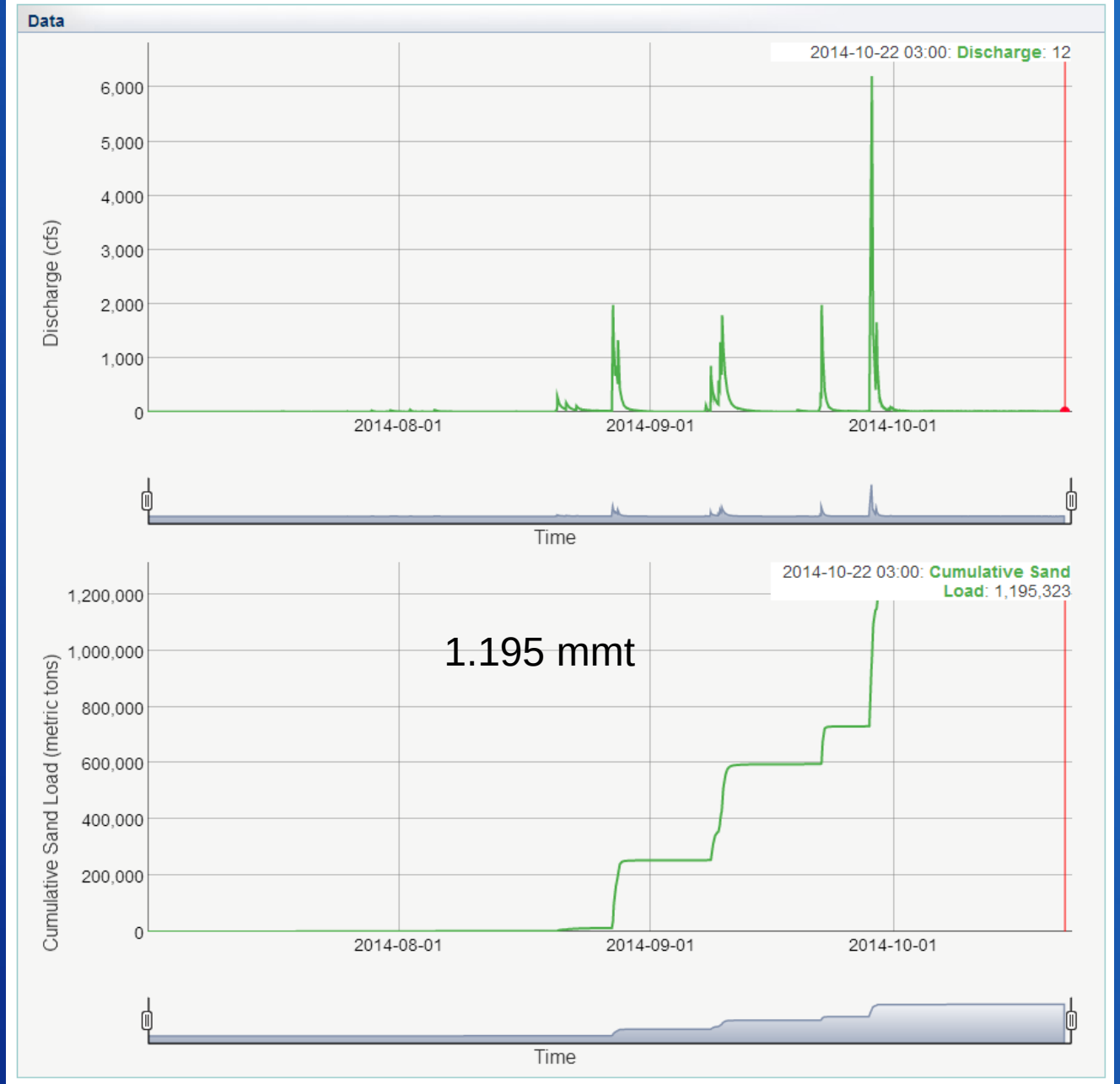
**Ramping rates**

- **Ramping rates are defined by 1996 ROD and 1997 Glen Canyon Dam Operating Criteria (62 FR 9447, 4,000 cfs up and 1,500 cfs down)**

