2.0 Description of Alternatives

This section describes the alternatives considered in this EA. A no action alternative is the present operation of Glen Canyon Dam under all approved NEPA compliance processes and ESA consultations. The proposed action alternative is the development and implementation of the proposed protocol for high-flow experimental releases from Glen Canyon Dam.

A no action alternative and a proposed action alternative are evaluated in this EA. There are two major reasons why no additional alternatives were evaluated. First, the preponderance of scientific evidence gained through the 15 years of GCDAMP investigations indicates that the proposed action is most likely to have desired effects in conserving resources and advancing learning. These investigations include advanced modeling of potential methods for sand conservation in sediment-limited rivers that has resulted in peer-reviewed publication in scientific journals (Wright et al. 2008; 2010; Wright and Grams 2010). The results of this modeling were first presented by USGS scientists in a workshop conducted in June 2010 attended by both scientists and resource managers, so it contains perspectives from research and management. A modification of the USGS approach was later provided by one of the cooperating agencies, and it was integrated into the proposed action. Second, no other competing alternatives were put forward by the public during the scoping period of this environmental assessment.

2.1 No Action Alternative

The no action alternative is the continued operation of Glen Canyon Dam in accordance with the 1996 Record of Decision on operation of Glen Canyon Dam (Interior 1996), and the 2007 Record of Decision for Interim Guidelines for Lower Basin Shortages and the Coordinated Reservoir Operations (Interior 2007). In addition, a 5-year program of experimental dam releases is in effect from 2008 through 2012 under an Environmental Assessment and Finding of No Significant Impact (Reclamation 2008) that deviates from the 1996 ROD in two ways: (1) an experimental high-flow test of approximately 41,500 cfs for a maximum duration of 60 hours that occurred on March 4, 2008, and (2) steady flows in September and October of each year, 2008 through 2012. Under the no action alternative, no high-flow experiments would be conducted and resource benefits would not accrue.

The MLFF flow regime was the Secretary of the Interior’s selected alternative of the 1996 ROD because it reduces daily flow fluctuations to protect or enhance downstream resources while allowing limited flexibility for hydropower operations. The 5-year experimental program was implemented in 2008 to further test an HFE for the first time under enhanced sediment conditions and to provide steady flows in the fall to evaluate the ability of such flows to stabilize habitat for juvenile humpback chub.

Elements of the MLFF are summarized in Table 3, and the hydrograph for 2008–2010 is presented in Figure 2, as an illustration of this operation. Dam releases during the 5-year period

(2008–2012) consist of MLFF from January 1 to August 31 and from November 1 to December 31 (except for 60-hour HFE in March 2008). Steady flows, adjusted to available water volume, would be released for all 5 years in September and October through 2012. After October 2012, releases would follow the provisions of MLFF as adopted by the Secretary of the Interior in the 1996 ROD and the 2007 ROD.

The 2008 Opinion on the 5-year experimental program concluded that the implementation of the March 2008 HFE and the 5-year implementation of MLFF with steady releases in September and October was not likely to jeopardize the continued existence of the humpback chub or the Kanab ambersnail, and was not likely to destroy or adversely modify designated critical habitat for the humpback chub (USFWS 2008). The 2008 Opinion was supplemented with a 2009 Supplement (USFWS 2009) that affirmed the 2008 Opinion as a result of a Court Order of May 26, 2009. The Court remanded the incidental take statement back to the Service, and a revised Incidental Take Statement was issued in 2010 (USFWS 2010) with incidental take exceeded if the population of humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon drops below 6,000 adults based on Age-Structured Mark-Recapture (ASMR) (Coggins et al. 2006). The Court upheld the revised incidental take statement on March 30, 2011.

Table 3. Summary of No Action and Modified Low Fluctuating Flow Preferred Alternative Criteria for the 1996 Record of Decision.

Flow Parameter or Element	Unrestricted Fluctuating Flows	Restricted Fluctuating Flows
	No Action	Moderate Low Fluctuating
Minimum releases (cfs)[1]	1,000 Labor Day–Easter 3,000 Easter–Labor Day[2]	8,000 between 7 a.m. and 7 p.m. 5,000 at night
Maximum releases (cfs)[3]	31,500	25,000 (exceeded during habitat maintenance flows)
Allowable daily flow fluctuations (cfs/24 hours)	30,500 Labor Day–Easter 28,500 Easter–Labor Day	5,000; 6,000; or 8,000[4]
Ramp rates (cfs/hour)	Unrestricted	4,000 up; 1,500 down
Common elements		Adaptive management (including long-term monitoring and research) Monitoring and protecting cultural resources Flood frequency reduction measures Beach-habitat building flows New population of humpback chub Further study of selective withdrawal Emergency exception criteria

[1] In high volume release months, the allowable daily change would require higher minimum flows (cfs).
[2] Releases each weekday during recreation season (Easter to Labor Day) would average not less than 8,000 cfs for the period from 8 a.m. to midnight.
[3] Maximums represent normal or routine limits and may necessarily be exceeded during high water years.
[4] Daily fluctuation limit of 5,000 cfs for monthly release volumes less than 600,000 acre-feet; 6,000 cfs for monthly release volumes of 600,000 to 800,000 acre-feet; and 8,000 cfs for monthly volumes over 800,000 acre-feet.

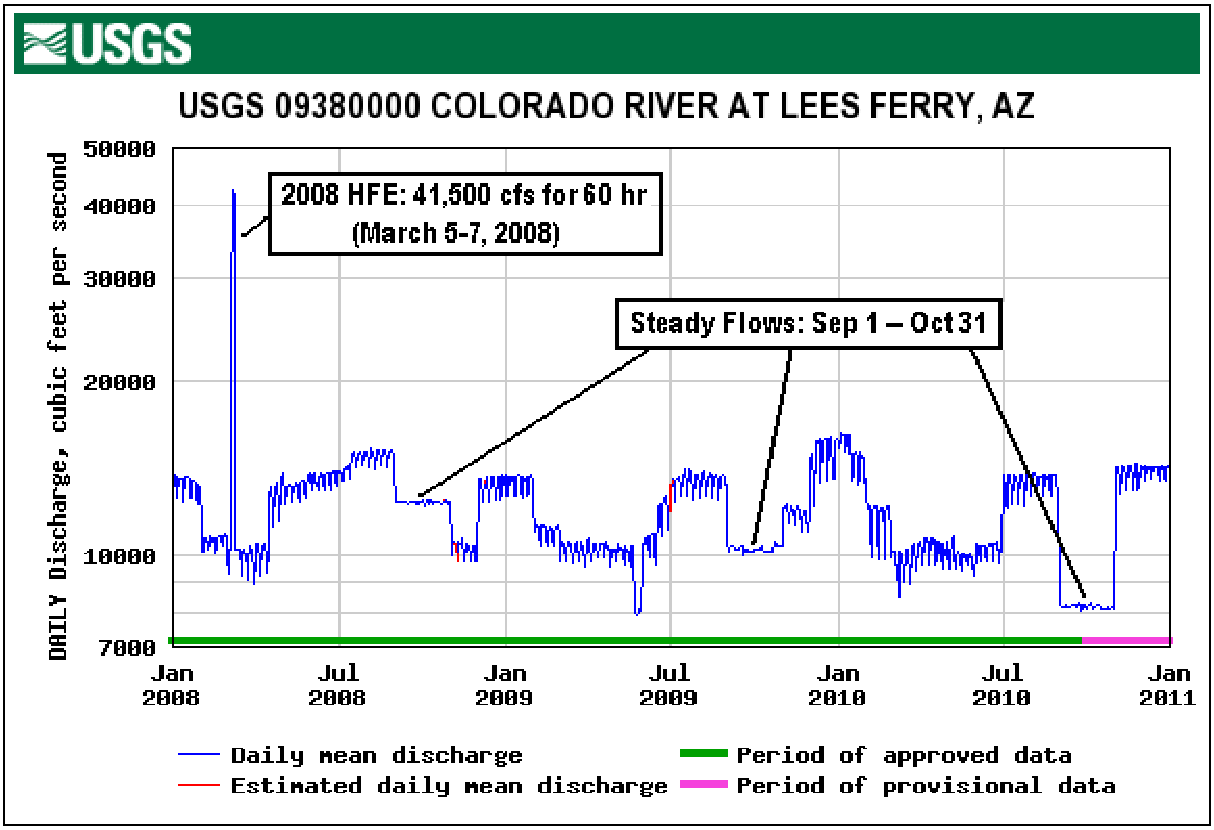


Figure 2. Mean daily discharge of the Colorado River at Lees Ferry from January 1, 2008 to December 31, 2010, showing the 2008 HFE, the September-October steady flows, and the intervening releases under modified low fluctuating flows (MLFF).

