2 DESCRIPTION OF ALTERNATIVES

Seven alternatives, including the No Action Alternative, were developed for consideration in the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) Draft Environmental Impact Statement (DEIS). These alternatives were assigned letter designations of A through G, with Alternative A being the No Action Alternative.

Alternative A (the No Action Alternative) represents continued implementation of existing operations and actions as defined by existing agency decisions. The other six "action" alternatives represent various ways in which operations and actions could be modified under an LTEMP. Four of the action alternatives (Alternatives C, D [the preferred alternative], F, and G) were developed by the joint-lead agencies for the DEIS—Bureau of Reclamation (Reclamation) and National Park Service (NPS)—with various levels of participation by other U.S. Department of the Interior (DOI) agencies, including the Bureau of Indian Affairs (BIA), U.S. Fish and Wildlife Service (FWS), and U.S. Geological Survey's (USGS's) Grand Canyon Monitoring and Research Center (GCMRC), Argonne National Laboratory (Argonne), Western Area Power Administration (WAPA), and Arizona Game and Fish Department (AZGFD), and input and comments from Cooperating Agencies and Tribes. Two of the action alternatives were developed and submitted for consideration by two stakeholder organizations, the Colorado River Energy Distributors Association (CREDA; Alternative B) and the Colorado River Basin States Representatives from Arizona, California, Colorado, Utah, Nevada, New Mexico, and Wyoming, and the Upper Colorado River Commission (UCRC) (Basin States; Alternative E) in response to an offer made by the DOI in April 2012 to consider alternatives submitted by Cooperating Agencies and Adaptive Management Working Group (AMWG) members. Grand Canyon Trust and the Irrigation and Electrical Districts Association of Arizona submitted letters with comments on alternatives, but did not submit complete alternative proposals. In instances where the DOI made modifications to alternatives submitted by stakeholders, they are noted in the alternative descriptions below. The general process used to develop alternatives is described in Section 2.1, and characteristics of the alternatives are described in Section 2.2.

Several alternative concepts were identified by the public during scoping for the LTEMP DEIS (Argonne 2012):

- Decommission Glen Canyon Dam
- Fill Lake Mead first
- Grand Canyon first
- Maximum powerplant capacity operations
- Naturally patterned flows
- Run-of-the-river

- Species community and habitat-based alternative

- Stewardship alternative

- 12-year experiment of two steady-flow alternatives

- Year-round steady flows

These concepts were considered by Reclamation and NPS for detailed analysis during the alternative development process. In some cases, these were included as an LTEMP alternative, or elements were incorporated within one of the alternatives. In other cases, the concept was eliminated from consideration or further analysis because it did not meet the purpose, need, or objectives of the proposed action; clearly violated existing laws or regulations; or lacked enough specifics to be developed into a full and unique alternative (Section 2.3).

In addition to these submitted alternative concepts, the public identified a variety of specific elements that should be considered for inclusion in LTEMP DEIS alternatives. These elements were considered for inclusion by the joint-lead agencies as they developed LTEMP alternatives. Elements considered but not analyzed in detail are presented in Section 2.4.

2.1 DEVELOPMENT OF ALTERNATIVES

The alternative development process began with identification of the proposed action (i.e., development of an LTEMP), purpose and need of the LTEMP, and the objectives and resource goals of the LTEMP (Sections 1.1, 1.2, and 1.4, respectively). Once these items were defined, NPS and Reclamation worked to develop a set of alternatives that represented the full range of reasonable experimental and management actions; met the purpose, need, and objectives of the proposed action; and were considered within the constraints of existing laws, regulations, and existing decisions and agreements.

Alternative operations that either used different operational strategies (e.g., consistent monthly release pattern or condition-dependent release pattern) or had different primary objectives (e.g., native fish, sediment, or restoration of a more natural flow pattern) were developed and refined. In developing alternatives for detailed analysis, NPS and Reclamation considered and evaluated concepts identified by the public during scoping, alternatives that had been identified for the cancelled Long-Term Experimental Plan (LTEP) Environmental Impact Statement (EIS), and alternatives that had been identified in several efforts led by the Glen Canyon Dam Adaptive Management Program (GCDAMP) (USGS 2006, 2008).

An "alternative screening tool" was developed by the LTEMP EIS team to aid in the development of alternatives by providing preliminary analysis of alternative concepts; it subsequently helped to identify specific operational characteristics of alternatives (e.g., monthly volumes, daily ranges) that would meet the purpose, need, goals, and objectives of the proposed action. This spreadsheet tool used a set of simple models to produce a screening-level appraisal of the impacts of alternatives on flow, sediment (sand) transport, water temperature, humpback chub (*Gila cypha*) growth, trout recruitment, and hydropower value (generation and capacity).

The screening tool was used primarily for rapid prototyping of alternative concepts and to supplement a full analysis of impacts. It was also used to evaluate potential modifications to Alternative D, after modeling was completed on the effects of alternatives on hourly changes in flow and other resources for the 20-year LTEMP period. The screening tool focused on the effects of monthly, daily, and hourly flow patterns in single years rather than the effects of multiple years. The screening tool produced:

- Daily, monthly, and annual estimates of sediment transport (metric tons/year) based on Figure 4a from Rubin et al. (2002);
- Mean monthly temperature at river mile (RM) 61 (confluence with the Little Colorado River) and RM 225 based on Wright, Anderson et al. (2008);
- Mean monthly and annual total growth rates for humpback chub at RM 61 and 225 based on a growth-temperature regression in Robinson and Childs (2001);
- Annual estimates of trout recruitment based on an empirical relationship developed by Korman et al. (2012);
- Daily, monthly, and annual estimate of hydropower value based on the value of hydropower ($/MWh) at different hours of the day and using a conversion factor for cfs to MWh using information from the GTMax model (Palmer et al. 2007); and
- Annual estimate of hydropower capacity based on the value of power generated by maximum daily flows during the peak power month of August.

Several iterations of preliminary draft alternative concepts developed by NPS and Reclamation were presented to the Cooperating Agencies and other stakeholders in workshops and webinars to explain the alternative development process, describe proposed alternative characteristics, and solicit feedback. Workshops included (1) a facilitated public workshop on April 4 and 5, 2012; (2) Cooperating Agency and Tribal meetings on August 10, 2012; (3) Tribal workshops on March 14, 2013; (4) a stakeholder workshop on August 5–7, 2013; (5) a stakeholder workshop on March 31–April 1, 2014; and (6) a stakeholder webinar on December 3, 2015. There were also monthly calls with Cooperating Agencies that included updates and information exchange related to the alternatives.

Alternative D was identified by the DOI as the preferred alternative in the DEIS, and WAPA, the Basin States, and the National Parks Conservation Association submitted letters of support for this alternative before the DEIS was published. DOI received both positive and negative feedback about this alternative from other stakeholders (see Appendix Q). Alternative D was developed by the DOI based on the results of the analysis of the impacts of the other original set of six alternatives. Alternative D adopted many of the best-performing characteristics of

Alternatives C and E. The effects of operations under these latter two alternatives were first modeled, and the results of that modeling suggested ways in which characteristics of each could be combined and modified to improve performance, reduce impacts, and better meet the purpose, need, and objectives of the LTEMP. The impacts of Alternative D were then evaluated using the same models employed for other alternatives (Section 4.1), and these results served as the basis for the assessments presented in Chapter 4. Subsequent to that modeling, relatively minor modifications were made to Alternative D based on discussions with Cooperating Agencies, and with the support of screening tool analyses.

To aid in the alternative development process, formal decision analysis tools were also used for the LTEMP DEIS. Such tools are useful because the LTEMP concerns the management of a very complex system with many—possibly competing—resources of interest, and it involves uncertainty about the relationships between management strategies and the responses of resources to those strategies. A structured decision analysis process for LTEMP alternative development and evaluation was facilitated by Dr. Michael Runge of the USGS to obtain multiple stakeholder viewpoints. This was accomplished through a series of workshops and webinars involving LTEMP project managers; EIS analysts; technical representatives from FWS, BIA, WAPA, Arizona Department of Water Resources, and AZGFD; and other AMWG stakeholders. See Section 1.7 for additional information on the role of decision analysis in the LTEMP EIS process, and Appendix C for a complete description of the structured decision analysis process as applied to the LTEMP EIS.

2.2 DESCRIPTIONS OF ALTERNATIVES CONSIDERED IN DETAIL

This section describes the seven alternatives considered for detailed analysis in the LTEMP EIS. Operations under all of these alternatives would use only existing dam infrastructure. There are a number of experimental and management actions that would be incorporated into all of the LTEMP alternatives, except where noted:

- High flow releases for sediment conservation. Implementation of high-flow experiments (HFEs) under all alternatives are patterned after the current HFE protocol (Reclamation 2011b), but some alternatives include specific modifications related to the frequency of spring and fall HFEs, the duration of fall HFEs, the triggers for HFEs, and the overall process for implementation of HFEs, including implementation considerations and conditions that would result in discontinuing specific experiments. For Alternative D, the specific components of the HFE protocol that will be followed are provided in Appendix P. Other alternatives would adopt the existing HFE protocol without modification.

- Nonnative fish control actions. Implementation of control actions for nonnative brown and rainbow trout are patterned after those identified in the Nonnative Fish Control Environmental Assessment (EA) (Reclamation 2011a) and Finding of No Significant Impact (FONSI) (Reclamation 2012b), but some alternatives include specific modifications related to the area where control actions would occur, the specific actions to be implemented, and the overall process for implementation of control actions, including implementation considerations and conditions that would result in discontinuing specific experiments. Nonnative fish control actions are not included in Alternative F. For Alternative D, components of the Nonnative Fish Control EA and FONSI were modified and integrated with other actions in a tiered approach to humpback chub conservation. This tiered approach is described in Section 2.2.4.6 and Appendix O. Other alternatives would adopt the Nonnative Fish Control EA and FONSI actions without modification.

- Conservation measures established by FWS in previous Biological Opinions (BOs). Conservation measures identified in the 2011 BO on operations of Glen Canyon Dam (FWS 2011c) included the establishment of a humpback chub refuge, evaluation of the suitability of habitat in the lower Grand Canyon for the razorback sucker (*Xyrauchen texanus*), and establishment of an augmentation program for the razorback sucker, if appropriate. Other measures include humpback chub translocation; Bright Angel Creek brown trout control; Kanab ambersnail (*Oxyloma haydeni kanabensis*) monitoring; determination of the feasibility of flow options to control trout, including increasing daily down-ramp rates to strand or displace age-0 trout, and high flow followed by low flow to strand or displace age-0 trout; assessments of the effects of actions on humpback chub populations; sediment research to determine effects of equalization flows; and Asian tapeworm (*Bothriocephalus acheilognathi*) monitoring. Most of these conservation measures are ongoing and are elements of existing management practices (e.g., brown trout control, humpback chub translocation, and sediment research to determine the effects of equalization flows), while others are being considered for further action under the LTEMP (e.g., trout management flows [TMFs]). Additional conservation measures were developed for the preferred alternative during Endangered Species Act (ESA) Section 7 consultation with the FWS. These additional conservation measures are described in Appendix O. Other alternatives would adopt the existing conservation measures without modification.

- Non-flow experimental and management actions at specific sites such as nonnative plant removal, revegetation with native species, and mitigation at specific and appropriate cultural sites. Included are pilot experimental riparian vegetation treatment actions planned by NPS. These actions would also have involvement from Tribes to capture concerns regarding culturally significant native plants, and would provide an opportunity to integrate Traditional Ecological Knowledge in a more applied manner into the long-term program.

- Preservation of historic properties through a program of research, monitoring, and mitigation to address erosion and preservation of archeological and ethnographic sites and minimize loss of integrity at *National Register* historic properties.

- Continued adaptive management under the GCDAMP, including a research and monitoring component, as more fully discussed in Section 1.6.

With operational flows limited to 45,000 cfs and below, the overall extent of the riparian area in Grand Canyon is expected to continue to decrease, primarily as a result of continuing lack of water in the old high water zone and continued declines at the upper edges of the new high water zone; however, the vegetation density within the riparian area is expected to continue to increase. Nonnative vegetation and monoculture species such as arrowweed are expected to continue to increase, and key native species (e.g., Goodding's willow) are expected to continue to decrease.

Experimental riparian vegetation treatment activities would be implemented by NPS under all alternatives except for Alternative A and would modify the cover and distribution of riparian plant communities along the Colorado River. All activities would be consistent with NPS Management Policies (NPS 2006d) and would occur only within the Colorado River Ecosystem in areas that are influenced by dam operations. NPS will work with Tribal partners and GCMRC to experimentally implement and evaluate a number of vegetation control and native replanting activities on the riparian vegetation within the Colorado River Ecosystem in Grand Canyon National Park (GCNP) and Grand Canyon National Recreation Area (GCNRA). These activities would include ongoing monitoring and removal of selected nonnative plants, species in the corridor, systematic removal of nonnative vegetation at targeted sites, and native replanting at targeted sites and subreaches, which may include complete removal of tamarisk (both live and dead) and revegetation with native vegetation. Treatments would fall into two broad categories, including the control of nonnative plant species and revegetation with native plant species. Principal elements of this experimental riparian vegetation proposal include:

- Control nonnative plant species affected by dam operations, including tamarisk and other highly invasive species;

- Develop native plant materials for replanting through partnerships and the use of regional greenhouses;

- Replant native plant species to priority sites along the river corridor, including native species of interest to Tribes;

- Remove vegetation encroaching on campsites;

- Manage vegetation to assist with cultural site protection.

None of the alternatives include specific experimental tests or condition-dependent treatments for historic site preservation or Tribal cultural properties and resources other than operations and treatments intended to build and retain sandbars and targeted experimental vegetation actions in relation to cultural sites as described above. Continued evaluation of site stability and integrity would be undertaken as well as continued sediment evaluations, including those related to HFEs. Similarly, NPS's continued evaluation of Traditional Cultural Properties and resources of cultural concern would be evaluated in consultation with traditional practitioners and knowledgeable Tribal scholars. Mitigation would be undertaken to address resource impacts as determined necessary in consultation with Tribes.

In addition to these common elements, there are recent plans and decisions of the joint-lead agencies and DOI-identified management actions that could be implemented under all alternatives (Section 1.10.2). The Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a), together with existing laws and regulations, were used to establish "sideboards" that constrain the breadth and nature of flow and non-flow actions that were considered in the LTEMP alternatives.

Under all alternatives, release patterns could be adjusted to provide ancillary services, including regulation and reserves for hydropower. Regulation is the minute-by-minute changes in generation needed to maintain a constant voltage within a power control area. Regulation affects instantaneous operations that deviate above and below the mean hourly flow without affecting mean hourly flow. Spinning reserves in the control area served by the Colorado River Storage Project are typically provided by power resources in the Aspinall Unit, a series of three hydropower dams on the Gunnison River. However, under rare hydrological and power resource conditions, Aspinall power resources cannot provide spinning reserves. When this occurs, the spinning reserve duty is typically placed on the Glen Canyon Dam powerplant. In the event that these reserves are placed on Glen Canyon and at the same time need to be deployed in response to a grid event, such as a system unit outage or downed power line, WAPA would invoke emergency exception criteria and within minutes or less increase the Glen Canyon Dam power generation level up to the spinning reserve requirement. Associated turbine water release rates would increase in tandem with higher power production.

Operations described under any alternative would be altered temporarily to respond to emergencies. The North American Electric Reliability Corporation (NERC) has established guidelines for the emergency operations of interconnected power systems. A number of these guidelines apply to Glen Canyon Dam operations. These changes in operations would be of short duration (usually less than 4 hr) and would be the result of emergencies within the interconnected electrical system. Examples of system emergencies include insufficient generating capacity; transmission system overload, voltage control, and frequency; system restoration; and humanitarian situations (search and rescue).

The original Notice of Intent to prepare the LTEMP EIS identified the need to determine whether to establish a recovery implementation program for endangered fish species below Glen Canyon Dam. The LTEMP team finds that identifying the need to determine whether to establish a recovery implementation program (RIP) for endangered fish species below Glen Canyon Dam does not meet the purpose and need for the action (Section 1.2). This decision does not preclude the implementation of a RIP for endangered fish species below Glen Canyon Dam in the future. Although the GCDAMP has undertaken a number of actions that have previously been identified as necessary for the recovery of humpback chub in FWS recovery planning documents, the emphasis of that program is on mitigation and conservation actions specified in the National Environmental Policy Act (NEPA) and ESA Section 7 BOs for federal actions—not on the endangered fish species' overall needs to reach recovery.

Specific details of each of the LTEMP alternatives are described in Sections 2.2.1 to 2.2.7. Operational characteristics of LTEMP alternatives are presented in Table 2-1, and condition-dependent and experimental elements are summarized in Table 2-2. In the descriptions below, typical monthly flow patterns, including the mean, minimum, and maximum daily flows, are presented for each alternative in years with an annual release volume of 8.23 million ac-ft (maf). It is known that a wide range of hydrologic conditions will occur over the LTEMP implementation time frame in response to intra-annual and inter-annual variability in basin-wide precipitation cycles. Within a year, monthly operations are typically adjusted (increased or decreased) based on numerous factors. For example, adjustments may be made because of changing annual runoff forecasts, and, since 2007, application of the Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a). To model each LTEMP alternative, reservoir operation rules that represent how Glen Canyon Dam would be operated under the alternative were developed for a range of hydrologic conditions and equalization requirements.

2.2.1 Alternative A (No Action Alternative)

The Council on Environmental Quality (CEQ) requires inclusion of an "alternative of no action" (Title 40, *Code of Federal Regulations*, Part 1502.14(d) [40 CFR 1502.14(d)]), which serves as a baseline against which the impacts of "action" alternatives can be compared. For the LTEMP EIS, the No Action Alternative (referred to here as Alternative A) represents a situation in which the DOI would not modify existing decisions related to operations. Alternative A represents continued operation of Glen Canyon Dam as guided by the 1996 Record of Decision (ROD) for operations of Glen Canyon Dam: Modified Low Fluctuating Flow (MLFF), as modified by recent DOI decisions, including those specified in the 2007 ROD on Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (until 2026) (Reclamation 2007b), the HFE EA (Reclamation 2011b), and the Nonnative Fish Control EA (Reclamation 2011a) (both expiring in 2020). As is the case for all alternatives, Alternative A also includes implementation of existing and planned NPS management activities, with durations as specified in NPS management documents (see Section 1.10).

Under Alternative A, daily flow fluctuations would continue to be determined according to monthly volume brackets as follows: 5,000 cfs daily range for monthly volumes less than 600 kaf; 6,000 cfs daily range for monthly volumes between 600 kaf and 800 kaf; and 8,000 cfs for monthly volumes greater than 800 kaf. Other operating criteria specified in the 1996 ROD are identified in Table 2-1. Since 1996, operations under the 1996 ROD have typically resulted in higher monthly water volume allocations in the high electrical demand months of December, January, July, and August (Tables 2-1 and 2-3; Figure 2-1); operators have typically targeted releases of slightly above 800 kaf in these high demand months in order to achieve the maximum allowable daily fluctuation range (8,000 cfs). Figure 2-1 shows minimum, mean, and maximum daily flows in an 8.23 maf year, assuming all days in a month adhere to the same mean daily flow within a month. Figure 2-2 shows the hourly flows in a simulated 8.23-maf year within the constraints of Alternative A. Figure 2-3 shows details of hourly flows during a week in July.

TABLE 2-1 Operational Characteristics of LTEMP Alternatives

Elements of Base Operations[a]	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
Monthly pattern in release volume	Historic monthly release volumes. Higher volumes in high electric demand months of Dec., Jan., Jul., and Aug.; volume released in Oct.–Dec. = 2.0 maf in ≥ 8.23-maf years and 1.5 maf in years ≤ 7.48 maf	Same as Alternative A	Highest volume in high electric demand months of Dec., Jan., and Jul.; Feb.–Jun. volumes proportional to contract rate of delivery; lower volumes Aug.–Nov.	Comparable to Alternative E, but Aug. and Sep. volume increased, with additional volume taken from Jan.–Jul.; volume released in Oct.–Dec. = 2.0 maf in ≥ 8.23-maf years and 1.5 maf in years ≤ 7.48 maf	Monthly volumes proportional to the contract rate of delivery, but with a targeted reduction in Aug.–Oct. volumes; volume released in Oct.–Dec. = 2.0 maf in ≥ 8.23-maf years and 1.5 maf in years ≤ 7.48 maf	Relative to Alternative A, higher release volumes in Apr.–Jun.; lower volumes in remaining months	Equal monthly volumes, adjusted with changes in runoff forecast
Minimum flows (cfs)	8,000 between 7 a.m. and 7 p.m. 5,000 between 7 p.m. and 7 a.m.	Same as Alternative A	Same as Alternative A	Same as Alternative A	Same as Alternative A	5,000	5,000
Maximum non-experimental flows (cfs)[b]	25,000	Same as Alternative A	Same as Alternative A	Same as Alternative A	Same as Alternative A	Same as Alternative A	Same as Alternative A
Daily range (cfs/24 hr)[c]	5,000 for monthly volumes <600 kaf 6,000 for monthly volumes 600–800 kaf 8,000 for monthly volumes >800 kaf	Dec. and Jan.: 12,000 Feb., Jul., and Aug.: 10,000 Oct., Nov., Mar., Jun., and Sep.: 8,000 Apr. and May: 6,000	Equal to 7 × monthly volume (in kaf) in all months	Equal to 10 × monthly volume (in kaf) in Jun.–Aug., and 9 × monthly volume (in kaf) in other months; daily range not to exceed 8,000 cfs	Equal to 12 × monthly volume (in kaf) in Jun.–Aug., and 10 × monthly volume (in kaf) in other months	0 cfs[d]	0 cfs[d]

TABLE 2-1 (Cont.)

Elements of Base Operations[a]	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
Ramp rates (cfs/hr)	4,000 up 1,500 down	4,000 up 4,000 down in Nov.–Mar. 3,000 down in other months	4,000 up 2,500 down	4,000 up 2,500 down	4,000 up 2,500 down	4,000 up 1,500 down	4,000 up 1,500 down

[a] Base operations are defined as operations in those years when no condition-dependent or experimental actions are triggered. Examples of experimental actions include HFEs, low summer flows, and TMFs (see Table 2-2).

[b] Maximum flows presented are for normal operations and may be exceeded as necessary for HFEs, emergency operations, and equalization purposes.

[c] Values presented are the normal daily range in mean hourly flow for each alternative. Some variation in instantaneous flows within hours is allowed in all alternatives to accommodate emergency conditions, regulation requirements, and reserve requirements. For several alternatives, reduced fluctuations would be implemented after significant sediment inputs or after HFEs as described in Table 2-2.

[d] Hourly water release volumes would be nearly the same among all hours, while allowing for fluctuations in instantaneous flow rates to accommodate regulation services and calls on reserve generation to respond to system emergencies. Regulation affects instantaneous operations that deviate above and below the mean hourly flow with minimal impact on the mean hourly flow.

TABLE 2-2 Condition-Dependent and Experimental Elements of LTEMP Alternatives

Condition-Dependent Elements	Trigger[a] and Primary Objective	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
High-Flow Experiments (HFEs)								
Spring HFE up to 45,000 cfs in Mar. or Apr.	Trigger: Sufficient Paria River sediment input in spring accounting period (Dec.–Jun.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Implement when triggered through 2020 when protocol expires	Implement when triggered during entire LTEMP period, but not to exceed one spring or fall HFE every other year	Implement when triggered during entire LTEMP period	Implement when triggered during entire LTEMP period, but no spring HFEs in first 2 years, and no spring HFE in the same water year as an extended-duration (>96 hr) fall HFE	Implement when triggered during entire LTEMP period, except no spring HFEs in first 10 years	Implement when triggered during entire LTEMP period	Implement when triggered during entire LTEMP period
Proactive spring HFE in Apr., May, or Jun., with maximum possible 24-hr release up to 45,000 cfs	Trigger: High-volume equalization year (≥10 maf) Objective: To build beaches and protect sand supply otherwise exported by high equalization release	No	No	Yes, if no other spring HFE in same water year	Yes, if no other spring HFE or extended-duration fall HFE in same water year; no proactive spring HFE in first 2 years	No	No	Yes, if no other spring HFE in same water year

TABLE 2-2 (Cont.)

Condition-Dependent Elements	Trigger[a] and Primary Objective	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
High-Flow Experiments (HFEs) (Cont.)								
Fall HFE (Oct. or Nov.)	Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Implement when triggered through 2020 when protocol expires	Implement when triggered during entire LTEMP period, but not to exceed one spring or fall HFE every other year	Implement when triggered during entire LTEMP period	Implement when triggered during entire LTEMP period	Implement when triggered during entire LTEMP period	Implement when triggered during entire LTEMP period	Implement when triggered during entire LTEMP period
Fall HFEs longer than 96-hr duration	Trigger: Paria River sediment input in fall Objective: Rebuild sandbars	No	No	Yes, but HFE volume limited to that of a 45,000-cfs, 96-hr flow (357,000 ac-ft)	Yes, magnitude (up to 45,000 cfs) and duration (up to 250 hr[b]) dependent on sediment supply; limited to no more than four in a 20-year period	No	No	Yes, magnitude (up to 45,000 cfs) and duration (up to 336 hr) dependent on sediment supply
Adjustments to Base Operations								
Reduced fluctuations before HFEs (“load-following curtailment”)[c]	Trigger: Significant sediment input from Paria River in Dec.–Mar. or Jul.–Oct. Objective: Conserve sediment input for spring or fall HFE	No	No	Yes, in Feb. and Mar. (spring HFE) or Aug.–Oct. (fall HFE)	No	Yes, in Aug.–Oct. (fall HFE)	No change in operations, which already feature steady flows throughout the year	No change in operations, which already feature steady flows throughout the year

TABLE 2-2 (Cont.)

Condition-Dependent Elements	Trigger[a] and Primary Objective	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
Adjustments to Base Operations (Cont.)								
Reduced fluctuations after HFEs (“load-following curtailment”)[c]	Trigger: HFE Objective: Reduce erosion of newly built sandbars	No	No	Yes, until Dec. 1 after fall HFEs, or May 1 after spring HFEs	No	No	No change in operations, which already feature steady flows throughout the year	No change in operations, which already feature steady flows throughout the year
Low summer flows (Jul., Aug., Sep.)	Trigger: Number of adult humpback chub, temperature at Little Colorado River confluence, and release temperature Objective: Improve recruitment of chub in mainstem	No	No	Test if number of adult chub <7,000, <12°C at Little Colorado River confluence, and release temperature is sufficiently warm to achieve 13°C only if low flows are provided; within-day range 2,000 cfs	Test in second 10 years if release temperature is sufficiently warm to achieve 14°C only if low flows are provided; within-day range 2,000 cfs. If initial test is successful, implement under same conditions when humpback chub population concerns warrant its use.	Test in second 10 years if releases have been cold, number of adult chub ≥7,000, and temperature of at least 16°C can be reached	No change in operations, which already feature low flows during summer	No
Macro-invertebrate production flows	Trigger: None Objective: Increase invertebrate production especially mayflies, stoneflies, and caddisflies	No	No	No	Test, but avoid confounding effects on TMFs. Minimum monthly flow would be held constant on Saturdays and Sundays in May through Aug.	No	No	No

TABLE 2-2 (Cont.)

Condition-Dependent Elements	Trigger[a] and Primary Objective	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
Adjustments to Base Operations (Cont.)								
Hydropower improvement flows (increased fluctuation levels)	Trigger: Annual volume ≤8.23 maf Objective: Test effect on sediment, humpback chub, and trout	No	Maximum daily flow (held for as long as possible): 25,000 cfs (Dec.–Feb., Jun.–Aug.) 20,000 cfs (Sep.–Nov.) 15,000 cfs (Mar.–May) Minimum daily flow all months: 5,000 cfs Ramp rate up and down: 5,000 cfs/hr Test in 4 years	No	No	No	No	No
Trout Management Actions								
Trout management flows	Trigger: Predicted high trout recruitment in Glen Canyon reach Objective: Improve fishery, reduce emigration to Little Colorado River reach, and subsequent competition and predation on humpback chub	Test	Test and implement if successful	Test and implement if successful; tests in first 5 years not dependent on high trout population	Test and implement if successful; test may be conducted early in the 20-year period even if not triggered by high trout recruitment[d]	2 × 2 factorial design testing with/without HFE and with/without TMFs under warm and cold conditions	No	Test and implement if successful

TABLE 2-2 (Cont.)

Condition-Dependent Elements	Trigger[a] and Primary Objective	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
Non-Flow Actions								
Tier 1: Expanded translocation of humpback chub within the Little Colorado River	Trigger: Number of adult or subadult humpback chub in the Little Colorado River reach below Tier 1 triggers Objective: Increase number of adult and subadult humpback chub	No	No	No	Yes	No	No	No
Tier 1: Implement head-start program for larval humpback chub	Trigger: Number of adult or subadult humpback chub in the Little Colorado River reach below Tier 1 triggers Objective: Increase number of adult and subadult humpback chub	No	No	No	Yes	No	No	No
Mechanical removal of nonnative fish in Little Colorado River reach[e]	Trigger: High trout numbers and low humpback chub numbers in Little Colorado River reach Objective: Increase number of adult and subadult humpback chub	Trout numbers are above and humpback chub numbers are below Nonnative Fish Control EA and FONSI triggers in Little Colorado River reach; implemented until 2020	Trout numbers are above and humpback chub numbers are below Nonnative Fish Control EA and FONSI triggers in Little Colorado River reach; implemented for entire LTEMP period	Trout numbers are above and humpback chub numbers are below Nonnative Fish Control EA and FONSI triggers in Little Colorado River reach; implemented for entire LTEMP period	Trout numbers are above and humpback chub numbers are below Tier 2 triggers in Little Colorado River reach	Trout numbers are above and humpback chub numbers are below Nonnative Fish Control EA and FONSI triggers in Little Colorado River reach; implemented for entire LTEMP period	No	Trout numbers are above and humpback chub numbers are below Nonnative Fish Control EA and FONSI triggers in Little Colorado River reach; implemented for entire LTEMP period

TABLE 2-2 (Cont.)

Condition-Dependent Elements	Trigger[a] and Primary Objective	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)	Alternative E	Alternative F	Alternative G
Non-Flow Actions (Cont.)								
Riparian vegetation treatments	Trigger: None Objective: Improve vegetation conditions at key sites	No	Yes	Yes	Yes	Yes	Yes	Yes

[a] Triggers will be modified as needed during the 20-year LTEMP period in an adaptive manner through processes including ESA consultation and based on the best available science utilizing the experimental framework for each alternative.

[b] The duration of extended-duration HFEs would be increased stepwise; the first test of an extended-duration HFE under Alternative D would be limited to 192 hr; depending on the results of that first test, subsequent durations could be up to 250 hr. Sediment concentration in the river would be monitored during the HFE at least during the first test.

[c] Hourly water release volumes would be nearly the same among all hours, while allowing for fluctuations in instantaneous flow rates to accommodate regulation services and calls on reserve generation to respond to system emergencies. Regulation affects instantaneous operations that deviate above and below the mean hourly flow with minimal impact on the mean hourly flow.

[d] For Alternative D, the decision to conduct TMFs in a given year would consider the resource conditions, as specified in Section 2.2.4.3, and would also involve considerations regarding the efficacy of the test based on those resource conditions.

[e] Trout removal in the Paria River–Badger Rapids reach was assessed in the Nonnative Fish Protocol EA. However, it may not be practical based on the estimated level of effort needed to accomplish significant reductions in numbers of trout in the Little Colorado River reach when trout numbers are high in Marble Canyon (Appendix D in Reclamation 2011a).

TABLE 2-3 Flow Parameters under Alternative A in an 8.23-maf Year[a]

Month	Monthly Release Volume[b] (kaf)	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	600	0.0729	9,758	6,000
November	600	0.0729	10,083	6,000
December	800	0.0972	13,011	8,000
January	800	0.0972	13,011	8,000
February	600	0.0729	10,804	6,000
March	600	0.0729	9,758	6,000
April	600	0.0729	10,083	6,000
May	600	0.0729	9,758	6,000
June	650	0.0790	10,924	6,000
July	850	0.1033	13,824	8,000
August	900	0.1094	14,637	8,000
September	630	0.0765	10,588	6,000

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts and other factors, such as application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

[b] Values have been rounded.

Under the current HFE protocol (Reclamation 2011b), high-flow releases may be made in spring (March and April) or fall (October and November). HFE magnitude would range from 31,500 cfs to 45,000 cfs. The duration would range from less than 1 hr to 96 hr. Frequency of HFEs would be determined by tributary sediment inputs, resource conditions, and a decision process carried out by the DOI. The HFE protocol uses a "store and release" approach, in which sediment inputs are tracked over two accounting periods, one for each seasonal HFE: spring (December 1 through June 30) and fall (July 1 through November 30). Implementation of an HFE may require reallocating water from other months in order to maintain at least minimum flows (i.e., 5,000 to 8,000 cfs). The protocol would implement the maximum possible magnitude and duration of HFE that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling.

One purpose of the HFE protocol is to assess whether multiple, potentially sequential, HFEs conducted under consistent criteria could better conserve sediment resources while not adversely affecting other resources (Reclamation 2011b). The 10-year (2011–2020) experimental period of the protocol provides opportunities for multiple HFEs to be conducted and analyzed. Because necessary sediment and hydrology conditions may not occur every year, the 10-year period increases the likelihood that multiple experiments can be conducted. The protocol incorporates annual resource reviews to provide information that will help to ensure that unacceptable impacts do not occur.