Current conditions from the GCMRC web page as of Oct. 22

Paria River at Lees Ferry discharge since July 1

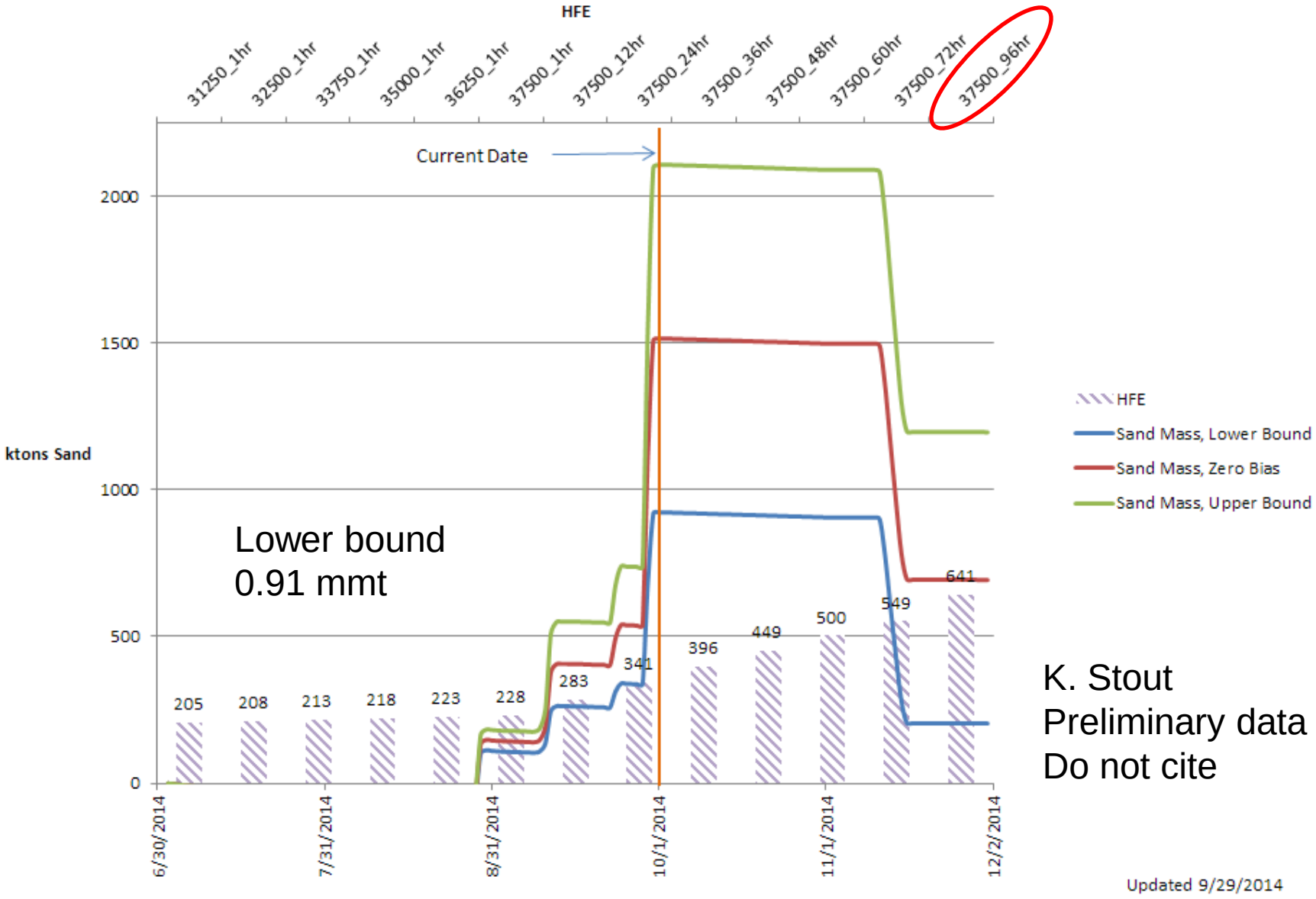
Paria River at Lees Ferry cumulative sand load since July 1