2.2 Proposed Action: Protocol for High-Flow Experimental Releases

2.2.1 Overview of HFE Protocol

The proposed action is the continued operation of Glen Canyon Dam in accordance with prior NEPA decisions, with the inclusion of a protocol for high-flow experimental releases from Glen Canyon Dam for the period 2011–2020. The proposed action is intended to meet the need for high-flow experimental releases, but restrict those releases to limited periods of the year when the highest volumes of sediment are most likely available. Water year releases would follow the MLFF preferred alternative as adopted by the Secretary of the Interior in the 1996 ROD with the added refinement of steady flows through 2012 as identified in the 2008 Opinion and the 2009 Supplement and the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead. For the remainder of the proposed action period, through 2020, dam releases would follow the provisions of MLFF as defined in the 1996 ROD and the 2007 ROD, unless changes are required as an outcome of future decisions. The timing of high-flow releases would be March-April or October-November; the magnitude would be from 31,500 cfs to 45,000 cfs. The duration would be from less than one hour to 96 hours. Frequency of HFEs would be determined by tributary sediment inputs, resource conditions, and a decision process carried out by Interior.

Developing this HFE Protocol is important to implement a strategy for high-flow releases over a period of time longer than one year or one event. In the past, Reclamation has done a variety of single-event high-flow experiments and the benefit to sandbar and beach maintenance has been temporary. One purpose for this HFE Protocol is to assess whether multiple, potentially sequential, predictable HFEs conducted under consistent criteria can better conserve sediment resources while not negatively impacting other resources The 10-year experimental window provides opportunities for multiple HFEs to be conducted and analyzed and the protocol to be modified as appropriate. Since necessary sediment and hydrology conditions may not occur every year, the 10-year window assures that multiple events can be conducted. It also allows for the flexibility needed to respond to sediment thresholds as they occur without delays for additional compliance. The HFE Protocol will incorporate annual resource reviews to provide information that will help to ensure that unacceptable impacts do not occur. Interior will conduct a comprehensive review of the protocol after multiple events (at least 3) have occurred.

A protocol in science, by definition, is a formal set of rules and procedures to be followed during a particular research experiment. These experimental HFEs would lead to a better understanding of how to conserve sediment in the Grand Canyon by building on knowledge acquired from previous adaptive management experiments. Sand deposited as sandbars was a primary component of the historic pre-dam Colorado River ecosystem, and determining how sediment conservation can be achieved in areas within GCNP downstream from Glen Canyon Dam is a high priority of the GCDAMP and Interior. Previous HFEs from Glen Canyon Dam were conducted in 1996, 2004, and 2008. Other high-flow releases, at or near powerplant capacity, were conducted in 1997 and 2000. These HFEs provided valuable information and have increased our understanding of responses by physical and biological resources to high-flow releases. For the purpose of this proposed action, all dam releases from 31,500 cfs to 45,000 cfs fall within the range of HFEs.

This HFE Protocol is intended to be experimental in nature, and is designed to learn how to incorporate high releases into future dam operations in a manner that effectively conserves sediment and sediment-dependent resources in the long term. A number of hypotheses may be tested through this experimental protocol. These hypotheses could be directed at varying the timing, magnitude, duration, and frequency of HFEs to determine the effectiveness on sandbar building and sand conservation. Two approaches have been put forward with respect to timing of a high release in response to the delivery of sediment into the river channel. The "store and release" approach was developed by USGS and was first introduced as the basis for the HFE Protocol in a June 2010 modeling workshop. The "rapid response" approach was proposed later in September by Western Area Power Administration, and is intended to test whether the desired sediment conservation can be achieved with dam releases at the time of the tributary sediment input using a powerplant capacity release of 31,500 cfs to 33,200 cfs.

The store and release approach relies on accumulation of sand during periods of above-average sediment input from tributaries to achieve sediment-enriched conditions called for in the development of the HFE Protocol (74 FR 69361). It is directed at sand since finer particles largely are transported downstream during the sand storage period. Conversely, the rapid response approach focuses on both sand and finer particles. Sand budget models used to estimate the magnitude and duration of HFEs that would maintain a positive sand budget also are not calibrated to estimate retention or transport of finer particle sizes. An approach similar to store and release was used for the 2004 and 2008 HFEs and these were effective at redepositing sand. Sand is accumulated over a period of several months at which time a recommendation is made to release or not release a high flow from the dam. In contrast, the rapid response approach relies on real-time measurements of flood events by stream gages in the tributary supplying the sediment (i.e., Paria River), which is a combination of clays, silts, sand, and organic matter. This information must be transmitted to dam operators in sufficient time so they can release water from the dam to coincide with the flood input from the tributary. The success of the rapid response approach requires coupling of tributary floods and dam releases to transport sediment-enriched water downstream. The decision process for rapid response must occur within a matter of hours. The rapid response authors identify several potential positive effects on various resources downstream from Glen Canyon Dam:

- The potential to build and maintain ecologically important sandbar complexes with greater efficiency than the storage and release approach for HFEs.
- An advantage in delivering high suspended sediment concentrations downstream, which has been shown to exert primary control on the building of sandbar complexes in previous HFEs.
- The combined Paria River flood and dam release flow magnitude is slightly lower than the previous HFEs, but evidence from previous HFEs suggests that sand deposition at high elevations zones is achievable.
- More frequent high-flow events and more variability with respect to their magnitude, frequency, and timing, which can potentially deliver a greater amount of sediments to sandbar complexes.
- A greater storage and deposition of fine, cohesive sediments (silts and clays) along with organic material that can help stabilize sandbars as well as enhance productivity in backwater habitats.

The rapid response approach has certain elements that exhibit promise and merit further testing. There are, however, several issues, concerns, and information needs that must be addressed prior to testing of this approach, including:

- It relies on the flow of the Paria River as the trigger for the HFE. The rapid response decision framework requires short-term decisions that must be based on the progression of floods in the Paria River. These floods are highly variable and of short duration, often 24 hours or less. This presents a major challenge in the coinciding of a dam release with a flood event. If a dam release misses the flood event, the high flow would scour sediment that is being accumulated in the river channel and could negatively impact the opportunity for future HFEs.

- The models used to develop and implement an HFE under store and release are not capable of evaluating the retention of sediment and organic matter finer than sand. These models could be developed with further refinement of the existing sand budget model.

- The rapid response proposal identifies that a high dam release coupled with a flood event from the Paria River would have to be made 'at a moment's notice.' Such a rapid response, which would have to occur in a matter of a few hours, could produce negative impacts on private property, recreation and safety, and dam operations. Prior to the initiation of a rapid response HFE, an appropriate warning system would need to be developed. An effective warning system will require coordination with dam operators and notices to anglers, boaters, rafters, and recreationists to ensure public safety.

- Average monthly sand load from the Paria River is greatest in August and September. Therefore, rapid response would most often be triggered in these months, which are outside the release windows for the store and release approach (March-April and October-November).

- The proposed action is intended to take advantage of sediment-enriched conditions to more efficiently conserve sediment. A large input from the Paria River during a time of low sediment storage might not meet these conditions.

It is expected that the above issues and concerns can be addressed sufficiently during the early stages of the implementation of the HFE Protocol to test a rapid response HFE within the same release windows (March-April and October-November) identified for the store and release HFE and Reclamation intends to test the rapid response method as soon as practicable. Initiation of this process would occur in 2012 and begin with a reevaluation of the habitat maintenance flow identified as the fourth hydrological scenario identified in the 2002 EA (Reclamation 2002). During the period of development for the rapid response approach: a science plan would need to be developed, models would have to be updated, safety warning systems would need to be developed, communication systems and dam operations protocols would need to be put in place, and real-time sediment input gages would have to be established. Additional compliance would be needed to evaluate the impacts of a rapid release HFE outside the October-November and March-April release windows. If a decision is made to proceed with the proposed action, all necessary steps would be completed to allow a rapid response HFE in 2014 if that is the outcome of the steps identified above and the HFE Protocol process.