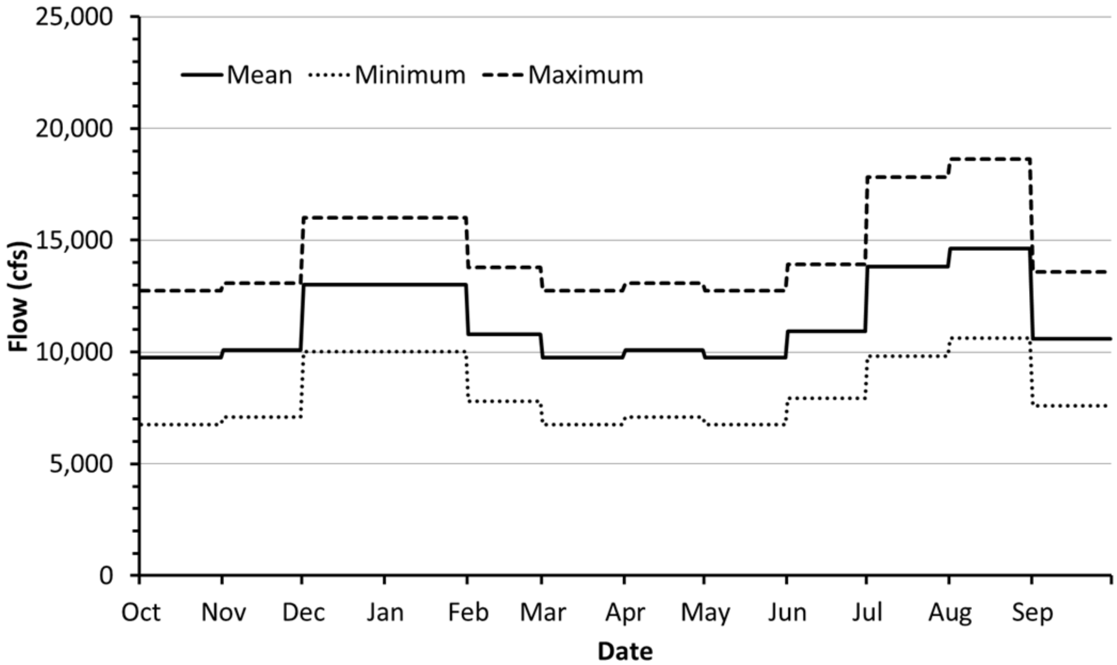


FIGURE 2-1 Mean, Minimum, and Maximum Daily Flows under Alternative A in an 8.23-maf Year Based on Values Presented in Table 2-3

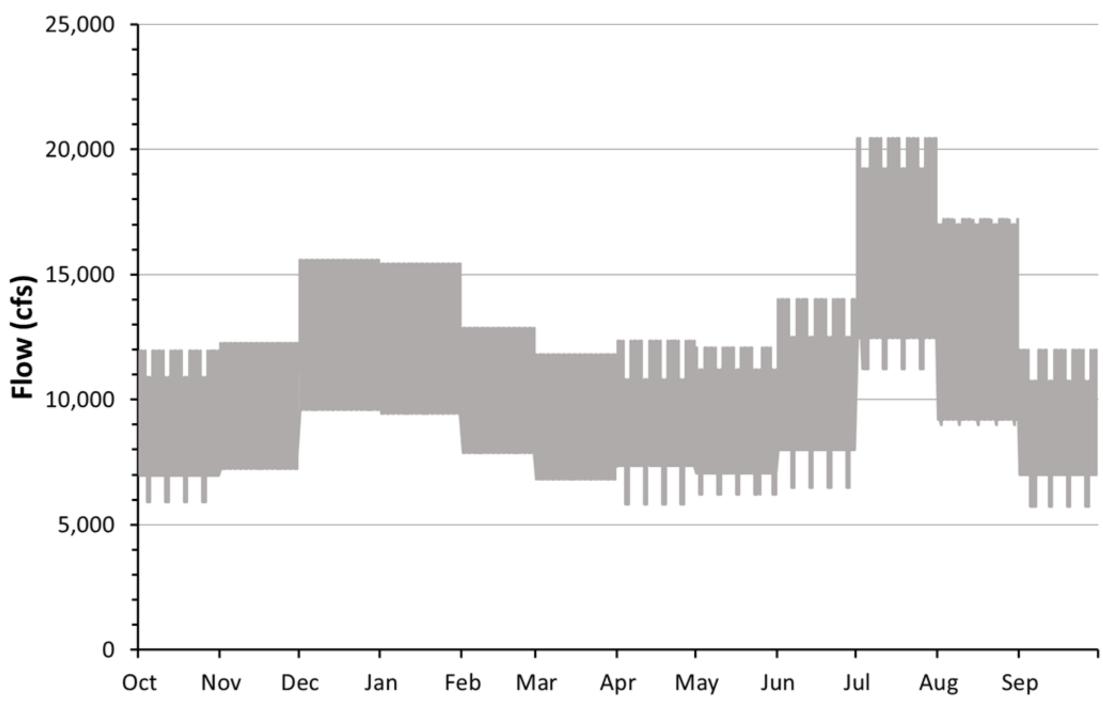


FIGURE 2-2 Simulated Hourly Flows under Alternative A in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 2-1. These differences reflect flexibility in operational patterns allowed within the constraints of the alternative.)

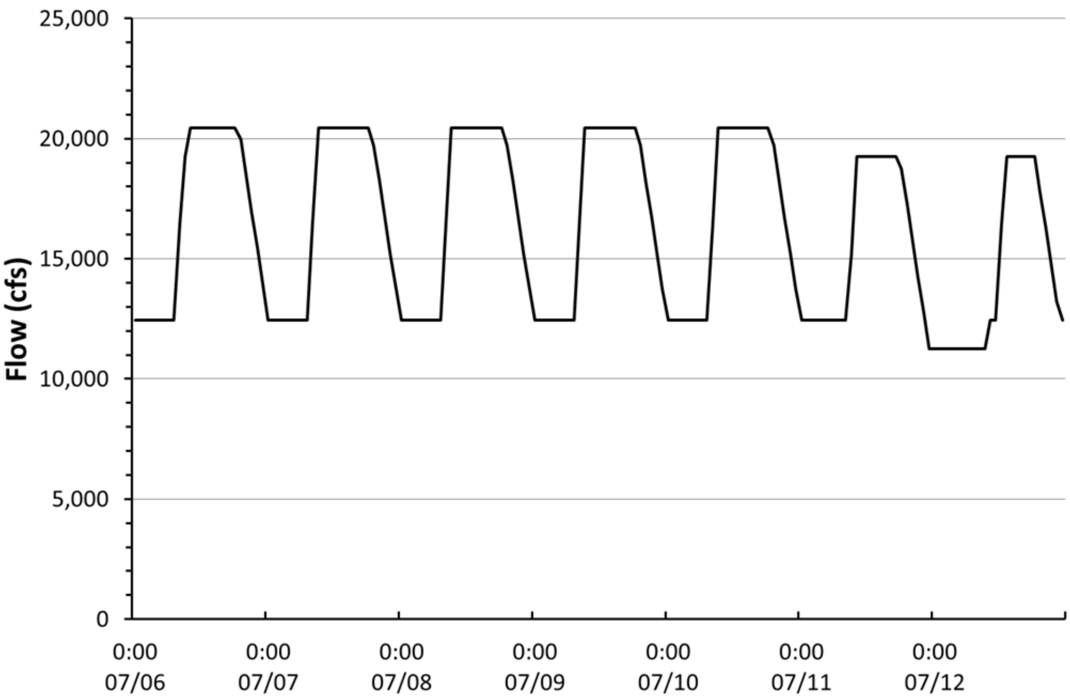


FIGURE 2-3 Simulated Hourly Flows under Alternative A for a Week in July in an 8.23-maf Year Showing Typically Lower Weekend Flows (The week starts on Monday and ends on Sunday.)

To date, three HFEs have been implemented using the HFE protocol,[1] and they took place on November 18–19, 2012 (24 hr at 42,300 cfs), November 11–16, 2013 (96 hr at 34,100 cfs), and November 10–15, 2014 (96 hr at 37,500 cfs).

Reclamation also recently established a 10-year protocol (to expire in 2020) for trout removal and tests of TMFs (Reclamation 2011a). In part, this protocol was established to coincide with the HFE protocol because there is evidence that HFEs may result in an increase in trout production (Korman, Kaplinski et al. 2011; Melis et al. 2011), which may have negative effects, through competition and predation, on humpback chub. Under the protocol, trout removal may occur in two reaches—the Paria River–Badger Rapids reach (RM 1–RM 8)[2] and the Little Colorado River reach (RM 56–RM 66). The impacts of implementing the protocol were originally described in the Nonnative Fish Control EA (Reclamation 2011a) and are further

1 In November 2015, there was sufficient sediment input from the Paria River to support a 96-hr HFE; however, an HFE was not implemented due to concerns that arose after the discovery of the invasive nonnative green sunfish (*Lepomis cyanellus*) in the Glen Canyon reach.

2 An initial planned test of trout removal in the Paria River–Badger Rapids reach in 2012 was cancelled due to concerns about whirling disease. Removal in the Paria River–Badger Rapids reach may not be practical based on the estimated level of effort needed to accomplish significant reductions in numbers of trout in the Little Colorado River reach when trout numbers are high in Marble Canyon (Appendix D in Reclamation 2011a).

analyzed in this EIS. Mechanical removal would primarily consist of the use of boat-mounted electrofishing equipment to remove all nonnative fish captured. Motorized electrofishing boats would operate during the night over a period of up to 2 weeks, utilizing gas generators to power lights and electrofishing equipment. Captured nonnative fish would be removed alive and potentially stocked into areas that have an approved stocking plan, unless live removal fails, in which case fish would be euthanized and used for later beneficial use (Reclamation 2011a). Since 2011, the presence of whirling disease prohibits live removal of trout due to the risk of spreading the disease to other waters.

Experimental components of Alternative A would be consistent with those that are part of the current program, including those detailed in the HFE and Nonnative Fish Control EAs and those identified as elements potentially common to all alternatives described above.

2.2.2 Alternative B

The objective of Alternative B is to increase hydropower generation while limiting impacts on other resources and relying on flow and non-flow actions to the extent possible to mitigate impacts of higher fluctuations. CREDA submitted this alternative for analysis and consideration in the LTEMP DEIS. The alternative is similar to the "Option A Variation," which was one of four options developed and evaluated by the GCDAMP and GCMRC in early planning efforts for the LTEP DEIS. Alternative B focuses on non-flow actions and experiments to address sediment resources, nonnative fish control, and native and nonnative fish communities. Alternative B originally included several elements that were determined to be either outside the scope of this EIS, were already part of a previous NEPA process, or were dismissed for other reasons. See Section 2.4 for elements that were considered but dismissed (i.e., sediment augmentation, bubblers in the Lake Powell forebay, bypass tube generators, and sediment check dams).

Under Alternative B, monthly volumes would be the same as under current operations, but daily flow fluctuations would be higher than under current operations in most months (Table 2-4; Figure 2-4). Increases would be greatest in February, which would have an approximately 66% increase in fluctuations over current operations (10,000 cfs versus the current 6,000 cfs range), while December and January would increase fluctuations approximately 50% (12,000 cfs versus the current 8,000 cfs range). Daily flow fluctuations would be increased by approximately 25% in March, June, September, October, and November (8,000 versus 6,000 cfs), and in July and August (10,000 versus 8,000 cfs). Fluctuations would remain unchanged relative to current operations (6,000 cfs) only in April and May (Tables 2-1, 2-2, and 2-4; Figure 2-4). Compared to current operations, the hourly up-ramp rate would remain unchanged at 4,000 cfs/hr, but the hourly down-ramp rate would be increased to 4,000 cfs/hr in November through March and 3,000 cfs/hr in other months. Figure 2-4 shows minimum, mean, and maximum daily flows in an 8.23-maf year, assuming all days in a month adhere to the same mean daily flow within a month. Figure 2-5 shows the hourly flows in a simulated 8.23-maf year within the constraints of Alternative B. Figure 2-6 shows details of hourly flows during a week in July.

TABLE 2-4 Flow Parameters under Alternative B in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	600	0.0729	9,758	8,000
November	600	0.0729	10,083	8,000
December	800	0.0972	13,011	12,000
January	800	0.0972	13,011	12,000
February	600	0.0729	10,804	10,000
March	600	0.0729	9,758	8,000
April	600	0.0729	10,083	6,000
May	600	0.0729	9,758	6,000
June	650	0.0790	10,924	8,000
July	850	0.1081	13,824	10,000
August	900	0.1045	14,637	10,000
September	630	0.0765	10,588	8,000

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts and other factors, such as application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

[b] Values have been rounded.

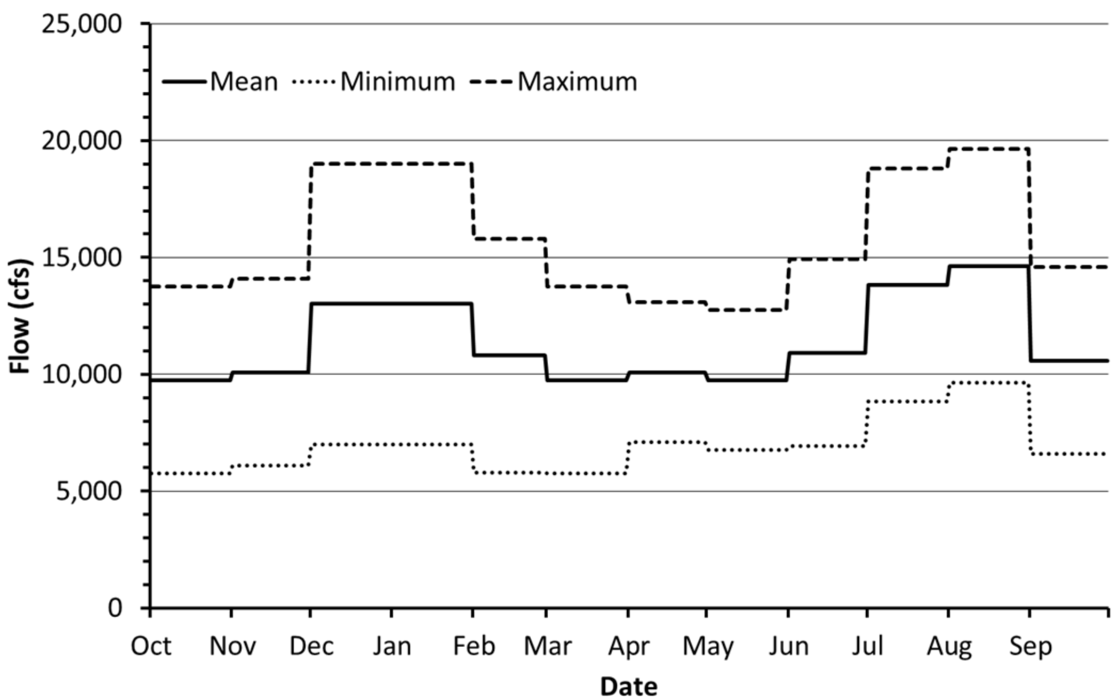


FIGURE 2-4 Mean, Minimum, and Maximum Daily Flows under Alternative B in an 8.23-maf Year Based on Values Presented in Table 2-4

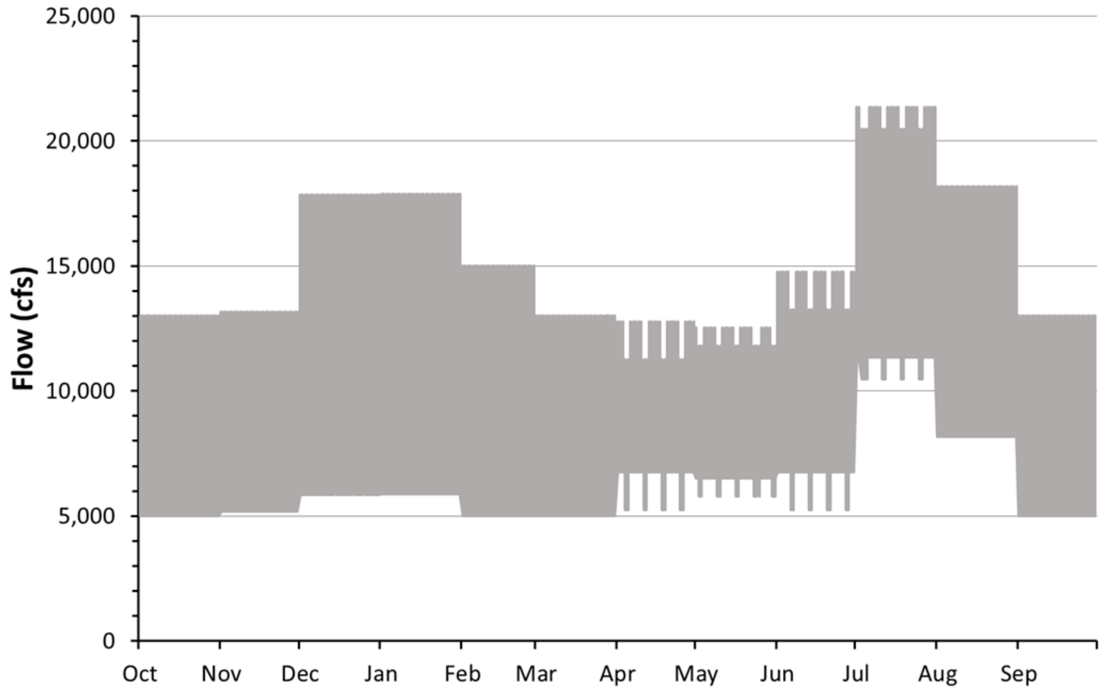


FIGURE 2-5 Simulated Hourly Flows under Alternative B in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 2-4. These differences reflect flexibility in operational patterns allowed within the constraints of the alternative.)

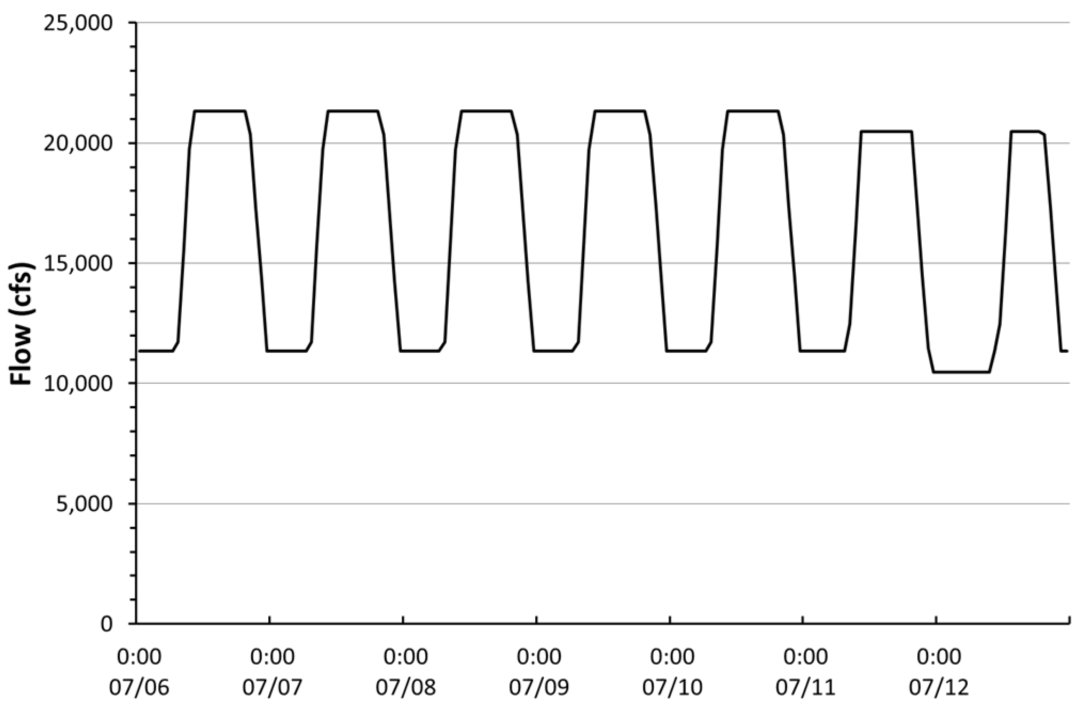


FIGURE 2-6 Simulated Hourly Flows under Alternative B for a Week in July in an 8.23-maf Year Showing Typically Lower Weekend Flows (The week starts on Monday and ends on Sunday.)

Alternative B includes these elements:

- Implementation of the Nonnative Fish Control protocol (Reclamation 2011a);
- Implementation of the HFE protocol (Reclamation 2011b), but limiting HFEs to a maximum of one every other year;
- Experimental vegetation removal and replanting activities where appropriate.

Experimental components of Alternative B would include those detailed in the HFE and Nonnative Fish Control EAs (Reclamation 2011a,b). Alternative B also includes experiments to analyze specific hypotheses. The specifics of the flows that would be tested in these experiments would be subject to reservoir levels, hydrologic conditions, powerplant maintenance, and economic considerations, and would include the following:

- **TMFs:** TMFs would maintain elevated flows for 2 or 3 days, followed by a very sharp drop in flows to a minimum level for the purpose of reducing annual recruitment of trout. TMFs are described in greater detail in Section 2.2.3.
- **Hydropower improvement experiment:** Alternative B includes testing maximum powerplant capacity releases in up to four years during the LTEMP period, but only in years with annual volumes ≤8.23 maf. Under hydropower improvement flows, within-day releases during the high-demand months of December, January, February, June, July, and August would vary between 5,000 cfs at night and 25,000 cfs during the day; from September through November within-day releases would vary from 5,000 to 20,000 cfs; and from March through May within-day releases would vary from 5,000 to 15,000 cfs (Figures 2-7, 2-8, and 2-9). Up- and down-ramp rates would be 5,000 cfs/hr throughout the year. Years with annual flows ≤8.23 maf typically require firming purchases by WAPA to meet contractual demand; thus, the experiment could mitigate some of those more costly purchases in the high-power months. The experiment is intended to evaluate the effects of maximum powerplant operations on critical resources in the Colorado River Ecosystem.

Under Alternative B, experimental treatments would be implemented as soon as feasible during the LTEMP period. Using this approach, experimental treatments would be implemented at the initiation of the LTEMP period, and they would be eliminated or retained based on their success in providing resource benefits and avoiding adverse resource impacts.

2.2.3 Alternative C

The objective of Alternative C is to adaptively operate Glen Canyon Dam to achieve a balance of resource objectives with priorities placed on humpback chub, sediment, and minimizing impacts on hydropower. Alternative C features a number of condition-dependent

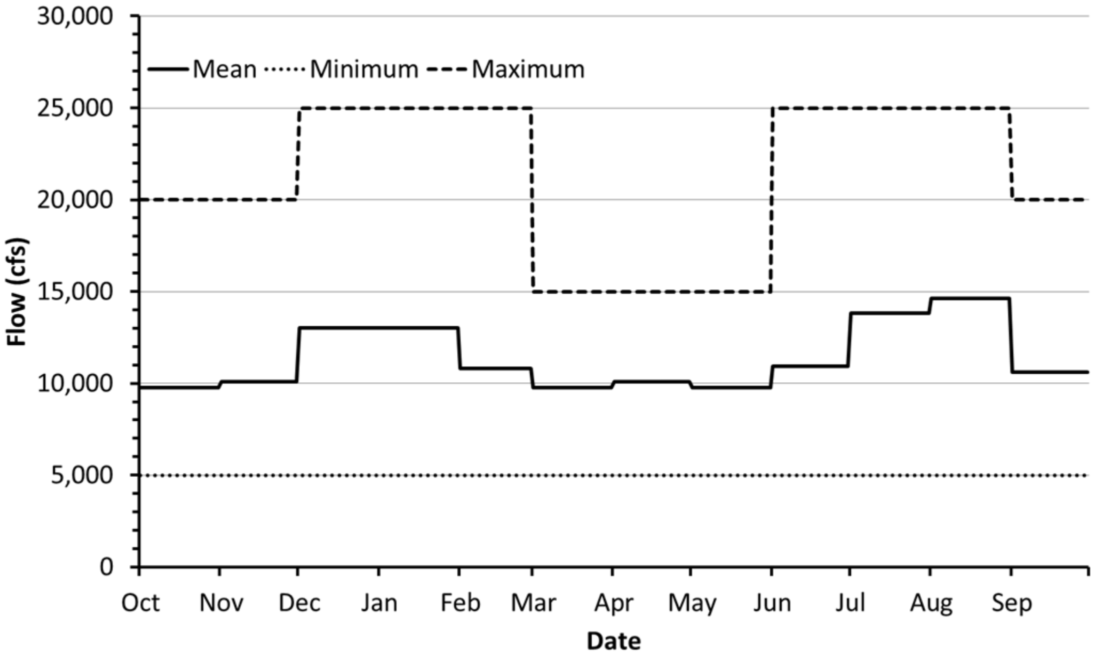


FIGURE 2-7 Example Mean, Minimum, and Maximum Daily Flows for a Hydropower Improvement Experiment under Alternative B in an 8.23-maf Year

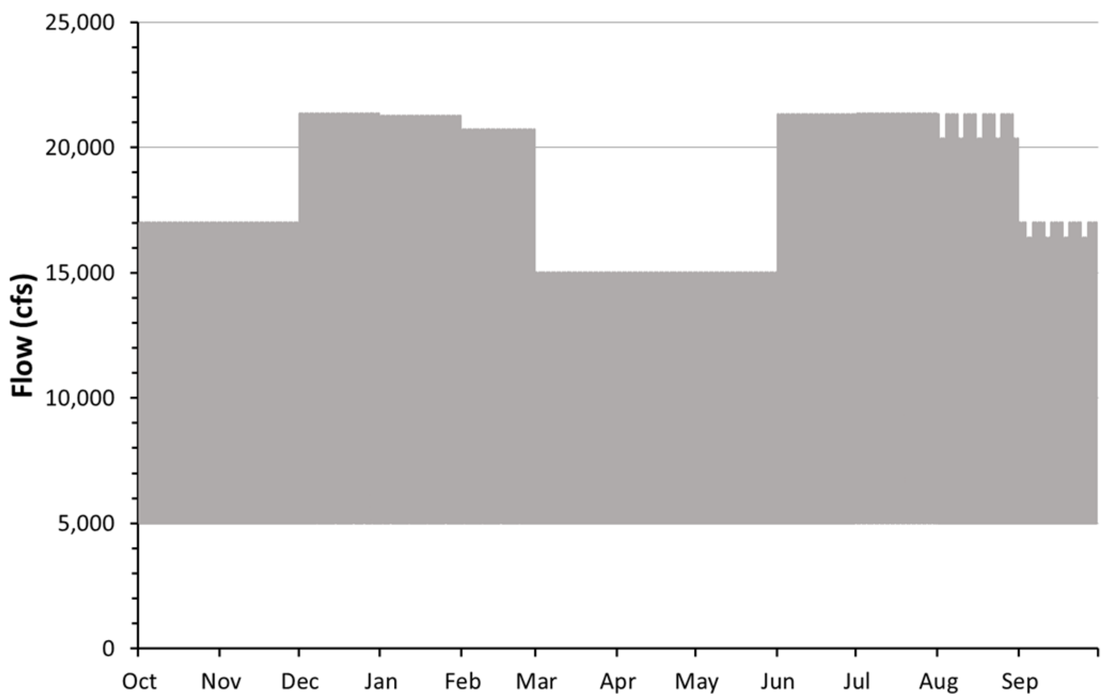


FIGURE 2-8 Simulated Hourly Flows for a Hydropower Improvement Experiment under Alternative B in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 2-7. These differences reflect flexibility in operational patterns allowed within the constraints of the alternative.)

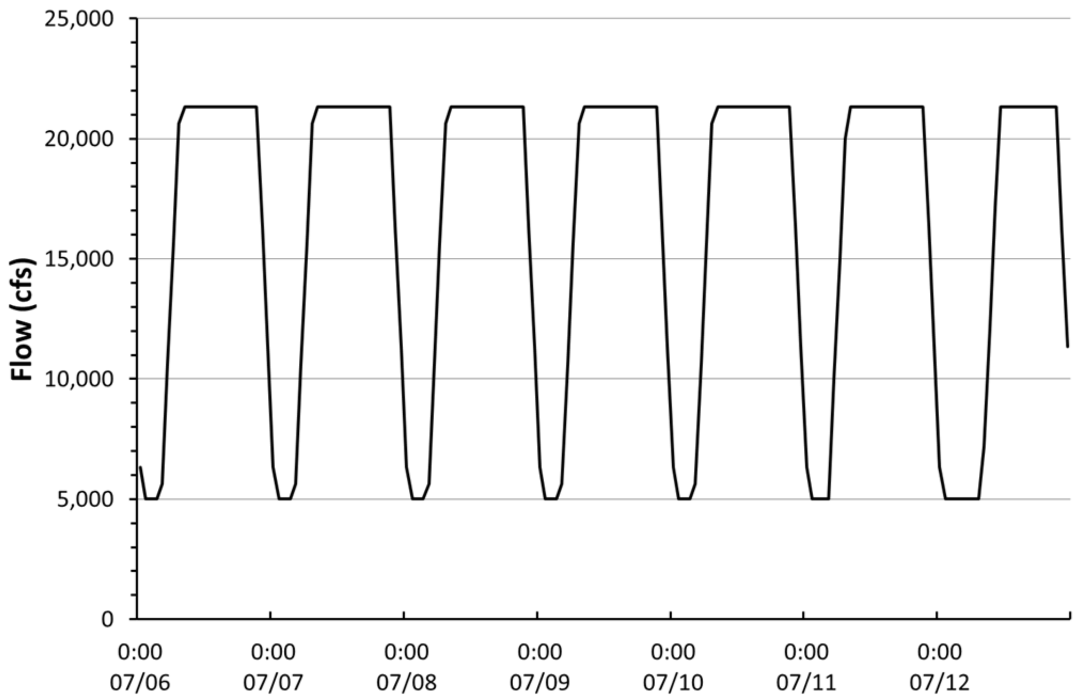


FIGURE 2-9 Simulated Hourly Flows for a Hydropower Improvement Experiment under Alternative B for a Week in July in an 8.23-maf Year (The week starts on Monday and ends on Sunday.)

flow and non-flow actions that would be triggered by resource conditions (Table 2-2). The alternative uses decision trees to identify when a change in base operations or some other planned action is needed to protect resources. Operational changes or implementation of non-flow actions could be triggered by changes in sediment input, humpback chub numbers and population structure, trout numbers, and water temperature.

2.2.3.1 Base Operations under Alternative C

Under base operations of Alternative C, monthly release volumes in August through November would be lower than those under most other alternatives to reduce sediment transport rates during the monsoon period. Release volumes in the high power demand months of December, January, and July would be increased to compensate for water not released in August through November, and volumes in February through June would be patterned to follow the monthly hydropower demand as defined by the contract rate of delivery (Tables 2-1 and 2-5; Figure 2-10).

TABLE 2-5 Flow Parameters under Alternative C in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	480	0.0583	7,806	3,360
November	480	0.0583	8,067	3,360
December	830	0.1009	13,499	5,810
January	830	0.1009	13,499	5,810
February	730	0.0887	13,148	5,111
March	771	0.0937	12,539	5,397
April	686	0.0833	11,524	4,800
May	710	0.0863	11,551	4,972
June	743	0.0903	12,485	5,200
July	830	0.1009	13,499	5,810
August	660	0.0802	10,734	4,620
September	480	0.0583	8,067	3,360

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts and other factors, such as application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

[b] Values have been rounded.

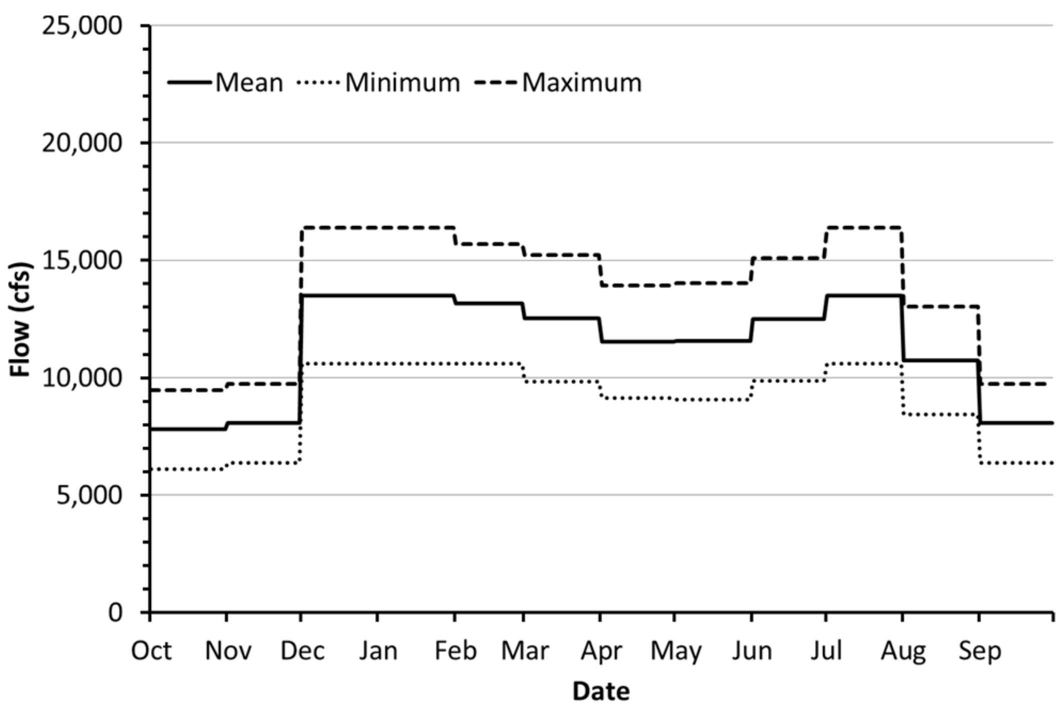


FIGURE 2-10 Mean, Minimum, and Maximum Daily Flows under Base Operations of Alternative C in an 8.23-maf Year Based on the Values Presented in Table 2-5

Reductions in August and September volumes also were intended to result in a slight increase in temperature relative to Alternative A at the confluence with the Little Colorado River. Warmer temperatures are expected to provide humpback chub and other native fish with some benefit during the critical time of year when many young-of-the-year (YOY) fish move from the Little Colorado River into the mainstem Colorado River.