RECLAMATION

# Sand Mass at Marble Canyon vs. 37,500 cfs HFE Load requirements



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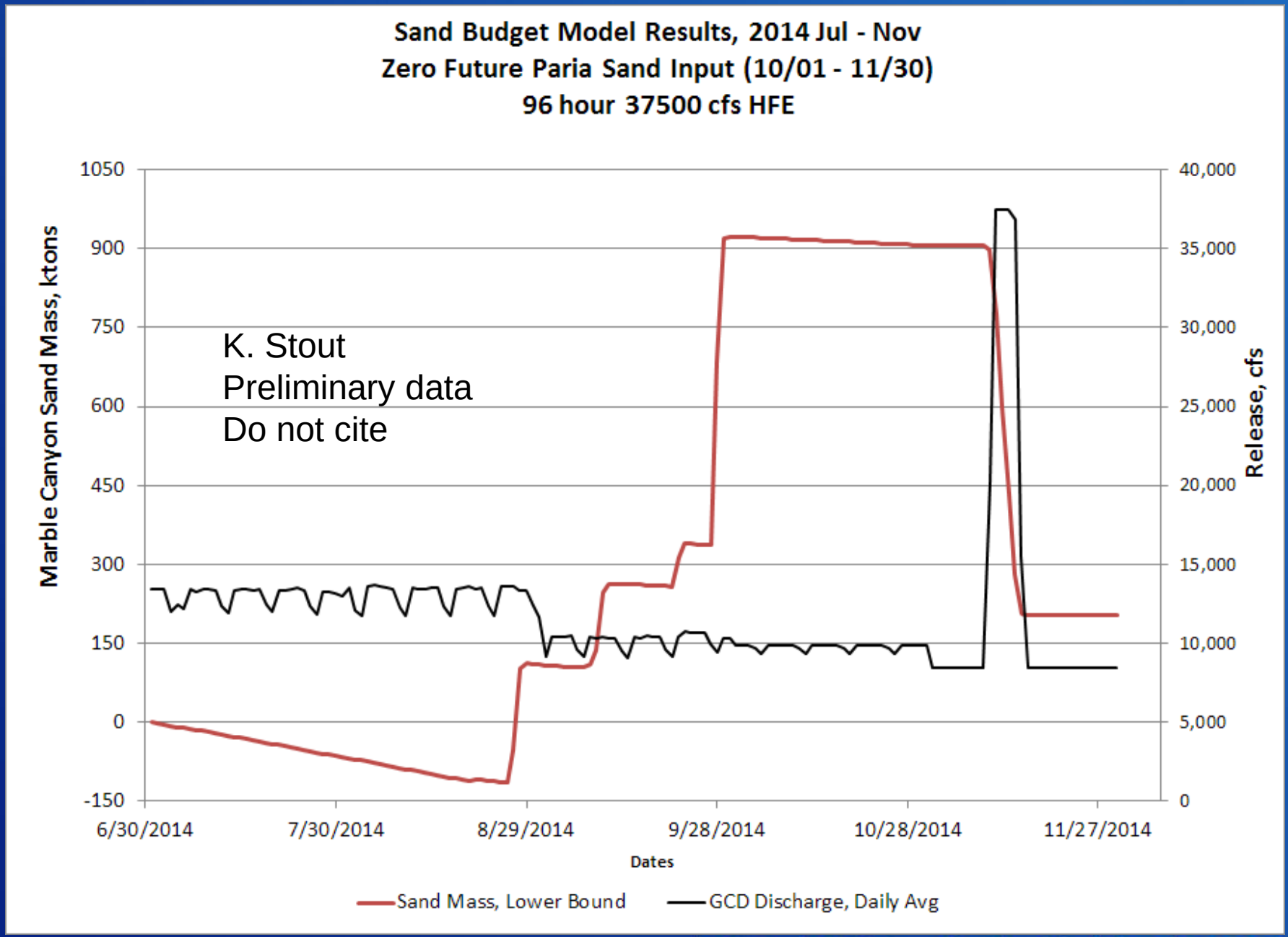
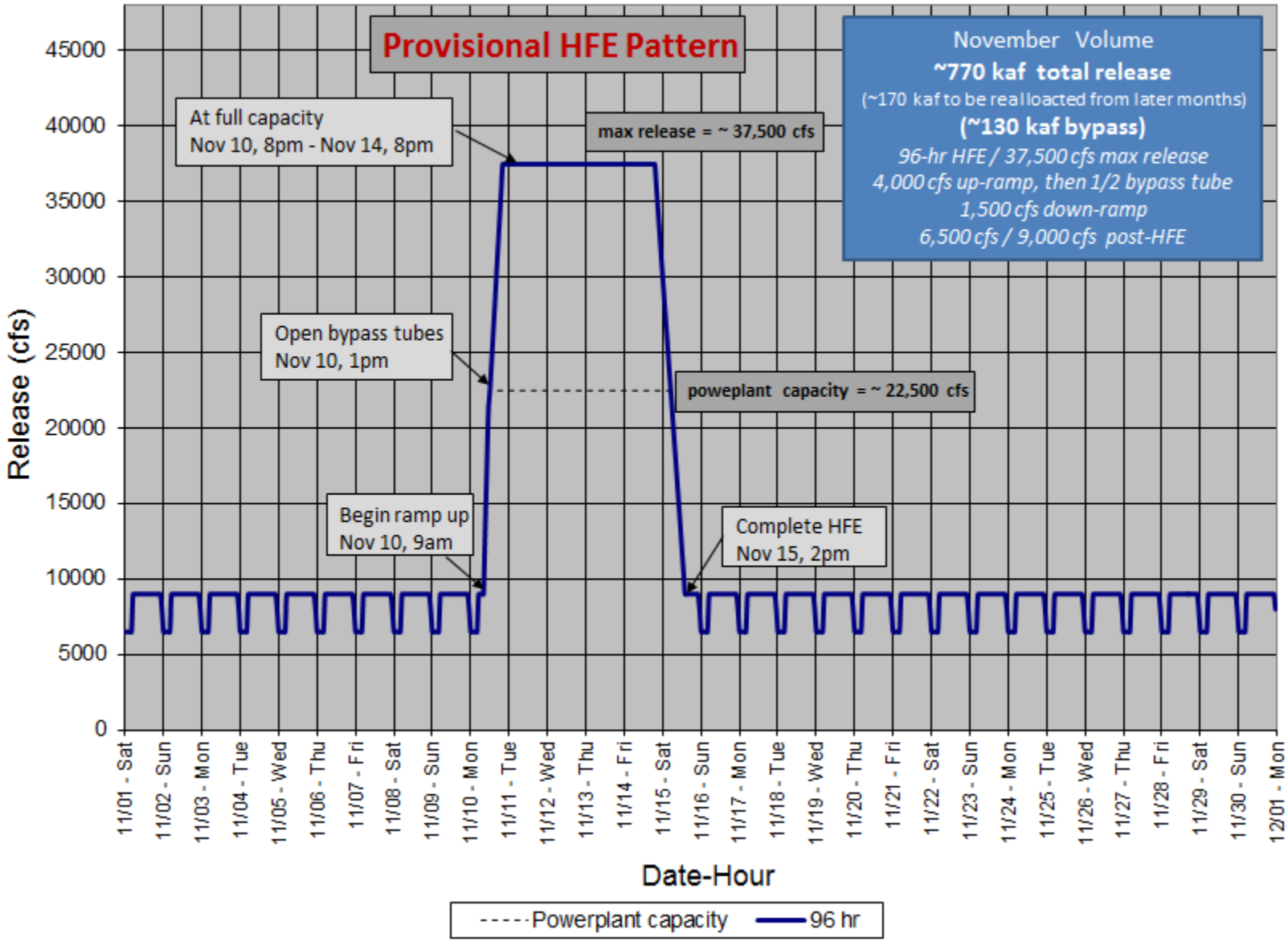





RECLAMATION

# Glen Canyon Dam Possible HFE Release Pattern






RECLAMATION

# Possible Monthly Release Volumes

Water Year 2015

2015 Most Probable (9.0 maf)

| | Typical MLFF Pattern | Possible 9.0 Hydrograph presented at AMWG | *Possible monthly release volumes: reallocated for HFE and 2015 Hydrograph targets, considers maintenance and hydropower scheduling* | | | |
|---|---|---|---|---|---|---|
| | | | **9.0 maf** | **96 hr HFE 9.0 maf** | **8.23 maf** | **96 hr HFE 8.23 maf** |
| October | 600 | 600 | 600 | 600 | 600 | 600 |
| November | 600 | 600 | 600 | 770 | 600 | 770 |
| December | 800 | 900 | 950 | 865 | 950 | 865 |
| January | 800 | 900 | 950 | 865 | 950 | 865 |
| February | 650 | 700 | 600 | 600 | 600 | 600 |
| March | 650 | 650 | 650 | 650 | 600 | 600 |
| April | 600 | 600 | 600 | 600 | 565 | 565 |
| May | 650 | 700 | 700 | 700 | 565 | 565 |
| June | 800 | **800** | 800 | 800 | 600 | 600 |
| July | 1000 | 1050 | 1050 | 1050 | 800 | 800 |
| August | 1050 | 800 | 800 | 800 | 800 | 800 |
| September | 800 | 700 | 700 | 700 | 600 | 600 |
| | 9000 | 9000 | 9000 | 9000 | 8230 | 8230 |

Monthly release patterns are provisional and subject to change.

# Resource Status Assessment

*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

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

# Cultural Resources

- HFE-caused erosion is a consideration, most sites already mitigated.
- The HFE MOA requires reporting and consultation after HFEs
- No impacts to sites were identified from the 2012 HFE, no reports of issues with access to sites
- The MOA for the HFE Protocol requires notification to all the consulting parties at least 30 days in advance of a HFE and will consult with tribes to resolve any issues
- A 30-day notification letter notifying MOA signatories of a possible HFE in November

Reclamation met with MOA signatories Feb. 12, 2014 to review effects of 2013 HFE and found none

30-day letter sent Oct. 9, 2014

# Hydropower/Socioeconomic Impacts

- HFEs impact hydropower production:
  - Water released during an HFE counts against the annual release and is not available to be programmed in peaking releases during high demand months (HFE windows of Mar/Apr and Oct/Nov are low-demand shoulder months).
  - 30-40% of HFE releases bypass the power plant.
  - Lake Powell is lowered, reducing hydrologic head.