Models to Assist in Development and Implementation of HFE Protocol

Mathematical models are used for two purposes for the HFE Protocol. The first is to estimate the magnitude, duration, and frequency of HFEs that could occur under the store and release approach using historic sediment and hydrologic data as inputs to maximize the potential for sandbar building with the available sand supply. The second is to make recommendations for future HFEs using contemporary sediment data and forecasted hydrologic data to determine whether suitable sediment and hydrology conditions exist for a high-flow experimental release.

Development of Data Input to Estimate Types of HFEs

The two basic inputs for the modeling are the water input or hydrology, which is taken from the Colorado River Simulation System (CRSS) (Reclamation 1988, 2007b) and the sediment, which in this case is restricted to inputs from the Paria River. A flow routing model (Wiele and Smith 1996) was used to simulate water passing downstream. A sediment budget model (Wright et al. 2010) was used to integrate the flow routing with the sediment inputs and outputs to determine whether or not a sediment mass balance is achieved for HFEs.

The hydrology model was used to develop dam release scenarios for 10-year periods under dry, moderate, and wet conditions (Grantz and Patno 2010, see Appendix D). The three hydrology time series were then used in conjunction with historical sediment input data (low, moderate, high) from the Paria River to create nine different sediment/hydrology combinations for input into the sediment budget model (Russell and Huang 2010, see Appendix E). The sand budget model uses the sediment inputs and estimates the outputs for three river reaches where sand is tracked: (1) from Lees Ferry/Paria River (RM 0) to RM 30, (2) from RM 30 to Little Colorado River (RM 61), and (3) from Little Colorado River to RM 87. For the purposes of this EA, only the first two reaches were used because results from the third reach would be confounded by Little Colorado River inputs. The major purpose of the sand budget model is to estimate the maximum possible magnitude and duration of an HFE that will not create a negative sand mass balance.

Data Inputs to Implement the HFE Protocol

The same mathematical models, with different data inputs, will be used to implement the modeling component of the HFE Protocol and to help make decisions whether or not to conduct an HFE under the storage and release approach. Whereas the hydrology data for the protocol development were drawn from historic records, hydrologic data for implementation would be based on forecasted monthly inflow volumes from the National Weather Service's Colorado Basin River Forecast Center (CBRFC) and Reclamation's 24-month study projected storage conditions. The 24-month study computer model projects future reservoir conditions and potential dam operations for the system reservoirs given existing reservoir conditions; inflow forecasts and projections; and a variety of operational policies and guidelines. Monthly volumes would be apportioned to daily dam releases by Western. Sediment data would be real-time accumulated inputs estimated from the Paria River streamflow gages. Wright and Grams (2010) demonstrated how the sand storage model can be used in conjunction with a flow routing model (Wiele and Smith 1996) to estimate sand storage conditions for a range of dam operations. Water supply forecasts and models are needed to make these projections and the uncertainty associated with these projections will need to be considered in the decision-making process (Grantz and Patno 2010).

2.2.2 Modeled Estimates of Types and Occurrences of HFEs

Thirteen HFEs having a range of magnitudes and durations of previously tested HFEs (Table 4) were used with the sediment/hydrology model to project the potential frequency of HFEs under the store and release approach. High releases of 41,000–45,000 cfs at durations of 60-168 hours were conducted in 1996, 2004, and 2008, and three releases of 31,000 cfs for 72 hours were conducted in 1997 and 2000. HFEs of less than 60 hours duration and magnitudes between 31,000 and 41,000 cfs have not been conducted.

Model runs were done using 10-year series of dry, moderate, and wet hydrology coupled with representative years of low (1983, 862,000 metric tons), moderate (1990, 1,334,000 metric tons), and high (1934, 1,649,000 metric tons) sediment input from the Paria River (Russell and Huang 2010; see Appendix E). Each run was evaluated against 13 described HFEs to determine their possible occurrence in the months of March-April or October-November. The magnitude and duration of a HFE was determined from the sand storage mass available on October 1st and March 1st of each water year and the forecasted hydrology (Grantz and Patno 2010). The model evaluates each of the 13 HFE types sequentially starting with the highest magnitude and duration of release. For example, the initial run determines if there is enough sediment available to release an HFE of 45,000 cfs for 96 hours.

Table 4. Flow magnitude and duration for 13 possible HFEs used with the sediment/hydrology model.

HFE No.	Flow Magnitude (cfs)	Duration (hours)	HFE No.	Flow Magnitude (cfs)	Duration (hours)
1	45,000	96	8	45,000	1
2	45,000	72	9	41,500	1
3	45,000	60	10	39,000	1
4	45,000	48	11	36,500	1
5	45,000	36	12	34,000	1
6	45,000	24	13	31,500	1
7	45,000	12			

If enough sediment is available to achieve a positive sand mass balance in Marble Canyon, that magnitude and duration of HFE can be implemented. A positive mass balance is defined as a condition in which the amount of sediment being delivered by tributaries into the system exceeds the amount being exported from the system by ongoing dam operations and HFEs. If the model run does not conclude that enough sediment is available to achieve a positive mass balance, the next lower magnitude or duration HFE is evaluated by the model. This is repeated until an HFE scenario is reached that can be implemented with the available sediment, or it is determined that an HFE cannot be implemented.

It is assumed that the highest magnitude and duration HFE possible without creating a negative sand mass balance is desirable, because larger HFEs will place sand at higher elevations and create larger beaches and sand bars without impacting the mass balance. Increase in area and volume of beaches and sandbars is a desired outcome of the HFE Protocol and previous powerplant capacity releases did little to improve sandbars and beaches relative to the higher releases conducted in 1996, 2004, and 2008. There is also an assumption that water is not limiting because reallocation of water from other months can be used to ensure that sufficient water is available for the HFE without violating any applicable legal or operational requirements (including applicable laws or compacts) to deliver water to the lower Colorado River basin.

The total number of occurrences for each HFE from Table 5 shows that certain types of HFEs are more likely to occur than others. Of the total number of HFEs for all nine sediment/ hydrology traces, an HFE of 45,000 cfs for 96 hours is 2.4 times more likely to occur than any other type of HFE. The second most likely type to occur is an HFE of 45,000 cfs for 1 hour. Based on sediment/hydrology conditions, modeling results indicate that HFEs in the range of 31,500 cfs to 39,000 cfs have a low chance of occurring. It is important to recognize that all HFEs do not have an equal opportunity to occur because the model starts considering HFEs from the top of the list (45,000 cfs for 96 hours) and works down the list. This is done to ensure that the most effective HFEs, based on previous research, have the greatest probability of occurring.

These model runs also indicate a potential of consecutive HFEs, either within the same year or between years. Another important finding is that there is the potential of up to 5 or 6 sequential HFEs. This has important implications for impact analysis, given that consecutive HFEs have not been conducted at Glen Canyon Dam. Given the uncertainty of resource responses to two or more consecutive HFEs, adaptive management monitoring will be used to weigh the risk of additional HFEs against the learning that can be acquired from their implementation. The results of modeling simulations for nine traces of sediment and hydrology (Table 5) do not necessarily reflect what may happen during the 10-year HFE Protocol period because it is highly unlikely that the same sediment/hydrology condition will persist for the full 10-year period. It also is unlikely that each sediment/hydrology condition will be equally represented. However, this table provides an insight into the potential frequency, magnitude, and duration of spring and fall HFEs and Reclamation considers this approach to be the best method of evaluating the proposed action.

Table 5. Type of HFE by month for each of the nine traces of sediment (Low, Moderate, and High) and hydrology (Dry, Moderate, Wet). See Table 4 for descriptions of HFEs (Russell and Huang 2010).