Under base operations, the allowable within-day fluctuation range from Glen Canyon Dam would be proportional to monthly volume (7× monthly volume in kaf; e.g., daily range in a month with a volume of 800 kaf would be 5,600 cfs). The factor of 7 was chosen because it would provide improvement in sediment conservation relative to MLFF while limiting the effect on hydropower capacity and value. The down-ramp rate would be 2,500 cfs/hr (an increase from 1,500 cfs/hr under Alternative A); the up-ramp rate would be 4,000 cfs/hr as under Alternative A. Figure 2-10 shows minimum, mean, and maximum daily flows in an 8.23-maf year, assuming all days in a month adhere to the same mean daily flow within a month. Figure 2-11 shows the hourly flows in a simulated 8.23-maf year within the constraints of Alternative C. Figure 2-12 shows details of hourly flows during a week in July.

2.2.3.2 Implementation Process for Experiments under Alternative C

Alternative C adopts a condition-dependent experimental approach. The underlying approach is to adopt a base operation that would serve as a long-term strategy to provide the conditions needed to support natural and cultural resources while reducing impacts on hydropower. Since there is uncertainty regarding future hydrologic conditions, sediment supply, and resource response to operational, experimental, and environmental conditions, Alternative C identifies condition-dependent flow and non-flow actions intended to safeguard against unforeseen adverse changes in resource impacts, and to prevent irreversible changes.

Alternative C would use decision trees, tied to information collected under a long-term monitoring program, that would be implemented annually or, in some cases, as needed, to determine operations and flow and non-flow actions in a given year. Implementation would be closely integrated with existing operational and experimental decision processes involving Reclamation, NPS, USGS, and GCDAMP. Decision trees for sediment-related and humpback chub–related actions are shown in Figures 2-13 and 2-14.

Implementation criteria for experimental elements of Alternative C are provided in Table 2-6. Included are the triggers for tests, conditions that would prevent a test from being conducted (implementation considerations), conditions that would cause the test to be terminated prior to completion (off-ramps), and the number of replicates needed. In general, two to three replicates are considered necessary for all tests. Only two tests may be needed if consistent results are obtained for each replicate (e.g., both tests showed a benefit, or both showed an adverse effect). Three tests may be needed if the first two tests showed opposite results (i.e., one benefit, one adverse effect).

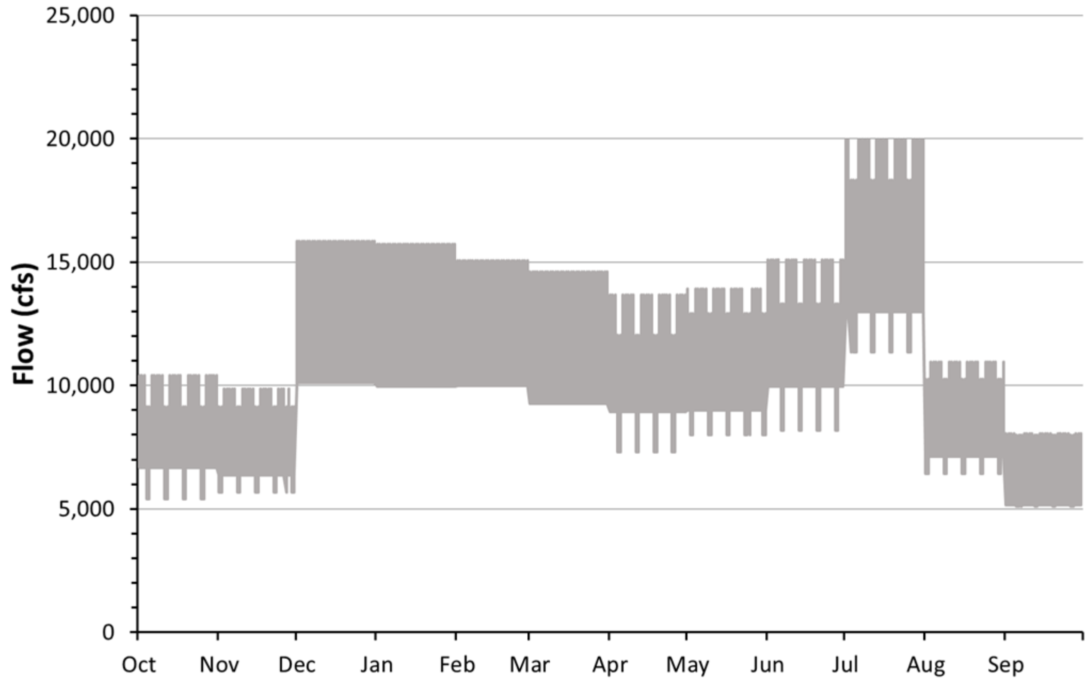


FIGURE 2-11 Simulated Hourly Flows under Alternative C in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 2-10. These differences reflect flexibility in operational patterns allowed within the constraints of the alternative.)

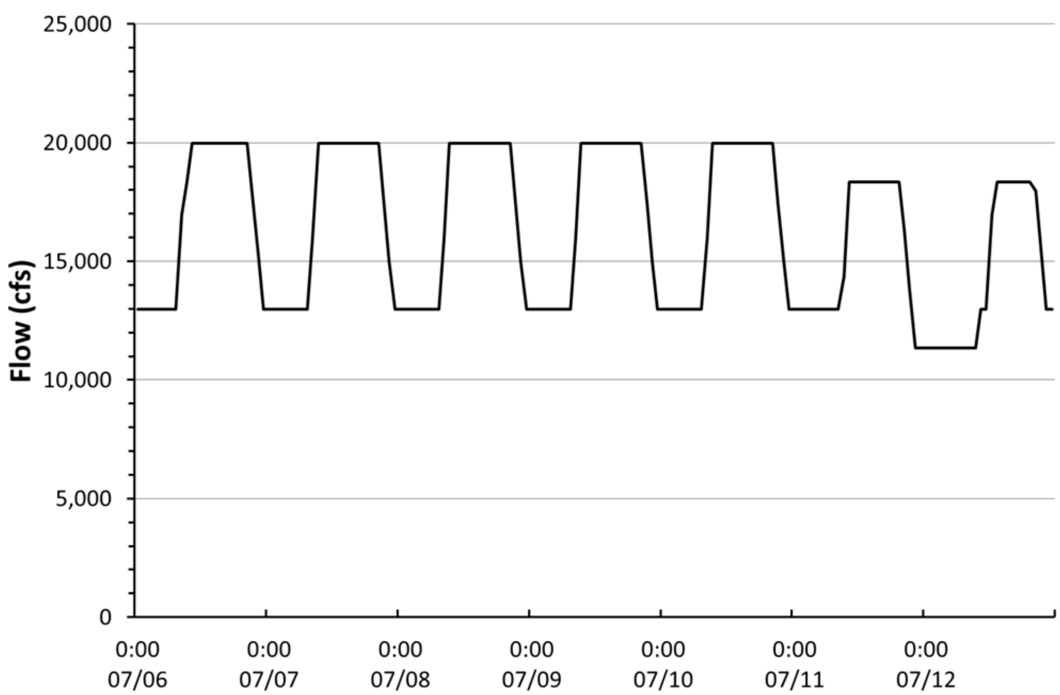
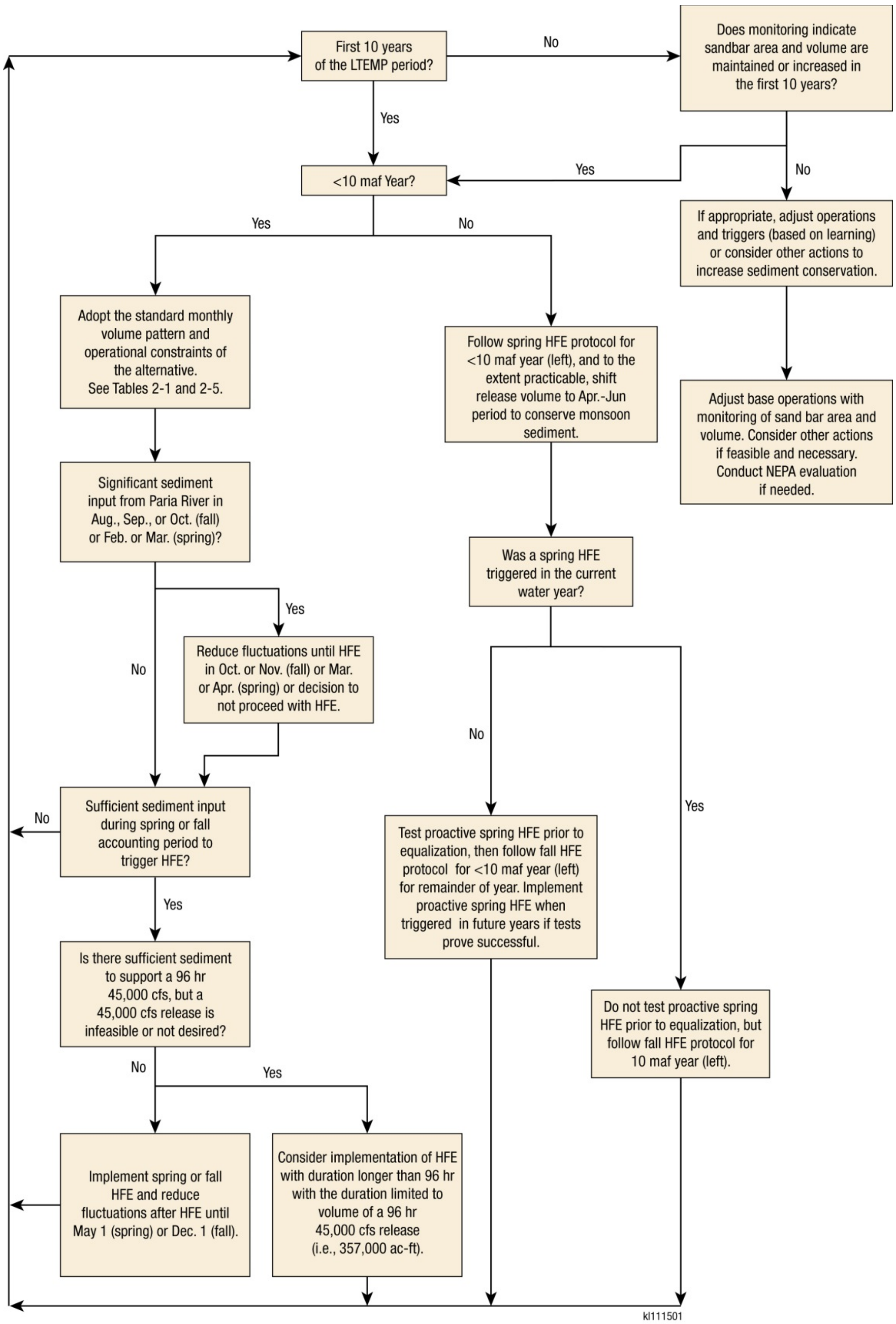


FIGURE 2-12 Simulated Hourly Flows under Alternative C for a Week in July in an 8.23-maf Year Showing Typically Lower Weekend Flows (The week starts on Monday and ends on Sunday.)



HFE = High-Flow Experiment
NEPA = National Environmental Policy Act

FIGURE 2-13 Decision Tree for Sediment-Related Actions under Alternative C (Implementation would be conditional on considerations presented in Table 2-6. If off-ramp conditions listed in Table 2-6 exist, related experimental treatments would be discontinued.)

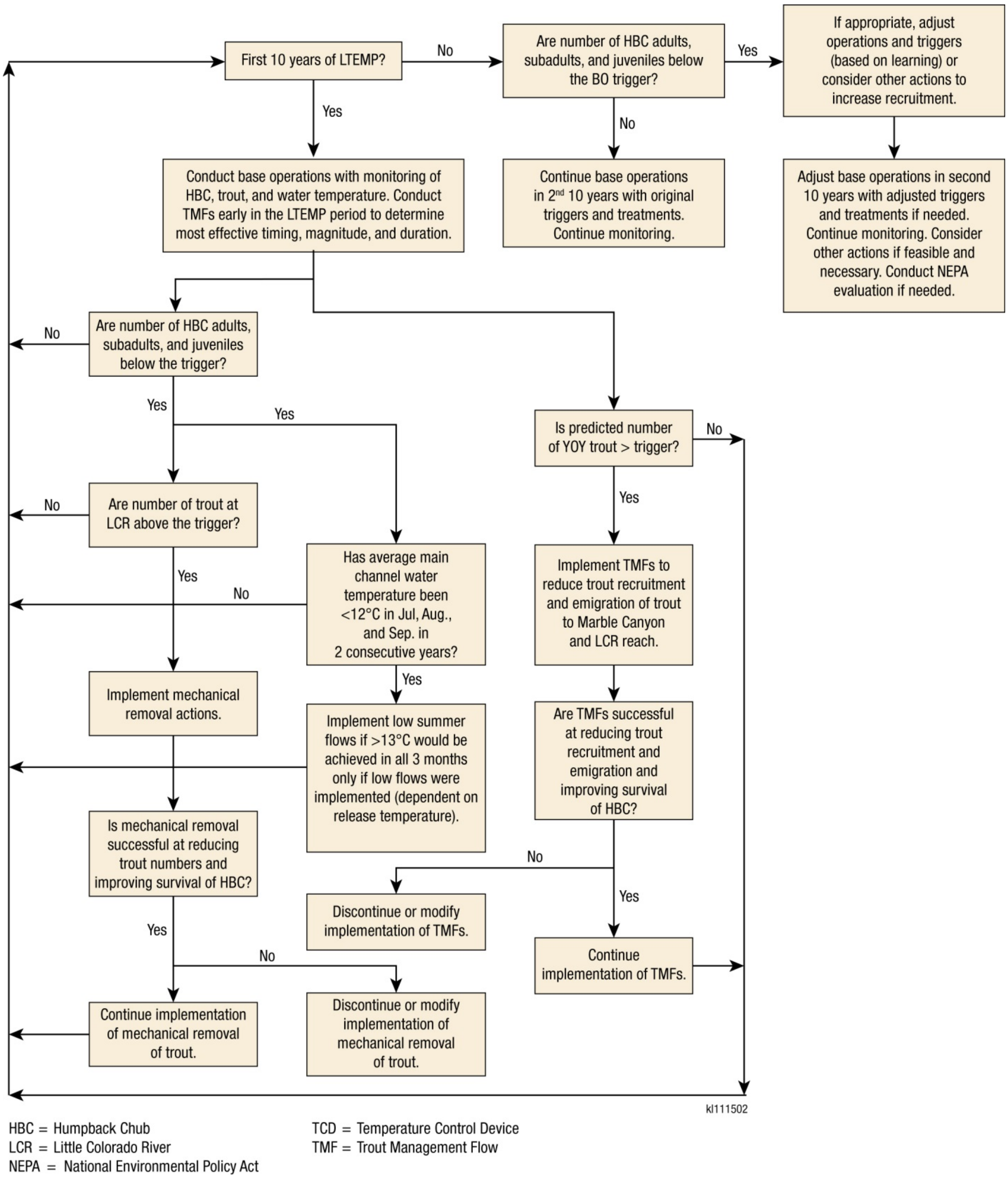


FIGURE 2-14 Decision Tree for Humpback Chub-Related Actions under Alternative C (Implementation would be conditional on considerations presented in Table 2-6. If off-ramp conditions listed in Table 2-6 exist, related experimental treatments would be discontinued.)

TABLE 2-6 Implementation Criteria for Experimental Treatments of Alternative C

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Sediment Experiments						
Spring HFE up to 45,000 cfs in Mar. or Apr.	Trigger: Sufficient Paria River sediment input in spring accounting period (Dec.–Jun.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Implement in each year triggered, dependent on resource condition and response	≤96 hr	Potential unacceptable impacts on water delivery or key resources such as humpback chub, sediment, riparian ecosystems, historic properties and traditional cultural properties, Tribal concerns, hydropower production and the Basin Fund, the rainbow trout fishery, recreation, and other resources; unacceptable cumulative effects of sequential HFEs	HFEs were not effective in building sandbars; or adverse impacts on the trout fishery, humpback chub population, or other resources	Implement as adaptive treatment when triggered and existing resource conditions allow
Proactive spring HFE up to 45,000 cfs (Apr., May, or Jun.)	Trigger: High-volume year with planned equalization releases (≥10 maf) Objective: Protect sand supply from balancing and equalization releases	Implement in each year triggered, dependent on resource condition and response	24 hr	Same as spring HFEs	Same as spring HFEs	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 2-6 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Sediment Experiments (Cont.)						
Fall HFE up to 45,000 cfs (Oct. or Nov.)	Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Implement in each year triggered, dependent on resource condition and response	≤96 hr	Potential unacceptable impacts on water delivery or key resources such as humpback chub, sediment, riparian ecosystems, historic properties and traditional cultural properties, Tribal concerns, hydropower production and the Basin Fund, the rainbow trout fishery, recreation, and other resources; unacceptable cumulative effects of sequential HFEs	Same as spring HFEs	Implement as adaptive treatment when triggered and existing resource conditions allow
Fall HFEs longer than 96-hr duration limited to the volume of a 96-hr 45,000-cfs release (357,000 ac-ft)	Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of a 96-hr 45,000-cfs HFE, but a 45,000-cfs release is either not possible due to turbine outages or not desired Objective: Mobilize as much sediment as possible within the volume constraints of the HFE protocol	Implement in each year triggered	Limited by the volume of a 96-hr 45,000-cfs release (357,000 ac-ft) (a 137-hr 31,500-cfs release would comply with this volume constraint)	Same as fall HFEs	HFEs were not effective in building sandbars and resulting sandbars were no bigger than those created by shorter-duration HFEs; or adverse impacts on the trout fishery, humpback chub population, or other resources	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 2-6 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Sediment Experiments (Cont.)						
Reduced fluctuations before and after HFEs (“load-following curtailment”)[d]	Trigger: Spring or fall HFE Objective: Retain sediment before HFE and reduce erosion of newly built sandbars after HFE	Implement when triggered	Up to 4 months before (Jul.–Nov.) and 2 months after (Oct. –Nov.)	Potential unacceptable impacts on water delivery or key resources such as humpback chub, sediment, riparian ecosystems, historic properties and traditional cultural properties, Tribal concerns, hydropower production and the Basin Fund, the rainbow trout fishery, recreation, and other resources	Resulting sandbars were no bigger than those created without reduced fluctuation; or adverse impacts on trout fishery, humpback chub population, or other resources	Implement as adaptive treatment in association with HFEs when existing resource conditions allow
Aquatic Resource Experiments						
Trout management flows	Trigger: Predicted high trout recruitment in the Glen Canyon reach Objective: Test efficacy of flow regime on trout numbers and competition and predation of chub	Implement as needed when triggered; test may be conducted early in the 20-year period even if not triggered by high trout recruitment; contingent on Tribal consultation	Implemented in as many as 4 months (May–Aug.)	Potential unacceptable impacts on water delivery or key resources such as humpback chub, sediment, riparian ecosystems, historic properties and traditional cultural properties, Tribal concerns, hydropower production and the Basin Fund, the rainbow trout fishery, recreation, and other resources	Little or no reduction in trout recruitment after at least three tests; or adverse impacts on trout fishery, humpback chub population, or other resources	Implement as adaptive treatment triggered by predicted high trout recruitment in Glen Canyon taking into consideration Tribal concerns

TABLE 2-6 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Aquatic Resource Experiments (Cont.)						
Mechanical removal of trout in Little Colorado River reach	Trigger: Number of trout in Little Colorado River reach and number of humpback chub Objective: Test efficacy of control on trout numbers and competition and predation of chub	Implement in each year triggered unless determined ineffective, contingent on Tribal consultation	Up to six monthly removal trips (Feb.–Jul.)	Potential unacceptable impacts on water delivery or key resources such as humpback chub, sediment, riparian ecosystems, historic properties and traditional cultural properties, Tribal concerns, hydropower production and the Basin Fund, the rainbow trout fishery, recreation, and other resources	Little or no reduction in trout density at the Little Colorado River, or unacceptable adverse impacts on humpback chub population or other resources	Implement as adaptive treatment when triggered taking into consideration Tribal concerns
Low summer flows (minimum daily mean 5,000 to 8,000 cfs) to target ≥13°C at Little Colorado River confluence	Trigger: Chub numbers are below trigger, water temperature has been <12°C for two consecutive years and target temperature of ≥13°C can only be achieved if drop to low flow Objective: Test efficacy of low summer flows on warming and humpback chub growth	If needed, two to three tests would be conducted in second 10 years of 20-year period; would not be implemented in first 10 years	3 months (Jul.– Sep.)	Potential unacceptable impacts on water delivery or key resources such as humpback chub, sediment, riparian ecosystems, historic properties and traditional cultural properties, Tribal concerns, hydropower production and the Basin Fund, the rainbow trout fishery, recreation, and other resources	No increase in growth and recruitment of humpback chub; increase in warmwater nonnative species or trout at the Little Colorado River; or adverse impacts on the trout fishery, humpback chub population, or other resources	Implement as adaptive treatment when conditions allow

TABLE 2-6 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Riparian Vegetation Experiment						
Non-flow vegetation treatment activities	Trigger: None Objective: Improve vegetation conditions at key sites	Not applicable	20 years if successful pilot phase	Potential unacceptable site-specific impacts on sediment, riparian ecosystems, historic properties and traditional cultural properties, Tribal concerns, recreation, or other resources	Control and replanting techniques not effective or practical	Implement as adaptive treatment if invasive species can be reduced and native species increased

a Triggers will be modified as needed during the 20-year LTEMP period in an adaptive manner through processes including ESA consultation and based on the best available science utilizing the experimental framework for each alternative.

b Annual determination by the DOI. Any implementation would consider resource condition assessments and resource concerns using the annual process described in Section 2.2.3.3.

c Temporary or permanent suspension if the DOI determines effects cannot be mitigated.

d Hourly water release volumes would be nearly the same among all hours, while allowing for fluctuations in instantaneous flow rates to accommodate regulation services and calls on reserve generation to respond to system emergencies. Regulation affects instantaneous operations that deviate above and below the mean hourly flow with minimal impact on the mean hourly flow.

In general, the first 10 years of base operations and strategic tests would be used to test the effects of operations and experimental elements on resources, to determine the strategy for the second 10 years of implementation, and, ultimately, to help determine a long-term strategy for Glen Canyon Dam operations and management actions that benefit important downstream resources, while minimizing impacts on hydropower to the extent practicable.

If sandbar area and volume are maintained or increased in the first 10 years of the LTEMP, the combination of base operations and HFE implementation would continue as prescribed above. If sandbar area and volume declines during the first 10 years of LTEMP, the HFE protocol and/or base operations may be modified, as allowable, to increase sediment conservation based on information learned in the first 10 years. In addition, the DOI would consider applicable planning processes for sediment augmentation and would conduct a separate NEPA evaluation of augmentation if it is considered feasible and necessary to prevent continued loss of sediment resources.

The relative effects of temperature and trout predation and/or competition on humpback chub recovery are uncertainties that affect the selection of a future management strategy; Alternative C would attempt to resolve this uncertainty. If after 10 years humpback chub are declining, nonstructural options for creating warmwater (i.e., flow manipulations) were not successful in providing warmer temperatures, and evidence suggests that trout control alone is not sufficient to improve humpback chub numbers, the DOI would consider a separate NEPA evaluation and other appropriate planning processes for a structural change such as a temperature control device (TCD). Research and monitoring during the first 10 years also could indicate that other factors (e.g., parasites, pathogens, warmwater nonnatives, or food base) are limiting humpback chub numbers. Such information would be used to develop additional condition-dependent actions or adjustments to base operations other than those included in the alternative at the start of the LTEMP.

No experimental flow actions are planned specifically for riparian vegetation under Alternative C. However, as described in the introduction to Section 2.2, a pilot experimental vegetation treatment program would be implemented under this and other alternatives to control nonnative vegetation encroachment and restore native vegetation at selected sites. If successful, vegetation treatment actions would be considered for inclusion as a regular non-flow action implemented throughout the LTEMP period. There are no specific experimental tests or condition-dependent actions that specifically focus on historic site preservation or Tribal cultural properties and resources other than operations and actions intended to reduce sediment transport in the active river channel. During the first 10 years of the LTEMP, continued evaluation of site stability and integrity would be undertaken in coordination with sediment evaluations consistent with the existing HFE protocol. Similarly, continued evaluation of Traditional Cultural Properties and resources of cultural concern would be evaluated by traditional practitioners and knowledgeable Tribal scholars. Mitigation would be undertaken to address resource impacts as determined necessary in consultation with Tribes. If monitoring indicates that historical properties preservation and Tribal cultural properties and resources are adversely affected by operations in the first 10 years of LTEMP implementation, the DOI would consider modification of operations to address aspects that, based on the results of monitoring and Tribal consultation, are causing degradation of these resources, and would consider an increase in non-flow actions, in consultation with the Tribes, to achieve these two resource goals.

Base operations under Alternative C would be experimentally modified in response to changes in resource conditions or the need for equalization as specified under the 2007 Interim Guidelines (Reclamation 2007a). The most important experiments relate to (1) implementation of HFEs in response to sediment inputs or equalization flows; (2) reductions in flow fluctuation in spring and fall in response to sediment inputs or the occurrence of HFEs; (3) flow actions in the spring and summer to control the Glen Canyon reach trout population; and (4) reductions in flows in certain years from July through September to provide warmer water for humpback chub near the confluence with the Little Colorado River. Non-flow actions are largely limited to those that are common to all alternatives as described at the beginning of Section 2.2.

2.2.3.3 Sediment-Related Experiments To Be Evaluated under Alternative C

Under Alternative C, the HFE protocol would be incorporated into the LTEMP process and extended to the end of the LTEMP period. Spring and fall HFEs would be implemented when triggered during the 20-year LTEMP period using the same Paria River sediment input thresholds as used under the existing HFE protocol (Reclamation 2011b). HFE releases would be 1 to 96 hr long and between 31,500 cfs and 45,000 cfs. Depending on the cumulative amount of sediment input from the Paria River during the spring (December 1 through June 30) or fall (July 1 through November 30) accounting periods, the maximum possible magnitude (not to exceed 45,000 cfs) and duration of HFE (up to approximately 140 hr) that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling, would be implemented (see Section 2.2.1 for a brief description of the existing HFE protocol).

Daily fluctuations for load-following would be reduced (except for instantaneous increases or decreases in flow to provide ancillary services)[3] after significant sediment input (sufficient input to trigger an HFE) from the Paria River in February or March (in anticipation of a spring HFE); or August, September, or October (in anticipation of a fall HFE) to increase the amount of sediment available for transport and deposition by spring and fall HFEs. These reduced fluctuations would occur until an HFE was implemented or a decision to not implement an HFE was made. If an HFE was implemented, the restriction in daily fluctuations would continue after the HFE occurred until May 1 (spring HFE) or December 1 (fall HFE) to reduce the erosion of newly formed sandbars. Under Alternative C, within-day fluctuations in hourly flows would be reduced to a within-day range of 2,000 cfs (i.e., ±1,000 cfs of the mean daily flow).

Sandbar monitoring after the 2011 equalization releases indicated that high rates of sandbar erosion and sediment transport occurred during equalization. To offset these high

[3] Instantaneous changes in flows could occur within an hour to accommodate regulation services and calls on reserve generation to respond to system emergencies. Regulation affects instantaneous operations that deviate above and below the mean hourly flow with minimal impact on the mean hourly flow.

erosion and transport rates, Alternative C includes a proactive spring HFE in years when the April forecast indicates an annual release ≥10 maf. In these years, a 24-hr spring high flow (up to 45,000 cfs) would be tested prior to the occurrence of high equalization releases to determine the effectiveness of using high flows to conserve sediment downstream of the Paria River confluence above the elevation of equalization flows. The high flow would be timed to occur after the need for equalization has been determined, but before it was actually implemented. This would likely result in proactive spring HFEs occurring in May or June.

Under Alternative C, a proactive spring HFE would not be tested if there had been a spring HFE in the same water year. In high-volume years (≥10 maf) when there were no proactive spring HFEs, higher monthly volumes would be shifted to the April through June time period to the extent practicable to avoid sustained higher monthly flows and sediment transport rates at the end of the year.

The existing HFE protocol allows for HFEs up to 96 hr long, but there will be some years when a 45,000-cfs HFE is not feasible (e.g., one or more generating units are not available) and a longer duration release would be possible and desirable to achieve sediment goals. Under Alternative C, longer duration HFEs that did not exceed the total volume of a 96-hr, 45,000-cfs HFE (i.e., 357,000 ac-ft) would be allowed.

2.2.3.4 Aquatic Resource-Related Experiments To Be Evaluated under Alternative C

Under Alternative C, experimental flow and non-flow actions could be triggered by estimated numbers of rainbow trout, a combination of estimated numbers of rainbow trout and humpback chub, or measured water release temperature at Glen Canyon Dam, depending on the action under consideration. Humpback chub triggers and trout triggers would be developed with FWS, and there would be consultation with the AZGFD and other entities as appropriate. These triggers may be modified based on experimentation conducted early in the LTEMP period.

The humpback chub population in Grand Canyon has increased considerably under MLFF operations since the early 2000s. During this period, relatively warmer temperatures began to be reached at the Little Colorado River confluence as a consequence of lower reservoir elevations and concomitantly higher release temperatures; this warming may have contributed to the increase in humpback chub recruitment (Section 3.5.3). Base operations under Alternative C are intended to support continued and possibly improved humpback chub recruitment. Ongoing monitoring would be used to determine the need to adjust base operations to benefit humpback chub.

Under Alternative C, water temperature and trout numbers would be considered when determining the actions to take when chub numbers drop below the trigger levels identified above. Triggers for temperature and trout numbers would be used under Alternative C to trigger two potential actions: (1) low summer flows and (2) mechanical removal of trout. These are discussed individually below.

Two types of trout control actions are considered under Alternative C: (1) TMFs; and (2) mechanical removal. Both of these experimental actions could be implemented to reduce trout competition with and predation of humpback chub in the Little Colorado River reach or to manage the Glen Canyon rainbow trout fishery.

Mechanical Removal of Trout under Alternative C

Mechanical removal would occur at the Little Colorado River confluence (rainbow and brown trout) and would follow the protocol evaluated in the Nonnative Fish Control EA (Reclamation 2011a; see Section 2.2.1 of this EIS for a brief description of the protocol). Mechanical removal in the Little Colorado River reach (RM 56–RM 66) would be triggered by low humpback chub and high trout abundance estimates in the Little Colorado River reach. Mechanical removal, however, may be initiated in response to ongoing management of the trout fishery by the NPS (an element common to all alternatives) or in response to declining humpback chub numbers. The DOI recognizes that lethal mechanical removal is a concern for Tribes, particularly the Pueblo of Zuni, because it is a taking of life in the canyon. To the extent practicable, removal practices would include finding beneficial uses for removed fish, as has been practiced for trout removal actions at Bright Angel Creek.

Trout Management Flows under Alternative C

TMFs are a special type of fluctuating flow designed to reduce the recruitment of trout by disadvantaging YOY trout (Figure 2-15). TMFs have been proposed and developed on the basis of research described in Korman et al. (2005). The underlying premise of TMFs is based on observations that YOY trout tend to occupy near-shore shallow-water habitats to avoid predation by larger fish. TMFs feature repeated fluctuation cycles that consist of relatively high flows (e.g., 20,000 cfs) sustained for a period of time (potentially ranging from 2 days to 1 week) followed by a rapid drop to a very low flow (e.g., 5,000 cfs to 8,000 cfs).[4] This low flow would be maintained for a period of less than a day (e.g., 12 hr) to prevent adverse effects on the food base. Low flows would be timed to start in the morning, after sunrise, to expose stranded fish to direct sunlight and heat. Up-ramp rates to the TMF would be the same as the limit for this alternative overall (i.e., 4,000 cfs/hr). The down-ramp from peak to base would be over a single hour (e.g., 15,000 cfs/hr for a drop from 20,000 cfs to 5,000 cfs). In a TMF flow cycle, YOY trout are expected to occupy near-shore habitat when flows are highest, and would be stranded by the sudden drop to low flow. Because older age classes of trout tend to occupy deeper habitats toward the middle of the river channel, they are less susceptible to stranding and are less likely to be directly affected by TMFs. TMFs would be used to control trout recruitment in the Glen Canyon reach to manage the rainbow trout fishery, and to limit emigration of juvenile trout to downstream reaches, particularly to habitat occupied by humpback chub near the confluence

[4] TMFs have the potential to result in stranding of boats in the Glen Canyon reach, as well as a potential risk to public safety. Public notification and outreach in advance of implementing TMFs, as is currently done for planned HFEs, would be necessary to avoid safety concerns.

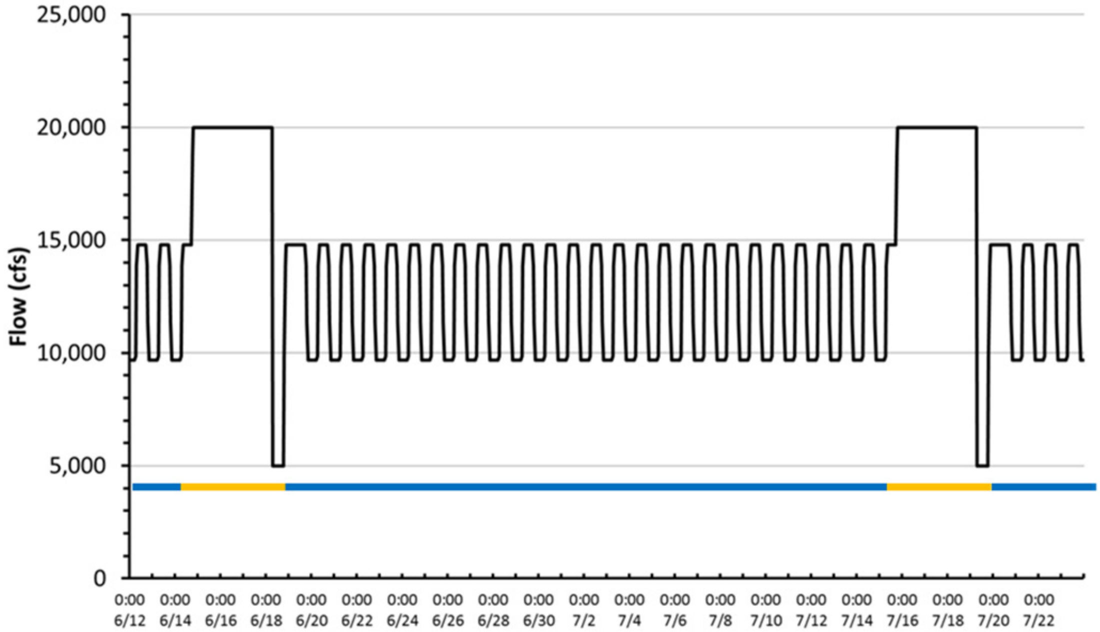


FIGURE 2-15 Example Implementation of a Two-Cycle TMF in June and July with Resumption of Normal Fluctuations between Cycles and Afterward (Monitoring for effectiveness would occur before and after each cycle. The horizontal line below the graph shows periods of normal fluctuation [blue] and TMFs [orange].)

with the Little Colorado River. Triggers for implementation of TMFs would be determined in consultation with the AZGFD.