**Western Area Power Administration estimates annual hydropower impacts of $1.749 M from Fall 2014 HFE**

**Savings of $200k by starting on Nov. 10**

# RM 22 R – Returned to pre-HFE size by February (about same response as 2012)




# RM 51 L – Still larger in May 2014 (not a “gainer” for 2012 HFE)




# Sandbar Response to 2013 HFE based on Analysis of Images from Remote Cameras

- **Response immediately after 2013 HFE**
  - **Substantial Gain (deposition): 21 sandbars (50% of sites)**
  - **No substantial change: 16 sandbars (38% of sites)**
  - **Substantial Loss (erosion): 5 sandbars (12% of sites)**
- **2013 HFE compared to 2012 HFE**
  - **Sandbar larger after 2013 HFE: 9 sandbars (27% of sites)**
  - **Sandbar larger after 2012 HFE : 2 sandbars (6% of sites)**
  - **About the same: 22 sandbars (67% of sites)**

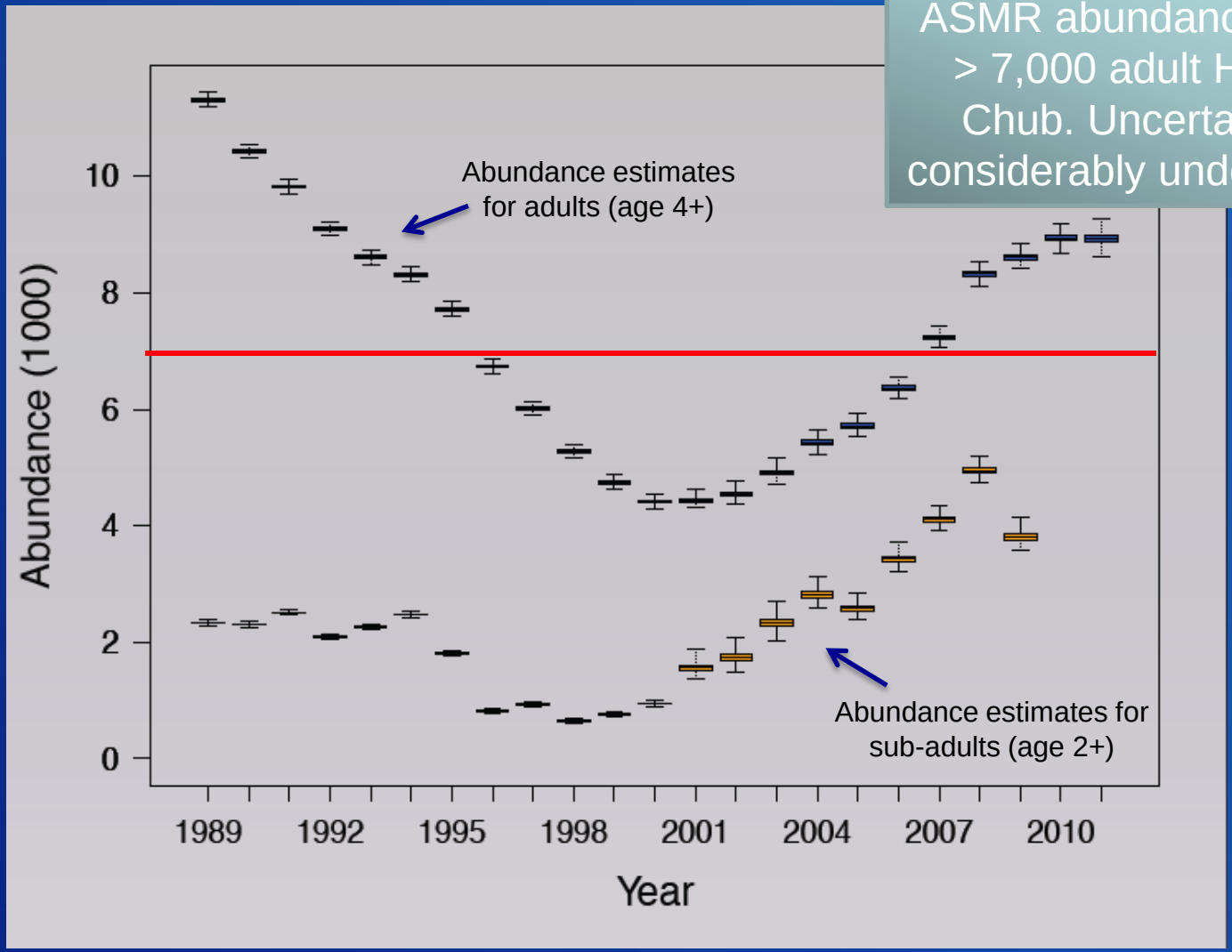
*Response to 2013 HFE similar to previous HFEs: substantial deposition followed by erosion of about half the new deposits with 6 months*

*Preliminary data*

USGS
RECLAMATION

# Adult and Sub-Adult Humpback Chub Abundance Estimates

ASMR abundance estimate: > 7,000 adult Humpback Chub. Uncertainty likely considerably underestimated.