Month/Year	Low, Dry	Low, Mod.	Low, Wet	Mod, Dry	Mod., Mod.	Mod., Wet	High, Dry	High, Mod.	High, Wet
Mar-Apr Yr 1	5	5					7	7	
Oct-Nov Yr 1	2	2		6	6		6	6	
Mar-Apr Yr 2									
Oct-Nov Yr 2		7							
Mar-Apr Yr 3	6	12		1	2	1	8		
Oct-Nov Yr 3	3	8	4	1	2	1	1	1	1
Mar-Apr Yr 4	10			1	1	1	2	8	3
Oct-Nov Yr 4	1	1	7	8	8		6	8	
Mar-Apr Yr 5							2	7	1
Oct-Nov Yr 5	1		4	8					
Mar-Apr Yr 6	11	8	8	5	1	1		12	9
Oct-Nov Yr 6			8				1	1	1
Mar-Apr Yr 7	8	8			8		9	10	
Oct-Nov Yr 7	7	7					1	1	1
Mar-Apr Yr 8			7	8		4	4	9	1
Oct-Nov Yr 8	4	3	3	1	1	1	6	7	8
Mar-Apr Yr 9									
Oct-Nov Yr 9	9	7		1	1	1			
Mar-Apr Yr 10	1	1	2						
Oct-Nov Yr 10	2	2	1	5	6	2	6	7	1
No. of HFEs	14	13	9	11	10	8	13	13	9

The numbers of HFEs for the nine sediment/hydrology traces indicate that HFEs are most likely to occur during low sediment/dry hydrology conditions, followed by a tie among low sediment/moderate hydrology, high sediment/dry hydrology, and high sediment/moderate hydrology. These conditions of suitability reveal the influence of hydrology and the consequent magnitude of dam releases. HFEs are most likely to occur in years of dry to moderate hydrology because lower seasonal releases from the dam cause less ongoing export of sediment. Low year-round dam releases allow for a greater accumulation of sediment than high releases that have higher velocity and a greater scouring effect.

The monthly water allocations for dam releases were generated through the CRSS model. Those allocations had to be adjusted to provide water necessary for HFEs of varying magnitude and duration. The amounts that were reallocated for the different HFE scenarios ranged from about 23,000 to 344,000 acre-feet (Table 6). The model assumed that all water necessary for an HFE could be provided in the month of the HFE and did not restrict that volume to follow MLFF. In reality, the reallocated amounts would first be drawn from the HFE month subject to MLFF minimum flows, then from other months based on hydropower production priorities (see Section 2.2.4).

Table 6. Projected volume of water (acre-feet) to be reallocated as a result of the selected HFE. See Table 4 for type of HFE (Russell and Huang 2010).

Month of Potential HFE	Low, Dry	Low, Mod.	Low, Wet	Mod, Dry	Mod., Mod.	Mod., Wet	High, Dry	High, Mod.	High, Wet
Mar-Apr Yr 1	154,673	154,673					84,733	84,733	
Oct-Nov Yr 1	256,536	256,536		118,024	118,024		118,024	118,024	
Mar-Apr Yr 2									
Oct-Nov Yr 2		83,395							
Mar-Apr Yr 3	118,024	23,010		325,792	256,536	325,792	48,767		
Oct-Nov Yr 3	221,938	48,767	187,279	325,792	256,536	325,792	325,792	325,792	325,792
Mar-Apr Yr 4	32,693			325,792	237,854	276,934	256,536	25,272	186,506
Oct-Nov Yr 4	325,792	325,792	83,395	48,767	48,767		118,024	48,767	
Mar-Apr Yr 5							268,375	53,922	278,784
Oct-Nov Yr 5	325,792		187,279	48,767					
Mar-Apr Yr 6	28,363	48,796	49,742	154,629	325,901	329,441		23,030	40,258
Oct-Nov Yr 6			48,767				325,792	325,792	325,792
Mar-Apr Yr 7	57,680	45,376			45,376		47,515	29,882	
Oct-Nov Yr 7	89,923	83,395					343,986	325,792	308,939
Mar-Apr Yr 8			84,286	53,628		188,851	198,808	20,184	328,272
Oct-Nov Yr 8	187,279	221,938	221,938	325,792	325,792	325,792	118,024	83,395	48,767
Mar-Apr Yr 9									
Oct-Nov Yr 9	39,366	83,395		325,792	325,792	325,792			
Mar-Apr Yr 10	334,188	317,046	256,600						
Oct-Nov Yr 10	256,536	256,536	308,078	152,652	118,024	242,068	118,024	83,395	308,078

2.2.3 Decision-Making Process

The HFE Protocol is a decision-making process that consists of three components: (1) planning and budgeting, (2) modeling, and (3) decision and implementation. The following three subsections describe each of these components.

Planning and Budgeting Component
The first component of the HFE Protocol is planning and budgeting (Figure 3). An important aspect of planning is the development and implementation of research and monitoring activities appropriate to monitor the effects of the HFEs. An annual agency report conducted in the early part of each calendar year prior to a decision on a spring HFE would evaluate the information on the status and trends of key resources. Any criteria set forth in biological opinions for ESA-listed species would be utilized as would the Desired Future Conditions objectives and metrics presently in development through the GCDAMP. This information would be provided to Interior to assist with the decision and implementation component of this protocol. Funding for previous HFEs was provided through the GCDAMP budget process and from Reclamation appropriations. The Adaptive Management Work Group (AMWG) federal advisory committee makes recommendations to Interior on allocation of these funds. Reclamation would be prepared to conduct an HFE if funding is provided, resource conditions are suitable, there is sufficient sediment input to trigger an HFE, and Interior determines all conditions are suitable for proceeding.

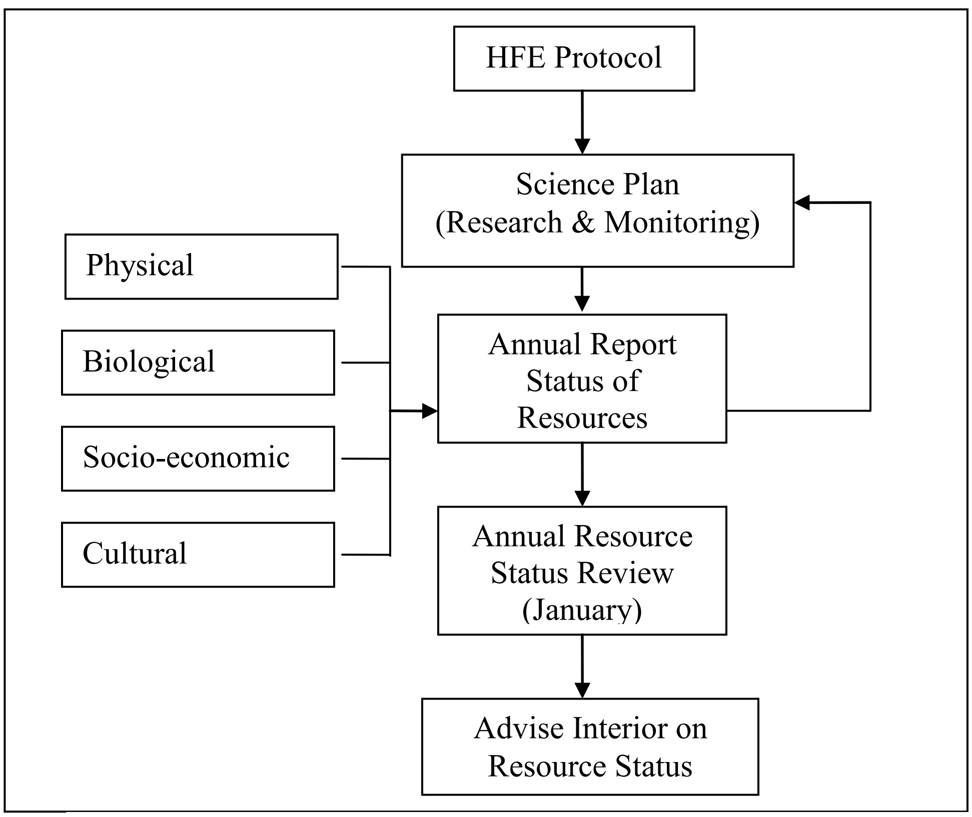


Figure 3. Planning and budgeting component for the HFE protocol.