It should be noted that several Tribes have expressed concerns about TMFs as a taking of life within the canyon without a beneficial use. The Pueblo of Zuni has expressed concern that the taking of life by trout stranding has an adverse effect on the Zuni value system. The joint-lead agencies will continue to work with the Tribes regarding options for trout management.

TMFs may be tested under this alternative early in the LTEMP period, even if not triggered by high trout recruitment. The intent of these early tests would be to determine the effectiveness of TMFs in reducing trout recruitment and the emigration of young trout to Marble Canyon and the Little Colorado River reach. The condition of the trout fishery, as determined in consultation with AZGFD, and potential impacts on other important resources would be considered prior to implementing TMFs. If TMFs are determined to be effective for these goals while minimizing impacts on other resources, they may be deployed on a regular or triggered basis. TMFs would be tested two to three times in the early part of the LTEMP period while attempting to minimize confounding effects with other experimental treatments. Tests would start with a conservative application of two cycles in June and July (Figure 2-15), but could be increased based on experimental testing to as many as three cycles per month for 3 months (May, June, and July).

Low Summer Flows under Alternative C

If water temperatures at the Little Colorado River confluence have been relatively cold (i.e., do not exceed 12°C, the minimum temperature for humpback chub growth) in two consecutive years,[5] low summer flows (no lower than a mean daily flow of 5,000 cfs) would be provided if the water released from the dam is sufficiently warm to result in at least 13°C at the confluence in the months of July, August, and September. A target temperature of 13°C was chosen because it represents an improvement over the minimum temperature needed for growth, 12°C. Note that reduction in summer flows would necessitate increasing flows in other months relative to base operations (Table 2-7; Figure 2-16).

The ability to achieve target temperatures at the Little Colorado River confluence by providing lower flows is dependent on release temperatures, which are in turn dependent on reservoir elevation. For example, using the temperature model of Wright, Anderson et al. (2008), in an 8.23-maf year, release temperatures of 9.6°C, 9.8°C, and 10.5°C would be needed in July, August, and September, respectively, to achieve a target temperature of 13°C at the Little Colorado River confluence at flows of 8,000 cfs.

Release temperatures fall into three categories for any temperature target: (1) too low to warm to target temperature even at low flow; (2) high enough to warm to target temperature only if low flows (5,000 cfs to 8,000 cfs) are provided; and (3) high enough to achieve target temperature regardless of the flow level. Low flows would only be triggered in years that fell into the second category. This is a fairly rare situation; modeling of 63 20-year periods determined that low summer flows would be triggered in at most four years per 20-year period.

A decision to conduct low summer flows in a year would be made by May 1. Such a decision would be based on reservoir and temperature modeling and other resource conditions, in addition to annual water delivery requirements. Because fluctuations have relatively little effect on mainstem water temperature and humpback chub, minor within-day flow fluctuations (i.e., ±1,000 cfs) would be allowed. If triggered, low summer flows would be provided in at least 2 years (not necessarily consecutive), and the response of chub would be determined.

2.2.4 Alternative D (Preferred Alternative)

The objective of Alternative D (the preferred alternative) is to adaptively operate Glen Canyon Dam to best meet the resource goals of the LTEMP (Section 1.4). Like Alternative C, Alternative D features condition-dependent flow and non-flow actions that would be triggered by resource conditions.

Alternative D was developed by the DOI after a full analysis of the other six LTEMP alternatives had been completed. This alternative was identified as the preferred alternative by

5 This temperature trigger is the same as that identified by FWS in the Nonnative Fish Control BO (FWS 2011c).

TABLE 2-7 Flow Parameters for a Year with Low Summer Flows under Alternative C in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	480	0.0583	7,806	3,360
November	480	0.0583	8,067	3,360
December	830	0.1009	13,499	5,810
January	830	0.1009	13,499	5,810
February	730	0.0887	13,148	5,111
March	771	0.0937	12,539	5,397
April	849	0.1032	14,273	5,945
May	880	0.1069	14,306	6,157
June	920	0.1118	15,462	6,440
July	492	0.0598	8,000	2,000
August	492	0.0598	8,000	2,000
September	476	0.0578	8,000	2,000

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts or other factors, and based on application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

[b] Values have been rounded.

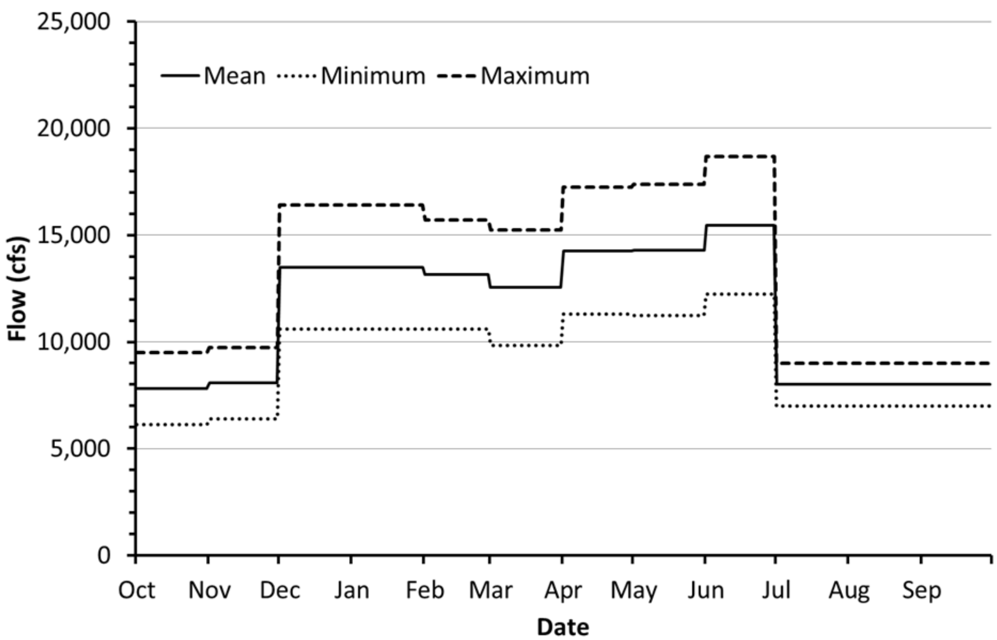


FIGURE 2-16 Mean, Minimum, and Maximum Daily Flows under Triggered Low Summer Flows of Alternative C in an 8.23-maf Year Based on the Values Presented in Table 2-6

the DOI, and its identification as the preferred alternative was supported by WAPA and the Basin States. Alternative D was also considered the environmentally preferred alternative, based on its relative impacts (compared to other alternatives) on the full range of environmental resources. Alternative D adopts operational and experimental characteristics from Alternative C and Alternative E. The effects of operations under Alternatives C and E were modeled, and the results of that modeling suggested ways in which characteristics of each could be combined and modified to improve performance and reduce impacts, while meeting the purpose, need, and objectives of the LTEMP EIS. Alternative D is expected to result in an improvement in conditions for humpback chub, trout, and the aquatic food base; have the least impact on vegetation, wetlands, and terrestrial wildlife; improve sandbar building potential and conserve sediment; sustain or improve conditions for reservoir and river recreation; improve preservation of cultural resources; respect and enhance Tribal resources and values; and have limited impacts on hydropower resources.

On the basis of modeling results for Alternative C and E, discussions with subject matter experts and Cooperating Agencies, and specific impact analyses of various potential Alternative D characteristics conducted using the screening tool (see Section 2.1 for a discussion of the models integrated in the screening tool), the DOI developed the operational and experimental characteristics of Alternative D. This formulation of the alternative then was modeled with the same models used for the analysis of the original six alternatives.

Adjustments were made to Alternative D after the integrated multiple-resource modeling, illustrated in Figure 4-1, was completed in March 2015, prior to the release of the DEIS in January 2016. This modeling considered a full-range of hydrology and sediment conditions, as described in Section 4.1. Adjustments to Alternative D included (1) an increase in release volume in August with corresponding decreases in May and June (in an 8.23-maf year, the increase was 50 kaf in August, i.e., from 750 to 800 kaf; and a reduction of 25 kaf each in May and June; these changes were applied proportionally to monthly volumes in drier and wetter years); (2) elimination of load-following curtailment prior to sediment-triggered HFEs; (3) an adjustment of the duration of load-following curtailment after a fall HFE; and (4) a prohibition on sediment-triggered spring HFEs in the same water year as an extended-duration (>96 hr) fall HFE. Adjustments made to Alternative D after the DEIS was published, and based on comments received from Cooperating Agencies and stakeholders on the DEIS, included (1) elimination of load-following curtailment after a fall HFE and (2) a prohibition on proactive spring HFEs in the same water year as an extended-duration fall HFE.

The description of Alternative D provided in this section represents the final version of the alternative that resulted from these changes.

Once the adjustments to Alternative D were made, analyzing them using multiple-resource modeling would have taken many months and incurred significant additional cost. Therefore, instead of performing multiple-resource modeling on the effects of these adjustments, the joint-leads chose to perform streamlined modeling using the screening tool (see Section 2.1 for a description of this modeling tool) and analysis to assess the magnitude and direction of these effects of the adjustments. As described in Section 4.1, for most resources, these adjustments to Alternative D are expected to result in little if any change in impacts relative to those predicted for the earlier modeled version of Alternative D. However, the streamlined analysis did show that the adjustments would result in some changes to the expected impacts on sediment and hydropower resources, but that for all resources other than hydropower these changes would not affect the relative performance of Alternative D compared to other alternatives (see discussion in Section 4.1). Because the adjustments to Alternative D would not change Alternative D's relative performance for most resources, and the changes to hydropower impacts would be reductions—not increases—in impact, the agencies chose not to perform additional multiple-resource modeling. In addition to presenting the original multiple-resource modeling results, the results of the streamlined modeling evaluating the effects of these adjustments on sediment and hydropower are presented in Sections 4.3.3.4 and 4.13.3.4, respectively. Because, for most resources, these adjustments are expected to result in little if any change in impact relative to those predicted for the earlier modeled version of Alternative D, the only quantitative analysis results presented in those sections of the EIS are those from the original multiple-resource modeling.

Operational characteristics of Alternative D are presented in Table 2-1, and condition-dependent experimental elements are summarized in Table 2-2. The alternative uses decision trees to identify when a change in the implementation of experimental actions may be considered; however, DOI will retain sufficient flexibility in the implementation of experiments to ensure the protection of resources (Section 2.2.4.3). Experimental flows and non-flow actions could be triggered by changes in sediment input, humpback chub numbers and population structure, trout numbers, and water temperature after consideration of effects on all resources. Alternative D differs from Alternatives C and E in the specific trigger conditions and actions that would be taken.

2.2.4.1 Base Operations under Alternative D

Under Alternative D, the pattern of monthly releases would be relatively even compared to under Alternative A. The total monthly release volume of October, November, and December would be equal to that under Alternative A (i.e., 2 maf in years with ≥ 8.23 maf annual release volume) to avoid the possibility of the operational tier differing from that of Alternative A, as established in the Interim Guidelines (Reclamation 2007a). The August volume was set to a moderate volume level (800 kaf in an 8.23-maf release year) to consider both sediment conservation prior to a potential HFE and power-production and capacity concerns. January through July monthly volumes were set at levels that roughly track WAPA's contract rate of delivery (CROD). This produced a redistribution of monthly release volumes under Alternative D that would result in the most even distribution of flows of any alternative except for Alternative G.

Under base operations of Alternative D, the allowable within-day fluctuation range from Glen Canyon Dam would be proportional to the volume of water scheduled to be released during the month (10 × monthly volume in kaf in the high-demand months of June, July, and August and 9 × monthly volume in kaf in other months; Table 2-8; Figure 2-17). For example, the daily fluctuation range in July with a scheduled release volume of 800 kaf would be 8,000 cfs, and the daily fluctuation range in December with the same scheduled release volume would be 7,200 cfs.

TABLE 2-8 Flow Parameters under Alternative D in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	643	0.0781	10,451	5,783
November	642	0.0780	10,781	5,774
December	716	0.0870	11,643	6,443
January	763	0.0927	12,409	6,867
February	675	0.0820	12,154	6,075
March	713	0.0866	11,596	6,417
April	635	0.0772	10,672	5,715
May	632	0.0768	10,278	5,688
June	663	0.0806	11,142	6,630
July	749	0.0910	12,181	7,490
August	800	0.0972	13,011	8,000
September	600	0.0729	10,083	5,400

[a] Within a year, monthly operations may be increased or decreased based on factors referenced in Section 2.2.4.2.

[b] Values have been rounded.

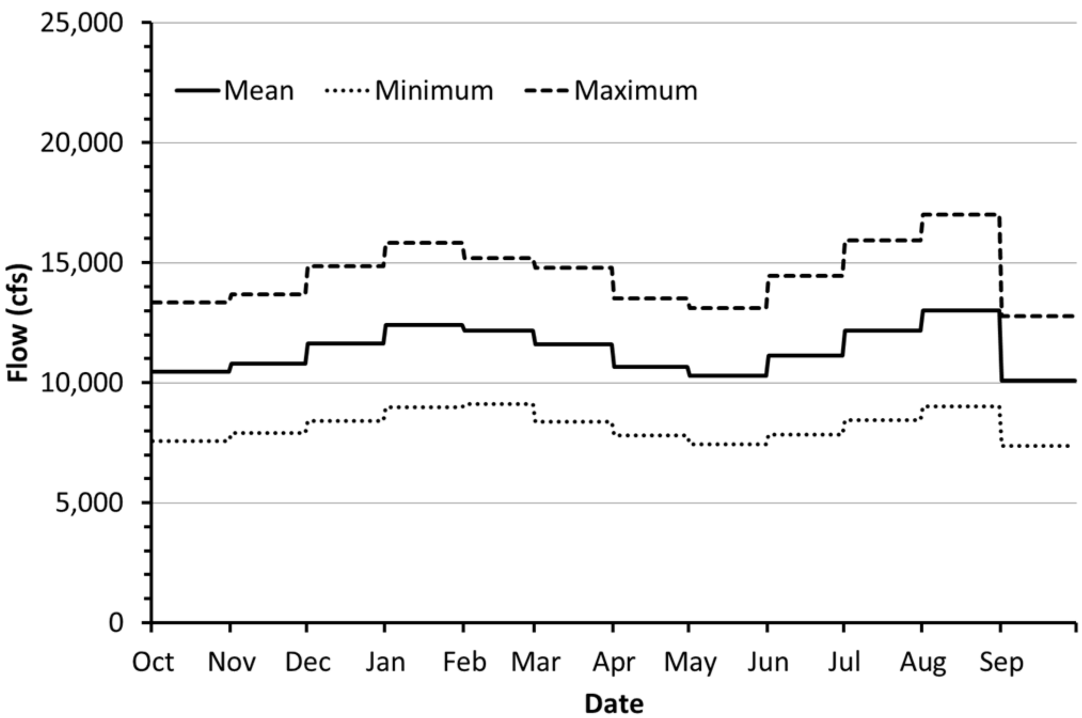


FIGURE 2-17 Mean, Minimum, and Maximum Daily Flows under Alternative D in an 8.23-maf Year Based on Values Presented in Table 2-8

The maximum allowable daily fluctuation range in flows in any month would be 8,000 cfs, which is also the maximum daily fluctuation range under Alternative A.

An 8,000-cfs maximum daily fluctuation limit was established in the 1996 ROD (Reclamation 2006) to address safety, recreation, and sediment concerns (Reclamation 1995). The analysis conducted for the LTEMP EIS has not identified new evidence to suggest that these concerns are no longer relevant or that this fluctuation limit is no longer appropriate. The determination of 8,000 cfs as a maximum daily fluctuation level that is suitable for recreation was based on Bishop et al. (1995). Bishop et al. surveyed both the river guides and the general public regarding preferences, and the river guides reported a preference for a maximum of 8,000 cfs daily change for a "tolerable recreation experience" under relatively high average daily flows. The current river guide community has continued to state the preference for retaining the 8,000-cfs maximum daily fluctuation that is currently in place.

The down-ramp rate under Alternative D would be limited to no greater than 2,500 cfs/hr, which is 1,000 cfs/hr greater than what is allowed under Alternative A. The up-ramp rate would be 4,000 cfs/hr, and this is the same as what is allowed under Alternative A.

Figure 2-17 shows minimum, mean, and maximum daily flows in an 8.23-maf year, assuming all days in a month adhere to the same mean daily flow within a month. Figure 2-18 shows the hourly flows in a simulated 8.23-maf year within the constraints of Alternative D. Figure 2-19 shows details of hourly flows during a week in July.

Annually, Reclamation will develop a hydrograph based on the characteristics above. Reclamation will seek consensus on the annual hydrograph through monthly operational coordination calls with governmental entities, and regular meetings of the GCDAMP Technical Working Group (TWG) and AMWG. Reclamation will conduct monthly Glen Canyon Dam operational coordination meetings or calls with the DOI bureaus (USGS, NPS, FWS, and BIA), WAPA, and representatives from the Basin States and UCRC. The purpose of these meetings or calls is for the participants to share and seek information on Glen Canyon Dam operations. One liaison from each Basin State and from the UCRC may participate in the monthly operational coordination meetings or calls.

2.2.4.2 Operational Flexibility under Alternative D

Reclamation retains the authority to utilize operational flexibility at Glen Canyon Dam because hydrologic conditions of the Colorado River Basin (or the operational conditions of Colorado River reservoirs) cannot be completely known in advance. Consistent with current operations, Reclamation, in consultation with WAPA, will make specific adjustments to daily and monthly release volumes during the water year. Monthly release volumes may be rounded for practical implementation or for maintenance needs. In addition, when releases are actually implemented, minor variations may occur regularly for a number of operational reasons that cannot be projected in advance.

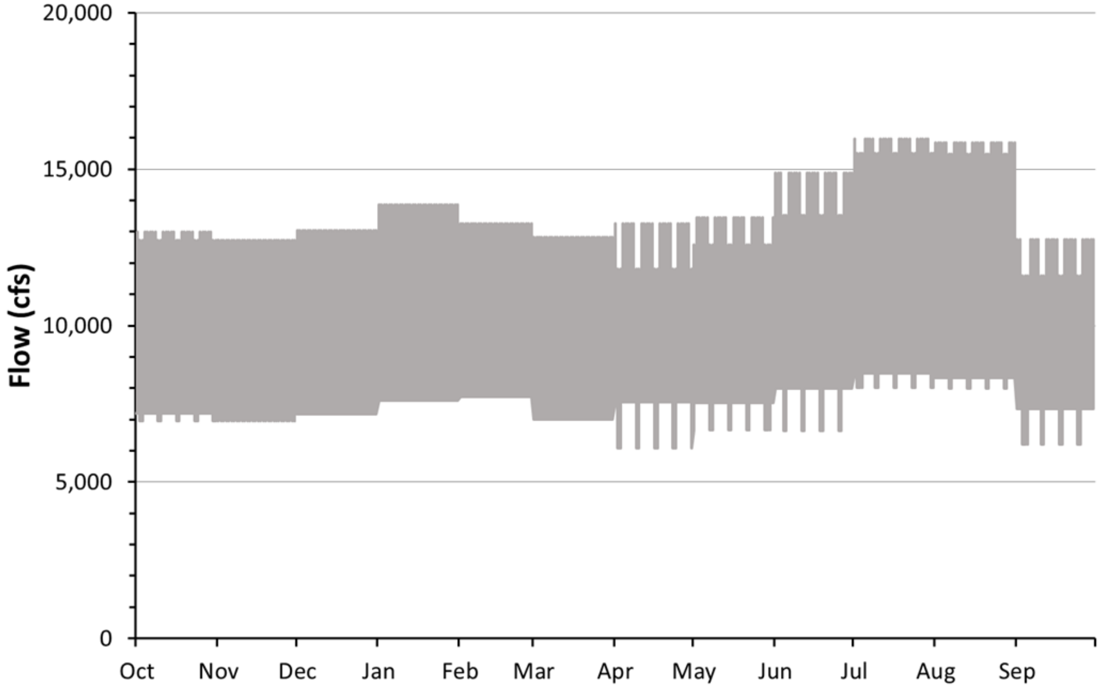


FIGURE 2-18 Simulated Hourly Flows under Alternative D in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 2-17. These differences reflect flexibility in operational patterns allowed within the constraints of the alternative.)

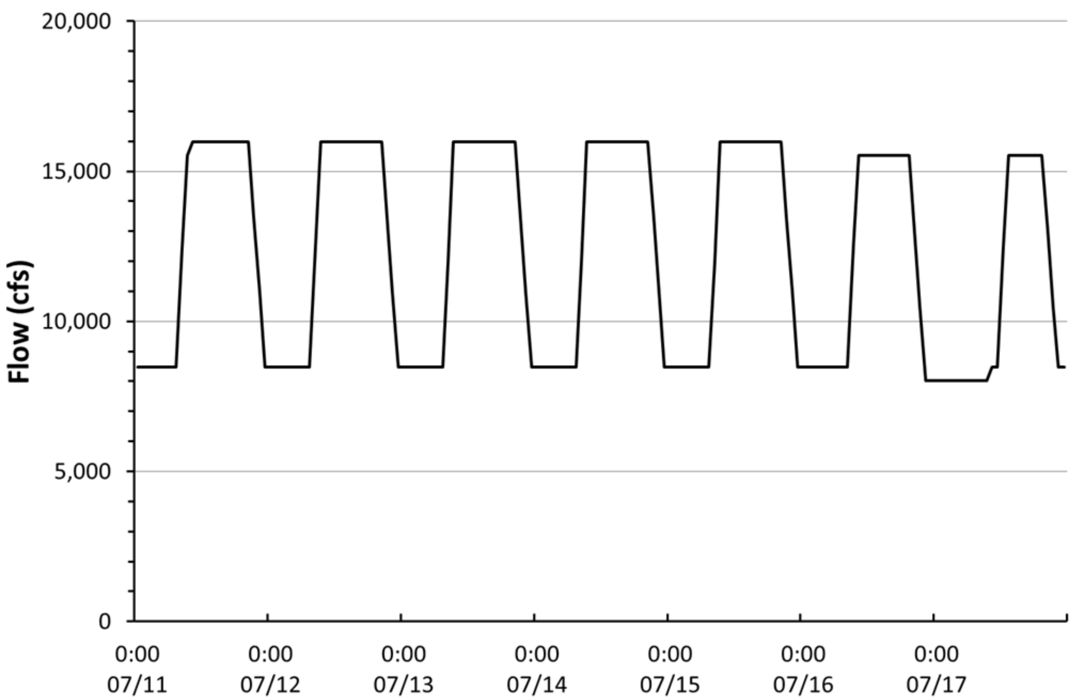


FIGURE 2-19 Simulated Hourly Flows under Alternative D for a Week in July in an 8.23-maf Year Showing Typically Lower Weekend Flows (The week starts on Monday and ends on Sunday.)

Reclamation also will make specific adjustments to daily and monthly release volumes, in consultation with other entities as appropriate, for a number of reasons, including operational, resource-related, and hydropower-related issues. Examples of these adjustments may include, but are not limited to, the following:

- For water distribution purposes, volumes may be adjusted to allocate water between the Upper and Lower Basins consistent with the Law of the River as a result of changing hydrology;

- For resource-related issues that may occur uniquely in a given year, release adjustments may be made to accommodate nonnative species removal, to assist with aerial photography, or to accommodate other resource considerations separate from experimental treatments under the LTEMP;

- For hydropower-related issues, adjustments may occur to address issues such as electrical grid reliability, actual or forecasted prices for purchased power, transmission outages, and experimental releases from other Colorado River Storage Project dams.

In addition, Reclamation may make modifications under circumstances that may include operations that are prudent or necessary for the safety of dams, public health and safety, other emergency situations, or other unanticipated or unforeseen activities arising from actual operating experience (including, in coordination with the Basin States, actions to respond to low reservoir conditions as a result of drought in the Colorado River Basin). In addition, the Emergency Exception Criteria established for Glen Canyon Dam will continue under this alternative. (See, e.g., Section 3 of the Glen Canyon Operating Criteria at 62 FR 9448, March 3, 1997.)

Section 2.2.4.3 addresses adjustments to base operations for adaptive management-based experimental operations with flow components.

2.2.4.3 Implementation Process for Experiments under Alternative D

Alternative D identifies condition-dependent flow and non-flow treatments intended to safeguard against unforeseen adverse changes in resource impacts, and to prevent irreversible changes to those resources. These condition-dependent treatments would be implemented experimentally during the LTEMP period unless they prove ineffective or result in unacceptable adverse impacts on other resources.

Prior to implementation of any experiment, the relative effects of the experiment on the following resource areas will be evaluated and considered: (1) water quality and water delivery, (2) humpback chub, (3) sediment, (4) riparian ecosystems, (5) historic properties and traditional cultural properties, (6) Tribal concerns, (7) hydropower production and WAPA's assessment of the status of the Basin Fund, (8) the rainbow trout fishery, (9) recreation, and (10) other resources. Although these key resources are listed for consideration on a regular basis, DOI intends to retain sufficient flexibility in implementation of experiments to allow for response to unforeseen circumstances or events that involve any other resources not listed here. The recent discovery of nonnative green sunfish in the Glen Canyon reach illustrates the need to be responsive to unforeseen conditions. DOI will engage in the communication and consultation process described in Section 2.2.4.4, when making decisions regarding implementation of experiments.

The proposed approach differs fundamentally from a more formal experimental design (e.g., before-after control-impact design, factorial design) that attempts to resolve uncertainties by controlling for or treating potentially influential or confounding factors. There are several reasons to avoid such a formal design and instead focus on the condition-dependent approach described here. Among these are (1) the difficulties in controlling for specific conditions in a system as complex as the Colorado River; (2) wide variability in temperature and flow conditions that are important drivers in ecological processes; (3) inherent risk of some experimentation to protected sensitive resources, in particular, endangered humpback chub; (4) conflicting multiple-use values and objectives; and (5) low expected value-of-information for the uncertainties that could be articulated, and around which a formal experimental design would be established. For these reasons, a condition-dependent adaptive approach is proposed.

The alternative utilizes the principle that a condition-dependent adaptive design is preferable to a formal experimental design because of the need for a flexible and adaptive program that is responsive to learning. A more formal experimental design, while potentially beneficial in resolving specific uncertainties, would involve multiple-year tests under different conditions, and with sufficient replicates of experimental conditions to statistically test the significance of treatment effects. Such an experimental design would necessarily span a period of years, during which environmental conditions would undoubtedly vary, and thus confound interpretation of results. The duration of the experiment could be lengthened and the potential for confounding effects increased if there was a desire to test system response under specific conditions that cannot be controlled (e.g., annual volume, water temperature, sediment load, and species population levels). These factors make a formal experimental design impractical in the Grand Canyon. Like Alternatives C and E, Alternative D would use condition-dependent triggers to inform operations and experimental flow and non-flow treatments in a given year.

Implementation criteria for condition-dependent experimental treatments of Alternative D are provided in Table 2-9, and decision trees for implementation of experimental treatments are presented in Figures 2-20 and 2-21. (Note: In both of these figures, triggering would also be conditional on annual implementation considerations and long-term off-ramps presented in Table 2-9. The nodes shown in rectangles are condition-dependent action nodes; the nodes shown in circles are information-dependent nodes that require the evaluation of accumulated evidence.) Included in Table 2-9 are the triggers for experimental changes in operations, implementation considerations for determining if an experimental treatment should proceed, conditions that would cause the treatment to be terminated prior to completion (i.e., off-ramps), and the number of replicates that are initially considered needed. In many cases, two to three replicates of an experimental treatment are considered necessary. The results of these tests would be used to determine if these condition-dependent treatments should be retained as part of the suite of long-term actions implemented under LTEMP. In other cases, following the process

TABLE 2-9 Implementation Criteria for Experimental Treatments of Alternative D

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long Term Off-Ramp Conditions[c]	Action if Successful
Sediment Treatments[d]						
Spring HFE up to 45,000 cfs in Mar. or Apr.	Trigger: Sufficient Paria River sediment input in spring accounting period (Dec.–Jun.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Not conducted during first 2 years of LTEMP, otherwise implement in each year triggered, dependent on resource condition and response	$\leq$96 hr	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3; unacceptable cumulative effects of sequential HFEs; sediment-triggered spring HFEs will not occur in the same water year as an extended-duration (>96 hr) fall HFE	Sediment-triggered spring HFEs are not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow
Proactive spring HFE up to 45,000 cfs (Apr., May, or Jun.)	Trigger: High-volume year with planned equalization releases ($\geq$10 maf) Objective: Protect sand supply from equalization releases	Not conducted during first 2 years of LTEMP, otherwise implement in each year triggered, dependent on resource condition and response	First test 24 hr; subsequent tests could be shorter, but not longer, depending on results of first tests	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3; unacceptable cumulative effects of sequential HFEs; would not be implemented in the same water year as a sediment-triggered spring HFE or extended-duration fall HFE	Proactive spring HFEs are not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 2-9 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long Term Off-Ramp Conditions[c]	Action if Successful
Sediment Treatments (Cont.)						
Fall HFE ≤96 hr up to 45,000 cfs in Oct. or Nov.	Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Implement in each year triggered, dependent on resource condition and response	≤96 hr	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3; unacceptable cumulative effects of sequential HFEs	This type of fall HFE is not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow
Fall HFEs longer than 96-hr duration up to 45,000 cfs in Oct. or Nov.	Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE longer than a 96-hr, up to 45,000-cfs flow Objective: Rebuild sandbars	Implement in each year triggered; limited to total of four tests in LTEMP period	Up to 250 hr depending on availability of sand duration of first test not to exceed 192 hr	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3; unacceptable cumulative effects of sequential HFEs	Extended-duration fall HFEs are not effective in building sandbars; resulting sandbars are no bigger than those created by shorter-duration HFEs; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 2-9 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long Term Off-Ramp Conditions[c]	Action if Successful
Aquatic Resource Treatments[e]						
Trout management flows	Trigger: Predicted high trout recruitment in the Glen Canyon reach Objective: Test efficacy of flow regime on trout numbers and survival of humpback chub	Implement as needed when triggered after consultation with Tribes; test may be conducted early in the 20-year period even if not triggered by high trout recruitment[f]	Implemented in as many as 4 months (May–Aug.)	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3	TMFs have little or no effect on trout recruitment after at least three tests; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment triggered by predicted high trout recruitment in Glen Canyon, taking into consideration Tribal concerns
Tier 1: Expanded translocation of humpback chub in the Little Colorado River	Trigger: Number of adult or subadult humpback chub in the Little Colorado River reach below Tier 1 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective	As needed	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3	Expanded translocation has little or no effect on increasing the number of adult or subadult humpback chub; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow
Tier 1: Implement head-start program for larval humpback chub	Trigger: Number of adult or subadult humpback chub in the Little Colorado River reach below Tier 1 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective	As needed	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3	Head-start program has little or no effect on increasing the number of adult or subadult humpback chub; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 2-9 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long Term Off-Ramp Conditions[c]	Action if Successful
Aquatic Resource Treatments (Cont.)						
Tier 2: Mechanical removal of nonnative fish in Little Colorado River reach	Trigger: Tier 1 actions ineffective; humpback chub numbers in Little Colorado River below Tier 2 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective after consultation with Tribes	Monthly removal trips (Feb.–Jul.) until "predator index" or adult humpback chub reach acceptable levels (see Appendix O)	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3	Mechanical removal has little or no effect on reducing predator index in the Little Colorado River reach; no population-level benefit on humpback chub; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment when triggered, taking into consideration Tribal concerns
Low summer flows (minimum daily mean 5,000 to 8,000 cfs) to target ≥ 14°C at Little Colorado River confluence	Trigger: Initial experiment: in the second 10 years of the LTEMP period, when target temperature of ≥14°C can be achieved only with low summer flow Objective: Increase humpback chub growth	Subsequent experimental use if: (1) initial test was successful, (2) humpback chub population concerns warrant their use, (3) water temperature appears to be limiting recruitment, and (4) target temperature of ≥14°C could be achieved only with low summer flow	3 months (Jul.–Sep.)	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3	Low summer flows do not increase growth and recruitment of humpback chub; increase in warmwater nonnative species or trout at the Little Colorado River; long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed; or sufficient warming does not occur as predicted	Implement as adaptive treatment when conditions allow

TABLE 2-9 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long Term Off-Ramp Conditions[c]	Action if Successful
Aquatic Resource Treatments (Cont.)						
Macroinvertebrate production flows	Trigger: None Objective: Improve food base productivity and abundance or diversity of mayflies, stoneflies, and caddisflies	Target two to three replicates	Up to 4 months (May–Aug.)[g]	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3; coordinate planning with other experiments to avoid confounding conditions or results	Steady weekend flows have little or no benefit on food base, trout fishery, or native fish; increase in warmwater nonnative species or trout at the Little Colorado River; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment in target months when conditions allow
Riparian Vegetation Treatments						
Non-flow vegetation treatments	Trigger: None Objective: Improve vegetation conditions at key sites	Not applicable	20 years if successful pilot phase	Potential short-term unacceptable impacts on resources listed in Section 2.2.4.3	Control and replanting techniques are not effective or practical; or long-term unacceptable adverse impacts on the resources listed in Section 2.2.4.3 are observed	Implement as adaptive treatment if invasive species can be reduced and native species increased

a Triggers will be modified as needed during the 20-year LTEMP period in an adaptive manner through processes including ESA consultation and based on the best available science utilizing the experimental framework for each alternative.

b Annual determination by the DOI. Any implementation would consider resource condition assessments and resource concerns using the annual processes described in Sections 2.2.4.3 and 2.2.4.4.

c Suspension of experiment if the DOI determines effects cannot be mitigated.

d Details of implementation of sediment experiments are presented in Section 2.2.4.5.

e Details of implementation of aquatic resource experiments are presented in Section 2.2.4.6.

f The decision to conduct TMFs in a given year would consider the resource conditions, as specified in Section 2.2.4.3, and would also involve considerations regarding the efficacy of the test based on those resource conditions.

g The duration and other characteristics of experimental macroinvertebrate production flows could be adjusted based on the results of initial experiments.