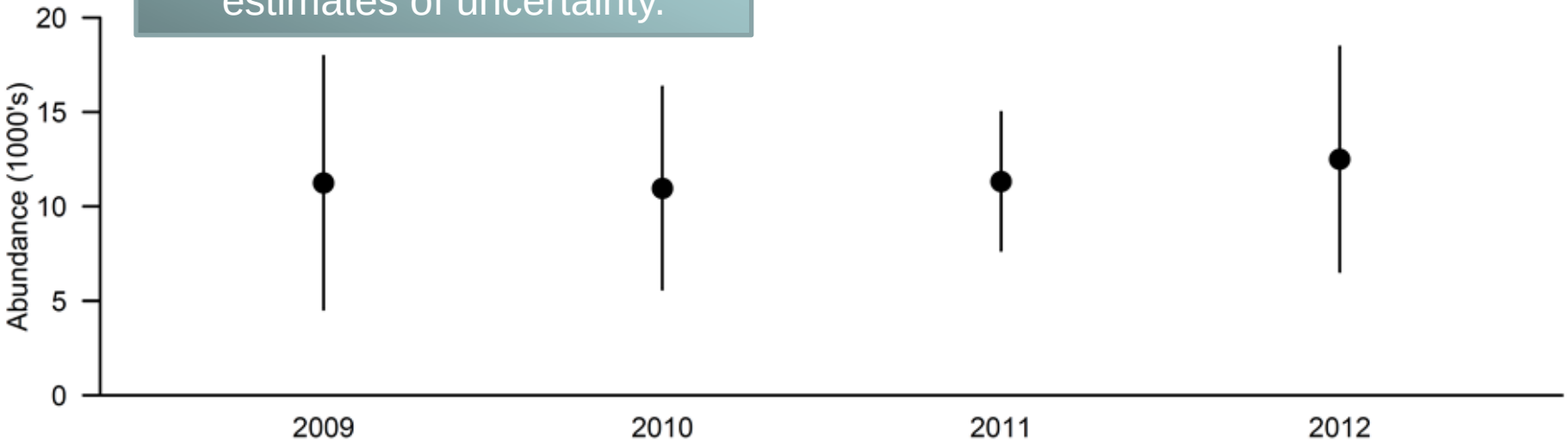

(S. Martell, preliminary data, do not cite)



USGS RECLAMATION

# Adult Humpback Chub Abundance Estimates: Multistate Population Model

Suggests adult Humpback Chub abundance stable from 2009 – 2012. Confidence intervals provide reasonable estimates of uncertainty.




(Yackulic et al. 2014)

USGS
RECLAMATION

# Annual spring abundances of humpback chub ≥ 150 mm and ≥ 200 mm in lower 13.6 km of LCR

2014 spring estimates indicate Humpback Chub abundance stable in the LCR

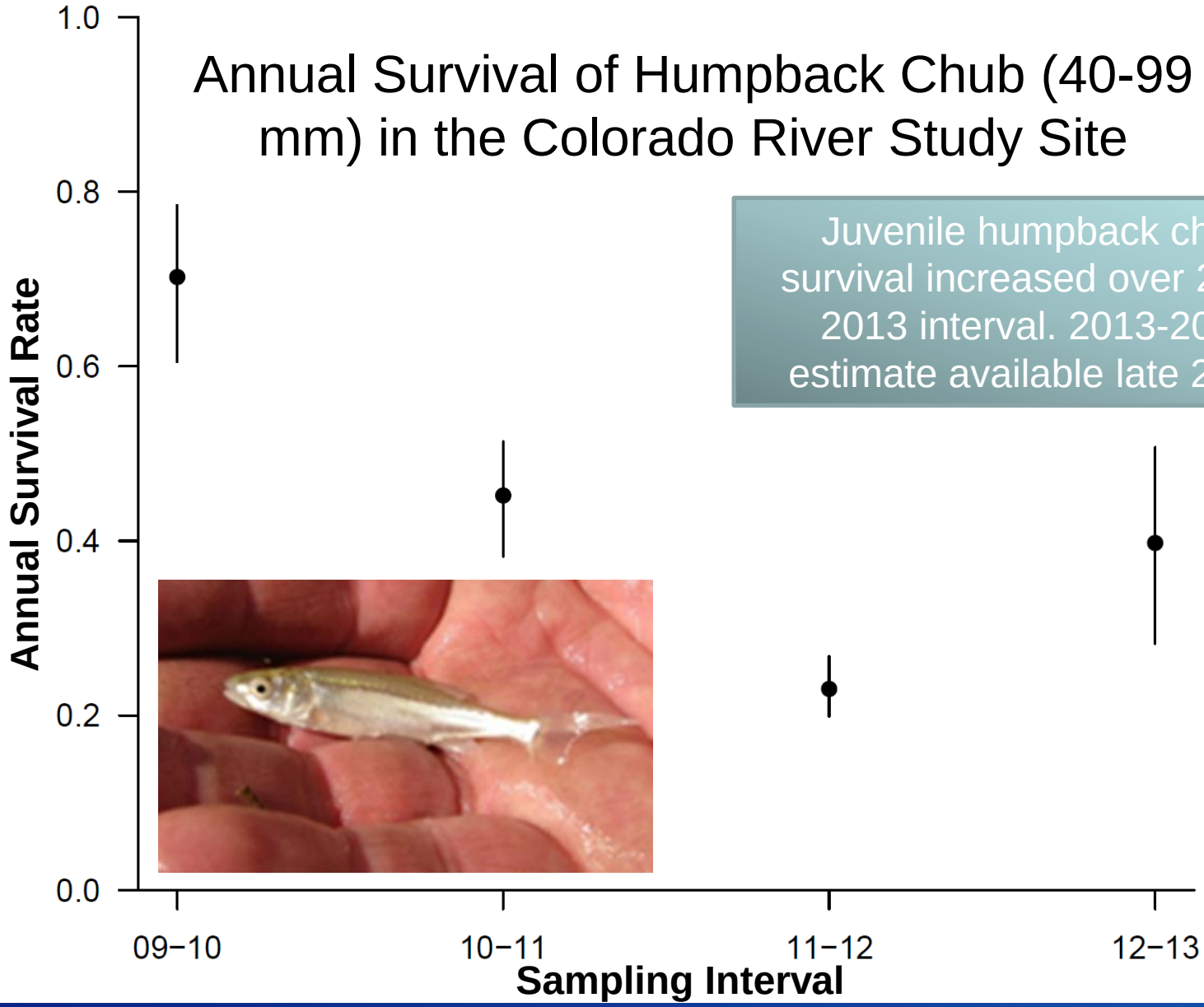



(Preliminary data from VanHaverbeke et al. 2014, Do Not Cite)



USGS RECLAMATION

# Annual Survival of Humpback Chub (40-99 mm) in the Colorado River Study Site




Juvenile humpback chub survival increased over 2012-2013 interval. 2013-2014 estimate available late 2014.