The details of the resource evaluation process have not been finalized, but it likely would be based on criteria similar to those proposed earlier for beach/habitat building flows, as initiated by Ralston et al. (1998) (Table 7). The criteria would be refined by GCMRC with input from the GCDAMP Technical Work Group. Additional key resources would be drawn from those being monitored under the HFE Protocol science plan (see Appendix B). In this way, the HFE Protocol would be evaluated annually for the effects of its implementation on resources. Resources that would be evaluated for determining whether or not an HFE would take place could include (but would not be limited to): in-channel sediment storage, sandbar campable area, high-elevation sand deposits, archaeological site condition and stability, sediment flux, aquatic food base, Lees Ferry fish monitoring, Lees Ferry fishery recreation experience quality, fish abundance and species composition in the mainstem and Little Colorado River (including abundance of humpback chub), riparian vegetation, Kanab ambersnail, Lake Powell and Lees Ferry water quality, and hydropower production and marketable capacity.

The results of the annual status of resources report and review would be used to help determine if future HFEs will take place. If monitoring shows that there are unacceptable impacts, such as a significant decline in humpback chub numbers, Reclamation would suspend implementation for that cycle and re-evaluate the HFE Protocol. In a separate EA process, Reclamation has developed a proposed action to control non-native fish. Because humpback chub is a key GCDAMP resource that could be adversely affected by HFEs through increases in trout numbers, a trigger has been identified in the 2011 Opinion (USFWS 2011b) that would be used to determine if removal of non-native fish would occur in the LCR reach of the Colorado River. A determination whether the trigger has been reached would be made from monitoring and modeling data gathered through the GCDAMP.

Table 7. Resource indicators for important resources potentially affected by BHBFs (Ralston et al. 1998).

Sediment Resources (Sandbars, beaches and backwaters)
Total number of sandbars above 20,000 cfs, by reach and stage. Average area of sandbars above 20,000 cfs, by reach and stage Number of suitable backwater habitats by reach at specific river stages between 8,000 cfs and 45,000 cfs Estimated quantity of river-stored sediment available for redistribution by reach
Terrestrial and Riparian Resources
Kanab ambersnail (as compared to 1996 pre-flood conditions)
Number of known populations of KAS in Arizona Populated KAS habitat (total area) outside impact zone Estimated total KAS population outside impact zone Analysis: Probable BHBF effects on long-term sustainability of known populations (e.g., recruitment, genetic integrity, sustainability of pre-dam habitats)
Southwestern willow flycatcher
Number of SWWF territories expected to be significantly affected by BHBF (describe effect) Number of breeding pairs expected to be displaced by BHBF Analysis: Probable effects of BIHBF on recruitment (reproduction, nest parasitism, survival of young, etc.)
Aquatic Resources
Aquatic foodbase
Foodbase species composition, population structure, density, and distribution in Glen and Grand Canyon reaches. Analysis: Probable effects of BHBF on composition, recovery rates of algal, macroinvertebrates and effects on organic drift.
Humpback chub, Razorback sucker, Flannelmouth sucker, other native fish, Rainbow trout
Number of successfully reproducing populations (including single trout population in Lees Ferry reach). Estimated number of successfully reproducing adult fish (creel catch rate; electrofishing catch rate by size class as an index of population size) Survival of juveniles and subadults Recruitment Growth rate Relative condition (length/weight relationship)

Modeling Component

The sand budget is the net amount of sand in metric tons that has accrued in the river channel over some period of time. In the Paria River, the two primary sand input periods are July through October and January through March (Figure 4). During these two periods, sand is being accumulated at a higher rate than in the remaining months. This progressive accumulation of sand is the fundamental basis of the store and release approach. If this inquiry was just about optimizing sand conservation, the release months would be November and April; however to accommodate the decision process that follows the modeling and to address other resource needs or concerns, the HFE windows were broadened to October-November and March-April. As this decision process is refined and made more efficient with the experience of conducting HFEs, it is likely that the time necessary to make HFE decisions can be decreased, when it is advantageous to do so.

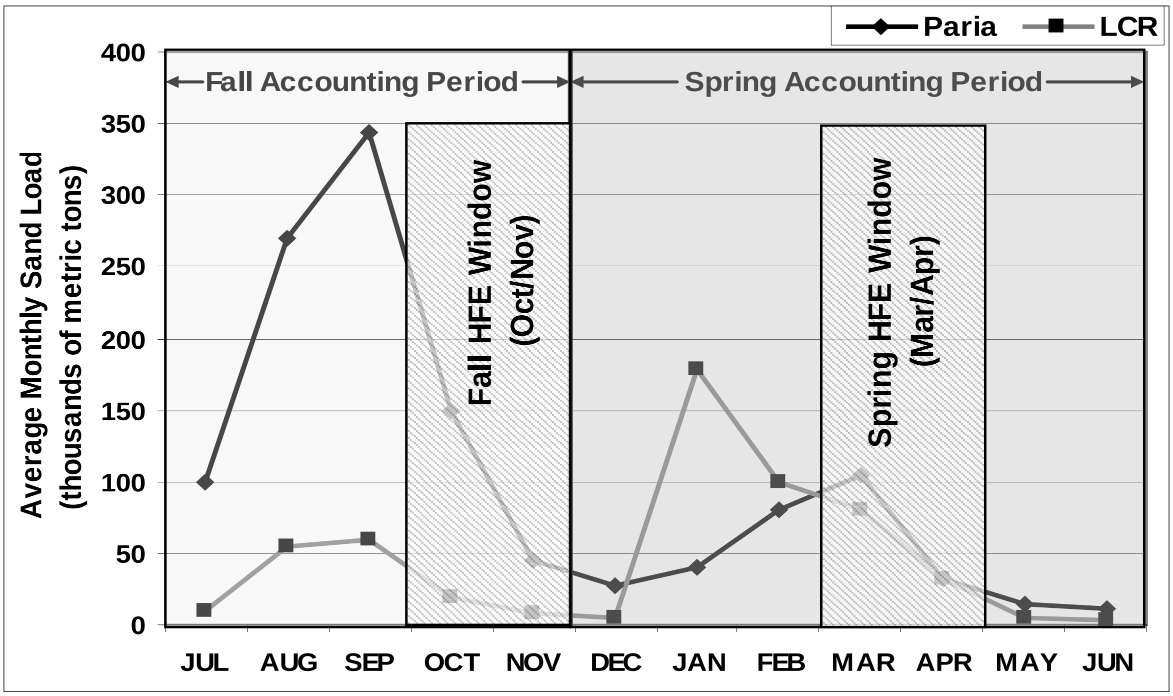


Figure 4. The two sand accounting periods and the two high-release periods with average monthly sand loads for the Paria River and the Little Colorado River (adopted from Scott Wright, U.S. Geological Survey, personal communication, and Wright and Kennedy 2011).

Sand availability at the onset of each release window is determined by the amount of sand received from the Paria River during the accrual period less the amount transported downstream to the Little Colorado River as estimated by the sand routing model. Sand in Grand Canyon received from the Little Colorado River is viewed as an added benefit to the amount received from the Paria River. The Little Colorado River input cycle largely follows the same accrual periods as the Paria River; however, only sand inputs from the Paria River would be used in HFE modeling recommendations.

The modeling component is based on four key analysis phases associated with the two sand budget accounting periods and the two HFE windows.

Phase 1 – Fall accounting period. The fall accounting period is from July 1 to November 30. Beginning on July 1 each year, monitoring data will be used to track the sand storage from Paria River inputs in Marble Canyon.