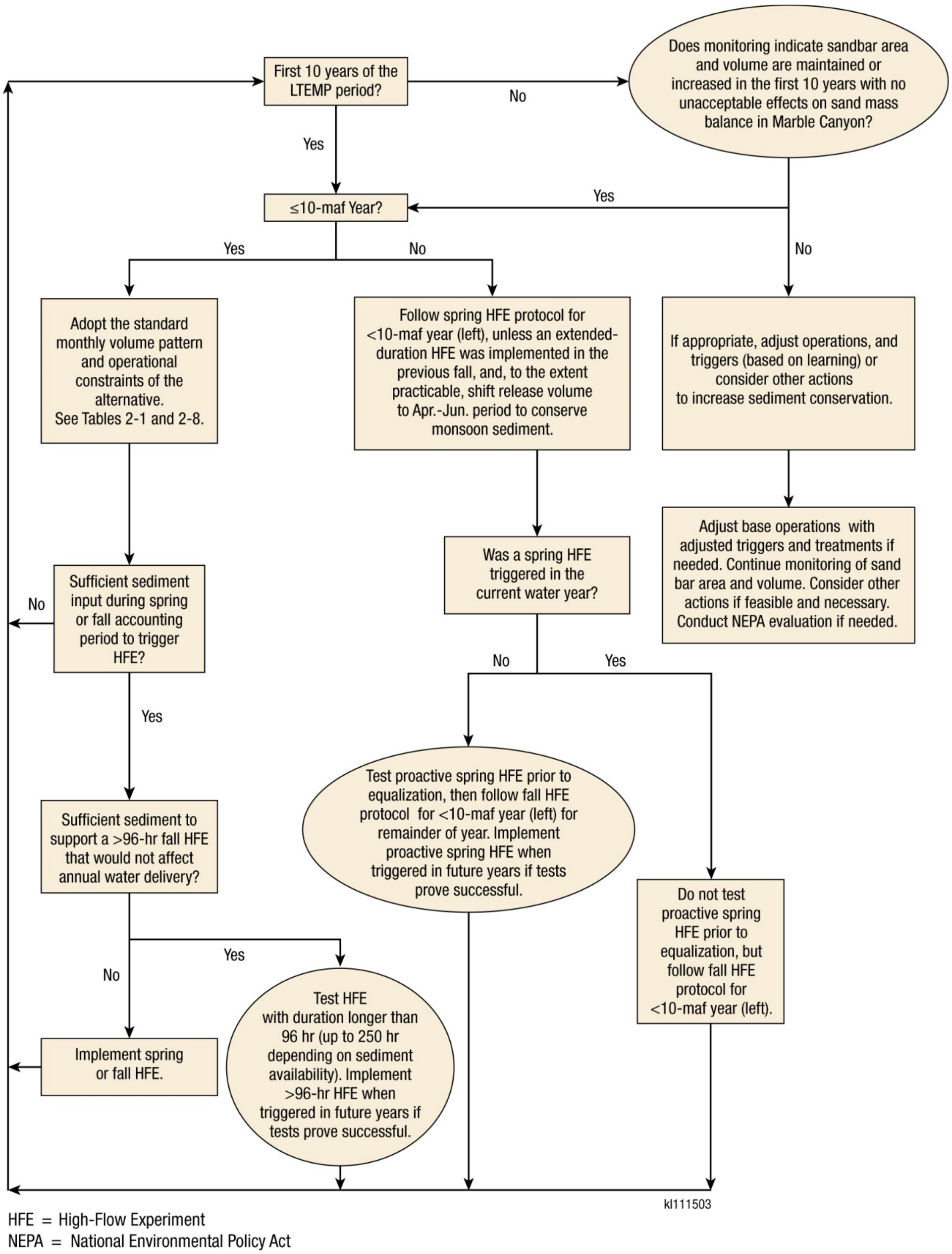
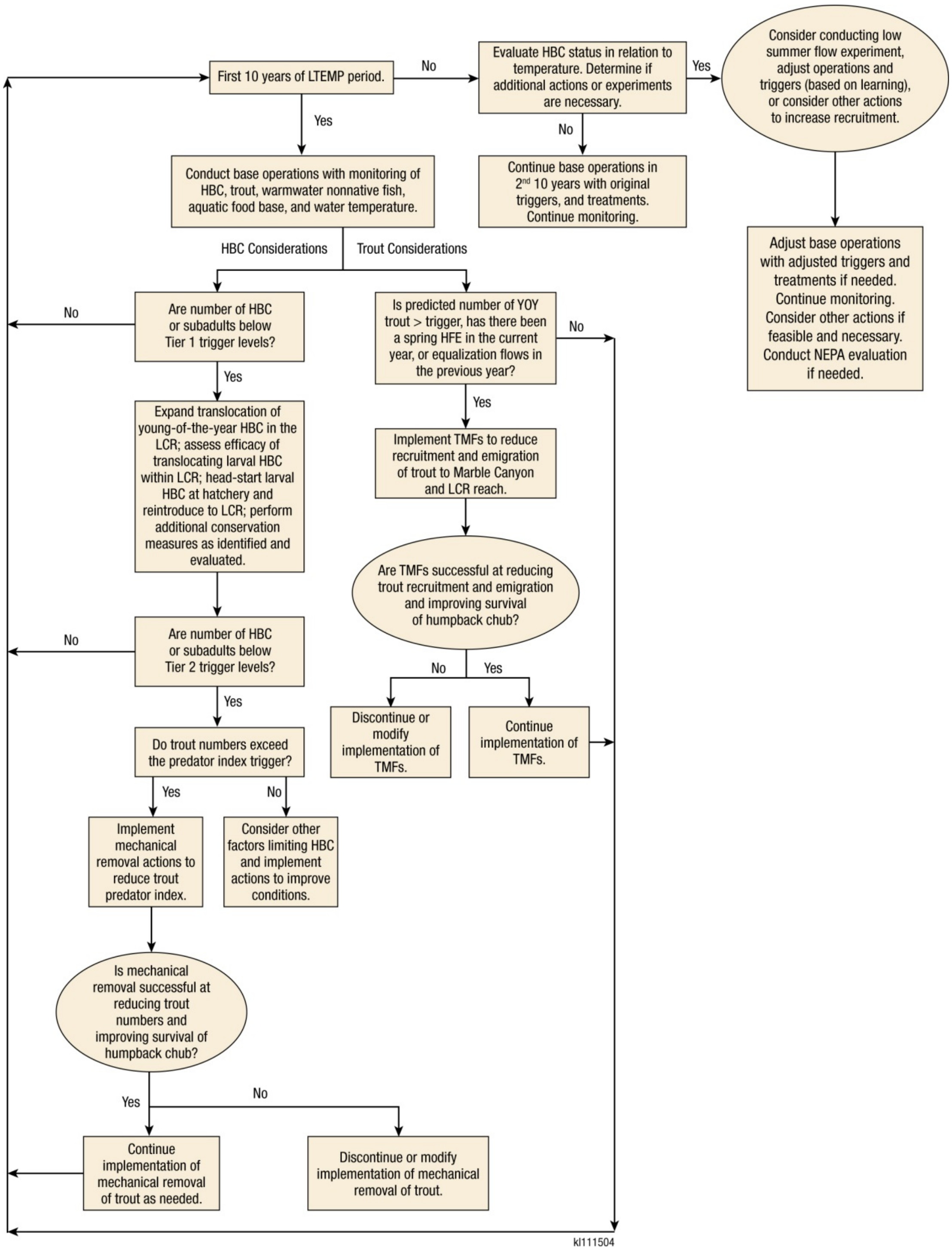


FIGURE 2-20 Decision Tree for Implementation of Sediment-Related Experimental Treatments under Alternative D (Implementation would be conditional on annual considerations presented in Section 2.2.4.3. If off-ramp conditions listed in Table 2-9 exist, related experimental treatments would be suspended.)



HBC = Humpback Chub
HFE = High-Flow Experiment
LCR = Little Colorado River
NEPA = National Environmental Policy Act
TMF = Trout Management Flow

FIGURE 2-21 Decision Tree for Implementation of Aquatic Resource-Related Experimental Treatments under Alternative D (Implementation would be conditional on annual considerations presented in Section 2.2.4.3. If off-ramp conditions listed in Table 2-9 exist, related experimental treatments would be suspended.)

described elsewhere in this section, implementation of experimental treatments would continue throughout the LTEMP period if triggered (e.g., spring and fall HFEs), except in years when it was determined that the proposed experiment could result in unacceptable adverse impacts on resource conditions. For these experiments, effectiveness would be monitored and the experiments would be terminated or modified, only if sufficient evidence suggested the treatment was ineffective or had unacceptable adverse impacts on other resources. All experimental treatments would be closely monitored for adverse side effects on important resources. At a minimum, an unacceptable adverse impact would include significant negative impacts on resources as a result of experimental treatments that have not been analyzed for Alternative D in the LTEMP EIS.

Sections 2.2.4.5 and 2.2.4.6 describe specific processes for the development and implementation of experiments related to sediment, aquatic resources, and riparian vegetation. The overall approach attempts to strike a balance between identifying specific experiments and providing flexibility to implement those experiments when resource conditions are appropriate. As discussed above, rather than proposing a prescriptive approach to experimentation, an adaptive management-based approach that is responsive and flexible would be used to adapt to changing environmental and resource conditions and new information. The potential for confounding interactions among individual experimental treatments is discussed when relevant for each of the proposed treatments. Given the size of the project area and the variability inherent in the system, this pragmatic approach to experimentation is warranted. Although confounding treatments are possible given the complexity of the experimental plan, they are not expected to limit learning over the life of the LTEMP.

2.2.4.4 Communication and Consultation Process for Alternative D

In implementing the processes described in Section 2.2.4.3 and the associated decision process shown in Figures 2-20 and 2-21, the DOI will exercise a formal process of stakeholder engagement to ensure decisions are made with sufficient information regarding the condition and potential effects on important resources. As an initial platform to discuss potential future experimental actions, the DOI will hold GCDAMP annual reporting meetings for all interested stakeholders; these meetings will present the best available scientific information and learning from previously implemented experiments and ongoing monitoring of resources. As a follow-up to this process, the DOI will meet with the TWG to discuss the experimental actions being contemplated for the year.

The DOI also will conduct monthly Glen Canyon Dam operational coordination meetings or calls with the DOI bureaus (USGS, NPS, FWS, BIA, and Reclamation), WAPA, AZGFD, and representatives from the Basin States and the UCRC. Each DOI bureau will provide updates on the status of resources and dam operations. In addition, WAPA will provide updates on the status of the Basin Fund, projected purchase power prices, and its financial and operational considerations. These meetings or calls are intended to provide an opportunity for participants to share and obtain the most up-to-date information on dam operational considerations and the status of resources (including ecological, cultural, Tribal, recreation, and the Basin Fund). One liaison from each Basin State and from the UCRC will be allowed to participate in the monthly operational coordination meetings or calls.

To determine whether conditions are suitable for implementing or discontinuing experimental treatments or management actions, the DOI will schedule implementation/planning meetings or calls with the DOI bureaus (USGS, NPS, FWS, BIA, and Reclamation), WAPA, AZGFD, and one liaison from each Basin State and from the UCRC, as needed or requested by the participants. The implementation/planning group will strive to develop a consensus recommendation to bring forth to the DOI regarding resource issues as detailed at the beginning of this section, as well as including WAPA's assessment of the status of the Basin Fund. The Secretary of the Interior will consider the consensus recommendations of the implementation/planning group, but retains sole discretion to decide how best to accomplish operations and experiments in any given year pursuant to the ROD and other binding obligations.

DOI will also continue separate consultation meetings with the Tribes, AZGFD, the Basin States, and UCRC upon request, or as required under existing RODs.

2.2.4.5 Sediment-Related Experiments To Be Evaluated under Alternative D

Under Alternative D, the existing HFE protocol was updated and incorporated into the LTEMP process as specified in Appendix P. Changes to the existing protocol were related to implementation of the new HFEs that are included under Alternative D and an extension of the protocol to the end of the LTEMP period. This new protocol would replace the existing protocol when the LTEMP ROD is issued. Spring and fall HFEs would be implemented when triggered during the 20-year LTEMP period based on the estimated sand mass balance resulting from Paria River sediment inputs during the spring and fall accounting periods, and the dam release pattern during the accounting period. HFE releases would be 1 to 250 hr long and between 31,500 cfs and 45,000 cfs. Depending on the cumulative amount of sediment input from the Paria River during the spring (December 1 through June 30) or fall (July 1 through November 30) accounting periods and the expected accumulation of sand, the maximum possible magnitude and duration of HFE that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling, would be implemented.

Sand mass balance modeling would be used to ensure that the duration and magnitude of an HFE are best matched with the mass of sand present in the system during a particular release window. The magnitude and duration of HFEs would not affect the total annual release from Glen Canyon Dam. Reclamation would consider the total water to be released in the water year when determining the magnitude and duration of an HFE.

Sediment-related experiments under Alternative D include (1) sediment-triggered spring and fall HFEs up to 96-hr duration; (2) short-duration (24-hr) proactive spring HFEs in high-volume equalization years prior to equalization releases; and (3) implementation of up to four extended-duration (>96-hr) HFEs, up to 250 hr long, depending on sediment conditions. The pattern of transferring water volumes from other months to make up the HFE volume would be discussed in the monthly Glen Canyon Dam operational coordination meetings described in Section 2.2.4.4.

If sediment resources are stable or improving, the combination of base operations, HFEs, and other treatments would continue as prescribed for Alternative D. If sediment resource conditions decrease to unacceptable levels during the LTEMP period, operations may be modified to the extent allowable under the LTEMP ROD or would be evaluated and considered under a separate NEPA process, potentially including additional studies of sediment augmentation or other actions.

For all sediment experiments, testing would be modified or temporarily or permanently suspended if (1) experimental treatments were ineffective at accomplishing their objectives, or (2) there were unacceptable adverse impacts on resources (Table 2-9). Monitoring results would be evaluated to determine whether additional tests, modification of experimental treatments, or discontinuation of experimental treatments were warranted.

Implementation of HFEs would consider resource condition assessments and resource concerns using the annual processes described in Sections 2.2.4.3 and 2.2.4.4. HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 2.2.4.3. In addition, there is uncertainty associated with cumulative impacts from sequential HFEs. These cumulative impacts would be considered before implementing an HFE.

Sediment-Triggered Spring HFEs under Alternative D

Under Alternative D, sediment-triggered spring HFEs would be implemented after an initial 2-year delay in order to enable testing of the effectiveness of TMFs, if warranted, and address concerns raised by the apparent positive response of trout to the 2008 spring HFE (Korman, Kaplinski et al. 2011; Melis et al. 2011). Modeling trout response to spring HFEs for the EIS was based on relationships developed from the observed response to the 2008 spring HFE. That modeling also evaluated uncertainty related to the effectiveness of TMFs to control excess trout produced by HFEs. Modeling indicated that even at a relatively low level of effectiveness (10% reduction in trout recruitment), TMFs could effectively reduce the number of trout out-migrants from Glen Canyon to the Little Colorado River reach (RM 61) where humpback chub occur.

After the first 2 years of the LTEMP period, spring HFEs would be implemented when triggered by sediment conditions, except in water years when an extended-duration fall HFE was conducted. Modeling indicates that there may be sufficient sediment input for spring HFEs in about 26% of the years in the LTEMP period. Sediment-triggered spring HFEs would be implemented when triggered during the entire LTEMP period unless new information indicated they were not effective in building sandbars, or there were unacceptable adverse effects on resources (Section 2.2.4.3).

Implementation of a spring HFE would provide important replication of the 2008 spring HFE and aid in understanding the effect of spring HFEs on the trout population. It is possible that the strong 2008 response was a result of the specific conditions present in 2008 (e.g., condition of the food base, trout population size). It is unclear whether implementation under current conditions would produce the same result, and there is a good deal of learning that could result from early implementation. Implementing a spring HFE early in the LTEMP period when chub numbers are relatively high may also be a relatively low-risk option. To provide a means of controlling trout recruitment following tests of spring HFEs, TMFs would be experimentally implemented and tested for efficacy as early in the LTEMP period as possible (see discussion of TMFs below).

Implementation of sediment-triggered spring HFEs would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. Spring HFEs may not be tested when there appears to be the potential for unacceptable adverse impacts on the resources listed in Section 2.2.4.3. In addition, there is uncertainty associated with the cumulative impacts of sequential HFEs on sediment, aquatic, and potentially other resources. These cumulative impacts would be considered before implementing a spring HFE, particularly if a fall HFE had been implemented in the same water year.

Proactive Spring HFEs under Alternative D

GCMRC scientists identified proactive spring HFEs as a potential experimental treatment to transport and deposit in-channel sand at elevations above those of equalization flows. These HFEs would be tested only in years with high annual water volume (i.e., ≥10 maf), and modeling suggests this would be a relatively rare treatment. A first test would be a 24-hr 45,000-cfs release conducted in April, May, or June. Duration in subsequent tests could be shortened depending on the observed response during the first tests. It would be preferable to test proactive spring HFEs at least two to three times in the 20-year LTEMP period, but being able to do so will be dependent upon annual hydrology. Modeling indicates that proactive spring HFEs would be triggered in about 10% of the years in the LTEMP period.

Proactive spring HFEs would not be tested in the first 2 years of the LTEMP. In addition, proactive spring HFEs would not be tested in years when there had been a sediment-triggered spring HFE or an extended-duration fall HFE earlier in the same water year. Proactive spring HFEs could be performed in the same water year as a 96-hr or shorter sediment-triggered fall HFE, although prior to implementation, the potential effects of these HFEs would be carefully evaluated using the processes described in Sections 2.2.4.3 and 2.2.4.4. The first test would be carefully evaluated to determine whether additional tests were warranted based on the efficacy of building and maintaining sandbars. If initial tests show positive results without unacceptable adverse effects on the resources listed in Section 2.2.4.3, proactive spring HFEs would be implemented when triggered during the entire LTEMP period.

Implementation of proactive spring HFEs would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. Proactive spring HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources identified in Section 2.2.4.3. The cumulative impacts of sequential HFEs would be considered before implementing a proactive spring HFE.

Sediment-Triggered Fall HFEs under Alternative D

The effects of sediment-triggered fall HFEs on trout recruitment are uncertain, but fall HFEs are expected to have less effect on trout production than spring HFEs. HFEs in November 2012, 2013, and 2014 resulted in little or no increase in the number of YOY trout (VanderKooi 2015; Winters et al. 2016), and this observation may be based on the observed resilience of the food base to disturbance in the fall (Kennedy et al. 2015). However, factors affecting trout response to fall HFEs are not well understood. Modeling for the EIS considered the effect of fall HFEs on trout and modeled fall HFEs in two ways: in one, the effect of fall HFEs was half as long as that of a spring HFE (i.e., it affected trout production only in the water year in which it occurred); in the other, fall HFEs had no effect on trout production. Modeling the effect of fall HFEs in these two ways had an effect on the overall predicted number of trout produced, the number of out-migrants, and ultimately their effect on humpback chub, but the relative performance among alternatives was unchanged.

Modeling indicates fall HFEs would be triggered in about 77% of the years in the LTEMP period. Testing fall HFEs is considered to be a relatively low-risk treatment due to the lack of observed or documented trout response from previous fall HFEs, and would be implemented when triggered during the entire LTEMP period unless new information indicated fall HFEs were not effective in building sandbars, or there were unacceptable adverse effects.

Implementation of sediment-triggered fall HFEs would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. Fall HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 2.2.4.3. The cumulative impacts of sequential HFEs would be considered before implementing a sediment-triggered fall HFE.

Extended-Duration Fall HFEs under Alternative D

Under Alternative D, sediment-triggered fall HFEs with durations longer than 96 hr (up to 250 hr) would be tested. The duration of these extended-duration fall HFEs would be based on the amount of sediment delivered from the Paria River during the fall accounting period and would be no more than the maximum magnitude and duration of HFE that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling. Based on examination of the observed historical sediment input from the Paria River, it was determined that HFEs up to 10.4 days in length (250 hr) could be supported before exhausting seasonal sediment inputs and affecting water delivery requirements. GCMRC scientists have suggested that increasing the duration of HFEs when sediment supply can support a longer duration may lead to more sand being deposited at higher elevations, resulting in bigger sandbars. Modeling indicates the sediment trigger for this treatment may be reached in 25% of the years in the LTEMP period. There would be no more than four extended-duration fall HFEs over the 20-year LTEMP period.

The duration of the first implementation of an extended-duration HFE would be limited to no more than 192 hr (twice as long as the current limit of 96 hr). This duration is considered long enough to produce a measurable result if the treatment represents an effective approach to building sandbars under enriched sediment conditions. The duration of all tests would be based on available sediment, current hydrology, reviews of available information, the expert opinion of GCMRC and other Grand Canyon scientists, and consideration of potential effects on the resources listed in Section 2.2.4.3. If feasible, monitoring would include real-time observations of sediment concentrations to determine if sediment deposition continues throughout the duration of the extended HFEs.

Implementation of extended-duration fall HFEs would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. Extended-duration fall HFEs may not be tested when there appears to be potential unacceptable impacts on the resources listed in Section 2.2.4.3. Because the effects of extended-duration HFEs on Lake Mead water quality are a concern, DOI will coordinate with relevant water quality monitoring programs or affected agencies prior to implementing any test of extended-duration HFEs. The cumulative impacts of sequential HFEs would be considered before implementing an extended-duration fall HFE.

Another important concern that results from the large volume of water bypassed is water delivery. Water delivery issues would be considered before deciding to implement an extended-duration fall HFE. An extended-duration HFE would not be implemented if annual release volume would be affected. It is possible that in lower volume years, there would not be sufficient water available to support an extended-duration HFE. A 250-hr extended-duration HFE would result in a monthly total release of approximately 1.2 maf. In lower volume release years (e.g., 7.0 maf or 7.48 maf), the maximum duration may be less than 250 hr. In addition, a sediment-triggered spring HFE or proactive spring HFE would not be conducted in the same water year as an extended-duration fall HFE. If an extended-duration fall HFE was triggered but not implemented for any of the reasons described above, a fall HFE 96 hr or less in duration could be implemented instead. Implementation would necessitate reducing water volume in other months of the same water year.

In order to fully test the efficacy of these longer HFEs, several replicates would be desirable in the 20-year LTEMP period. Extended-duration HFEs would be considered successful and would be continued up to a total of four times in the 20-year LTEMP period as part of an adaptive experimental treatment if there was a widespread increase in bar size relative to ≤96-hr HFEs, and if sand mass balance was not significantly compromised relative to the ability to maintain a long-term equilibrium. Extended-duration HFEs would not continue to be tested if they were not effective in building sandbars, if resulting total sandbar volumes were no bigger than those created by shorter-duration HFEs, or if unacceptable adverse impacts on the resources listed in Section 2.2.4.3 were observed.

2.2.4.6 Aquatic Resource-Related Experiments To Be Evaluated under Alternative D

Under Alternative D, most experimental flow and non-flow actions would be triggered by either estimated numbers of nonnative fish, a combination of estimated numbers of nonnative fish and humpback chub, or measured water release temperature at Glen Canyon Dam, depending on the action under consideration. Humpback chub triggers and nonnative fish triggers were developed during formal Section 7 ESA consultation with the FWS. These triggers may be modified based on experimentation conducted during the LTEMP period.

Aquatic resource experiments that may be tested under Alternative D include (1) TMFs, (2) Tier 1 conservation actions for humpback chub, (3) Tier 2 mechanical removal of nonnative fish, (4) low summer flows in the second 10 years of the LTEMP, and (5) macroinvertebrate production flows. Aquatic resource experiments would seek to refine our understanding of the impacts of water releases, HFEs, and TMFs on these resources. The primary uncertainty surrounding HFEs revolves around the extent to which the seasonality of HFEs or the number of adult rainbow trout determines the strength of rainbow trout recruitment.

Experimental nonnative fish control actions would be implemented if the humpback chub population declined, and proactive conservation actions had failed to reverse declining populations. Two different tiers of population metrics would be used to trigger responses, including actions to increase growth and survival of humpback chub (Tier 1) and mechanical removal of nonnative fish (Tier 2), which would only be implemented when Tier 1 actions fail to slow or reverse the decline in the humpback chub population. This tiered approach and the triggers that would be used to implement it are described below and in the LTEMP Biological Assessment and BO presented in Appendix O.

For all aquatic resource experiments, testing would be modified or temporarily or permanently suspended if (1) experimental treatments were ineffective at accomplishing their objectives, or (2) there were potential unacceptable adverse impacts on the resources listed in Section 2.2.4.3. Monitoring results would be evaluated to determine whether additional tests, modification of experimental treatments, or discontinuation of experimental treatments were warranted.

Implementation of aquatic resource experiments would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. Aquatic resource experiments may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 2.2.4.3.

Trout Management Flows under Alternative D

TMFs (described in Section 2.2.3.2) are a potential tool that could be used to control annual trout production in the Glen Canyon reach for purposes of managing the trout fishery and for limiting emigration from the Glen Canyon reach to Marble Canyon and the Little Colorado River reach. If resource conditions are appropriate, TMFs may be tested under Alternative D early in the experimental period, preferably in the first 5 years. These first tests could be triggered by modeled trout recruitment levels or otherwise implemented to test the effectiveness of TMFs.[6] The intent of these early tests would be to determine the effectiveness of TMFs and a best approach to trout management. If TMFs are determined to be effective for controlling trout numbers while minimizing impacts on other resources, they may be deployed as an adaptive experimental treatment triggered by estimated trout recruitment.

It should be noted that several Tribes have expressed concerns about TMFs as a taking of life within the canyon without a beneficial use. The Pueblo of Zuni has expressed concern that the taking of life by trout stranding has an adverse effect on the Zuni value system. The joint-lead agencies will continue to work with the Tribes regarding options for trout management, and to determine the most appropriate means of mitigating impacts on Tribal values if TMFs are implemented.

As many as three TMF cycles/month (see Section 2.2.3.2) in a period of up to 4 months during May through August could be tested, depending on the results of early tests. Aspects of TMF design that would be investigated include:

- Duration of high flows needed to lure YOY rainbow trout into near-shore habitats,
- Magnitude of the high flow that would be more effective in luring YOY trout to near-shore habitats,
- Whether or not moving to high flows first is needed to reduce YOY trout numbers (as opposed to simply dropping rapidly from normal flows to minimum flows),
- Timing of TMF cycles during the May–August period of trout emergence, and
- Number of cycles necessary to effectively limit trout recruitment.

If TMFs prove to be effective in controlling trout production and emigration to the Little Colorado River reach, and they become an integral part of the LTEMP, regular implementation of TMFs may need to include variable timing to prevent adaptation of the population to specific timing (e.g., increase in recruitment by fall-spawning rainbow trout).

Certain aspects of TMF effectiveness can be addressed through observational studies (e.g., the number of YOY rainbow trout observed in the near-shore environment in daily increments after the high flow is initiated);[7] others may be addressed through consideration of the physical environment in Glen Canyon (i.e., what areas are inundated or exposed at different

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6 The decision to conduct TMFs in a given year would consider the resource conditions as specified in Section 2.2.4.3 and would also involve considerations regarding the efficacy of the test based on those resource conditions.

7 Because older age classes of trout tend to occupy deeper habitats toward the middle of the river channel, they are less susceptible to stranding and are less likely to be directly affected by TMFs.

flows). Ultimately, however, effectiveness would be judged based on comparison of fall trout recruitment estimates to expectations based on prior years. It may take several years to make this determination, depending on the strength of the response and the type of TMFs tested. Ultimately, however, effectiveness would be based on the ability of TMFs to reduce recruitment in and emigration from the Glen Canyon reach. The driving forces behind emigration are not fully understood, but are expected to be related to population size and food base in the Glen Canyon reach.

For the EIS modeling, a trigger of 200,000 YOY trout was used to determine when TMFs would be implemented. A regression equation based on annual volume, the variability in flows from May through August, and the occurrence of a spring HFE was used to predict the number of YOY. The actual trigger used could be higher or lower depending on the results of experiments that will be conducted on the effectiveness of TMFs. In addition, the predictive regression equation could be modified based on new information. The trigger and predictive equation used would be modified as needed in an adaptive management context utilizing the process described in Section 2.2.4.3. Triggers for implementation of TMFs would also be developed in consultation with the AZGFD and other entities as appropriate.

Monitoring of other resources, particularly food base and the physiologic condition of adult rainbow trout, would also be considered. In addition, the number of YOY trout at the end of the summer would be estimated to determine if it equals or exceeds the estimated number of recruits needed to sustain the desired number of adult trout. If the estimated number of recruits is less than the recruitment target, TMFs would be re-evaluated for modification before implementation in subsequent years. It is anticipated that the trout population could rebound from a 1-year drop below this target level.

As discussed in relation to sediment experiments above, there is concern among scientists and stakeholders with regard to the risk associated with implementation of spring HFEs as related to trout response and subsequent effects on the humpback chub population. For this reason, TMFs would be implemented and tested for effectiveness as early in the LTEMP period as possible, preferably before the first spring HFEs are triggered, even if not triggered by high trout recruitment. TMFs could be implemented in years that feature a spring HFE and in the water year that follows an equalization flow because of the expected positive effects of equalization on rainbow trout recruitment. Any implementation of TMFs would consider the status of the trout fishery prior to implementation. Modeling indicates TMFs would be triggered by trout recruitment numbers in 32% of the years in the LTEMP period.

There is potential for confounding effects when coupling TMFs with HFEs. If trout recruitment is still high after implementation of TMFs that follow HFEs, this would suggest TMFs were not effective as designed for that trial. If recruitment is lower than expected after TMF implementation, however, uncertainty will remain about whether an HFE failed to stimulate trout recruitment or whether TMFs were effective in suppressing otherwise strong recruitment. It may not be necessary to determine the underlying effect on trout numbers unless TMFs have undesirable side effects on other resources or the trout population.

If TMFs are found to be highly effective in controlling trout recruitment and emigration of trout, and emigration only occurs or primarily occurs immediately following high recruitment years, it may be possible to limit TMF implementation and achieve multiple resource goals, particularly if unintended impacts of TMFs on other resources such as native fish become evident. Timing of TMFs may also be adjusted based on the best scientific information available related to trout emigration behavior. If adverse impacts of TMFs become evident, this may also suggest revisiting whether or not TMFs are necessary in response to spring HFEs. Lastly, if, there is an observed increase in trout recruitment due to fall HFEs, then application of TMFs in the spring following a fall HFE would be considered.

Implementation of TMFs would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. TMFs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 2.2.4.3.

Tier 1 Conservation Actions for Humpback Chub under Alternative D

Tier 1 conservation actions designed to improve rearing and recruitment of juvenile humpback chub would be implemented if the combined point estimate for adult (≥200 mm) humpback chub in the Colorado River mainstem Little Colorado River aggregation (RM 57–RM 65.9) and in the Little Colorado River falls below 9,000 (2,000 in the mainstem and 7,000 in the Little Colorado River), as estimated by the currently accepted humpback chub population model, or if recruitment of subadult (150 mm–199 mm) humpback chub does not meet or exceed estimated adult mortality (Appendix O). Tier 1 actions would include expanded translocations of YOY humpback chub within the Little Colorado River to areas within the river that have relatively few predators (i.e., above Chute Falls, Big Canyon), or larval fish would be taken to a rearing facility and released in the Little Colorado River inflow area once they reach 150 mm to 200 mm. In addition to these translocation activities, 300 to 750 larval or YOY humpback chub would be collected from the Little Colorado River and reared in a fish hatchery to less vulnerable sizes before releasing them. Once these fish reach 150 mm to 200 mm, they would be translocated to the Little Colorado River in the following year.

Tier 2 Mechanical Removal of Nonnative Fish under Alternative D

Mechanical removal of nonnative fish in the Little Colorado River reach (potentially from RM 50–RM 66) would be conducted if the Tier 1 conservation actions described in the previous section were not successful in halting a decline in the number of adult humpback chub. Mechanical removal, using the methods described in Section 2.2.1 and Appendix O, would be conducted if the point estimate of adult humpback chub falls below 7,000 (the trigger level used in Reclamation 2011b), as estimated by the currently accepted humpback chub population model. Up to six monthly removal trips (February through July) would be implemented in each year triggered.

Mechanical removal would stop if the "predator index" is depleted to less than 60 rainbow trout/km (see Appendix O) for at least 2 years in the reach between RM 63 and RM 64.5, and immigration rate is low, or the adult humpback chub population estimates exceed 7,500, and recruitment of subadult chub exceeds adult mortality for at least 2 years. The predator index calculates predator densities by incorporating additional species, in addition to rainbow trout, and makes assumptions about their relative predation rates compared to rainbow trout. For example, brown trout are estimated to be about 17 times more predacious on humpback chub than are rainbow trout (Ward and Morton-Starner 2015). Additional predators (e.g., smallmouth bass) could be included based on their piscivory level relative to that of rainbow trout.

If humpback chub adult numbers continue to decline and Tier 1 and Tier 2 actions are not working, FWS, in coordination with Reclamation, NPS, and the Tribes, will consider other actions to stop the decline. Triggers will be reviewed and modified as necessary, and actions and triggers will be modified if humpback chub are found to be affected by other factors.

Implementation of mechanical removal would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4.