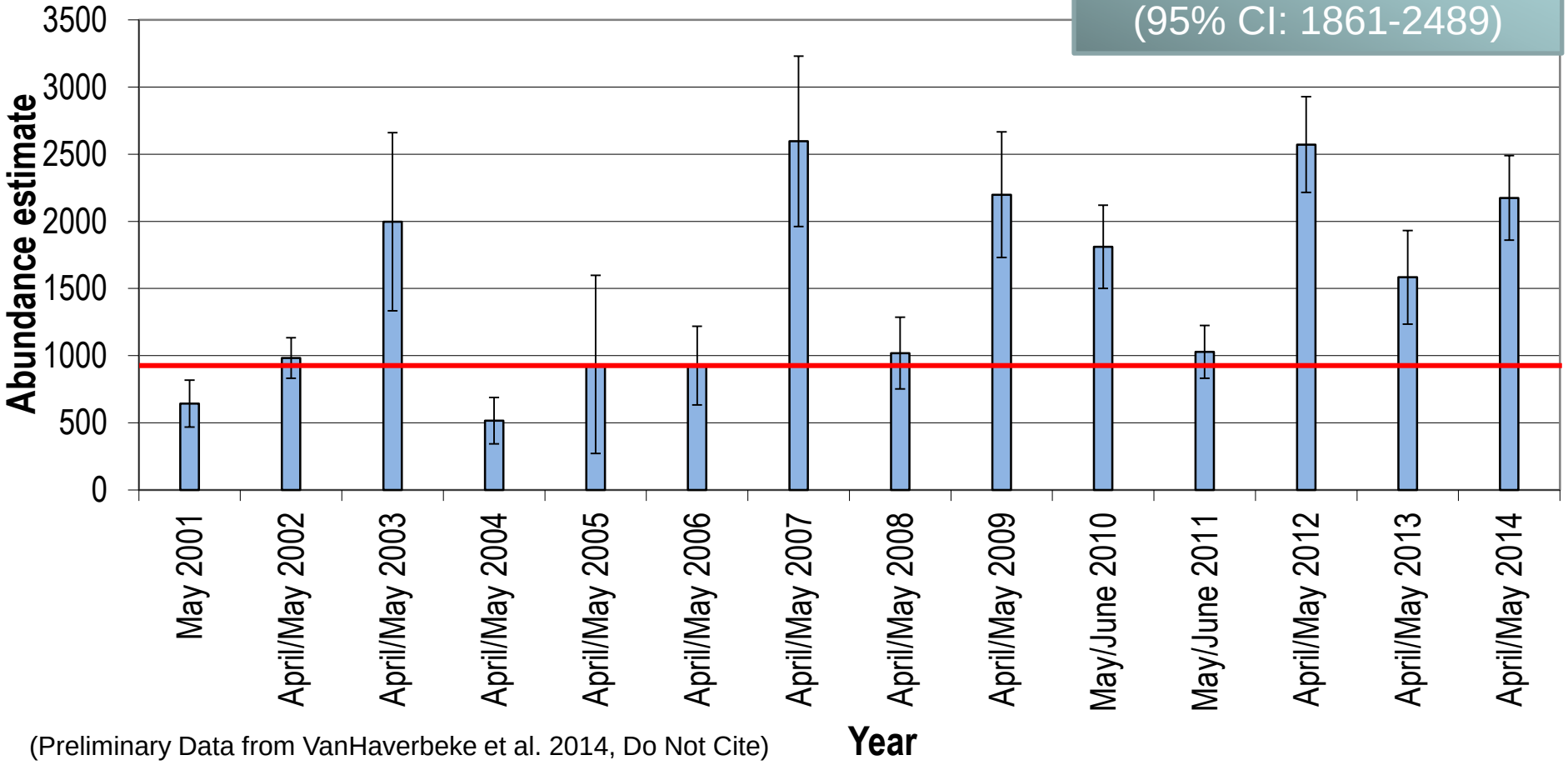


(Preliminary Data from Yackulic 2014. Do Not Cite.)

USGS RECLAMATION

# Spring LCR 150-199 mm humpback chub abundance estimates

2014 spring abundance estimate of 150-199 mm HBC = 2175
(95% CI: 1861-2489)