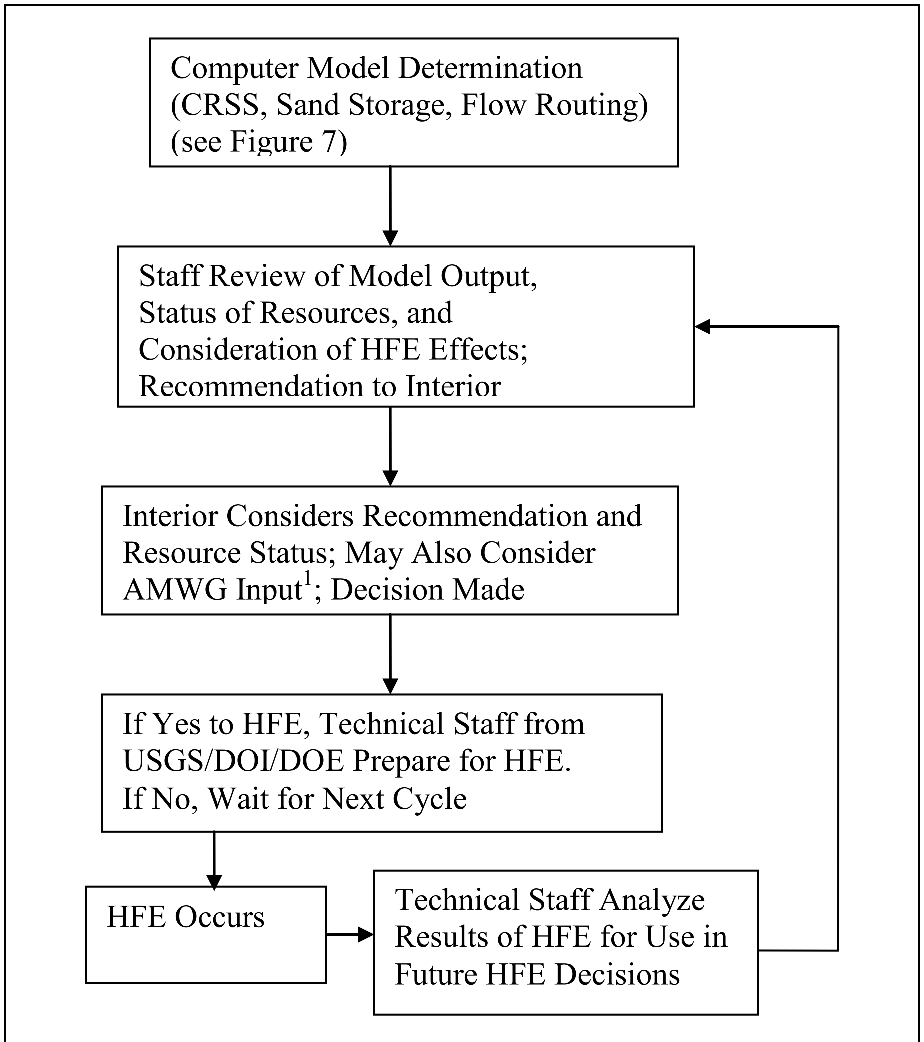
Phase 2 – October-November HFE window. Beginning October 1, sand storage, and forecast hydrology are evaluated using the sediment budget model to determine whether conditions are suitable for an HFE. The model determines what magnitude and duration of the HFE, if any, will produce a positive sand balance at the end of the accounting period. If the model produces a positive result, the largest HFE that will result in a positive mass balance is forwarded to the decision and implementation component (see below), which also allows for other factors (biological, economic, societal) to be considered in the planning process. During the decision process, sediment input would continue to be measured, the model would continue to be run and results or output would be forwarded to decision-makers to allow for refinement of the previously recommended magnitude and duration of the HFE. If the model produces a negative result, the model will be rerun using more recent sediment input to determine whether a positive mass balance will be reached in time to have an HFE in the release window.

Phase 3 – Spring accounting period. The spring accounting period is December 1 to June 30. As with the fall accounting period, monitoring data would be used to track the sand storage conditions in Marble Canyon during this time period. This accounting would be conducted regardless of whether or not a previous October or November HFE was conducted such that two HFEs could theoretically occur in the same year. The accounting would continue to consider sand storage conditions present at the end of phase 2, whether or not an HFE has occurred.

Phase 4 – March-April HFE window. The evaluation in this phase is the same as for the October-November HFE window (see Phase 2) with the model output being forwarded to the decision and implementation component. The model output would be used in the same way as for the October-November determination. If no tributary inputs were included in this period, a spring HFE would likely not occur, and the process would begin again on July 1. Whether or not an HFE is scheduled, sediment inputs would continue to be monitored through the end of the spring accounting period for use in the next accounting period.

Decision and Implementation Component

The third component of the HFE Protocol is decision and implementation component for conducting an HFE (Figure 5). This component could span a portion or most of the HFE window, depending on when conditions are deemed suitable for an HFE. The output from the model runs described above is used to determine if sediment and hydrology conditions are suitable for an HFE of a given magnitude and duration. For example, if the scenario that is identified by the model cannot be implemented because of facility limitation to 42,000 cfs or less (see Section 1.5.2), managers would assess the need to modify the range of magnitude and duration of the HFE. Because this assessment has considered the effects of 45,000 cfs HFEs for 1 to 96 hours, it also serves to assess the effects of HFEs at lower magnitudes and equivalent durations.



[1]Issues and concerns expressed at AMWG meetings, as appropriate.

Figure 5. Decision and implementation component of HFE protocol.

Because the model only considers water and sediment, an added purpose of this protocol component is to consider potential effects on other resources. The model output would be provided to Interior staff, who would consider the status and trends of key resources before making a recommendation to managers. Managers would consider the staff recommendation and resource status, and may also consider input from the AMWG before making a decision to conduct or not conduct an HFE. If the decision is made to conduct an HFE, the technical staff of the USGS would prepare to conduct monitoring and research in cooperation with other agencies. If not, the process would be repeated during the next accounting window. For each HFE, technical staff would analyze results and integrate information from other HFEs for use in future HFE decisions.

The decision process could result in an HFE being considered whether or not a positive sand balance is projected for that release, since the decision must be made in advance of the actual HFE release and there is an admitted uncertainty in the modeled forecast for both sediment inputs and dam releases. Caution will be exercised, however, because the sand mass balance only accounts for the difference between inputs and outputs, and does not adequately portray the degradation of sand already resident in the river channel. Successive HFEs or intervening periods of degradation without HFEs could negatively impact the ability of future HFEs to form sandbars and beaches. Furthermore, this degradation could impact other resources and it is advisable to ensure that the net amount of sand in the river channel is not depleted so as to compromise other ecosystem components. The output of the model would be integrated with an assessment of the status and trend of other resources, as an acknowledgement that the decision cannot be focused solely on the condition of the sediment to ensure that the decision fully encompasses the impacts on all important resources.

Operation in Accordance with the 2007 Interim Guidelines

The decision making process would be in conformance with Reclamation's obligations to deliver water under existing law and Secretarial decisions including under the December 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a). Reclamation will not implement an HFE that is inconsistent with the 2007 Interim Guidelines. The 2007 Interim Guidelines provide that the Secretary may consult with the Basin States as appropriate; Reclamation will consult with the Basin States prior to undertaking an HFE. Reclamation will utilize the most current information available in the Colorado River Annual Operating Plan 24-month Study to ensure that an HFE will not alter annual water deliveries under the 2007 Interim Guidelines. An HFE would only be conducted if it would not alter annual water deliveries or the operational tiers or elevations that would have otherwise been dictated by the 2007 Interim Guidelines in the absence of an HFE.

2.2.4 Operation of Glen Canyon Dam to Achieve HFE Protocol

The scenarios considered below describe how Reclamation would modify the operation of Glen Canyon Dam to reallocate monthly volumes when necessary to achieve high-flow events as called for by the HFE Protocol. Implementation of the protocol for HFEs from Glen Canyon Dam will be done in concert with coordinated river operations. Since 1970, the annual volume of water released from Glen Canyon Dam has been made according to the provisions of the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs (LROC) that includes a minimum objective release of 8.23 maf.

The 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a) for lower basin shortages and the coordinated reservoir operations (Interior 2007) implements relevant provisions of the LROC for an interim period through 2026. This allows Reclamation to modify these operations by allowing for potential annual releases both greater than and less than the minimum objective release under certain conditions. A more thorough description of Reclamation's process for determining and implementing annual release volumes is available in the 2007 EIS and Record of Decision and the biological opinion (USFWS 2007a).

Pursuant to the 2007 Colorado River Interim Guidelines, the annual release volume from Lake Powell is projected and updated each month in response to the monthly 24-Month Study model run. This projected annual release volume is allocated to produce projected monthly release volumes and becomes the basis for scheduled monthly releases from Glen Canyon Dam. It is important to note that, regardless of the timing of releases, implementation of the HFE Protocol would not affect annual release volumes.