The DOI recognizes that lethal mechanical removal is a concern for Tribes, particularly the Hopi Tribe and Pueblo of Zuni, because it is a taking of life in the canyon without a beneficial use. (See Sections 3.5.3.4 and 4.9.1.3 for more information regarding concerns of the Tribes.) Reclamation had committed in agreements with the Tribes in 2012 to consider live removal when feasible (Reclamation 2012b); however, the presence of whirling disease prohibits live removal of trout due to the risk of spreading the disease to other waters. Reclamation and NPS have worked with the Tribes to determine a beneficial use of the removed fish on other projects and understand that what is considered beneficial use may not be the same for all Tribes. Reclamation and NPS are committed to consult further with the Tribes to determine acceptable mitigation for nonnative fish control.

Low Summer Flows under Alternative D

Low summer flows could be considered a potential tool for improving the growth and recruitment of young humpback chub if temperature had been limiting these processes for a period of years. Low summer flows may lead to warmer water temperatures in the Little Colorado River reach and farther downstream, as well as contribute to enhanced growth rates of young humpback chub. There are also potential negative effects from low summer flows on several resources such as hydropower, sediment, water quality, vegetation, and recreation. Low summer flows may also negatively affect humpback chub due to an increase in warmwater nonnative fish or a decrease in the aquatic food base. There was one test of low steady summer flows below Glen Canyon Dam in 2000; however, the results relative to humpback chub were not conclusive (Ralston et al. 2012).

Because of the uncertainty related to the effects of low summer flows on humpback chub, other native fish, warmwater nonnative fish, water quality, and potentially other resources, DOI will ensure that the appropriate baseline data are collected throughout the implementation of the

LTEMP. In addition, DOI will convene a scientific panel that includes independent experts prior to the first potential use of low summer flows to synthesize the best available scientific information related to low summer flows. The panel may meet periodically to update the information, as needed. This information will be shared as part of the AMWG annual reporting process.

It is thought that the potential benefit of an increase in temperature could be greatest if a water temperature of at least 14°C could be achieved, because these warmer temperatures could favor higher humpback chub growth rates (nearly 60% higher). For comparison, the July through September growth increments of YOY humpback chub are estimated to be 4, 7, 11, 14, and 17 mm at temperatures of 12, 13, 14, 15, and 16°C, respectively, based on a growth-temperature regression in Robinson and Childs (2001). Note that reduction in summer flows would necessitate increasing flows in other months relative to base operations (Table 2-10; Figure 2-22).

If tested, low summer flows would occur for 3 months (July, August, and September), and only in the second 10 years of the LTEMP period. The duration of low summer flows could be shortened to less than 3 months in successive experiments if supported by the scientific panel described above or based on the scientific data and observed effects. The probability of triggering a low summer flow experiment is considered low (about 7% of years), because the water temperature conditions that would allow such a test occur infrequently (see Appendix D).

TABLE 2-10 Flow Parameters for a Year with Low Summer Flows under Alternative D in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	643	0.0781	10,451	5,783
November	642	0.0780	10,781	5,774
December	716	0.0870	11,643	6,443
January	764	0.0928	12,423	6,874
February	675	0.0820	12,153	6,074
March	691	0.0840	11,245	6,223
April	859	0.1044	14,433	7,730
May	851	0.1034	13,841	7,659
June	930	0.1130	15,631	8,000
July	492	0.0598	8,000	2,000
August	492	0.0598	8,000	2,000
September	476	0.0578	8,000	2,000

[a] Within a year, monthly operations may be increased or decreased based on factors referenced in Section 2.2.4.2.

[b] Values have been rounded.

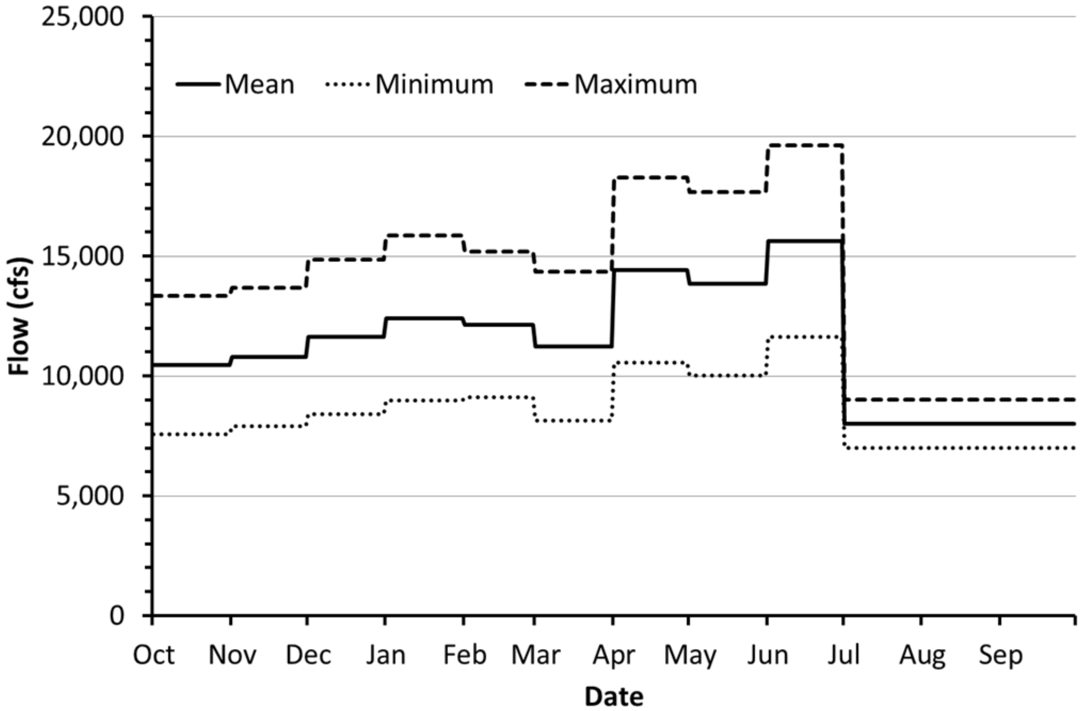

FIGURE 2-22 Mean, Minimum, and Maximum Daily Flows under Triggered Low Summer Flows of Alternative D in an 8.23-maf Year Based on the Values Presented in Table 2-10

Low summer flows would only be implemented in years when the projected annual release was less than 10 maf, and if the temperature at the Little Colorado River confluence was below 14°C without low summer flows, and the release temperature was sufficiently high that 14°C could be achieved at the Little Colorado River with the use of low summer flows.

The ability to achieve target temperatures at the Little Colorado River confluence by providing lower flows is dependent on release temperatures, which are in turn dependent on reservoir elevation. For example, using the temperature model of Wright, Anderson et al. (2008) in an 8.23-maf year, release temperatures of 10.8°C, 11.0°C, and 11.7°C would be needed in July, August, and September, respectively, to achieve a target temperature of 14°C at the Little Colorado River confluence at flows of 8,000 cfs.

Release temperatures fall into three categories for any temperature target: (1) too low to achieve the target temperature at the Little Colorado River even at low flow; (2) high enough to achieve the target temperature at the Little Colorado River only if low flows (5,000 cfs to 8,000 cfs) are provided; and (3) high enough to achieve target temperature at the Little Colorado River regardless of the flow level. Low summer flows would only be triggered in years that fell into the second category.

Implementation of a low summer flow experiment is complicated by two factors: the earliest date at which it could be determined that a target temperature of at least 14°C could be achieved in all 3 months, and the ability to release the remaining annual volume once that determination is made. The earliest time a determination could be made would be in early April of each year, and it would be based on the April 1 forecast of reservoir elevation. Because low summer flows could be implemented in the 3 months at the end of the water year, it is possible that by the time a determination was made to conduct a low summer flow experiment, it may not be possible to release enough water in the remainder of the spring to compensate for the low flow period. A low summer flow experiment would only be tested in years when performing the experiment would not result in a deviation from the annual Glen Canyon Dam release volumes made pursuant to the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

A first test of low summer flows would feature low flows of 8,000 cfs and relatively little fluctuation (±1,000 cfs per day). Depending on the results of the first test with regard to warming and humpback chub response, the magnitude of the low flow could be adjusted up or down (as low as 5,000 cfs), and the level of fluctuation also modified up to the range allowed under Alternative D (i.e., 10× monthly volume [in kaf] in July and August, and 9 × monthly volume [in kaf] in September).

The first test of low summer flows will be determined to be successful or unsuccessful for humpback chub based on input from an independent scientific panel review. If the first test was determined to be unsuccessful (and it was determined to have been implemented without major confounding factors), then additional tests would not be performed. Low summer flows would be considered successful if it can be determined that they produced sufficient growth of YOY humpback chub and that growth resulted in an increase in recruitment, but avoided unacceptable increases in warmwater nonnative fishes, trout, or aquatic parasites, or resulted in unacceptable adverse impacts on other aquatic resources. If it was determined to be successful, then additional low summer flows would occur only when humpback chub population concerns warranted them and water temperature has been colder for a period of years, and the desired warming could be achieved only with low summer flows. The temperature target could be adjusted 1°C higher based on the results of the first test or the limitations between predicted and measured temperatures.

Implementation of low summer flows would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. Low summer flows may not be conducted in years when there appears to be the potential for unacceptable impacts on the resources listed in Section 2.2.4.3.

The effects of low summer flows on Lake Mead water quality are an identified concern. DOI will coordinate with relevant water quality monitoring programs or affected agencies prior to implementing any test of low summer flows. There are additional concerns related to the risk of warmwater nonnative fish expansion or invasion (e.g., the elevation of Lake Mead was high or the number of warmwater nonnative fish was high). These issues are potential off-ramps as described in Section 2.2.4.3 using the process described in Section 2.2.4.4.

Macroinvertebrate Production Flows under Alternative D

A more diverse and productive aquatic food base could benefit a variety of priority resources, including native fish (including the endangered humpback chub), the rainbow trout fishery, and other riparian species that occur in Glen, Marble, and Grand Canyons. Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), collectively referred to as EPT, are important components of a healthy aquatic food base, but they are notably absent from the Glen and Marble Canyon reaches and very low in abundance and diversity in the Grand Canyon. GCMRC has hypothesized that EPT taxa are recruitment limited, because daily flow fluctuations to meet hydropower demand cause high egg mortality, and the absence of EPT has an adverse effect on the carrying capacity and condition of the trout fishery and native fish communities. EPT are thought to be recruitment limited because Glen Canyon Dam fluctuations create a large varial (intermittently wetted) zone along shorelines. Because the Colorado River in Glen, Marble, and Grand Canyons is canyon-bound and the tributaries that join the river all have comparatively low flow, the size of the varial zone does not appreciably decrease with distance downstream. Thus, although water temperature regimes become more naturalized with distance downstream, the effect that daily flow fluctuations to meet hydropower demand have on the stability of shoreline habitat does not attenuate much with distance from the dam.

This hypothesis attributes the absence of EPT and the poor health of the invertebrate assemblage to the width of the varial zone, similar to earlier investigations (Blinn et al. 1995), but focuses on the effects unstable shorelines have on the eggs of these species. This hypothesis assumes that egg-laying by EPT occurs principally along shorelines. According to the hypothesis, EPT taxa downstream of Glen Canyon Dam are recruitment limited, because daily flow fluctuations to meet hydropower demand negatively affect habitat quality along the shorelines where egg laying is assumed to occur.

To test this hypothesis, macroinvertebrate production flows would be provided every weekend from May through August (34 days total).[5] The flow on weekends would be held steady at the minimum flow for that month, which would ensure that the insect eggs laid during weekends would remain submerged throughout larval development. If the hypothesis is true, there would be an increase in insect production due to the reproductive success of insects that laid eggs during weekends. No change in monthly volumes, ramping rates, or the maximum daily range in flow during weekdays would be required for this experiment. To offset the smaller water releases that would occur during weekends within a given month, larger releases would need to occur during the weekdays within a given month.

Implementation of macroinvertebrate production flows would consider resource condition assessments and resource concerns using the processes described in Sections 2.2.4.3 and 2.2.4.4. These flows may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 2.2.4.3.

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5 The duration and other characteristics of experimental macroinvertebrate production flows could be adjusted within the range of the analysis based on the results of initial experiments.

Effects of the tests would be evaluated using observation to determine the location where insect eggs are deposited and the emergence rates of species. Depending on the outcome of the tests, the experiment could be discontinued if there were unacceptable effects on other resources. There is also the possibility that implementation would result in confounding interactions with TMF experiments, and this will be discussed during the communication and consultation process as described in Section 2.2.4.4.

2.2.4.7 Conservation Measures under Alternative D

Applicable conservation measures identified in previous BOs related to Glen Canyon Dam operations would be carried forward in Alternative D and are described fully in Appendix O. Additional conservation measures to minimize or reduce the effects of actions under Alternative D, or that benefit or improve the status of listed species as part of the LTEMP, also are described in Appendix O.

2.2.5 Alternative E

The objective of Alternative E is to provide for recovery of the humpback chub while protecting other important resources including sediment, the Glen Canyon rainbow trout fishery, aquatic food base, and hydropower resources. Alternative E features a number of condition-dependent flow and non-flow actions that would be triggered by resource conditions (Table 2-2). The alternative uses decision trees to identify when a change in base operations or some other action is needed to protect resources. Of particular focus under Alternative E are changes in sediment input, humpback chub numbers and population structure, trout numbers, and water temperature. The Basin States submitted this alternative for analysis and consideration in the LTEMP EIS.

Some aspects of Alternative E originally proposed by the Basin States were not included in the alternative evaluated in the EIS. These include new infrastructure in the form of a pump-back system that would be used to pump water from the mainstem Colorado into the Paria River to mobilize fine sediment that would then flow into the Colorado River and increase turbidity to reduce the predation efficiency of trout on young humpback chub. The Basin States also proposed implementation of rapid-response HFEs that would be implemented by timing high releases from Glen Canyon Dam to coincide with sediment inputs from the Paria River. See Section 2.4 for a discussion of elements considered but dismissed from analysis in the LTEMP EIS.

2.2.5.1 Base Operations under Alternative E

Under Alternative E, monthly volumes would closely follow the monthly hydropower demand as defined by the contract rate of delivery (Table 2-11). The total monthly release volume of October, November, and December, however, would be equal to that under Alternative A (i.e., 2 maf in years with ≥8.23 maf annual release volume) to minimize the

TABLE 2-11 Flow Parameters under Alternative E in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	643	0.0781	10,451	6,426
November	642	0.0780	10,781	6,415
December	716	0.0870	11,643	7,159
January	781	0.0949	12,707	7,813
February	691	0.0840	12,449	6,914
March	730	0.0887	11,870	7,298
April	650	0.0790	10,922	6,499
May	672	0.0817	10,935	6,724
June	704	0.0855	11,829	8,446
July	767	0.0932	12,471	9,202
August	659	0.0801	10,721	7,911
September	575	0.0699	9,668	5,753

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts or other factors, and based on application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

[b] Values have been rounded.

possibility of the operational tier differing from that of Alternative A, as established in the Interim Guidelines (Reclamation 2007a). In addition, lower monthly volumes (relative to Alternative A) would be targeted in August and September (15% of the annual release volume for August and September combined) to reduce sediment transport during the monsoon period, when most sediment is delivered by the Paria River.

Under base operations, the allowable within-day fluctuation range from Glen Canyon Dam would be proportional to the volume of water scheduled to be released during the month (12 × monthly volume in kaf in high power demand months of June, July, and August, and 10 × monthly volume in kaf in other months; Table 2-1; Figure 2-23). For example, the daily fluctuation range in July with a scheduled release volume of 800 kaf would be 9,600 cfs, and the daily fluctuation range in December with the same scheduled release volume would be 8,000 cfs. The down-ramp rate under this alternative would be limited to no greater than 2,500 cfs/hr, which is 1,000 cfs/hr greater than what is allowed under Alternative A. The up-ramp rate would be 4,000 cfs/hr, and this is the same as under Alternative A. Figure 2-23 shows minimum, mean, and maximum daily flows in an 8.23-maf year, assuming all days in a month adhere to the same mean daily flow within a month. Figure 2-24 shows the hourly flows in a simulated 8.23-maf year within the constraints of Alternative E. Figure 2-25 shows details of hourly flows during a week in July.

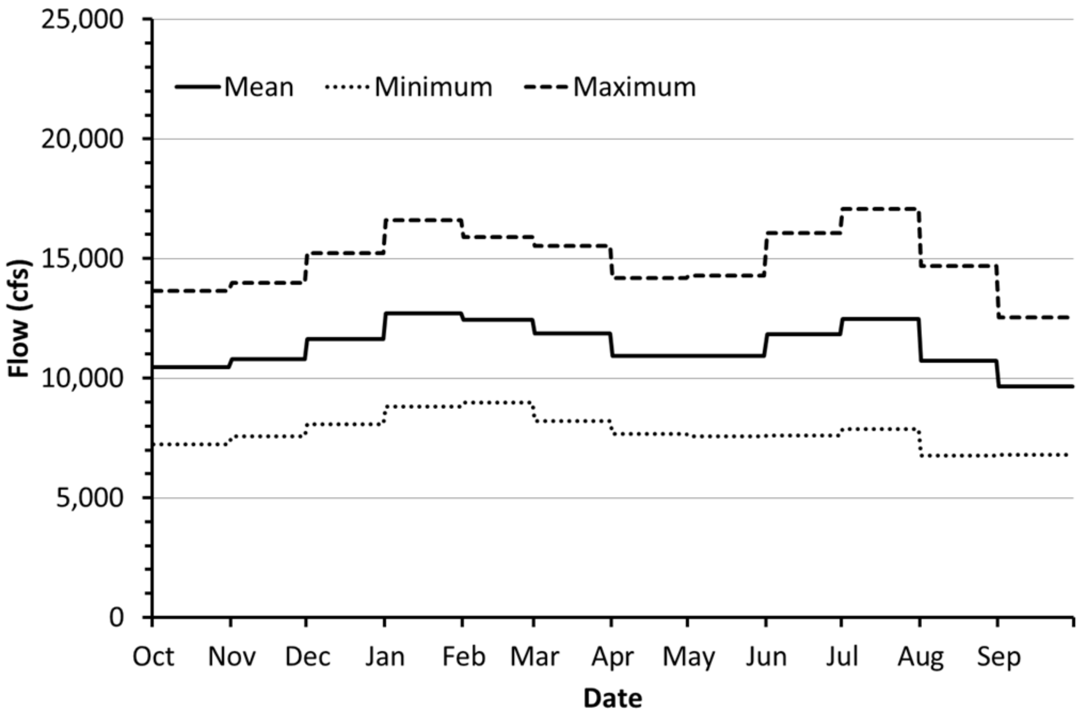


FIGURE 2-23 Mean, Minimum, and Maximum Daily Flows under Alternative E in an 8.23-maf Year Based on the Values Presented in Table 2-11

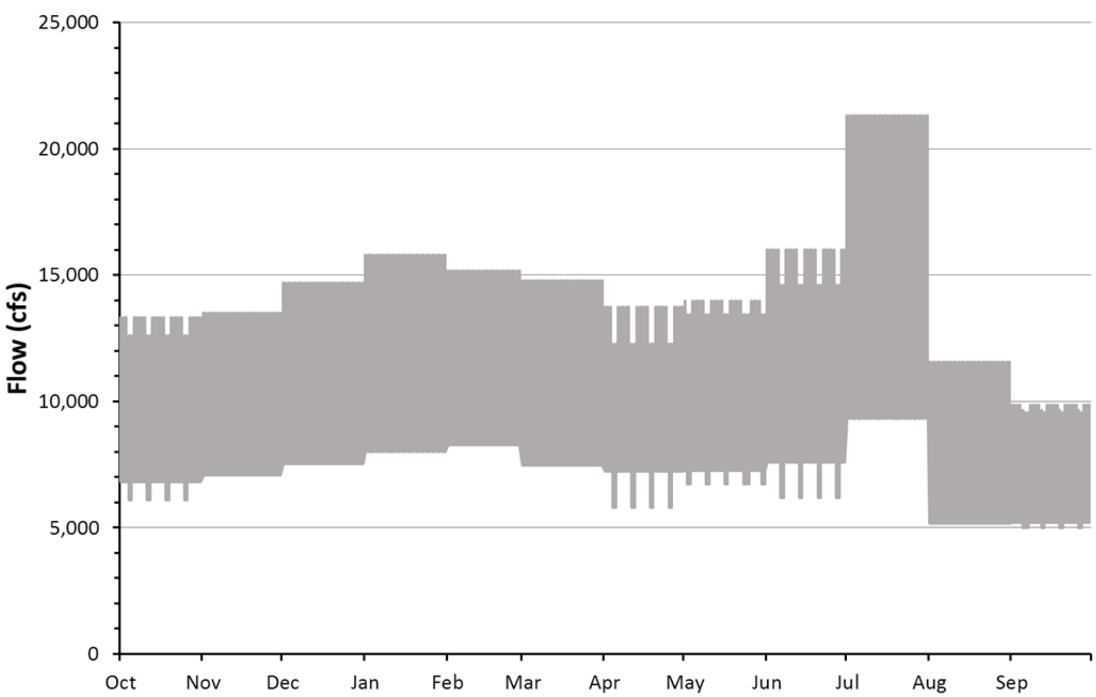


FIGURE 2-24 Simulated Hourly Flows under Alternative E in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 2-23. These differences reflect flexibility in operational patterns allowed within the constraints of the alternative.)

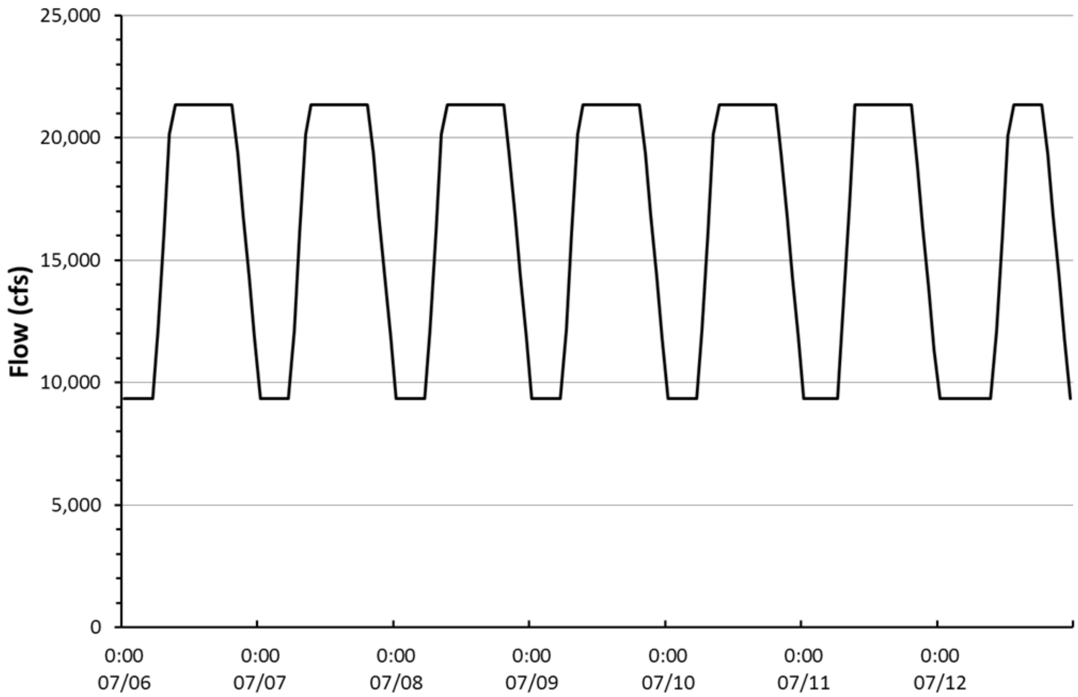
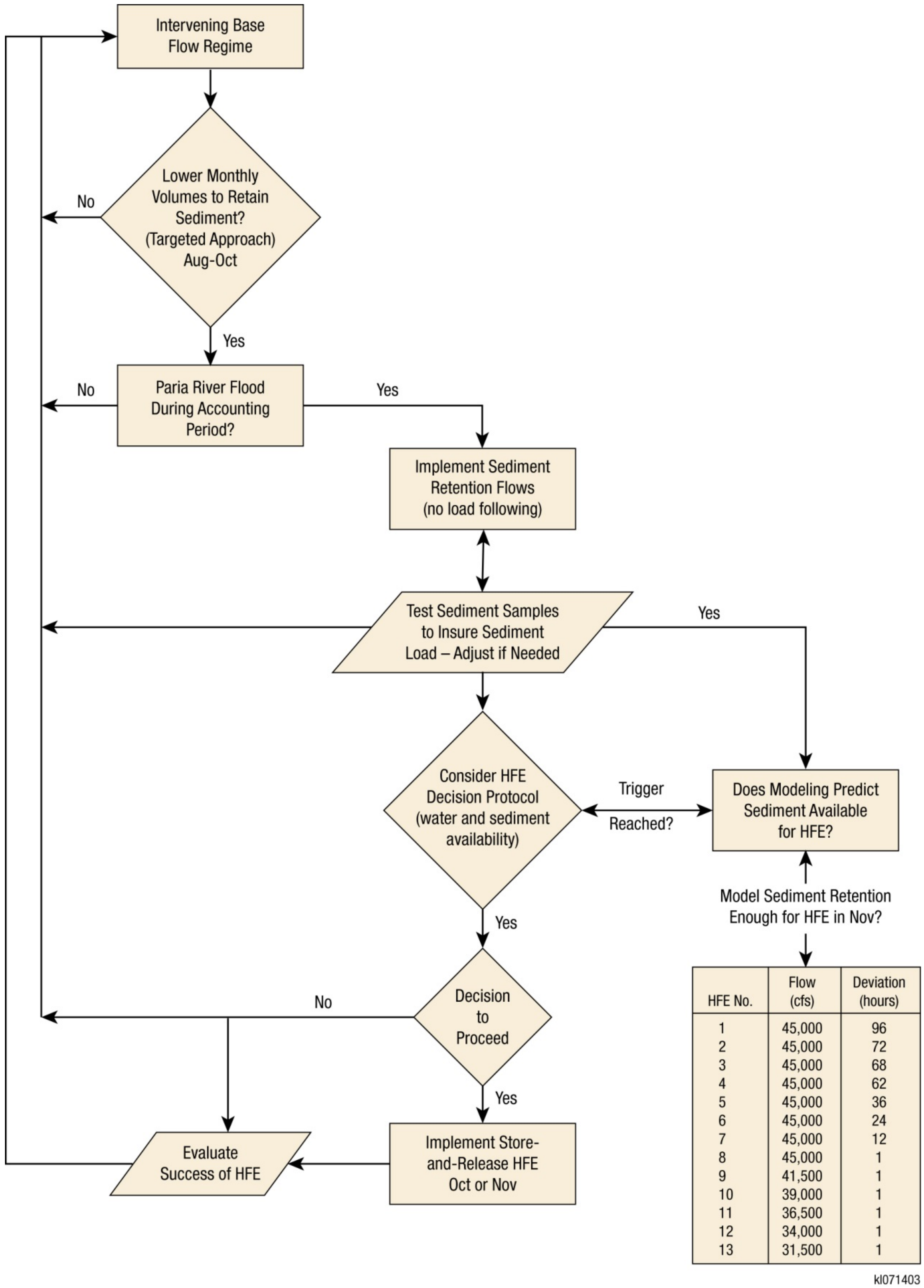


FIGURE 2-25 Simulated Hourly Flows under Alternative E for a Week in July in an 8.23-maf Year Showing Typically Lower Weekend Flows (The week starts on Monday and ends on Sunday.)

2.2.5.2 Experimental Framework for Alternative E

Alternative E uses a condition-dependent approach to implement experimental elements. The alternative would use decision trees, tied to information collected under a long-term monitoring program that would be implemented annually to determine operations and flow and non-flow actions in a given year (Figures 2-26 and 2-27). In general, the experimental framework considered under Alternative E is more structured than that proposed under other alternatives, especially for the experimental evaluation of TMFs. Alternative E would incorporate a 2 × 2 factorial science design to test TMFs.

Base operations under Alternative E would be experimentally modified in response to changes in resource conditions or the need for equalization as specified under the 2007 Interim Guidelines (Reclamation 2007a). The most important experiments relate to (1) implementation of HFEs in response to sediment inputs; (2) reductions in fluctuation in certain parts of the year in response to sediment inputs; and (3) reductions in flows in certain years from July through September to provide warmer water for humpback chub near the confluence with the Little Colorado River. Non-flow actions are largely limited to those that are common to all alternatives as described at the beginning of Section 2.2.



HFE No.	Flow (cfs)	Deviation (hours)
1	45,000	96
2	45,000	72
3	45,000	68
4	45,000	62
5	45,000	36
6	45,000	24
7	45,000	12
8	45,000	1
9	41,500	1
10	39,000	1
11	36,500	1
12	34,000	1
13	31,500	1

FIGURE 2-26 Decision Tree for Sediment-Related Actions under Alternative E (modified from Figure 1 in original Basin States submittal)

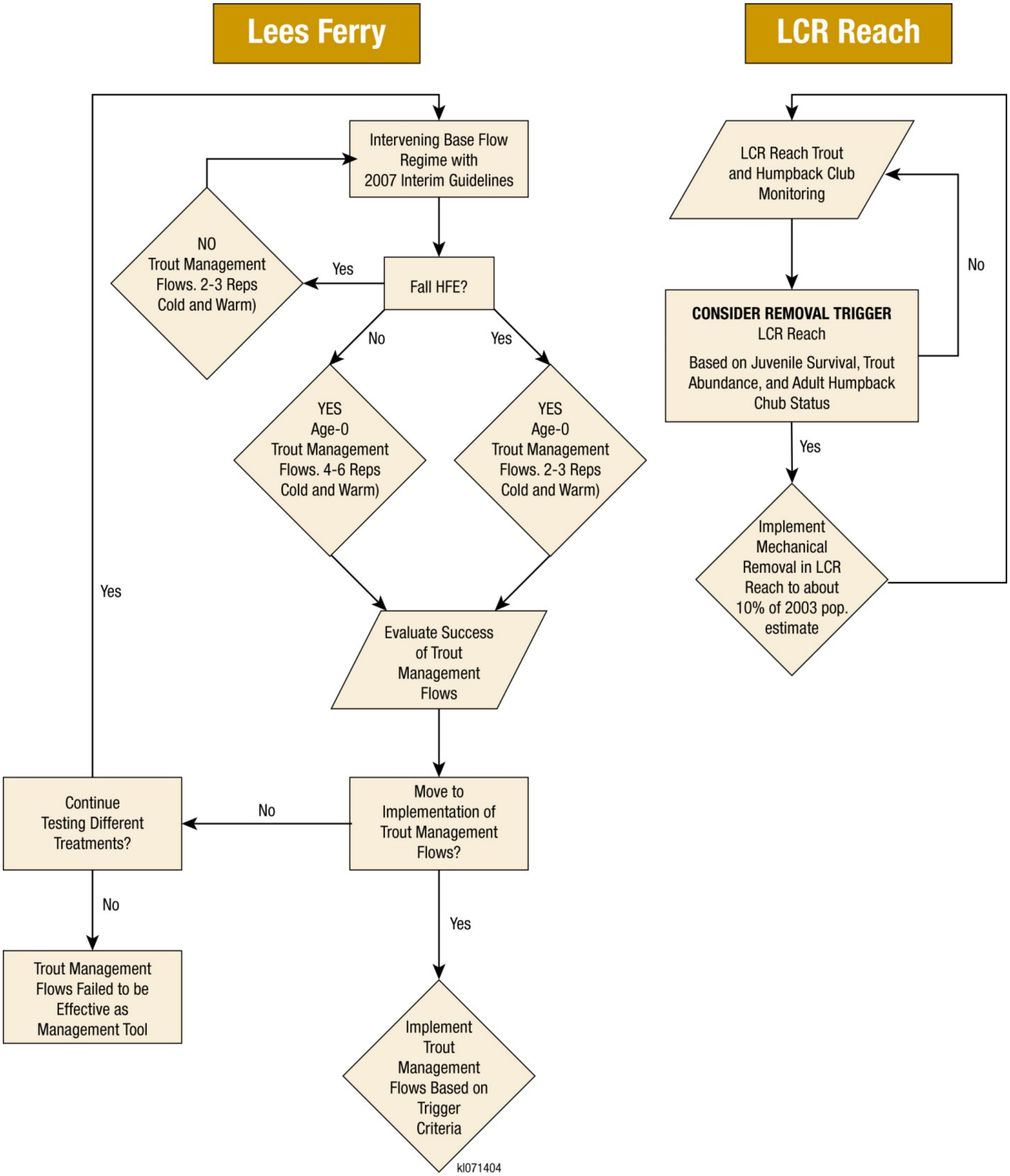


FIGURE 2-27 Decision Tree for Trout-Related Actions under Alternative E (Figure 2 in original Basin States submittal)

Sediment-Related Experiments To Be Evaluated under Alternative E

Under Alternative E, the HFE protocol would be incorporated into the LTEMP process and extended to the end of the LTEMP period. Spring and fall HFEs would be implemented when triggered using the same Paria River sediment input thresholds used under the existing HFE protocol (Reclamation 2011b). HFE releases would be 1 to 96 hr long and between 31,500 cfs and 45,000 cfs. Depending on the cumulative amount of sediment input from the Paria River during the spring (December through March) or fall (July through October) accounting periods, the maximum possible magnitude and duration of HFE that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling, would be implemented (see Section 2.2.1 for a brief description of the existing HFE protocol).

Under Alternative E, only fall HFEs would be conducted during the first 10-year period. This delay of implementation of spring HFEs is intended to allow for the testing of TMFs to control trout numbers and emigration rates, and is based on the response of the trout population to the spring HFE of 2008.

Under Alternative E, daily fluctuations for load-following would be reduced (except for instantaneous increases or decreases in flow to provide regulation services)[6] after significant sediment input (sufficient input to trigger an HFE) from the Paria River in August, September, or October to increase the amount of sediment available for transport and deposition by fall HFEs. These reduced fluctuations would occur until an HFE was implemented or a decision to not implement an HFE was made. Under Alternative E, within-day fluctuations in hourly flows would be reduced to a within-day range of 2,000 cfs (i.e., ±1,000 cfs of the mean daily flow).