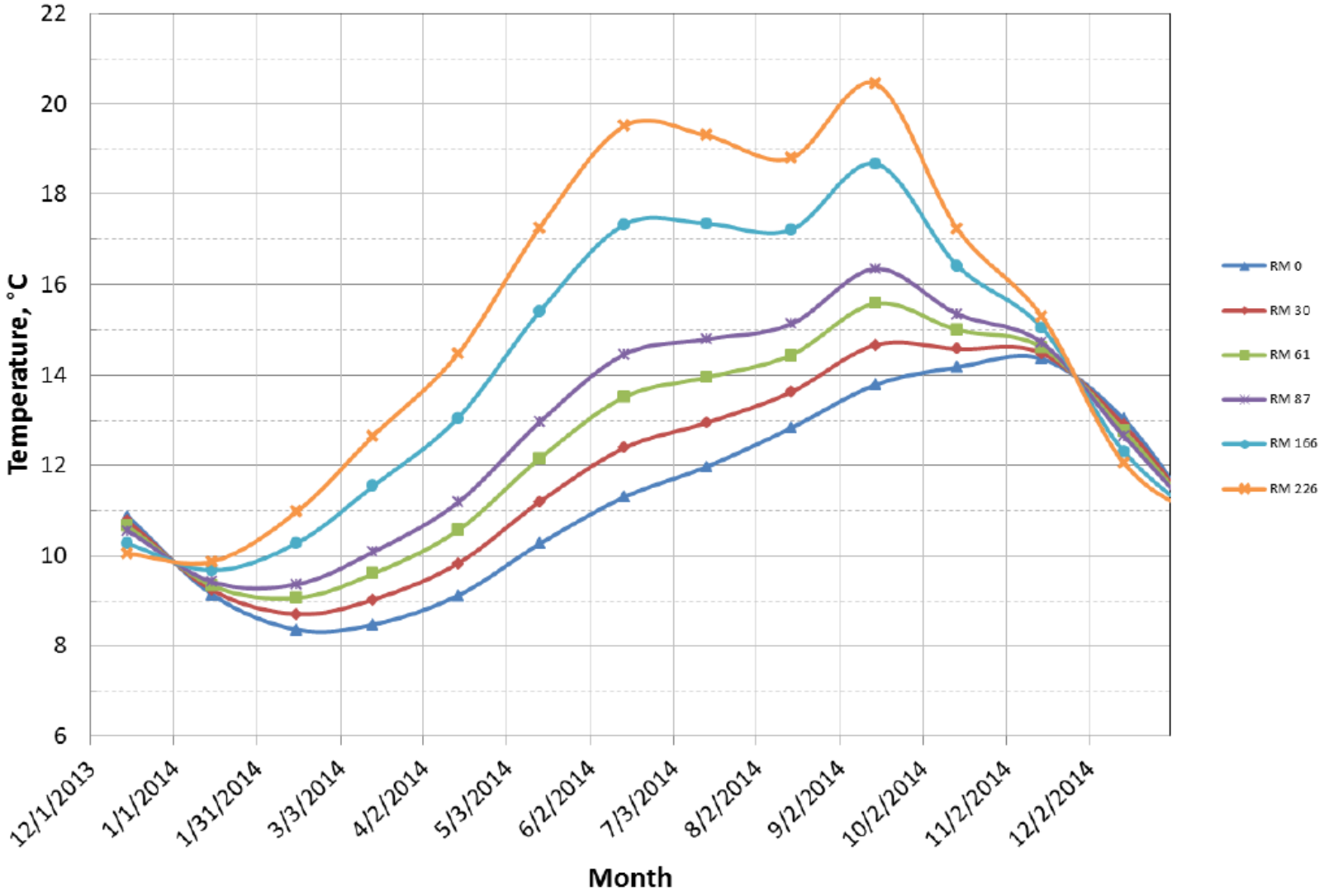

(Preliminary Data from VanHaverbeke et al. 2014, Do Not Cite)