The HFE Protocol is anticipated to call for high-flow events during a fall HFE implementation period (October and November) and a spring HFE implementation period (March and April). High-flow events under the HFE Protocol could require more water than what is scheduled for release through the coordinated operating process described above. In order to perform these high-flow events called for by the HFE Protocol, reallocation of monthly releases from Glen Canyon Dam may be necessary. Monthly reallocations for an HFE would not affect annual release volumes.

Potential Operation of Glen Canyon Dam during the Fall HFE Implementation Period

When releases during October are not scheduled to be steady and consistent with September releases, following completion of commitments in the 2008 Experimental Releases EA, Reclamation would reduce release volumes during October to conserve water for potential high-flow events. If the annual release volume was projected to be 8.23 maf or less, the monthly release volume for October could be scheduled at 500,000 acre-feet (500 kaf) in order to conserve water for potential high-flow events. If the annual release volume was projected to be greater than 8.23 maf, the monthly release volume for October could be scheduled at 500 kaf or greater without impacting potential high-flow events.

Reclamation would attempt to achieve fall high-flow events by lowering the remaining shoulder days within the fall HFE period to the degree practicable up to as low as allowed under the Operating Criteria for Glen Canyon Dam and 1996 Record of Decision in order to release the projected October and November volume in the 24-Month Study. Reclamation would conduct high-flow events as soon as practicable within the fall HFE implementation period. If the fall high-flow event could be achieved within the release volume projected for October and

November in the 24-Month Study, no reallocation of the monthly volumes from other months would need to be performed.

If Reclamation determined that it would not be possible to achieve the high-flow event within the monthly release volume projected for October and November, Reclamation would reduce the projected monthly release volumes as necessary for the following December through March period. For these months, the projected monthly release volumes would be reduced to the minimum MLFF thresholds of 600 kaf and 800 kaf as practicable and reductions would be reallocated to October and November. This process would be performed in reverse order where practicable from March to December (i.e., where March would first be lowered to 600 kaf, then February to 600 kaf, then January to 800 kaf and finally December to 800 kaf). Reallocation would only be conducted up to the amount necessary to result in the projected monthly volume for October and November being sufficient to conduct the high-flow event. If additional reallocation of the monthly volumes is required to achieve the high-flow event, Reclamation would approach this with the intent of protecting the release volume for December and January to be at least 800 kaf.

Potential Operation of Glen Canyon Dam during the Spring HFE Implementation Period
Reclamation would attempt to achieve spring high-flow events by lowering the remaining shoulder days within the spring HFE implementation period to the degree practicable up to as low as allowed under the Operating Criteria for Glen Canyon Dam and 1996 Record of Decision to release the volume projected for March and April in the 24-Month Study. Reclamation would conduct high-flow events as soon as practicable within the spring HFE implementation period. If the spring high-flow event could be achieved within the release volume projected for March and April in the 24-Month Study no reallocation of the monthly volumes from other months would need to be performed.

If Reclamation determined that it would not be possible to achieve the high-flow event within the monthly release volume projected for March and April, Reclamation would reduce the projected monthly release volumes as necessary for the following May through August period. For these months, the projected monthly release volumes would be reduced to the minimum MLFF thresholds of 600 kaf and 800 kaf as practicable and reductions would be reallocated to March and April. This process would be performed in order where practicable from May to August (i.e., May would first be lowered to 600 kaf, then June to 600 kaf, then July to 800 kaf and finally August to 800 kaf). This reallocation process would only be conducted up to the amount necessary to result in the projected monthly volume for March and April being sufficient to conduct the high-flow event. If additional reallocation of the monthly volumes is required to achieve the high-flow event, Reclamation would approach this with the intent of protecting the release volume for July and August to be at least 800 kaf.

2.2.5 Role of Adaptive Management in HFE Implementation

The protocol for high-flow experimental releases will be conducted as a component of the ongoing implementation of the Glen Canyon Dam Adaptive Management Program (GCDAMP).

The GCDAMP is administered through a designated senior Department of the Interior official who chairs the Adaptive Management Work Group (AMWG). Consistent with Grand Canyon Protection Act, the AMWG provides advice and recommendations to the Secretary of the Interior relative to the operation of Glen Canyon Dam. Implementation procedures will follow guidelines issued by Interior for incorporation of adaptive management into NEPA compliance and take into account recommendations issued by the NEPA Task Force to the Council on Environmental Quality (2003). These procedures provide guidance on addressing uncertainty, monitoring, public participation, communication and permitting or other regulatory requirements.

Adaptive Management Science through the GCDAMP

The details of the HFE Protocol and the role of the AMWG in its implementation are provided in Section 2.2.3 of this EA. Fundamentally, the decision to conduct an HFE under this protocol is made by Interior. This decision will be based on a determination by scientists and federal managers of the suitability of the hydrology, sediment, and other resource conditions. This intersection of scientists and managers is a fundamental principle of adaptive management and uses the best available scientific information to make decisions about dam management. The AMWG will continue its role as advisory to the Secretary on the 10-year HFE Protocol and the adaptive management process. The 10-year high-flow protocol lays the foundation for a process of "learning by doing," which is another fundamental principle of adaptive management.

The GCDAMP has an extensive research and monitoring program. A HFE science plan, prepared by GCMRC, is attached to this EA for the HFE Protocol (see Appendix B) and will be used to supplement the extensive monitoring already being conducted under the GCDAMP. This plan addresses research and monitoring activities necessary to evaluate HFEs both as individual and related experiments. The plan was developed through the adaptive management program as part of the overall science-planning process used by the GCMRC to provide independent, objective science support to the GCDAMP. This plan was drawn from the FY 2011 and FY 2012 Work Plans of the GCDAMP. Similar science plans were developed for the experimental flow treatments and mechanical removal activities in water years 2002-2004 (USGS 2003) and for the 2008 HFE (USGS 2007a). In addition, a Strategic Science Plan has been developed to support the GCDAMP (USGS 2009).

Continuing development of the science plan likely would benefit from the convening of a workshop of scientists and managers as was done in 2005 (Melis et al. 2006) and 2007 (USGS 2007a). Highly qualified scientists with expertise in fields of science relevant to Grand Canyon issues would ensure that the most accurate and up-to-date information is used in developing the final HFE science plan. The adaptive management program has a group of eminent scientists, the Science Advisors, who would provide valuable additional expertise. Participation by managers with familiarity of Colorado River resource management challenges would ensure that the HFE science plan addressed important resource and management concerns.

In 2005, as part of long-range experimental planning, GCMRC conducted an assessment of the current knowledge on resource responses to various management actions in Grand Canyon (e.g., BHBFs, HMFs) (Melis et al. 2006). This assessment concluded that there was a wide range of certainty associated with predicting the direction of response for different resources. Hydropower capacity and replacement costs for a BHBF or HMF were very certain, whereas predicting response direction for physical variables (i.e., sediment and water temperature) was relatively certain to uncertain. The assessment also concluded that response directions for the aquatic foodbase and fish were uncertain or highly uncertain. A subsequent knowledge assessment has not been published, but the process for conducting the next assessment is underway and will be completed in 2012 through the GCDAMP. The knowledge of some resources has improved. However, while response by sediment to high flows is fairly well understood, responses by biotic resources continue to be less well understood. Hence, it is important to remember that for this high-flow release protocol, designed HFEs may effectively conserve sediment on beaches and sandbars but will have less certain effects on biotic resources (see Kennedy and Ralston 2011).

A corollary process being conducted through the GCDAMP is the development of desired future conditions for resources of high importance to the program. A set of desired future conditions has been drafted and is presently moving through a process for recommendation to the Secretary of the Interior. Priorities associated with the desired future conditions have been identified for four major resource areas: (1) the Colorado River ecosystem (CRE) which encompasses the Colorado River from the forebay of Glen Canyon Dam to its inflow into Lake Mead, and lies between the pre-dam high water zone terraces. The ecosystem also includes relevant additional habitats needed to sustain the CRE or that may be useful as scientific monitoring controls. The CRE includes aquatic and riparian processes and components (e.g., species) as well as terrestrial components that are influenced by riverine processes; (2) hydropower; (3) cultural resources; and (4) recreation. When completed, very likely during the duration of this proposed action, they will serve as a basis for determining through resource monitoring whether these desired conditions are being achieved by the GCDAMP.