During high-volume (≥10-maf release volume) release years (i.e., equalization years), an HFE would be conducted quickly (i.e., days) following an unusually large input of sediment from the Paria River to redistribute the new sediment from the main river channel before high-volume releases can transport it downstream. This “quick response” HFE is different from the proactive spring HFEs proposed under Alternatives C and D because it is sediment-triggered; could occur in the spring, summer, or fall of the year; and would not be limited in duration to 24 hr.

Aquatic Resource-Related Experiments To Be Evaluated under Alternative E

Mechanical removal of trout would be conducted at the confluence of the Little Colorado River under certain conditions (i.e., low survival rate of juvenile humpback chub, trout abundance exceeds the level seen in 2003 of about 6,900 individuals in the Little Colorado River reach (RM 56.3 and RM 65.7), or the number of humpback chub adults drops by 1,000 individuals (during the same time the abundance of trout exceeds 690 in the same reach). The removal protocol would follow the Nonnative Fish Control protocol (Reclamation 2011a).

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6 Although instantaneous changes in flows could occur within an hour to provide for regulation services, these flow changes would not affect the mean hourly flow.

Alternative E would evaluate potential methods for using releases (TMFs) from Glen Canyon Dam to reduce production of YOY rainbow trout to improve the quality of the Glen Canyon trout fishery and potentially help conserve humpback chub and other native fishes.

This strategy has two potential benefits: (1) flow manipulations are likely to be much less expensive and intrusive than large-scale mechanical removal efforts downstream, and (2) trying to manage trout densities in the Little Colorado River reach without reducing trout production upstream will be difficult to overcome during years with high production (e.g., trout response to 2008 HFE and response to 2011 high steady flows). The goal is to develop a management action based on condition-dependent criteria. Key metrics for a high-quality trout fishery would need to be developed in consultation with the AZGFD, such as targets for adult and juvenile numbers, individual fish condition, YOY numbers, and information and value determined through creel surveys. TMFs could be used to help attain these goals with other management tools employed by the AZGFD and NPS. TMF treatments should address the following:

- Evaluate the potential for utilizing changes in down-ramp rates to strand or displace juvenile trout and reduce recruitment,
- Evaluate different types and magnitudes of TMFs, and
- Determine whether flow and non-flow actions at Lees Ferry would be effective in improving the Lees Ferry trout fishery.

TMFs would be tested in a 2 × 2 factorial design with HFEs over a 20-year period to evaluate their potential effectiveness in reducing trout recruitment levels in the Glen Canyon reach over a variety of environmental conditions. The status of the trout fishery would be considered in any decision to proceed with implementation of TMFs in a given year. The goal is to develop management tools that are robust to a range of natural and human caused conditions. The following treatment combinations would be implemented with a goal of achieving two to three replicates for each combination under warm and cold temperature conditions over the 20-year LTEMP period:

- No fall HFE and no TMF, to measure trout recruitment with neither factor in place;
- No fall HFE, but with a TMF, to test effects of TMFs alone;
- Fall HFE, but no TMF, to test effects of HFEs alone; and
- Both fall HFE and TMF, to test the effects of both in the same year.

Two options for implementation would be considered (1) begin with moderate treatments (e.g., one cycle); or (2) begin with more robust treatments (e.g., three or more cycles) to establish easily observable results. With this latter approach, successive treatments would evaluate more moderate treatments if the first tests showed an effect.

At least four types of TMFs would be evaluated: (1) YOY stranding and displacement flows from May through June, (2) YOY stranding and displacement flows from July through August, (3) YOY stranding and displacement flows without moving to high flows (e.g., 20,000 cfs) prior to dropping to a minimum, and (4) flow reductions applied only at night to the above scenarios with the objective of reducing food base impacts from desiccation.

YOY stranding and displacement flows would consist of 3 days at steady 20,000 cfs followed by a rapid drop (unrestricted down-ramp rate) to 5,000 cfs or 8,000 cfs to be held for 6 hr during daylight hours (6 a.m.–noon). Three such cycles would be conducted over the month. A 3-day flow cycle would be followed by 7 days of normal flows, and this 3- to 7-day pattern would be repeated three times over the month. This option would include tests of this method in May and June, and then in July and August if sediment retention flows were not in effect (see Figure 2-15 for an illustration of TMFs).

A test without moving to high flows first would determine if it is necessary to attract trout to higher elevations (e.g., steady 20,000 cfs) before a rapid drop. Trout generally reside at the normal minimum flow (Korman and Campana 2009). Thus, they may be susceptible to a rapid drop in flow without the need to raise flows for an extended period beforehand. This test would stabilize flows near the normal minimum (within the varial zone), and would then apply a rapid down-ramp below the minimum.

If reservoir elevations are not variable enough during the first 10 years to produce years with warm releases, a steady flow test aimed at achieving warmer temperatures would be considered. If the evaluation is warranted, implementation would be conditioned on the status of the humpback chub and other critical resources. A low summer flow experiment would not be conducted at a time when the humpback chub population is low or declining. Under Alternative E, a low summer flow experiment would only be conducted in a warm release year to increase contrast with more typical coldwater years.

The transition in flow volume from one month to the next can be substantial. Low-volume months, such as a 600-kaf month, can be followed by a month that exceeds 900 kaf. These large transitions may have a negative impact on productivity of the aquatic food base (i.e., organisms including algae, plants, and invertebrates that serve as the foundation of the aquatic food web). Alternative E would include a stepped transition between months when substantial differences in the amount of water releases occur. The decision rules for transition flows would need to be developed to take into account the difference in volume that would trigger these flows, and the amount of time necessary to provide suitable transition to minimize impacts on the food base.

2.2.6 Alternative F

The objective of Alternative F is to a provide flows that follow a more natural pattern while limiting sediment transport and providing for warming in summer months. In keeping with this objective, Alternative F does not feature some of the flow and non-flow actions of the other alternatives.

Flows under Alternative F would follow the same basic monthly pattern as the Seasonally Adjusted Steady Flow Alternative in the 1995 EIS (Reclamation 1995), but the pattern is modified to achieve higher, more variable spring peak flows, lower summer, fall, and winter flows, and warmer temperatures starting in July. Peak flows would be lower than pre-dam magnitudes to reduce sediment transport and erosion given the reduced sand supply downstream of the dam. There would be no within-day fluctuations in flow under Alternative F (see Tables 2-1 and 2-12; Figure 2-28).

Under Alternative F, peak flows would be provided in May and June, which corresponds well with the timing of the pre-dam peak. The overall peak flow in an 8.23-maf year would be 20,000 cfs (scaled proportionately in drier and wetter years); it would include a 24-hr 45,000-cfs flow at the beginning of the spring peak period (e.g., on May 1) if there was no triggered spring HFE in the same year, and a 168-hr (7-day) 25,000 cfs flow at the end of June. Following this peak, there would be a rapid drop to the summer base flow. The initial annual 45,000-cfs flow would serve to store sediment above the flows of the remainder of the peak, thus limiting sand transport farther downstream and helping to conserve sandbars. The variability in flows within the peak would also serve to water higher-elevation vegetation.

Low base flows would be provided from July through January. These low flows would provide for warmer water temperatures, especially in years when releases are warm, and would also serve to reduce overall sand transport during the remainder of the year.

Under Alternative F, the only adjustment to base operations would be sediment-triggered HFEs implemented according to the HFE protocol (Reclamation 2011b) for the entire LTEMP period. There would be no mechanical removal of trout or TMFs. However, the rapid drop from peak flow to base at the end of June could incidentally serve much the same function as a TMF, thus acting to reduce the overall high trout production rates expected under a steady flow regime.

Other than testing the effectiveness of HFEs as implemented under the HFE protocol, there would be no explicit experimental or condition-dependent triggered actions under Alternative F. As with other alternatives, an ongoing monitoring program would be used to determine the response of resources to operations, and adjustments to those operations would be made consistent with adaptive management.

2.2.7 Alternative G

The objective of Alternative G is to maximize the conservation of sediment, in order to maintain and increase sandbar size. The alternative is based on the hypothetical best-case scenario suggested by Wright, Schmidt et al. (2008) for conservation of sand inputs from tributaries downstream of Glen Canyon Dam. Under Alternative G, flows would be delivered in a steady pattern throughout the year with no monthly differences in flow other than those needed to adjust operations in response to changes in forecast and other operating requirements such as equalization (Tables 2-1 and 2-13; Figure 2-29). In an 8.23-maf year, steady flow would be approximately 11,400 cfs.

TABLE 2-12 Flow Parameters under Alternative F in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	506	0.0615	8,229	0
November	490	0.0595	8,229	0
December	506	0.0615	8,229	0
January	506	0.0615	8,229	0
February	611	0.0742	11,000	0
March	861	0.1046	14,000	0
April	1,012	0.1229	17,000	0
May	1,230	0.1494	20,000	0
June	1,190	0.1446	20,000	0
July	445	0.0540	7,229	0
August	445	0.0540	7,229	0
September	430	0.0523	7,229	0

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts and other factors, such as application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

[b] Values have been rounded.

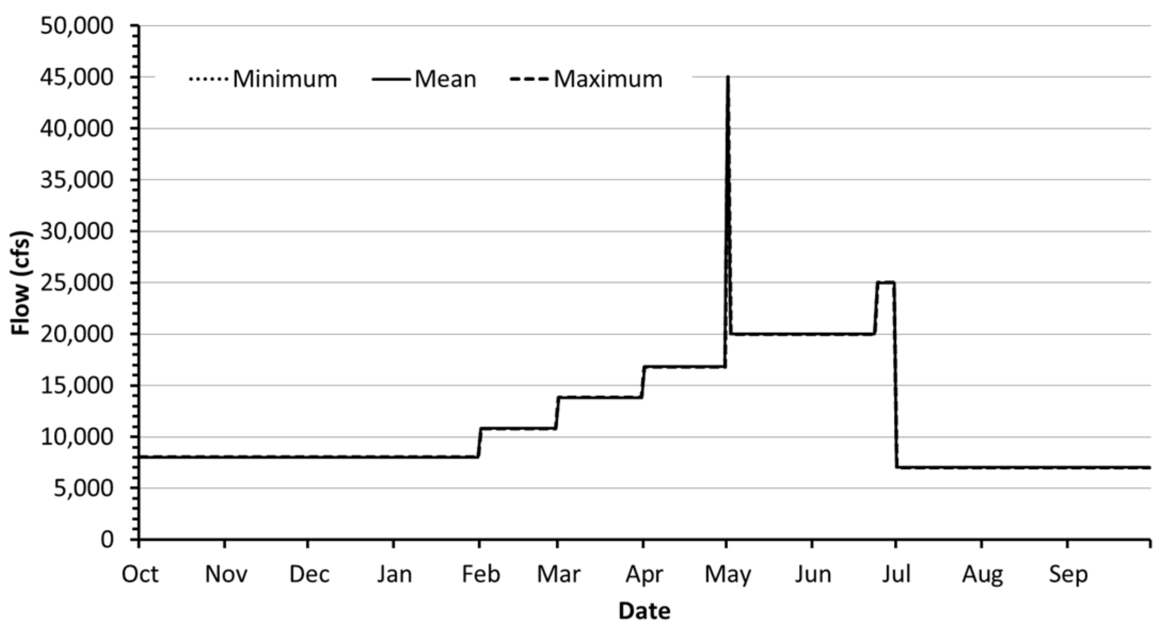

FIGURE 2-28 Mean, Minimum, and Maximum Daily Flows under Base Operations of Alternative F in an 8.23-maf Year Based on the Values Presented in Table 2-12

TABLE 2-13 Flow Parameters under Alternative G in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	699	0.0849	11,368	0
November	699	0.0849	11,747	0
December	677	0.0823	11,010	0
January	699	0.0849	11,368	0
February	676	0.0821	12,172	0
March	699	0.0849	11,368	0
April	699	0.0849	11,747	0
May	631	0.0767	10,262	0
June	699	0.0849	11,747	0
July	676	0.0821	10,994	0
August	699	0.0849	11,368	0
September	677	0.0823	11,377	0

[a] Within a year, monthly operations may be increased or decreased based on changing annual runoff forecasts and other factors, such as application of the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a).

[b] Values have been rounded. Variation among months reflects adjustments based on changing forecasts.

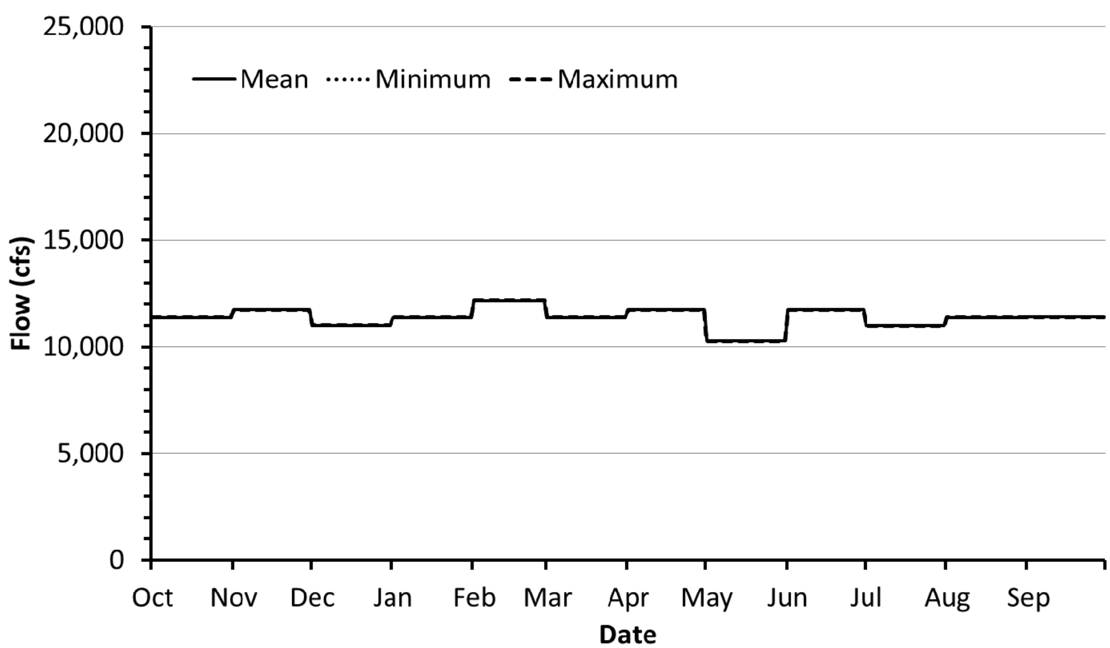

FIGURE 2-29 Mean, Minimum, and Maximum Daily Flows under Alternative G in an 8.23-maf Year Based on Values Presented in Table 2-13

Under Alternative G, spring and fall HFEs would be implemented in accordance with the HFE protocol (Reclamation 2011b), but with experimental modifications as described under the Alternative C (Section 2.3.3.2) including (1) adjustments of operations before and after HFEs occur; (2) implementing spring proactive HFEs in high-volume equalization years prior to equalization releases; and (3) implementation of longer duration (>96-hr) HFEs. Under Alternative G, however, the volume of a longer duration HFE would not be constrained by the volume of a 96-hr 45,000-cfs HFE, but instead could be as long as 336 hr (14 days), depending on the amount of sediment available for transport.

Under Alternative G, mechanical removal of trout would be implemented consistent with the Nonnative Fish Control protocol (Reclamation 2011a) in the Little Colorado River reach. Testing and implementation of TMFs as triggered by trout recruitment would occur as described for Alternative C (Section 2.3.3.3).

2.3 ALTERNATIVES CONSIDERED AND ELIMINATED FROM DETAILED STUDY

During the scoping and analysis periods for the LTEMP DEIS, a number of alternative concepts were either (1) developed and explored by the DOI's LTEMP team; (2) developed as complete alternative proposals by the Cooperating Agencies or other stakeholders; or (3) suggested by the public as alternatives that should be included in the LTEMP DEIS. Four of the alternative concepts developed by the DOI's LTEMP team are described in Section 2.2 (Alternatives C, D, F, and G). Also described in Section 2.2 are two complete alternative proposals submitted by stakeholders. Alternative E was submitted by the Basin States and Alternative B was submitted by CREDA, a non-profit association of energy customers of the Colorado River Storage Project, in response to the DOI's request to all stakeholders for alternative concepts. Other alternatives are identified below with an explanation of why they were not included as an alternative in the EIS.

2.3.1 Modified Low Fluctuating Flows with Extended Protocols

The DOI's LTEMP team identified an alternative that would be comparable to Alternative A, but that would extend the existing HFE and Nonnative Fish Control protocols past their current expiration date of 2020 through the entire LTEMP period. This alternative was in part identified to enable a more direct comparison of impacts with the remaining alternatives that would extend the protocols through the LTEMP period. Alternative A, by definition, would only implement existing decisions up to their expiration dates. Preliminary analyses indicated that this alternative would perform similarly to Alternative A, especially for hydropower generation value (based on monthly release volumes and daily flow fluctuations), and would be similar to Alternative E with respect to humpback chub, trout, and sediment resources (because of alternative-specific flow fluctuations and the frequency of HFEs). The analysis of the seven alternatives evaluated in the EIS evaluates a reasonable range of possible operational and experimental variations, including those of this alternative, without requiring additional detailed analysis for NEPA compliance purposes.

2.3.2 Naturally Patterned Flow Alternative

A Naturally Patterned Flow Alternative, similar to the Historic Pattern Alternative, described in the 1995 EIS (Reclamation 1995), was identified by the DOI's LTEMP team as a possible alternative early in the LTEMP EIS process. Under this alternative, flows would vary from month to month in conformance with the historic flow pattern and would not include daily fluctuations. HFEs would be sediment triggered, but their timing would be shifted to conform to natural flood timing. Minimum flows could be lower than the current minimum, and maximum flows as high as full bypass, scaled for the annual hydrologic condition. Transitions between months would be relatively smooth, with established limitations on the rate of change between days.

Preliminary modeling indicated that sand transport under this alternative, as originally defined, would be far higher than under other alternatives. When originally conceived, this alternative featured sediment augmentation as a critical element. Without sediment augmentation (see rationale for not including sediment augmentation or other new infrastructures in alternatives in Section 2.4.1), estimated sand transport would be too great to sustain downstream sediment resources, and, as a consequence, this alternative was considered to not meet the purpose, need, and objectives of the LTEMP. High rates of erosion were also identified for the Historic Pattern Alternative in the 1995 EIS (Reclamation 1995), and were considered as the primary reason for eliminating it from further consideration. It should be noted that Alternative F was developed by the DOI in response to the findings of the preliminary analysis of the Naturally Patterned Flow Alternative, and was included in the EIS to provide an alternative that achieved the original objectives of the Naturally Patterned Flow Alternative while reducing overall sediment transport, and thus, meeting the purpose, need, and objectives of the LTEMP.

2.3.3 Seasonal Fluctuations with Low Summer Flow Alternative

The Seasonal Fluctuations with Low Summer Flow Alternative would feature low summer (July through September) flows each year, and was developed by the DOI's LTEMP team to provide warmer water temperatures for native fish and other aquatic resources. Excess water volume not released in the summer would be released in the winter (December through February) and late spring (May and June). Fluctuations would be low in the summer (2,000 cfs daily range), but would conform to MLFF-level fluctuations the remainder of the year. The alternative would use the existing HFE and Nonnative Fish Control protocols for the entire LTEMP period. Preliminary analyses for this alternative were completed, but it was not included as an LTEMP alternative because the analyses suggested that the alternative did not perform better than others with regard to impacts on native fish populations and other aquatic resources. This is largely a consequence of the marginal gains in temperature (about 1 or 2°C at the Little Colorado River confluence) that are expected to occur under low flows. Since the alternative did not meet its intended objectives, there was no compelling reason to include it as an alternative in the EIS. Other alternatives, such as Alternatives C, D, and E, were determined to provide benefits to native fish and aquatic resources, and therefore met the objectives of the Seasonal Fluctuations with Low Summer Flow Alternative.

2.3.4 Grand Canyon First! Alternative

A "Grand Canyon First!" Alternative was proposed as an alternative concept in a number of public scoping comments. In this alternative, consideration of the ecology and wildlife of Grand Canyon would be the paramount consideration, restoring Grand Canyon to its historical state to the extent possible. This alternative would recognize the Grand Canyon Protection Act (GCPA) as the primary source to inform the LTEMP EIS, and the operations of Glen Canyon Dam should help to preserve the natural and cultural resources of Grand Canyon. Public comment provided objectives but not an operational regime, non-flow actions, or experimental plan to achieve those objectives; therefore, this alternative was not sufficiently well-defined to include as an LTEMP alternative. Although this concept was not included as an alternative in the EIS, all LTEMP alternatives include many of the concepts that are in this proposal; for example, operations to achieve sediment and native fish objectives are included in LTEMP alternatives, including Alternatives C, D, E, F, and G.

2.3.5 Species Community and Habitat-Based Alternative

Several members of the public suggested that a Species Community and Habitat-Based Alternative be included in the LTEMP DEIS. This proposed alternative concept was intended to contribute to the conservation or recovery of endangered or extirpated species, such as the humpback chub, razorback sucker, southwestern willow flycatcher (*Empidonax traillii extimus*), and Kanab ambersnail. It would also contribute to the conservation of other non-listed aquatic and riparian species (including flannelmouth sucker [*Catostomus latipinnis*], bluehead sucker [*Catostomus discobolus*], and speckled dace [*Rhinichthys osculus*]) to reduce the need to list them under the ESA. This would include an ESA Recovery Implementation Program focused on supporting native species communities that ensures that their habitat-based needs are met. This alternative would include a management program for the trout at Lees Ferry that also provides for protection of humpback chub and other native fish populations downriver, and a quality recreational fishery at Lees Ferry. Public comment provided objectives, but not an operational regime, non-flow actions, or experimental plans to achieve those goals, and, therefore, was not sufficiently well-defined to include as an LTEMP alternative. Although this concept was not included as an alternative in the EIS, other elements of the concept, such as operations to achieve sediment, native fish, and trout management objectives, are included in several alternatives, including Alternatives B, C, D, E, F, and G. Each of these LTEMP alternatives identifies operations to protect existing ecological resources.

2.3.6 Stewardship Alternative

During public scoping, commenters suggested consideration of a Stewardship Alternative that utilized a flow regime that would best serve Grand Canyon and be aligned with the GCPA, with no consideration given to hydropower. Commenters provided objectives but not an operational regime, non-flow actions, or experimental plan to achieve those objectives, and, therefore, this alternative was not sufficiently well-defined to include as an LTEMP alternative. In addition, the suggestion that hydropower generation should not be considered as an objective is counter to the purpose, need, and objectives of the proposed action. Although this concept was not included as an alternative in the EIS, all LTEMP alternatives include many concepts in this proposal; for example, operations to achieve sediment and native fish objectives are included in several LTEMP alternatives, including Alternatives C, D, E, F, and G. Each of these LTEMP alternatives places high priority on protecting downstream resources and identifies flow and non-flow actions to protect those resources.

2.3.7 Twelve-Year Experiment of Two Steady-Flow Alternatives

Grand Canyon Trust proposed a 12-year series of three 4-year experimental blocks. Operations during the first 4-year period would be seasonally adjusted steady flows. Operations during the next 4-year block would be MLFF. The final 4-year block would feature year-round steady flows. All three flow regimes would include high-flow releases under sediment-enriched conditions. After 12 years, the three regimes would be analyzed to determine which had the most favorable results consistent with the GCPA.

This alternative was not included in the EIS, because the proposed experimental design would most likely lead to confounding of effects by the hydrologic patterns that occurred during the LTEMP period, differences in annual volumes, the potential need for equalization operations during one or more years, and differences in sediment supply between treatments. These confounding factors would make it difficult to interpret the results of the proposed experiment. The three operational regimes proposed for this alternative were, however, included as separate alternatives.

2.3.8 Decommission Glen Canyon Dam Alternative

During the public scoping period, several members of the public suggested that an alternative that would result in the decommissioning of Glen Canyon Dam should be considered. Comments suggested that the dam could be either left in place or removed. If left in place, reservoir levels would be equalized to upstream inflows. Lake Powell water levels would drop, and the sediments would begin to cut new banks and form a new channel that would flow around and through the dam. Public comments advocating the decommissioning of the dam mentioned the benefits of opening currently submerged areas to new recreational activities; restoring the environmental, recreational, and cultural resources of the Grand Canyon and the Colorado River basin to their pre-dam conditions; and positively affecting the health of the Colorado River Ecosystem. One commenter suggested transferring the contents of Lake Powell and Lake Mead to underground storage locations to avoid losing water to evaporation. The commenter stated that there are abundant nearby natural underground locations that could accommodate the volume of water from 6 years of the Colorado River's annual flow.

The Decommission Glen Canyon Dam Alternative was not included in the EIS because it would not meet the purpose, need, or objectives of the proposed action. The alternative would not allow compliance with water delivery requirements, including the Law of the River and 2007 Interim Guidelines (Reclamation 2007a,b), and would not comply with other federal requirements and regulations, including the GCPA. This alternative was proposed by members of the public during scoping for the 1995 EIS on Glen Canyon Dam operations, and was not considered for detailed study for reasons similar to those presented above.

2.3.9 Fill Lake Mead First Alternative

The Fill Lake Mead First Alternative was proposed by members of the public during the public scoping comments. Under this alternative, primary water storage would shift from Lake Powell to Lake Mead, using Lake Powell as a backup for seasonal and flood control purposes. According to the commenters, there would likely be less water lost to evaporation and seepage, and there would be greater flexibility for implementing Grand Canyon restoration strategies. This alternative was not included in the EIS because it would not meet the purpose, need, or objectives of the proposed action. The alternative would not allow compliance with water release requirements, including, but not limited to, the division and apportionment of the use of the waters of the Colorado River system under the Colorado River Compact, as well as other portions of the Law of the River and 2007 Interim Guidelines (Reclamation 2007a,b). In addition, the alternative would not comply with other federal requirements and regulations, including the GCPA.

2.3.10 Full-Powerplant Capacity Operations Alternative

During the public scoping period, members of the public suggested inclusion of an alternative that allowed for full powerplant capacity operations. Commenters suggested that pre-1996 ROD operations be considered as one alternative to allow for a better understanding of the effects of MLFF operations. The Full-Powerplant Capacity Operations Alternative was not included in the EIS because it would not meet the purpose, need, and objectives of the LTEMP, including compliance with the GCPA. Although the Full-Powerplant Capacity Operations Alternative was not considered as a separate alternative in the EIS, Alternative B described in Section 2.3.2 and analyzed in Chapter 4 includes a test of "hydropower improvement flows" that would feature wide daily fluctuations (up to 20,000 cfs in some years and months).

2.3.11 Run-of-the-River Alternative

Some members of the public suggested that Glen Canyon Dam could be re-engineered to operate as a modified run-of-the-river facility. A Run-of-the-River Alternative would restore natural water and sediment flows to the greatest extent possible by reconnecting old river bypass tunnels or constructing new tunnels to bypass Glen Canyon Dam. This alternative would utilize elements of the "Fill Lake Mead First" alternative above. This alternative was not included in the EIS because it would not meet the purpose, need, or objectives of the proposed action. The alternative would not allow compliance with water delivery requirements, including the Law of the River and 2007 Interim Guidelines (Reclamation 2007a,b), and would not comply with other federal requirements and regulations, including the GCPA.

2.4 ALTERNATIVE ELEMENTS ELIMINATED FROM DETAILED STUDY

A number of elements were considered by the DOI's LTEMP team for inclusion in LTEMP alternatives, including those identified by the public during the scoping process and alternative workshop in April 2012. Many are included in the alternatives described in Section 2.2. Those eliminated from detailed study are described in this section.

2.4.1 New Infrastructure

Several infrastructure additions and modifications were initially discussed by the DOI during alternative development, including (1) sediment augmentation, (2) a TCD, (3) retrofitting of the bypass tubes to install power generation, and (4) re-engineering of the spillways if needed to allow for more frequent use. Prior to initiation of LTEMP alternative development, options for sediment augmentation, bypass generation, and a TCD were evaluated by Reclamation from engineering assessment and cost perspectives. Several of these options were described in Randle et al. (2006), Reclamation (1999b), and Vermeyen (2008).

In addition to infrastructure additions or modifications considered by the DOI, the Basin States and CREDA included several infrastructure considerations in the alternatives they proposed. These are described in the following paragraphs.

Under Alternative E, the Basin States proposed an investigation to determine the feasibility of using a pump-back system in the Paria River drainage to increase turbidity in the mainstem. This feasibility study would evaluate options, limitations, and cost-benefit. The study would investigate the possibility of installing a pumping system at Lees Ferry to transport a small amount of water up into the Paria River drainage to increase turbidity for a few weeks in the mainstem to disadvantage rainbow trout.

For Alternative B, CREDA proposed utilizing bubblers in the Glen Canyon forebay to break down the temperature differential between the surface and deeper waters and consequently provide warmer water near the turbine intakes for release downstream. To increase turbidity downstream of the dam, CREDA proposed installing one or more small check dams in the Paria River that would be used to trap sediment for release during a time when young humpback chub are entering the mainstem from the Little Colorado River, thereby enhancing their survival chances by reducing trout predation.

The DOI considers any infrastructure modifications or additions to be outside the scope of the LTEMP EIS because they are currently economically infeasible and would require additional congressional authorizations. However, the DOI does not rule out future new infrastructure if resource conditions warrant. Any infrastructure addition or modification would require additional time and study. Future potential infrastructure modifications would need to be evaluated in NEPA assessments (EAs or EISs) that fully considered the environmental impacts of construction and operation. These assessments and the construction of the infrastructure would necessarily result in some delay from the time of the LTEMP ROD and actual start of operation of the infrastructure. It could take as many as 10 years or more to evaluate and construct a TCD or sediment augmentation.

2.4.2 Flow and Non-Flow Actions

A number of flow and non-flow actions were considered by the DOI or proposed by the Cooperating Agencies, stakeholders, or the public for inclusion in the LTEMP DEIS. For various reasons, as described below, these actions were not evaluated in any of the LTEMP alternatives.

For Alternative E, the Basin States proposed that after every three store-and-release fall HFEs, the next triggered fall HFE would be a "rapid response" HFE in which Glen Canyon Dam releases would be increased within hours or days of a significant input of sediment from the Paria River. Under the alternative, more than one rapid response HFE could occur within a given fall period in response to multiple inputs of sediment. Rapid-response HFEs were not considered in the EIS because of implementation concerns, including the difficulty in coordinating releases with tributary inputs, insufficient lead time to fully notify the public and other stakeholders, and potential safety concerns associated with insufficient notification.

For Alternative B, CREDA proposed including several experiments that were not included in the alternative as analyzed. These included ponding flows and fluctuating flow experiments. Ponding flows are those relatively high flows that produce low-velocity areas in tributary mouths for the benefit of humpback chub. However, there is little evidence that ponding flows would provide benefit to YOY humpback chub; therefore, ponding flows were not included as an experimental element in Alternative B or any other alternative. Power production experiments would be short-term flow experiments intended to investigate alternative fluctuating flow parameters that might be compatible with downstream resource objectives. Because specific details of these experiments were not provided by CREDA, they were not included as an experimental element in Alternative B as evaluated in the LTEMP EIS.

Some members of the public suggested that the equalization flows identified in the Interim Guidelines (Reclamation 2007a) be released in ways that minimize impacts and provide benefits. Adverse impacts of 2011 equalization flows on sediment resources were mentioned by several commenters. It was suggested that alternatives should consider adjusting timing and magnitude of equalization flows to coincide with available sediment from the Paria and Little Colorado Rivers to help rebuild beaches in the Grand Canyon. It was also suggested that equalization flow releases should be implemented over several years rather than in a single year, as currently implemented under the 2007 ROD. This suggested adjustment to an existing recent decision would not meet the purpose, need, or objectives of the LTEMP, which requires compliance with existing, laws, regulations, and decisions.

Members of the public suggested considering introducing variability in flows by including ≥45,000-cfs flows. It was suggested that flows of 60,000 cfs and more would be beneficial for sediment-dependent resources in the Grand Canyon. This alternative element was not considered for inclusion in alternatives because it would require use of the dam's spillway, which was designed for occasional use in cases of high inflow and dam safety. The spillway is not engineered for repeated use during normal operations, and any modifications to the dam's infrastructure are considered outside the scope of the EIS, as discussed in Section 2.4.1. In addition, the spillways can only be used when the reservoir levels are very high; it is not possible to use the spillways at low reservoir elevations. It should be noted that, over the course of the LTEMP period, it is possible that such very high flows would occur as a result of normal hydrologic variation, as happened in the very wet years of 1983 and 1984.

Mechanical removal of trout in the Glen Canyon reach was considered initially by the DOI during the development of Alternative C. This alternative element was not included in the EIS because modeling indicated that the effort necessary to effect a reduction in the Glen Canyon trout population with electrofishing would be expensive, impractical, and largely ineffective. TMFs, as included in several LTEMP alternatives, were considered a much more practical way of managing trout population size in the Glen Canyon reach.

2.5 SUMMARY COMPARISON OF ALTERNATIVES

The analysis of alternatives used both quantitative and qualitative approaches (see Section 4.1). As described in Section 2.1, a structured decision analysis approach was used to help develop alternatives and to provide a basis for assessing the performance of alternatives. For this latter function, performance metrics for various resource goals were developed by subject matter experts in Reclamation, NPS, GCMRC, Argonne, FWS, and WAPA, with input from other Cooperating Agencies, AMWG stakeholders, and Tribes (see Appendices B and C). The structured decision analysis approach was not the only method by which the alternatives were analyzed, and a preferred alternative was identified. The identification of a preferred alternative was based on the full EIS analysis and considerations relating to qualitative and quantitative evaluations of impacts. Public comment, socioeconomic considerations, AMWG stakeholder input, and other factors were also considered in this decision.

For those metrics that could be quantitatively assessed with mathematical models that estimated the response of resources to environmental conditions, a full range of potential hydrologic conditions and sediment conditions were evaluated for a 20-year period (water years 2013–2033) that represented the 20 years of the LTEMP. Twenty-one potential Lake Powell inflow scenarios for the 20-year LTEMP were sampled from the 105-yr historic record (water years 1906–2010). This method produced 21 separate hydrology traces (sequence of monthly and annual water volumes) for analysis that represented a range of possible conditions from dry to wet. In addition to these 21 hydrology traces, three 20-year sequences of sediment input from the Paria River sediment record (water years 1964–2013) were analyzed that represented low, medium, and high sediment input. In combination, the 21 hydrology traces and three sediment traces resulted in an analysis that considered 63 possible hydrology-sediment scenarios for analysis.