USGS RECLAMATION

# Colorado River, Grand Canyon Water Temperatures

## Projections based on September 2014, Most Probable Hydrology

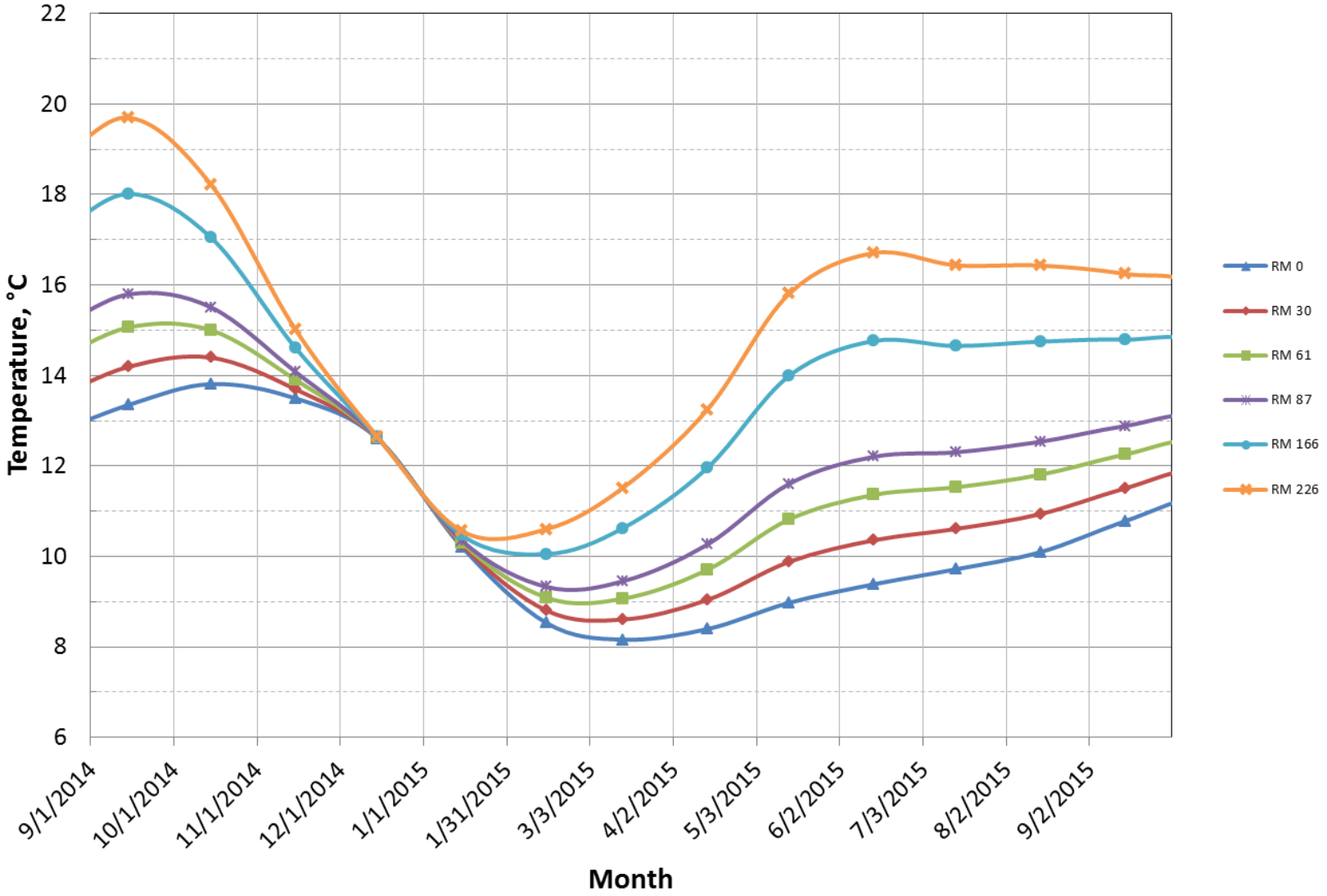





RECLAMATION

# Colorado River, Grand Canyon Water Temperatures

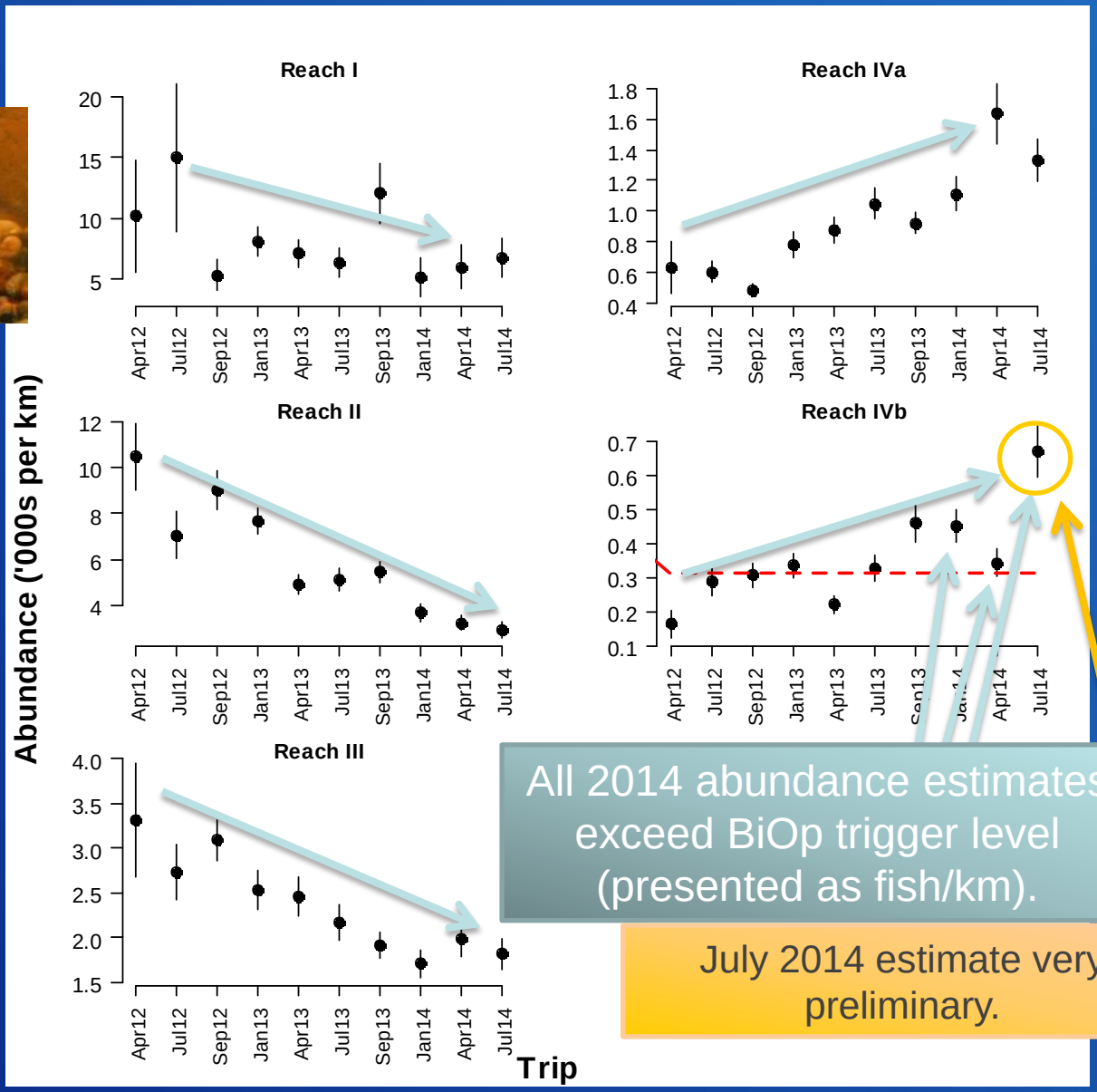
## Projections based on October 2014, Most Probable Hydrology






RECLAMATION

# Rainbow Trout Abundance By Reach




**I – Glen Canyon/Lees Ferry**

**II – House Rock**

**III – Buck Farm**

**IVa – Upstream of LCR**

**IVb – Downstream of LCR**

USGS

All 2014 abundance estimates exceed BiOp trigger level (presented as fish/km).

July 2014 estimate very preliminary.



(Preliminary Data from Korman and Yard 2014. Do Not Cite.)

RECLAMATION

# 2011 USFWS Biological Opinion Non-native Fish Control Trigger

- Adult humpback chub <7000 fish? **No**
- OR
- ALL THREE? **No**
  - 3 of 5 years 150-199 mm humpback chub in the LCR drops below 910? **No**
  - Temperature <12° C for 2 consecutive years at LCR? **No**
  - Annual survival of 40-99 mm humpback chub in JCM drops 25% from preceding year? **TBD**

# 2011 USFWS Biological Opinion Non-native Fish Control Trigger

- **AND**
- **Rainbow trout abundance over 760?**

**Yes**

Open model estimates exceed threshold for all trips to date in 2014
(Korman and Yard, preliminary data)

- **AND**
- **Brown trout abundance over 50?**

**Unknown**

2014 catches lower than in 2013, only 7 total caught in Jul. 2014 – catches too low to generate abundance estimate
(Yard and Korman, preliminary data)

# 2014 HFE Summary and Next Steps

1. Resource conditions support a 2014 HFE
2. HFE Tech Team recommends a fall HFE, 37,500 cfs for 96 hours Nov. 10-15, 2014
3. Consultation with Basin States Oct. 7
4. 30-day HFE MOA letter Oct. 9, 2014
5. TWG Webinar Oct. 17
6. DOI Leadership Team memo
7. US Fish and Wildlife Service report in December
8. If an HFE occurs in FY 2014, convene a workshop to review results of first 3 HFEs in 2015