Reclamation conducted three high-flow tests in 1996, 2004, and 2008. These tests have shown valuable findings about resource responses, but they have also revealed unknowns and uncertainties that need to be addressed as part of this HFE Protocol. Uncertainty of outcome is an inherent aspect of experimentation conducted under adaptive management. Uncertainty can be expressed as testable models, however, and can be addressed through a monitoring system established to ensure that outcomes are detected before they negatively impact resources of concern. The research and monitoring identified in the accompanying HFE science plan, coupled with a workshop of scientists and managers to refine the plan, are important components of addressing the uncertainty. The following two over-arching questions relate to sand conservation and impacts to other resources and are a main focus of the science plan:

- Over-arching Question #1: Is there a “Flow Only” operation (that is, a strategy for dam releases, including managing tributary inputs with HFEs, without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal timescales (USGS 2007a, 2009)?

- Over-arching Question #2: How can an HFE Protocol be implemented without causing significant impacts to other resources?

Key research questions are tiered from the over-arching questions and addressed in greater detail in the final HFE science plan. These research questions include, but are not be limited to the following:

- Research Question #1a: Given that sandbars are naturally dynamic and go through cycles of building and eroding, can a protocol of frequent high flows under sediment-enriched conditions be effective in sustaining these dynamic habitat features?

- Research Question #1b: Are there optimal times to conduct high flows in regard to sediment building, humpback chub survivability, and ecosystem response?

Summary: The goal of this experimental protocol is to identify a long-term program of high flows under sediment-enriched conditions for improving downstream resource conditions.

- Research Question #2: What is the effect of HFEs on humpback chub and native fish populations located downstream from Glen Canyon Dam?

Summary: Ongoing research and monitoring of humpback chub and native fish populations downstream from Glen Canyon Dam have shown that the status and trends of these populations are influenced by complex interactions of river flows, temperature, water clarity, tributary influences, and non-native predators and competitors. The humpback chub population declined from about 11,000 adults in 1989 to about 5,050 adults in 2001, and subsequently stabilized and increased to 7,650 adults in 2008 (Coggins and Walters 2009). Focused investigations are needed to better understand how aspects of an HFE (timing, magnitude, duration, frequency) affect these native fish populations, including nearshore habitat, dispersal of young from the Little Colorado River, foodbase, and predation and competition by non-native fish species.

- Research Question #3: Is sediment conservation more effective following a sediment enrichment period in the context of multi-year, multi-event experiments?

Summary: Previous high-flow tests were conducted under depleted to enriched sediment conditions, and there is a strong need to determine if sediment conservation is more effective when releases are made under an established HFE Protocol during sediment-enriched conditions.

- Research Question #4: Is sediment conservation more effective when an HFE is held in rapid response to sediment input from the Paria River?

Summary: A rapid response HFE has not been tested, in which a high-flow release is made during a sediment-laden flood from the Paria River. This approach is hypothesized to redeposit a range of sediment sizes, from coarse sand and fine organic matter, that will help to build sandbars and beaches and provide nutrients for riparian plants and backwaters. A rapid response HFE will require real-time monitoring of the Paria River to accurately determine the sediment load, protocols for timely responses by dam operators to Paria River inputs, and public notices to ensure safety for recreational users and property owners. At this time, these requirements have not been met.

- Research Question #5: How can erosion of sandbars after an HFE be minimized or offset?

Summary: Sandbars and beaches rebuilt with previous high-flow tests eroded shortly afterward, and a better strategy is needed to conserve sediment and protect and enhance other key resources.

- Research Question #6: What is the effect of a fall HFE on the foodbase at Lees Ferry?

Summary: Monitoring of the spring 1996 and 2008 HFEs showed scouring of a large portion of the foodbase that was followed by from 4 to 15 months of biomass recovery during spring and summer. Designed effects monitoring was not conducted before, during, and after the November 2004 HFE. There is concern that a fall HFE would scour the foodbase at a time when photoperiodicity and hence, photosynthesis are reduced, and recovery of the foodbase would be delayed until the following spring.

- Research Question #7: What is the effect of a fall HFE on the trout population at Lees Ferry?

Summary: Fish monitoring around the November 2004 HFE showed lower than normal survival and condition of rainbow trout, although there were many confounding factors at the time (warm dam releases from low reservoir, low dissolved oxygen, trout suppression flows, downstream mechanical removal of trout). Fall HFEs should be tested for their effects on the rainbow trout population.

- Research Question #8: What effect would consecutive HFEs (spring followed by fall, or fall followed by spring) have on the foodbase and trout population at Lees Ferry?

Summary: Consecutive HFEs at intervals of a year or less have not been conducted. The 1996, 2004, and 2008 HFEs were spaced several years apart. The interval between HFEs was sufficient time for the system to recover. Impacts of a consecutive fall and spring event could be severe on the foodbase and trout population and needs to be tested.

- Research Question #9: What is the relationship of high-release magnitude and duration on the extent of foodbase scouring in the Lees Ferry reach?

Summary: High-flow releases of 41,000 to 45,000 cfs were shown to scour about 90 percent of the foodbase on sediments and much of the foodbase on rock substrates in the Lees Ferry reach.

The relationship of the extent of scouring and flow magnitude is important information as a potential management tool for stimulating production. Hence, flow magnitude of less than 41,000 cfs should be evaluated to determine the scouring effect on the foodbase.

- Research Question #10: Is it possible to manage the Lees Ferry trout population with a spring HFE held at slightly different times than previous spring HFEs?

Summary: The peak of rainbow trout spawning in Lees Ferry is early March. High-flow releases prior to spawning can cleanse the spawning beds of fines and increase survival of eggs and alevins, whereas high flows during the latter stages of incubation can potentially negatively affect incubation rates and survival of eggs and alevins. The effect of high releases timed to trout incubation is important information as a potential management tool for the trout population. A healthy trout population in the Lees Ferry reach is a desirable resource. Conditions that encourage emigration downstream and rainbow trout population increase at the mouth of the Little Colorado River are not desirable, because rainbow trout are documented predators of the endangered humpback chub and other native fish.

Public Involvement

As part of the adaptive management process, Reclamation has conducted three HFEs (1996, 2004, and 2008) and three HMFs (1997 and two in 2000). Each of these actions has had public involvement that has helped to provide feedback to high-flow experiments and has helped to inform the development of this HFE Protocol. The effects of each HFE have been documented to provide this information to the scientific community and to the public, including the 1996 HFE (Webb et al. 1999), and the 2004 and 2008 HFEs (Gloss et al. 2005; Makinster et al. 2010a; 2010b; Ralston 2010; Rosi-Marshall et al. 2010; Korman et al. 2011; Melis 2011). Prior public involvement and peer-reviewed scientific publications have helped to better inform the development and implementation of this HFE Protocol.

The idea for this HFE Protocol was first presented to the public, agencies, and tribes beginning with an announcement from the Secretary of the Interior, Ken Salazar, on December 10, 2009. This announcement was published in the *Federal Register* on December 31, 2009 (74 FR 69361) to develop an experimental high-flow protocol and to hold a public meeting of the AMWG in Phoenix, Arizona, on February 3-4, 2010 in order to provide scoping information for the EA process. Scoping from prior high-flow experiments was also included and used to discover alternatives, identify issues that needed to be analyzed in the EA, and to help develop mitigation measures for potentially adverse environmental impacts. Reclamation also had a meeting with the local businesses in Glen Canyon on August 20, 2010 and in December 2010, where comments on the proposed action were received (Reclamation 2010b).

In addition to scoping, Reclamation also used available information from an assimilation and synthesis of information by the U.S. Geological Survey on the three HFEs in Grand Canyon (Melis 2011). To benefit from the preliminary findings of this synthesis, a workshop was held in Salt Lake City on June 15-16, 2010. The information from of this workshop, as well as ongoing communications with GCMRC and the researchers involved in the synthesis, has also been used in the development of the HFE Protocol and in the analysis contained in this EA. Feedback from the public was received during the course of two review periods, from January 14 to March 18, 2011, and from July 5 to July 19, 2011. Each of these public reviews was preceded by cooperating agency reviews.