Mathematical models were used to predict resource metric values for each of the alternatives under the 63 hydrology-sediment combinations. For resource impacts that could not be modeled, a qualitative approach that relied on observed effects of flows and other factors on resources, as published in the scientific literature, was used to assess impacts. See Chapter 4 for a description of the modeling and assessment approaches used for each resource topic.

After this modeling of Alternative D was completed, several adjustments were made to specific operational and experimental characteristics based on discussions with the Cooperating Agencies and stakeholders. These adjustments included (1) an increase in release volume in August with corresponding decreases in May and June (in an 8.23-maf year, the increase was 50 kaf in August, i.e., from 750 to 800 kaf; and a reduction of 25 kaf each in May and June; these changes were applied proportionally to monthly volumes in drier and wetter years); (2) elimination of load-following curtailment prior to sediment-triggered HFEs; (3) an adjustment of the duration of load-following curtailment after a fall HFE; and (4) a prohibition on sediment-triggered spring HFEs in the same water year as an extended-duration (>96 hr) fall HFE. Adjustments made to Alternative D after the DEIS was published, and based on comments received from stakeholders on the DEIS, included (1) elimination of load-following curtailment after a fall HFE and (2) a prohibition on proactive spring HFEs in the same water year as an extended-duration fall HFE. As described in Section 4.1 of the EIS, for most resources other than sediment and hydropower, these adjustments to Alternative D are expected to result in little if any change in impacts relative to those predicted for the earlier modeled version of Alternative D. In addition, for all resources but hydropower, the relative performance of Alternative D as compared to that of other alternatives is not expected to change as a consequence of these adjustments.

Table 2-14 presents a summary of impacts anticipated under each alternative by resource topic. For resources where the effects of the adjustments to Alternative D mentioned in the previous paragraph could be noticeable (i.e., sediment and hydropower), the effects are identified in footnotes to Table 2-14. More detailed information on the impacts of alternatives is provided in Chapter 4.

TABLE 2-14 Summary of Impacts of LTEMP Alternatives on Resources

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Water (hydrology and water quality)	No change from current condition in reservoir elevations, annual operating tiers, monthly release volumes, mean daily flows, or mean daily changes in flow (up to 8,000 cfs). No change in temperature or other water quality indicators.	Compared to Alternative A, no change from current condition related to reservoir elevations, annual operating tiers, monthly release volumes, or mean daily flows, but higher mean daily changes in flow in all months (up to 12,000 cfs). Hydropower improvement flows would cause even greater mean daily flow changes. Negligible differences in temperature or other water quality indicators.	Compared to Alternative A, some change from current condition related to reservoir elevations (<2 ft difference for each reservoir at end of Dec.), annual operating tiers (2.1% of years), monthly release volumes and mean daily flows (lower in Aug. and Sept.); lower mean daily changes in flow in all months (up to 6,200 cfs). Some increase in summer water temperature and potential for bacteria and pathogens.	Compared to Alternative A, some change from current condition related to reservoir elevations (0.2-ft difference for Lake Powell, no difference for Lake Mead at end of Dec.); no change in annual operating tiers; more even monthly release volumes and mean daily flows; similar mean daily changes in flow in most months (up to 8,000 cfs). Some increase in summer water temperature and potential for bacteria and pathogens.	Compared to Alternative A, some change from current condition related to reservoir elevations (0.3-ft difference for Lake Powell, 0.1-ft difference for Lake Mead at end of Dec.); no change in annual operating tiers; more even monthly release volumes and mean daily flows (lower in Aug. and Sept.); higher mean daily changes in flow in all but Sept. and Oct. (up to 9,600 cfs). Some increase in summer water temperature and potential for bacteria and pathogens.	Compared to Alternative A, some change from current condition related to reservoir elevations (about a 3-ft difference for each reservoir at the end of Dec.) and annual operating tiers (2.1% of years); large changes in monthly release volumes and mean daily flows (high volume in May and June, low in other months); steady flows throughout the year. Greatest summer water temperature and increased potential for bacteria and pathogens.	Compared to Alternative A, some change from current condition related to reservoir elevations (0.4-ft difference for Lake Powell, 1.4-ft difference for Lake Mead at end of Dec.) and annual operating tiers; even monthly release volumes and mean daily flows; steady flows throughout the year. Some increase in summer water temperature and potential for bacteria and pathogens.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Sediment	Least HFEs of any alternative would result in lowest potential for building sandbars (highest impact of alternatives), highest sand mass balance (lowest impact of alternatives.	Compared to Alternative A, sandbar building potential would increase 10%, but higher fluctuations would result in lower sand mass balance (80% decrease).	Compared to Alternative A, sandbar building potential would increase 157%, but sand mass balance would decrease 112%.	Compared to Alternative A, sandbar building potential would increase 152%, but sand mass balance would decrease 47%.[b]	Compared to Alternative A, sandbar building potential would increase 119%, but sand mass balance would decrease 96%.	Compared to Alternative A, sandbar building potential would increase 167%, but sand mass balance would decrease 230% (highest impact of alternatives).	Compared to Alternative A, sandbar building potential would increase 176%; lowest impact of alternatives), but sand mass balance would decrease 182%.
Natural processes	Existing natural processes related to flow, water temperature, water quality, and sediment resources would continue, but replenishment of sandbars would diminish after 2020 when HFEs would cease.	Compared to Alternative A, most natural processes would be unchanged, but there would be less nearshore habitat stability as a result of greater within-day fluctuations.	Compared to Alternative A, there would be more nearshore habitat stability as a result of lower within-day fluctuations, slightly higher summer and fall water temperatures due to lower flows, and more frequent sandbar building resulting from more frequent HFEs.	Compared to Alternative A, there would be comparable nearshore habitat stability as a result of similar within-day fluctuations, slightly higher summer water temperatures due to lower flows, and more frequent sandbar building resulting from more frequent HFEs.	Compared to Alternative A, there would be lower nearshore habitat stability as a result of lower within-day fluctuations, slightly higher summer water temperatures due to lower flows, and more frequent sandbar building resulting from more frequent HFEs.	Compared to Alternative A, flow-related processes, water temperature, and water quality would more closely match a natural seasonal pattern with little within season variability; more frequent sandbar building resulting from more frequent HFEs.	Compared to Alternative A, year-round steady flows would result in the greatest nearshore habitat stability, slightly higher summer water temperatures, and the highest potential of any alternative to build sandbars and retain sand in the system.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Aquatic ecology	No change from current conditions for the aquatic food base, nonnative fish, and native fish.	Compared to Alternative A, slightly lower productivity of benthic aquatic food base, but short-term increases in drift associated with greater fluctuations in daily flows; habitat quality and stability and temperature suitability for both nonnative and native fish may be slightly reduced; lower trout abundance; slightly higher humpback chub abundance.	Compared to Alternative A, slightly higher productivity of benthic aquatic food base and drift; habitat quality and stability for nonnative and native fish may be higher; higher trout abundance even with implementation of TMFs and mechanical removal; no difference in humpback chub abundance.	Compared to Alternative A, slightly higher productivity of benthic aquatic food base and drift; experimental macroinvertebrate production flows (only featured in this alternative) may further increase productivity and diversity; habitat quality and stability for nonnative and native fish are expected to be slightly higher; negligible change in trout abundance with implementation of TMFs, and mechanical removal; slightly higher humpback chub abundance.	Compared to Alternative A, slightly higher productivity of benthic aquatic food base, and similar or increased drift; habitat quality and stability for nonnative and native fish would be slightly lower; lower trout abundance with implementation of TMFs and mechanical removal; slightly higher humpback chub abundance.	Compared to Alternative A, increased productivity of aquatic food base and drift in spring and early summer, but lower rest of year; positive effects on nonnative and native fish and their habitats by providing a greater level of habitat stability than would occur under any of the non-steady flow alternatives; higher trout abundance; slightly lower humpback chub abundance.	Compared to Alternative A, relatively high productivity of aquatic food base and long-term drift; greater habitat stability for nonnative and native fish; higher trout abundance even with implementation of TMFs and mechanical removal; slightly lower humpback chub abundance.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Vegetation	Overall index = 3.66 reflecting an adverse impact relative to current condition resulting from: narrowing of Old High Water Zone; an expected decrease in New High Water Zone native plant community cover, decrease in native diversity, increase in native/nonnative ratio, increase in arrowweed; decrease in wetland community cover; impacts on special status species.	Compared to Alternative A, a 6% increase in overall index reflecting an improvement in vegetation conditions (but a decline under hydropower improvement flows); impacts include a narrowing of the Old High Water Zone, a decrease in New High Water Zone native plant community cover, an increase in arrowweed, an increase in native diversity (decrease under hydropower improvement flows), an increase in native/nonnative ratio (decrease under hydropower improvement flows), and a decrease in wetland community cover.	Compared to Alternative A, a 13% decrease in overall index reflecting a decline in vegetation conditions; impacts include a narrowing of the Old High Water Zone; decrease in New High Water Zone native plant community cover, a decrease in native diversity, a decrease in native/nonnative ratio, a decrease in arrowweed, and a decrease in wetland community cover.	Compared to Alternative A, an 8% increase in overall index reflecting an improvement in vegetation conditions; impacts include a narrowing of the Old High Water Zone, a decrease in New High Water Zone native plant community cover, an increase in native diversity, a decrease in native/nonnative ratio, a decrease in arrowweed, and a decrease in wetland community cover. Lowest impact of alternatives.	Compared to Alternative A, a 3% decrease in overall index reflecting a decline in vegetation conditions; impacts include a narrowing of the Old High Water Zone, a decrease in New High Water Zone native plant community cover, a decrease in native diversity, a decrease in native/nonnative ratio, an increase in arrowweed, and a decrease in wetland community cover.	Compared to Alternative A, a 14% decrease in overall index reflecting a decline in vegetation conditions; impacts include a narrowing of Old High Water Zone, a decrease in New High Water Zone native plant community cover, a decrease in native diversity, a decrease in native/nonnative ratio (the largest increase in tamarisk of any alternative), a decrease in arrowweed, and a decrease in wetland community cover. Highest impact of alternatives.	Compared to Alternative A, a 7% decrease in overall index reflecting a decline in vegetation conditions; impacts include a narrowing of Old High Water Zone, a decrease in New High Water Zone native plant community cover, a decrease in native diversity, a decrease in native/nonnative ratio, a decrease in arrowweed, and a decrease in wetland community cover.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Wildlife	No change from current conditions for most wildlife species, but ongoing wetland decline could affect wetland species.	Compared to Alternative A, negligible impacts on most terrestrial wildlife species; less nearshore habitat stability would result in decreased production of aquatic insects and would adversely impact species that eat insects or use nearshore areas, especially with the implementation of hydropower improvement flows; less decline of wetland habitat; however, hydropower improvement flows would cause a greater decline of wetland habitat.	Compared to Alternative A, negligible impacts on most terrestrial wildlife species; greater nearshore habitat stability would result in increased production of aquatic insects and would benefit species that eat insects or use nearshore areas; greater decline of wetland habitat.	Compared to Alternative A, negligible impacts on most terrestrial wildlife species; greater nearshore habitat stability would result in increased production of aquatic insects and would benefit species that eat insects or use nearshore areas; least decline of wetland habitat of any alternative.	Compared to Alternative A, negligible impacts on most terrestrial wildlife species; increased production of aquatic insects due to more even monthly volumes could benefit species that eat insects or use nearshore areas, but benefits may be offset by higher within-day flow fluctuations.	Compared to Alternative A, negligible impacts on most terrestrial wildlife species; greater nearshore habitat stability would result in increased production of aquatic insects and would benefit species that eat insects or use nearshore areas; greatest decline of wetland habitat of any alternative.	Compared to Alternative A, negligible impacts on most terrestrial wildlife species; greater nearshore habitat stability would result in increased production of aquatic insects (highest among alternatives) and would benefit species that eat insects or use nearshore areas; greater decline of wetland habitat.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Cultural resources	No change from current conditions regarding the slumping of terraces in Glen Canyon during HFEs (Glen Canyon flow effects index [GFEI] = 22.7); availability of sand for wind transport to protect stability of archaeological sites in the Grand Canyon (wind transport of sediment index [WTSI] = 0.16); stability of Spencer Steamboat; and visitor time off river (time off river index [TORI] = 0.82).	Compared to Alternative A, an increase in the potential for slumping of terraces in Glen Canyon (1.5% increase in GFEI), an increase in the availability of sand for wind transport to protect the stability of archaeological sites in the Grand Canyon (7.5% increase in WTSI); no change in the stability of Spencer Steamboat or visitor time off river. Experimental hydropower improvement flows would increase the potential for slumping compared to Alternative A (1.6% increase in GFEI and a decrease in the availability of windblown sand (−9.5% decrease in WTSI).	Compared to Alternative A, a decrease in the potential for slumping of terraces in Glen Canyon (4.4% decrease in GFEI), an increase in the availability of sand for wind transport to protect the stability of archaeological sites in the Grand Canyon (137% increase in WTSI); negligible effect on stability of Spencer Steamboat or visitor time off river (<1% change in TORI).	Compared to Alternative A, an increase in the potential for slumping of terraces in Glen Canyon (3.1% increase in GFEI), an increase in the availability of sand for wind transport to protect stability of archaeological sites in the Grand Canyon (139% increase in WTSI); negligible effect on stability of Spencer Steamboat; a decrease in visitor time off river (1.6% increase in TORI).	Compared to Alternative A, a decrease in the potential for slumping of terraces in Glen Canyon (6.4% decrease in GFEI), an increase in the availability of sand for wind transport to protect the stability of archaeological sites in the Grand Canyon (96% increase in WTSI); negligible effect on stability of Spencer Steamboat; a decrease in visitor time off river (1.9% increase in TORI).	Compared to Alternative A, an increase in the potential for slumping of terraces in Glen Canyon due to sustained high flows in the spring (62% increase in GFEI), an increase in the availability of sand for wind transport to protect the stability of archaeological sites in the Grand Canyon (88% increase in WTSI); negligible effect on stability of Spencer Steamboat; an increase in visitor time off river (8.9% decrease in TORI).	Compared to Alternative A, an increase in the potential for slumping of terraces in Glen Canyon (8.7% increase in GFEI), an increase in the availability of sand for wind transport to protect stability of archaeological sites in the Grand Canyon (193% increase in WTSI); negligible effect on the stability of Spencer Steamboat; a decrease in visitor time off river (2.1% increase in TORI).

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Tribal resources	Operations would result in no change in the amount of sand available for wind transport to cultural resource sites; a negligible loss of riparian diversity; a small loss of wetlands and no impact on Tribal water and economic resources. No TMFs, but mechanical trout removal could be triggered. After 2020, potential adverse impact on culturally important archaeological sites.	Compared to Alternative A, operations would result in a slight increase in the amount of sand available for wind transport to cultural resource sites except during hydropower improvement flows, when there would be a slight decrease. There would be a slight loss in riparian diversity and slightly more loss in wetlands. There would be no impact on Tribal water and economic resources. TMFs and mechanical trout removal could be triggered. A small increase in sediment near Hualapai recreation operations; more frequent HFEs could affect docks.	Compared to Alternative A, operations would result in an increase in the amount of sand available for wind transport to cultural resource sites; the second largest loss in wetlands and a decrease in riparian plant diversity. Tribally operated marinas could experience a negligible drop in income. TMFs and mechanical trout removal could be triggered. A small increase in sediment near Hualapai recreation operations; more frequent HFEs could affect docks.	Compared to Alternative A, operations would result in an increase in the amount of sand available for wind transport to cultural resource sites; the least amount of wetlands loss across alternatives; and similar riparian plant diversity. Tribally operated marinas could experience a negligible drop in income. TMFs and mechanical trout removal could occur with or without triggers. A small increase in sediment near Hualapai recreation operations; more frequent HFEs could affect docks.[c]	Compared to Alternative A, operations would result in an increase in the amount of sand available for wind transport to cultural resource sites; an increase in wetlands loss; and similar riparian plant diversity. Tribally operated marinas could experience a negligible drop in income. TMFs and mechanical trout removal could be triggered. A small increase in sediment near Hualapai recreation operations; more frequent HFEs could affect docks.	Compared to Alternative A, operations would result in an increase in the amount of sand available for wind transport to cultural resource sites but would result in an increase in the potential for river runners to explore and potentially damage places of cultural importance during May and June. The greatest loss of wetlands, largest increase in invasive species, and lowest riparian plan diversity occur under this alternative. Tribally operated marinas could experience a slight loss of income under this alternative. There would be no TMFs	Compared to Alternative A, operations would result in the greatest potential increase in the amount of sand available for wind transport to cultural resource sites; the third-largest wetlands loss across alternatives; and a decrease in riparian plant diversity. Tribally operated marinas could experience a negligible drop in income. TMFs and mechanical trout removal could be triggered. A small increase in sediment near Hualapai recreation operations; more frequent HFEs could affect docks.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Tribal resources (Cont.)						or mechanical trout removal. A small increase in sediment near Hualapai recreation operations; more frequent HFEs could affect docks.	
Recreation, visitor use, and experience	No change from current conditions. Fewest HFEs, moderate fluctuations, intermediate trout catch rates, few navigability concerns, few lost day-rafting visitor days (49 over 20-year period), and declining camping area.	Compared to Alternative A, a comparable number of HFEs and higher fluctuations result in more lost day-rafting visitor days (45% increase) in Glen Canyon, highest number of large trout (13% increase), lowest trout catch rates, most navigability concerns, and similar camping area (5% increase in index).	Compared to Alternative A, more HFEs and lower fluctuations result in more lost day-rafting visitor days in Glen Canyon (543% increase), similar number of large trout (3% decrease), higher trout catch rates; fewer navigation concerns, and more camping area (170% increase in index).	Compared to Alternative A, more HFEs and comparable fluctuations result in more lost day-rafting visitor days in Glen Canyon (610% increase), similar number of large trout (5% increase), similar trout catch rates, similar navigation concerns, and more camping area (158% increase in index).	Compared to Alternative A, more HFEs, higher fluctuations, and more frequent flows below 8,000 cfs result in more lost day-rafting visitor days in Glen Canyon (261% increase), more large trout (8% increase), lower trout catch rates, more navigation concerns, and more camping area (118% increase in index).	Compared to Alternative A and all other alternatives, frequent HFEs, steady flows, and lack of trout management actions result in most lost day-rafting visitor days in Glen Canyon (1,776% increase), higher trout catch rates, but fewest large trout (22% decrease); very few navigability concerns, and more camping area (191% increase in index).	Compared to Alternative A, more HFEs and steady flows result in few additional lost day-rafting visitor days in Glen Canyon (4% increase), higher trout catch rates, but fewer large trout (9% decrease); very few navigability concerns, and greatest potential increase in camping area (220% increase in index).

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Wilderness	No change from current conditions. Declining camping area following cessation of HFEs would reduce opportunity for solitude; intermediate effects on crowding at rapids and levels of fluctuations; lowest disturbance from experimental actions.	Compared to Alternative A, similar decline in camping area, somewhat more crowding at rapids, greatest level of fluctuations, greater disturbance from non-flow actions, especially under experimental hydropower improvement flows.	Compared to Alternative A, reversal of camping area decline, somewhat less crowding at rapids, lower level of fluctuations, and greater disturbance from non-flow actions.	Compared to Alternative A, reversal of camping area decline, similar crowding at rapids, similar level of fluctuations, and greater disturbance from non-flow actions.	Compared to Alternative A, reversal of camping area decline, most crowding at rapids, higher level of fluctuations, and greater disturbance from non-flow actions.	Compared to Alternative A, reversal of camping area decline, less crowding at rapids, no fluctuations, greater disturbance from non-flow actions, but no mechanical removal of trout.	Compared to Alternative A, greatest reversal of camping area decline, least crowding at rapids, no fluctuations, greater disturbance from non-flow actions.
Visual resources	No change from current condition.	Negligible change from current condition.	Negligible change from current condition.	Negligible change from current condition.	Negligible change from current condition.	Negligible change from current condition.	Negligible change from current condition.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Glen Canyon Dam hydropower economic and retail rate impacts	No change from current condition. Second-highest firm capacity and sixth-lowest total cost to meet electric demand over the 20-year LTEMP period. No change in average electric retail rate or average monthly residential electricity bill.	Compared to Alternative A, a 0.3% decrease in average daily generation (MWh) and a 3.8% increase in firm capacity (MW); a 0.02% decrease in the cost of generation, a 0.45% decrease in the cost of capacity, and a 0.04% decrease in total cost to meet electric demand over the 20-year LTEMP period; a small decrease in the average electric retail rate (−0.27%) and the average monthly residential electricity bill (−$0.27) in the year of maximum rate impact.	Compared to Alternative A, a 0.8% decrease in average daily generation (MWh) and a 17.5% decrease in firm capacity (MW); a 0.08% increase in the cost of generation, a 6.09% increase in the cost of capacity, and a 0.41% increase in total cost to meet electric demand over the 20-year LTEMP period; a small increase in average retail electric rate (0.43%) and average monthly residential electricity bill ($0.40) in the year of maximum rate impact.[d]	Compared to Alternative A, a 1.1% decrease in average daily generation (MWh) and a 6.7% decrease in firm capacity (MW); a 0.12% increase in the cost of generation, a 3.12% increase in the cost of capacity, and a 0.29% increase in total cost to meet electric demand over the 20-year LTEMP period; a small increase in average retail electric rate (0.39%) and average monthly residential electricity bill ($0.38) in the year of maximum rate impact.[e]	Compared to Alternative A, a 0.7% decrease in average daily generation (MWh) and a 12.2% decrease in firm capacity (MW); a 0.06% increase in the cost of generation, a 3.52% increase in the cost of capacity, and a 0.25% increase in total cost to meet electric demand over the 20-year LTEMP period; a small increase in average retail electric rate (0.50%) and average monthly residential electricity bill ($0.47) in the year of maximum rate impact.[f]	Compared to Alternative A, a 1.9% decrease in average daily generation (MWh) and a 42.6% decrease in firm capacity (MW) (lowest of alternatives); a 0.42% increase in the cost of generation, a 4.03% increase in the cost of capacity, and a 1.17% increase (highest of alternatives) in total cost to meet electric demand over the 20-year LTEMP period; highest increase in average retail electric rate (1.21%) and average monthly residential electricity bill ($1.02) in the year of maximum rate impact.	Compared to Alternative A, a 1.7% decrease in average daily generation (MWh) and a 24.2% decrease in firm capacity (MW); a 0.34% increase in the cost of generation, a 7.39% increase in the cost of capacity, and a 0.73% increase in total cost to meet electric demand over 20-year LTEMP period; a small increase in average retail electric rate (0.64%) and average monthly residential electricity bill ($0.59) in the year of maximum rate impact.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Hoover Dam hydropower economic impacts	No change in the value of generation.	Compared to Alternative A, no change in the value of generation.	Compared to Alternative A, a 2.0% increase in the value of generation.	Compared to Alternative A, a 1.0% increase in the value of generation.	Compared to Alternative A, a 1.2% increase in the value of generation.	Compared to Alternative A, a 4.1% increase in the value of generation.	Compared to Alternative A, a 1.4% increase in the value of generation.
Socioeconomics	No change from current conditions in use values or economic activity, with no change in reservoir levels or river conditions. Lowest non-use value of alternatives.	Compared to Alternative A, no change in use values and economic activity associated with Lake Powell recreation, and declines in use values (up to 5.2%) associated with most forms of river recreation. No change in economic activity for most forms of river recreation except angling, with declines during HFEs. Minimal decrease in use values (<0.1%), and no change in economic activity associated with Lake Mead recreation. Minimal increase in economic activity	Compared to Alternative A, declines (0.7%) in use values and economic activity (0.6%) associated with Lake Powell recreation, and in use values (up to 11.5%) associated with most forms of river recreation. No change in economic activity for most forms of river recreation except angling, with declines during HFEs. Increases in use values (0.3%) and economic activity (0.3%) associated with Lake Mead recreation. Increased economic activity from capacity expansion (up to 4.5%), and	Compared to Alternative A, declines in use values (0.4%) and economic activity (0.4%) associated with Lake Powell recreation, and in use values (up to 11.7%) associated with most forms of river recreation. No change in economic activity for most forms of river recreation except angling, with declines during HFEs. Increases in use values (0.3%) and economic activity (0.3%) associated with Lake Mead recreation. Increased economic activity from capacity	Compared to Alternative A, declines in use values (0.5%) and economic activity (0.5%) associated with Lake Powell recreation, and in use values (up to 14.0%) associated with most forms of river recreation. No change in economic activity for most forms of river recreation except angling, with declines during HFEs. Increases in use values (0.3%) and economic activity (0.3%) associated with Lake Mead recreation. Increased economic activity from	Compared to Alternative A, declines in use values (1.1%) and economic activity (1.1%) associated with Lake Powell recreation, and in use values (up to 8.9%) associated with most forms of river recreation. An increase in use values (0.5%) associated with Upper and Lower Grand Canyon private boating. A decrease in economic activity for angling, with declines during HFEs. Increases in use values (0.5%) and economic activity (0.5%) associated with	Compared to Alternative A, declines in use values (0.4%) and economic activity (0.4%) associated with Lake Powell recreation, and in use values (up to 13.2%) associated with most forms of river recreation. An increase in use values (0.3%) associated with Lower Grand Canyon private boating. A decrease in economic activity for angling, with declines during HFEs. Increases

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Socioeconomics (Cont.)		(<0.1%) from lower residential electric bills compared to Alternative A. Annual increase in non-use value of $1,511 million at the national level.	minimal decrease in economic activity from higher residential electric bills (< 0.1%). Annual increase in non-use value of $3,985 million at the national level.	expansion (up to 4.5%), and a minimal decrease in economic activity from higher residential electric bills (<0.1%). Highest non-use value of alternatives. Annual increase in non-use value of $4,486 million at the national level.	capacity expansion (up to 4.5%), and a minimal decrease in economic activity from higher residential electric bills (<0.1%). Annual increase in non-use value of $3,963 million at the national level.	Lake Mead recreation. Increased economic activity from capacity expansion (up to 9.3%), and minimal decrease in economic activity from higher residential electric bills (<0.1%). Annual increase in non-use value of $2,353 million at the national level.	in use values (0.3%) and economic activity (0.3%) associated with Lake Mead recreation. Increased economic activity from capacity expansion (up to 4.5%), and a minimal decrease in economic activity from higher residential electric bills (<0.1%). Annual increase in non-use value of $3,524 million at the national level.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Environmental justice	No change from current conditions. No disproportionately high and adverse impacts on minority or low-income populations.	TMFs and mechanical removal triggered in 3 years and <1 year, respectively, of LTEMP period; financial impacts related to electricity sales similar to those under Alternative A. No disproportionately high and adverse impacts on minority or low-income populations.	TMFs and mechanical removal triggered in 6 years and 0–3 years, respectively, of LTEMP period; financial impacts related to electricity sales would be slightly higher (<$1.00/MWh) than those on non-Tribal customers, and those under Alternative A. No disproportionately high and adverse impacts on minority or low-income populations.	TMFs and mechanical removal triggered in 8 years and 2–3 years, respectively, of LTEMP period; financial impacts related to electricity sales would be slightly higher (<$1.00/MWh) than those on non-Tribal customers, and those under Alternative A. No disproportionately high and adverse impacts on minority or low-income populations.	TMFs and mechanical removal triggered in 3 years and 0–2 years, respectively, of LTEMP period; financial impacts related to electricity sales would be slightly higher (<$1.00/MWh) than those on non-Tribal customers, and those under Alternative A. No disproportionately high and adverse impacts on minority or low-income populations.	No impact; TMFs and mechanical removal not allowed under this alternative; financial impacts related to electricity sales would be slightly higher (<$1.00/MWh) than those on non-Tribal customers and would be greater (as much as $3.26/MWh) than those under Alternative A. No disproportionately high and adverse impacts on minority or low-income populations.	Highest impact of all alternatives; TMFs and mechanical removal triggered in 11 years and 3 years, respectively, of LTEMP period; financial impacts related to electricity sales would be slightly higher (as much as $1.34/MWh) than those on non-Tribal customers, and would be greater (as much as $2.84/MWh) than those under Alternative A. No disproportionately high and adverse impacts on minority or low-income populations.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G
Air quality	No change from current conditions in air quality or visibility.	Compared to Alternative A, a negligible increase (0.01%) in SO_2 and NO_x emissions; no change in visibility.	Compared to Alternative A, a negligible decrease (–0.01%) in SO_2 emissions and no change in NO_x emissions; no change in visibility.	Compared to Alternative A, no change in SO_2 emissions and negligible increase in NO_x emissions; no change in visibility.	Compared to Alternative A, a negligible increase (<0.005%) in SO_2 and NO_x emissions; no change in visibility.	Compared to Alternative A, a negligible decrease (–0.04%) in SO_2 and NO_x emissions; no change in visibility.	Compared to Alternative A, a negligible decrease (–0.03%) in SO_2 and negligible increase in NO_x emissions; no change in visibility.
Climate change	No change from current conditions.	Compared to Alternative A, a 0.011% increase in GHG emissions.	Compared to Alternative A, a 0.033% increase in GHG emissions.	Compared to Alternative A, a 0.042% increase in GHG emissions.	Compared to Alternative A, a 0.030% increase in GHG emissions.	Compared to Alternative A, a 0.081% increase in GHG emissions.	Compared to Alternative A, a 0.074% increase in GHG emissions.
Cumulative impacts	Contribution to cumulative impacts would be negligible compared to the effects of past, present, and reasonably foreseeable future actions.	Compared to Alternative A, similar sandbar building, lower trout numbers, slightly higher humpback chub numbers, greater value of hydropower generation and capacity.	Compared to Alternative A, more sandbar building, higher trout numbers, slightly lower humpback chub numbers, lower value of hydropower generation and capacity.	Compared to Alternative A, more sandbar building, higher trout numbers, slightly higher humpback chub numbers, and slightly lower value of hydropower generation and capacity.	Compared to Alternative A, more sandbar building, similar trout numbers, and slightly lower value of hydropower generation and capacity.	Compared to Alternative A, more sandbar building, much higher trout numbers, slightly lower humpback chub numbers, and lower value of hydropower generation and capacity.	Compared to Alternative A, more sandbar building, higher trout numbers, slightly lower humpback chub numbers, and lower value of hydropower generation and capacity.

Footnotes on next page.

TABLE 2-14 (Cont.)

Resource	Alternative A (No Action Alternative)	Alternative B	Alternative C	Alternative D (Preferred Alternative)[a]	Alternative E	Alternative F	Alternative G

[a] The quantitative results presented here are from modeling conducted prior to making several adjustments to Alternative D, including prohibition of sediment-triggered and proactive spring HFEs in the same water year as an extended-duration fall HFE, elimination of experimental load-following curtailment after fall HFEs, and an adjustment in the monthly release volumes such that releases in August would be 50 kaf higher (800 kaf instead of 750 kaf) and releases in May and June would each be 25 kaf lower. The actual number of HFEs would be about 19.8 (1.3 fewer). As described in Section 4.1 of the EIS, for most resources, these adjustments to Alternative D are expected to result in little if any change in impacts relative to those predicted for the earlier modeled version of Alternative D. In addition, for all resources but hydropower, the relative performance of Alternative D as compared to that of other alternatives is not expected to change as a consequence of these adjustments. Potentially noticeable effects are identified for sediment and hydropower in footnotes (b) and (e).

[b] Impacts on sediment presented for Alternative D in this table were based on modeling performed prior to making several adjustments to the alternative (see footnote [a]). The actual number of HFEs would be lower and would result in a slightly lower sand load index (SLI) and higher sand mass balance index (SMBI). Change in monthly release volumes would result in a slight increase in sediment transport (1.2%), resulting in a lower SLI and a lower SMBI. Elimination of load-following curtailment would result in a 0.6% decrease in SMBI. The relative performance of Alternative D as compared to that of other alternatives is not expected to change as a consequence of these adjustments. See Section 4.1 for more detail.

[c] Adjustments made to Alternative D after modeling was completed included a prohibition of sediment-triggered and proactive spring HFEs in the same water year as an extended-duration fall HFE. The number of spring HFEs would be reduced from 6.8 to 5.5 after the prohibition (1.3 fewer), and this reduction in frequency could reduce the impacts on Hualapai docks under Alternative D.

[d] The results presented here do not include the cost of experimental low summer flows. Adding these costs would increase the relative cost of Alternative C compared to Alternative A, estimated at $148 million, by about $24.5 million resulting in a total cost difference of about $173 million over a 20-year period. This addition increases the percent difference relative to Alternative A from a 0.41% increase in cost to a 0.48% increase in cost. The relative ranking of Alternative C compared to other alternatives would not change as a result of adding the cost of experimental low summer flows.

[e] Impacts on hydropower resources presented for Alternative D in this table were based on modeling performed prior to making several adjustments to the alternative (see footnote [a]), and they do not include the cost of experimental low summer flows. Experimental low summer flows would increase costs by $15 million, while the adjustments would reduce costs by $58.9 million. Combined, the cumulative effect of these adjustments may reduce the relative cost of Alternative D compared to Alternative A, estimated at $104 million, by approximately $44 million over a 20-year period; the resulting difference from Alternative A would be $60 million. These adjustments reduce the percent difference relative to Alternative A from a 0.29% increase in cost to a 0.17% increase in cost. These adjustments would also result in slight reductions to the retail rate costs. The relative ranking of Alternative D compared to other alternatives would change from fourth to third lowest cost. See Section 4.13.3.4 for more detail.

[f] The results presented here do not include the cost of experimental low summer flows. Adding these costs would increase the relative cost of Alternative E compared to Alternative A, estimated at $91 million, by about $9.95 million resulting in a total cost difference of about $101 million over a 20-year period. This addition increases the percent difference relative to Alternative A from a 0.25% increase in cost to a 0.28% increase in cost. The relative ranking of Alternative E compared to other alternatives would change from third to fourth lowest cost.

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